U.S. Fish & Wildlife Service

# Draft Revised Recovery Plan for the `Alalā *(Corvus hawaiiensis)*

Drawing of adult `Alalā feeding nestlings by Patrick Ching, used with permission.

# Draft Revised Recovery Plan for the `Alalā (*Corvus hawaiiensis*)

(October 2003)

(Original recovery plan approved October 28, 1982)

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

Approved: XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
Regional Director, U.S. Fish and Wildlife Service

Date: ______________________________

## U.S. FISH AND WILDLIFE SERVICE'S MISSION IN RECOVERY PLANNING

Section 4(f) of the Endangered Species Act of 1973, as amended, directs the Secretary of the Interior and the Secretary of Commerce to develop and implement recovery plans for species of animals and plants listed as endangered or threatened, unless such plans will not promote the conservation of the species. The U.S. Fish and Wildlife Service and the National Marine Fisheries Service (National Oceanic and Atmospheric Administration [NOAA] Fisheries) have been delegated the responsibility of administering the Endangered Species Act. Recovery is the process by which the decline of an endangered or threatened species is arrested or reversed and threats to its survival are neutralized, so that its long-term survival in nature can be ensured. The goal of this process is the maintenance of secure, self-sustaining wild populations of species with the minimum necessary investment of resources. A recovery plan delineates, justifies, and schedules the research and management actions necessary to support recovery of a species. Recovery plans do not, of themselves, commit personnel or funds, but are used in setting regional and national funding priorities and providing direction to local, regional, and State planning efforts. Means within the Endangered Species Act to achieve recovery goals include the responsibility of all Federal agencies to seek to conserve endangered and threatened species, and the Secretary's ability to designate critical habitat, to enter into cooperative agreements with the States, to provide financial assistance to the respective State agencies, to acquire land, and to develop Habitat Conservation Plans and Safe Harbor Agreements with applicants.

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Recovery plans delineate reasonable actions that are determined to be necessary for recovery and/or protection of listed species. Plans are published by the U.S. Fish and Wildlife Service, and are often prepared with the assistance of recovery teams, contractors, State agencies, and others. 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. Costs indicated for recovery action implementation and/or time for achievement of recovery are only **estimates** and are subject to change. Recovery plans do not necessarily represent the views nor the official positions or approval of any individuals or agencies involved in the plan formulation, other than the U.S. Fish and Wildlife Service. They represent the official position of the U.S. Fish and Wildlife Service **only** after they have been signed by the Director or Regional Director as **approved**. Approved recovery plans are subject to modification as dictated by new findings, changes in species status, and completion of recovery tasks.

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An electronic copy of this plan will be made available at <http://pacific.fws.gov/ecoservices/endangered/recovery/default.htm> and also at <http://endangered.fws.gov/recovery/index.html>.

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# EXECUTIVE SUMMARY

Previous Recovery Plan: The first `Alalā Recovery Plan was published on October 28, 1982 (U.S. Fish and Wildlife Service [USFWS] 1982). Since January 4, 1993, guidance for the recovery program has also been based on the "Long-term Management Plan for the `Alalā" (USFWS 1993), and management recommendations formulated periodically by the `Alalā Recovery Team.

Current Species Status: The Hawaiian Crow, or `Alalā (*Corvus hawaiiensis*), is listed as endangered without critical habitat. There currently are no individuals known to exist in the wild. As of 2003, there are 40 `Alalā, representing the entire population of the species, in captivity at the Keauhou and Maui Bird Conservation Centers on Hawai`i and Maui islands, respectively.

Habitat Requirements and Distribution: The `Alalā is endemic to the island of Hawai`i. Historically, the species was restricted to the dry and mesic forests in the western and southern portions of the island, from Pu`uanahulu in the North Kona District to the vicinity of Kīlauea Crater in the Ka`ū District. The species is associated with `ōhi`a (*Metrosideros polymorpha*) and `ōhi`a-koa (*Acacia koa*) forests with an understory of native fruit-bearing trees and shrubs.

Threats to Species Recovery: Current threats include predation by non-native mammals and the endemic Hawaiian Hawk or `Io (*Buteo solitarius*), introduced diseases, and habitat loss and fragmentation. Inbreeding depression may be reducing the reproductive success of the captive population. Because the population is small and confined to captivity, the `Alalā is highly susceptible to stochastic environmental, demographic, and genetic events. These threats will challenge the species for many years, even after the `Alalā has been reintroduced to the wild.

Recovery Objective: The ultimate recovery objective is to restore multiple self-sustaining populations within the historical range, and subsequently to delist the `Alalā. However, the population sizes and parameters necessary to consider downlisting or delisting will be determined when necessary biological and demographic data become available. The interim objectives over the next 5 years

are to minimize loss of genetic variability in captivity, restore suitable habitat, and begin reestablishment of `Alalā populations in the wild.

Recovery Actions:

1. **Manage the population of `Alalā**, including both captive and eventual reintroduced subpopulations, to minimize loss of genetic diversity.
2. **Manage threats in suitable habitat**, including disease and predation; prevent habitat loss and degradation; and restore historical habitat and other potential suitable habitat.
3. **Establish new populations in suitable habitat**, once this habitat is managed to allow population persistence and growth.
4. **Garner public support**, both to facilitate captive propagation of `Alalā and for recovery activities including habitat management and `Alalā reintroduction.
5. **Conduct research and adaptively manage the recovery program**, to increase effectiveness of captive propagation, release methods, and habitat management and to minimize the time to recovery.

Date of Recovery: Because the `Alalā currently survives only in captivity and numbers fewer than 50 individuals, and because future reproduction and success of reintroductions cannot be predicted, it is not possible to establish a date of recovery at this time.

Total Estimated Cost of Recovery: It is not possible to determine the total estimated cost of recovery at this time. The estimated cost to implement all recovery actions described in the Implementation Plan Table over the next 5 years is $11,840,000. It can be assumed that continued intensive management will be required for several decades at similar or increased cost for successive 5-year management periods.

# TABLE OF CONTENTS

## LIST OF FIGURES

# Part I. INTRODUCTION AND OVERVIEW

## A. Structure of the Recovery Plan

The total number of `Alalā or Hawaiian Crow (*Corvus hawaiiensis;* Peale 1848) has been declining precipitously for at least a century, and the species is apparently now extinct in the wild. A variety of factors have contributed to its decline, including many types of habitat change caused directly or indirectly by human activity. Significant features of the species' life history, behavior, ecological interactions, and habitat needs remain unknown. Due to these uncertainties, detailed long-term recovery planning is difficult, and the exact needs of the recovery program cannot be specified beyond a relatively short time horizon. Recovery of this species will require both sustained, long-term conservation actions and repeated experimentation to determine the optimal means to reestablish wild populations.

This recovery plan is therefore divided into three parts. Part I, the Introduction and Overview, provides information on the biology of the species, the history of its decline, and a summary of past recovery efforts. Part II, the Strategic Plan, outlines the overall long-term goals and broad strategies which we anticipate shall remain effective throughout the recovery process for this species. Part III is the first of what will become a series of short-term Implementation Plans, which summarize relevant data gathered to date and outline actions needed to advance to the next steps in recovery. These implementation plans will use an adaptive management approach, *i.e*., they will be used to manage the program by proposing actions as tests of hypotheses relevant to program management and by incorporating lessons learned in the previous cycle. Every 3 to 5 years we will prepare a new implementation plan reflecting the knowledge gained and consequent refinements to our management program to further enhance the effectiveness of our recovery efforts for the `Alalā.

## B. Status Overview

The `Alalā or Hawaiian Crow is a bird endemic to the island of Hawai`i. Once abundant within its forested habitat on the island, the species has been in sharp decline for many years. This species is now believed to be extinct in the wild, as the last free-living pair has not been sighted since June 2002. There are currently 40 `Alalā, representing the entire remaining population of the species, in captivity at the Keauhou and Maui Bird Conservation Centers on the islands of Hawai`i and Maui, respectively.

The `Alalā has been on the Territory (now State) of Hawai`i's list of protected birds since 1931, and is currently listed as an endangered species under Hawaii State law (Hawai`i Revised Statutes §195D *et seq*.). In March 1967, the `Alalā was one of the first species listed as an endangered in the United States under the Endangered Species Preservation Act of 1966 (16 United States Code [USC] 668aa(c)), and is now protected under the Endangered Species Act of 1973, as amended (16 USC 1531 *et seq*.). This species has a recovery priority ranking of 2C on a scale from 1 (highest) to 18 (lowest), reflecting a high degree of threat, high potential for recovery, and its status as a full species; the "C" indicates the potential for conflict with economic activities (U.S. Fish and Wildlife Service [USFWS] 1983a,b). Critical habitat has not been designated for this species.

The first recovery plan for the `Alalā was published on October 28, 1982 (USFWS 1982). In 1991, we, the U.S. Fish and Wildlife Service, commissioned the National Research Council of the National Academy of Sciences to undertake a review of the status of the `Alalā and recommend appropriate recovery actions. The National Research Council released its report in 1992 (NRC 1992), and based upon their recommendations, we developed a new long-term management plan for the recovery of the `Alalā which has directed our efforts since that time (USFWS 1993). The `Alalā Recovery Team was also established at this point in time, and their periodic management recommendations have also assisted in guiding our recovery actions. The status of the `Alalā and the strategy for the recovery of this species have undergone some significant changes in the last decade, resulting in the need for new management direction. As a result, this draft revised recovery plan has been developed to incorporate our current state of knowledge of the species and guide future recovery actions.

## C. Species Description and Taxonomy

The `Alalā is a member of the family Corvidae, the family of birds that includes, amongst others, ravens, crows, jays, and magpies. Members of the crow family are recognized for having a high degree of intelligence and excellent memory. They are generally relatively raucous and gregarious birds, and are known for their complex "language-like" vocalizations. In appearance, the `Alalā is a typical medium-sized crow, from dark brown to black in color (see cover illustration). However, the `Alalā is endemic to the island of Hawai`i, and is the only surviving member of a group of crow species (three described, at least two undescribed) that inhabited the archipelago prior to human colonization (James and Olson 1991; Banko *et al.* 2002). Although the `Alalā bears some resemblance to the Common Raven (*Corvus corax*), the number of extinct Hawaiian corvids and the degree of morphological difference among them suggest that the group colonized the islands several hundred thousand years ago and may be only distantly related to other crows (R. Fleischer, unpubl. data). As with all members of the crow family, the sexes appear outwardly alike. The full description of the `Alalā and its relationship to other living and extinct corvids can be found in Banko *et al.* 2002.

## D. Cultural Significance

`Alalā translates from Hawaiian as: "to bawl, bleat, squeal, cry..."; the Hawaiian Crow; a talkative person; and a style of chanting (Pukui and Elbert 1986). The herald of a battle formation was also known as the `Alalā (L. Naone-Salvador, pers. comm. 2002). Munro (1944) suggested the bird's name might also reflect its habit of rising (*ala*) with the sun (*lā*). The largest forest bird after the Hawaiian Hawk or 'Io (*Buteo solitarius*), and among the most charismatic, the `Alalā was highly regarded by the Hawaiian people before the arrival of Europeans. It was kept as a ceremonial pet, regarded as a family guardian spirit or *`aumakua*, and its feathers were used to decorate statues and *kahili* (Cook 1784; Brigham 1899; Malo 1951; Handy *et al.* 1972; Medway 1981).

## E. Historical and Current Range and Population Decline

Recent discoveries of subfossil bird and plant remains in Hawai`i have shown that the original distributions of native species prior to human colonization were often very different from what has been assumed based on historical observations (James and Olson 1991; Olson and James 1991). Polynesian settlers and the nonnative species that accompanied them completely transformed the Hawaiian lowlands prior to European contact (Athens 1997; Burney *et al.* 2002). Not only were many species rendered extinct by these changes, as on other oceanic islands, but species now known only from single islands or isolated locales were originally widespread and occupied a surprising range of habitats. Among birds, the Laysan duck (*Anas laysanensis*), once thought to be endemic to remote Laysan Island, is now known to have previously inhabited upland forests of all of the main Hawaiian islands (Cooper *et al.* 1996), and several honeycreepers historically reported only from high elevations previously inhabited forests near sea level (Palila, *Loxioides bailleui*; Greater koa- finch, *Rhodacanthis palmeri*; Lesser koa-finch, *Rhodacanthis flaviceps;* Po`ouli, *Melamprosops phaeosoma*; Olson and James 1982a,b; James and Olson 1991).

Historical distribution records for the `Alalā (Figure 1) therefore should be presumed to be snapshots of an ongoing history of range contraction and fragmentation. Similarly, documented habitat use may not reflect the full range of habitats originally used. This historical record, compiled by European and American naturalists and collectors, indicates that in the century following European contact the `Alalā inhabited a mid-elevation (300 to 2,500 meter [984 to 8,202 foot]) belt of native dry woodlands, and mesic `ōhi`a (*Metrosideros polymorpha*) and `ōhi`a-koa (*Acacia koa*) forests along the slopes of the Hualālai and Mauna Loa volcanoes (Perkins 1893, 1903; Munro 1944; Banko and Banko 1980). The species' range may well have originally extended to sea level, to other parts of the island of Hawai`i, and possibly other islands. Nevertheless, corvid fossils have been found only in dry or mesic sites (James and Olson 1991); no species is known to have occupied wet forest habitats. Subfossil bones of a corvid recovered on Maui may be those of a subspecies of `Alalā or of an ecologically equivalent sister taxon of similar size, according to preliminary DNA tests (R. Fleischer, pers. comm. 2002).

