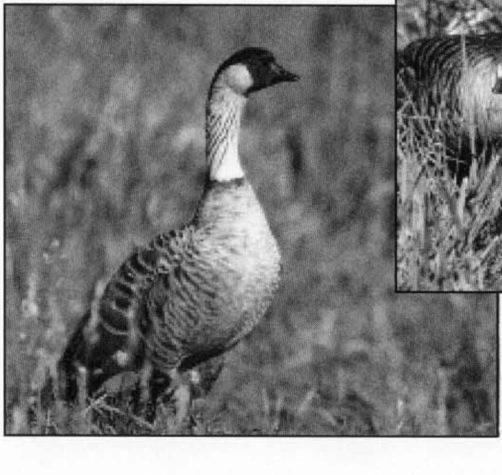
U.S. Fish & Wildlife Service

Draft Revised Recovery Plan for the Nēnē or Hawaiian Goose

(Branta sandvicensis)



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Draft Revised Recovery Plan for the Nēnē or Hawaiian Goose (*Branta sandvicensis*)

(First Revision, July 2004)

(Original Approval: 1983)

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

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

Date: XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX

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ACKNOWLEDGMENTS

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EXECUTIVE SUMMARY

Current Species Status: The nēnē or Hawaiian goose (*Branta sandvicensis*) is listed as endangered by the Federal government and the State of Hawai`i. It is considered the eighth most endangered waterfowl species in the world (Green 1994). Currently, there are populations in the wild on the islands of Hawai`i, Maui, and Kaua`i composed of an estimated 349, 251, and 620 individuals, respectively. In addition, 55 captive-bred nēnē have been released on the island of Moloka`i since December 2001, as part of a Safe Harbor Agreement. It is hoped that a population of around 200 nēnē will become established on Moloka`i as a result of this Safe Harbor Agreement and an island-wide programmatic Safe Harbor Agreement for nēnē issued in April 2003.

Habitat Requirements and Limiting Factors: The nēnē is highly terrestrial, exhibiting several structural features demonstrating adaptation to life on an island with limited freshwater. Their historic distribution (after 1778) reflects only a portion of the range nēnē once occupied as indicated by fossil remains, but it is likely they utilized grasslands, grassy shrublands, and dryland forest. Nesting is believed to have occurred primarily in leeward lowlands (under 700 meters [2,300 feet]) during the winter months with birds moving to montane habitats (above 900 meters [2,900 feet]) in the nonbreeding season. Their present statewide distribution has been determined largely by the locations of release sites of captive-bred birds (Banko *et al*. 1999). Nēnē seem to be adaptable and are currently found at elevations ranging from sea level to almost 2,500 meters (8,000 feet) in a variety of habitats including nonnative grasslands (such as golf courses, pastures, and rural areas); sparsely vegetated, high elevation lava flows; cinder deserts; native alpine grasslands and shrublands; open native and nonnative alpine shrubland-woodland community interfaces, mid-elevation (approximately 700 to 1,200 meters [2,300 to 3,900 feet]) native and nonnative shrubland; and early successional cinderfall.

The exploitation of nēnē for food by Hawaiians and non-Polynesian settlers is believed to have been responsible for substantial population declines in lowland areas, and hunting was a major limiting factor until a hunting ban was passed and enforced in 1907 (Banko *et al*. 1999). The main limiting factors currently affecting nēnē recovery are predation by introduced mammals, insufficient nutritional resources for both breeding females and goslings, limited availability of suitable habitat, and human-caused disturbance and mortality. Additional factors that play a role include behavioral problems associated with small population sizes and captive-bred birds, genetic homogeneity and expression of deleterious recessive genes, and possibly avian disease.

Recovery Priority Number: The recovery priority number for the nēnē is 2. Recovery priority numbers are assigned to a species based on degree of threat, recovery potential, taxonomic status, and conflict with human activities. Numerical ranks range from 1 to 18 with a letter designation of "C" indicating conflict. The highest priority is 1C; the lowest priority is 18. The nēnē's recovery priority number of 2 indicates it has a high degree of threat, a high recovery potential, it has full species status, and it is generally not in conflict with human activities.

Recovery Goal: The goal of this recovery plan is to remove the nēnē from the Federal List of Endangered and Threatened Wildlife and Plants (delisting). The interim goal is to accomplish increases in population sizes and geographic distribution sufficient to consider reclassification or downlisting of this endangered species to threatened status.

Recovery Objective: Restore and maintain multiple self-sustaining nēnē populations on Hawai`i, Maui Nui (Maui, Moloka`i, Lāna`i, Kaho`olawe), and Kaua`i. Additionally, the threats to the species must be reduced to allow for the long-term viability of these populations, and sufficient suitable habitat must be identified, protected, and managed in perpetuity on each of these islands such that the species no longer meets the definition of endangered or threatened under the Endangered Species Act.

Recovery Criteria: Consideration for **downlisting** the nēnē to threatened status can occur when each of the following criteria have been reached and maintained for a period of 15 years:

1) **Self-sustaining populations exist on Hawai`i, Maui Nui (Maui, Moloka`i, Lāna`i, Kaho`olawe), and Kaua`i.** In this case, self-sustaining is defined as maintaining (or increasing) established

population levels without additional releases of captive-bred nēnē, although habitat manipulation, such as predator control or pasture management, may need to be continued. At least 7 populations must exist with the following minimum sizes: 2 populations with 500 breeding adults each, 1 population with 300 breeding adults, 2 populations of 250 breeding adults each, and 2 populations of 100 breeding adults each. The larger three populations must be distributed on Hawai`i, East Maui, and Kaua`i while two of the smaller populations must occur on two of the following: East Maui, Moloka`i, Kaho`olawe, or Lāna`i. Increasing population sizes, establishing multiple populations, and providing for breeding in the wild will address threats to the nēnē associated with reduced genetic diversity, behavioral issues stemming from captive conditions, and the potential for disease transmission.

2) **Sufficient suitable habitat to sustain the target nēnē population levels on each island is identified, protected, and managed in perpetuity.** Securing high quality nesting and rearing habitat and associated summer flocking habitat is key to nēnē population stability and growth. Where migration continues to be important, particularly Hawai`i, the management of established routes and new altitudinal migration routes must be taken into account to ensure the persistence of all habitats necessary for the recovery and long-term existence of nēnē. Both public and private lands are important to nēnē recovery and portions of some nēnē populations may need to be managed on private lands. Critical elements of habitat identification, protection, and management will include addressing the threats to nēnē posed by introduced predators, loss of suitable lowland habitats, poor nutrition, and human-caused disturbance and mortality.

A downlisting determination can only be made on a "listable entity" under the Endangered Species Act; listable entities include species, subspecies, or distinct population segments of vertebrate animals, as defined by the Endangered Species Act and U.S. Fish and Wildlife Service policy (USFWS 1996). We have not analyzed whether any of the current nēnē populations may constitute a distinct population segment, and there is insufficient information at this time to make such a determination, but in the future, if warranted by additional information, downlisting may be considered separately for a subset of the nēnē population if that population subset is shown to meet the definition of a distinct population segment. In addition, to be proposed for downlisting, any such population subset must be self-sustaining, have been increasing in size from a minimum of 500 to at least 1,000 breeding adult birds over a period of 15 years, and sufficient suitable habitat (per #2 above) must be determined to exist.

Consideration for **delisting** can occur once all of the downlisting criteria have been met, and population levels on Hawai`i, Maui Nui, and Kaua`i have all shown a stable or increasing trend (from downlisting levels) for a minimum of 15 additional years (*i.e.*, for a total of 30 years). A monitoring plan shall be in place and ready for implementation for a minimum of 5 years post-delisting to ensure the continuing effectiveness of management actions and the welfare of the species.

Recovery Actions Needed:

1) **Identify and protect nēnē habitat** which focuses on the identification and protection of sufficient habitat to sustain target population levels;
2) **Manage habitat and existing populations for sustainable productivity and survival** complemented by monitoring changes in distribution and abundance;
3) **Control alien predators** which addresses control of introduced mammals to enhance nēnē populations;
4) **Continue captive propagation program** which describes techniques and priorities for the captive propagation and release of nēnē into the wild;
5) **Establish additional nēnē populations** which focuses on partnerships with private landowners;
6) **Address conflicts between nēnē and human activities** which addresses potential management and relocation of nēnē in unsuitable areas;
7) **Identify new research needs and continue research** which describes general categories of research needed to better evaluate threats to nēnē and develop and evaluate management strategies to address these threats;
8) **Provide a public education and information program** which describes important outreach and education activities; and

9) **Validate recovery actions** which calls for formalizing the Nēnē Recovery Action Group and evaluating management and research projects to determine if recovery objectives have been met.

Date of Recovery: Downlisting to threatened could be initiated in 2019 and delisting could be initiated in 2034, if recovery criteria are met.

Total Estimated Cost of Recovery (next 5 years): $9,958,500

Priority 1 actions[1]: $7,664,800
Priority 2 actions: $1,607,000
Priority 3 actions: $686,700

The total cost of the nēnē recovery program over the next 30 years cannot be realistically projected at this time. Future recovery actions will depend upon the continual evaluation and adjustment of management actions recommended in this recovery plan to maximize their effectiveness (adaptive management; see Recovery Action 9). We therefore present our best estimate of recovery costs over the 5-year timeframe presented in our recovery action implementation schedule; there are likely to be additional costs that are yet to be determined. We anticipate updating and revising this recovery plan on a 5-year time schedule, as needed, and recovery cost projections will be updated accordingly at that time.

[1] **Priority 1**: Actions that must be taken to prevent extinction or prevent the species from declining irreversibly in the foreseeable future. **Priority 2**: Actions 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.

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I. INTRODUCTION

The Hawaiian Archipelago is among the world's most isolated group of islands. This isolation has produced a high level of endemism in the flora and fauna and many groups exhibit outstanding examples of adaptive radiation (Scott *et al*. 1986; Banko *et al.* 2001). Hawai`i's remaining flora and fauna are vulnerable to extinction, and of the 1,258 animal and plant species federally listed as threatened or endangered nationwide, Hawai`i is home to 322 or roughly 25 percent of all listed species (U.S. Fish and Wildlife Service 2002). A total of 142 endemic (*i.e.*, found only in Hawai`i) species and subspecies of birds known from collected specimens or nonmineralized fossils have been described from the Hawaiian Islands (James and Olson 1991; Olson and James 1991; Giffen 1993; Pyle 1997). Following human colonization of the Hawaiian Islands in approximately 400 AD, endemic species declined markedly in both numbers and distribution (James and Olson 1991; Olson and James 1991; Banko *et al.* 2001). Of the 142 endemic bird species and subspecies, about 95 have been extirpated since the advent of human colonization (Banko *et al*. 2001). The remaining 45 endemic taxa are also vulnerable to extinction with 32 taxa listed as endangered or threatened, including 30 landbirds and 2 seabirds.

Over 11 species of waterfowl evolved in the Hawaiian Islands, of which only 3 are extant today, and the other 8 or so are known only from fossil evidence. These species comprise an unusual assemblage of waterfowl as most were flightless and many were terrestrial, herbivorous, goose-like derivatives of ducks or ancestors of unknown affinity (Banko *et al*. 1999). In the isolated Hawaiian Islands, all large native herbivores were waterfowl (Olson and James 1991; Paxinos *et al.* 2002a).

Of the five or so endemic goose species described from the Hawaiian Islands, only the Hawaiian goose (*Branta sandvicensis*, Vigors), better known by its Hawaiian name, nēnē, has survived to the present day (Olson and James 1984; Olson and James 1991). Fossil remains of nēnē have been discovered on most of the main Hawaiian Islands, including Hawai`i, Maui, Kaho`olawe, Lāna`i, Moloka`i, and Kaua`i (Olson and James 1991). Historically (after 1778), nēnē are known with certainty only from the island of Hawai`i. Reports of nēnē occurring on Maui in the nineteenth century are unverifiable (Baldwin 1945; Kear and Berger 1980; Olson and James 1991). On Oahu, the *Branta* fossils discovered so far have been of an extinct form with reduced wings similar to, but not identified as, nēnē (Olson and James

1991). Although anecdotal evidence indicates nēnē may have occurred on Ni`ihau (Baldwin 1945), fossils have not been found there either.

Prior to the arrival of westerners, the extent of the nēnē population on the Island of Hawai`i was unknown. Although Baldwin roughly estimated it to be at least 25,000 birds (Baldwin 1945), recent genetic work by Paxinos *et al.* (2002b) indicates there were many fewer nēnē on Hawai`i prior to the early 1800's. Genetic evidence indicates that the nēnē suffered a great loss in genetic variability during prehistoric human population growth (900 to 350 years ago), which likely was associated with large declines in the number of nēnē. During this time period, nēnē were extirpated on Kaua`i and at least five of the nine large ground-dwelling Hawaiian birds went extinct (Paxinos *et al.* 2002b). In historic times, Baldwin (1945) and Fisher *et al.* (1969) noted that a significant decline in the nēnē population on Hawai`i began after 1800 as birds became extirpated in lowland habitats (under 700 meters [2,300 feet]). The primary causes of this decline were habitat loss, hunting during the nēnē breeding season (fall and winter), and the impacts of alien mammals introduced during both Polynesian and western colonization. A variety of alien mammals continue to negatively impact nēnē. Dogs (*Canis familiaris*), cats (*Felis cattus*), mongooses (*Herpestes auropunctatus*), rats (*Rattus* spp.), and pigs (*Sus scrofa*) prey on nēnē while feral cattle (*Bos taurus*), goats (*Capra hircus*), pigs, and sheep (*Ovis aries*) can alter and degrade nēnē habitat through their foraging activities. By 1952, Smith estimated the remaining nēnē population to number about 30 birds (Smith 1952).

While little concern about the fate of the nēnē had been shown previously in spite of work by authors such as Dole (1879), Wilson (Wilson and Evans 1893), Perkins (1903), and Henshaw (1902), the Hawai`i Board of Agriculture and Forestry did attempt to establish a captive flock in 1927. Unfortunately, this effort was short-lived and the flock was broken up in 1935 due to fears that disease would wipe it out, with the consequence that only one bird was left in 1942, many of the birds having been released (Kear and Berger 1980). Finally, in part due to the suggestions and efforts of J. Donald Smith (Board of Agriculture and Forestry) and Charles and Elizabeth Schwartz who, after 18 months of intensive field work, wrote that nēnē were facing “imminent extinction” (Schwartz and Schwartz 1949), money was appropriated for a nēnē restoration program (Kear and Berger 1980). The captive propagation program began in 1949 and captive-bred nēnē have been released into the wild since 1960 (Appendix A). The success of the captive rearing program, though off to a slow start in the early stages (because of inbreeding, diet, and unreliable avicultural techniques), was due to Herbert Shipman, John Yealland and Peter Scott of the Wildfowl Trust, Paul Breese, Director of the Honolulu Zoo, and Ah Fat Lee who cared for the birds at Pōhakuloa on Hawai`i (Kear and Berger 1980). The first two pairs of nēnē in the program were from Shipman's captive flock, with the addition of a wild female around 1950 to 1951, and another pair were taken from the wild population on Mauna Loa in 1960 (Kear and Berger 1980). These efforts certainly saved the nēnē from extinction; however, survival and breeding success in the wild remains low in most populations (Banko 1988; Baker and Baker 1995; Black *et al.* 1997; Banko *et al.* 1999). With the current exception of Kaua`i, most populations in the wild still rely on captive releases to sustain their population levels (Stone *et al*. 1983a; Black *et al*. 1991; Banko 1992). Although the Kaua`i population is currently increasing without further releases, active predator control for nesting birds has been ongoing and mongooses have not become established on the island (T. Telfer, pers. comm. 1998).

The nēnē was declared a federally endangered species in 1967 (U.S. Fish and Wildlife Service 1967). It is considered one of the most endangered geese in the world, the second most endangered waterfowl in the United States, and the eighth most endangered waterfowl species in the world out of 65 endangered waterfowl of the 231 waterfowl species world-wide (Green 1994; Black 1998). Critical habitat has not been designated for this species. The nēnē has a recovery priority number of 2 (U.S. Fish and Wildlife Service 1983a,b). Recovery priority numbers are assigned to a species based on degree of threat, recovery potential, taxonomic status, and conflict with human activities. Numerical ranks range from 1 to 18 with a letter designation of "C" indicating conflict. The highest priority is 1C; the lowest priority is 18. The nēnē's recovery priority number of 2 indicates it has a high degree of threat, a high recovery potential, its taxonomic rank is a full species, and it is generally not in conflict with human activities.

A considerable amount of new information has been amassed since the Nēnē Recovery Plan was first written in 1983 (U.S. Fish and Wildlife Service 1983c). Progress in the fields of genetics, paleontology, nutrition, behavior, the effects of predation, and predator control warrant a shift in recovery efforts to include more intensive habitat management and releases of captive-reared birds at lower elevations. Changes in captive breeding techniques have already been adopted following several studies illustrating the importance of parent-rearing of goslings (Marshall and Black 1992; Black *et al*.

1997). This revised recovery plan attempts to integrate the new information into descriptions of the biology of the nēnē and to use it to update the goals, management actions, and research needs in order to achieve the recovery of the nēnē in the State of Hawai`i. A list of peer and stakeholder reviewers to whom the draft recovery plan was sent for review is provided in Appendix I. A glossary of technical terms is provided in Appendix H.

II. SPECIES ACCOUNT

A. TAXONOMY

The nēnē or Hawaiian goose (*Branta sandvicensis*) is in the family Anseridae, subfamily Anserinae, tribe Anserini, with other true geese. This species is endemic to the Hawaiian Islands and is the only one of five or so endemic Hawaiian goose species to survive into historic times (Olson and James 1984; Olson and James 1991). Using genetic information, Quinn *et al*. (1991) speculated that nēnē and Canada geese (*B. canadensis*) diverged from a common North American ancestor less than 3 million years ago. Paxinos (1998) estimated that nēnē diverged from a subspecies of Canada goose 0.82 to 1.08 million years ago, based on evidence from mitochondrial DNA and geologically calibrated estimates of time. Recent DNA analysis suggest that a single population of Canada goose became resident on the Hawaiian Islands and gave rise to a number of diverse true geese of the islands, thus the nēnē is the only extant member of an overlooked radiation of Hawaiian *Branta* (Paxinos *et al*. 2002a).

In the past, specializations of nēnē for terrestrial life and other skeletal features have prompted some authors to assign the nēnē to the monotypic genus *Nesochen* (Miller 1937; Woolfenden 1961; American Ornithologists' Union 1983; Quinn *et al*. 1991) and Quinn *et al*. (1991) suggested it was premature to place nēnē in the genus *Branta* without further genetic testing. However, most recent treatments place the nēnē in the genus *Branta* rather than the genus *Nesochen* due to the small degree of divergence from their mainland ancestor (Berger 1972; Weller 1980; Olson and James 1991; American Ornithologists' Union 1993; Paxinos *et al.* 2002a,b). The genus *Branta* consists of the following five species (some of which have subspecies): nēnē, Canada goose, barnacle goose (*B. leucopsis*), brant (or brent, *B. bernicla*), and red-breasted goose (*B. ruficollis*).

B. SPECIES DESCRIPTION

The nēnē is a medium-sized goose, with an overall length of approximately 63 to 69 centimeters (25 to 27 inches). The plumage of both sexes is similar. The crown and back of the neck are black, with a bright, buffy (cream-colored) cheek patch. The sides of the neck are a paler beige color with deep furrows which are unique among waterfowl (Banko *et al*. 1999). The bill, legs, feet, and tail feathers are black. Contour feathering of the back and upper wing areas are gray-brown with lighter distal edges, which gives a heavily scaled or barred appearance. The feathering of the sides, chest, and belly are lighter gray-brown with a much less scaled appearance. The rump is pure white. The irises of the eyes are a deep chestnut brown. Adaptations to a terrestrial life include greatly reduced webbing between the toes, reduced wings, and a relative increase in the size of the hind-limbs (Olson and James 1991).

Hatchlings have gray and white downy feathering, gray bills, and light yellowish-gray legs and feet. Hatchlings often possess a single claw on the tips of their aluli (the reduced first digit that projects from the bend of the wing), which are apparently shed at a young age. Until the first pre-basic molt, juveniles are more dull in color than adults, with much less beige and more black on the sides of the neck. Juveniles resemble the Canada goose more than adults do (Miller 1937). A key to ageing nēnē goslings was developed by Hunter (1995). By 5 months of age, juveniles are nearly indistinguishable from adults (Banko *et al*. 1999).

Males are slightly larger and heavier than females. Weights of wild and captive adult nēnē vary over an annual cycle, with the birds, especially females, weighing most at the onset of nesting (prebreeding season) (Kear and Berger 1980). Wild females weigh from 1,500 to 2,100 grams (53 to 74 ounces) and males weigh between 1,800 and 2,500 grams (63 to 88 ounces) (Banko 1988; Black *et al*. 1994). The weights of captive birds are generally higher than the weights of birds in the wild (Kear and Berger 1980). Although the sexes are very similar, it is possible to distinguish between males and females in the field by their size, the shape of the head, and behavior (Kear and Berger 1980; A. Marshall, pers. comm. 2002).

The vocalizations of adult nēnē include soft mewing or mooing sounds (a low murmuring *nay* or *nay-nay*), loud cackling calls when alarmed, and sonorous high-pitched, and typically goose-like trumpeting sounds for long distance communication (Kear and Berger 1980). The shrill, trumpeted calls are generally disyllabic often followed by a series of shorter, more staccato notes and ending with a moan (Banko *et al*. 1999). Vocalizations are similar to, but quieter than, those of the Canada goose (Johnsgard 1965). Kear and Berger (1980) described four types of calls given by goslings: soft pleasure calls that maintain family contact; a louder greeting call that may also serve to maintain contact and family recognition; a sleepy call given when tired that may synchronize rest periods; and a loud, high-pitched distress call given when lost, cold, or hungry that encourages parents to locate and attend the gosling. The approach of predators or other threats also elicit soft or loud alarm calls. Goslings begin to develop adult-like calls around fledging, but gosling-like calls may persist up to a year later (Banko *et al*. 1999).

As noted above, it seems clear that nēnē are derived from the genus *Branta*, but this species demonstrates adaptations to a terrestrial and largely nonmigratory lifestyle on islands with limited freshwater habitat (Olson and James 1991; Banko *et al*. 1999), including increased hindlimbs, decreased forelimbs, and reduced foot-webbing in comparison to other species of *Branta* (Miller 1937; Olson and James 1991). Nēnē also stand taller and more upright than geese of similar weight (Kear and Berger 1980; Banko *et al*. 1999). Olson and James (1991) showed that the sternum, bill, mandible, and frontal bones of nēnē and other now extinct species of endemic Hawaiian geese are unique, suggesting that the nēnē and the extinct Hawaiian *Branta* geese constitute a monophyletic assemblage derived from a single colonization of the Hawaiian Islands (Olson and James 1991). The ancestor of the Hawaiian radiation of *Branta* underwent two important changes in life history: 1) a niche shift from mainly wetland to mainly terrestrial habitats; and 2) loss of migration (Paxinos *et al*. 2002a)

C. PREHISTORIC AND HISTORIC RANGE AND POPULATION SIZE

Olson and James (1982, 1991) speculated that nēnē or closely related taxa occurred on all of the main Hawaiian islands, although subfossil evidence has not yet been found on the islands of Ni`ihau or O`ahu. The fossil record shows that the distribution and diversity of *Branta* in the Hawaiian Islands was formerly much greater; however, the complexity involved in the systematics of the fossils has not allowed the conclusive establishment of all species' geographic limits at the time (Olson and James 1991). More recent analysis has more definitively established the range of at least two of the extinct Hawaiian *Branta* (Paxinos *et al*. 2002a).

Olson and James (1991) reported that bones of *Branta sandvicensis* are regularly found in lava tubes in various locations on the island of Hawai`i, and bones inseparable from these have been found in dune and archaeological deposits on Moloka`i, dune deposits on Lāna`i and Kaua`i, and from lava tubes on the east slope of Haleakalā on east Maui. Remains are also now known from archaeological deposits on Kaho`olawe (Olson 1992) and from a large sinkhole and cave system on Kaua`i (Burney *et al.* 2001). No nēnē remains have yet been identified from O`ahu, where all *Branta* fossils appear to be an extinct form having reduced wings (Olson and James 1991).

Although anecdotal evidence indicates nēnē may have occurred on Ni`ihau (Baldwin 1945), fossils have not been found there and it is by no means clear whether nēnē did occur there.

There is limited information at this time for estimating population numbers of nēnē, either pre-Polynesian or pre-European contact. Our ability to estimate these populations is hampered by a limited understanding of species composition, or even the gross structure, of the vegetation prior to the arrival of the Polynesians. While we have some knowledge of vegetation in uplands from remnant forests and shrublands, information about lowland areas is only recently coming to light. A recent examination of sediments and their fossil contents on Kaua`i has revealed a diverse lowland biota prior to human arrival (Burney *et al.* 2001). This study found that lowland vegetation on the south coast of Kaua`i consisted of a herbaceous component with strand plants and grasses, and a woody component that included trees (*e.g.*, *Pritchardia* [loulu palm], *Cordia subcordata* [kou], and *Pandanus tectorius* [hala or screw pine]) and shrubs now mostly restricted to a few higher, wetter, and less disturbed parts of the islands. Human arrival has greatly altered these lowland areas resulting in a different assemblage of plants and animals today. These changes need to be considered when restoring nēnē habitat and reintroducing nēnē to unoccupied areas. Beyond their distribution as indicated by fossil evidence to date (Olson and James 1982; Burney et *al*. 2001), we have little idea of the past nēnē populations on the different islands.

According to Kirch (1985), nēnē occurred on all or most of the main Hawaiian Islands before and during Polynesian colonization (around 1,600 years before present). Since the arrival of Europeans (in the late 1700's), naturally occurring nēnē have been known with certainty only from the island of Hawai`i. Baldwin (1945) wrote that early records indicate there was a large population of nēnē on Hawai`i until at least 1823, with declines noted by 1864. Perkins (1903) noted that nēnē were widely distributed on Hawai`i and fairly common in some localities. Reports from Ellis (1917 *in* Baldwin 1945) of vast flocks of nēnē in the interior of the island of Hawai`i are based on second- and third-hand reports from local residents. Although Baldwin (1945) determined that 25,000 nēnē is a reasonable estimate for what he terms the original (eighteenth century) population of nēnē on Hawai`i, there is no concrete evidence to support this number, and actually, Baldwin notes that he made up this population estimate for convenience. Recent genetic work indicates that nēnē populations on Hawai`i lost most of their mitochondrial DNA variability long before the historic population decline (Paxinos *et al*.

2002b). According to this research, the nēnē's loss of genetic variability took place during prehistoric human population growth (900 to 350 years ago), during which time nēnē were extirpated on Kaua`i and at least five of the nine large ground-dwelling Hawaiian birds went extinct. Paxinos *et al*. (2002b) found a nēnē haplotype diversity of 0.802 in the paleontological samples, but only 0.067 in the archaeological and museum samples. The data suggest that there was a prehistoric population bottleneck and that there were far fewer nēnē on Hawai`i prior to the early 1800's than the 25,000 estimated by Baldwin (Paxinos *et al*. 2002b).

Baldwin (1945) and Fisher *et al*. (1969) noted that the historic decline in the nēnē population on Hawai`i began after 1800 as birds became extirpated in lowland habitats. The range of nēnē, as roughly estimated by Baldwin (1945), shrank from 6,410 square kilometers (2,475 square miles) in 1800 to 2,979 square kilometers (1,150 square miles) during the period from 1900 to 1944, a loss of over half the nēnē habitat remaining on Hawai`i following European contact. Between 1900 and 1944, their range and numbers were further restricted to the upland habitats in more remote areas, with the majority of the population located in the Hualalai-Pu`uwa`awa`a area which was then the most important breeding area for nēnē. Baldwin (1945) also reported many observations of nēnē on Mauna Loa above Kīlauea Crater. Smith (1952) estimated that the population in 1952 was about 30 birds.

Baldwin (1945) believed that although there was not complete proof, there were enough records to indicate that a wild goose, which he presumed identical to nēnē, formerly occurred on Maui. Anecdotes suggest that nēnē were seen on Haleakalā Volcano, Maui, as late as 1914 (Baldwin 1945). However, if there was a Maui population of nēnē at the time of European contact, it was probably extirpated before 1890 (Henshaw 1902). Anecdotal accounts of nēnē on Kaua`i and Ni`ihau in the 1800's have been generally discounted (Henshaw 1902; Baldwin 1945; Banko *et al*. 1999).

Fossil evidence suggests that on islands less than 1,600 meters (5,248 feet) in elevation, nēnē populations were once abundant in lowland habitats (Olson and James 1991). Following human colonization, these lowland populations declined or were lost due to habitat alteration, hunting, and predation by introduced mammals. Populations on the higher, larger islands (Maui and Hawai`i), however, persisted into the historic period likely due to the availability of larger tracts of habitat, particularly in remote, rugged, upland areas with less intense hunting and predation pressure (Banko *et al*. 1999). Burney *et al*. (2001) also noted that many plant and animal species, including nēnē, may be restricted to high elevations today because these areas have resisted most human-induced changes more effectively than the coastal (0 to 300 meters [0 to 984 feet]) lowlands. The alteration of lowlands by humans was caused by clearing of land for settlements, roads, and agriculture, browsing by introduced ungulates, increased frequency of fires, and the spread of alien plants and animals (Baldwin 1945, 1947; Kirch 1982, 1983; Scott *et al*. 1986; Cuddihy and Stone 1990; Banko *et al*. 1999).