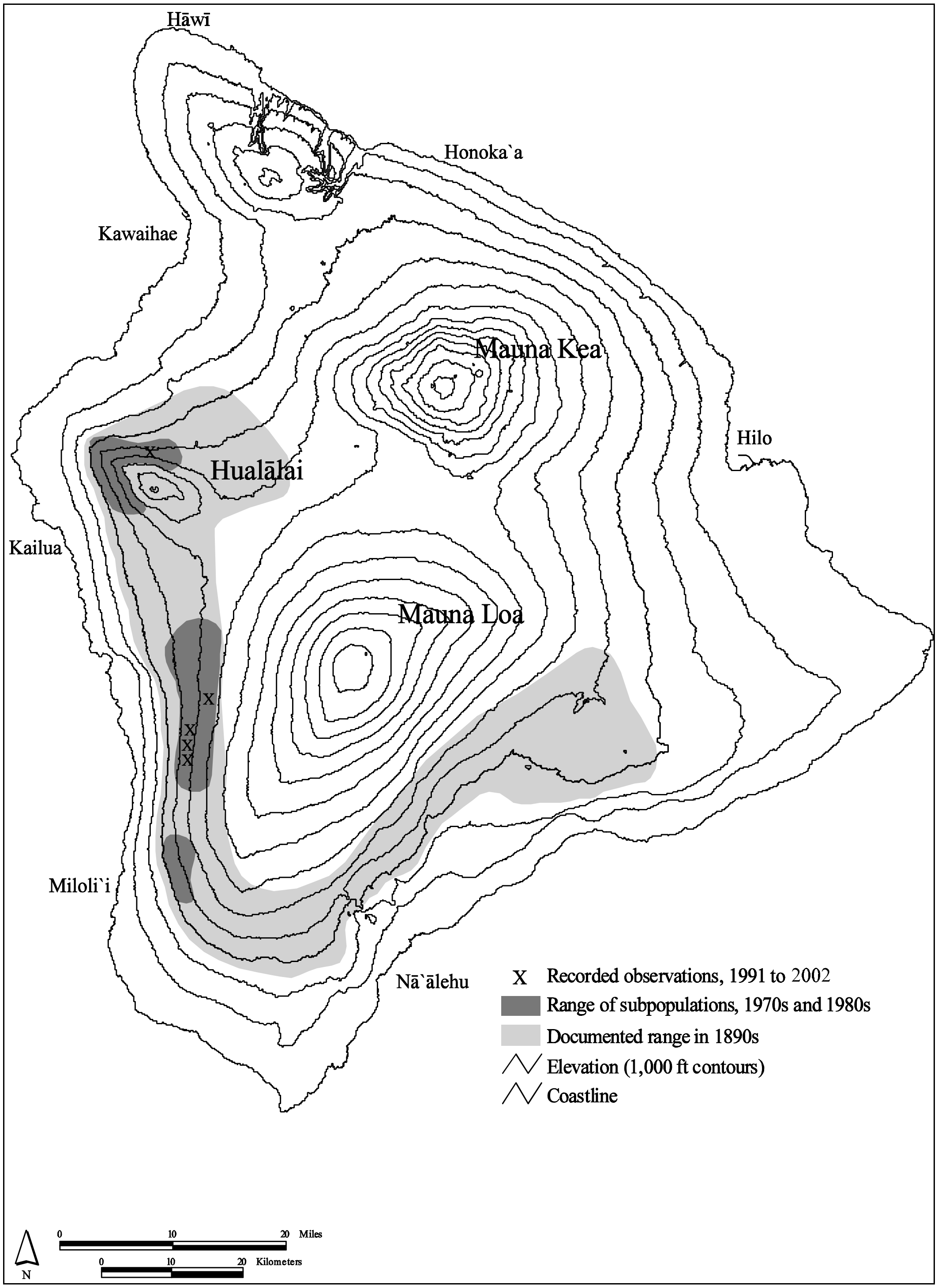


**FIGURE 1.** Range contraction and fragmentation of the `Alalā population on the island of Hawai`i

`Alalā occupied their entire documented historical range during the 1890's, and were observed in large numbers in both closed and disturbed forests (Perkins 1903; Munro 1944; Banko and Banko 1980). Subsequent observations document a pattern of range reduction and fragmentation typical of species in rapid decline. In the early 1900's, the population density of `Alalā was noticeably reduced and their range was becoming fragmented (Munro 1944; Baldwin 1969). The species was extirpated from lower elevations by the 1940's, and occupied only small areas of its historical range by the 1950's (Baldwin 1969; Banko and Banko 1980). Further substantial declines occurred through the 1960's and early 1970's, and it was during this period that numerous extra-limital sightings of `Alalā were reported. In 1976, an estimated population of 76 (± 18, 95 percent confidence interval) birds was restricted to elevations of from 900 to 1,900 meters (2,953 to 6,234 feet) in three areas in the Kona District (*i.e*., Hualālai, Hōnaunau Forest Reserve/McCandless Ranch, and Honomalino), and one area in the Ka`ū District (Scott *et al.* 1986). `Alalā have not been encountered in the Ka`ū District since 1977, when a single bird was observed in Hawai`i Volcanoes National Park in the easternmost part of its known historical range (Banko and Banko 1980).

Declines in the Kona subpopulations during the period from 1975 to 1990 were well documented as a result of breeding season surveys and field studies conducted by biologists of the U.S. Fish and Wildlife Service, the Hawai`i Division of Forestry and Wildlife, and personnel from other agencies and organizations (cf. Banko 1974, 1976; Sakai and Ralph 1980; Temple and Jenkins 1981; USFWS 1982; Giffin 1983; Sakai and Jenkins 1983; Sakai *et al.* 1986; Giffin *et al.* 1987; Jenkins *et al.* 1989; Sakai and Carpenter 1990). `Alalā populations in Honomalino (the southernmost Kona subpopulation), Hōnaunau (part of the middle Kona subpopulation), and on Hualālai (the northernmost Kona subpopulation) demonstrated similar rates of decline from 1975 to 1985, and limited banding information indicated unsustainably high rates of adult mortality (NRC 1992). `Alalā were extirpated from Honomalino and Hōnaunau by 1986. By 1987, the wild population had been reduced to a single 12-year-old female on Hualālai and an undetermined number on the McCandless Ranch near Hōnaunau (NRC 1992). The Hualālai female was last observed in late 1991. A thorough survey of the McCandless Ranch in 1992 indicated a wild population of 12 birds, including a single juvenile (Engbring 1992). No additional `Alalā were found during a subsequent survey of extensive forest tracts around the island (Klavitter *et al.* 1995a).

After 1993, the wild population of `Alalā was observed intensively, as the number of birds gradually declined to a single pair in 2002, which inhabited parts of Keālia Ranch and the Kona Forest Unit of Hakalau Forest National Wildlife Refuge in South Kona. This pair has not been located since June 2002 and presumably no longer survives. Unconfirmed reports suggest that a single `Alalā inhabited the western slopes of Hualālai in 2001; this might possibly have been an individual that disappeared from the McCandless Ranch area[1] between 1994 and 2000.

Concern over the rapid declines observed in the population led the State of Hawai`i to begin opportunistically acquiring sick or injured `Alalā for maintenance in captivity. Beginning in 1970, a few birds were variously kept in the research aviary at Hawai`i Volcanoes National Park, at the Patuxent Wildlife Research Center in Maryland, and in the State's endangered species breeding facility at Pohakuloa, Hawai`i. Between 1970 and 1981, a total of 12 `Alalā were brought into captivity. Inadequate facilities and a low success rate instigated the transfer of this program, with nine captive birds, to Olinda, Maui, in 1986. Improvements in facilities and methods over the years has resulted in some increased reproductive success. Although captive propagation of the `Alalā has proven difficult and remains a challenge, the existence of this captive flock, which currently numbers 40 individuals housed at captive breeding centers on Hawai`i and Maui, has prevented the complete extinction of this endemic Hawaiian bird. The recovery of the species now relies entirely upon this captive population.

## F. Habitat Requirements and Life History

The full range of habitats that the `Alalā potentially could exploit cannot be defined adequately with available information because limiting factors are

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[1]This area refers to the adjacent properties of Keālia Ranch, the Kona Forest Unit, and McCandless Ranch, all formerly part of a larger McCandless Ranch which was divided in 1992.

incompletely known and recent subpopulations were confined to a subset of current habitat types. Historical habitats, associated plant communities, foods, and known life history parameters are detailed by Banko *et al.* (2002), USFWS (1999), and NRC (1992), and are summarized below. Most of what is known about the `Alalā has come from observations of highly fragmented and declining populations, rendering our knowledge of the species' habitat needs, social behavior, movements, and life history incomplete. For example, when the species was relatively abundant, flocks of `Alalā were observed to make extensive seasonal movements in response to weather and the availability of the `ie`ie vine (*Freycinetia arborea*) and other native fruit-bearing plants (Munro 1944). Such movements have not been documented in recent observations, and flocking behavior has not been well studied due to low population densities in recent decades.

Since it was first observed by naturalists, the `Alalā has been associated with closed to moderately open native forests with fruit-bearing understory vegetation. The habitat with the highest breeding densities of `Alalā during the period 1970 to 1982 was relatively undisturbed `ōhi`a-koa forest; `Alalā avoided disturbed forest (Giffin et al. 1987). In addition, a significant amount of protective understory cover appears to be important to `Alalā in avoiding predation by 'Io (USFWS unpubl. data). The `Alalā feeds on native and introduced fruits, invertebrates gleaned from tree bark and other sites, and eggs and nestlings of other forest birds. Nectar, flowers, and carrion are minor diet components. A strong association was noted with`ie`ie, which formerly blanketed extensive tracts of mid-elevation mesic and wet forest (Menzies 1920); however, `Alalā were not observed in wet forests where `ie`ie is abundant. This plant has edible flowering bracts and fruit, and was a prominent item in the 'Alalā diet. This close association with forested habitats and reliance upon fruit as a primary component of its omnivorous diet sets the `Alalā apart from its continental relatives.

`Alalā are known to have lived 18 years in the wild (female) and 25 years in captivity (male; Banko *et al.* 2002). Age at first breeding for females is approximately 2 years, for males 2 to 3 years. In captivity, males 18 months old have copulated. `Alalā are monogamous and often have long-term pair bonds, although extra-pair copulations have been observed. In captivity, behavioral compatibility of potential mates is a prime consideration for pair formation.

Nest construction usually begins in March and first clutches are laid in April. Recorded nests have been predominantly in ‘ōhi‘a, although other trees and ‘ie‘ie vines may be used (Tomich 1971). All recorded nests have been at elevations between 1,000 and 1,800 meters (3,280 and 5,905 feet), although the species nested at lower elevations in the recent past (Munro 1944). Known nest sites have been in areas with 600 to 2,500 millimeters (24 to 98 inches) of annual rainfall (USFWS 1999). Nesting territory size probably varies with resource and population density; the shortest distance between active nests observed in recent times is 300 meters (984 feet). Pairs normally lay from two to five (usually three) eggs per clutch in the wild and raise one brood of one to two chicks per season (Banko *et al.* 2002). Pairs will relay upon loss or removal of the first, and, at times, the second clutch, allowing for increased reproduction in captivity. Incubation lasts approximately 19 to 22 days. Juveniles fledge approximately 40 days after hatching, but are poor flyers initially and can remain near the ground for long periods. Wild juveniles remain dependent for 8 months or more and associate with their parents at least until the following breeding season. Past reports of flocking behavior suggest that prolonged association of multiple generations occurred when the species was abundant, as is the case with other corvid species (Madge and Burn 1994).

## G. Reasons for Decline and Current Threats

The historical decline of the `Alalā and the associated changes in its habitat have been examined in detail (NRC 1992; USFWS 1999; Banko *et al.* 2002). The following summary is largely abridged from these sources. Because reliable data on causes of wild `Alalā mortalities are lacking, and because many changes in the habitat have occurred simultaneously (Cuddihy and Stone 1990), the key processes driving the decline of the species are incompletely known. However, the entire historical range of the `Alalā has been modified by alien species and human activities with negative effects on the `Alalā’s survival and/or reproduction. In addition, significant threats to the species are inherent in the small size of the surviving captive population.

We consider five major threats to species in order to list, delist, or reclassify a species:

A – Present or threatened destruction, modification or curtailment of habitat or range;
B – Overutilization for commercial, recreational, scientific, or educational purposes;
C – Disease or predation;
D – Inadequacy of existing regulatory mechanisms; and
E – Other natural or man-made factors affecting the continued existence of a species.

Three of these threats: (A) present or threatened destruction, modification or curtailment of habitat or range; (C) disease or predation; and (E) other natural or man-made factors affecting the continued existence of the species, are considered the most significant factors impacting the `Alalā today. In addition, existing regulatory mechanisms (D) are not adequate to protect `Alalā from diseases such as West Nile virus. Overutilization for commercial, recreational, scientific, or educational purposes (B) is a factor that does not threaten the `Alalā. The `Alalā is not used for commercial or recreational purposes, and scientific and educational uses are designed to eliminate potential negative effects.

**Factor A - Present or threatened destruction, modification or curtailment of habitat or range**

Habitat alteration on Hawai`i has been large-scale and is continuing. There is no existing forest within the historical range of the `Alalā that has not been substantially altered from its pre-European condition (Cuddihy and Stone 1990), much less from its condition prior to human colonization of the islands. The `Alalā evolved in pre-human Hawai`i, where closed-canopy forest was the dominant vegetation type. Extensive grasslands were absent, understory vegetation was dense, grazing mammals were absent, fires were rare and localized, and many plants were dependent on birds for pollination and seed dispersal. Major changes in vegetation followed the arrival of Polynesians (Cuddihy and Stone 1990; Athens 1997; Burney *et al.* 2002), and these changes were greatly accelerated after European contact. Habitat changes include complete and partial deforestation, selective species loss, and invasion or replacement by nonnative plants. These changes are the result of a variety of processes linked to human activities. Aside from the obvious case of outright deforestation, the individual and collective importance of forest changes to `Alalā is conjectural, but probably have played a role in the species' range reduction and extirpation. Because of the landscape-scale movements that allowed historical populations of `Alalā to exploit patchy food resources and escape harsh weather, alteration of small but crucial parts of their range and reduction in some food plants (*e.g*., clearing low elevation forest for agriculture and vegetation changes throughout the species' range) may have reduced the `Alalā's ability to persist over large areas. In addition, opening of the forest structure through grazing and tree cutting may have made `Alalā more vulnerable to predation by `Io.

**Factor C - Disease or predation**

Avian diseases known to affect native forest birds, including the `Alalā, arrived with European settlement. Avian malaria and avian pox probably arrived in Hawai`i in the early 1800's and became highly transmissible when mosquitoes were introduced (Atkinson *et al.* 1993a,b). The sharp apparent decline in the `Alalā population between 1890 and 1910 coincided with a decline of other native birds in the mid-elevations, and may have been due to a malaria outbreak (Munro 1944). The lethality of avian malaria for `Alalā in the wild is unknown (Jenkins *et al.* 1989). Juvenile captive-reared `Alalā are able to survive malaria and pox infection with supportive care.

Recent studies have shown that `Alalā are highly susceptible to toxoplasmosis, a disease caused by a parasite (*Toxoplasma gondii*) that is spread by feral cats, which now exist throughout historical `Alalā habitat (Work *et al.* 2000). Whether this pathogen played any role in the decline of the wild population is unknown, but it has caused mortality of young `Alalā released into the wild. The potential establishment of a mosquito-borne pathogen, West Nile virus, could be devastating to `Alalā in the future due to its high lethality in corvids (Komar *et al.* 2003).

Other than a bat species, pre-human Hawai`i had no terrestrial mammals, and no ground-based predators. The only potential predators of the `Alalā or any other large Hawaiian bird were the `Io and some now-extinct raptors. As a result, in their evolution `Alalā appear never to have developed behavioral protection against mammalian predators, and fledgling `Alalā are extremely vulnerable to feral cats, mongooses, dogs, and other mammals. Feral cats have spread into all forested areas of the main islands since their introduction in the early 19th century. Mongooses were introduced to the island of Hawai`i in 1883 (Tomich 1969), and are now common throughout historical `Alalā habitat. Mammalian predators are strongly implicated in the endangerment and extinction of many Hawaiian birds (Atkinson 1977, 1989; VanderWerf and Smith 2002), are known to kill `Alalā (USFWS unpubl. data), and undoubtedly have impacted the `Alalā population.

Predation on `Alalā by `Io was not reported prior to 1992. However, intensive study in connection with the reintroduction program that begain in 1993 showed that juvenile and adult `Alalā raised in captivity can be killed and eaten by `Io in the wild. Wild adult `Alalā were also observed being harassed and struck by `Io, and some individuals may have been killed. `Io depredation may be linked to altered forest structure, unnaturally high `Io densities, low `Alalā numbers, behavioral traits of released birds, or some combination of factors. No data exist to determine the role, if any, of `Io in the historical decline of the wild population.

Human predation on `Alalā has occurred (Munro 1944), although the level of hunting and its effects on the `Alalā were never measured. Anecdotal reports of shooting in the 20th century suggest that legal protection of the `Alalā by the Territory of Hawai`i beginning in 1931 was not fully effective. Because the `Alalā has a relatively low reproductive rate, population persistence and growth depends upon high adult survivorship (NRC 1992). High mortality of adults, noted as the proximate cause of recent population loss in the NRC report (1992), may have been partly due to illicit shooting of the conspicuous and relatively tame `Alalā.

**Factor D - Inadequacy of existing regulatory mechanisms**

The `Alalā is federally listed as an endangered species and is listed as an endangered species by the State of Hawai`i and thus receives protection under the Federal and Hawai`i State Endangered Species Acts. However, State and Federal regulations controlling shipment of poultry and game birds to Hawai`i via first class mail, quarantine of pet birds shipped to Hawai`i, and cargo inspection programs may not be adequate to prevent the inadvertent importation of new diseases such as West Nile virus and the transfer of disease strains among islands that could seriously reduce the potential to recover the `Alalā.

**Factor E - Other natural or man-made factors affecting the continued existence of the species**

In addition to the extrinsic factors of habitat loss and degradation, disease, and predation that increased `Alalā mortality rates and/or decreased their reproduction, factors intrinsic to small populations may have played a role in the decline of the species. Fragmentation of the formerly contiguous population would have limited genetic exchange and increased the risk of inbreeding and genetic drift. Small populations of monogamous species are subject to demographic accidents which can further reduce the number of breeding pairs, or increase disruption of breeding pairs by unmated birds (USFWS, unpubl. data). Over the past several years, it appears that lethal abnormalities are occurring at a higher rate in the captive flock, suggesting inbreeding depression (Zoological Society of San Diego, unpubl. data).