D. CURRENT RANGE AND POPULATION SIZE

Populations of nēnē currently exist on the islands of Hawai`i, Maui, and Kaua`i with an estimated statewide population of around 1,300 birds (Table 1). This estimate includes the nēnē released since 2001 on the Island of Moloka`i at Puu O Hoku Ranch as part of their Safe Harbor Agreement with the Hawai`i Division of Forestry and Wildlife and the U.S. Fish and Wildlife Service. Although the Moloka`i birds are too recently reintroduced to be considered established, they have already begun to breed and three goslings have been fledged to date. With additional releases on Moloka`i, it is hoped that this population will become self-sustaining in the near future.

The statewide population estimate represents an increase from the 1998 estimate of around 885 birds, primarily due to increases of the number of nēnē on Kaua`i. In particular, the Crater Hill population on Kaua`i is believed to be doing well for several reasons: 1) the area is fenced and there is an active predator control program; 2) mongoose do not appear to be established on Kaua`i, though there are increasing verified and unverified reports of individual mongoose on the island; 3) it is a lowland site that may provide better habitat for nēnē; and 4) irrigation of areas around Kilauea Point may attract nesting birds and may increase gosling survival (Telfer 2003; Telfer and Hu, pers. comm. 2001). There are currently an estimated 144 nēnē in Hawai`i Volcanoes National Park, around 205 on other scattered sites around Hawai`i, 200 to 230 in Haleakalā National Park, 85 on west Maui, and 620 on Kaua`i (C. Bailey, D. Hu, T. Kaiakapu, J. Medeiros, J. Mello, K. Sherry, and J. Tamayose, pers. comm. 2003). All populations have been or are being supplemented by captive-bred birds (see Section H, 1. Captive Propagation and Release). It is believed that many of the nēnē populations have suffered from the recent drought years, including populations on Kaua`i, and of particular concern is a nearly 50 percent decline in the number of wild (in this instance wild refers to nēnē that were not captive-bred) birds in Hawai`i Volcanoes National Park since the mid-1990's

TABLE 1. Total releases of captive-bred nēnē in Hawai`i and current estimated population size by island[1].

Hawai`i

	Release Sites[2]							TOTAL Hawai`i
	Hakalau NWR	Hawai`i Volcanoes NP	Kahuku	Kea`au	Keauhou	Keauhou II	Kīpuka `Āinahou	
Total nēnē released	33	290	418	15	418	348	319	1841
Estimated 2003 nēnē population	50	144	10	60	15	5	10	349[3]

Maui

	Release Sites East Maui		Total East Maui	Release Site West Maui	TOTAL Maui
	Hosmer Grove	Palikū		Hana`ula	
Total nēnē released	16	495	511	87	598
Estimated 2002 nēnē population			251	85	336

TABLE 1 (continued). Total releases of captive-bred nēnē in Hawai`i and current estimated population size by island[1].

Moloka`i		
	Puu O Hoku Ranch	**TOTAL Moloaka`i**
Total nēnē released	55	55
Estimated 2003 nēnē population		55

Kaua`i					
	Release Site				**TOTAL Kaua`i**
	Hanalei NWR	**Kīlauea Point NWR/Crater Hill**	**Kīpū Kai**	**Nā Pali Coast**	
Total nēnē released	24	38	25	62	149
Estimated 2002 nēnē population	24	238	219	83	564

[1] Sources: Nēnē Restoration Project, Hawai`I Division of Forestry and Wildlife, unpublished data; Hawai`I Division of Forestry and Wildlife 2000; J. Jeffrey, D. Hu, J. Medeiros, J. Mello, C. Natividad, J. Tamayose, T. Kaiakapu, and T. Telfer, pers. comms. 2001-2003.

[2] NWR = National Wildlife Refuge; NP = National Park.

[3] This estimate includes an estimated 55 wild birds at Pu`uwa`awa`a and surrounding areas.

(Telfer 2003; D. Hu and K. Sherry, pers. comms. 2003).

1. Hawai`i

On the Island of Hawai`i, nēnē currently are found in a number of areas from sea level to 2,400 meters (7,900 feet), with population centers of nēnē in the wild at the following locations: Hakalau Forest National Wildlife Refuge; Hawai`i Volcanoes National Park; Kahuku; Keauhou area including Kūlani; Kīpuka `Āinahou area including Pu`u `Ō`ō Ranch and Pu`u 6677 (a nearby kīpuka [vegetated area within a lava bed]); Pōhakuloa area including Saddle Road, and the Pu`uwa`awa`a area including Pua Lani and Pu`uanahulu. Semi-captive (birds that are fed and quite tame, but are not kept in a fenced enclosure) flocks occur at Kings Landing and Shipman Estate at Kea`au near Hilo (Figure 1). Supplements of captive-bred nēnē to the wild nēnē population on Hawai`i have occurred since 1960 in various locations (Appendix A-1). For many years, the largest population of nēnē on Hawai`i has occurred in Hawai`i Volcanoes National Park. Other locations around the island have much smaller numbers ranging from an estimated 5 to 60 nēnē in 2003 (Table 1). The six to seven discrete flocks on Hawai`i have experienced low to moderate levels of interchanges (Black *et al*. 1997).

2. Maui

Thirty captive-bred nēnē from The Wildfowl and Wetlands Trust in Slimbridge, England, and five nēnē from the State's Pōhakuloa propagation project on Hawai`i were first released at Palikū in Haleakalā Crater, Haleakalā National Park on July 26, 1962 (Walker 1969; Kear and Berger 1980). These nēnē were the first captive-bred birds to be released into the wild on Maui. On east Maui, nēnē currently are found primarily within the boundaries of Haleakalā National Park, at elevations of around 2,000 to 2,300 meters (6,300 to 7,700 feet). The last major release of captive-bred nēnē at this location numbered 47 birds and occurred in 1977 (Appendix A-2). The east Maui population ranged from 125 (± 25) in 1980 (Devick 1981a) to 144 in 1990 (Natividad-Hodges 1991; Hawai`i Division of Forestry and Wildlife-Maui, and Haleakalā National Park, unpubl. data). The Haleakalā National Park nēnē population has fluctuated from 200 to 250 birds for the last 8 to 10 years (C. Bailey, pers. comm. 2001; Table 1). Nēnē have also been observed in the Kahikinui, Kiheo, Kula, Lahaina, Olinda, Wailuku, and West Maui areas on the outer slopes of Haleakalā Crater (J. Medeiros, pers. comm. 1998; Figure 2).

The State is attempting to establish a second population of nēnē on Maui through releases at a new site on west Maui at Hana`ula. Eighty-seven nēnē

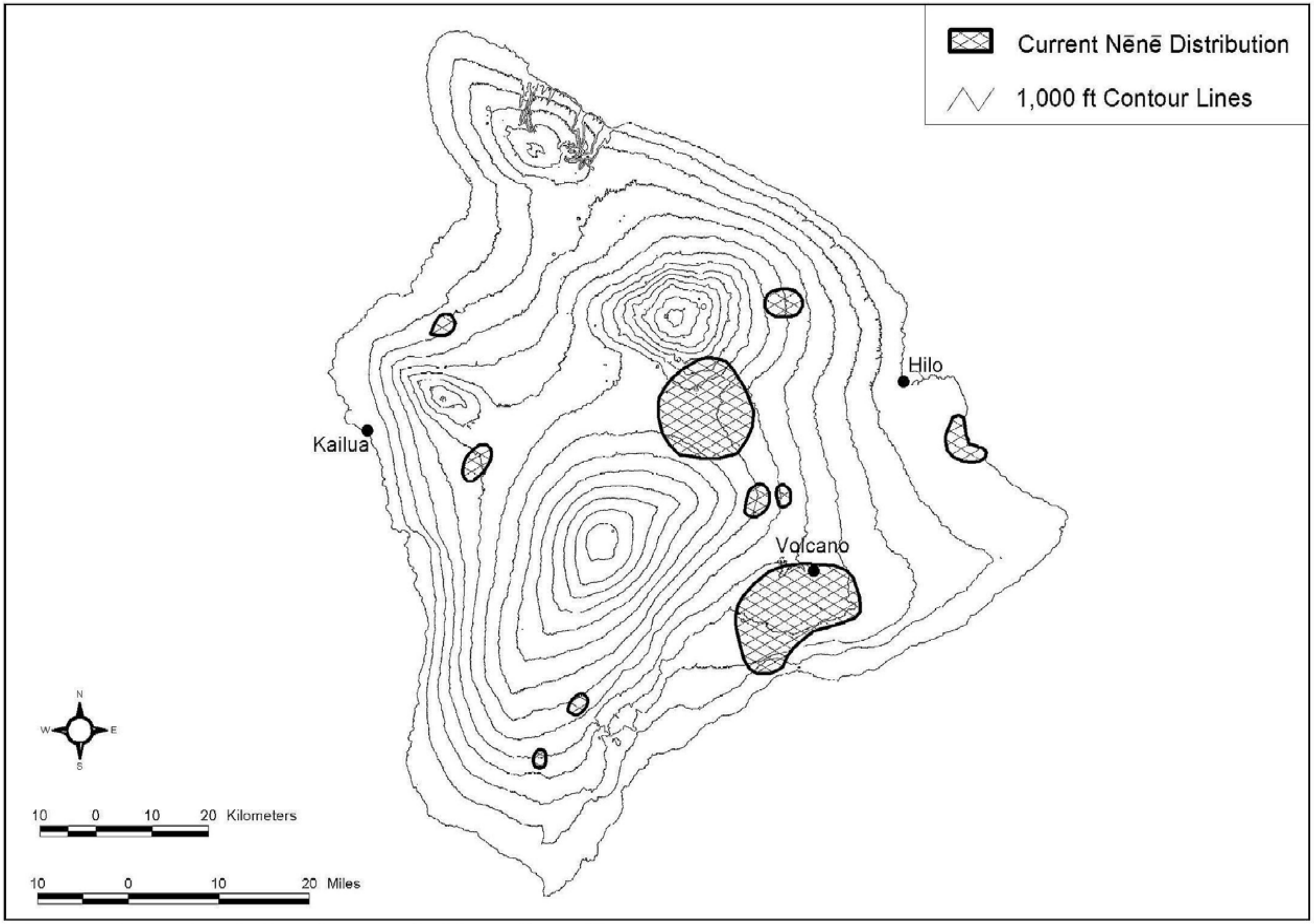

Figure 1. Current distribution of nēnē on the island of Hawai'i.

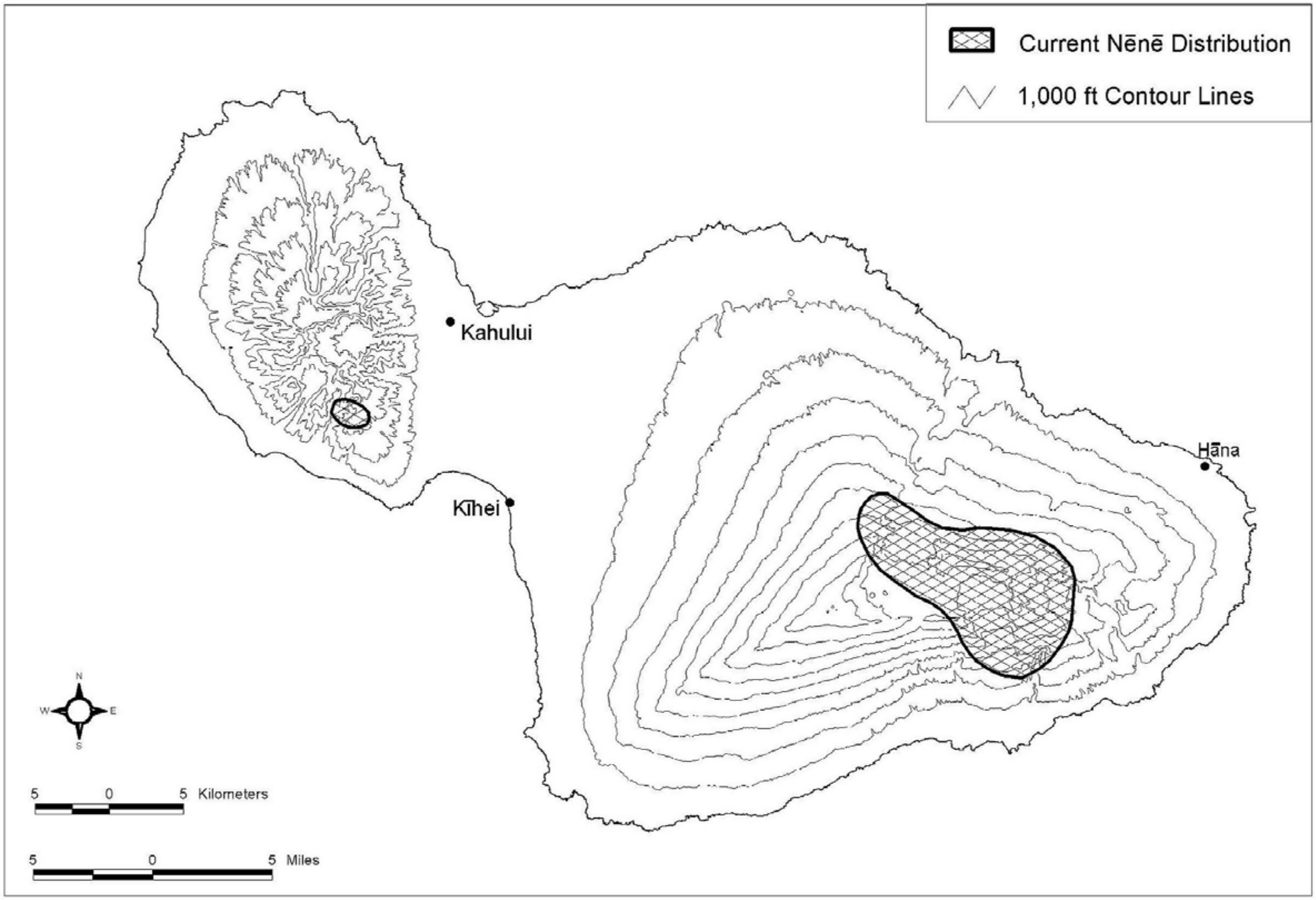

Figure 2. Current distribution of nēnē on the island of Maui.

have been released at this site between 1995 and 2003 (Appendix A-2; Hawai`i Division of Forestry and Wildlife 2000; J. Medeiros, pers. comm. 2003). The released birds are apparently doing well in this lower elevation site and in 1998, four goslings were successfully fledged from the first nest recorded in the area (Hawai`i Division of Forestry and Wildlife 2000).

3. Moloka`i

On August 22, 2001, we issued a Federal permit for a Safe Harbor Agreement[2] with Puu O Hoku Ranch on Moloka`i and with the Hawai`i Division of Forestry and Wildlife. This Safe Harbor Agreement gives the landowner assurances that if they maintain or improve nēnē habitat for at least 7 years, no additional restrictions will be placed on the property because of the presence of endangered species. With the establishment of this first Safe Harbor Agreement to be authorized in the State of Hawai`i, 11 nēnē (10 young of the year and 1 adult) were released in December 2001 into an open-top pen on the ranch. A total of 55 nēnē have been released through 2003 (Appendix A-3; Figure 3). Two of the nēnē released in December 2001 paired and bred successfully, fledging one gosling in 2002, and two more in 2003 (J. Medeiros, pers. comm. 2002, 2003). Additional releases are planned to supplement this group in the near future.

According to the Safe Harbor Agreement, the ranch eventually could support as many as 75 nēnē, with a goal of reaching an island-wide population of 200 birds. It is hoped that other landowners on Moloka`i will sign onto a programmatic island-wide Safe Harbor Agreement that was recently developed by the Hawai`i Division of Forestry and Wildlife and the U.S. Fish and Wildlife Service to help recover nēnē and their habitat. As nēnē are expected to spread out over the island from Puu O Hoku Ranch, other landowners can sign onto the programmatic Safe Harbor Agreement and would then also be covered for maintaining nēnē and their habitat while continuing operational activities on their lands.

4. Kaua`i

There are currently four nēnē population centers on Kaua`i, each resulting from releases of captive-bred birds at different times (Appendix A-4). With the exception of the Nā Pali Coast population, all of the Kaua`i populations are found at low elevations, ranging from sea level to 180 meters (600 feet) (Figure 4). Approximately 25 captive nēnē were released by Kīpū Kai Ranch in 1985 on the southeast coastline of Kaua`i. These birds were originally obtained from the Shipman Estates on Hawai`i in the late 1960's. Another 38

[2] See Appendix E for an explanation of Safe Harbor Agreements.

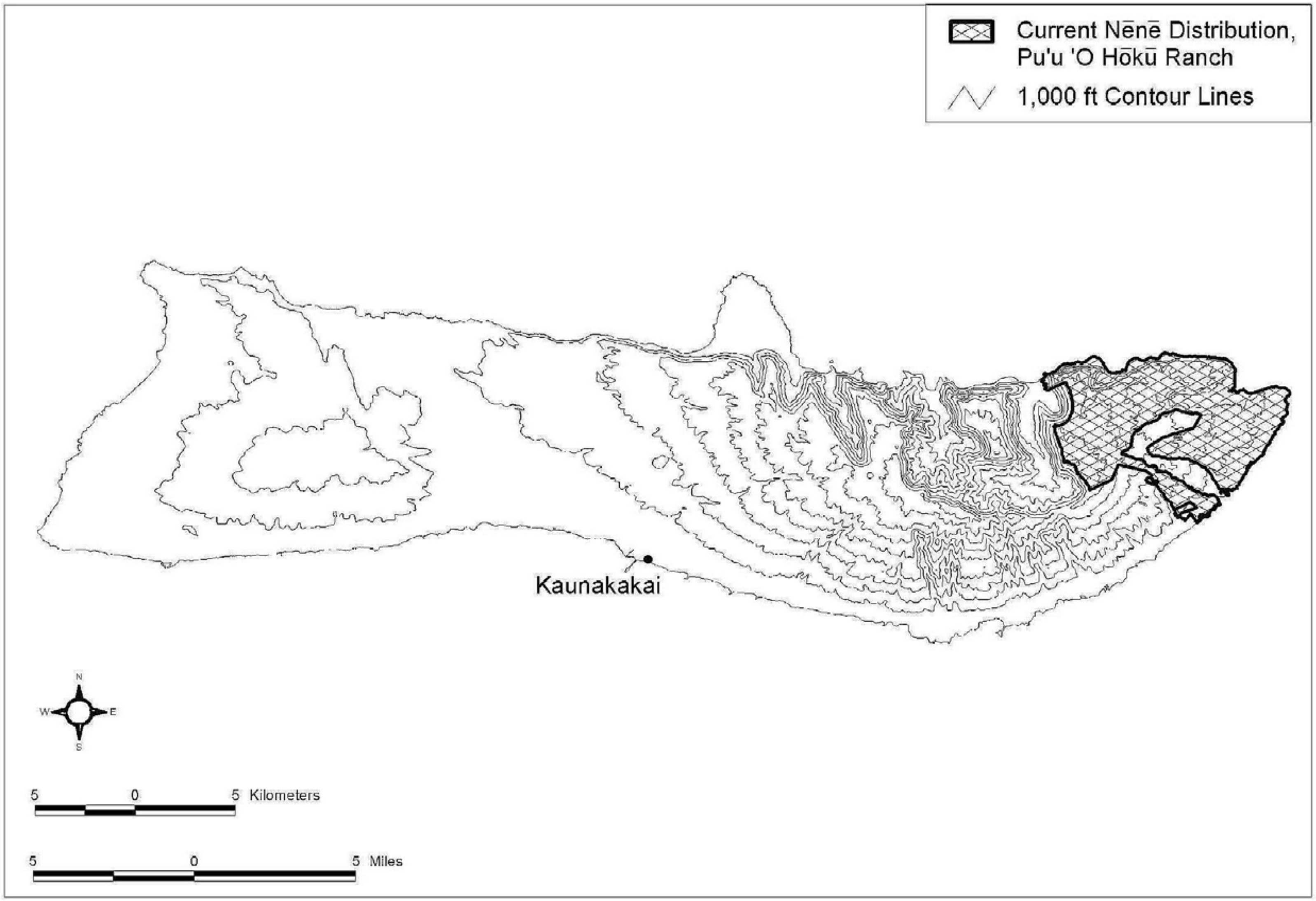

Figure 3. Current distribution of nēnē on the island of Moloka'i.

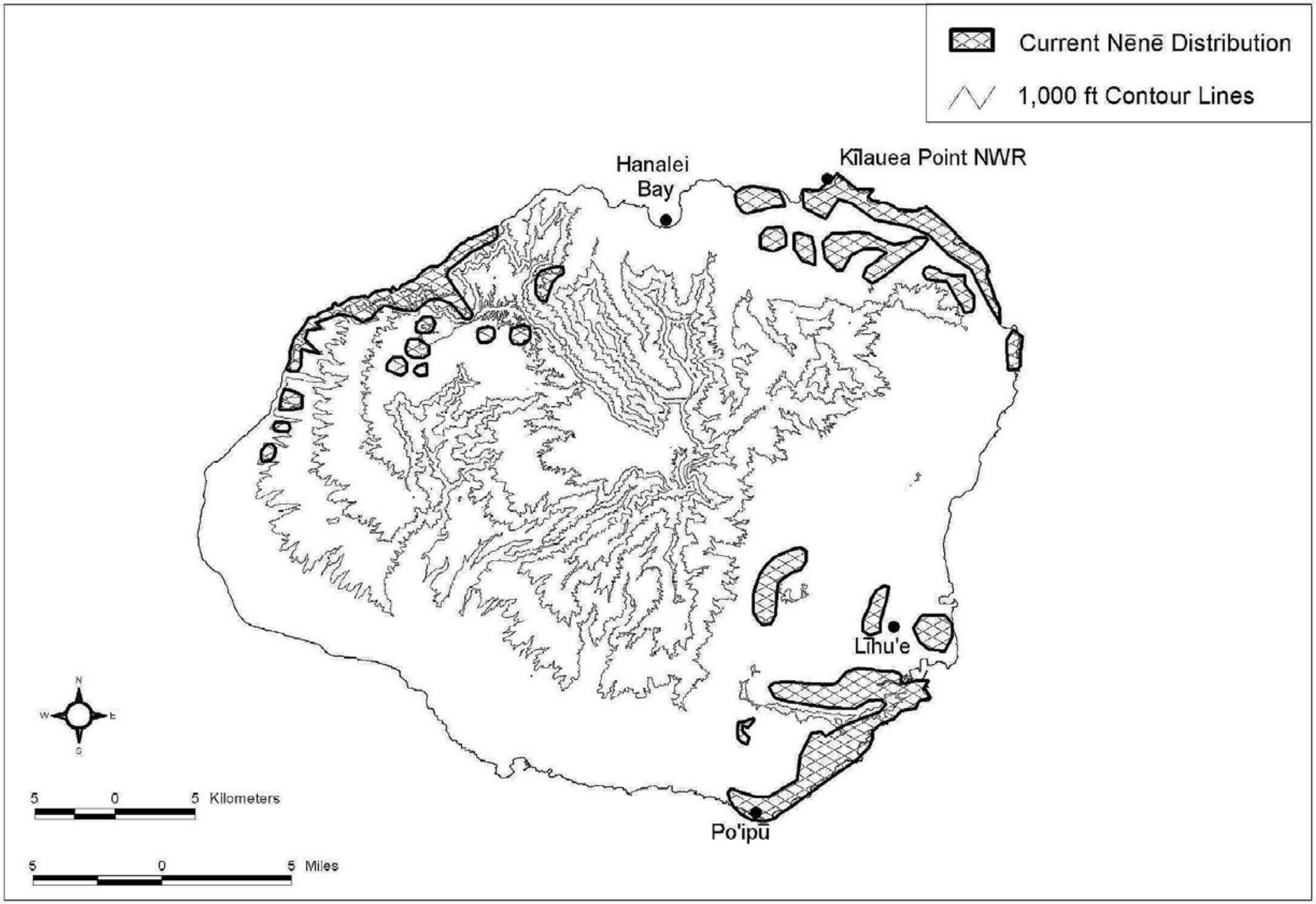

Figure 4. Current distribution of nēnē on the island of Kaua'i.

captive-bred nēnē have been released at the Kīlauea Point National Wildlife Refuge since 1991. These birds have bred successfully, and together these populations are now estimated to number 358 individuals. A third population was initiated on the Nā Pali Coast of northwestern Kaua`i with the release of 62 captive nēnē from 1995 to 1996. This population was released at 100 meters (330 feet) elevation but the birds subsequently moved to a higher elevation to breed (500 meters [1,650 feet]); this population currently numbers about 61 birds. Twenty-four nēnē were introduced to the Hanalei National Wildlife Refuge in April 2000. The total Kaua`i population was estimated at 525 nēnē as of April 2002 (T. Telfer, pers. comm. 2002; Table 1) and the 2003 population estimate was 620 birds (Telfer 2003).

Rave (1995) found that nēnē on Kaua`i had a significantly higher similarity coefficient distribution (*i.e.*, the lowest level of genetic variation) of all birds sampled from six wild populations on Hawai`i, Maui, and Kaua`i. Rave (1994) also found evidence that as inbreeding increased, hatchability and survivorship decreased in the captive Hawai`i population, and hatchability decreased in the The Waterfowl and Wetlands Trust population. The addition of wild birds to captive populations helps to reduce inbreeding and increase productivity (Kear and Berger 1980; Rave 1994).

The expansion of the Kauai population in the 1990's, while likely due primarily to the lack of an established mongoose population on the island, as well as the availability of lush lowland habitat, may have also profited by the introduction of other captive-reared nēnē in the early part of that decade. Additional genetic studies would establish whether genetic variation of nēnē on Kaua`i had increased after more captive releases occurred. Further discussion on genetics is provided in Section G6 - Genetic Issues.

E. LIFE HISTORY

Historical reports indicate that nēnē bred and molted primarily in the lowlands during the winter months and moved up-slope (above 1,200 meters [3,900 feet]) in the hotter and drier summer months (Henshaw 1902; Perkins 1903; Munro 1944; Banko 1988). It is thought that not only were food resources in the lowlands improved during the winter rains, but nesting success and gosling survival in the warmer, low elevation areas were likely better as well (Henshaw 1902; Perkins 1903; Munro 1944; Baldwin 1945). Likewise, some foods (berries and some grasses) were abundant in the uplands in the summer when nēnē returned with their fledged goslings (Henshaw 1902; Baldwin 1947). Local movements, perhaps within a 10 kilometer (6 mile) area, of nēnē flocks out of specific nesting areas after offspring have fledged has been reported as occurring between June and September; however, no pronounced seasonal altitudinal movements have been observed in recent times (Stone *et al*. 1983b; Banko 1988; Banko *et al*. 1999). These seasonal movements are best known from a relict population nesting on Keauhou Ranch, Mauna Loa Volcano, Hawai`i, in the 1950's (Woodside 1956; Elder and Woodside 1958). According to Banko *et al*. (1999), populations there today seem to behave similarly, with birds beginning to visit nesting areas from August to September, remaining at these sites until April after the adults molt and goslings fledge, and then flocking and wandering to summering areas in mid-June. It is not known how the introduction of captive birds has affected the remaining wild population, in terms of integrating with the relict flock; however, as noted, a population does still occur in the area.

Because of the changes in habitats and the fact that most existing nēnē populations in the wild are the result of reintroductions of captive-bred birds, traditional movement patterns have been mostly lost, though it appears new ones may be forming: although not well developed, flocks move seasonally among at least four major areas around Hawai`i Volcanoes National Park (Stone *et al*. 1983; Hoshide *et al*. 1990; Banko *et al*. 1999). Banko and Manuwal (1982) observed that nēnē disperse from breeding areas during the nonbreeding season and wander extensively. Today, nēnē tend to move primarily within mid- and high-elevation habitats on Hawai`i and Maui where lowland habitats are generally unsuitable because of predation and changes in vegetation (Banko and Elder 1990; Banko *et al*. 1999). Many nēnē at Haleakalā National Park move from the crater floor to surrounding ridges and outer slopes of the volcano during the summer (Bailey and Medeiros, pers. comms. cited in Banko *et al*. 1999). On Kaua`i, nēnē tend to move between lowland agricultural and other modified habitats near the coast, generally traveling less than 13 kilometers (8 miles) (Telfer 1996; Banko *et al*. 1999).

The nēnē has an extended breeding season with eggs reported from all months except May, June, and July. This timeframe constitutes the longest nesting season reported for wild geese (Banko *et al*. 1999). However, the majority of birds in the wild nest during the rainy (winter) season between October and March, with the greatest numbers of first clutches produced between October and December (Kear and Berger 1980). Nesting peaks in December and most goslings hatch from December to January (Banko *et al*. 1999).

Nēnē are ground-nesters. The nest consists of a shallow scrape, moderately lined with plant materials and down, which is usually well-hidden in the dense shade of a shrub or other vegetation. Nest sites include various habitat types ranging from beach strand, shrubland, and grassland to lava rock, and elevations ranging from coastal lowlands to alpine areas (Banko 1988; Banko *et al*. 1999). On Hawai`i and Maui, most nests are built under native vegetation, which predominates in the nesting areas, including *Styphelia tameiameia* (pūkiawe), *Dodonaea viscosa* (`a`ali`i), *Vaccinium reticulatum* (`ōhelo), and *Metrosideros* spp. (`ōhia) (Appendix C). On Kaua`i, however, alien plant species dominate most nesting areas and nēnē build their nests under species such as *Schinus terebinthifolius* (christmasberry), *Lantana camara* (lantana), and *Casuarina equisetifolia* (ironwood) (Banko *et al*. 1999). While the female incubates the eggs, the male stands guard nearby, often from an elevated location. When the female leaves the nest to forage, the male generally follows her to forage and to guard her rather than guarding the nest (Marshall, pers. comm. 2002). If the female remains near the nest while foraging, the male will guard both the female and the nest (Banko 1988).

Banko (1988) reported that nēnē generally nest in areas associated with release sites. Recent analysis shows that during the early stages of the reintroduction program, the majority of nēnē reared and released in low- to mid-elevation sites in Hawai`i Volcanoes National Park nested close to those areas but began moving away and utilizing other breeding areas as bird density around release pens increased and maintenance of the lowland pens was discontinued (Woog 2000). Most of the breeding areas that were colonized were at mid-elevations, but whether this is due to preference of sites with higher rainfall or simply the result of greater availability of such sites is unknown (Woog 2000). Additional research is needed to determine if variation in natal dispersal distances is the result of adaptation to fluctuating environmental conditions (Woog 2000). In general, however, females remain near natal fledging sites for nesting while males tend to disperse, although wild females tend to be more philopatric than released ones (Banko and Manuwal 1982; Woog 2000). Nēnē usually pair for life and the birds typically remain in close proximity to each other during the year (Banko *et al*. 1999; U. Zillich and J. Black, unpubl. data). Extra birds have occasionally been associated with nesting attempts, but extra-pair copulations have never been observed (Banko *et al*. 1999). On average, approximately 80 percent of all birds are paired in any given year, and 40 to 60 percent of these pairs will attempt to nest (Banko 1988). A clutch typically contains 3 to 5 eggs (mean 3.13 $\pm$ 1.07, range 1 to 6, n = 552 nests in the wild; Black, unpubl. data) laid at 2 day intervals (n = 8 nests) (Banko 1988; Banko *et al*. 1999). Incubation, by the female only, begins immediately following laying of the last egg and lasts for 29 to 31 days. If eggs are abandoned or destroyed prior to hatch, relaying may occur (Banko 1988), usually within 14 to 60 days depending on female condition and duration of prior incubation. Banko (1988) found that at least 9 percent of females in the wild renested after predators destroyed their first nest or the first brood died. The fertility of second clutch eggs is less than that of eggs in first clutches (F. Duvall, pers. comm. 1994). Second clutches of nēnē in the wild were laid during January to March with goslings hatching 1 month later (Banko 1988).

Generally, all eggs in a clutch hatch within a 24-hour period. The young remain in the nest for 1 to 2 days (Banko *et al*. 1999). Fledging of captive birds occurs at 10 to 12 weeks post-hatch, but may be longer in the wild (D. Hu, pers. comm. 1999). During molt, adults are flightless for a period of 4 to 6 weeks, generally attaining their flight feathers at about the same time as their offspring. Goslings are virtually indistinguishable from adults at 4 to 5 months of age (Banko *et al*. 1999). When flightless, goslings and adults are extremely vulnerable to predators such as dogs, cats, and mongooses. From June to September, family groups join others in postbreeding aggregations (flocks), often far from nesting areas. Family break-up occurs just prior to a new nesting season, when the goslings are 10 to 11 months old. Family groups also may reunite after nesting and siblings may continue to associate with each other in the nonbreeding season over their lifetimes (10+ years) (D. Hu, pers. comm. 1999).

Compared to the Canada goose, nēnē wings are reduced by about 16 percent in size and their flight is weak. Nonetheless, nēnē are capable of both inter-island and high altitude flight (Miller 1937; Banko *et al*. 1999). There are at least 10 records of nēnē that have flown from Maui to Hawai`i and 1 record of a nēnē that flew from Hawai`i to Maui (Banko and Elder 1990). There is little information on movements of nēnē prior to human contact; however, no geographic variation is described, probably because of inter-island immigration (Banko *et al*. 1999). Nēnē currently range within areas of less than 200 square kilometers (772 square miles) in size, with little dispersal occurring from fledging to breeding (Banko *et al*. 1999). Some variability in movements of nēnē has been noted by various authors, and this may be the result of a combination of factors, including food availability, weather conditions, and predation (Black *et al*. 1997; Woog 2000).

Sexual maturity may be reached by 11 months post-hatch, however pair formation typically occurs in the second year of life (Kear and Berger 1980; Banko 1988; Banko *et al*. 1999). Fertile eggs have been produced at ages ranging from 11 months to 22 years post-hatch, both in captivity and in the wild. Wild females produce fertile eggs for many years, ranging from 2 to at least 14 years of age, while eggs have been fertilized by wild males from 2 to 19 years of age (Banko 1988; Banko *et al*. 1999). The oldest recorded nēnē in the wild was 28 years, a bird hatched at the Waterfowl and Wetlands Trust and released as a gosling at Haleakalā National Park. The oldest captive bird, from a collection in Cleres, France, was 42 years old (Banko *et al*. 1999). Studies of released birds show that survival and mortality of nēnē is affected by year of release, age class, and methods of release (Black *et al*. 1997). Hu (1998) found that annual mortality of wild adult females aged 4 years or older was 13.2 percent ± 4.14 SD (n = 218) and 11.3 percent ± 5.22 SD (n = 186) for males more than 3 years old in habitats below 1,220 meter (4,003 foot) elevation in Hawai`i Volcanoes National Park. There also appears to be differential survival of males versus females in released birds, such that males tend to be more prevalent in the older (more than 1-year of age) populations on Hawai`i, Maui, and Kaua`i (Banko *et al*. 1999).

A list of all known nēnē food plants is being compiled in a database using published literature, unpublished notes, and field observations (Hu 2000; Sherry 2000). The database will also include information on nutrient analysis, with an emphasis on endemic and indigenous plants, though it also includes information on nonnative species. The information from this database is also being used to develop a list of native Hawaiian plants known to be currently or formerly utilized by nēnē for use by managers interested in habitat restoration for nēnē (Appendix B). Nēnē are browsing grazers, eating over 50 species of native and introduced plants (Baldwin 1947; Black *et al*. 1994; Banko *et al*. 1999). The composition of their diet depends largely on the vegetative composition of their surrounding habitats and they appear to be opportunistic in their choice of food plant as long as they meet nutritional demands (Banko *et al*. 1999; Woog 2000). Because most habitats in Hawai`i are highly altered and have a high proportion of nonnatives, there is a high proportion of nonnative foods in the nēnē diet (Black *et al.* 1994; Banko *et al*. 1999; Woog 2000). For example, in 1947, Baldwin identified a native grass, *Deschampsia nubiena*, as the most abundant food item for nēnē on Hawai`i. However, in the early 1990's, Black *et al*. (1994) found *Deschampsia* only in droppings of nēnē at Haleakalā National Park, likely because of a change in the vegetation structure over the past 50 years, since endemic species such as *Deschampsia* are outcompeted by more vigorous, introduced species (Cuddihy and Stone 1990). It seems apparent that such adaptability in their utilization of food items has allowed nēnē to survive in marginal habitats to which they were relegated as their traditional habitats were lost (Black *et al*. 1994, 1997; Banko *et al*. 1999).

The majority of nēnē food items are leaves and seeds of grasses and sedges, leaves and flowers of various herbaceous composites, and various fruits of several species of shrubs (Black *et al*. 1994; Banko *et al*. 1999). Some native foods that have been shown through fecal sample analysis to have a high occurrence in the nēnē diet include `ōhelo and pūkiawe berries, *Carex wahuensis* (a sedge), and *Deschampsia* (a grass) (Baldwin 1947; Black *et al*. 1994; Appendix B). Nonnative foods that are frequently used as forage by nēnē include *Pennisetum clandestinum* (kikuyu grass), *Holcus lanatus* (Yorkshire fog or mesquite grass), *Sporobolus africanus* (rattail grass), and *Hypochoeris radicata* (gosmore) (Baldwin 1947; Black *et al*. 1994). These formal studies on the diet composition of nēnē have been conducted on Hawai`i and Maui (Baldwin 1947; Black *et al*. 1994; Hu 2000; Sherry 2000; Woog 2000). Anecdotal observations of nēnē on Kaua`i indicate that they feed on introduced grasses such as *Eleusine indica* (wire grass) and *Digitaria adscendens* (crabgrass), as well as gosmore and the berries of the native *Scaevola sericea* (naupaka kahakai) (T. Telfer, pers. comm. 2000).

In general, it is believed that nēnē are generalists and currently require a diverse suite of food availability that may include nonnative and native vegetation (Black *et al*. 1994; Banko *et al*. 1999). While nēnē readily feed in both highly altered nonnative and remaining remnant native habitats, there have been concerns raised about whether breeding females and goslings in highly altered habitats are receiving adequate nutrition since productivity is so low in many populations, particularly on Hawai`i and Maui (Banko 1992; Black and Banko 1994; Black *et al*. 1994; Baker and Baker 1995, 1999; Banko *et al*. 1999). Baker and Baker (1995, 1999) suggested that starvation and dehydration may be the primary cause of gosling mortality at Haleakalā National Park. However, these results are not definitive and more research is needed. Banko (1988, 1992) found that starvation or dehydration was a major factor in the mortality of goslings during 1978 to 1981 on Hawai`i. Black *et al*. (1994) observed that nēnē take their broods to areas where foods may have higher protein values in Hawai`i Volcanoes National Park. Protein is known to be important for developing goslings (Sedinger and Raveling 1984). Females need to accumulate adequate fat reserves for laying and incubation, and low productivity in nēnē populations has been partly attributed to the poor nutritional value of altered habitats (Black *et al*. 1994, 1997; Banko *et al*. 1999). Recently, poor nutrition has also been raised as a possible problem on Kaua`i although it is believed that reproduction is better there because of the lack of an established mongoose population as well as a greater availability of food (Telfer 1995, 1996; Telfer, pers. comm. 1998). Studies on diet and nutrition should be conducted on Kaua`i to examine these questions.

The development of foraging behavior in nēnē goslings has recently been assessed (Rojek 1994b; Rojek and Conant 1997). Nēnē goslings were found to exhibit food preferences, possibly based on their early experience with food items, but which could not be attributed to protein or water content. However, prior food experience did not preclude them from consuming novel foods (Rojek and Conant 1997). Rojek and Conant (1997) also found that captive-bred goslings, raised on a limited diet in captivity until adulthood, do not try novel food items (berries) as readily as wild goslings; wild-caught adult nēnē placed in captivity also consume berries. This suggests that the length of time in captivity is important in considering the diet for nēnē that are reared for release (Rojek and Conant 1997). Rojek (1994b) also found that goslings raised on a standard diet (grain plus various plants such as kikuyu grass and gosmore) in captivity tried a variety of foods once released, though there was an initial reliance on grain. Hawai`i Volcanoes National Park is currently funding studies on the nutritional values of native food plants and conducting palatability trials with goslings (Sherry 2000).

F. HABITAT DESCRIPTION

The historical distribution of nēnē (after 1778, the time of first European contact) reflects only a portion of the range nēnē once occupied as indicated by fossil remains, and while the vegetation structure and composition of habitats occupied by nēnē before human settlement are not described, it is likely they utilized grasslands, grassy shrublands, and dryland forest (Banko *et al*. 1999). Historical data indicates that they frequented lowland dry forest, shrubland, and grassland and montane dry forest and shrubland (Baldwin 1945). The current distribution of nēnē has been highly influenced by the location of release sites for captive-bred nēnē (Banko *et al*. 1999). Nēnē currently inhabit elevations ranging from sea level to 2,500 meters (8,000 feet) and habitat and vegetation community types currently utilized by nēnē range from coastal dune vegetation and nonnative grasslands (such as golf courses, pastures, and rural areas) to sparsely vegetated low- and high-elevation lava flows, mid-elevation native and nonnative shrubland and early successional cinderfall, cinder deserts, native alpine grasslands and shrublands, and open native and nonnative alpine shrubland-woodland community interfaces. The areas nēnē inhabit typically have less than 229 centimeters (90 inches) of annual rainfall.

Some early accounts suggested that nēnē nested primarily in the highlands (Peale 1848; Dole 1869, 1879). However, more recent interpretations of information indicate that the majority of the population formerly bred and molted in the lowlands (below 400 to 700 meters [1,320 to 2,310 feet]), exploiting the flush of plant foods which occurred during the usually wetter winter months, and retreating to higher elevations (above 1,220 to 1,520 meters [4,026 to 5,016 feet]) during summer when drier conditions generally prevailed (Henshaw 1902; Perkins 1903; Munro 1944; Baldwin 1945, 1947; Olson and James 1982). Banko (1988) found nests in the wild as low as 235 meters (775 feet) at Pu`u Kaone, Hawai`i Volcanoes National Park, and as high as 2,300 meters (7,546 feet) at Kuiki, Haleakalā National Park. The distribution of nests generally has been associated with the location of release sites of captive-bred nēnē since 1960. Consequently, the ecological zones (Mueller-Dombois and Fosberg 1974; Mueller-Dombois 1976) currently utilized for nesting by nēnē range from coastal lowland to subalpine. Hawai`i Volcanoes National Park has had at least one pair of nēnē that nested at sea level (Hu, pers. comm. 1999). The apparent success of the recently established (1985) Hanalei National Wildlife Refuge population on Kaua`i supports the belief that lowland habitats may be best able to support viable nēnē populations, especially when mongoose are not established.

There is great variability in the range of physiographic features of the sites currently used by nēnē for nesting (Banko *et al*. 1999). In the Kau desert, Hawai`i Volcanoes National Park, nest sites were located in sparsely vegetated areas with vegetation density ranging from 0 to 16 plants per square meter (0 to 1.5 plants per square foot) and a substrate of volcanic rocks intermingled with sandy patches (Black *et al*. 1994). Pūkiawe was relatively numerous at all nest sites, while the number of other plant species varied considerably. Nest sites studied at Haleakalā National Park were located in well vegetated habitat, 13 to 676 plants per square meter (1.2 to 62.8 plants per square foot), and the most abundant species were `ōhelo seedlings, gosmore, and Yorkshire fog

(Black *et al*. 1994). During the breeding season, nēnē feed mainly on berries and other plant items found on lava flows near their nest sites, although some birds supplemented their berry diet by feeding in grasslands, perhaps due to declining berry density, while during the pre- and nonbreeding season, their principal foods are cultivated grasses (Black *et al.* 1994). There was a seasonal decline in food quality and density that may restrict the time available for breeding. Woog and Black (2001) found that nēnē selected habitats with food plants of high protein content.

Areas used by nēnē outside of the breeding season are less well studied, although as noted above grasslands may be important. In some sites, such as Hakalau Forest National Wildlife Refuge, it is unclear where the birds go after breeding (Black *et al.* 1994; J. Jeffrey, pers. comm. 2003). A recent study on the effects of mowing pasture grasses on grazing intensity at Hawai`i Volcanoes National Park showed that adult nēnē grazed more in areas with the sward-forming[3] kikuyu grass than in areas with bunch grasses (grasses that grow in tufts), and they preferred patches with legumes as opposed to pure grass sward (Woog and Black 2001). Adult nēnē also selected sites with grass having a high water content, grazed most in grasses shorter than 11 centimeters (4.3 inches), and used grasslands less during dry periods though they may be more likely to move to grass habitats during drought (Black *et al*. 1997; Woog and Black 2001). Grass with low water content is lower in protein (Woog and Black 2001).

The presence of standing or flowing water is not necessary for successful breeding, although observations of nēnē in the lowland coastal regions of Hawai`i and Kaua`i indicate that when standing water is present it is often readily utilized for drinking and bathing. Bodies of water may also be used to escape from predators when goslings have not yet fledged and when adults molt their primary flight feathers. Even during the non-nesting season, nēnē on Kaua`i spend much of their time near and in water, whether at irrigation reservoirs, golf course water hazards, or natural or artificial lagoons and ponds. Little standing water is available in most nēnē habitats and water is obtained primarily from their diet (Banko *et al*. 1999). As noted above, nēnē are more terrestrial than most other waterfowl species, having evolved in habitats with limited freshwater availability.

As mentioned previously, there is limited understanding of the vegetation structure, composition, and dynamics of Hawaiian habitats occupied by nēnē and other native species prior to human

[3] A sward refers to an expanse of short grass with continuous cover.

contact and there is little doubt that changes to these habitats have been extensive, especially in the lowlands (Cuddihy and Stone 1990; Banko *et al*. 1999; Burney *et al*. 2001). More recent archaeological work is allowing examination and improved understanding of the environmental history of Hawai`i, including species composition and the timing of changes, extinctions, and exotic introductions (Burney *et al*. 2001). It is likely that this work will aid in habitat restoration efforts for all native species, including nēnē. The information being developed for the nēnē food database should also prove helpful in current and future habitat restoration and management efforts for nēnē (Hu 2000; Sherry 2000). Efforts to conduct habitat restoration by outplanting native plants known to be utilized by nēnē are increasing, for example, in concert with Safe Harbor Agreements (see Section H - Conservation Efforts), and at Hawai`i Volcanoes National Park. Such restoration projects will result in a greater suite of food availability from which it may be expected that nēnē will realize a benefit in productivity and gosling survival (Banko *et al*. 1999; Hu and Marshall, pers. comms. 2002).

G. REASONS FOR DECLINE AND CURRENT THREATS

Fossil evidence indicates nēnē were once abundant on most of the major Hawaiian islands (Olson and James 1991). The first humans to reach Hawai`i exploited nēnē for food, destroyed lowland habitat, and introduced the first mammalian predators (Polynesian rats ([*Rattus exulans*], dogs, and pigs), factors that led to the first substantial declines of nēnē (Olson and James 1991; Banko *et al*. 1999).

It is generally agreed that the major reasons for continued declines during the early part of this century were hunting, which occurred in the fall and winter during the nēnē breeding season, continued habitat loss, and predation by additional alien mammals introduced by westerners after 1778 including dogs, cats, mongooses, pigs, and rats, which prey upon nēnē adults, eggs, and young. Humans, feral cattle, goats, pigs, and sheep also altered and degraded nēnē habitat.

Currently, it is believed that the following threats are major limiting factors to nēnē recovery: predation, nutritional deficiency due to habitat degradation, lack of lowland habitat, human-caused disturbance and mortality, behavioral problems, and inbreeding depression. Predation is believed to be the greatest factor limiting nēnē populations at this time, and developing effective and economical predator control will likely play a key role in the recovery of the species. Disease may also be a limiting factor; however, its role in affecting nēnē recovery is poorly documented and not well understood and should be studied further.

The threats to the nēnē are detailed below and classified according to the five factors that may negatively impact a species, leading to its decline, as identified in section 4(a) of the Endangered Species Act. Those five factors are:

(A) the present or threatened destruction, modification, or curtailment of its habitat or range;
(B) overutilization for commercial, recreational, scientific, or educational purposes;
(C) disease or predation;
(D) the inadequacy of existing regulatory mechanisms;
(E) other natural or manmade factors affecting its continued existence.

1. Predation (Factor C)

Before Polynesian colonization, only avian predators existed in Hawai`i (Banko *et al*. 1999). Most of these avian predators are now extinct, and what impacts these avian predators may have had on nēnē in the past is unknown. The extant Hawaiian hawk or `io (*Buteo solitarius*) has never been observed killing nēnē, though they have been observed stooping on broods and harassing adults (Rojek 1994a; Hu, pers. obs., as cited in Banko *et al*. 1999). It is the introduced mammalian predators that have been identified as causing significant mortality of nēnē in the wild. A study conducted in Hawai`i Volcanoes National Park demonstrated that 77 percent of eggs lost between 1978 and 1981 were lost to mongooses (Banko 1988). Banko (1992) found that nesting success (at least one egg hatched) was nearly twice as high for nēnē nesting in enclosures as it was for nēnē that were not provided such protection. Black and Banko (1994) reported that a study of predation on chicken eggs found that mongooses were the most serious egg predator in all habitats studied and that clutches placed in low elevation sites were destroyed most rapidly (see also Stone *et al*. 1983).

Predation of nēnē eggs was studied by Baker and Baker (1995) from 1994 to 1995 at Haleakalā National Park. This study indicated that both rats and mongooses were visiting nests and taking eggs. Mongooses predated 9 nests in 1993 to 1994 and 10 in 1994 to 1995, and rats predated 7 nests in 1993 to 1994 and 3 nests in 1994 to 1995 (Baker and Baker 1995). The significant decrease in rat predation between years is presumably due to the extensive trapping and diphacinone poisoning program conducted against rats by Haleakalā National Park staff in 1994 to 1995. The success of this predator control effort was reflected by data collected at the Palikū site: in 1993 to 1994, 12 of 19 nests were predated, while only 1 full and 2 partial predations of 17 nests occurred in 1994 to 1995 (Baker and Baker 1995). Goslings have also been taken by mongooses, rats, and cats (Hoshide *et al*. 1990; Banko 1992). Dogs and mongooses are responsible for most of the known cases of predation on adult birds, though cats and possibly poachers also kill adults (Banko and Elder 1990). Adult nēnē that are incubating eggs, have goslings, or that are molting, are at an especially high risk of predation.

On Kaua`i, increasing nēnē populations to date attest to the advantage of not having an established mongoose population. However, mongoose sightings have occurred on the island since 1968, with at least one lactating female killed on the road in 1976, and there is a fear that mongooses may become established in the future. Efforts are currently underway to get better tools for detecting mongooses, and it will be important to raise public awareness and increase the reporting of mongoose sightings for analysis. Data currently indicate that dogs, both feral and domestic, and feral cats, are a primary cause of death of adult nēnē on Kaua`i, and possibly have an impact on the Hawai`i population as well (Telfer, pers. comm 1998; C. Terry, pers. comm. 1999). Telfer (2003) reported that dogs have been a continual problem to nēnē on Kaua`i and found that 4 of 10 nēnē mortalities recorded from July 1, 2001, to June 30, 2002, were attributed to predation by dogs.

Feral pigs impact nēnē by destroying nests and predating eggs, young, and adults during their flightless stage (Kear and Burger 1980; Hu, pers. comm. 2002). Pigs may roam over nearly the entire extent of the range of nēnē. Their foraging activities can result in trampled ground cover, heavily furrowed ground, and loss of seedlings and understory plants which can impact nēnē forage plants. The presence of pigs can also attract feral dogs to an area which may then predate nēnē (Banko *et al.* 1999).

2. Inadequate Nutrition (Factors A and E)

Some studies (Banko 1992; Black *et al*. 1994; Baker and Baker 1995) indicate that inadequate nutritional quality is a limiting factor on nēnē reproduction and gosling survival, especially on Hawai`i and Maui. For instance, Baker and Baker (1995) found that 81.5 percent of gosling mortality in Haleakalā National Park during the 1994 to 1995 breeding season was due to starvation and dehydration. Lack of adequate food or water also appears to be a limiting factor in Hawai`i Volcanoes National Park. Over 3 seasons in Hawai`i Volcanoes National

Park, 16 gosling carcasses were recovered via telemetry. None of these carcasses showed signs of predation and postmortem analysis from the first two seasons failed to find any overt sign of disease or toxins. The carcass conditions were consistent with a lack of adequate food or water (R. Schmidt, unpubl. reports in Hu 1998). Additional discussion on this topic is provided in Section F - Habitat Description.

3. Lack of Lowland Habitat (Factor A)

Today, many nēnē nest in mid- and high-elevation sites, although it is believed that they once nested primarily in leeward lowlands (Baldwin 1947; Banko *et al*. 1999). Lowland areas are used by nēnē populations on Kaua`i year-round and are seasonally important habitats for nēnē populations on Hawai`i. In light of this information and the fact that the nēnē population in the lowland Kaua`i sites have been the most successful, managers have expanded efforts to find lowland areas for potential nēnē reintroduction. Recent nēnē introductions in lowland sites include the Hana`ula West Maui site and Puu O Hoku Ranch on Moloka`i. A programmatic Safe Harbor Agreement for private lands on the Island of Moloka`i was recently finalized and it is hoped this will allow the expansion of nēnē into additional lowland sites there. The Hawai`i Division of Forestry and Wildlife and the U.S. Fish and Wildlife Service intend to continue to work cooperatively to develop Safe Harbor Agreements for appropriate lowland sites on other islands.

The National Park Service is exploring the possibility of introducing nēnē to a lowland site (near sea level) located in the `Ohe`o area of Haleakalā National Park. This project has the additional benefit of attempting to mesh a native Hawaiian project, growing organic *Colocasia esculenta* (taro), with an endangered species project. The coexistence of Hawaiian cultural practices and native species also offers a variety of public educational opportunities.

4. Human-Caused Disturbance and Mortality (Factor E)

There are a variety of human activities that negatively impact nēnē. These activities include direct harm, such as that caused by vehicles and golf balls, as well as possible disturbance by hikers, hunters, and other outdoor recreators. For instance, a nēnē was intentionally killed by a golfer in 1998 on the Island of Maui. In addition, at least six nēnē on Hawai`i have been struck by golf balls, and five of these died as a result (Banko *et al*. 1999; G. Phocas, pers. comm. 2002). Road casualties are a major cause of nēnē deaths in Hawai`i Volcanoes National Park and in Haleakalā National Park (Hu and Bailey, pers. comms. 1998). At least 41 birds were killed by cars in

Hawai`i Volcanoes National Park between 1989 and 1999 (Hu, unpubl. data) and 14 nēnē were killed by cars in Haleakalā National Park during 1988 to 1998 (Bailey, unpubl. data). Mortality of nēnē from cars has also been a continual problem on Kaua`i (Telfer 2003). Limited facilities and veterinarians to care for nēnē has hampered efforts to aid injured birds.

A State-sponsored monitoring effort during the 1992 to 1993 Kapapala gamebird hunting season and several biological opinions of the U.S. Fish and Wildlife Service (1993, 1994, 1996) concluded that properly conducted gamebird hunting is not a problem for nēnē in the area (Hawai`i Division of Forestry and Wildlife 1993). However, the effects of gamebird hunting on nēnē (*e.g.*, potential injury from hunting dogs, general harassment during the breeding season, potential for shooting a nēnē by mistake) at Kapapala and other areas is the subject of continuing debate. Nēnē may also be impacted by human activities through the application of pesticides and other contaminants, ingestion of plastics and lead, collisions with stationary or moving structures or objects, entanglement in fishing nets, habitat degradation, disturbance at nest and roost sites, attraction to hazardous areas through human feeding and other activities, and mortality or disruption of family groups through direct and indirect human activities (Banko *et al*. 1999). At least one nēnē has died from lead poisoning from an unknown source (Telfer 1995).

5. Behavioral Issues (Factor E)

Problems with nēnē breeding success may be related to social dynamics resulting from nēnē release strategies. Continuing releases of nēnē siblings, and prefamiliarized nonsiblings, for a number of years in identical release locations may result in pairings between siblings or may cause birds, especially males, to leave release areas in search of appropriate nonfamiliar partners. In addition, parent or foster parent-reared goslings may be more socially adept than group-reared goslings (raised without parents or foster parents) and more likely to survive (Marshall and Black 1992). This study showed that parent-reared birds were dominant to, more vigilant, and vigilant for longer periods than goslings raised without parents or in sight of adult birds. The parent-reared birds also integrated into the adult flock sooner than other goslings. These results have been integrated into the nēnē management program and most captive-bred nēnē are currently raised with their own parents or with foster parents. Woog (1994) found that goslings raised in sibling groups and released into the wild had lower reproductive success than parent-reared goslings in both Hawai`i Volcanoes National Park and Haleakalā National Park.

Captive-bred nēnē may not have the behavioral traits (such as avoidance of predators) necessary to succeed in the wild. Zillich (1995) has shown that while captive goslings exhibit an innate response to predators, the response may not automatically result in appropriate avoidance behavior as they grow older. Studies are ongoing to determine if nēnē can be taught to show appropriate predator avoidance (U. Zillich, pers. comm. 1998). Preliminary results show that captive-reared goslings can be taught to run from predators, but forget the experience quickly and need one or more follow-up training sessions (Zillich, pers. comm 1998). However, not all problems with predation are due to a lack of experience. As noted above, both goslings and adults that are incubating, have goslings, or are molting, are highly susceptible to predation.