***Efforts to Reduce Threats***

Habitat threats directly related to human activity are present but are potentially easier to control or eliminate than threats of disease or predation. Clearing of mid-elevation native forest for house lots and agriculture is continuing in Kona as the human population grows. Loss of dry forests to fire and fire-associated introduced fountain grass (*Pennisetum setaceum*) continues, but new control strategies are being developed. Logging of old-growth koa continues on private lands, reducing the quality of upland forests, but reforestation with koa is becoming commercially attractive. Commercial cattle grazing in native forests is becoming less economically viable, and has been discontinued in some areas of historical habitat. Substantial areas of upland forest may see complete ungulate removal within the next decade.

None of the threats related to alien species that are suggested as contributing to the decline of the `Alalā have been eliminated within historical habitat. Feral and domestic cattle grazing is being reduced in much of central Kona, potentially leading to some vegetation response, but feral pigs and other ungulates remain common, and mouflon sheep populations are expanding into historical `Alalā habitat. Mosquitoes, rats, cats, and mongooses have yet to be reduced over significant areas of forest, although some promising control technologies exist or are being developed (Innes *et al.* 1995). Alien bird species, which act as potential disease reservoirs or competitors with `Alalā, are expanding their range in upland forests, as are invasive plant species (Van Riper and Scott 2001; Loope *et al.* 2001). Serious avian diseases are well-established, and potentially devastating new pathogens, such as West Nile virus, are spreading in North America (Centers for Disease Control and Prevention 2002). Currently, protection can be provided to captive birds either by placing mosquito netting over aviaries and/or possible immunization.

## H. Review of Recovery Program 1993 to 2003

Recovery actions and status of the captive and wild `Alalā between publication of the first `Alalā Recovery Plan (USFWS 1982) and 1992 were summarized by the National Research Council (NRC 1992). An intense period of recovery work began in 1993; these most recent recovery efforts will be briefly summarized below. This recovery work included field studies of wild and released `Alalā on McCandless Ranch, Hawai`i, and captive propagation at the Maui Bird Conservation Center on the island of Maui and Keauhou Bird Conservation Center on the island of Hawai`i. Data collected since 1992 are being managed, documented with metadata, and archived by the U.S. Geological Survey, Biological Resources Division, at its Kīlauea Field Station with financial support from us. Additional funding will allow more detailed and thorough analyses of the data, allowing further refinement of our management efforts as the recovery program advances.

**Wild Population**

The wild population on the McCandless Ranch, South Kona, Hawai`i, declined from 12 birds in 1992 to 2 birds in 2002, with the apparent loss of this population by 2003. As no other `Alalā are known to exist in the wild, the extirpation of the South Kona/McCandless population means the `Alalā is presumed extinct in the wild. The annual survival rate of the wild birds calculated during this period (79.8 percent; Figure 2) was similar to the value modeled in the National Research Council report from banded birds at this site (81 percent; NRC 1992). Because these wild birds were not telemetered, their carcasses were not recovered and the causes of death are unknown. The only wild juvenile known to be produced between the years 1992 and 2003 (from a pair in Kalahiki in 1992) was last seen in 1997.

Wild `Alalā often would disappear from the study area for extended periods. Their actual home ranges were therefore probably larger than documented. The median home range recorded was 480 hectares (1,186 acres) (range 59 to 1,456 hectares [146 to 3,598 acres] n = 20; USFWS 1999). Several reports of `Alalā outside the McCandless area between 1992 and 2001 were investigated by our biologists, but none were confirmed.

Behavioral observations were conducted and allowed limited comparisons of foraging and activity budgets of wild versus released birds (Sherman *et al.* 1994). Interactions of wild birds with juveniles in the field aviary and post-release were usually aggressive. One wild male courted a captive-reared female and limited nest building ensued, but no reproduction occurred.

From 1993 to 1996, 8 clutches of 1 or more eggs were collected or salvaged from wild nests for captive rearing, yielding 13 chicks. Although several pairs renested, and second clutches were not routinely collected, no chicks fledged from second nesting attempts. Reproduction in wild `Alalā ceased in 1996. The last remaining pair (last observed June 2002) were adults in 1992, and

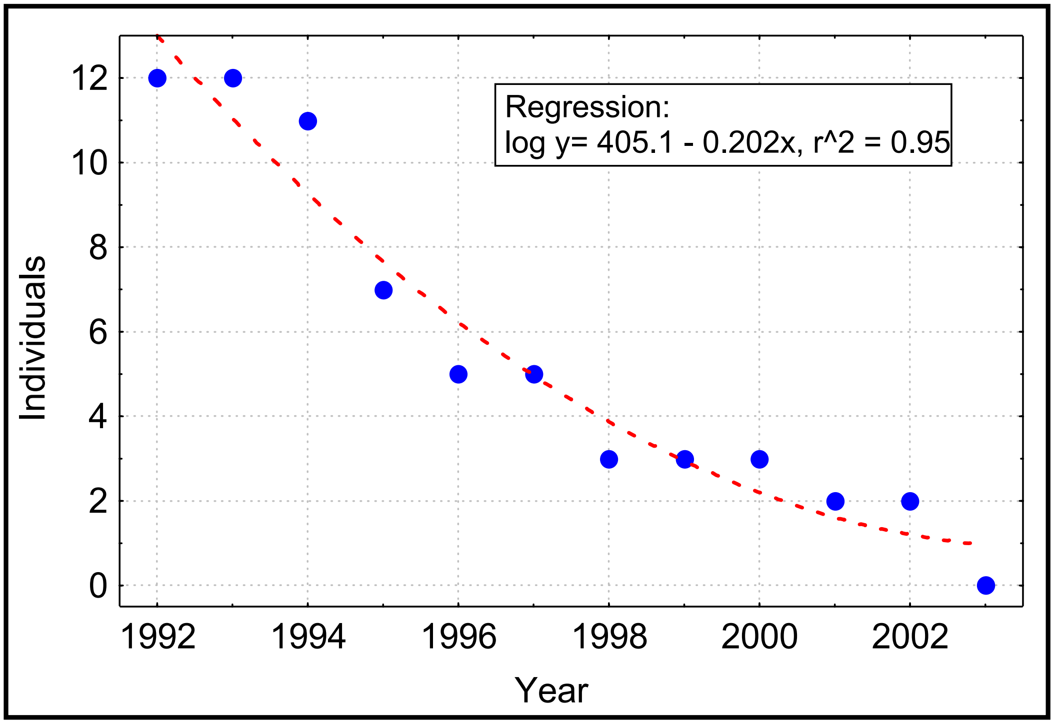


**FIGURE 2.** The decline of the wild `Alalā population in the South Kona/McCandless Ranch area fits a 20.2 percent mortality rate.

so are presumed to have hatched prior to 1989. Observations of behavior and reproductive history suggest that after 1995 this was a recombined pair, consisting of a male and female from former neighboring pairs (Keālia and Ki‘ilae, respectively, referring to their area of geographic origin). Consistently aberrant nesting behavior and lack of egg production since 1997 suggest that the female was reproductively defective or senescent.

### Captive Propagation

Maintenance of the species in captivity began with the occasional acquisition of sick or injured `Alalā by the State of Hawai`i in 1970. In 1986, the nine `Alalā in captivity at Pohakuloa were transferred to a new breeding facility in Olinda, Maui (Banko *et al.* 2002 provide a history of the captive propagation program from 1970 to 1995). In 1993, The Peregrine Fund assumed management of the program to hatch, rear and release `Alalā; this organization was also commissioned to build a new captive propagation facility dedicated to reproduction of `Alalā and other endangered species of Hawaiian forest birds. This new facility, near Volcano on the island of Hawai`i, was finished in 1996 and was designated the Keauhou Bird Conservation Center. In 1996, the Peregrine Fund also assumed the operations of the Olinda Endangered Species Propagation Facility from the State of Hawai`i, and renamed it the Maui Bird Conservation Center. The Zoological Society of San Diego took over the operation of both the Keauhou and Maui Bird Conservation Centers in 2000, and titled the combined program the Hawai`i Endangered Bird Conservation Program.

The captive propagation program was intended to produce juvenile `Alalā for release into the wild, both from captive-laid and wild-collected eggs, and did not attempt to capture or retain all genetic diversity present in the wild population. The program at inception assumed continued reproduction in the wild and integration of released juvenile birds into the wild breeding population (NRC 1992). As it happened, neither of these assumptions held true. Due to the termination of the release program in South Kona and the demise of the wild flock, as of 2003 the total `Alalā population is represented by the 40 individuals in the captive flocks at the Keauhou and Maui Bird Conservation Centers (Figure 3).

Suboptimal rearing conditions prior to 1993 severely limited reproduction and created behavioral problems in some of the captive `Alalā (Harvey *et al.* 2002). These problems have been corrected as much as possible, but reproductive rates and viability of eggs in captivity are lower than those documented from the wild. In general, this species does not breed well in captivity: pairs require separate aviaries, many potential mates prove to be incompatible, infertile eggs are common, and males tend to interfere with egg laying and incubation. In addition, inbreeding is apparently affecting fertility and reproductive outcomes (Zoological Society of San Diego, unpubl. data).

Founder representation and gene diversity analyses for the captive flock (Appendix A) are based on the assumption that founders are unrelated and that the wild population is extinct. However, the assumption that all founders are

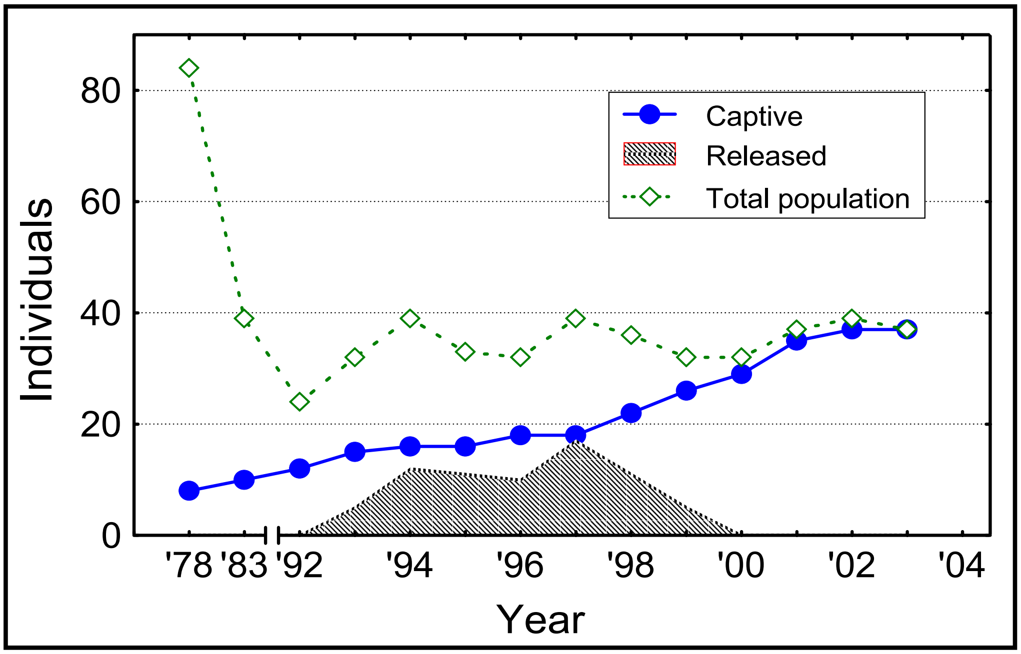


**FIGURE 3.** Components of the `Alalā population over time. Population estimate in 1979 from Scott *et al.* (1986). Wild population is zero as of 2003.

unrelated may not be accurate given the size of the wild population and the geographic distribution of the birds at the time of collection. Currently, the estimated mean inbreeding coefficient (F) is 0.097, and this will increase with time due to the small size of the population and the lack of additional genotypes. Actual inbreeding may be higher if some of the population founders, assumed to be unrelated, were in fact related; therefore current gene diversity may be lower than currently estimated. An increasing inbreeding coefficient is often associated with a reduction in traits closely associated with fitness, such as body size, fecundity, and longevity (Lande and Barrowclough 1987). As previously unmated birds have begun to breed, the proportion of breeders to the total population ($N_e/N$) has increased over time, and now stands at 0.29. Currently, generation length is 10.1 years, and the rate of population increase ($\lambda$ or lambda) is 1.07, representing a growth rate of 7 percent per year. Current gene diversity (as percent of the original founding population, not of the original species' genetic diversity) is 81.7 percent. One lineage (Keālia, named for its area of geographic origin) has disappeared from the captive flock due to mortality of captive and released offspring.

The current combined capacity of both captive propagation facilities is 10 breeding pairs. Limited aviary space is available for juveniles, which become aggressive toward each other at about 18 months of age. The total captive population of 40 birds includes several adults that do not breed due to various problems. In 2003, there were nine laying pairs of `Alalā.

The achievement of an optimal genetic and demographic composition in the population requires active management consistent with maintenance of all possible existing genetic diversity, consistent with our policy regarding controlled propagation of listed species (U.S. Department of the Interior 2000) and American Zoo and Aquarium Association guidelines (Appendix B), for a period of at least 20 years. Twenty years is thought to be the minimum period of time during which the genetic and demographic security of this species will depend wholly or largely upon the maintenance of the captive flock. Depending upon success in establishing self-sustaining wild populations, it may be necessary to continue maintenance of all possible existing genetic diversity within the captive flock for a period greater than 20 years.

**Reintroduction**

Twenty-seven juvenile `Alalā, originating from both captive and wild parents, were raised in captivity and released in South Kona at the McCandless Ranch between 1993 and 1998. This location was chosen to allow maximal interaction and integration with the remaining wild population. All birds were telemetered and relocated at frequent intervals, allowing detailed observations of behavior. Foraging behavior of juveniles was less efficient than that of wild adults but was sufficient for survival (Klavitter *et al.* 1995b). Twenty-one of the released birds died over the program’s duration, and the remaining 6 were recaptured in 1998 and 1999 for reintegration into the captive flock (Figure 4). Many of the birds died before reaching the age of sexual maturity (approximately 2 years), and the rate of mortality did not appear to decline as the released birds matured, as normally expected in birds. The predicted maximum life span of released birds under these conditions would be about 5 years.

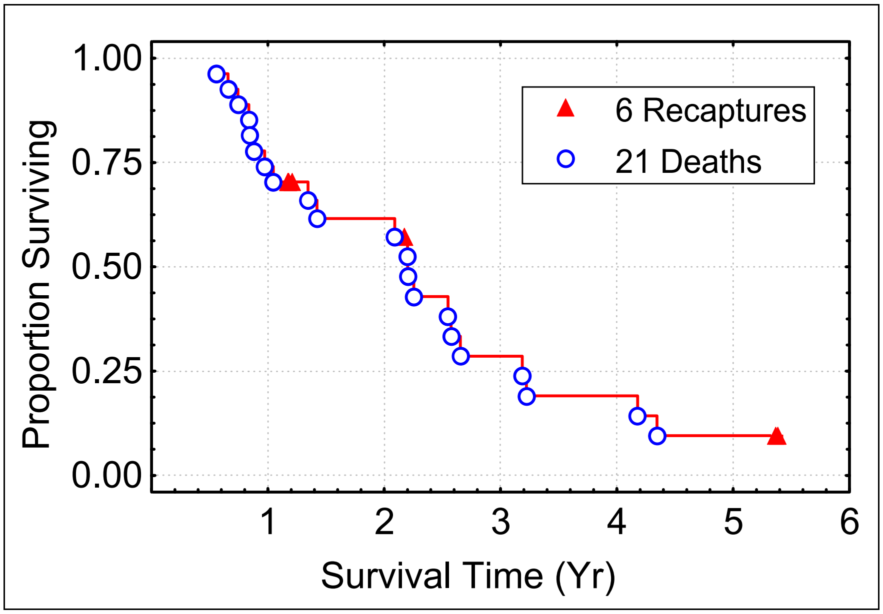


**FIGURE 4.** Survival function of the 27 `Alalā released at McCandless Ranch 1993 to 1998. Survival time is age at death/disappearance or recapture (since all birds were released as juveniles, survival time is roughly equivalent to the age of the bird). Two birds of the original 1993 cohort were recaptured after over 5 years in the wild.