Black *et al*. (1997) found that nēnē that emigrated from drought-stricken habitats to habitats with grasslands were better able to survive than birds that remained at their release sites, even though, enigmatically, nēnē may use grasslands less during dry periods (Woog and Black 2001). Black *et al*. (1997) speculated that this emigration behavior was learned from other nēnē in the wild. Emigration during times of drought and the knowledge of migration routes may have been lost when nēnē populations were very low. Although Rojek and Conant (1997) found that released nēnē do not have trouble finding food, these nēnē may not know where the most productive areas for feeding are located and they may not exhibit movement patterns to take advantage of seasonal food availability, traits that they may have learned from their parents. However, if captive-bred nēnē are able to learn such behaviors from nēnē living in the wild, they may survive better. To enhance the establishment of appropriate behaviors and 'cultural traditions' in future generations of nēnē, their chances of learning appropriate behaviors should be optimized prior to releasing them in the wild. Birds that are captive-bred for release should continue to be raised with parents and should be released via a soft-release technique using open-top pens.

6. Genetic Issues (Factor E)

a. Genetic Variation

Low genetic variation may be limiting reproductive success and survival of nēnē. Kear and Berger (1980) had evidence that captive nēnē showed symptoms of inbreeding depression, though Carson (1989) later stated that inbreeding has been neither deleterious nor decreased the vigor of nēnē. Recent research supports Kear and Berger's observation by providing evidence that yearly mean fertility, hatchability, and gosling survivorship decreased in captive nēnē as the coancestry coefficient (level of inbreeding) increased (Rave 1994; Rave *et al*. 1999). Genetic diversity was examined for captive populations at the Maui Bird Conservation Center captive propagation facility and at the Waterfowl and Wetlands Trust (Rave 1994; Rave *et al*. 1994). While both populations showed low levels of genetic diversity, the Maui Bird Conservation Center birds showed greater genetic diversity than those at the Waterfowl and Wetlands Trust, possibly because there were more founders at the Maui Bird Conservation Center than in the Waterfowl and Wetlands Trust population (24 versus 7; Kear and Berger 1980; Rave *et al*. 1994). As might be expected, within each captive flock related birds had higher mean similarity coefficients (*i.e.*, a higher level of inbreeding) than unrelated birds (Rave *et al*. 1994). DNA fingerprints did identify one nēnē that had several bands not found in other captive birds, and this bird was subsequently released as part of the recovery effort to maintain or increase genetic diversity in the population (Rave *et al*. 1994).

The genetic diversity of nēnē captured from six populations in the wild on Hawai`i (Hawai`i Volcanoes National Park, Kahuku, Kea`au, and Pu`uwa`awa`a), Maui, and Kaua`i was also investigated (Rave 1994, 1995). Nēnē sampled from Hawai`i Volcanoes National Park had a significantly lower similarity coefficient distribution (*i.e.*, the highest level of genetic variation) than all other populations tested except Kahuku; nēnē from Haleakalā National Park had intermediate similarity coefficient distribution values (*i.e.*, an intermediate level of genetic variation); and nēnē from Kaua`i had the lowest level of genetic variation compared to the other populations tested (Rave 1995). Rave (1995) therefore suggested that eggs from wild nēnē of known origin, especially from Hawai`i Volcanoes National Park, should continue to be added to captive flocks to help reduce genetic similarity and inbreeding depression. No unique DNA fingerprint fragments were found in nēnē from the wild, however, not all the Hawai`i populations were tested (Rave 1995). None of the nēnē from the Saddle Road/Mauna Loa area where the last wild birds were found in the 1950's were tested.

b. <u>Hairy-Down Plumage in Goslings</u>

In captivity, some goslings exhibit a condition called hairy-down or cottony plumage that seems to result from a recessive gene causing some of the short plumules to be missing, making the longer ones seem more prominent (Kear and Berger 1980). By 1973, 20 percent of the goslings at the Waterfowl and Wetlands Trust exhibited this trait. This recessive gene also appeared in some wild stock birds at Pōhakuloa, Hawai`i.

The thin down exhibited by nēnē goslings with this condition makes the goslings appear scruffy, and they are also not waterproof and apparently less resilient to cold weather; however, if they survive, the adults appear normal (Kear and Berger 1980). It has been suggested that the hairy-down trait may be adaptive in lower, warmer elevations and abundant food resources (Kear and Berger 1980; Banko *et al*. 1999; Duvall, pers. comm. 1994). It has also been suggested that hairy-down goslings produced in captive conditions should only be released in lowland sites (Bailey, pers. comm. 1999). However, at this time, no studies on this condition have been conducted.

7. Disease (Factor C)

The role that diseases may play, or have played, in the decline of the nēnē has been poorly documented and is not well understood. Bailey and Black (1995) conducted a short study of parasites, and reported on other previously published (*e.g*. Gassmann-Duvall 1987) and unpublished findings of parasites and diseases. They found that endoparasites are not currently limiting nēnē recovery, but suggest that work should continue on other diseases that may cause poor survival and productivity of nēnē. Omphalitis, an infection of the umbilical stump, has been found to cause mortality in both wild and captive nēnē goslings. Pox-like lesions have been reported in adult birds (Kear and Brown 1976; Kear and Berger 1980), but there is currently no evidence of pox being implicated in nēnē deaths. In fact, pox scars on many birds in the wild on Hawai`i and Maui indicate that avian pox is common, but generally not fatal to nēnē (Banko *et al*. 1999).

There have been no research studies on the impact of malarial infections, particularly to nēnē goslings, but evidence from salvaged nēnē does not indicate that malaria is a problem (T. Work, pers. comm. 1998). Avian malaria has been reported in at least one wild bird on Maui, but it appears possible that avian pox and avian malaria are not causing significant declines of nēnē populations, unlike their effects on most of the Hawaiian forest birds (van Riper *et al*. 1986; Banko *et al*. 1999). However, concern about potentially transferring unique regional strains of avian malaria between islands with the release of infected captive-bred nēnē has recently impacted the nēnē captive propagation program. Nēnē currently are tested for the presence of malarial infections prior to release. Nēnē that cannot be certified malaria-free are not released off island. Release restrictions on infected nēnē could affect the restoration of nēnē populations on islands without a captive propagation facility. However, as long as there are concerns about the spread of diseases, disease screening will remain a routine part of the release program. Where current management for disease and parasite transmission conflicts with other management directions (*e.g.*, maximize genetic diversity), the Hawaiian Endangered Bird Conservation Program (see pages 36 and 37) will need to determine the best course of action. Such actions will also need to address the potential for transferring unique regional strains of avian malaria to whole island avifaunas.

While disease has not been shown to be a major cause of nēnē deaths, it could become one in the future as captive releases continue and as nēnē populations increase. Recent concern regarding the spread of West Nile Virus in the mainland United States has serious implications for Hawaiian avifauna. Although Canada geese appear to be little affected by West Nile Virus, the virus kills domestic geese in Israel and nēnē may also be vulnerable, especially young birds (J. Burgett, *in litt*. 2003). Given the impact disease could have on nēnē recovery, it is critical that the potential for disease introduction be prevented or minimized and be considered an important part of all nēnē management decisions.

H. CONSERVATION EFFORTS

Conservation efforts to date have included a variety of actions such as captive propagation and release, creation of a studbook, limited predator control, habitat enhancement, research studies, monitoring efforts, development of cooperative agreements, formation of the Nēnē Recovery Action Group, and public education. In the past, much of the recovery efforts have focused on captive propagation and release. However, while releases of captive-bred birds will continue to be important in the nēnē recovery program, they should not be relied upon as the sole management tool to produce a self-sustaining nēnē population (Banko 1992). Other tools, such as increased and more effective predator control, habitat enhancement for wild-breeding birds, private conservation efforts, and research on increasing the effectiveness of predator control, for example, should be fully utilized in the recovery program for nēnē. The following sections provide a brief overview of some past and current conservation efforts.

1. Captive Propagation and Release

a. Captive Propagation in Hawai`i

Early conservation efforts emphasized captive breeding of nēnē in Hawai`i and England. These efforts were initiated primarily by Sir Peter Scott at the Severn Wildfowl Trust in Slimbridge, England, and Mr. Herbert C. Shipman from Kea`au, Hawai`i (Banko *et al*. 1999) and conducted by Territory (State) of Hawai`i biologists. The Territory of Hawai`i initiated a captive propagation program in 1927 on

O`ahu but this effort dissipated by 1935 for various reasons and was considered a failure (Smith 1952; Kear and Berger 1980). In 1949, the Hawaiian goose or nēnē restoration program was initiated to release captive-bred birds into native habitat. The State of Hawai`i, with the support of the U.S. Fish and Wildlife Service, continues to operate a propagation program to release captive-bred nēnē into the wild. Birds are raised in captivity and the young are introduced into the wild utilizing a soft release method to help habituate the birds to the release area.

The soft release method includes the use of open-top outdoor pens which provide predator-free areas for breeding and release. These pens are fenced to deter predators and provide sufficient foraging habitat as well as shrubs for shelter from adverse weather. If needed, supplemental food and water are provided. For open-top pen propagation, nēnē pairs are caught in the wild and their primary feathers clipped before the nēnē are placed in the pens. Adults normally molt after the eggs hatch. Adults therefore become flighted again at approximately the same time as their offspring, allowing them to leave the pen together. If it is appropriate, adult primary feathers may be clipped in subsequent years, for the following years' propagation. Goslings may be reared with their parents or cross-fostered into existing family groups for rearing and release. Captive-bred or translocated nēnē may also be placed into open-top pens for soft release. Nēnē are free to leave the pen once flight feathers develop and they often return to the pens freely in subsequent years. Closed-top, "gentle release" pens have also been used, in which nēnē are released by opening the gates at the appropriate time. As the captive propagation program has matured, various changes have been made to the program in order to enhance survival and reproductive success of released birds, including releasing nēnē at low-elevation sites and assessment of birds for exposure to malaria prior to release on other islands.

The captive breeding program began in 1949 at Pōhakuloa on the island of Hawai`i and was subsequently downsized and relocated to the Olinda Endangered Species Captive Propagation Facility (now the Maui Bird Conservation Center) in Olinda, Maui, in August 1989. The Keauhou Bird Conservation Center on the island of Hawai`i has maintained nēnē for propagation from 1997 to the present.

Since their inception, the Keauhou Bird Conservation Center and Maui Bird Conservation Center captive propagation facilities were overseen by the Hawai`i Division of Forestry and Wildlife and the U.S. Fish and Wildlife Service, and for most of those years they were operated by The Peregrine Fund. A unique partnership, composed of these three organizations, was formalized in 1994. This partnership, known as the Hawaiian Endangered Bird Conservation Program, works in collaboration with many organizations statewide to breed native and endangered Hawaiian birds in captivity to aid in the recovery of endangered species. The goal of this program is to collaborate with partners and others to develop self-sustaining populations of wild nēnē and other Hawaiian birds. In 2000, captive propagation operations were transferred from The Peregrine Fund to the Zoological Society of San Diego.

Captive nēnē are now housed at both the Keauhou Bird Conservation Center and the Maui Bird Conservation Center. Although the numbers of breeding pairs have varied among years, each facility currently houses four breeding pairs. Nēnē raised at these facilities have been released on Hawai`i, Maui, Moloka`i, and Kaua`i. Concerns regarding genetic management of the flock and transfer of malaria strains between islands may affect the future management of the nēnē captive-rearing program.

In addition to the captive propagation efforts of the Hawaiian Endangered Bird Conservation Program, the National Park Service has also reared nēnē for release into park lands. In 1972, the National Park Service, in cooperation with the Hawai`i Division of Forestry and Wildlife (known then as the Hawai`i Division of Fish and Game), initiated a nēnē restoration project within Hawai`i Volcanoes National Park. This project involved the construction of predator-resistant, fenced enclosures in areas thought to be utilized or formerly utilized by nēnē. The enclosures were approximately 0.1 to 1.2 hectares (0.3 to 3 acres) in size. A pair of wing-clipped adult birds was confined to each enclosure so that they might live and breed under semi-natural conditions. Offspring were permitted to fledge from the pens on the theory that they would occupy adjacent habitat. Concomitantly, habitat was improved by such actions as the control of feral animals and alien plants, reintroduction of native plants, and trapping of feral cats, mongooses, and rats. Nine enclosures were constructed in locations ranging from sea level to 1,200 meters (4,000 feet) in elevation. Use of most open-top pens was discontinued due to the difficulty in accessing the remote sites. The use of the last original open-top pens was discontinued in the 1996/1997 breeding season. Hawai`i Volcanoes National Park now maintains one open-top pen that provides nesting and brooding habitat for four to five free-flying pairs of nēnē annually. Maintenance of this enclosure may facilitate successful reproduction, even in years of poor nest and gosling survival.

Haleakalā National Park conducted an open-top pen propagation program from 1972 to 1983 with several breeding pairs provided by the State of Hawai`i. Two pens were located behind the Park Headquarters and subsequently moved below the Park residences due to vehicular mortalities; one large pen was located near Hosmer Grove. During this time period, 151 eggs were produced, 28 eggs hatched (18.5 percent), and 25 goslings fledged (Haleakalā National Park, unpubl. data). Reproduction was very low, possibly due to inadequate nutrition and weather conditions. Due to the low reproduction and mortality of nēnē from vehicles, the project was slowly phased out when the breeding pairs became old or died (R. Nagata, pers. comm. 2002). Two of the pens remain in place and are occasionally used as holding areas for sick or injured birds. An open-top pen was also constructed at Paliku in 1992 for a backcountry propagation program. Nēnē released into this pen produced 11 goslings in the 1995 to 1996 breeding season. The Paliku pen is still standing and has been used intermittently for releasing captive-bred nēnē. It is also used as a temporary holding pen for sick or injured birds.

b. Captive Propagation in England

Nēnē were first brought to Europe in 1823 where they were successfully raised in private collections and zoos for nearly 75 years (Smith 1952). By 1900, nēnē had become scarce and they had completely disappeared from European facilities by 1940. European captive propagation efforts were reinitiated in 1950 by the Severn Wildfowl Trust (now the Waterfowl and Wetlands Trust) in England with the transfer of three nēnē from the Shipman Estate. In spite of declines due to inbreeding, this propagation effort has been successful and has distributed nēnē breeding stock to many zoos and aviaries as well as contributed birds for release on Maui.

c. Release of Captive-Bred Nēnē

As of 2003, a total of 2,643 captive-bred nēnē (from England and Hawai`i) have been released statewide either on public lands or on private lands managed under cooperative agreements with State or Federal resource agencies. Appendix A summarizes nēnē releases from 1960 to 2003. On Hawai`i, nēnē have been released at seven sites ranging from low to high elevation: Hakalau National Wildlife Refuge, Hawai`i Volcanoes National Park, Kahuku, Kea`au, Keauhou, Keauhou II, and Kīpuka Āinahou (Black *et al*. 1997) beginning in 1960. Nēnē released at Hawai`i Volcanoes National Park apparently survive better than those released at the other sites on Hawai`I, and several factors apparently set these birds apart: this was the only low to mid-elevation site, the birds at this site had been parent or foster-parent reared, and they had access to more grassland habitats (Black *et al*. 1997). Nēnē released in upland sites on Hawai`i moved away from their release sites to areas with grasslands or supplemental feeders, while nēnē released in Hawai`i Volcanoes National Park tend to move less, also possibly due to better access to more grassland habitat.

Releases on East Maui began in 1962 with the release of 35 birds at Palikū, an upland site in Haleakalā National Park. Nēnē were also released at Hosmer Grove in Haleakalā National Park and at Hana`ula in West Maui. Released birds originated from the Keauhou Bird Conservation Center, the Waterfowl and Wetlands Trust, a private collection in Connecticut, and Haleakalā National Park pens on Maui. In contrast to nēnē released in upland sites on Hawai`i, the nēnē released at Haleakalā National Park have fared better and have had lower levels of mortality, again possibly due to greater access to more grassland habitat (Black *et al*. 1997). Fifty-five nēnē have also been released at Puu O Hoku Ranch on Moloka`i following completion of a Safe Harbor Agreement in 2001.

An estimated 25 nēnē were released at Kīpū Kai on Kaua`i in 1985. Concerted release efforts began in 1991 with the release of 12 nēnē at Kīlauea Point National Wildlife Refuge followed by subsequent releases along the Nā Pali Coast and at Hanalei National Wildlife Refuge. Releases on Kaua`i consisted of soft releases of primarily fledging-age goslings from closed-top pens, following a holding period of 1 to 2 weeks. These fledglings were not accompanied by foster parent birds. Each of these populations is currently expanding with an estimated island-wide total of 620 birds (Telfer 2003).

The release of captive-bred nēnē has likely prevented the extinction of this species, however most wild populations are not self-sustaining (Black *et al*. 1997). Poor survival, low productivity, predation, and high emigration from upland release sites, especially in dry years, has impacted many of the populations. However, the continued existence of the Hawai`i Volcanoes National Park, Haleakalā National Park populations, and the expanding Kaua`i population demonstrate that predator control, vegetation management, and human cooperation may lead to self-sustaining nēnē populations.

The distribution of nēnē to zoos and aviaries by the Waterfowl and Wetlands Trust, the Patuxent Wildlife Research Center in Patuxent, Maryland, which once maintained a captive breeding flock, and the State of Hawai`i resulted in approximately 1,250 nēnē in captivity by 1980 (Kear and Berger 1980).

2. Studbook

Plans have been discussed for the creation of a Species Survival Plan and a studbook for all captive nēnē, including nēnē in accredited zoo collections in the contiguous United States. A Nēnē Studbook now exists for captive birds in Hawai`i (Zoological Society of San Diego, unpubl. data). Cataloging and analyses of DNA for both wild and captive nēnē in the State of Hawai`i has been initiated. Genetic management of all Hawaiian nēnē (captive and wild) should help to counteract future increases in homozygosity. All aspects of nēnē management should incorporate genetic management goals. To this end, developing a master genetics management plan should be a high priority and should include the formation of a genetics consulting group of population genetics experts. This genetics working group will be able to review captive flock status, status of the population in the wild, suggest new studies and additional collection of genetic samples, rerun demographic models, and prepare a summary for the Nēnē Recovery Action Group that it can use to make management decisions. At this time, the Zoological Society of San Diego, with input from the Nēnē Recovery Action Group, is making decisions regarding breeding captive birds and Nēnē Recovery Action Group members are making decisions about where and how many birds are being released.

3. Predator Control

A key limiting factor to nēnē recovery is predation on eggs, goslings, and adults (see Section G1 - Predation). A variety of predator control programs have been initiated in areas where nēnē currently reside. For example, Haleakalā National Park staff conducted an extensive trapping and diphacinone poisoning program to control rats in 1994 to 1995. Ongoing efforts on the different islands include predator control programs aimed at mongooses, dogs, feral cats, rodents, and pigs. Federal and State agencies are also seeking approval of multi-species toxicants and the ability to aerially broadcast toxicants. Some open-top pens previously used to rear captive nēnē on National Park Service lands are now often used to provide predator-free nesting and brooding habitat for free-flying pairs or as temporary holding pens for sick or injured birds.

While these control programs have proven effective in localized areas, recovery of nēnē is dependent on more aggressive and widespread control of alien predators. Despite documentation of the impact of mongooses, dogs, feral cats, rodents, and pigs on nēnē (Hoshide *et al*. 1990; Banko 1992; Black and Banko 1994; Baker and Baker 1995; Telfer 1996), as well as other native birds, there are few predator control programs and they are not being implemented over areas large enough to elicit a population response by native species (Scott *et al*. 2001). Known control techniques should be applied at all habitats needed to recover nēnē. Furthering public understanding and support of these predator control efforts will be essential to the recovery of nēnē.

4. Habitat Enhancement for Wild-Breeding Birds

Many of the areas where nēnē occur in the wild are afforded some level of habitat enhancement that focuses on increasing the survival and reproduction of nēnē. Habitat enhancement can include predator control, mowing, outplanting, and supplemental feeding. Hawai`i Volcanoes National Park has areas where many of these types of enhancement occur. For instance, at Kīpuka Nēnē Campground, the surrounding area is kept mowed during the breeding season. In addition, some areas are closed to human use during the nēnē breeding season. The Hawai`i Division of Forestry and Wildlife also provides supplemental food for nēnē populations on Hawai`i. Haleakalā National Park has a predator control program and horses intermittently graze in Palikū pasture. Kaua`i also has predator control programs and may provide supplemental feed during drought years. Mowing, grazing, and irrigating grass can improve its attractiveness to geese by increasing the protein content (Sedinger and Raveling 1986;Woog and Black 2001).

Habitat restoration has not yet been well developed as a tool for nēnē recovery. However, habitat restoration and management are increasingly believed to be important to attaining self-sustaining nēnē populations in some areas, and Hawai`i Volcanoes National Park in particular is concentrating on enhancing and creating native habitat for nēnē and other species (Hu 1998; Banko *et al*. 1999; Sherry 2000). To supplement previous research efforts, additional information is needed on: 1) areas where nēnē may be supported with predominantly native vegetation; 2) the former composition and distribution of native grass and shrub communities known or believed to be important to nēnē pre-historically; 3) the nutritional value, palatability, and ecological requirements of native plants utilized by nēnē; and 4) methods for converting nutritionally poor habitats dominated by invasive alien species to nutritionally rich habitats dominated by natives (Hu 1998; Banko *et al*. 1999; Sherry 2000; Woog and Black 2001).

Although many nēnē nest in mid- and high-elevation sites today, evidence indicates that they once nested primarily in leeward lowlands (Baldwin 1947; Banko *et al*. 1999). Understanding the former vegetation composition of low-, mid-, and high-elevation sites prior to human arrival will assist managers in restoring native species important to nēnē reproduction and survival.

However, the role of highly altered landscapes and of alien vegetation in nēnē recovery should not be discounted. For example, nēnē on Kaua`i primarily utilize lowland areas in highly altered, human-impacted habitats such as pastures, agricultural fields, golf courses, and highly degraded waste areas (Telfer, pers. comm. 2002). Nēnē have been very successful in these areas, indicating their adaptability to a variety of habitats. The recovery of nēnē is dependent on a variety of habitats ranging from highly altered, managed habitats to habitats consisting of primarily native species and it may not be feasible or necessary to restore habitats to native species in all areas utilized by nēnē. It is believed that nēnē currently require a diverse suite of food availability that may include both nonnative and native vegetation.

5. Research

Black and Banko (1994) conducted a Population Viability Analysis using the VORTEX software program to model the long-term fate of nēnē under three different management scenarios: 1) no further releases or management; 2) releases mirroring those of the past 30 years; and 3) increased management without further releases. The report concludes that only under the third scenario can all three populations (Hawai`i, Maui, and Kaua`i`) survive for 200 years and that reintroduction as a management tool may continue to be effective in delaying extinction on Hawai`i, but will not lead to a self-sustaining population. The study concludes that enhanced management efforts which include an appropriate predator control effort will enable nēnē to reach a self-sustaining level.

Another Population Viability Analysis was recently conducted on nēnē in Hawai`i Volcanoes National Park to examine management options more specific to Hawai`i Volcanoes National Park (Hu 1998). First year mortality was identified as the primary limiting factor for Hawai`i Volcanoes National Park nēnē. In 1990 to 1996, survival of fledglings averaged 84 percent for females and 95 percent for males, while survival from laying to fledging ranged from 7 to 19.5 percent (mean 12 percent; Hu 1998). While predator control has reduced egg predation, fledging success remained low, largely due to nutritional inadequacies. The study found that open-top pens cannot sustain a viable nēnē population in Hawai`i Volcanoes National Park. The study suggests that while management techniques, such as grassland management, supplemental feeding, and cultivation of native food plants may sustain nēnē in Hawai`i Volcanoes National Park, such efforts are considerable and would require increasing resource expenditures. Thus, Hu (1998) suggested that nēnē would be more secure if they were integrated into habitat management instituted on a larger scale that would involve the creation of native-dominated, fire-adapted landscapes at low and mid-elevations in Hawai`i Volcanoes National Park; more efficient, wide-spread predator control techniques; and the reestablishment of seasonal movements patterns of nēnē between various locations.

Black *et al*. (1997) analyzed survival data from 1960 through 1990 for released nēnē on the island of Hawai`i and found that the highest mortality rate was found among newly released goslings during drought years. They also found that nēnē at Hawai`i Volcanoes National Park had the lowest annual mortality rates. The three main factors affecting mortality rates were found to be release method, age at time of release, and year of release. Releasing pre-fledged goslings with parents or foster parents present from open-top pens during years with sufficient rainfall was found to be the most successful release method on the island of Hawai`i (Black *et al*. 1997). On Kaua`i, where mongoose are not yet established, protecting the nesting area from other predators, such as dogs and cats, has been extremely successful (Telfer, pers. comm. 1998).

A number of reports have reviewed past nēnē research and management and provided recommendations for future work in these areas (Stone *et al*. 1983a; Morin 1986; Black *et al*. 1991, 1994, 1997; Black 1994; Banko *et al*. 1999; Woog and Black 2001). Most of these recommendations have been incorporated into or are discussed in this plan.

6. Monitoring Efforts

Managers of each nēnē population have established monitoring programs for individual populations. These programs include protocols for monitoring population trends. However, monitoring efforts remain uneven and highly dependent on year-to-year funding for some nēnē populations. Inconsistent compilation and analysis of monitoring data due to insufficient agency resources presents a serious impediment to the timely evaluation of recovery actions. The establishment of funds for yearly nēnē monitoring and analysis should be a high priority in nēnē recovery actions. To the extent possible, managers should agree on utilizing similar monitoring protocols so that analysis of population trends is easily accomplished. A statewide nēnē data base that was developed in 1994 (Hunter and Black 1995) could serve as a starting point for coordinating monitoring efforts. A single entity, such as the Nēnē Recovery Action Group, should assimilate the monitoring data from the various agencies and annually compile the status of nēnē statewide.

7. Private Conservation Efforts

A variety of private individuals and organizations have contributed to nēnē recovery efforts. The Hawai`i Division of Forestry and Wildlife and the U.S. Fish and Wildlife Service have been working together since 1997 to develop private landowner projects. The first Safe Harbor Agreement in the State of Hawai`i was finalized on September 4, 2001, with Puu O Hoku Ranch, Moloka`i, for nēnē. Under this Safe Harbor Agreement, the ranch owners agreed to maintain or improve nēnē habitat for at least 7 years in return for assurances that no additional restrictions would be placed on the property because of the presence of endangered species. In addition, the owners agreed to the reintroduction of nēnē to the ranch. Nēnē had been extirpated from Moloka`i for over 100 years when 11 nēnē were released at Puu O Hoku Ranch on December 21, 2001. A total of 55 captive-bred nēnē have been released to date. Additional releases are planned for the future to increase the probability that the nēnē will thrive at the ranch.

In anticipation that these nēnē will breed and expand onto other lands on Moloka`i, the U.S. Fish and Wildlife Service and Hawai`i Division of Forestry and Wildlife recently developed and finalized a programmatic Safe Harbor Agreement for the entire Island of Moloka`i. Under this Safe Harbor Agreement, interested landowners will be able to develop individual cooperative agreements with the Hawai`i Division of Forestry and Wildlife that will allow monitoring, predator control, and increased access to suitable habitat for the nēnē. In return, the landowners enrolled in the program are allowed "incidental take" of any nēnē in excess of those that occur on the property at the time they enter into the cooperative agreement. It is hoped that with these two Safe Harbor Agreements in place, up to 200 nēnē may eventually reside on Moloka`i. The Hawai`i Division of Forestry and Wildlife and the U.S. Fish and Wildlife Service are currently developing a similar Safe Harbor Agreement that would include building release pens, releasing captive-bred nēnē, and native habitat restoration for Piiholo Ranch on Maui.

In December 2001, a second Safe Harbor Agreement was approved with Umikoa Ranch on Hawai`i for both nēnē and the Hawaiian duck or koloa (*Anas wyvilliana*). Under this agreement, nēnē will not be translocated but it is hoped that nēnē will disperse naturally into the area. To improve the site for nēnē, the ranch is implementing management actions including habitat improvements (*e.g.*, outplanting of native food species and fencing) and predator control. Such actions will increase the probability that birds finding the area will remain on-site and will be successful in rearing young.

Currently, the Hawai`i Division of Forestry and Wildlife and the U.S. Fish and Wildlife Service are developing another Safe Harbor Agreement for nēnē and koloa with Ulupalakua Ranch, Maui. This project will include fenced areas with created wetlands and outplanted native vegetation for both species. No translocations are planned at this time for this project and it is hoped that nēnē and koloa will disperse naturally to the improved habitat.

Ducks Unlimited is working closely with the Hawai`i Division of Forestry and Wildlife and the U.S. Fish and Wildlife Service on several private landowner projects that include native species of waterfowl such as the nēnē and koloa. Ducks Unlimited is currently developing a plan for outplanting native plants used by nēnē which would be initiated at Ulupalakua Ranch. Once this plan has been developed and finalized, it can then be modified as needed for use with other projects where it is anticipated that nēnē will be translocated or will disperse to naturally. The plan could also be used to outplant native vegetation in areas where nēnē are currently found.

The Hawai`i Division of Forestry and Wildlife and the U.S. Fish and Wildlife Service expect that additional projects with private landowners to benefit nēnē will be developed on all the other islands, and both agencies are especially interested in other island-wide programmatic agreements. Programmatic agreements are beneficial because they streamline the Safe Harbor Agreement process, reduce the timeframe for developing such agreements, and can allow a more unified ecosystem approach to the conservation of the species. The island-wide programmatic approach could be particularly useful on Kaua`i where nēnē are utilizing a number of private properties in lowland habitats. Given the differences among islands in factors affecting nēnē populations both within and among islands, a statewide programmatic agreement is not being pursued at this point (Appendix E provides a description of the various types of Safe Harbor Agreements).

Private organizations contributing to nēnē recovery include Nēnē O Moloka`i and the Anheuser-Busch Foundation. Nēnē O Moloka`i is a nonprofit corporation created to establish and preserve nēnē in the wild on the island of Moloka`i. This corporation was founded in 1994 and emphasizes education through community involvement. Through the National Fish and Wildlife Foundation, the Anheuser-Busch Foundation contributed a combined $127,500 towards seven conservation and education projects in 2002. These projects will aid our understanding of nēnē and enhance our management activities. Given the limited funds and resources available for recovery of listed plants and animals in Hawai`i, the dedication and contributions of these individuals and groups have been instrumental in the recovery of nēnē.

8. Nēnē Recovery Action Group

The Nēnē Recovery Action Group is an ad hoc organization of State and Federal resource agencies. It was created in 1990 with the specific purpose of enhancing communication between government agencies with responsibility for managing and recovering nēnē. It has continued to perform that function and, because it has no official legal status, it has been able to provide an open forum for addressing nēnē management and recovery issues in Hawai`i. A Hawai`i Division of Forestry and Wildlife representative chairs the group, however the composition of the group has changed as the nēnē management responsibilities of personnel, organizations, and agencies have changed. The current group consists primarily of Hawai`i Division of Forestry and Wildlife, National Park Service, and U.S. Fish and Wildlife Service biologists and the organization responsible for captive propagation, the Zoological Society of San Diego (see Appendix D).

9. Public Awareness

A variety of activities have been undertaken to inform the public about the plight of nēnē and the need for recovery. Examples of these efforts include the Territory of Hawai`i's active publicity campaign in the early 1950's to acquaint people with the scarcity of nēnē and the need for protecting them. On May 7, 1957, the nēnē was designated as Hawai`i's State Bird. Since this time, the nēnē has been used as a symbol of the State's efforts to recover endangered species in publications, classroom activities, plays, and tourism promotions. Hawai`i's elementary and middle school children have voted for their favorite fiction book and presented the author with the prized Nēnē Award since 1959. The American Zoo and Aquarium Association also advances public education on the need for wildlife conservation and preservation with their collections of nēnē. Nēnē O Moloka`i focuses on community involvement in nēnē recovery. The Adopt-a-Nēnē Program was formed as a partnership between Haleakalā National Park and the Friends for the Nēnē Adoption Project. Funds are used to protect the nēnē and important habitats in Haleakalā Park from destruction by feral goats and pigs, invasion by alien plants, and predation by mongooses, feral cats, and rats. All of these programs have been effective in raising public awareness and enhancing the recovery of endangered nēnē.

III. RECOVERY

A. GENERAL RECOVERY STRATEGY

In order for nēnē populations to survive they must be provided with generally predator-free breeding areas and sufficient food resources. Human-caused disturbance and mortality must be minimized, and genetic and behavioral diversity maximized. The goal of this recovery plan is to enable the conservation of nēnē by utilizing a mix of natural and human-altered habitats in such a way that the life history needs of the species are met and the populations become self-sustaining at or above recovery target levels. While it is important to restore species as a functioning component of the native ecosystem to ensure long-term species survival, it should be noted that nēnē successfully utilize a gradient of habitats ranging from highly altered to completely natural. Additionally, some populations exhibit behaviors that differ from what it is believed wild birds historically displayed. Nēnē are a highly adaptable species which bodes well for our ability to recover the species.

Conservation needs and activities to recover nēnē vary among islands due to differences in factors affecting nēnē populations both within and among islands. For example, although mongoose occur on Hawai`i, Maui, and Moloka`i, Kaua`i does not yet have an established mongoose population, thus predator control issues are different for Kaua`i than for the other islands. Elevations utilized by nēnē vary among sites and among islands, and vegetation available to nēnē also differs between sites and by island.

Hawai`i and Maui Nui

On Hawai`i and Maui Nui, captive releases are still considered an important strategy for nēnē recovery, to establish new populations and to supplement existing unstable populations, but releases must occur in conjunction with predator control and habitat manipulation. Predator control is conducted in both Hawai`i Volcanoes National Park and Haleakalā National Park, particularly during the breeding season. In Hawai`i Volcanoes National Park, human access to certain areas is restricted during the nēnē breeding season and areas utilized by nēnē around other parts of the island are still supplemented with food and water. It is likely that the new founder group of nēnē on Moloka`i will continue to rely on captive releases for several years to come. Surveys conducted by the Hawai`i Division of Forestry and Wildlife on Hawai`i suggest that the number of nēnē in the wild began to decrease when the number of captive-bred birds released into the wild was sharply reduced (Devick 1981). Studies have shown that when reintroducing captive animals, a reasonable number of founder individuals and subsequent supplementation improves the probability of establishing a self-sustaining population (Pimm *et al*. 1988; Griffith *et al*. 1989; Stanley Price 1989).

Kaua`i

Currently, the four Kaua`i nēnē populations appear to be sustaining themselves, with more annual reproduction than mortality (Telfer, pers. comm. 1998). At this time, therefore, it may be most productive to increase management efforts on Kaua`i, such as controlling established predators, improving genetic diversity, and improving foraging conditions for goslings, rather than releasing additional captive birds in the same locations. Recovery efforts should also focus on preventing the establishment of mongoose on the island and a biosecurity plan addressing potential mongoose introduction needs to be developed. It would still be feasible to establish new breeding populations on Kaua`i in some areas where nēnē have not nested before and where predators can be controlled effectively, however, there may be only a few potential future release sites due to limited availability of habitat (Telfer, pers. comm. 1998). Because little upper elevation habitat is available on Kaua`i, altitudinal migration may not arise on this island. As the nēnē population on Kaua`i is currently increasing, it is possible that it may become self-sustaining and be of sufficient size to be considered separately from the other populations for downlisting to threatened status[4] as well as serve as a source of nēnē for release on other islands.

The basic steps for recovering nēnē are as follows:

- Identify and protect year-round and seasonally-used nēnē nesting and rearing habitat, and associated summer flocking habitat, necessary to sustain target population levels for each island.

- Actively manage habitat and populations in order to maximize the productivity and survival of existing and new populations of nēnē. Depending on the location, management may or will include: predator control during the breeding season; vegetation management to provide sufficient nutritional resources, particularly thorough outplanting indigenous food items; release of captive-bred nēnē to augment populations and to maximize genetic diversity; release

[4] Such an action would first require a regulatory rulemaking designating the Kauai population of nēnē as a distinct population segment; see further discussion of this possibility on page 51 of the Recovery Criteria section.

of captive-bred nēnē in lowland sites to establish new populations in optimal habitats; monitoring nēnē populations using a standard monitoring protocol; and minimization of human-caused disturbance and mortality.

- Nēnē managers should develop a long-range, statewide plan for establishing and maintaining all nēnē populations based on the knowledge gained from implementing the recovery actions outlined in this plan. Island-specific implementation plans should form the basis of the statewide plan. A genetics management plan should also be developed.

- Conduct further research to better define limiting factors, estimate carrying capacity of habitats, and determine how carrying capacity can be improved through various management techniques, including restoration of native vegetation.

- Measure efficiency and improve success of predator control techniques.

- As nēnē populations increase, plans must be developed to address conflicts between nēnē and humans (*e.g.*, crop depredation and nuisance problems).

- Provide informational and educational opportunities to build public support for nēnē recovery efforts.

- Review and scientifically verify recovery objectives.

A table identifying the factors currently limiting nene recovery that will be addressed by the specific actions identified in this plan is provided in Appendix F.

B. GOALS, OBJECTIVES, AND RECOVERY CRITERIA

The goal of this recovery plan is to remove the nēnē from the Federal List of Endangered and Threatened Wildlife and Plants (delisting). This plan establishes the framework within which recovery actions are undertaken to ensure the long-term survival of the nēnē and to control or reduce the threats to the species to the extent that it is no longer in danger of extinction and warrants delisting. The interim goal is to accomplish increases in population sizes and geographic distribution of nēnē concomitant with control of threats sufficient to consider reclassification or downlisting of this endangered species to threatened status.

To reach the recovery goal, the target objectives are to restore and maintain multiple self-sustaining nēnē populations on Hawai`i, Maui Nui (Maui, Moloka`i, Lāna`i, Kaho`olawe), and Kaua`i. Additionally, the threats to the species must be reduced to allow for the long-term viability of these populations, and sufficient suitable habitat must be identified, protected, and managed in perpetuity on each of these islands such that the species no longer meets the definition of endangered or threatened under the Endangered Species Act[5].

We set recovery criteria to serve as objective, measurable guidelines to assist us in determining when a listed entity (species, subspecies, or distinct population segment) has recovered to the point that the protections afforded by the Endangered Species Act (Act) are no longer necessary. However, the actual change in status (downlisting or delisting) requires a separate rulemaking process based upon an analysis of the same five factors considered in the listing of a species[6]. The recovery criteria presented in this recovery plan thus represent our best assessment of the conditions that would most likely result in a determination that downlisting or delisting of the nēnē is warranted (*i.e.*, that the nēnē no longer meets the definition of threatened or endangered under the Act) as the outcome of a formal five factor analysis in a subsequent regulatory rulemaking. Achieving the prescribed recovery criteria is an indication that the species is no longer threatened or endangered, but this must be confirmed by a thorough analysis of the five listing factors.

Downlisting and Delisting Criteria

Downlisting and delisting criteria were developed through discussions with nēnē managers on each of the islands. To estimate population level criteria, current populations, threats, and the potential for expansion were considered (Bailey, Hu, and Telfer, pers. comms. 1998). Criteria established for downlisting and delisting will be revised, if necessary, as additional information is provided by research projects and monitoring programs.

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[5] An endangered species is defined in section 3 of the Endangered Species Act as "any species which is in danger of extinction throughout all or a significant portion of its range." A threatened species is defined as "any species which is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range."

[6] The five factors considered in downlisting or delisting decisions are the same as those considered in the initial listing process for a species under section 4(a)(1) of the Act: a) the present or threatened destruction, modification, or curtailment of its habitat or range; b) overutilization for commercial, recreational, scientific, or educational purposes; c) disease or predation; d) the inadquacy of existing regulatory mechanisms; and e) other natural or manmade factors affecting its continued existence.

Downlisting Criteria

Consideration for downlisting the nēnē to threatened status can occur when each of the following criteria have been reached and maintained for a period of 15 years:

1) Self-sustaining populations exist on Hawai`i, Maui Nui (Maui, Moloka`i, Lāna`i, Kaho`olawe), and Kaua`i. In this case, self-sustaining is defined as maintaining (or increasing) established population levels without additional releases of captive-bred nēnē, although habitat manipulation, such as predator control or pasture management, may need to be continued. At least 7 populations must exist with the following minimum sizes: 2 populations with 500 breeding adults each, 1 population with 300 breeding adults, 2 populations of 250 breeding adults each, and 2 populations of 100 breeding adults each. The larger three populations must be distributed on Hawai`i, East Maui and Kaua`i, while two of the smaller populations must occur on two of the following: East Maui, Moloka`i, Kaho`olawe, or Lāna`i. Increasing population sizes, establishing multiple populations, and providing for breeding in the wild will address threats to the nēnē associated with reduced genetic diversity, behavioral issues stemming from captive conditions, and the potential for disease transmission.

2) Sufficient suitable habitat to sustain the target nēnē population levels on each island is identified, protected, and managed in perpetuity. Securing high quality nesting and rearing habitat and associated summer flocking habitat is key to nēnē population stability and growth. Where migration continues to be important, particularly Hawai`i, the management of established routes and new altitudinal migration routes must be taken into account to ensure the persistence of all habitats necessary for the recovery and long-term existence of nēnē. Both public and private lands are important to nēnē recovery and portions of some nēnē populations may need to be managed on private lands. Critical elements of habitat identification, protection, and management will include addressing the threats to nēnē posed by introduced predators, loss of suitable lowland habitats, poor nutrition, and human-caused disturbance and mortality.

A downlisting determination can only be made on a "listable entity" under the Endangered Species Act; listable entities include species, subspecies, or distinct population segments of vertebrate animals, as defined by the Endangered Species Act and U.S. Fish and Wildlife Service policy (USFWS 1996). We have not analyzed whether any of the current nēnē populations may constitute a distinct population segment, and there is insufficient information at this time to make such a determination, but in the future, if warranted by additional information, downlisting may be considered separately for a subset of the nēnē population if that population subset is shown to meet the definition of a distinct population segment. In addition, to be proposed for downlisting, any such population subset must be self-sustaining, have been increasing in size from a minimum of 500 to at least 1,000 breeding adult birds over a period of 15 years, and sufficient suitable habitat (per #2 above) must be determined to exist.

Delisting Criteria

Consideration for delisting can occur once all of the downlisting criteria have been met, and population levels on Hawai`i, Maui Nui, and Kaua`i have all shown a stable or increasing trend (from downlisting levels) for a minimum of 15 additional years (*i.e.*, for a total of 30 years). A monitoring plan shall be in place and ready for implementation for a minimum of 5 years post-delisting to ensure the continuing effectiveness of management actions and the welfare of the species.

IV. RECOVERY ACTIONS

The Step-Down Outline and Step-Down Narrative Outline of Recovery Actions are organized into nine broad categories:

1) **Identify and protect nēnē habitat** which focuses on the identification and protection of sufficient habitat to sustain target population levels;

2) **Manage habitat and existing populations for sustainable productivity and survival** complemented by monitoring changes in distribution and abundance;

3) **Control alien predators** which addresses control of introduced mammals to enhance nēnē populations;

4) **Continue captive propagation program** which describes techniques and priorities for the captive propagation and release of nēnē into the wild;

5) **Establish additional nēnē populations** which focuses on partnerships with private landowners;

6) **Address conflicts between nēnē and human activities** which addresses potential management and relocation of nēnē in unsuitable areas;

7) **<u>Identify new research needs and continue research</u>** which describes general categories of research needed to better evaluate threats to nēnē and develop and evaluate management strategies to address these threats;

8) **<u>Provide a public awareness and information program</u>** which describes important outreach and education activities; and

9) **<u>Validate recovery actions</u>** which calls for formalizing the Nēnē Recovery Action Group and evaluating management and research projects to determine if recovery objectives have been met.

These general step-down categories listed above do not have priority numbers for implementation, but each specific recovery action within each category was assigned an implementation priority number (see Implementation Schedule, page 86).

A. STEP-DOWN OUTLINE OF RECOVERY ACTIONS

1. **Identify and protect nēnē habitat**.

1.1. Identify year-round and seasonally-used suitable nēnē nesting and rearing habitat, and associated summer flocking habitat, necessary to sustain target populations.

1.1.1. Develop criteria for identifying suitable nēnē recovery habitat.

1.2. Protect and restore sufficient suitable nēnē habitat to sustain target population levels on each island.

1.2.1. Develop strategies and techniques for protecting and restoring nēnē habitat.

1.2.2. Identify the desired outcome of restoration activities.

1.3. Identify, map, and, where necessary, protect present and potential migratory routes as populations increase in size.

1.4. Develop island-specific implementation plans to meet population level targets for downlisting and delisting criteria.

2. **Manage habitat and existing populations for sustainable productivity and survival**.

    2.1. Manage habitat to provide sufficient nutrition.

    2.2. Minimize human-caused disturbance and mortality.

    2.3. Continue release of captive-bred nēnē to improve demographic (*e.g.*, sex ratio and age structure) and genetic characteristics of nēnē populations in the wild, where warranted.

    2.4. Develop a genetics management plan.

    2.5. Develop an injured bird salvage protocol for each nēnē population.

    2.6. Continue banding adults and young of the year.

    2.7. Monitor nēnē populations and evaluate annual trends.

3. **Control alien predators** in nēnē habitat.

    3.1. Develop and implement a mongoose control program for Hawai`i, Maui, and Moloka`i.

    3.2. Develop and implement a mongoose prevention and interdiction program for Kaua`i.

    3.3. Develop and implement a dog control program.

    3.4. Develop and implement a feral cat control program.

    3.5. Develop and implement a rodent control program.

    3.6. Develop and implement a pig control program.

4. **Continue captive propagation program**.

    4.1. Maintain captive breeding flocks at Keauhou Bird Conservation Center and Maui Bird Conservation Center.

    4.2. Establish or maintain captive breeding flocks in open-top pens.

    4.3. If warranted, explore the possibility of releasing zoo-bred nēnē.

    4.4. If warranted, explore propagation of nēnē by private organizations.

    4.5. Prevent or minimize disease and parasite transmission.

        4.5.1 Prevent or minimize transmission of avian malaria and other diseases or parasites between captive and wild nēnē flocks.

        4.5.2. Prevent, detect, and minimize transmission of novel diseases and parasites.

    4.6. Where warranted by the environmental conditions of the release site, incorporate improved rearing and release techniques into the captive propagation and release program.

        4.6.1. Depending on the environmental conditions of the release site, provide captive nēnē with a structurally diverse environment.

        4.6.2. Depending on the environmental conditions of the release site, implement prerelease human and predator-avoidance training of nēnē.

    4.7. Monitor captive-released birds.

5. **Establish additional nēnē populations** in suitable, uninhabited areas that are protected.

    5.1. Establish cooperative agreements on private lands.

5.2. Establish new populations of nēnē on existing managed lands and on private lands with cooperative agreements.

6. **Address conflicts between nēnē and human activities**.

6.1. Develop safe and effective methods for managing nēnē in unsuitable habitats.

6.2. Develop contingency plans for relocating nēnē utilizing unsuitable habitats or causing human safety hazards.

7. **Identify new research needs and continue research** on known limiting factors and management techniques.

7.1. Identify limiting factors.

7.2. Conduct research on the control of predators.

7.2.1. Conduct research on the prevention, interdiction, and control of mongooses.

7.2.2. Conduct research on the control of dogs.

7.2.3. Conduct research on the control of feral cats.

7.2.4. Conduct research on the control of rodents.

7.2.4. Conduct research on the control of pigs.

7.3. Conduct research to improve nutritional quality and availability of nēnē food.

7.3.1. Develop methods for improving the quality and availability of nēnē food.

7.4. Conduct research on habitat restoration.

7.5. Conduct research on nēnē movements and evaluate the importance of seasonal habitat use.

7.6. Determine minimum viable population size for nēnē on Hawai`i, Maui Nui, and Kaua`i.

7.7. Determine carrying capacity of different habitats and methods to enhance carrying capacity.

7.8. Refine monitoring methods.

7.9. Utilize results of genetic studies on wild and captive nēnē flocks to enhance flock management.

7.10. Identify, evaluate, and incorporate improved rearing and release techniques for release sites with limited environmental conditions.

7.11. Conduct research on inter-island malarial strains.

7.12. Conduct research on topics of management concern.

7.13. Report results on all aspects of nēnē research and management at least every 5 years.

8. **Provide a public awareness and information program** to build public support for nēnē recovery.

8.1. Work with nonprofit organizations to promote nēnē appreciation.

8.2. Provide educational and informational opportunities for the public about the need for predator control and the application of control methods for conservation purposes.

8.3. Enlist the public's aid in nēnē recovery efforts through responsible pet ownership and minimization of human disturbance.

8.4. Promote interpretation and educational programs.

9. **Validate recovery objectives**.

9.1. Formalize the Nēnē Recovery Action Group.

9.1.1. Conduct semi-annual Nēnē Recovery Action Group meetings.

9.1.2. Annually compile monitoring data and determine the status of nēnē statewide.

9.1.3. Develop and distribute annual reports on nēnē recovery actions.

9.2. Review recovery objectives at every 5 years, or as appropriate.

B. NARRATIVE OUTLINE OF RECOVERY ACTIONS

1. Identify and protect nēnē habitat.

Nēnē were once abundant on most of the main Hawaiian islands. Although many nēnē nest in mid- and high-elevation sites today, it is believed they once nested primarily in lowland areas. Reintroduced populations in lowland areas have been the most successful and additional effort should be made to identify, protect, and manage lowland sites in addition to mid- and high-elevation sites. Upland sites are also an important component in the life cycle of nēnē, particularly in certain areas, and efforts should be made to protect areas that birds may migrate/move to in the summer.

1.1. Identify year-round and seasonally-used suitable nēnē nesting and rearing habitat, and associated summer flocking habitat, necessary to sustain target populations.

Key habitats for nēnē introductions were previously determined based largely on the locations of the last historically known wild populations. However, these remaining wild populations are now known to have been stranded in marginal habitats due to human development and the introduction of alien species. The present locations of reestablished nēnē populations have been determined largely by the locations of release sites. Therefore, existing and potential nēnē habitats should be reevaluated using archaeological evidence and nēnē fossils, in addition to Baldwin’s observations (1945), to better identify areas that were historically used by nēnē. This information should be used to guide future management actions of releasing nēnē and restoring or enhancing habitat. Areas that can provide the best habitat for sustaining nēnē populations with the least management effort should be emphasized with a focus on low- to mid-elevation sites. Habitats used both year-round or which are seasonally important should be identified.

Potential nēnē habitat may exist on lands that are either currently protected (such as National Parks, National Wildlife Refuges, and State Natural Area Reserves) or unprotected. These areas need to be identified and utilized to expand nēnē populations and distribution. The amount of nesting, rearing, and associated summer flocking habitat necessary to sustain target population levels on each island should be identified. Lands on currently unoccupied islands (such as Lāna`i and Kaho`olawe) that may have potential nēnē habitat also should be identified for future release efforts.

1.1.1. Develop criteria for identifying suitable nēnē recovery habitat.

Criteria for identifying suitable habitat for nēnē should be developed utilizing recent scientific findings. Criteria to consider include: availability and quality of nutritious forage plants, water, and shelter over time and space; habitat type (*e.g.*, alpine shrubland, wetland, managed grassland, etc.); spatial geography (*i.e.*, size, configuration, elevation, leeward verses windward, topography); predator and disease levels; feasibility of managing the area; potential for human disturbance and mortality (*e.g.*, roads, residential threats, poaching, contaminants, etc.); fire regime and ecology; potential interchange of nēnē among nearby areas; potential for population growth or estimated carrying capacity of the area; year-round and seasonally important habitats; as well as historic use by nēnē. These and other criteria should be used to evaluate all existing and potential nēnē habitat areas. Consideration should be given to moving existing populations living in areas not meeting the criteria, particularly if they are not doing well in those locations.

The 1983 Nēnē Recovery Plan identifies some recovery habitat, including Tax Map Keys and landownership (U.S. Fish and Wildlife Service 1983c). These areas should be incorporated into a Geographic Information Systems database. Other recovery habitats must also be identified with Tax Map Keys and landownership and incorporated into the Geographic Information Systems database.

From the above evaluation, a list of areas where nēnē management would be the most successful should be produced with Geographic Information Systems, including private lands.

1.2. Protect and restore sufficient suitable nēnē habitat to sustain target population levels on each island.

Sufficient habitat to sustain target population levels on each island as identified under Recovery Action 1.1 must be protected and restored through conservation easements, agreements, leases, land acquisition, or other means, where possible. Without a specific goal to manage for nēnē, changing priorities by land managers may jeopardize nēnē populations. Habitat protection and restoration will require an indefinite commitment by current land managers, whether public or private, for nēnē habitat management. A variety of habitats (low-, mid-, and high-elevation) should be protected and restored to ensure adequate breeding and foraging, and summer and winter habitat for nēnē recovery.

1.2.1. Develop strategies and techniques for protecting and restoring nēnē habitat.

Land managers will need to develop strategies and techniques for protecting and restoring nēnē habitat which may be identified on public and private lands. Landownership, elevation, and habitat type may influence protection and restoration opportunities and methods. Restoration activities should take into account that nēnē are generalists and are currently believed to require a diverse suite of food availability that may include nonnative and native vegetation (Black *et al*. 1994; Banko *et al*. 1999).

1.2.2. Identify the desired outcome of restoration activities.

Managers need to identify the desired condition of restored habitat to be able to determine if restoration goals are being met. Research is needed on the former or potential composition and distribution of native grass and shrub communities (Banko *et al*. 1999).

1.3. Identify, map, and, where necessary, protect present and potential migratory routes as populations increase in size.

As nēnē populations expand and traditional patterns of migration between breeding and foraging grounds become reestablished, or new ones established, these migratory routes should be identified and mapped. Additional areas that are utilized by nēnē for feeding, roosting, resting, and nesting should also be identified and mapped. By documenting these sites, nēnē managers can focus their habitat protection and management efforts to incorporate these habitats.

1.4. Develop island-specific implementation plans to meet population level targets for downlisting and delisting criteria.

Implementation plans for each island which address all of the factors influencing nēnē recovery should be developed within 3 years. These plans should utilize the results gathered from the preceding and other appropriate recovery tasks to determine the best island-based process for meeting the population target levels resulting in self-sustaining nēnē populations in suitable, protected habitats. Given the differences in habitat use, forage quality, predators, genetic diversity, and human pressures on each island, these plans should be developed on an island by island basis. Members of the Nēnē Recovery Action Group, with assistance from other experts as needed, should take the lead in developing the island-specific plans. These plans should then form the basis of a long-range, statewide plan for identifying, protecting, and managing sufficient suitable habitats and establishing additional nēnē populations.

2. Manage habitats and existing populations for sustainable productivity and survival.

Habitat must be actively managed in order for populations of nēnē to exist without the continued release of captive-bred birds. Habitat management plans should be written for all protected areas. Management of various nēnē habitat areas should be a cooperative effort to allow the use of pooled resources and information and to take into account the fact that nēnē frequently move between various habitat areas.

The following factors are necessary for successful nēnē populations:

- Predator-free areas or areas where predator populations are minimized.
- Sufficient food resources.
- Minimal human-caused disturbance and mortality.
- Maximum genetic diversity.

The basic steps for managing nēnē habitat are listed below. Not all of these actions are possible or needed in each nēnē habitat area. The priority of recovery actions may differ from area to area.

2.1. Manage habitat to provide sufficient nutrition.

Active habitat management in protected nesting and brooding areas should improve productivity and survival, as well as keep birds within areas that can be protected. Such efforts will occur on a site-by-site basis. Each land manager should incorporate habitat manipulation consistent with their organization's overall objectives and available resources. Where appropriate, work with researchers, non-governmental organizations, and private landowners to develop outplanting plans for native habitat restoration efforts.

Management actions may include:

- Mow, fertilize, and irrigate existing pasture areas to improve nēnē foraging areas.
- Plant foods such as native berries (*e.g.*, `ōhelo and pūkiawe), native grasses (*e.g.*, *Agrostis avenacea*), and other species such as sedges and *Canavalia hawaiiensis* that are known to be nutritious or important foods for nēnē (Appendix B). Native plant species should be emphasized for enhancement of nēnē foraging areas.
- If needed, provide watering areas such as water units or ponds or catchments designed to be safe for goslings.
- Managers may provide temporary supplemental feeding and watering stations when appropriate, such as under extreme environmental conditions (*e.g.*, drought or fire).
- If mechanical mowing of pastures is not feasible, explore alternate methods of keeping grass short, such as grazing.
- Larger-scale restoration of native habitat.

2.2. Minimize human-caused disturbance and mortality.

Human-caused disturbance and mortality takes many forms and includes direct injury caused by vehicles, golf balls, and poaching as well as less direct disturbance by outdoor recreationists and roadside feeding of nēnē. Public education can aid in minimizing such impacts to nēnē. Actions to prevent disturbance and mortality include:

- Place signs (*e.g.*, road signs noting the presence of nēnē, educational signs stating 'Please do not feed the nēnē,' interpretive displays, posters, or flyers) in areas subject to human disturbance, including hunting areas.
- Work with government transportation and maintenance departments to decrease vehicular speed in areas frequented by nēnē (*e.g.*, speed bumps, speed limits, and road signs) and to decrease attraction of nēnē to roadsides through appropriate vegetation management.
- Evaluate impact of pesticide and herbicide use on nēnē forage, health, and reproduction.
- Develop and implement a public education and information program.
- Manage operational activities, such as maintenance and other resource management activities, to prevent or minimize disturbance to nēnē, particularly during the breeding season.
- Manage recreational activities, such as camping, hiking, and hunting, to prevent or minimize disturbance to nēnē.

2.3. Continue release of captive-bred nēnē to improve demographic (*e.g.*, sex ratio and age structure) and genetic characteristics of nēnē populations in the wild, where warranted.

In order to augment populations and to maximize the genetic diversity of nēnē populations in the wild, captive-bred nēnē representing select genotypes should be released in suitable habitats as identified under the development of island-specific implementation plans (see Recovery Action 1.4). Nēnē released into these areas could be from breeding pens in the wild or from an established captive propagation facility. Appendix G contains general criteria for reestablishing nēnē populations.

2.4. Develop a genetics management plan.

No genetics management plan has been developed for nēnē and given concerns about inbreeding depression, a plan should be developed within the next 5 years. A genetics consulting group of population genetics experts, including the flock manager, should be established. This group will be able to review the captive flock status, status of the population in the wild, suggest new studies, rerun demographic models, and prepare an annual summary for the Nēnē Recovery Action Group that it can use to make management decisions.