The cause of death was determined for most of the released birds (Figure 5). Seven died from lethal interactions with `Io, three died from toxoplasmosis (Work *et al.* 2000), two died from other infections (Work *et al.* 1999), and one died from mammal predation. The bodies of eight of the birds were not recovered, so the cause of death for these individuals remains unknown. Necropsies of the remains that were found showed poor condition in some birds but not others. Although a positive determination is not possible, it is conceivable that poor condition may have predisposed some birds to death by infection or predation.

Contrary to predictions (NRC 1992), avian malaria and pox were found not to be sources of mortality for released `Alalā, since all of the released birds survived exposure to these pathogens. However, several birds were provided with active veterinary support prior to release when weakened by apparent malarial infections.  Toxoplasmosis, carried by cats and possibly contracted by manipulation of cat feces (which has been observed in several birds), was a previously unknown source of mortality, as were the bacterial and fungal pathogens responsible for two deaths.  Predation by `Io was also previously unknown.  `Io were observed to chase and strike both captive-reared juveniles and wild adults.  Wild adults appeared to have a larger and more effective behavioral repertoire to address `Io, engaging in distraction displays and in some cases being observed to chase `Io.  Additionally, most wild birds were paired, perhaps improving their ability to detect and avoid predator attacks.  No actual predation by `Io on released birds was observed, but circumstantial evidence was compelling.

No reproduction, and only limited sexual activity, was observed in the released birds despite 12 birds reaching an age of at least 2 years, when reproduction in wild `Alalā is known to begin (Banko *et al.* 2002).  One pair

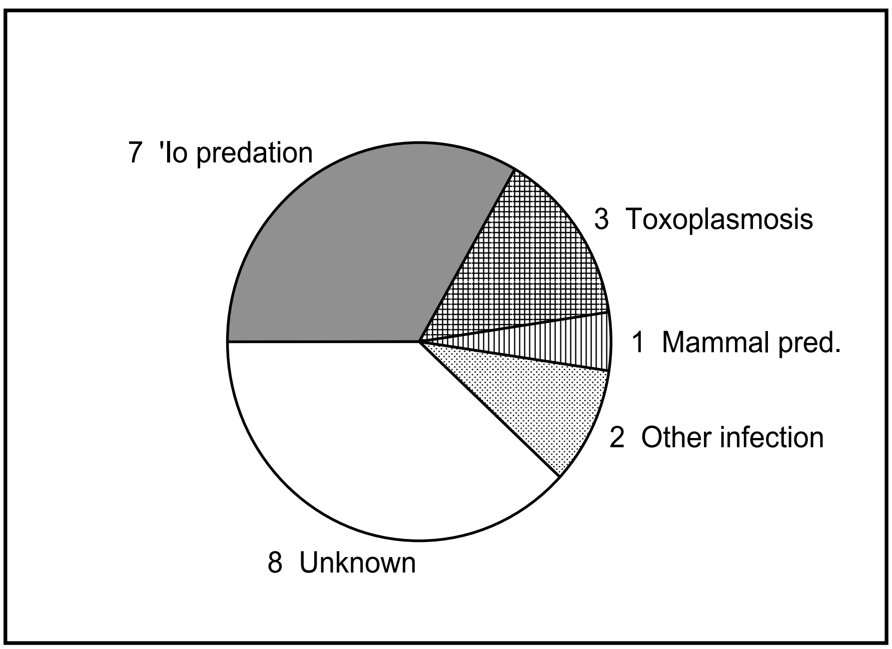


**FIGURE 5.** Causes of mortality of 21 captive-reared `Alalā released at McCandless Ranch.  Cause could not be determined for eight birds whose remains were not recovered.

formed from released birds but did not reproduce. A second released female was courted by a wild male and showed early signs of nest initiation (carrying and placing a few sticks), but did not continue beyond this stage. The causes of this failure by released birds to reproduce are unknown, but may include the instability of the juvenile social group due to releases and mortalities, negative interactions with adult pairs, and incest avoidance mechanisms triggered by rearing birds together.

The prediction that released birds would integrate into the wild population was not borne out. The majority of interactions with the wild population were aggression by adults toward released birds. The released birds ranged more widely and to lower elevations, possibly to avoid interactions with the wild birds but perhaps also to exploit abundant and easily obtained food.

**Habitat Management**

The Kona Forest Unit of Hakalau Forest National Wildlife Refuge was purchased in 1999. This tract (Figure 6) of 2,145 hectares (5,300 acres) was acquired in order to begin intensive habitat improvements in the core of the `Alalā's former range. However, due to legal and operational constraints on activities, significant habitat improvement actions have not yet begun. A private foundation grant of $1 million was obtained in 1999 to fence the Unit and eradicate feral ungulates, but the work could not be done because of legal disputes on access and other topics with the former landowners. Because the project was not completed, the grant was reclaimed by the grantor in 2003.

No organized feral ungulate removal actions took place in occupied `Alalā habitat during the release program. Trapping of mammalian predators was begun by the McCandless Ranch and continued by us during this time. Although data on captured predators were collected, the program's effect on predator populations was not measured. Trials in 2002 of predator-proof fencing show that this technology could keep all small mammals out of natural areas in Hawai`i, but would require large capital investment and maintenance costs. Using American Crow (*Corvus brachyrhynchos*) as surrogates for `Alalā, studies were conducted to assess the non-target risk posed by potential use of the toxicant diphacinone to

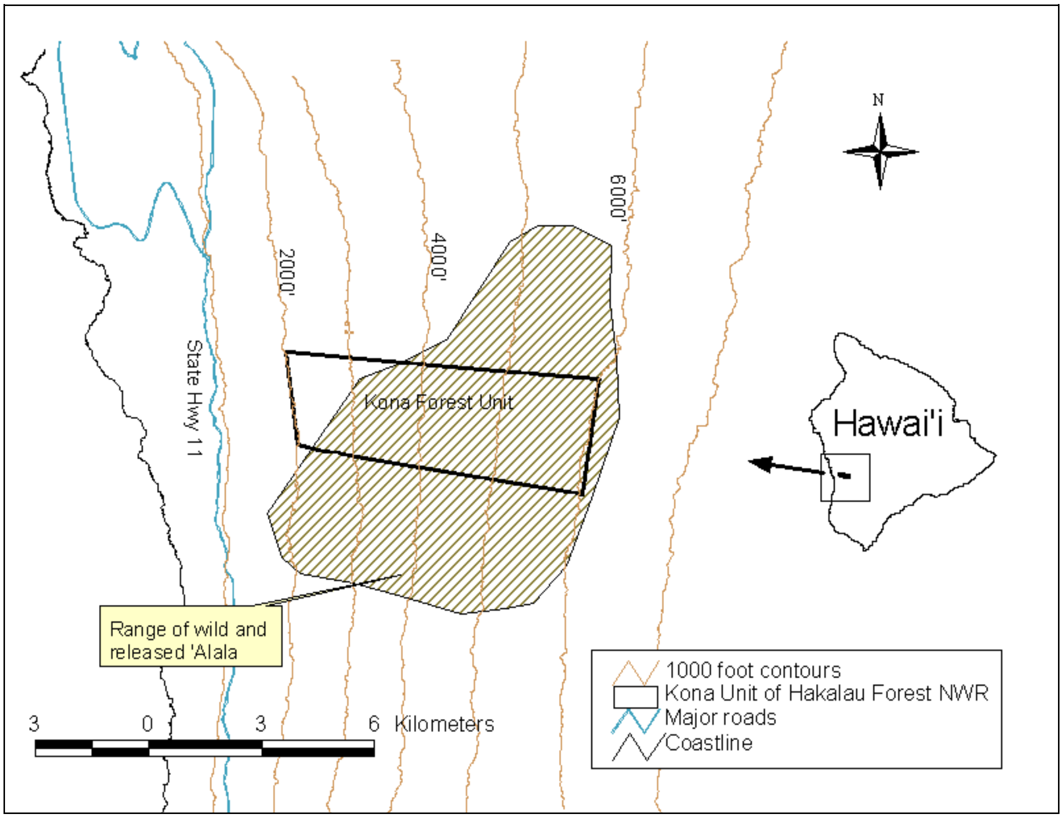


**FIGURE 6.** Location of Kona Forest Unit and approximate boundaries of `Alalā population during release program, circa 1997.

control rats. The crows were found to tolerate the toxicant with no significant ill effects (Massey *et al.* 1997). However, no toxicants have been used to date in `Alalā habitat.

Once `Io were recognized as a threat to released `Alalā, some capture and relocation of resident `Io in the release area occurred. Ten `Io were taken from the release area in 1997 and 1998 and sent to mainland zoos for captive breeding. Relocation efforts were not successful in reducing the numbers of `Io for more than a few weeks because the `Io that were moved to other parts of Hawai`i soon returned to their capture area, and territories vacated were rapidly filled by adjacent `Io. `Io taken to the mainland served an educational purpose, promoting the recovery of the species, but did not breed.

Observations of `Io/`Alalā interactions by program biologists strongly suggested that forest areas lacking dense vegetation structure, especially in the subcanopy and understory layers, afforded few opportunities for `Alalā to evade aggressive `Io. These "park-like" areas of native trees with alien grasses, typically found in forest areas grazed by feral and domestic ungulates, were common at the South Kona release site. A study of `Io densities around the island of Hawai`i found that this habitat type had higher densities of 'Io than did native forest with intact understory (Klavitter 2003).

Consultation with the `Io Recovery Working Group (an advisory team appointed by the U.S. Fish and Wildlife Service) resulted in their recommendation to release `Alalā in sites without resident `Io (*i.e.*, on another island) in order to remove the major documented mortality agent for the released birds (`Io Recovery Working Group 2001). This group felt that other proposed actions to deal with `Io predation were infeasible or of questionable efficacy in the short term. However, the generally poor and fragmented condition of dry and mesic forests on other Hawaiian islands suggests that releases outside the historical range of the species might not offer an advantage despite the absence of `Io.

Based on sites prioritized by the `Alalā Recovery Team, a draft Environmental Assessment was prepared in 1999 examining the potential of five sites on Hawai`i to support an `Alalā release program (USFWS 1999). The sites were publicly owned lands at Pu`u Wa`awa`a, Honomalino, Kapāpala, Kūlani, and Hakalau Forest, in addition to the McCandless Ranch area. Public comments were received on the draft Environmental Assessment, and these included suggested additional sites and the suggestion that we consider introduction of the `Alalā in areas outside of its historical range, where some threats, notably `Io, may be reduced or absent. A number of new sites will be scored and ranked with the assistance of the recovery team before a final Environmental Assessment is prepared proposing the next release sites for the `Alalā program. Completion of this public notification process is a high priority action in the Implementation Plan.

**Public Awareness**

During much of the release program, the McCandless Ranch and Cattle Company operated an ecotourism business that highlighted the `Alalā. Personnel from both the U.S. Fish and Wildlife Service and The Peregrine Fund interpreted the release program for clients. Substantial numbers of bird enthusiasts were able to see the `Alalā and understand the recovery efforts underway.

The Keauhou Bird Conservation Center has had an active outreach program throughout its existence. Emphasis is on elementary school students, but adults are also exposed to the plight of native birds and the role of captive propagation in their recovery. As one example, for several years under The Peregrine Fund, names for hatchling `Alalā were solicited from schoolchildren in a "Name the `Alalā" contest.

As a direct outcome of collaboration between landowners and agency personnel working on `Alalā recovery, the State of Hawai`i's law concerning endangered species was amended in 1997 to allow incidental take of listed species and Safe Harbor agreements. In 2000, following publication of the draft Environmental Assessment for `Alalā reintroduction, meetings were held with large landowners with parcels bordering proposed release sites. At these meetings, the we described the Safe Harbor program as a tool for reintroduction of `Alalā that provides assurances to landowners. We also discussed concerns held by the landowners regarding endangered species recovery. Most recently, in 2003, representatives from the U.S. Fish and Wildlife Service, the State of Hawai`i, Keauhou Bird Conservation Center managers, and Federal researchers met with Hawaiian cultural practitioners to discuss the `Alalā as part of the Hawaiian community cultural heritage.

**Program Management**

The `Alalā Recovery Team, formed in 1992, contains delegates representing private landowners and conservation organizations in addition to technical experts and agency personnel. This configuration was intended to facilitate resolution of non-biological issues in the recovery planning process.

Meetings occurred once or twice per year from 1993 to 1998 during the period of releases.

A second group, termed the `Alalā Partnership, was formed to work out problems of program implementation on private lands in the release area. This group included some members of the recovery team as well as additional landowner representatives, and met monthly during the release program. After the recapture of the remaining captive-released `Alalā from the wild in 1999 and the decline of the wild population to three birds in 2000, the `Alalā Partnership ended its meetings.

Field monitoring of the `Alalā under the leadership of the U.S. Fish and Wildlife Service and the U.S. Geological Survey Biological Resources Division involved the extensive use of volunteers which reduced costs but also affected the continuity of data collection. Following the recapture of the last released birds in 1999, monitoring of the remaining three wild birds was conducted solely by biologists from the U.S. Fish and Wildlife Service.

# Part II. STRATEGIC PLAN

## A. Recovery Strategy Overview

The `Alalā survives today only because a captive flock has been established and maintained; it would otherwise be extinct. This is the first Hawaiian forest bird whose extinction has been prevented by captive propagation. However, this captive flock (40 individuals in 2003) represents the progeny of only 9 founding individuals, and thus is an extremely small sample of the species' original gene pool. Because no `Alalā are known to remain in the wild, no further genetic variation can be added to the captive population. For all practical purposes, genetic diversity, once lost, cannot be regained, and the rate of loss in small, closed populations is high (Lande & Barrowclough 1987). Therefore, an urgent recovery need is to increase the size of the population, to slow this loss and retain all possible genetic diversity for the future.

The original recovery strategy (NRC 1992) aimed to achieve this necessary population growth in the wild, by augmenting the wild flock using captive rearing. This was the most cost-effective strategy and had many potential advantages, but was not successful due to high mortality rates of captive-reared `Alalā and a lack of integration and reproduction with the wild flock. It now appears that the habitat at the site used for the releases from 1993 to 1998, as well as throughout the historical range of the species, requires restoration in order to support an `Alalā population.

Because habitat restoration will be required to reduce mortality rates, it is not considered feasible at this time to reestablish a reproductive flock in the wild to achieve population expansion. Instead, increasing the population size in captivity, where reproduction can be maximized and mortality minimized, is the most rapid and efficient means to protect the genetic potential of the species. This recommendation to focus on captive propagation in the near term represents a major shift in recovery strategy for the `Alalā.

The `Alalā is difficult to breed in captivity, requires expert husbandry and separate aviaries for each pair, and has a relatively low rate of successful reproduction. These factors all make captive propagation a challenging and expensive enterprise requiring sustained funding growth to keep pace with growth of the population. Current levels of funding were intended only to support a small captive flock that would supplement a growing wild population. All of this growth must now occur in captivity, and until populations are recovering in the wild, the captive flock must become large enough to maintain the genetic potential of the species. With the change to a near-term captive propagation strategy outlined in this document, additional funds must be found to meet the expanding needs of this aspect of the `Alalā recovery program.