2.5. Develop an injured bird salvage protocol for each nēnē population.

Adult survival is critical to long-term persistence of nēnē populations; thus nēnē that are injured in the wild must be evaluated by biologists in each area. Biologists must determine if an injured nēnē should be salvaged (*i.e.*, removed from the wild for examination or treatment) or left in the wild. Managers of each population must develop salvaging protocols for injured, dying, or dead nēnē, as well as for goslings and eggs. Protocols should be as consistent as possible among populations and reviewed for commentary by the Nēnē Recovery Action Group. Protocols must incorporate the following items:

- Objectives of salvage.
- Methods for salvage.
- Final disposition of salvaged nēnē or eggs.
- Authorization protocol - State and Federal permits and policies require authorization from the State biologist and the Federal biologist. The approval of an attending veterinarian may also be required before salvage of live nēnē.

2.6. Continue banding adults and young of the year.

The use of individually recognizable plastic leg bands along with U.S. Fish and Wildlife Service aluminum leg bands permits the most accurate method for tracking nēnē movements, assessing their genealogy, longevity, productivity, and population size. Due to the importance of banding in nēnē population assessment, banding of adults and young of the year should continue.

2.7. Monitor nēnē populations and evaluate annual trends.

Monitoring various parameters is necessary to determine the effectiveness of recovery actions and evaluate recovery of the species. Population and flock numbers, habitat use, dispersal, reproductive success, survival, mortality, predator control effectiveness, and health are among the parameters that should be monitored. Information from banded nēnē will be valuable in assessing populations. Survey methods currently vary between locations, but have generally been consistent within a given location. Ideally, managers responsible for nēnē restoration should evaluate monitoring methods and coordinate with each other to gather core monitoring parameters with customization for their particular populations and resources. Combining this information into a single database will allow statewide evaluation of population trends. To the extent possible, managers should try to develop similar or standardized monitoring protocols for all locations so that analysis of population trends is easily accomplished.

Specific monitoring and evaluation actions may include:

- Implant microchips in goslings when possible.
- Continue annual surveys of all known nēnē populations.
- Locate nests and determine nesting success.
- Survey nesting attempts by identifying females with brood patches.
- Conduct radio-telemetry studies.

3. Control alien predators in nēnē habitat.

Control of predators in nēnē habitat, especially during the breeding season, is essential. One of the major threats to nēnē populations is predation of eggs, goslings, and adults by introduced mammals. Nēnē evolved in the absence of mammalian predators and are thus extremely vulnerable to these species.

Mongooses, dogs, cats, pigs, and rats must be controlled using available legal methods. Methods of predator control include fencing, trapping, shooting, and poisoning. As additional methods are developed and approved, they should be incorporated into management protocols. In particular, multi-species toxicants and aerial broadcasts of toxicants are control methods currently being developed that may be appropriate for use in remote areas. Under toxicant label restrictions, no impacts to nontarget species are expected (K. Swift, pers. comm. 2003). If other predators are identified, such as the introduced barn owl (*Tyto alba*), predator control methods for those species also should be developed and implemented. The importance of each predator species should be evaluated in order to focus predator control efforts cost effectively. The importance of a particular predator species to nēnē populations is likely to vary among islands. For example, mongoose predation currently does not appear to be an issue on Kaua`i, but dog control is a concern, while mongoose and feral cat control is important at Haleakalā National Park (Telfer and Bailey, pers. comm. 1998).

3.1. Develop and implement a mongoose control program for Hawai`i, Maui, and Moloka`i.

As evidenced by the success of nēnē on Kaua`i, mongoose predation is believed to be a primary factory preventing the recovery of nēnē. Control of mongoose in other areas could lead to similar increases in nēnē populations and possibly natural dispersal and range expansion.

Immediate mongoose control actions can include:

- Develop mongoose control programs in prime nēnē breeding areas.
- Develop effective predator-proof fencing.
- Continue to pursue approval and registration of additional toxicants.
- Evaluate current control programs in all locations.
- Research improved methods of detection and control.
- Increase public awareness of mongoose impacts on nēnē recovery and build support for mongoose control actions.

3.2. Develop and implement a mongoose prevention and interdiction program for Kaua`i.

The lack of an established mongoose population on Kaua`i has enhanced the ability of nēnē populations to expand on this island. Preventing mongoose from becoming established on Kaua`i and detection of mongoose accidentally released is critical to the continued recovery of nēnē on Kaua`i.

Immediate mongoose prevention and interdiction actions can include:

- Develop improved detection techniques.
- Investigate the temporal and geographic pattern of mongoose sightings.
- Develop improved techniques to capture mongoose.
- Develop effective predator-proof fencing.
- Develop a biosecurity plan.

3.3. Develop and implement a dog control program.

Dogs are known to be serious predators of nēnē. Both feral and stray dogs have preyed upon adult nēnē in the Nā Pali and Crater Hill populations on Kaua`i. The agencies responsible for nēnē restoration must develop a control program sensitive to public response. Awareness programs should be implemented that incorporate information for both the general public and hunters that hunt with dogs on the danger dogs present to nēnē populations.

Immediate dog control actions can include:

- Develop dog control programs in prime nēnē breeding areas.
- Enlist the aid of Wildlife Services (U.S. Department of Agriculture) or local resource management agencies to remove dogs from areas accessible by the public.
- Develop effective predator-proof fencing.
- Use box traps, leg-hold traps, or other appropriate means to capture dogs.
- Allocate funds for use of helicopters to remove dogs from remote areas.
- Send press releases to local media to provide information to the public on the impacts of dogs on nēnē.
- Incorporate discussion of the problem uncontrolled or escaped hunting dogs pose to nēnē in hunter education efforts.
- Consider enacting no hunting zones near important nesting or molting habitat.
- Support the development of humane capture and control techniques.
- Increase public awareness of dog impacts on nēnē recovery and build support for dog control actions.

3.4. Develop and implement a feral cat control program.

Feral cats have been documented to predate goslings.

Immediate feral cat control actions can include:

- Develop feral cat control programs in prime nēnē breeding areas.
- Develop effective predator-proof fencing.
- Evaluate current trapping efforts in all locations.
- Increase public awareness of feral cat impacts on nēnē recovery and build support for feral cat control actions.

3.5. Develop and implement a rodent control program.

Rodents have been documented to predate nēnē eggs and goslings.

Immediate rodent control actions can include:

- Develop rodent control programs in prime nēnē breeding areas.
- Develop effective predator-proof fencing.
- Continue to pursue approval and registration of additional toxicants.
- Evaluate current trapping efforts in all locations.
- Increase public awareness of rodent impacts on nēnē recovery and build support for rodent control actions.

3.6. Develop and implement a pig control program.

Pigs have been documented to predate nēnē eggs, goslings, and flightless adults.

Immediate pig control actions can include:

- Develop pig control programs in prime nēnē breeding areas.
- Develop effective predator-proof fencing.
- Evaluate current trapping efforts in all locations.
- Increase public awareness of pig impacts on nēnē recovery and build support for pig control actions.

4. Continue captive propagation program.

In order to maximize genetic diversity, augment existing populations, and establish new populations, captive flocks should be maintained. Captive propagation programs are developed in accordance with the guidelines established by the U.S. Department of the Interior's Policy on Controlled Propagation (U.S. Department of the Interior 2000), the International Union for the Conservation of Nature (IUCN), World Conservation Union's Conservation Breeding Specialist Group's policy on captive propagation (International Union for the Conservation of Nature 1987, 2000), the World Conservation Union's Reintroduction Specialist Group's Guidelines for Reintroduction (International Union for the Conservation of Nature 1998), the American Zoo and Aquarium Association Reintroduction Advisory Group's guidelines (Beck 1992), Conservation Breeding Specialist Group's Conservation Assessment Management Plan recommendations (Ellis *et al*. 1992), and the Small Population Management Advisory Group Guidelines (American Zoo and Aquarium Association 2003).

4.1. Maintain captive breeding flocks at Keauhou Bird Conservation Center and Maui Bird Conservation Center.

The captive breeding facilities at the Keauhou Bird Conservation Center and the Maui Bird Conservation Center should continue in order to produce nēnē to augment populations in the wild, establish new populations, and to maximize genetic diversity. Salvaged eggs from populations in the wild may provide an additional source of genetic diversity. Emphasis should continue to be placed on producing parent-reared goslings as opposed to sibling-reared groups because parent-reared goslings adapt better to living in the wild.

Captive breeding stocks should be managed for maximum genetic diversity (*i.e.*, composed of birds from different populations and diverse genetic stocks). Egg from pairs from the wild of known origin, especially from Hawai`i Volcanoes National Park, should be added to the captive flocks to further reduce similarity among captive nēnē breeding stock (Rave 1995). The pedigree of pairs from the wild will be important in selecting appropriate eggs for inclusion in the captive flock. Where management for maximum genetic diversity conflicts with other management directions (*e.g.*, prevention and minimization of disease transmission), the Hawaiian Endangered Bird Conservation Program will need to determine the best course of action.

The nēnē captive propagation strategy should be evaluated and implemented through the development of annual work plans and 5-year work plans established between the operators of the captive propagation facilities, the Hawai`i Division of Forestry and Wildlife, and the U.S. Fish and Wildlife Service. The plans should include input from the public, Nēnē Recovery Action Group, and related working groups. The plans should incorporate the most current nēnē information including the dynamics of the population in the wild, available funding, research developments, disease information, available release sites, the relative benefit of captive release strategies compared to other recovery strategies, and the progress made in the captive maintenance and propagation of nēnē.

4.2. Establish or maintain captive breeding flocks in open-top pens.

Captive breeding in open-top pens in the wild may be necessary if existing propagation facilities cannot produce sufficient nēnē needed for release. Management of open-top pen propagation should be complimentary to and part of captive propagation efforts. Such coordination will ensure that the same guidelines will be followed for both open-top and captive breeding facilities and allow for unified genetic management.

4.3. If warranted, explore the possibility of releasing zoo-bred nēnē.

The potential for releasing nēnē or utilizing eggs produced by nēnē from locations such as the Honolulu Zoo or the Waterfowl and Wetlands Trust facility in England should be examined. These facilities have the potential to contribute a large number of captive-bred nēnē or eggs in the event that Recovery Actions 4.1 and 4.2 cannot be accomplished. However, the genetic characteristics of these captive animals may preclude their usefulness for supplementing populations in the wild and establishing new nēnē populations. Wildlife health officials should be consulted regarding the risk of introducing diseases to nēnē flocks in the wild. Guidelines for health screening and studbook records would also need to be established if this recovery action were to be undertaken. The high costs in time and resources associated with the identification of zoos, and quarantining and testing of animals, limit the viability of this action for repopulating or expanding nēnē into unoccupied habitat.

4.4. If warranted, explore propagation of nēnē by private organizations.

Propagation of nēnē by private organizations and zoos should be explored, particularly in the event that Recovery Actions 4.1, 4.2, and 4.3 cannot be accomplished. Nēnē produced by these organizations can be utilized as sources of nēnē for release into the wild if deemed appropriate. The selected organization(s) must agree to work cooperatively with the agencies that manage nēnē, for the release of nēnē to augment or establish populations in the wild. They must have a written, Nēnē Recovery Action Group-approved agreement to propagate nēnē (*i.e.*, a Memorandum of Understanding or a Safe Harbor Agreement). The organization(s) must also agree to abide by health screening standards and other permit conditions including studbook record guidelines.

4.5. Prevent or minimize disease and parasite transmission.

Although diseases and parasites have the potential to seriously impact nēnē recovery efforts (Kear and Brown 1976; Kear and Berger 1980), fortunately they have not seriously impacted wild or captive nēnē flocks to date (Banko and Manuwal 1982; Gassmann-Duvall 1987; Bailey and Black 1995; Banko *et al*. 1999). Guidelines are in place to prevent or minimize the transmission of diseases and parasites within captive flocks and all birds are given health screenings prior to being moved to release sites. However, the impact of avian malaria on nēnē populations is unknown and could potentially be minor. However, further research is needed given malaria's devastating impacts on native Hawaiian forest birds (van Riper *et al*. 1986; Banko *et al*. 1999; Shehata *et al*. 2001). In the absence of this information, additional methods (*e.g.*, raising captive birds under mosquito netting) to address avian malaria transmission and genetic considerations need to be further explored. Plans also need to be developed to address novel diseases such as West Nile Virus.

4.5.1 Prevent or minimize transmission of avian malaria and other diseases or parasites between captive and wild nēnē flocks.

The inter-island transport and release of birds that are reared in captive propagation facilities can be a route for movement of disease organisms between isolated populations and facilities if these birds are not reared under mosquito netting or in isolation from wild and domestic birds. Currently, captive nēnē are not reared under mosquito netting nor are they all raised in isolation from wild and domestic birds. Due to concerns about potentially transferring unique regional strains of avian malaria among islands with the release of infected captive-bred nēnē, nēnē are currently tested for the presence of malarial infections prior to release. Nēnē that cannot be certified malaria-free are not released off island. These protocols are important to protect both nēnē as well as the more susceptible native forest birds.

Release restrictions on infected nēnē could potentially affect the restoration of nēnē populations on islands without a captive propagation facility. Until disease concerns are ruled out, methods to prevent or minimize the potential for disease introduction should continue to be incorporated into all nēnē management decisions. However, these decisions will also need to take into the account the impact of disease prevention and minimization methods on both the genetic heterozygosity in the captive flock and the behavioral management of the flock. Where current management for disease and parasite transmission conflicts with other management directions (*e.g.*, maximize genetic diversity), the Hawaiian Endangered Bird Conservation Program will need to determine the best course of action (*e.g.*, raising nēnē under mosquito netting, transferring fertile eggs or goslings between facilities). Such actions will also need to address the potential for transferring unique regional strains of avian malaria to whole island avifaunas. Disease screening should be expedited to minimize any release restrictions and allow for maximum flock management while still maintaining disease precautions.

4.5.2. Prevent, detect, and minimize transmission of novel diseases and parasites.

Nēnē and other Hawaiian avifauna may be threatened by the introduction of novel diseases, such as West Nile Virus, or parasites. Some of these diseases have the potential to decimate nēnē populations. Managers should interface with other agencies to identify potential threats, reduce the chances of introducing novel diseases or parasites, and to produce strategies to minimize the threat of diseases and parasites that are detected or become established in Hawai`i. Specific actions could include:

- Work with State and Federal agencies to prevent the introduction of novel diseases and parasites.
- If needed, develop methods to detect diseases and parasites.
- Evaluate the risk of novel diseases and parasites to nēnē.
- Identify potential remedies such as vaccines.
- Develop biosecurity plans addressing emergency salvage of healthy birds, protection of genetic stock, process for emergency exemptions for effective vaccines, etc.

4.6. Where warranted by the environmental conditions of the release site, incorporate improved rearing and release techniques into the captive propagation and release program.

Current captive-breeding techniques have been very successful in producing nēnē for release. However, the environmental conditions of different release sites may necessitate some changes in the rearing and release techniques to enable newly released nēnē to better adapt to their surroundings. Results from studies on captive-breeding and release techniques should be incorporated into the captive propagation program, where appropriate, to enhance survival of released birds.

4.6.1. Depending on the environmental conditions of the release site, provide captive nēnē with a structurally diverse environment.

If nēnē are to be released in areas with a limited range of environmental conditions (*e.g.*, Hawai`i Volcanoes National Park), mimicking nēnē habitat as closely as possible in the captive environment may enhance the ability of newly released nēnē to adapt to their environment. Incorporation of native forage plants and plants used for nesting habitat may also enhance the survival and future reproduction of recently released birds in areas where native forage is available.

4.6.2. Depending on the environmental conditions of the release site, implement pre-release human and predator-avoidance training of nēnē.

Nēnē generally show little fear of humans. This lack of fear has resulted in inappropriate behaviors, such as begging, that have proven to lead to injuries or deaths (*e.g.*, nēnē begging for food have been struck by cars). Human contact in the captive-rearing process should be reduced whenever possible. Prerelease predator-avoidance training of nēnē may increase the survival rate of released captive-bred nēnē. While it does appear that captive goslings recognize and respond to predators by freezing and becoming quieter, they may not automatically exhibit appropriate avoidance behavior later on (Zillich 1995). Various methods of teaching goslings predator avoidance are also being examined (Zillich 1995; Zillich, pers. comm. 1998). If proven effective, methods of reducing predator interactions could be incorporated into the captive propagation program if it is deemed appropriate for the targeted release site.

4.7. Monitor captive-released birds.

Birds which are released from the captive propagation program should be monitored to determine their behavior, habitat use, survival, and reproduction following release. Results from the monitoring can potentially be used to further refine rearing and release techniques (see Recovery Action 2.6).

5. Establish additional nēnē populations in suitable, uninhabited areas that are protected.

Areas with current nēnē populations are not producing nēnē without intensive management. Following the identification and protection of suitable nēnē habitat (see Recovery Action 1), additional nēnē populations should be established.

5.1. Establish cooperative agreements on private lands.

Private lands identified as potential nēnē habitat should be considered for cooperative agreements. Landowners should be made aware of Safe Harbor

Agreements and Habitat Conservation Plans that allow such cooperative agreements. Tax incentives should be sought for private landowners that are interested in having endangered species on their lands. The U.S. Department of Agriculture has a conservation division that administers the Wildlife Habitat Enhancement Program that may be a source of funds to private landowners wishing aid for nēnē conservation efforts on their lands. Where possible, agreements should be established on an island-wide basis.

5.2. Establish new populations of nēnē on existing managed lands and on private lands with cooperative agreements.

Nēnē should be released on private or public lands that have been identified as suitable and where landowners have agreed to cooperate with Federal and State resource managers. These releases will be conducted using the most appropriate methods, agreed on by the managing agencies, and should include long-term maintenance and monitoring.

6. Address conflicts between nēnē and human activities.

As nēnē populations increase, particularly in heavily populated lowland areas, they may often come into conflict with human activities. For example, nēnē on Kaua`i utilize a variety of lowland areas including truck farms, golf courses, and airport runway aprons. Nēnē utilizing these areas may present a safety hazard to humans. Humans may also inadvertently harm nēnē by feeding them which could result in nēnē showing aggressive behaviors towards humans, being injured or killed by vehicles, or being placed at increased risk from predators. Methods and plans to prevent and address these potential human-nēnē conflicts must be developed. Such methods and plans will alleviate potential safety problems, provide managers with flexible and effective means to deal with problem nēnē, and provide for continued public support of nēnē recovery actions. Addressing these conflicts will allow nēnē to coexist with areas of established human activity.

6.1. Develop safe and effective methods for managing nēnē in unsuitable habitats.

Measures for safely and effectively managing nēnē in unsuitable habitats such as airport runways, need to be developed. These measures should be made available to land managers as a tool to address nēnē conflicts.

6.2. Develop contingency plans for relocating nēnē utilizing unsuitable habitats or causing human safety hazards.

If removal of nēnē from unsuitable habitats or from areas where they are causing human safety hazards is warranted, plans must be in place to govern the methods and processes for relocating nēnē to other habitats. Nēnē managers should develop and periodically reevaluate these plans with assistance from the Nēnē Recovery Action Group.

7. Identify new and continue research on known limiting factors and management techniques.

Research on factors limiting nēnē recovery and improved management techniques should be conducted in order to enhance the effectiveness of nēnē recovery actions.

7.1. Identify limiting factors.

Although many factors limiting nēnē recovery have been identified and at least partially addressed, there still remains uncertainty regarding the factors affecting some populations. Despite controlling known limiting factors, some nēnē populations are still not doing well. Identification of additional factors that may be limiting the growth or survival of these populations needs to be conducted. Once identified, research on these limiting factors should be considered to develop appropriate management techniques.

7.2. Conduct research on the control of predators.

Predation continues to be a major limiting factor for nēnē populations. The effectiveness of current predator control efforts needs to be evaluated and methods that are practical for management in nēnē habitat should be identified. Managers need to know the relative efficacy and cost of whatever method is used. In addition, the measure of success of predator control techniques should be evaluated independently of nēnē reproductive success, as factors other than predator control also influence nēnē reproductive success (E. Campbell, pers. comm. 2002).

Live-trapping, shooting, and toxicants are the predator control methods currently in use. Live trapping is extremely labor-intensive and costly, and its effectiveness varies depending upon the targeted species. A rodenticide, diphacinone, is used in bait stations to control rats and mongooses. Within the next few years diphacinone should be approved by the State of Hawai`i and the U.S. Environmental Protection Agency for aerial broadcast to cover larger areas more effectively. Better control methods for cats, dogs, and pigs must be identified. The development of better lures, and more effective humane live-trapping techniques for these species is critically needed (Campbell, pers. comm. 2002).

7.2.1. Conduct research on the prevention, interdiction, and control of mongooses.

Development of mongoose detection and control techniques needs to focus on the identification of effective lures for traps. Effective lures are particularly important for the island of Kaua`i which does not yet have an established population of mongooses. Trapping in areas in which sightings have occurred has not been successful, likely because of an abundant prey source and/or low density of mongooses (Campbell, pers. comm. 2003; Telfer, *in litt*. 2003).

Numerous sightings since 1968 suggest that there may be individual mongooses that have arrived on Kaua`i which could become established. If mongooses are determined at any time to be present on Kaua`i, it could prove a serious blow to nēnē and other native species on the island.

7.2.2. Conduct research on the control of dogs.

The development of humane live-trapping techniques is necessary for increasing the effectiveness of dog control. Techniques already in use for coyotes and wolves on the mainland United States could be adapted relatively easily to target dogs in Hawai`i.

7.2.3. Conduct research on the control of feral cats.

Currently, there are no effective techniques for controlling feral cats. Better lures for use in live traps and the adaptation of humane traps, such as padded leg-holds, is needed. Design and testing of predator-proof fences may prove to be the most useful deterrent.

7.2.4. Conduct research on the control of rodents.

Diphacinone, a rodenticide, is used in bait stations to control rodents. Aerial broadcast of diphacinone in select areas will allow managers to more effectively control rodents. Following approval of this control technique, rodent populations should be monitored and the effectiveness of this technique evaluated.

7.2.5. Conduct research on the control of pigs.

Techniques currently employed for controlling pigs include fencing, dogs trained to hunt pigs, and hunting in select areas. Research funds should be used to monitor the effectiveness of these various techniques.

7.3. Conduct research to improve nutritional quality and availability of nēnē food.

Recent studies have looked at the nutritional needs of adult nēnē and their use of habitats in Hawai`i Volcanoes National Park as well as in Haleakalā National Park showing that a diversity of foods are utilized by adults (Black *et al.* 1994; Woog and Black 2001). Additional studies need to be initiated to look at the nutrition of food items utilized by goslings. Preliminary work shows that starvation and/or dehydration may be primary causes of gosling death in Haleakalā National Park (Baker and Baker 1995). It has been noted that gosling mortality is high in certain areas (Haleakalā National Park and Hawai`i Volcanoes National Park) and recently, gosling mortality appeared to be a problem on Kaua`i (Baker and Baker 1995; Telfer, pers. comm. 1999). At this time, native food plants have been poorly studied. Hawai`i Volcanoes National Park is currently funding studies on nutritional values of native food plants and conducting palatability trials with goslings (Sherry 2000).

7.3.1. Develop methods for improving the quality and availability of nēnē food.

Recent work (see above) shows high rates of gosling mortality which may be due to food quality and availability. Methods for determining and improving food quality and availability for nēnē goslings should be field tested and critically analyzed. The focus of these studies should be to determine why available nutritional resources are not sufficient for gosling growth and to develop methods that can be utilized for enhancing nutritional resources for goslings. Recent studies show that adult nēnē selected sites with grass having a high water content, grazed most in grasses shorter than 11 centimeters (4.3 inches), and used grasslands less during dry periods though they may be more likely to move to grass habitats during drought (Black *et al*. 1997,;Woog and Black 2001). Grass with low water content is lower in protein (Woog and Black 2001).

There have been recent concerns on Kaua`i regarding gosling mortality due to nutritional deficiencies. Since formal studies on nutrition have only been conducted on Hawai`i and Maui, there is a need to conduct such studies on Moloka`i and Kaua`i as well.

7.4. Conduct research on habitat restoration.

Habitat restoration and management is increasingly believed to be important to attaining self-sustaining nēnē populations, particularly in certain areas (Hu 1998; Banko *et al*. 1999), however, habitat restoration has not yet been well developed as a tool for nēnē recovery. Previous research efforts need to be supplemented by gathering additional information on: 1) areas within their former range where nēnē may be supported with predominantly native vegetation; 2) the potential former composition and distribution of native grass and shrub communities with reference to native plant species known or believed to be important to nēnē prehistorically; 3) the nutritional value, palatability, and ecological requirements of native plants utilized by nēnē; and 4) methods for converting habitats dominated by invasive alien species to habitats dominated by natives (Hu 1998; Banko *et al*. 1999; Sherry 2000; Woog and Black 2001).

7.5. Conduct research on nēnē movements and evaluate the importance of seasonal habitat use.

Telemetry studies should be undertaken to elucidate movements of some nēnē populations and determine their habitat use and migration pathways. For example, it is not known where the nēnē that nest in the Hakalua National Wildlife Refuge go during the nonbreeding season (Jeffrey, pers. comm. 2003). New and existing data should be further analyzed to better evaluate the importance of seasonal habitat use by some nēnē populations.

7.6. Determine minimum viable population size for nēnē on Hawai`i, Maui Nui, and Kaua`i.

Ecological, demographic and genetic data should be compiled and used to devise more comprehensive Population Viability Analysis models, using current knowledge of parameters and planned recovery actions. Population Viability Analysis or other population modeling programs should be run periodically (at least every 2 years). A Population Viability Analysis workshop should be conducted for nēnē managers in which the most recent data are run at the workshop and the results discussed during the workshop by the managers and Federal and State agency personnel. Managers should be trained to perform this analysis and to understand its implications for nēnē management. Data needs to be collected in a consistent manner in order to compare the different populations.

7.7. Determine carrying capacity of different habitats and methods to enhance carrying capacity.

The carrying capacity of habitats utilized by nēnē and identification of management methods to enhance the carrying capacity of these areas should be determined. Understanding the carrying capacity of different habitat types will allow land managers to better plan habitat protection and develop more specific habitat restoration and management goals.

7.8. Refine monitoring methods.

Monitoring methods need to be reviewed and altered if necessary so that census results are comparable between years and sites. Managers of each population should periodically review their monitoring methods with each other and with the agencies responsible for nēnē restoration. It would also be useful if monitoring protocols were standardized so that analysis of population trends is easily accomplished and if monitoring was designed with the potential for use in post-delisting monitoring. Population and flock numbers, habitat use, reproductive success, predator control effectiveness, and avian health are among the parameters that should be monitored.

The use of implantable identification markers (microchips), in addition to leg bands, should be used to mark goslings when they can be captured along with parent birds, so that their family identity can be determined if they are subsequently recaptured as adults. Efforts should continue to find long-lasting, readable colored plastic or metal bands for field identification, especially as most birds will be resighted rather than recaptured.

7.9. Utilize results of genetic studies on wild and captive nēnē flocks to enhance flock management.

Recent studies showed that nēnē within some populations are more inbred, but are not necessarily related between populations (Rave *et al*. 1994; Rave 1995). Nēnē on Kaua`i are more closely related to each other than Hawai`i Volcanoes National Park nēnē are to each other, for example (Rave 1995). To increase genetic diversity, nēnē can be translocated between populations that are least related.

Captive breeding stocks should include the most genetically diverse stock of nēnē as possible. Eggs from pairs in the wild of known origin, should be added to propagation facilities to further reduce similarities among captive nēnē breeding stock (Rave 1995).

7.10. Identify, evaluate, and incorporate improved rearing and release techniques for release sites with limited environmental conditions.

A review of past rearing and release techniques has shown that nēnē survival is affected by both how nēnē are reared and how they are released (Marshall and Black 1992; Black *et al*. 1997). Managers should continue to parent-rear nēnē goslings. Releases should continue to be from open-top or closed-top gentle release pens and with parents or foster parents. These techniques have proven highly successful in producing nēnē. Rearing and release techniques that enhance the survival of released nēnē, particularly when nēnē are released into areas lacking a diversity of habitat types (*e.g.*, Hawai`i Volcanoes National Park), should continue to be developed and implemented. The effects of reduced human contact prior to release should be researched. Human-avoidance training should also be explored to enhance nēnē survival in the wild.

7.11. Conduct research on inter-island malarial strains.

The potential for transferring unique regional strains of avian malaria between islands with the release of infected captive-bred nēnē has led to the testing of all nēnē for malarial infections prior to release. Nēnē that cannot be certified malaria-free are not released off island since it is currently unknown if different malarial strains exist on each island. Research to determine the presence or absence of unique regional strains of avian malaria should be conducted and the results incorporated into the captive propagation and release of nēnē.

7.12. Conduct research on topics of management concern.

Increasing nēnē populations and expansion of nēnē into unoccupied habitats may lead to additional areas of management concern. For example, as nēnē populations increase and migrate between low and high elevation areas, research projects should address the establishment of new flyways. The introduction of nēnē to unoccupied habitats and the role of nēnē in managed habitats should also be examined.

The impact of alien species on nēnē should also be assessed. For instance, the alien plant *Senecio madagascariensis* is toxic to livestock and may also be toxic to nēnē (Hu, pers comm. 2002). This plant is found on the islands of Hawai`i, Maui, and Kaua`i. Its spread could have negative consequences for nēnē if it is proved to be toxic and nēnē inadvertently forage on it.

7.13. Report results on all aspects of nēnē research and management at least every 5 years.

Successful management of nēnē populations is dependent on knowledge gained from research projects and testing of management techniques. Regular reporting of research and management activities will aid managers in the recovery of this species. Activities should be summarized on a regular basis with 5 years as a maximum time period. The Nēnē Recovery Action Group would be an appropriate venue to compile and report on nēnē research and management activities.

8. Provide educational and informational opportunities to build public support for nēnē recovery.

A public awareness and information program is crucial for increasing both general public and lawmaker support for nēnē recovery actions. Land managers should work with existing public information divisions within their agencies and with nonprofit organizations to develop information materials and programs to build public support for nēnē recovery.

8.1. Work with nonprofit organizations to promote nēnē appreciation.

Nonprofit and volunteer organizations can develop and implement educational strategies and materials that can be made available to all sectors of the public about nēnē. Information should be disseminated on current conservation measures, threats to nēnē, methods for keeping nēnē from becoming suburban nuisances, status on nēnē in Hawaiian culture, and basic biology. Media for transmitting this information could include interpretive displays, television and radio spots, newspaper and magazine articles, posters, t-shirts, classroom materials, and the internet. An Adopt-A-Nēnē program, developed through the Friends of Haleakalā National Park, Inc., is proving to be a successful means of public awareness and fund raising and could be carried out on other islands.

8.2. Provide educational and informational opportunities to the public about the need for predator control and the application of control methods for conservation purposes.

Predator control is an extremely important and effective recovery action. Public understanding and support of predator control efforts is essential to the recovery of nēnē. The public education campaign explaining the need for aerial broadcast of diphacinone for conservation purposes and the relative risk(s) of this predator control method should be continued. Other predator control measures should also be brought to the public's attention to aid in their understanding of nēnē recovery actions and to build public support for nēnē recovery. The role of humans in contributing to nēnē predation should also be addressed in educational programs and materials.

8.3. Enlist the public's aid in nēnē recovery efforts through responsible pet ownership and minimization of human disturbance.

The public should be informed about the role of humans in nēnē recovery. Release of domesticated dogs and cats, and human feeding and disturbance of nēnē in the wild can all negatively affect nēnē survival, reproduction, and behavior. The public should be encouraged to be responsible pet owners and to obey signs and regulations regarding interactions with nēnē.

8.4. Promote interpretation and educational programs.

Public awareness and environmental education should be promoted and supported through development of interpretive and educational displays, establishment of visitor centers, and implementation of school educational programs. Increased public awareness and support for native species and their habitats can be accomplished through development of visitor centers and interpretive materials. Funding and support of teacher education programs and the development and distribution of educational materials will aid in educating the community and increasing support for recovery actions.

9. Validate recovery objectives.

The scientific validity of the stated recovery objectives must be evaluated periodically to assess whether the projected number of populations and individuals will prove to be adequate to safeguard against catastrophic events and long-term processes over the next 200 years.

9.1. Formalize the Nēnē Recovery Action Group.

Nēnē management and recovery actions are currently coordinated by the Nēnē Recovery Action Group. The Nēnē Recovery Action Group is comprised of nēnē experts and resource managers but its effectiveness has been hampered due to infrequent meetings resulting in limited coordination and evaluation of management and research projects across the main Hawaiian Islands.

Formalizing the Nēnē Recovery Action Group through semi-annual meetings and annual reporting of activities should aid managers in their recovery work. If the Nēnē Recovery Action Group is unable to accomplish these recovery actions, consideration should be given to reestablishing and funding a formal Nēnē Recovery Team.

9.1.1. Conduct semi-annual Nēnē Recovery Action Group meetings.

Conducting semi-annual meetings will provide a venue for land managers and researchers to discuss and evaluate their activities. These meetings will also allow the Nēnē Recovery Action Group to evaluate the recovery objectives on a regular basis and revise them if necessary.

9.1.2. Annually compile monitoring data and determine the status of nēnē statewide.

Various agencies are responsible for monitoring nēnē populations. Since these agencies are represented in the Nēnē Recovery Action Group, the Nēnē Recovery Action Group should compile the monitoring data from these agencies and annually determine the status of nēnē statewide. Such a compilation would provide managers with a measure of the success of recovery actions and the ability to identify areas where additional work is needed.

9.1.3. Develop and distribute annual reports on nēnē recovery actions.

The Nēnē Recovery Action Group should compile and distribute annual reports on management, research, and public education activities addressing nēnē recovery. These reports will allow the Nēnē Recovery Action Group and others to assess the progress being made in implementing recovery actions.

9.2. Review recovery objectives every 5 years, or as appropriate.

Recovery objectives should be reviewed on a regular basis with a maximum review period of 5 years. If analysis suggests that the current objectives are inadequate to recover nēnē, the recovery objectives should be revised.

V. IMPLEMENTATION SCHEDULE

The Implementation Schedule that follows outlines the actions and estimated costs for the nēnē recovery program, as set forth in this plan. It is a ***guide*** for accomplishing the objectives and actions suggested in this recovery plan. The schedule describes and prioritizes recovery actions, provides an estimated timeframe for performance of recovery actions, the parties responsible for the actions (either funding or carrying out), and estimates costs. The actions identified in this Implementation Schedule, when accomplished, should achieve the recovery of the nēnē.

We have the statutory responsibility for implementing this recovery plan; only Federal agencies are mandated to take part in recovery efforts. However, nēnē recovery will require the involvement of the full range of Federal, State, private, and local interests. The expertise and contributions of additional agencies and interested parties has been and will continue to be needed to implement certain recovery actions and to accomplish education and outreach objectives. The "responsible parties" identified in the implementation schedule are those agencies, non-governmental organizations, or interested individuals, such as private landowners, that may voluntarily participate in any aspect of implementation of recovery actions listed. Responsible parties may willingly participate in project planning, funding, provide technical assistance, staff time, or any other means of implementation. The listing of a party in the Implementation Schedule does not require the identified party to implement the action(s) or to secure funding for implementing the action(s).

Definition of Action Priorities:

Priority 1—An action that must be taken to prevent extinction or prevent the 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 the recovery objectives.

Definition of Action Durations:

Continual (C)—An action that will be implemented on a routine basis once begun.

Ongoing (O)—An action that is currently being implemented and will continue until it is no longer necessary.

To Be Determined (TBD)—Either action duration or associated costs are not known at this time or implementation of the action is dependent on the outcome of other recovery actions.

Key to Responsible Parties (potential lead parties identified in bold type)**:**

BRD	U.S. Geological Survey, Biological Resources Division
DOFAW	Hawai`i Division of Forestry and Wildlife
NGO	Non-Governmental Organization
NPS	National Park Service
NWR	National Wildlife Refuge
NRAG	Nēnē Recovery Action Group
TBD	To Be Determined
USDA	U.S. Department of Agriculture
USFWS	U.S. Fish and Wildlife Service
ZSSD	Zoological Society of San Diego

Implementation Schedule for Nēnē Draft Revised Recovery Plan Actions

Statewide Priority Number	Island Priority Number[1]	Action Number	Action Description	Action Duration (Years)	Responsible Parties	Cost Estimates (in $1,000 units)					
						Total Costs	FY 2004	FY 2005	FY 2006	FY 2007	FY 2008
1		1.1	Identify year-round and seasonally-used suitable nēnē nesting and rearing habitat, and associated summer flocking habitat, necessary to sustain target populations.	2	NRAG	100.8	80	20.8	—	—	—
1		1.1.1	Develop criteria for identifying suitable nēnē habitat.	1	NRAG	11.2	11.2	—	—	—	—
1		1.2	Protect and restore sufficient suitable nēnē habitat to sustain target population levels on each island.	O	**USFWS/DOFAW NPS**/NGO/private	232.0	46.4	46.4	46.4	46.4	46.4
1		1.2.1	Develop strategies and techniques for protecting and restoring nēnē habitat.	O	**USFWS/DOFAW NPS**/NGO/Private	100.0	30	30	20	10	10
1		1.2.2	Identify the desired outcome of restoration activities.	5	USFWS/DOFAW NPS/BRD/**NRAG**	120.0	40	30	20	20	10
1		1.4	Develop island-specific implementation plans to meet population level targets for downlisting and delisting criteria.	3	NRAG	225.0	75	75	75	—	—
1		2.1	Manage habitat to provide sufficient nutrition.	C	**NWR/NPS DOFAW**/NGO Private	174.0	34.8	34.8	34.8	34.8	34.8

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						Total Costs	FY 2004	FY 2005	FY 2006	FY 2007	FY 2008
1	K-3	2.3	Continue release of captive-bred nēnē to improve demographic and genetic characteristics of nēnē populations in the wild, where warranted.	O	NRAG	50.0	10	10	10	10	10
1		2.4	Develop a genetics management plan.	5	NRAG	14.0	4	4	2	2	2
1		2.6	Continue banding adults and young of the year.	O	NRAG	30.0	6	6	6	6	6
1		2.7	Monitor nēnē populations and evaluate annual trends.	O	NRAG	676.0	135.2	135.2	135.2	135.2	135.2
1	K-3	3.1	Develop and implement a mongoose control program for Hawai`i, Maui, and Moloka`i.	O	**NWR/DOFAW NPS**	120.0	24	24	24	—	—
1	H-3 M-3	3.2	Develop and implement a mongoose prevention and interdiction program for Kaua`i.	C	**NWR/DOFAW NPS**	200.0	25	25	50	50	50
1		3.3	Develop and implement a dog control program.	O	**NWR/DOFAW NPS**	350.0	50	50	50	—	—
1		3.4	Develop and implement a feral cat control program.	C	**NWR/DOFAW NPS**	625.0	125	125	125	125	125
1		3.5	Develop and implement a rodent control program.	O	**NWR/DOFAW NPS**	925.0	185	185	185	185	185
1		3.6	Develop and implement a pig control program.	O	**NWR/DOFAW NPS**	50.0	10	10	10	10	8

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						Total Costs	FY 2004	FY 2005	FY 2006	FY 2007	FY 2008
1	K-3	4.1	Maintain captive breeding flocks at Keauhou Bird Conservation Center and Maui Bird Conservation Center.	O	USFWS/DOFAW **ZSSD**	175.0	35	35	35	35	35
1	K-3	4.5.1	Prevent or minimize transmission of avian malaria and other diseases or parasites between captive and nēnē flocks in the wild.	O	USFWS/DOFAW **ZSSD**/BRD	55.0	20	20	5	5	5
1		4.5.2	Prevent, detect, and minimize transmission of novel diseases and parasites.	C	USFWS/DOFAW **ZSSD**/BRD	47.4	22.4	10	5	5	5
1	K-3	4.7	Monitor captive-released birds.	O	**NWR/NPS DOFAW**	52.5	10.5	10.5	10.5	10.5	10.5
1		5.1	Establish cooperative agreements on private lands.	5	**USFWS/DOFAW** NGO/private	550.0	110	110	110	110	110
1	K-2	5.2	Establish new populations of nēnē on existing managed lands and on private lands with cooperative agreements.	O	**USFWS/DOFAW** NGO/private	100.0	20	20	20	20	20
1		7.2.1	Conduct research on the prevention, interdiction, and control of mongooses.	2	**USFWS/DOFAW NPS**/BRD Research Institutions	200.0	100	100	—	—	—

Implementation Schedule for Nēnē Draft Revised Recovery Plan Actions

Statewide Priority Number	Island Priority Number[1]	Action Number	Action Description	Action Duration (Years)	Responsible Parties	Cost Estimates (in $1,000 units)					
						Total Costs	FY 2004	FY 2005	FY 2006	FY 2007	FY 2008
1		7.2.2	Conduct research on the control of dogs.	3	**USFWS/DOFAW** **NPS**/BRD Research Institutions	150.0	50	50	50	—	—
1		7.2.3	Conduct research on the control of feral cats.	C	**USFWS/DOFAW** **NPS**/BRD Research Institutions	1,875.0	375	375	375	375	375
1		7.2.4	Conduct research on the control of rodents.	2	**USFWS/DOFAW** **NPS**/BRD Research Institutions	50.0	10	10	10	10	10
1		7.2.5	Conduct research on the control of pigs.	C	**USFWS/DOFAW** **NPS**/BRD Research Institutions	50.0	10	10	10	10	10
1		7.8	Refine monitoring methods.	3	NRAG	22.4	11.2	5.6	5.6	—	—
1		8.2	Inform the public about the need for predator control. and the application of control methods for conservation purposes.	C	NRAG	220.0	44	44	44	44	44
1		9.1.1	Conduct semi-annual NRAG meetings.	O	NRAG	112.0	22.4	22.4	22.4	22.4	22.4
1		9.1.2	Annually compile monitoring data and determine the status of nēnē Statewide.	C	NRAG	2.5	.5	.5	.5	.5	.5

Implementation Schedule for Nēnē Draft Revised Recovery Plan Actions

Statewide Priority Number	Island Priority Number[1]	Action Number	Action Description	Action Duration (Years)	Responsible Parties	Cost Estimates (in $1,000 units)					
						Total Costs	FY 2004	FY 2005	FY 2006	FY 2007	FY 2008
2		2.2	Minimize human-caused disturbance and mortality.	O	**NWR/NPS** **DOFAW**/NGO Private	185.5	59.5	31.5	31.5	31.5	31.5
2	K-3	4.2	Establish or maintain captive breeding flocks in open-top pens.		**NPS/ZSSD**	50.0	10	10	10	10	10
2		7.1	Identify limiting factors.	C	**USFWS/DOFAW** **NPS**/BRD Research Institutions	60.0	15	15	10	10	10
2		7.3.1	Develop methods for improving the quality and availability of nēnē food.	6	**USFWS/DOFAW** **NPS**/BRD Research Institutions	339.0	67.8	67.8	67.8	67.8	67.8
2		7.4	Conduct research on habitat restoration.	C	**USFWS/DOFAW** **NPS**/BRD Research Institutions	375.0	75	75	75	75	75
2	K-3	7.5	Conduct research on nēnē movements and evaluate the importance of seasonal habitat use.	C	**USFWS/DOFAW** **NPS**/BRD Research Institutions	200.0	40	40	40	40	40
2		7.6	Determine minimum viable population size for nēnē on Hawai`i, Maui-Nui, and Kaua`i.	2	**USFWS/DOFAW** **NPS**/BRD/ZSSD Research Institutions	100.0	—	50	50	—	—

Implementation Schedule for Nēnē Draft Revised Recovery Plan Actions

Statewide Priority Number	Island Priority Number[1]	Action Number	Action Description	Action Duration (Years)	Responsible Parties	Cost Estimates (in $1,000 units)					
						Total Costs	FY 2004	FY 2005	FY 2006	FY 2007	FY 2008
2		7.9	Utilize results of genetic studies on wild and captive nēnē flocks to enhance flock management.	C	**NRAG** Research Institutions	15.0	3	3	3	3	3
2		7.11	Conduct research on inter-island malarial strains.	3	**NRAG, BRD,** Research Institutions	150.0	60	50	40	—	—
2		7.13	Report results on all aspects of nēnē research and management at least every five years.	C	**NRAG** Research Institutions	15.0	15	—	—	—	—
2		8.3	Enlist the public's aid in nēnē recovery efforts through responsible pet ownership and minimization of human disturbance.	C	NRAG	100.0	20	20	20	20	20
2		9.1.3	Develop and distribute annual reports on nēnē recovery actions.		NRAG	17.5	3.5	3.5	3.5	35.	3.5
3		1.3	Identify, map, and, where necessary, protect present and potential migratory routes as populations increase in size.	C	NRAG	3.6	—	1.8	—	1.8	—
3		2.5	Develop an injured bird salvage protocol for each nēnē population.	1	NRAG	5.6	—	—	5.6		—
3		4.3	If warranted, explore the possibility of releasing zoo-bred nēnē.	2	**NRAG/Zoos**	TBD	—	—	—	—	—

Implementation Schedule for Nēnē Draft Revised Recovery Plan Actions

Statewide Priority Number	Island Priority Number[1]	Action Number	Action Description	Action Duration (Years)	Responsible Parties	Cost Estimates (in $1,000 units)					
						Total Costs	FY 2004	FY 2005	FY 2006	FY 2007	FY 2008
3		4.4	If warranted, explore propagation of nēnē by private organizations.	2	**NRAG**/Private	TBD	—	—	—	—	—
3		4.6.1	Depending on the environmental conditions of the release site, provide captive nēnē with a structurally diverse environment.	C	NRAG	40.0	8	8	8	8	8
3		4.6.2	Depending on the environmental conditions of the release site, implement pre-release predator-avoidance training of nēnē.	C	NRAG	5.0	1	1	1	1	1
3	K-1	6.1	Develop safe and effective methods for managing nēnē in unsuitable habitats.	C	NRAG	35.0	10	5	5	5	5
3	K-1	6.2	Develop contingency plans for relocating nēnē utilizing unsuitable habitats or causing human safety hazards.	C	NRAG	35.0	10	5	5	5	5
3		7.7	Determine carrying capacity of different habitats and methods to enhance carrying capacity.	3	**USFWS/DOFAW** **NPS**/BRD Research Institutions	300.0	—	100	100	100	—
3		7.10	Identify, evaluate, and incorporate improved rearing and release techniques for release sites with limited environmental conditions.	C	**NRAG** Research Institutions	45.0	15	15	5	5	5

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Statewide Priority Number	Island Priority Number[1]	Action Number	Action Description	Action Duration (Years)	Responsible Parties	Cost Estimates (in $1,000 units)					
						Total Costs	FY 2004	FY 2005	FY 2006	FY 2007	FY 2008
3		7.12	Conduct research on topics of management concern.	C	**NRAG** Research Institutions	150.0	30	30	30	30	30
3		8.1	Work with non-profit organizations to promote nēnē appreciation.	C	**NRAG**/NGO	20.0	2	2	2	2	2
3		8.4	Promote interpretation and educational programs.	C	NRAG	25.0	5	5	5	5	5
3		9.2	Review recovery objectives every 5 years, or as appropriate.		NRAG	22.5	—	—	—	—	22.5
			TOTAL			9,958.5					

[1] Island Priority Number: priority numbers are noted by island (H=Hawai`i, M=Maui Nui, K=Kaua`i) if the island priority differs from the statewide priority number.
Note: These actions are not required by law, but are recommended in this recovery plan. Actions can only be implemented subject to available funding and landowner permission.

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Appendix A-1.

Releases of captive-bred nēnē on the island of Hawai`i, 1960-2003[1].

Year	Release Sites[2]							Total Released Island-wide	Population Estimate
	Hakalau NWR	HAVO	Kahuku	Kea`au	Keauhou	Keauhou II	Kīpuka `Āinahou		
1960	0	0	0	0	20	0	0	20	<50[3]
1961	0	0	0	0	11	20	0	31	no data
1962	0	0	0	0	0	35	0	35	<100[4]
1963	0	0	0	0	0	42	0	42	no data
1964	0	0	0	0	0	0	0	0	200[5]
1965	0	0	0	0	30	19	0	49	no data
1966	0	0	0	0	0	0	0	0	~160[6]
1967	0	0	75	0	0	0	0	75	~240[6]
1968	0	0	85	0	0	0	0	85	~220[6]
1969	0	0	122	0	0	33	0	155	~480[6]
1970	0	0	0	0	106	0	0	106	no data
1971	0	0	0	0	94	0	0	94	~490[6]
1972	0	0	0	0	2	35	0	37	no data
1973	0	0	0	0	13	0	61	74	~490[6]
1974	0	0	0	0	0	0	123	123	~650[6]
1975	0	4	0	0	0	0	135	139	650[6]
1976	0	15	0	0	0	164	0	179	396[6]
1977	0	16	0	0	0	0	0	16	457[6]
1978	0	4	47	0	0	0	0	51	306[6]
1979	0	5	35	0	0	0	0	40	268[6]
1980	0	8	12	0	0	0	0	20	300[6]
1981	0	8	0	0	0	0	0	8	75[7]
1982	0	6	0	0	19	0	0	25	no data
1983	0	0	0	0	0	0	0	0	390±120[8]

Appendix A-1 (continued). Releases of captive-bred nēnē on the island of Hawai`i, 1960-2002[1].

Year	Release Sites[2]							Total Released Island-wide	Population Estimate
	Hakalau NWR	HAVO	Kahuku	Kea`au	Keauhou	Keauhou II	Kīpuka `Āinahou		
1984	0	37	0	4	5	0	0	46	no data
1985	0	23	0	0	0	0	0	23	no data
1986	0	17	25	2	17	0	0	61	no data
1987	0	17	2	0	8	0	0	27	128
1988	0	13	0	0	25	0	0	38	179[7]
1989	0	8	7	0	0	0	0	15	no data
1990	0	14	8	9	6	0	0	37	260-339[9]
1991	0	17	0	0	8	0	0	25	no data
1992	0	9	0	0	20	0	0	29	158
1993	0	2	0	0	34	0	0	36	no data
1994	0	6	0	0	0	0	0	6	160
1995	0	3	0	0	0	0	0	3	195
1996	10	4	0	0	0	0	0	14	201
1997	0	4	0	0	0	0	0	4	393[10]
1998	0	0	0	0	0	0	0	0	411[11]
1999	0	0	0	0	0	0	0	0	390[11]
2000	0	0	0	0	0	0	0	0	no data
2001	17	36	0	0	0	0	0	53	no data
2002	6	4	0	0	0	0	0	10	331-343[12]
2003	0	10	0	0	0	0	0	10	349[12]
Total released	33	290	418	15	418	348	319	1841	

[1] Source: Nēnē Restoration Project, DOFAW, unpublished data; J. Mello and D. Hu, pers. comms. 2001-2003.
[2] NWR = National Wildlife Refuge; HAVO = Hawai`i Volcanoes National Park.
[3] Banko and Elder 1990, [4] Scott 1962, [5]Kridler 1964 *in litt.*, [6] Devick 1981a, [7] Hoshide *et al*. 1990,
[8] Scott *et al*. 1986, [9] Black *et al*. 1991, [10] Banko *et al*. 1999,[11] Hu 2000
[12] Includes an estimated 50-55 wild birds at Pu`uwa`awa`a and surrounding areas.

Appendix A-2.

Releases of captive-bred nēnē on the island of Maui, 1962-2003[1].

Year	Release Sites East Maui		Total East Maui	Release Site West Maui	Total Released Island-wide	Population Estimate
	Hosmer Grove	Palikū		Hana`ula		
1962	0	35	35	0	35	no data
1963	0	29	29	0	29	no data
1964	0	28	28	0	28	85[2]
1965	0	34	34	0	34	no data
1966	0	25	25	0	25	52[3]
1967	0	0	0	0	0	39[3]
1968	0	20	20	0	20	40[3]
1969	0	72	72	0	72	59[3]
1970	0	55	55	0	55	117[3]
1971	0	0	0	0	0	87[3]
1972	0	44	44	0	44	86[3]
1973	5	50	55	0	55	127[3]
1974	4	0	4	0	4	103[3]
1975	2	0	2	0	2	150-200[4]
1976	4	34	38	0	38	80-100[5]
1977	0	47	47	0	47	80-100[5]
1978	1	0	1	0	1	80-100[5]
1979	0	0	0	0	0	106[6]
1980	0	0	0	0	0	118[6]
1981	0	0	0	0	0	130[6]
1982	0	0	0	0	0	108[6]
1983	0	0	0	0	0	112[6]
1984	0	0	0	0	0	119[6]
1985	0	0	0	0	0	128[6]

Appendix A-2 (continued). Releases of captive-bred nēnē on the island of Maui, 1962-2003[1].

Year	Release Sites East Maui		Total East Maui	Release Site West Maui	Total Released Island-wide	Population Estimate
	Hosmer Grove	Palikū		Hana`ula		
1986	0	0	0	0	0	129[6]
1987	0	0	0	0	0	no data
1988	0	0	0	0	0	104[6]
1989	0	0	0	0	0	119[6]
1990	0	0	0	0	0	145[6]
1991	0	0	0	0	0	140[6]
1992	0	4	4	0	4	288[6]
1993	0	0	0	0	0	171[6]
1994	0	0	0	0	0	156[6]
1995	0	0	0	22	22	245-275[7]
1996	0	0	0	12	12	227[6]
1997	0	0	0	16	16	201[6]
1998	0	4	4	12	16	229[6]
1999	0	10	10	4	14	208[6]
2000	0	0	0	0	0	219[6]
2001	0	0	0	13	13	249[6]
2002	0	4	4	6	10	~251[6]
2003	0	0	0	2	2	217[8]
Total nēnē released	16	495	511	87	598	

[1] Sources: Nēnē Restoration Project, DOFAW, unpublished data; J. Medeiros, C. Bailey, and J. Tamayose, pers. comms. 2001-2003.
[2] Kridler 1964 *in litt.*, [3] Banko and Elder 1990, [4] Devick 1981b, [5] Conant and Stemmerman 1979
[6] DOFAW 2000, [7] Baker and Baker 1995 estimate for east Maui
[8] Survey conducted August 2003.

Appendix A-3.

Releases of captive-bred nēnē on the island of Moloka`i, 2001-2003[1].

Year	Puu O Hoku Ranch	Total Released	Population Estimate
2001	11	11	11
2002	13	13	25
2003	31	31	55
Total nēnē released		55	

[1] Sources: Nēnē Restoration Project, DOFAW, unpublished data; J. Medeiros, pers. comm. 2003.

Appendix A-4.

Releases of captive-bred nēnē on the island of Kaua`i, 1985-2003[1].

Year	Release Site				Total Released	Population Estimate
	Hanalei NWR	Kīlauea Point NWR/Crater Hill	Kīpū Kai	Nā Pali Coast		
1985	0	0	25[2]	0	25	18[3]
1990	0	0	0	0	0	32[3]
1991	0	12	0	0	12	no data
1992	0	0	0	0	0	120
1993	0	6	0	0	6	100[4]
1994	0	20	0	0	20	156[5]
1995	0	0	0	32	32	200
1996	0	0	0	30	30	280
1997	0	0	0	0	0	256[6]
1998	0	0	0	0	0	292[7]
1999	0	0	0	0	0	337[7]
2000	24	0	0	0	24	no data
2001	0	0	0	0	0	440
2002	0	0	0	0	0	564[8]
2003	0	0	0	0	0	620
Total nēnē released	24	38	25	62	149	

[1] Sources: Nēnē Restoration Project, DOFAW, unpublished data; T. Telfer and T. Kaiakapu, pers. comms. 2001-2003.

[2] This number is an estimate of birds released as the exact number was never known (Telfer, pers. comm. 2001)

[3] Black *et al*. 1991, [4] Telfer 1994, [5] Telfer 1995, [6] Banko *et al*. 1999, [7] Hu 2000, [8] Telfer 2003

Appendix B.

Native Hawaiian plants known to be food items for nēnē for use by managers interested in nēnē habitat restoration.

Family	Common Name (Scientific Name)	Status[1]	Part Eaten	Protein Rank[2]	Islands[3]/Elevation	Information Source[4]
Asteraceae (Sunflower family)	Kookoolau (*Bidens hawaiensis*)	E	leaves	high	H/50-1,400 m	HAVO field notes, Sherry 2001
	Naenae (*Dubautia scabra*)	E	flowers, leaves, seeds	low	H, L, M, Mo/75-2,500 m	Black *et al*. 1994, Swift 2000
	`Ena`ena (*Pseudognaphalium sandwicensium*)	E	flowers, leaves	high	H, K, L, M, Mo, N, O/0-3,000 m	Baldwin 1947, Swift 2000
Caryophyllaceae (Pink family)	Catchfly (*Silene hawaiiensis*)	E	leaves	high	H/900-1,300(-3,050) m	Sherry 2001
Cyperaceae (Sedge family)	Sedge (*Carex macloviana*)	I	leaves, seeds	not tested	H, M /1,190-2,740 m	Baldwin 1947
	Sedge (*Carex wahuensis*)	E	seeds	low	H, K, L, M, Mo, O /(10-)250-2,500 m	Baldwin 1947, Rojek 1994
	Mau`u `aki`aki (*Fimbristylis cymosa*)	I	leaves, seeds	not tested	H, K, L, M, Mo, N, O/0-60 m	Sherry 2001
	Kilioopu (*Cyperus polystachyos*)	I	leaves, seeds	low	H, K, L, M, Mo, N, O/0-1,420 m	Baldwin 1947, Swift 2000
Epacridaceae (Epacris family)	Pūkiawe (*Leptecophylla tameiameiae*)	I	berries, leaves	low	H, K, L, M, Mo, O (may have occurred on N and Ko in past)/15-3,230 m	Baldwin 1947, Black *et al.* 1994, Kear and Berger 1980, Rojek 1994, Swift 2000, Woog 1993

Appendix B (continued). Native Hawaiian plants known to be food items for nēnē for use by managers interested in nēnē habitat restoration.