The second strategic imperative for `Alalā recovery is restoration of native forests to the point that released `Alalā can survive and reproduce. Forests within the historical range of the `Alalā have been severely impacted by human activities, alien predators, alien diseases, and alien competitors (Atkinson 1989; Atkinson *et al.* 1993b; Cuddihy and Stone 1990), to the extent that the `Alalā can no longer persist unaided in its native habitat. While some direct mortality factors are known, the levels to which direct and indirect threats must be reduced to support recovery of the `Alalā are not clear, and will be the subject of specific research as restoration proceeds. Ecosystem recovery is a slow process, so restoration of sites that will be used for `Alalā recovery must begin at once. Otherwise the program risks producing birds for which no suitable habitat exists.

Downlisting and eventual delisting of the `Alalā will require the repopulation of extensive landscapes within which the birds' resource needs are met and mortality rates are low enough for the population to be sustainable. Restoration of Hawaiian mesic and dry forests requires intensive and sustained management (Stone *et al.* 1992), and is currently constrained by financial resources and competing priorities for land use. Innovative financial and political solutions must be found to the problems that currently impede restoration of those large areas of `Alalā habitat that are in public ownership. Full use must be made of the fact that recovery of numerous listed plants and animals that exist within the `Alalā's historical range will require land management actions that are also key to `Alalā recovery.

Protected natural areas managed for native biodiversity conservation will be important restoration sites, but expanding populations of `Alalā will eventually inhabit larger areas that will include private lands as well.  It is likely that much of the area required for `Alalā recovery will be managed primarily for goals other than conservation, given the limited size of protected areas.  Some means of keeping `Alalā mortality rates low in these altered landscapes must be found, through enhancement of key habitat components and development of threat reduction strategies in collaboration with private landowners.

Recovery of the `Alalā will initially be based on the reintroduction of captive-reared birds to the wild.  Such reintroductions are an active area of conservation research, and often require multiple attempts and innovative methods before success is achieved (Armstrong & McLean 1995; Haight *et al.* 2000).  The high initial mortality risks and high value of each bird necessitate careful design of the release program and intensive field monitoring to gain maximum information (Seddon & Cade 1999; Collazo *et al.* 2003).  A variety of rearing and release protocols may need to be tested to determine those that yield the highest rates of survival and reproduction in `Alalā.

In social species such as the `Alalā, many learned parental behaviors are transferred to young birds, increasing their survival skills (Bolles 1970).  Birds reared in captivity are thought to be at a disadvantage in the wild, at least initially, due to lack of parent rearing and/or lack of exposure to real-world resources and threats (Griffin *et al*. 2000).  It may be possible to provide learning experiences prior to release that will increase the lifespan of released `Alalā, as has been shown in other species (Van Heezik *et al.* 1999).  There is evidence that corvids have critical periods for learning (Heinrich 1995, Harvey *et al.* 2002), which could be used to better prepare `Alalā for release if the proper stimuli are provided at those times.  Of course, reproduction and parent rearing in the wild should eventually produce young `Alalā with an effective and naturally-acquired behavioral repertoire.

The `Alalā is a potent symbol of Hawai`i's natural heritage, and exposure of the public to this species and its plight is needed for many aspects of the recovery program to succeed. Financial support for the captive program and habitat restoration, acceptance of ungulate and predator management in natural areas, and cooperation by private landowners all depend on broad public understanding of the program's goals. The program managers will seek professional assistance in articulating these goals and needs to key groups and the general public.

The ultimate objective of this recovery plan is to restore multiple self-sustaining populations of the `Alalā within its historical range, and to reduce or eliminate the threats to its existence to the point that it will no longer require the protections of the Endangered Species Act and may be delisted. The size, extent, age structure and dynamics that the population must posses to be delisted are collectively referred to as the recovery criteria, and are not defined in this recovery plan. As noted above, much of the biological and demographic data necessary to determine the population sizes and parameters needed for recovery of the species do not exist. These data will become available over the next few decades as the species is reintroduced to the wild and the characteristics of those expanding populations are measured. After multiple years of survival and reproductive data on reintroduced populations are available, population modeling will allow us to propose recovery criteria in a future revision of this plan.

## B. Recovery Actions

As the recovery of the `Alalā will in part depend on characteristics of the species that are unknown at this time, characteristics of the environment that will continue to change during the recovery process, and the elucidation of threats to the species, it makes little sense to develop a detailed plan at an early stage in the recovery program when these factors are not well understood. Rather, the most efficient way to determine these unknown characteristics and refine the course of the recovery program is through the continuous application of adaptive management (Johnson 1999). We are applying this concept here by the development of 1) this Strategic Plan, which sets out the broad principles that we believe will hold for the duration of the recovery process; and 2) incremental

Implementation Plans, where results of the program to date are integrated, and detailed short-term plans are proposed for specific program actions which carry out this strategy.

In this Strategic Plan we have described long-term goals to achieve the recovery of the `Alalā; each recovery goal refers to one of five primary Recovery Actions identified for this species. These recovery actions and goals are presented below, together with guiding principles that should be adhered to when promulgating recovery actions in the Implementation Plans, and several priority issues that merit focused research or management action. The interim short-term goals to achieve recovery are presented in the 5-year Implementation Plan in Section III-A. The intersection between the recovery actions proposed in this plan and the threats (listing factors) that will be addressed by those actions is provided in the Implementation Plan Schedule in Section III-B.

**Action 1. Manage the Population of `Alalā**

***Recovery Goal***: The population has been managed to recovery when the genetic diversity present in the `Alalā population in 2003 has been preserved to the maximum extent possible, the population as a whole is demographically stable, two or more subpopulations exist in the wild, persistence of wild subpopulations does not require supplementation from a captive flock, and population models yield a probability of extinction within 100 years of less than 5 percent.

Principles:

1. Until the recovery goal is achieved, the purpose of the captive flock is primarily to act as a safe repository of the species' genetic diversity, and secondarily to produce birds for release and population reestablishment.
2. The achievement of an optimal genetic and demographic composition in the population requires active management consistent with maintenance of all possible existing genetic diversity for a period of at least 20 years. This management must be consistent with our policy regarding controlled propagation of listed species (USDOI 2000) and American Zoo and Aquarium Association guidelines (Appendix B).

3. Only birds that are genetically and demographically surplus to the captive flock or are post-reproductive may be subjected to higher mortality risk than exists under normal captive propagation conditions (*e.g*., reintroduction, parent rearing, zoo display).
4. Because techniques that may increase behavioral competence of `Alalā for release (*e.g*., parent rearing, pair releases) could reduce population growth rate, explicit consideration of the population consequences of such tradeoffs should be part of each Implementation Plan.
5. Populations in the wild should be managed together with the captive flock as a single population for purposes of genetic and demographic optimization, until the recovery goal is achieved. Subsequently, management of wild subpopulations should aim to prevent genetic drift and subpopulation decline.

Priorities for Research and Management:

1. Securing sufficient financial and institutional resources to adhere to the above principles and allowing the captive flock to support growth, maintenance, and other needs of the population.
2. Increasing the population growth rate, increasing the proportion of breeding birds, and increasing the reproductive success of under-represented birds.
3. Maintenance and inter-generational transmission of a behavioral repertoire that is as natural as possible under captive conditions, in order to maximize the potential success of reintroductions.

**Action 2: Manage Threats in Suitable Habitat**

***Recovery Goal***: Threats in suitable habitat have been managed to recovery when `Alalā subpopulations in the wild are growing or stable in landscapes which include areas managed for native biodiversity and lands managed for other compatible uses.

Principles:

1. The captive flock will be crucial to the `Alalā's recovery for the foreseeable future, but to fulfill its purpose there must be appropriate

habitat for release. Therefore, growth and maintenance of the captive flock should have equal priority with habitat restoration, and both should have priority over other uses of limited funds for `Alalā conservation.

2. Efforts to reestablish wild `Alalā populations should be focused on the largest and most intact areas of native vegetation. To the extent possible, forest ecosystems in these areas should be restored to the conditions thought to have supported stable populations of `Alalā in the past.
3. Restoration of forest vegetation in `Alalā habitat should be achieved by active management of disturbance agents, *e.g.*, through removal or effective control of herbivorous mammals and invasive alien plants, increasing the density of plants utilized by `Alalā, and control of fire and fine fuel loads where needed.
4. Habitat restoration efforts to benefit `Alalā should be fully integrated with other, complementary efforts to conserve other elements of native biodiversity within historical `Alalā habitat.
5. The ability of `Alalā to exploit patchy, seasonal food resources should be ensured by preserving or restoring areas of native forest at a range of elevations within foraging distance of each subpopulation.
6. The threat posed by avian diseases should be determined for each pathogen, and should be addressed as needed by controlling disease vectors and other factors linked with these diseases within areas used for population reestablishment (*e.g.*, mosquitoes and feral pigs associated with malaria, feral cats associated with transmission of toxoplasmosis).
7. The threat posed by predatory mammals should be addressed by removing these predators from areas used for population reestablishment, and working with neighboring landowners to extend predator control to surrounding areas.
8. Recognizing that `Io are endemic and valuable components of the native ecosystem, the lethality of interactions between `Io and `Alalā should be reduced or eliminated through habitat management, improved `Alalā rearing and release techniques, or other indirect methods.
9. The threat of human-caused mortality of `Alalā should be eliminated by fostering broad public awareness about, and support for, the `Alalā and its needs.

10. The threats in `Alalā habitat should be kept from increasing in number and severity by a strong statewide program to prevent new alien species introductions and to remove incipient threats before they become broadly distributed.

Research/Management Priorities:

1. Removal of alien herbivores and active restoration of vegetation from large areas of historical range, while controlling the threat of fire, in a range of forest types between 300 and 1,800 meters (984 to 5,905 feet) elevation.
2. Testing of the effectiveness of forest understory restoration, prey base reduction, and other habitat manipulations on `Io density and `Io\`Alalā interactions.
3. Testing and implementation of techniques for maintaining significant forest areas free of mammalian predators.
4. Use of regulatory incentives and other programs to increase effective management of `Alalā habitat on private lands, in order to expand the area and variety of sites for reestablishment, and to promote planting/restoration of native fruit-bearing plants at middle and low elevations.
5. Creating high local awareness of, and support for, `Alalā restoration in the communities surrounding potential release sites.
6. Establishment and maintenance of a state-wide alien species interdiction and incipient control program that includes wildlife diseases and their vectors.
7. Determination of the impact of avian diseases, including malaria and pox on `Alalā survival and reproductive success.
8. Testing and implementing techniques for maintaining significant habitat areas free of mosquito vectors of avian disease.

**Action 3: Establish New Populations in Suitable Habitat**

***Recovery Goal***: Reintroduction has achieved recovery when a successful program has resulted in multiple self-sustaining wild populations, and the maintenance of the captive flock is no longer necessary.

Principles:

1. Each release of captive-reared `Alalā should be designed around defined management questions and be conducted and monitored so as to obtain data needed to answer these questions.
2. Because not all threats to `Alalā are known or quantified, causes of mortality should be determined for all `Alalā released. This will require telemetry of all released birds and a field crew to monitor and recover birds as needed.
3. Reintroduction sites should be managed to reduce or eliminate threats to `Alalā, and site management practices should be modified in response to analyses of mortality and morbidity of released birds.
4. Support for `Alalā reintroduction at the local level is a prerequisite for a successful program. Partnerships, focused on the needs of the program, should be actively fostered with the communities surrounding release sites to facilitate habitat management, monitoring of the subpopulation, and to reduce one potential cause of `Alalā mortality.
5. Mortality rates, mortality factors, and population trends of released `Alalā and resulting wild subpopulations should be reviewed annually, to enable adjustment of the release program to achieve the recovery goal in the shortest possible time.
6. The acquisition and intergenerational transfer of adaptive behaviors should be exploited whenever possible to reduce vulnerability of reintroduced `Alalā to documented threats.
7. `Alalā intended for release should be so designated at the earliest possible stage and reared so as to maximize acquisition of behaviors intended to reduce mortality risks and increase reproductive success.

Research/Management Priorities:

1. Designation of one or more `Alalā release sites and commencement of habitat management meant to reduce threats to `Alalā.
2. Securing sufficient financial resources and cooperative agreements to support necessary management of release sites and adjacent lands with suitable habitat.
3. Determination of the habitat criteria that must be met prior to initiation of a release program at a particular site.

4. Planning and refining release and monitoring protocols to maximize potential success of `Alalā reintroductions while ensuring adequate tests of important management hypotheses.
5. Gaining the participation of experts to assist in behavioral management of birds intended for release, predator control, forest restoration, and public/private liaison.
6. Determination of the route of *Toxoplasma* exposure, and potentially developing behavioral protocols to minimize risk of infection while reducing disease reservoirs by removing feral cats.
7. Development of protocols to enhance the ability of `Alalā to respond appropriately to small mammalian predators and `Io.
8. Initiation of a breeding population in the wild as soon as possible given the need to safeguard the genetic and demographic integrity of the population. This will allow parental transmission of behaviors in a natural context, and provide for estimation of vital rates in a reintroduced population.

**Action 4: Garner Public Support**

***Recovery Goal***: At recovery, the `Alalā is seen by the public as a cultural asset, funding is adequate to support program needs, and active public support for the recovery program is evident.

Principles:
1. Financial and in-kind support for the `Alalā recovery program should be broad-based, including governmental and non-governmental sources, so that the resources necessary for flock growth and habitat management are available as they are needed.
2. Public support for the `Alalā recovery program should be widespread locally and nationally so that the local cooperation and participation, and overall financial support, necessary for success exist.
3. Public support for `Alalā conservation within the state of Hawai`i should be informed by Hawaiian cultural values and the best available science.

Management/Research Priorities:

1. Projection of the monetary needs for the captive flock for the time period covered by the current Implementation Plan, assuming optimum population growth rate.
2. Projection of the monetary and other needs of release site habitat management, for the time period covered by the current Implementation Plan.
3. Developing and maintaining an income stream to supplement government funding. The combined stream must be adequate to meet the projected needs for flock maintenance and habitat management.
4. Similar funding, as needed, of contracts with outside consultants to help garner public support for the `Alalā, increase acceptance of reintroduction, and promote habitat management on private lands.
5. Coordination of efforts with other conservation programs in Hawai`i to increase public support for forest bird recovery and native ecosystem restoration.
6. Use of existing incentives and development of new incentives for landowners to conserve and restore `Alalā habitat and support reintroduction.
7. Establishment and maintenance of productive relationships among all parties active in `Alalā recovery, including the `Alalā Recovery Team, Hawaiian cultural leaders, and private landowners.
8. Prior to reintroduction, working with the surrounding community and hunters to eliminate possible danger to `Alalā either through accidental shooting or intentional shooting or harm.

**Action 5: Conduct Research and Adaptively Manage the Recovery Program**

***Recovery Goal***: Program research and management will have achieved recovery of the `Alalā when research, monitoring and habitat management is focused on the self-sustaining reintroduced subpopulations and active program management and review are not needed.

Principles:

1. Management of all aspects of the recovery program should be based on an adaptive management cycle. In this cycle, proposed actions are treated as hypotheses to be tested by monitoring measurable outcomes. The results of these actions should be reviewed as soon as outcomes are analyzed, and subsequent actions proposed and tested in an iterative cycle.
2. The `Alalā Recovery Team should review management actions and results on at least a yearly basis, and prepare a new Implementation Plan at 5-year intervals summarizing program results and proposing further actions and tests, with estimated completion times and costs. The Implementation Plans should be fully peer reviewed before being published as Addenda to the Revised Recovery Plan.
3. All biological research to be conducted in the `Alalā recovery program should be prioritized based on immediate program needs.
4. An unbiased, outside appraisal of progress in meeting the goals of the recovery program should be part of each Implementation Plan. This extends the adaptive management principle to the management of the program itself, and cannot be performed by the Recovery team due to inherent conflicts of interest.

Research/Management Priorities:

1. Convening Recovery team meetings on a regular, fixed schedule to include reviews of all program aspects.
2. Review of all program data collected to date in both captive and field programs, and financially supporting analysis and publication of important data sets.
3. Establishing performance goals for the Recovery team and management/regulatory agencies based on program needs outlined in the most recent Implementation Plan.

# Part III-A. IMPLEMENTATION PLAN FOR YEARS 2003 THROUGH 2007

In order to achieve the long-range recovery goals of the `Alalā, the following short-term objectives must be accomplished. Goals for the implementation period covered by this plan and the actions needed to accomplish those goals are defined below for each Recovery Action in light of results from the program to date and following the principles set out in the Strategic Plan (Part II of this plan). Special emphasis is given to those Research and Management Priorities that can be addressed within the 5-year Implementation Plan timeframe. Each action in the plan has been assigned a priority number from 1 (highest priority) to 3 (lowest priority) (see p. 50 for definitions). The Implementation Plan is provided to assist in selecting the most important recovery actions for implementation. Note that there are no priority 3 recovery actions listed. To move this species effectively closer to recovery, all actions described must be completed.

**Action 1: Manage the Population of `Alalā**

> ***Short-term Goal**:* Expand the size of the captive flock in order to make it genetically and demographically stable, and large enough to generate juveniles for release.

Because the `Alalā is apparently extinct in the wild, continuing appropriate management of the captive flock is the first and most important step to recover the species. Given that the current level of inbreeding is apparently affecting reproduction and fitness, retention of the highest possible level of genetic diversity is essential to maintaining recovery potential. Maximum genetic diversity can be retained only by increasing the size of the captive population rapidly and by minimizing mortality risk. Flock managers suggest that population growth rate and proportion of breeders may increase, respectively, to $\lambda = 1.10$ and $N_e/N = 0.35$. These estimates are based on an evaluation of the potential growth rate of the captive flock after the removal of birds released to the wild, which did not breed and which had a higher mortality rate than in captivity. Maintenance of the maximum possible genetic diversity (79.4 percent) at the end of 5 years will require increasing the number of birds to approximately 77 (see Appendix A). This is consistent with the strategic goal to conserve maximal genetic diversity in the species for at least 20 years.

The need to minimize mortality risk in order to meet this goal requires that the flock be managed in captivity during this period because of the high mortality of previously released birds. The financial costs of this strategy are substantial, amounting to a doubling of capital and operating expenses over the next 5 years, but are unavoidable. Yearly increments of increased aviary space and support personnel will be needed to keep pace with population growth. Securing funding sources beyond the current Federal and State government allocations is the only feasible means to accomplish this. To that end, professional fundraising assistance is needed (see Action 4).

In the event that adequate funding cannot be obtained to support the target increase in flock size at the Keauhou and Maui Bird Conservation Centers, options for expanding the flock using existing facilities in North America should be considered. This approach is less desirable because of biosecurity concerns (*e.g.*, risk that birds held at mainland facilities could contract diseases not found in Hawai`i) and added difficulties of flock management, but must be considered if the required rate of flock increase is inhibited due to lack of aviary space.

Although it appears at this time that the `Alalā is extinct in the wild, should any wild `Alalā be located, this individual or individuals should be captured, if possible, and efforts initiated through pairing with a captive individual to incorporate wild genes into the captive flock. In such an event, juvenile `Alalā should be exposed to the behavioral repertoire of these individuals, including their calls.

1. Manage the captive population of `Alalā. (Priority 1)
    1.1 Stabilize the captive flock genetically and demographically. (Priority 1)
        1.1.1 Manage the captive flock according to the American Zoo and Aquarium Association (AZA) small population

guidelines, attempting to conserve maximal existing gene diversity in the species for at least 20 years. (Priority 1)

1.1.1.1 Increase the number of individuals in the captive flock from 40 to 77 over the next 5 years. (Priority 1)

1.1.1.2 Confirm and/or reevaluate pedigree and founder relatedness using results of DNA analysis in progress. (Priority 1)

1.1.1.3 Continue existing research aimed at improving breeding and reproductive success of captive flock. (Priority 1)

1.1.1.4 Incorporate genes of any wild `Alalā located via temporary or permanent capture and captive breeding. (Priority 1)

1.1.1.5 Protect captive flock from infection with West Nile virus by mosquito exclusion and/or immunization. (Priority 1)

1.1.1.6 Establish consulting group of at least three small-population experts including the flock manager. The group will, on a yearly basis, review captive flock status, suggest new studies, rerun demographic models, and prepare a summary for the `Alalā Recovery Team. (Priority 2)

1.1.2 Increase capacity of captive facilities to allow all potentially breeding birds to mate. (Priority 1)

1.1.2.1 Build two new breeding aviaries and three new holding aviaries each year over the next 5 years at current facilities. (Priority 1

1.1.2.2 Adjust base funding for current facilities and secure additional funding from non-government sources to support increased staff, operations needs, and construction costs for item 1.1.2.1. (Priority 1)

1.1.2.3 Contact potential mainland facilities to provide for flock growth. (Priority 2)

1.1.2.3.1 If `Alalā must be moved to the mainland, obtain authorization from the American Zoo and Aquarium Association for the `Alalā Studbook and to develop a Species Survival Plan, as required for species held in multiple American Zoo and Aquarium Association institutions. (Priority 2)

1.2 If wild birds are discovered and brought into captivity, maximize potential transmission of their behaviors to juvenile birds. (Priority 1)

**Action 2: Manage Threats in Suitable Habitat**

***Short-term Goal***: By the end of 2007 more than one forest site containing suitable habitat for the `Alalā should be under active management as a potential release site. At least one managed site within historical range, of at least 1,000 hectares (2,470 acres) in size, should have vegetation structure and predator densities superior to those that existed at the previous release site.

In order to eventually restore self-sustaining wild populations of `Alalā, active habitat management is needed to restore understory vegetation and reduce predator and disease abundance to reduce mortality rates in released birds. Final designation of release sites must be made in the very near future (*i.e.*, in 2003 or early 2004) to allow preparation of the sites by the time birds are available for release.

Once designated, prerequisites for managing these areas are acquisition of funds or cooperative agreements sufficient to conduct needed management actions, and full support of the public and of private landowners for all measures required for eventual use of the area for `Alalā reintroduction. With these factors in place, habitat and threat reduction work can begin in time for the site or sites to be ready when `Alalā numbers are sufficient to support a release program aimed at population reestablishment.

Regulatory mechanisms currently in place may not be sufficient to keep some threats out of Hawai`i. Alien predators and diseases that would make `Alalā recovery all but impossible are prevalent on other Pacific Islands (*e.g*., brown treesnake, *Boiga irregularis*, on Guam) and in North America (*e.g*., West Nile virus). All available means must be used to keep these and other alien threats to forest birds from becoming established in Hawai`i.

2. Manage threats in suitable habitat. (Priority 1).
   - 2.1 Prevent pathogens and predators from becoming established in Hawai`i that would preclude recovery of `Alalā (*e.g*. West Nile virus, brown treesnake). (Priority 1)
   - 2.2 Begin enhancement of understory vegetation at sites of at least 1,000 hectares each, at various elevations within historical range of `Alalā on Hawai`i and within suitable habitat if identified outside historical range. (Priority 1)
     - 2.2.1 Finalize the Environmental Assessment for population reestablishment of the `Alalā, selecting one or more release sites for `Alalā on Hawai`i and possibly other islands. (Priority 1)
     - 2.2.2 Secure agreements to manage selected sites (Priority 1)
       - 2.2.2.1 Use regulatory incentives and other programs, for example, Safe Harbors and Partnership agreements, to increase effective management of `Alalā habitat on private lands. (Priority 1)
       - 2.2.2.2 Design and implement a program to inform the communities near release sites of the recovery program and its benefits (see action 4.3). (Priority 2)

2.2.2.3 Coordinate `Alalā recovery actions to benefit from funding and management of other endangered species programs and to assist these programs. (Priority 2)

2.2.3 Fence and remove feral ungulates from all sites. (Priority 1)

2.2.4 Document initial vegetation condition and measure response to ungulate exclusion, comparing to pre-established criteria for release sites. (Priority 2)

2.2.5 Bolster populations of selected native plants as needed to restore food base for `Alalā. (Priority 1)

2.3 Reduce threats from alien predators and diseases at all designated release sites. (Priority 1)

2.3.1 Remove all feral cats from sites and maintain cat-free status. (Priority 1)

2.3.2 Reduce rodent and mongoose populations in all sites and maintain at less than 20 percent of initial densities. (Priority 1)

2.3.3 Establish a mammal-free area within one of the sites and document ecological response and cost of maintenance. (Priority 2)

2.4 Reduce threat of `Io predation on `Alalā at all designated release sites on Hawai`i. (Priority 1)

2.4.1 Establish baseline `Io densities at all designated release sites, and monitor yearly. (Priority 2)

2.4.2 Determine by experiment if `Io density can be reduced by controlling rodent and game bird prey base. (Priority 1)

2.4.3 Establish relationship between vegetation structure and ability of `Io to locate prey such as `Alalā. (Priority 1)

**Action 3: Establish New Populations in Suitable Habitat**

***Short-term Goal***: Determine the captive rearing conditions that best prepare juvenile `Alalā for survival after release. In the event that flock growth targets are exceeded, release excess juveniles reared under optimum conditions into managed habitat.

During the timeframe of this Implementation Plan, captive `Alalā will be considered for release only under the following conditions:

a) Their removal from the captive population will not negatively impact the demographic stability of the captive population or reduce the ability of the population to achieve growth targets.
b) Each of the founders from which they are descended are represented in the captive flock to the maximum extent feasible. The goal is maintenance of 96 percent of the genetic diversity of each founder line (*e.g.*, five F1 [first generation] offspring). Founders that died before producing five F1 descendants will require more representatives in the captive flock to minimize the loss of genetic diversity.  The 96 percent goal may not be feasible for all founder lines.
c) Population growth targets for that year have been exceeded and birds fitting these criteria are projected to be available for at least 2 more years, enough to justify starting a release program (*i.e.*, a sufficient number of birds are projected to be available for 3 consecutive years of releases).
d) Forest habitat appropriate for release is being actively managed to reduce known mortality factors, including predation by ‘Io.
e) Highest priority for release will be birds reared by their parents and adults that are paired or have formed a pair bond.

Because it is doubtful that a cohort of such juveniles and/or pairs will be available for release within the time period covered by this Implementation Plan, activities under this action focus on habitat management, planning and behavioral experimentation.

Management of the captive flock must focus primarily on increasing population size and maintaining genetic diversity (Action 1).  To the extent possible without compromising those goals, investigations aimed at optimizing rearing techniques to increase survival rates in the wild should be conducted. Because there is a risk that some of these potential modifications may reduce breeding efficiency, maximal use will be made of birds that are genetically and demographically surplus or post-reproductive.

3. Conduct experimental releases at a managed site as soon as genetically and demographically redundant birds are available. (Priority 2)
   - 3.1 Using demographic models, project when birds suitable for release will be available, updating projections yearly. (Priority 2)
   - 3.2 Determine the potential efficacy of behavioral management of juvenile `Alalā in reducing post-release mortality rates. (Priority 1)
     - 3.2.1 Appoint a subcommittee of the recovery team that includes outside experts, to draft (within 1 year) a set of hypotheses, tests, and conditions for determining the effectiveness of behavioral conditioning in `Alalā. (Priority 1)
     - 3.2.2 Experimentally test whether `Alalā can be trained to avoid cat feces as a means to reduce risk of toxoplasmosis. (Priority 2)
     - 3.2.3 Experimentally test whether `Alalā can be trained to flee small mammals. (Priority 2)
     - 3.2.4 Experimentally test whether `Alalā can be trained to avoid predation by `Io. (Priority 2)
   - 3.3 Optimize aviaries and techniques to allow parent-rearing by well-represented pairs and compare the behavior of juveniles reared by parents to those reared using the standard puppet method. (Priority 2)

**Action 4: Garner Public Support**

***Short-term Goal***: Fund the recovery program sufficiently to achieve all goals of this Implementation Plan, while measurably increasing the support of people in Hawai`i for `Alalā recovery.

Expansion of the captive flock and active management of large forest areas for releases will require a significant increase in funding over existing program support available through the budgets of the implementing agencies. Captive flock growth will require capital expenditures of approximately $150,000 per year for the implementation plan period, and an increase in operational base funding of $50,000 every other year. Fencing, ungulate control, and predator control are expensive and will require ongoing commitments of personnel: the estimated cost of fencing and ungulate eradication at the 2,145 hectare (5,300 acre) Kona Forest Unit was nearly $1 million.

Because habitat management actions and endangered species conservation will take place on some private lands, and public lands managed for multiple uses, it is very important to identify key stakeholders and to achieve cooperation with them.

To effectively raise funds from the private sector and to design and manage a public awareness campaign requires expertise and flexibility not available in government agencies. Therefore, contracting professional services for `Alalā recovery is essential. Fundraising efforts should benefit from increased public awareness, and will in turn generate on-the-ground results that further increase public support.

The `Alalā itself can help to increase awareness and support due to its intrinsic appeal and status as a bird of spiritual significance to the Hawaiian people. Using non-breeding birds for education to increase public exposure to live `Alalā also will free some cage space at the captive propagation facilities.

4. Garner public and funding support. (Priority 1)
    - 4.1 Secure funding adequate to support the `Alalā recovery program through 2007. (Priority 1)
        - 4.1.1. Determine the financial and non-financial needs of the program, including flock management, habitat management, and public awareness programs. (Priority 1)
        - 4.1.2 Contract with a successful development specialist to design and implement a funding strategy adequate to meet these needs. (Priority 1)
    - 4.2 Bring Hawaiian cultural viewpoints into recovery planning and implementation by asking one or more experts to participate in the public portion of all `Alalā Recovery Team meetings. (Priority 1)
    - 4.3 Begin dialog with local communities near initial release sites to

prepare for toxicant use, cat control, ungulate control, and `Alalā presence. (Priority 1)

4.3.1 Contract with a specialist in public/private landowner relationships to design and conduct a program to enlist landowner collaboration as outlined in action 2.2.2.1. (Priority 2)

4.3.2 In coordination with the Hawai`i Forest Bird Recovery Team, contract with an independent public outreach specialist to meet public outreach performance milestones set in action 2.2.2.2. (Priority 2)

4.4 Display non-breeding `Alalā in one or more educational settings within the State of Hawai`i. (Priority 2)

**Action 5: Conduct Research and Adaptively Manage the Recovery Program**

***Short-term Goal***: Achieve short-term goals for all recovery actions through exemplary program management and have the next Implementation Plan completed by the end of 2007.

Adaptive management requires actions that are posed as well-framed questions, collection of data to address them, analyses that answer the questions, and incorporation of these answers into further management. Data generated from the recovery program to date must be managed, catalogued, and analyzed or made available for analysis in order to manage the recovery program adaptively.

A well-functioning recovery team is essential to manage a complex and multi-faceted recovery program such as this. Team meetings should occur at least twice per year, preceding and following the `Alalā breeding season. Meetings should include a public session for data review, public comment, and assessment of progress in achieving implementation plan goals. In addition, the team should meet in private to discuss and formulate recommendations. We should approve or disapprove any recommendations within 1 month of the meeting.

This Implementation Plan is itself a proposed management action, and like all actions in adaptive management, it should not be assumed to be effective. Progress toward the short-term goals must be continually monitored, methods changed as needed, and an overall assessment conducted prior to the formulation of the next Implementation Plan.

5. Conduct research and adaptively manage the recovery program. (Priority 1)
    - 5.1 Utilize existing data sets to address questions regarding `Alalā management. (Priority 1)
        - 5.1.1 Complete the inventory of field data collected from 1992 through 2001, and present to recovery team by end of 2003. (Priority 2)
        - 5.1.2 Formulate list of relevant questions to be addressed by analysis of these data (action 5.1.1) and fund these analyses. (Priority 2)
    - 5.2 Prioritize new research based on relevance to implementation plan tasks, and modify management actions based on analysis of results. (Priority 2)
    - 5.3 Hold recovery team meetings at least twice per year, or as necessary, on a fixed schedule. (Priority 1)
    - 5.4 In consultation with the recovery team, performance milestones for the recovery team, ourselves, and private contractors should be adopted, progress measured annually, and corrective actions proposed if milestones are not achieved. (Priority 2)
    - 5.5 Beginning in early 2006, prepare implementation plan for 2008 through 2012. (Priority 2)
        - 5.5.1 In 2006 obtain a thorough, impartial assessment of the `Alalā recovery program's progress toward stated goals and identifying structural or other impediments to goal achievement. Incorporate this review into the next Implementation Plan and, following peer review, publish as an addendum to the revised recovery plan. (Priority 2)

# Part III-B. IMPLEMENTATION PLAN SCHEDULE

The Implementation Plan Schedule lists actions from the Goals and Recovery Action Outline requiring funding. Some general Recovery Action Outline statements embrace a number of more specific actions; these more general actions that do not require specific funding are not repeated in the Implementation Schedule. In addition, the Schedule identifies which of the five listing factors (current threats) will be ameliorated by each proposed action.