Family	Common Name	Status[1]	Part Eaten	Protein Rank[2]	Islands/Elevation	Information Source[2]
Ericaceae (Heath family)	\`Ōhelo[5] (*Vaccinium reticulatum*)	E	berries	low	H, M, (rare on K, Mo, O)/640-3,700 m	Balwin 1947, Black *et al*. 1994, Hu 1998, Kear and Berger 1980, Rojek 1994, Woog 1993
Fabaceae (Pea family)	\`Āwikiwiki (*Canavalia hawaiiensis*)	E	leaves, pods?	high	H, L, M/120-1,220 m	Banko 1988, Sherry 2001
	Kolomona, heuhiuhi (*Senna gaudichaudii*)	I	leaves	high	H, K, Ko, L, M, Mo, O/5-920 m	HAVO field notes 1973, Sherry 2001
Goodeniaceae (Goodenia family)	Naupaka kuahiwi (*Scaevola kilaueae*)	E	leaves	not tested	H/1,000-1,460 m	HAVO field notes
	Naupaka kahakai (*Scaevola taccada*)	I	berries	not tested	H, K, Ko, L, M, Mo, N, O/0-300 m	Tom Telfer Kauai field notes
Iridaceae (Iris family)	Mau\`u lā\`ili (*Sisyrinchium acre*)	E	seeds	not tested	H, Maui (east)/ 1,550-2,950 m	Baldwin 1947
Juncaceae (Rush family)	Wood rush (*Luzula hawaiiensis*)	E	seeds?	low	H, K, L, M, Mo, O/ 730-2,5600 m	Baldwin 1947
Lythraceae (Loosestrife family)	Pūkāmole, nīnika (*Lythrum maritimum*)	I?			H, K, L, M, Mo, O/ 0-2,450 m	Sherry 2001
Malvaceae (Mallow family)	\`Ilima (*Sida fallax*)	I			H, K, Ko, L, M, Mo, N, O/0-1,980 m	Sherry 2001
Poaceae (Grass family)	He\`upueo (*Agrostis avenacea*)	I	leaves, seeds	high	H, K, Ko, L, M, Mo, O/260-2,520 m	Baldwin 1947, Sherry 2001

Appendix B (continued). Native Hawaiian plants known to be food items for nēnē for use by managers interested in nēnē habitat restoration.

Family	Common Name	Status[1]	Part Eaten	Protein Rank[2]	Islands/Elevation	Information Source[2]
	Hair grass (*Deschampsia nubigena*)	E	seeds, leaves, stems?	low	H, K, M, Mo/ (30-)600-2,830 m	Baldwin 1947, Black *et al*. 1994, Rojek 1994, Woog 1993
	Kūkaepua`a, Itchy crabgrass (*Digitaria setigera*)	I?	leaves, seeds	high	H, K, L, M, Mo, N, O/10-980 m	Baldwin 1947, Sherry 2001
	Kāwelu (*Eragrostis variabilis*)	E	leaves, seeds?	low	H, K, Ko, L, M, Mo, N, O/0-1,130 m	HAVO field notes
	Pili (*Heteropogon contortus*)	I?	leaves, seeds?	low	H, K, Ko, L, M, Mo, N, O/0-700m	Hu 1998, Sherry 2001
	Mountain pili (*Panicum tenuifolium*)	E	leaves, seeds	low	H, K, L, M, Mo, O/ 1,200-2,300 m	Baldwin 1947
Polygonaceae (Buckwheat family)	Pāwale (*Rumex skottsbergii*)	E	leaves	high	H/460-1,300 m	Baldwin 1947, Sherry 2001, Woog 1993
Rosaceae (Rose family)	`Ōhelo papa, white strawberry (*Fragaria chiloensis*)	I	berries	not tested	H, M (east)/ 1,160-3,070 m	Pope 1932
	`Ūlei (*Osteomeles anthyllidifolia*)	I	berries	not tested	H, K, L, M, Mo, O/ 2-2,320 m	Sherry 2000
	`Ākala (*Rubus hawaiensis*)	E	berries	not tested	H, K, M, Mo/ 660-3,070 m	Pope 1932
	`Ākala (*Rubus macraei*)	E	berries	not tested	H, M (east)/ 1,610-2,080 m	Pope 1932

Appendix B (continued). Native Hawaiian plants known to be food items for nēnē for use by managers interested in nēnē habitat restoration.

Family	Common Name	Status[1]	Part Eaten	Protein Rank[2]	Islands/Elevation	Information Source[2]
Rubiaceae (Coffee family)	Kūkaenēnē (*Coprosma ernodeoides*)	E	berries, leaves?	low	H, M (east)/ 1,220-2,590 m	Baldwin 1947, Black *et al.* 1994, Kear and Berger 1980, Rojek 1994, Woog 1993
	Pilo (*Coprosma montana*)	E	berries?	not tested	H, M (east)/ 1,830-3,050 m	Black *et al*. 1994
Solanaceae (Nightshade family)	Pōpolo, glossy nightshade (*Solanum americanum*)	I?	berries, leaves	high	H, K, Ko, L, M, Mo, N, O/0-2,380 m	Baldwin 1947, HAVO field notes 1973, Sherry 2001
Urticaceae (Nettle family)	Māmaki (*Pipturus albidus*)	E	berries	low	H, K, L, M, Mo, O/ (0-)70-1,870 m	Black *et al*. 1994, Rojek 1994

[1] E=endemic, I=indigenous, I?=questionably indigenous (see Wagner *et al*. 1999)
[2] Protein Rank = % crude protein. High = ≥12%, Low <12% (K. Sherry, unpublished data)
[3]H=Hawai`i, K=Kaua`i, Ko=Kaho`olawe, L=Lāna`i, M=Maui, Mo=Moloka`i, N=Ni`ihau, O=O`ahu
[4] The following information sources are unpublished data: HAVO field notes, Hu, Sherry, Swift, and Telfer.
[5] The natural dispersal of `ōhelo, according to Guppy (1906), is affected by nēnē (Wagner *et al*. 1999)

Appendix C.

Native Hawaiian plants nēnē are known to nest under.

Family	Common name (Scientific name)	Status[1]	Island(s)[2]	Elevation	Habitat	Information source
Vascular Plants[3]						
Epacridaceae (Epacris family)	Pūkiawe *(Leptecophylla tameiameiae)*	I	H, K, L, M, Mo (may have occurred in the past on Ko, N)	15-3,230m	Ranges from dry to wet habitats; mesic forest to open areas of low elevation or montane wet forest, fogswept alpine shrubland, and bogs, rarely windward coastal sites.	Banko *et al*. 1999, Black *et al*. 1994
Ericaceae (Heath family)	ʻŌhelo[4] (*Vaccinium reticulatum*)	E	H, M, rare on K, Mo, O	640-3,700m	Common shrub of disturbed sites, usually occurring as member of the pioneer community found on lava flows, ash dunes, and cinder beds, or of exposed sites such as alpine or subalpine shrubland; much less common in mature or stable plant communities such as grassland, wet forest, or bogs.	Banko *et al*. 1999
Goodeniaceae (Goodenia family)	Naupaka kahakai (*Scaevola taccada*)	I	H, K, Ko, L, M, Mo, N, O	0-300m	Common in coastal sites.	Banko *et al*. 1999
Myrtaceae (Myrtle family)	ʻŌhiʻa, ʻŌhiʻa lehua[5] (*Metrosideros polymorpha*)	E	H, K, L, M, Mo, O	from near sea level to 2,200m	Ranges from dry to wet habitats; inhabits many ecological situations. 8 varieties recognized.	Banko *et al*. 1999, Black *et al*. 1994

Appendix C (continued). Native Hawaiian plants nēnē are known to nest under.

Family	Common name (Scientific name)	Status[1]	Island(s)[2]	Elevation	Habitat	Information source
Rubiaceae (Coffee family)	ʻAiakanēnē, Kūkaenēnē (*Coprosma ernodeoides*)	E	H, M (east)	1,220-2,590m	Dry? Primarily occurs in open sites, often on lava or cinder fields in subalpine woodland.	Banko *et al*. 1999
Sapindaceae (Soapberry family)	ʻAʻaliʻi, ʻAʻaliʻi kū makani, kūmakani (*Dodonaea viscosa*)	I	H, K, L, M, Mo, N, O	3-2,350m	Ranges from dry to wet habitats, from coastal dunes, low elevation shrublands to dry mesic and wet forest and subalpine shrubland.	Banko *et al*. 1999
Ferns [6]						
Blechnaceae	\`Ama\`u (*Sadleria cyatheoides*)	E	H, K, Ko, L, M, Mo, O, N	(5-)75-2,200m	Common in exposed habitats, mesic and wet forests and shrublands and a primary invader of new lava flows.	Banko and Manuwal 1982

[1] E=endemic, I=indigenous, I?=questionably indigenous (see Wagner *et al*. 1999)
[2] H=Hawaii, K=Kauai, Ko=Kahoolawe, L=Lanai, M=Maui, Mo=Molokai, N=Niihau, O=Oahu
[3] From Wagner *et al*. 1999
[4] Although flowering and fruiting occur year round, flowering is most prolific from April to September, and the peak of berry production occurs from June to September (Wagner *et al*. 1999).
[5] Banko and Manuwal (1982) found 3 nēnē nests in the wild under short (less than 4m) ʻŌhiʻa plants
[6] From Palmer 2003

Appendix D.
Nēnē Recovery Action Group

Nēnē Recovery Action Group (NRAG) - Agency Representatives

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Appendix E.
Private Landowner Incentives for Implementation of Conservation Measures

U.S. Fish and Wildlife Service Programs

1. Safe Harbor Agreements

Safe Harbor Agreements (SHAs) are voluntary, cooperative ventures between a non-Federal landowner and the U.S. Fish and Wildlife Service and/or National Oceanic and Atmospheric Administration Fisheries (NOAA Fisheries) that can provide benefits to both the landowners and listed species. Under these agreements, a landowner would be encouraged to maintain or enhance existing populations of listed species, to create, restore, or maintain habitats, and/or to manage their lands in a manner that will benefit listed species. In return, the U.S. Fish and Wildlife Service and NOAA Fisheries would provide assurances that future landowner activities would not be subject to Endangered Species Act of 1973, as amended (Act), restrictions above those applicable to the property at the time of enrollment in the program.

The Safe Harbor Agreement spells out the existing responsibility of the landowner (*e.g.*, the baseline or agreed upon target conditions), what activities the landowner is willing or intends to do that will benefit listed species, and the expected benefit to those species. The arrangements of the Safe Harbor Agreement are then formalized through an enhancement of survival permit that authorizes take above the baseline or target condition. Before the U.S. Fish and Wildlife Service or NOAA Fisheries issues these permits, there is a notice of availability published in the Federal Register and a 30-day public review period.

The primary benefit to landowners is that the Safe Harbor Agreement creates an incentive for them to participate in proactive species conservation. These Safe Harbor Agreements also allow flexibility in managing the land and provide regulatory certainty. Benefits to the species include reducing habitat fragmentation rates, providing for habitat connectivity, increasing available habitat by restoration or enhancement, and providing buffers for protected areas. It is important to note that the Safe Harbor Agreement mechanism may really aid conservation efforts for those species that rely on habitats that need continual management.

2. Habitat Conservation Plans

Non-Federal property owners, such as private landowners, corporations, or state or local governments, wishing to conduct activities on their land that might result in incidental take of a listed species must first obtain an incidental take permit from the U.S. Fish and Wildlife Service. To obtain a permit, the applicant must develop a Habitat Conservation Plan (HCP) designed to offset any harmful effects the proposed activity might have on the species. The Habitat Conservation Plan process allows private development to proceed while promoting endangered species conservation.

While U.S. Fish and Wildlife Service personnel provide detailed guidance and technical assistance throughout the process, the development of a Habitat Conservation Plan is driven by the applicant. The applicant is responsible for submitting a completed permit application. The necessary components of a completed permit application are: a standard application form, a Habitat Conservation Plan, an Implementing Agreement (if required), and, if appropriate, a draft National Environmental Policy Act (NEPA) analysis. While processing the permit application, the U.S. Fish and Wildlife Service will prepare an intra-Service biological opinion under section 7 of the Act and the incidental take permit, and finalize the NEPA analysis documents. Consequently, an incidental take permit has a number of associated documents besides the Habitat Conservation Plan. The contents of a Habitat Conservation Plan are defined in section 10 of the Act and its implementing regulations. The Habitat Conservation Plan must detail, among other things: an assessment of impacts likely to result from the proposed taking of the listed species; measures the applicant will undertake to monitor, minimize, and mitigate for such impacts; the funding that will be made available to implement such measures; and the procedures to deal with unforseen or extraordinary circumstances; alternative actions to the taking that the applicant analyzed and the reasons why the applicant did not adopt such alternatives; and additional measures that the U.S. Fish and Wildlife Service may require as necessary or appropriate.

Mitigation measures can take many forms, such as: preservation (via acquisition or conservation easement) of existing habitat; enhancement or restoration of degraded or a former habitat; creation of new habitats; establishment of buffer areas around existing habitats; modifications of land use practices; and restrictions on access.

The Habitat Conservation Plan process includes a public comment period on the application for the incidental take permit as public comments must be considered in the permit decision. The Regional Director of the U.S. Fish and Wildlife Service's Region decides whether to issue the permit based on findings that: the taking will be incidental to an otherwise lawful activity; the impacts will be minimized and mitigated to the maximum extent practicable; adequate funding will be provided; the taking will not appreciably reduce the likelihood of the survival and recovery of the species; and any other necessary measures are met.

The permit allows a landowner to legally proceed with an activity that would otherwise result in the illegal take of a listed species. The U.S. Fish and Wildlife Service also developed a regulation to address the problem of maintaining regulatory assurances and providing certainty to landowners thorough the Habitat Conservation Plan process, the "No Surprises" regulation. Although an incidental take permit is required only for listed species, many Habitat Conservation Plans provide conservation measures for proposed and candidate species under the Act, as well as other rare or vulnerable species that live in the plan area. By adequately covering such unlisted species, developers and landowners can help prevent their decline and avoid having to add new conservation measures during the length of the permit. Habitat Conservation Plans offer the opportunity to address conservation issues on a landscape or ecosystem level and help conserve biological diversity.

3. Partners for Fish and Wildlife

Partners for Fish and Wildlife is the U.S. Fish and Wildlife Service's habitat restoration cost-sharing program for private landowners. The program was established to offer technical advice and financial assistance to landowners who wish to restore wildlife habitat on their property. On-the-ground habitat improvement projects that benefit Federal trust species include restoration of wildlife habitat on degraded or converted wetlands, riparian areas, native grasslands, and streams. The assistance provided by the U.S. Fish and Wildlife Service can range from giving informal advice on the design and location of a potential restoration project, to designing a project and funding up to 50 percent of the implementation costs under a formal cooperative agreement with the landowner. Projects with the highest priorities are those that reestablish the natural historical communities and provide benefits to migratory birds, anadromous fish, and threatened and endangered species. Projects include efforts such as creating shallow water areas, revegetating with native plants, erecting fences along riparian areas to exclude livestock, developing grazing plans to benefit livestock and wildlife; reducing pesticide use, and improving soil and water quality.

To initiate the partnership, the landowner and the U.S. Fish and Wildlife Service, and any representative from other cooperating agencies or organizations, meet on the property to discuss the landowner's goals and objectives. Technical advice on project design, material, and engineering is provided by the U.S. Fish and Wildlife Service as appropriate. Cost sharing is proposed. A habitat restoration proposal, developed by the landowner and U.S. Fish and Wildlife Service staff, is submitted to one of our State offices to compete for funds. After funding is approved, the Wildlife Extension Agreement is signed. Upon project completion, the U.S. Fish and Wildlife Service will reimburse the landowner after receipts and other documents are submitted according to the agreement.

Hawaii Department of Lands and Natural Resources Programs

1. Safe Harbor Agreements and Habitat Conservation Plans

The Endangered Species Act of the State of Hawaii, HRS 195D, with the addition of Act 380 in 1997, provides for the development of Safe Harbor Agreements and Habitat Conservation Plans. The Department of Lands and Natural Resources (DLNR) and the U.S. Fish and Wildlife Service's Pacific Islands Fish and Wildlife Office have cooperated in streamlining the process an applicant must go through to develop such projects. Although the two agencies work hand-in-hand with private landowners to develop Safe Harbor Agreements and Habitat Conservation Plans, there are some differences. The main differences between the State process and the Federal process are that: 1) the State law mandates that an Endangered Species Committee oversees the processing and monitoring of projects; 2) the State Board of Land and Natural Resources must approve the project; and 3) the public comment period is 60 days.

Appendix F.

Recovery actions proposed in this plan to address factors currently limiting the recovery of nēnē; the factors addressed by each action are identified by a solid circle.

Primary Recovery Action Number*	Predation (Factor A)	Inadequate Nutrition (Factors A and E)	Lack of Lowland Habitat (Factor A)	Human-caused Disturbance and Mortality (Factor E)	Behavioral Issues (Factor E)	Genetic Issues (Factor E)	Disease (Factor C)
1.Identify and protect nēnē habitat.	●	●	●	●		●	
2. Manage habitat and existing populations for sustainable productivity and survival.	●	●	●	●		●	
3. Control alien predators.	●						
4. Continue captive propagation.					●	●	●
5. Establish additional nēnē populations in suitable, uninhabited areas that are protected.		●	●			●	
6. Address conflicts between nēnē and human activities.				●			
7. Identify new and continue research on known limiting factors and management techniques.	●	●	●	●	●	●	●
8. Conduct a public awareness and information program to build public support for nēnē recovery.	●			●			
9. Validate recovery objectives.	●	●	●	●	●	●	●

* Includes all subcategories identified under the primary recovery action number in the step-down narrative outline of recovery actions (page 58).

Appendix G.

Criteria for Reestablishment of Nēnē Populations

Reestablishment of nēnē populations is necessary for managers to recover the species. Attempts to reintroduce or establish nēnē should be made only if the following list of criteria applies. The basis for each criterion is also explained.

Reestablishment Criteria:

1. **Habitat Suitability:** Habitat elements are suitable and the habitat is under long-term protection (*e.g.*, the release site occurs on State or Federal lands or on private lands managed under a cooperative agreement). Habitat restoration or enhancement, such as outplanting of native food items for nēnē, may need to occur at selected release sites. Summer and winter habitat needs must be met. Potentially hazardous sites should be avoided.

   Background: Nēnē habitat has been described in Section II, F. Habitat Description. Various accounts suggest nēnē bred in lowlands in the winter and retreated to higher elevations in the summer. Because habitats, particularly in the lowlands have been highly altered, there is a high proportion of non-native food plants in the nēnē diet. With concerns raised regarding whether highly altered habitats offer adequate nutrition for both breeding females and goslings, managers should be attuned to whether habitat improvements may aid in the reintroduction and restoration of nēnē populations. Because research on habitat restoration for nēnē is still being developed, managers should offer a mix of habitats that include suitable breeding, rearing and non-breeding areas. Outplanting of native food plants in habitats where nēnē are found or will be introduced should also be incorporated into management plans. Nēnē move seasonally and most sites do not sustain birds year-round. It may therefore be important to have links between winter and summer habitat. In addition, a reasonable effort should be made to keep birds away from potentially hazardous sites such as major roads, airports, water sources that may trap goslings, and possibly golf courses. Habitat restoration or enhancement efforts may eventually be modified based on ongoing and future research results.

   Areas selected for nēnē reintroduction or establishment should be under long-term protection. This protection may be in the form of private landowner agreements, such as Habitat Conservation Plans which may be long term, conservation easements, or public lands including National Parks, National

Wildlife Refuges, or State Natural Area Reserves. Reintroduction sites should not be located near potentially hazardous areas.

2. **Predator Control:** Predators, particularly mongooses, pigs, cats, dogs, and rats, can either be eliminated or kept to manageable levels.

Background: Predation is a major limiting factor for nēnē populations (see Section H, 1. Predation). Managers should evaluate which predators are a problem in each area where nēnē occur or will be introduced, and the most effective predator control techniques should be utilized. Control measures should be evaluated on a consistent basis for cost, success, and whether new techniques or methods are available and should be employed.

3. **Captive Propagation and Release:** Captive-bred nēnē identified for release must be free of parasites and diseases which could pose a risk to wild populations. Several successive groups of nēnē should be introduced to the release site over a period of time to maximize the probability of successful establishment of nēnē in the area. Genetic management must also be taken into account to prevent inbreeding depression.

Background: Protocols have been drafted for screening captive-bred nēnē for the presence of parasites and diseases prior to release. The results of the screening tests determine where, and if, the nēnē can be released. Adherence to these protocols will help reduce the possibility of transferring parasites or diseases to nēnē populations in the wild. The introduction of unique regional strains of avian malaria or other disease and parasites to other areas will also be limited by following screening protocols

For reintroductions to new areas, several groups of nēnē will be introduced to the area over a period of time. Continued releases at the same location maximizes the probability of successful establishment of nēnē in the area.

4. **Proximity to Other Nēnē Populations:** The release site will not be completely isolated from other nēnē populations in the long-term (*i.e.*, other release sites will occur nearby within 5-8 years, if not already present).

Background: The isolation of reintroduction sites from other nēnē populations should be considered in identifying appropriate release sites. Other potential release sites or sites that may be managed for nēnē (*e.g.*, as in a Safe Harbor Agreement) should be present nearby within 5 to 8 years, if not already present, to facilitate the dispersal and exchange of nēnē between populations. Movement of nēnē between populations will reduce the possibility of isolated nēnē groups being scattered over the islands with no chance of contributing to the overall recovery of nēnē in the State.

5. **Monitoring:** Annual monitoring and reporting on the nēnē population will be conducted for at least 10 years after the final release. Annual reports should include numbers and sex of birds released by location, mortalities, reproduction, problems, and suggestions for improvements (adaptive management).

   Background: Monitoring must be conducted during releases and continue after the final release to increase the probability of success of the reintroduction. Monitoring will allow managers to determine the status of the population, identify problems, and develop and implement adaptive management measures to ensure the establishment of the nēnē population.

6. **Public Outreach:** Informational materials and programs should be developed to build public support for the nēnē program. Public support for predator control will also be crucial.

   Background: Public information campaigns may increase funding opportunities. The possibility of human-nēnē interactions will increase as the number of birds increases state-wide and it will be important to have public acceptance. The nēnē is the State bird and could therefore promote conservation measures that may also help conserve other native Hawaiian species and their habitats.

Appendix H.

Glossary of Technical Terms

Term	Definition
allele	alternate forms of genes that code for the same trait (at the same locus in homologous chromosomes)
alpine	pertaining to habitats at high elevations (over 3,000 m), especially above tree line
altitudinal migration	a vertical pattern of migration in which populations that breed in one zone (elevation) move to a lower or higher zone (elevation) at the end of the breeding season (Welty 1975)
alula/aluli	first digit located at the bend of the wrist area of the wing (Proctor and Lynch 1993)
auto-thermoregulate	the ability to regulate one's own body temperature
Branta	genus of true geese, often called the 'black" geese, and including nēnē, brant, barnacle,and red-breasted geese as well as the Canada goose complex.
chromosome	a self-duplicating body composed of DNA (deoxyribonucleic acid), the repository for genetic information
coancestry coefficient	the probability that genes, taken at random from each of the concerned individuals, are identical by descent
dispersal	the movement or organisms away from the place of birth or from centers of population density (Ricklefs 1979)
disyllabic	having two syllables
DNA	deoxyribonucleic acid, the genetic material of most living organisms
egg tooth	a small pointed knob on the tip of the upper surface of the beak that helps the young bird break out of its shell more easily and that disappears within a few days to a week after hatching (Anderson Brown 1979)
endemic	native or restricted to a limited or certain geographical region (Fiedler and Subohd 1992)
endoparasite	a parasite that lives within its host

Term	Definition
extirpation	the elimination of a species from an island, local area, or region (Koford *et al*. 1994)
extinction	the loss of a species throughout its entire range
feral	animals that have escaped from domestication or their descendants (Long 1981)
first prebasic molt	the postjuvenile molt, between juvenile plumage and the first basic (or first winter) plumage (Humphrey and Parkes 1959; Van Tyne and Berger 1976)
fledging success	the average number of offspring that fledge per female (May and Robinson 1985) or the percentage of hatched young that fledge (Robinson and Rotenberry 1991)
fledgling	a juvenile bird that has acquired the feathers necessary for flight and has left the nest
gene	a unit of heredity composed of DNA
genus	a subdivision of a family that includes one or more closely related species
generalist	a species with broad food preferences (Ricklefs 1979)
genetic homogeneity	consisting of homologous parts, lacking genetic diversity
gosling	a subadult goose
habitat	the environment in which a species or populations lives; different habitats may be used at different life stages; often characterized by a dominant plant form or physical characteristic (Ricklefs 1979)
haplotype	a combination of alleles of closely linked loci that are found in a single chromosome and tend to be inherited together
hatchling	a bird that has recently hatched
Hawaiian Islands (main)	Hawai`i, Maui, Kaho'olawe, Lāna`i, Moloka`i, O`ahu, Kaua`i, and Ni`ihau
herbivore	an herbivorous animal
herbivorous	feeding or subsisting entirely on plants or plant products

Term	Definition
historic period for Hawai`i	after 1778
homologous	a pair of chromosomes which have identical genes or their alleles located at corresponding loci
homozygous	in which the pair of alleles for a trait is composed of the same genes (either dominant or recessive)
incipient	beginning to exist or manifest itself
indigenous	native, belonging to the locality; not imported (Wagner *et al*. 1990)
introduced species	a species that has been introduced and become established outside its former range through the deliberate or accidental involvement of humans
iris	the pigmented portion of the eye
kīpuka	an oasis within a lava bed where there may be vegetation
lava tube	the longest and most complicated of volcanic caves formed by channels of flowing rivers of lava and by the effects of volcanic gases
locus/loci	the position of a gene on a chromosome
lowlands	elevational zone of terrestrial habitats at 15-2,000 m, beyond the immediate influence of sea spray
Maui nui	includes the islands of Maui, Moloka`i, Lāna`i, and Kaho'olawe
migration	regular, extensive, seasonal movement of animals between their breeding/nesting areas to their "wintering" feeding areas (Welty 1975)
molt	the process of shedding and replacing worn feathers (Proctor and Lynch 1993)
mongoose	*Herpestes auropunctatus* is a carnivorous mammal of the Family Viverridae distributed throughout Asia and Africa
monitoring	measuring population trends using any of various counting or survey techniques
monophyletic	derived from a single ancestral stock or type

Term	Definition
monotypic	in taxonomy, having only one subordinate unit, as a genus with a single species
montane	elevational zone from 500-2,700 m, includes an assemblage of communities, including bogs, grasslands, shrublands, and forests
MVP	minimum viable population size is the smallest population of a species that will ensure (with some probability level) that a population will persist for some "relatively long temporal interval" (Gilpin and Soulé 1986)
natal	pertaining to birth
nēnē	local name for the Hawaiian goose (*Branta sandvicensis*)
omphalitis	an infection of the umbilical stump
paleontology	the study of plants and animals of former geological periods as represented by their fossil forms
philopatric	tendency for offspring to breed in their natal home range
Polynesian colonization of Hawai`i	around 400 A.D. or 1600 years before present
pox	a viral condition of nēnē that closely resembles avian pox, a disease thought to have been absent from Hawaii until the introduction of non-native songbirds and that is carried by the mosquito, *Culex pipiens fatigans* (Kear and Berger 1980)
plumage	feather 'coats' or covering worn by birds between molts (Proctor and Lynch 1993)
plumule	a down feather
pre-historic period in Hawai`i	before 1778
PVA	population viability analysis uses models and numerical estimation procedures to determine minimum viable population size (MVP)
recessive gene	a gene that is only expressed when two identical copies coding for the same trait are present, one from the mother, one from the father

Term	Definition
refugium	an area that remains unchanged while areas surrounding it change markedly, thus the area serves as a refuge for species that require specific habitats (Brown and Gibson 1983)
riparian	along the bank of a river or lake (Ricklefs 1979)
soft release	when animals are held at or near the release site (with food and water available) in a pen or other structure for at least 24 hours before release to allow animal to become somewhat familiar with local conditions
species	a group of actually or potentially interbreeding populations that are reproductively isolated from all other kinds of organisms (Ricklefs 1979)
staccato	cut short or apart in performing
subalpine	elevational zone of 1,700 - 3,000 m
survey	an enumeration or index of the number of individuals in an area from which inferences about the population can be made (Ralph 1981)
sternum	breastbone
taxonomy	the science of classification; the arrangement of organisms into groups based on their natural relationships
terrestrial	adapted to and living on the land; not aquatic
translocation	a management technique often used for conservation of species in which individuals of a species are removed from their habitat and established in another area of similar habitat (Fiedler and Subohd 1992)
uplands	higher elevations of terrestrial habitats not included in riparian zones
viability	capability or capacity to survive
waterfowl	ducks, geese, and swans of the Anatidae family

Appendix I.
Peer and Stakeholder Reviewers

In addition to public review of this recovery plan, the plan will be sent to the following peer and stakeholder reviewers for comment prior to development of the final recovery plan. A technical draft of the recovery plan was sent to members of the Nēnē Recovery Action Group in October 1999 and July 2002.

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