A. Definition of Action Priorities

Priorities in the Implementation Schedule are assigned according to the following definitions for recovery actions:

**Priority 1** – an action that must be taken to prevent extinction or to prevent a species from declining irreversibly in the foreseeable future.

**Priority 2** – an action that must be taken to prevent a significant decline in species population or habitat quality or some other significant negative impact short of extinction.

**Priority 3** – all other actions necessary to meet recovery objectives.

B. Listing/Delisting Factors

The Service evaluates five major factors when considering whether to list, delist, or reclassify a species:

A – Present or threatened destruction, modification or curtailment of habitat or range;

B– Overutilization for commercial, recreational, scientific, or educational purposes;

C – Disease or predation;

D – Inadequacy of existing regulatory mechanisms; and

E – Other natural or man-made factors affecting the continued existence of a species.

The Listing Factor column in the Implementation Plan Schedule indicates which of the five factors the recovery action addresses for recovery goals described in the `Alalā Recovery Strategic Plan and Implementation Plan. The majority of recovery actions in the Implementation Plan Schedule address threats to habitat (factor A), disease and predation (factor C), and preventing loss of genetic diversity in the captive flock, garnering public support, and formulating relevant questions and data analysis (factor E).

The `Alalā is federally listed as an endangered species and is listed as an endangered species by the State of Hawai`i and thus receives protection under the Federal and Hawai`i State Endangered Species Acts. However, inadequacy of regulatory mechanisms (factor D) may pose a threat to the `Alalā. State and Federal regulations controlling shipment of poultry and game birds to Hawai`i via first class mail, quarantine of pet birds shipped to Hawai`i, and cargo inspection programs may not be adequate to prevent the inadvertent importation of new diseases such as West Nile virus and the transfer of disease strains among islands that could seriously reduce potential to recover the `Alalā. Overutilization for commercial, recreational, scientific, or educational purposes (factor B) is not a threat to `Alalā at this time.

C. Action Duration and Responsible Parties

We have the statutory responsibility for implementing this recovery plan. Only Federal agencies are mandated to take part in the effort. Recovery actions identified in this plan imply no legal obligations of State and local government agencies or private landowners. However, recovery of the `Alalā will require the involvement and cooperation of Federal, State, local, and private interests. For each recovery action described, the column titled "Responsible Parties" lists the primary Federal and State agencies we have identified as having the authority and responsibility for implementing recovery actions and other groups, partners, and partnerships, who are actively involved in recovery implementation.

## D. Cost Estimates for Recovery Actions

The Implementation Plan Schedule provides total estimated costs of implementing recovery actions for the years 2003 through 2007. Estimates for recovery actions are based on average costs of similar actions implemented to date for habitat management, predator control, and captive propagation. For habitat management, these costs may vary considerably depending upon the condition of the forest habitat, features of terrain, and type of management actions and actions already occurring in the area.

Cost by year: 2003 = $2,356,000
2004 = $2,331,000
2005 = $2,461,000
2006 = $2,321,000
2007 = $2,371,000

Total cost to implement Implementation Plan for years 2003 through 2007:
$11,840,000.

## E. Key to Acronyms and Responsible Parties

ART – `Alalā Recovery Team
AZA – American Zoo and Aquarium Association
DLNR – Hawai`i Department of Land and Natural Resources
HDOA – Hawai`i Department of Agriculture
HFBRT – Hawaiian Forest Bird Recovery Team
NMNH – National Museum of Natural History
TBD – To Be Determined
USFWS – U.S. Fish and Wildlife Service
USGS – U.S. Geological Survey
ZSSD – Zoological Society of San Diego

## F. `Alala Revised Recovery Plan: Implementation Plan Schedule 2003 through 2007

| Action Number | Priority Number | Listing Factor | Action Description | Action Duration | Responsible Parties | Cost Estimate (in $100,000 units) | | | | | Comments/Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | FY 03 | FY 04 | FY 05 | FY 06 | FY 07 | |
| 1.1.1.2 | 1 | E | Confirm and/or reevaluate pedigree and founder relatedness using results of DNA analysis in progress. | 1 year | ART, USFWS, ZSSD*, DLNR, USGS, NMNH | 0.05 | 0 | 0 | 0 | 0 | |
| 1.1.1.3 | 1 | E | Continue existing research aimed at improving breeding and reproductive success of captive flock. | 5 years | ZSSD*, USFWS, DLNR | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | |
| 1.1.1.4 | 1 | E | Incorporate genes of any wild `Alal located via temporary or permanent capture and captive breeding. | 2 years | ZSSD*, USFWS, DLNR | 0.5 | 0.5 | 0 | 0 | 0 | Although it appears at this time that the `Alala is extinct in the wild, should any wild `Alala be discovered, this individual or individuals will be immediately captured and efforts initiated through pairing with a captive individual to incorporate wild genes into the captive flock. |
| 1.1.1.5 | 1 | C | Protect captive flock from infection with West Nile virus by mosquito exclusion and/or immunization. | 5 years | ZSSD*, USFWS, DLNR | 1.0 | 0.5 | 0.2 | 0.2 | 0.2 | |
| 1.1.2.1 | 1 | A, C | Build two new breeding aviaries and three new holding aviaries each year over the next five years at current facilities. | 5 years | ZSSD*, USFWS, DLNR | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | To increase the number of individuals in the captive flock from 40 to 77 over the next 5 years. |
| 1.1.2.2 | 1 | E | Adjust base funding for current facilities and secure additional funding from non-government sources to support increased staff, operations needs, and construction costs for item 1.1.2.1. | 5 years | ZSSD, USFWS*, DLNR | 0.5 | 0.5 | 0.5 | 0.5 | 1.0 | To increase the number of individuals in the captive flock from 40 to 77 over the next 5 years. |

## F. `Alalā Recovery Plan: Implementation Plan Schedule 2003 through 2007 (continued)

| Action Number | Priority Number | Listing Factor | Action Description | Action Duration | Responsible Parties | Cost Estimate (in $100,000 units) | | | | | Comments/Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | FY 03 | FY 04 | FY 05 | FY 06 | FY 07 | |
| 1.2 | 1 | E | If wild birds are discovered and brought into captivity, maximize potential transmission of their behaviors to juvenile birds. | 2 years | ZSSD*, USFWS, DLNR | 0.1 | 0.1 | 0 | 0 | 0 | |
| 2.1 | 1 | C, D | Prevent pathogens and predators from becoming established on Hawai`i that would preclude recovery of `Alala (*e.g.*, West Nile virus, brown treesnake). | 5 years | HDOA*, USFWS, DLNR, TBD | TBD | TBD | TBD | TBD | TBD | The effectiveness of these actions is key to the recovery of the `Alala and other threatened or endangered species on the islands. These ongoing interdiction programs involve a multitude of partners and far-reaching goals that extend well beyond the scope of this recovery plan, however, and the amount of funding required from the `Alala recovery program, if any, is unknown at this time. |
| 2.2 | 1 | A, C | Begin enhancement of understory vegetation at sites of at least 1,000 ha (2,471 ac) each, at various elevations within historical range of `Alala on Hawai`i and within suitable habitat identified outside historical range. | 5 years | USFWS*, DLNR*, TBD | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | |
| 2.2.1 | 1 | A, C | Finalize Environmental Assessment for population reestablishment of the `Alala, selecting one or more release sites for `Alala on Hawai`i and other islands. | 2 years | USFWS*, DLNR | 0.2 | 0.2 | 0 | 0 | 0 | |

## F. `Alalā Recovery Plan: Implementation Plan Schedule 2003 through 2007 (continued)

| Action Number | Priority Number | Listing Factor | Action Description | Action Duration | Responsible Parties | Cost Estimate (in $100,000 units) | | | | | Comments/Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | FY 03 | FY 04 | FY 05 | FY 06 | FY 07 | |
| 2.2.2 | 1 | A, C, E | Secure agreements to manage selected sites. | 2 years | USFWS*, DLNR, TBD | 0.2 | 0.2 | 0 | 0 | 0 | |
| 2.2.2.1 | 1 | A, C, E | Use regulatory incentives and other programs, for example, Safe Harbors and Partnership agreements, to increase effective management of `Alala habitat on private lands. | 5 years | USFWS*, DLNR, TBD | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | |
| 2.2.3 | 1 | A, C | Fence and remove feral ungulates from all sites. | 5 years | USFWS*, DLNR*, TBD | 7.0 | 7.0 | 7.0 | 7.0 | 7.0 | |
| 2.2.5 | 1 | A, C | Bolster poulations of selected native plants as needed to restore food base for `Alala. | 5 years | USFWS*, DLNR*, TBD | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | |
| 2.3.1 | 1 | A, C | Remove all feral cats from sites and maintain cat-free status. | 5 years | USFWS*, DLNR*, TBD | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | |
| 2.3.2 | 1 | A, C | Reduce rodent and mongoose populations in all sites and maintain at less than 20% of initial densities. | 5 years | USFWS*, DLNR*, TBD | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | |
| 2.4.2 | 1 | C | Determine by experiment if `Io density can be reduced by controlling rodent and game bird prey base. | 5 years | USFWS*, DLNR*, TBD | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | |
| 2.4.3 | 1 | C | Establish relationship between vegetation structure and ability of `Io to locate prey such as `Alala. | 5 years | USFWS*, DLNR*, TBD | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | |

## F. `Alalā Recovery Plan: Implementation Plan Schedule 2003 through 2007 (continued)

| Action Number | Priority Number | Listing Factor | Action Description | Action Duration | Responsible Parties | Cost Estimate (in $100,000 units) | | | | | Comments/Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | FY 03 | FY 04 | FY 05 | FY 06 | FY 07 | |
| 3.2 | 1 | C | Determine the potential efficacy of behavioral management of juvenile `Alala in reducing post-release mortality rates. | 5 years | ART, ZSSD*, USFWS, DLNR, TBD | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | |
| 3.2.1 | 1 | C | Appoint a subcommittee of the recovery team that includes outside experts, to draft (within 1 year) a set of hypotheses, tests, and conditions for determining the effectiveness of behavioral conditioning in `Alala. | 1 year | ART*, ZSSD, USFWS, DLNR, TBD | 0.2 | 0 | 0 | 0 | 0 | |
| 4.1.1 | 1 | E | Determine the financial and non-financial needs for the program, including flock management, habitat management, and public awareness programs. | 5 years | TBD | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | |
| 4.1.2 | 1 | E | Contract with a successful development specialist to design and implement a funding strategy adequate to meet these needs. | 5 years | TBD | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | |
| 4.2 | 1 | E | Bring Hawaiian cultural viewpoints into recovery planning and implementation by asking one or more experts to participate in the public portion of all `Alala Recovery Team meetings. | 5 years | USFWS*, DLNR, TBD | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | |

## F. `Alalā Recovery Plan: Implementation Plan Schedule 2003 through 2007 (continued)

| Action Number | Priority Number | Listing Factor | Action Description | Action Duration | Responsible Parties | Cost Estimate (in $100,000 units) | | | | | Comments/Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | FY 03 | FY 04 | FY 05 | FY 06 | FY 07 | |
| 4.3 | 1 | E | Begin dialog with local communities near initial release sites to prepare for toxicant use, cat control, ungulate control, and `Alala presence. | 5 years | USFWS*, DLNR, TBD | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | |
| 5.3 | 1 | A, C, E | Hold recovery team meetings at least twice per year, or as necessary on a fixed schedule. | 5 years | ART*, USFWS, DLNR, | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | |
| 1.1.1.6 | 2 | E | Establish consulting group of at least three small-population experts to include the flock manager. The group will, on a yearly basis, review captive flock status, suggest new studies, rerun demographic models, and prepare a summary for the `Alala Recovery Team. | 5 years | ART*, USFWS, ZSSD, DLNR, USGS, NMNH | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | |
| 1.1.2.3 | 2 | E | Contact potential mainland facilities to provide for flock growth. | 2 years | ZSSD*, USFWS, DLNR | 0.1 | 0.1 | 0 | 0 | 0 | In the event that adequate funding cannot be obtained to support the target increase in flock size, consider options for expanding the flock to mainland facilities. |
| 1.1.2.3.1 | 2 | E | If `Alala are moved to the mainland, obtain authorization for the `Alala studbook and to develop a Species Survival Plan as required for species held in multiple AZA institutions. | 3 years | ZSSD*, USFWS, DLNR | 0 | 0 | 0.1 | 0.1 | 0.1 | |

## F. `Alalā Recovery Plan: Implementation Plan Schedule 2003 through 2007 (continued)

| Action Number | Priority Number | Listing Factor | Action Description | Action Duration | Responsible Parties | Cost Estimate (in $100,000 units) | | | | | Comments/Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | FY 03 | FY 04 | FY 05 | FY 06 | FY 07 | |
| 2.2.2.2 | 2 | A, C, E | Design and implement a program to inform the communities near release sites of the recovery program and its benefits (see 4.3). | 5 years | USFWS*, DLNR, TBD | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | |
| 2.2.2.3 | 2 | A, C, E | Coordinate `Alala recovery actions to benefit from funding and management of other endangered species programs and to assist these programs. | 5 years | USFWS*, DLNR, TBD | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | |
| 2.2.4 | 2 | A, C | Document initial vegetation condition and measure response to ungulate exclusion, comparing to pre-established criteria for release sites. | 5 years | USFWS*, DLNR*, TBD | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | |
| 2.3.3 | 2 | A, C | Establish a mammal-free area within one of the sites and document ecological response and cost of maintenance. | 3 years | USFWS*, DLNR*, TBD | 0 | 0 | 2.0 | 0.2 | 0.2 | |
| 2.4.1 | 2 | C | Establish baseline `Io densities at all designated release sites, and monitor yearly. | 5 years | USFWS*, DLNR*, TBD | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | |
| 3.1 | 2 | E | Using demographic models, project when birds suitable for release will be available, updating projections yearly. | 4 years | ZSSD*, USFWS, DLNR, TBD | 0 | 0.1 | 0.1 | 0.1 | 0.1 | |
| 3.2.2 | 2 | C | Experimentally test whether `Alala can be trained to avoid cat feces as a means to reduce risk of toxoplasmosis. | 3 years | ZSSD*, USFWS, DLNR, TBD | 0 | 0 | 0.2 | 0.2 | 0.2 | |

## F. `Alalā Recovery Plan: Implementation Plan Schedule 2003 through 2007 (continued)

| Action Number | Priority Number | Listing Factor | Action Description | Action Duration | Responsible Parties | Cost Estimate (in $100,000 units) | | | | | Comments/Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | FY 03 | FY 04 | FY 05 | FY 06 | FY 07 | |
| 3.2.3 | 2 | C | Experimentally test whether `Alala can be trained to flee small mammals. | 3 years | ZSSD*, USFWS, DLNR, TBD | 0 | 0 | 0.2 | 0.2 | 0.2 | |
| 3.2.4 | 2 | C | Experimentally test whether `Alala can be trained to avoid predation by `Io. | 3 years | ZSSD*, USFWS, DLNR, TBD | 0 | 0 | 0.2 | 0.2 | 0.2 | |
| 3.3 | 2 | C | Optimize aviaries and techniques to allow parent-rearing by well-represented pairs and compare the behavior of juveniles reared by parents to those reared using the standard puppet method. | 5 years | ZSSD*, USFWS, DLNR, TBD | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | |
| 4.3.1 | 2 | E | Contract with a specialist in public/private landowner relationships to design and conduct a program to enlist landowner collaboration as outlined in 2.2.2.1 | 5 years | USFWS*, DLNR, TBD | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | |
| 4.3.2 | 2 | E | In coordination with the Hawai`i Forest Bird Recovery Team, contract with an independent public outreach specialist to meet public outreach performance milestones set in 2.2.2.2. | 5 years | USFWS*, DLNR, HFBRT, TBD | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | |
| 4.4 | 2 | E | Display non-breeding `Alala in one or more educational settings within the State of Hawai`i. | 5 years | ZSSD, USFWS, DLNR, HZ*, TBD | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | |

## F. `Alalā Recovery Plan: Implementation Plan Schedule 2003 through 2007 (continued)

| Action Number | Priority Number | Listing Factor | Action Description | Action Duration | Responsible Parties | Cost Estimate (in $100,000 units) | | | | | Comments/Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | FY 03 | FY 04 | FY 05 | FY 06 | FY 07 | |
| 5.1.1 | 2 | A, C, E | Complete the inventory of field data collected from 1992 to 2001, and present to the recovery team by end of 2003 | 1 year | USGS | 0.1 | 0 | 0 | 0 | 0 | |
| 5.1.2 | 2 | A, C, E | Formulate list of relevant questions to be addressed by analysis of these data (5.1.1) and fund these analyses. | 4 years | ART*, ZSSD, USFWS, DLNR, USGS, TBD | 0 | 0.5 | 0.5 | 0.5 | 0.5 | |
| 5.2 | 2 | A, C, E | Prioritize new research based on relevance to implementation plan tasks, and modify management actions based on analysis of results. | 5 years | ART*, ZSSD, USFWS, DLNR, TBD | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | |
| 5.4 | 2 | A, C, E | In consultation with the recovery team, set performance milestones for the team, ourselves, and private contractors , measure progress annually, and propose corrective actions if milestones are not achieved. | 5 years | ART*, ZSSD, USFWS, DLNR, TBD | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | |
| 5.5 | 2 | A, C, E | Beginning in early 2006, and if appropriate, prepare Implementation Plan for 2008-2012. | 2 years | USFWS*, DLNR, TBD | 0 | 0 | 0 | 0.1 | 0.1 | |
| 5.5.1 | 2 | A, C, E | In 2006 obtain a thorough, impartial assessment of progress toward goals and identify impediments to goal achievement. Incorporate this review into the next Implementation Plan. | 2 years | USFWS*, DLNR, TBD | 0 | 0 | 0 | 0.3 | 0.3 | |

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# APPENDIX A

## Genetic Diversity Modeling using PM2000 (Population Management 2000)

Cyndi Kuehler, `Alalā Studbook Keeper for the Zoological Society of San Diego, modeled gene diversity for the captive flock of `Alalā using Population Management 2000 software (PM2000; Pollak et al. 2000), assuming 4 to 8 `Alalā young fledged per year. Given the reproductive history of the captive flock approximately this number of young fledged is an achievable goal. If some of the founders are discovered to be related, current gene diversity will be lower. Modeling will be redone on an annual basis and estimates may change based on actual captive production. The target gene diversity result of 79.4 percent to be maintained represents the maximum that can be preserved assuming all founders are not related and the target or managed population size of 77 birds is met within a 5 to10 year time frame (flock size was 37 individuals at the time the modeling was done). $N_e/N = 0.35$ represents the potential proportion of breeders to total population, not the current actual proportion, which is 0.29.

**Definition of Terms**:

<u>Founder</u> (F) is an individual at the top of a pedigree, assumed to be unrelated to all other founders. An individual is not yet a founder of the captive-hatched population until it has living descendants in the population.

<u>Founder Genome Equivalents</u> (fge) is the number of equally represented founders with no loss of alleles that would produce the same gene diversity as that observed in the living descendant population. Equivalently, the number of animals from the source population that contains the same gene diversity as does the descendant population.

<u>Founder Genomes Surviving</u> is the sum of allelic retentions of the individual founders.

<u>Gene Diversity</u> (GD) is the heterozygosity expected in a population if the population were in Hardy-Weinberg equilibrium. Gene diversity is calculated from allele frequencies, and is the heterozygosity expected in a progeny produced by random mating. It is important for the population as it defines in part the rate of genetic drift as well as the rate of genetic adaptation to a given selection pressure. Gene diversity can be viewed as the variation in the founder's representatives in the living descendant population. Gene diversity is lost when founder lines become over-represented relative to or at the expense of other founder lines.

Gene Value (GV) is the expected heterozygosity or gene diversity that would be expected in the next generation if all animals bred at random and produced a number of progeny for the next generation equal to their reproductive values.

Heterozygosity is a measure of the percent of loci that are polymorphic within an individual and is calculated as one minus an individual's inbreeding coefficient (F). Heterozygosity is important for the health and vitality of birds, by masking the effect of deleterious recessive alleles and maintaining hybrid vigor. Loss of heterozygosity occurs as a result of inbreeding, and reduces fertility, survivability, disease resistance, and reproduction in domestic and exotic captive populations.

Mean F is the probability that two alleles at a genetic locus are identical by descent from a common ancestor to both parents. The mean inbreeding coefficient of a population will be the proportional decrease in the observed heterozygosity relative to the expected heterozygosity of a founder population.

Mean Kinship (MK) is the average relatedness of an animal to all animals in the living descendant population. Individuals with low mean kinships have genes that are on the average under-represented in the population and are therefore animals with high breeding priority. A drawback to using mean kinship is that full sibships have identical mean kinship values until they produce offspring. This means that full siblings would often be paired if only mean kinship was used to make pairings resulting in substantial loss of heterozygosity. Therefore, the inbreeding coefficient of potential offspring is evaluated secondarily when pairings are made.

**Definition of Terms for Actual Data:**

Lambda (λ), the population growth rate, and r, mortality rate, are used to calculate the populations growth rate.

T is generation length.

N is current number of males and females.

N (at 20 years) is the projected number of individuals at the end of 20 years.

$N_e/N$ is the potential proportion of breeders to the total population size.

***Customized Report***

*Project: Alala*

*Report compiled under Population Management 2000, version 1.06*

*7:30:02 AM, 6/3/03*

***Comments:***

*Date to be used for calculations: 6/3/03*

*Demographic data from: D:\sparks\Alala\mAlala.prn and*

*D:\sparks\Alala\fAlala.prn*

*Genetic data from: D:\sparks\Alala\Alala.ped*

*Additional demographic information:*

*Data exported on: 6 Apr 2003*

*Data compiled by: Alan Lieberman for ZSSD*

***Additional Genetic Information**:*

*Assumption 1: All founders are unrelated.*
*Assumption 2: Wild population extinct.*

*Founders = 9*
*Potential Founders = 1 additional*
*Living Descendants = 36.00*
*GD = 0.8168*
*Potential GD = 0.9265*
*GV = 0.8305*
*fge = 2.73*
*Potential fge = 6.80*
*Founder Genomes Surviving = 5.80*
*Potential Founder Genomes Surviving = 6.80*
*Mean F = 0.0966*

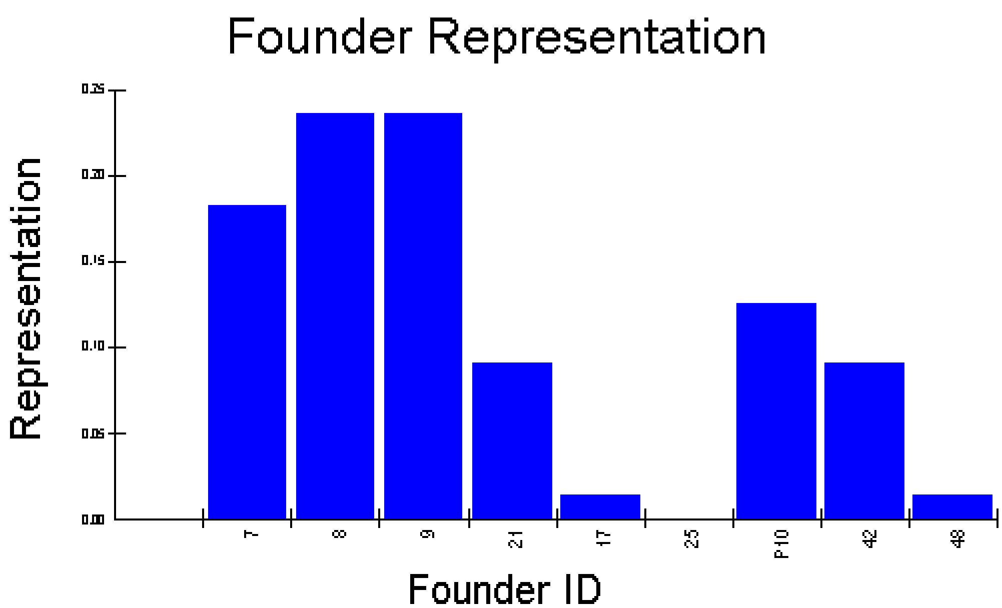
*N = 37*
*% Known = 100.00*
*MK = 0.1832*
*GD = 0.8168*
*GV = 0.8305*
*fge = 2.73*

***Males: Actual Data***

*r = 0.0698*
*lambda = 1.0723*
*T = 9.61*
*N = 19.00*
*N(at 20 yrs) = 76.79*

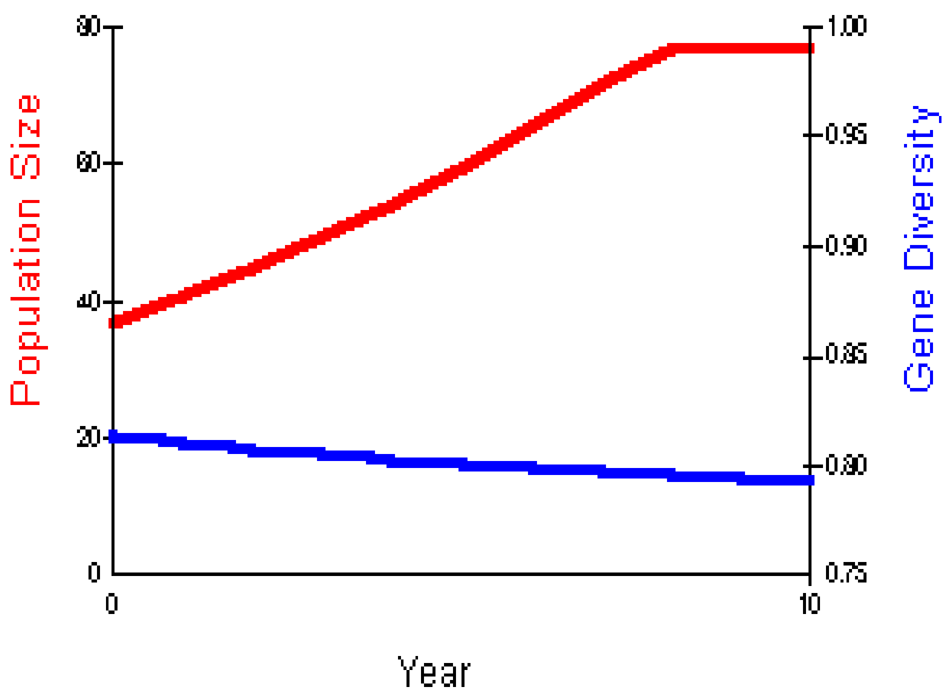
***Females: Actual Data***

*r = 0.0555*
*lambda = 1.0571*
*T = 10.62*
*N = 18.00*
*N(at 20 yrs) = 54.61*



*Target or Managed Population Size Needed = 77*
*Program Objectives: 79.4% Gene Diversity at the end of 5 years*

*Other variables:*
*Generation Length = 10.1000*
*Maximum Potential Population Growth Rate = 1.1000*
*Current Population Size = 37.0000*
*Current Effective Size = 13.0000*
*Ratio of Ne/N = 0.3500*
*Current Gene Diversity = 0.8168*
*Maximum Allowable Population Size = 500.0000*



# APPENDIX B

## American Zoo and Aquarium Association (AZA) 2003 Population Management Handbook: Integrating Data Analyses for Breeding Recommendations

Once the goals of the population have been set, the number of offspring needed to be produced each year to meet those goals can be determined. Once the number of offspring required per year has been determined the managers must decide which animals in the population should produce them. This leads to the managers making animal-by-animal recommendations. Each animal in the managed population should receive a recommendation. In this way there is no confusion over what is to be done with the animal. The recommendation for the majority of animals may be to simply hold the animal in the current condition without breeding. The recommendation may be to move the animal to another location with the managed population, to breed the animal, to use the animal for a specific research program, or to move the animal out of the managed population.

STRATEGY FOR PAIRING ANIMALS FOR BREEDING

For those animals that are to be bred in an effort to maintain gene diversity in the managed population, the following strategy is recommended by the AZA.

I. The first priority is to breed individuals of the lowest Mean Kinship (MK) that are under represented and, therefore, possess the rarest alleles in the population.

II. If breeding is limited due to space considerations, among individuals with low MK, the second priority is to breed those whose alleles may be lost soon. This priority setting should be determined by the manager’s knowledge of the individual’s age, health, and or reproductive condition. If the population has a long history of breeding in captivity and good demographic information, low Kinship Value (KV), can be used.

III. During Pairing, pair individuals according to the following ordered criteria:

1ST mate individuals with roughly similar MK to avoid combining rare and common alleles in offspring. Breeding animals with the same MK increases retention of gene diversity in the long-term. Long-term inbreeding is also reduced even if short-term inbreeding rises faster.

2ND mate individuals whose offspring will have low inbreeding coefficients (f), for the best probability of viable, healthy offspring. As a general rule, inbreeding coefficients below the population's mean MK should be accepted.

3RD maximize mating success based on the species' biology, including suitable age of individuals, mate choice, social structure, behavior, etc.

4TH minimize logistical difficulties of moves (*e.g.*, distance, cost, quarantine).

5TH maximize inter-institutional harmony and minimize political conflicts, hopefully this will never enter into the final decision which should be based on the science.

# APPENDIX C

## Glossary of Technical Terms

| | |
|---|---|
| ***allele*** | Alternative forms of a gene that code for the same trait. Alleles usually occur in pairs, one at the same genetic locus on each of a pair of chromosomes. For example, in humans there are multiple alleles for blood type: O, A, and B. If both of the alleles are the same (*e.g.*, AA), the individual is said to be *homozygous* at that locus. If the alleles are different (*e.g.*, AB), the individual is *heterozygous*. |
| ***effective population size*** | The functional size of a population, from a genetic perspective, based on the number of breeding individuals (often abbreviated $N_e$). The effective population size is generally smaller than the census population size (*i.e.*, there may be numerous individuals in the total population that are not reproducing, such as juveniles or senescent adults). |
| ***genetic drift*** | Random changes in the frequency or proportional occurrence of a particular gene in a small population due purely to chance (*i.e.*, not due to selection). Large populations tend to be insulated from the effects of genetic drift. |
| ***heterozygosity*** | A measure of the degree of genetic diversity in a population, as measured by the proportion of heterozygous loci across individuals (see ***allele***, above). |
| ***Hardy-Weinberg equilibrium*** | The stable proportions of genes in a large population with opportunities for random mating, assuming no migration, mutation, or selection. |
| ***polymorphic*** | Having more than one form; in regard to genes, refers to the existence of multiple alternative alleles for the same gene. |
| ***recessive*** | An allele that is expressed only when it occurs in the homozygous state (both alleles are recessive). When a recessive allele is paired with a *dominant* allele (the heterozygous condition), the recessive trait is masked, and only the dominant trait is expressed. Deleterious recessive alleles begin to impact a population as homozygosity increases (diversity decreases) and these alleles are expressed. |
| ***ungulate*** | Any hoofed grazing mammal. Typically refers to animals in the orders Perissodactyla (odd-toed animals such as horses) and Artiodactyla (even-toed animals such as cows, goats, sheep, deer, and pigs). |