U.S. Fish & Wildlife Service

Recovery Plan for Hawaiian Waterbirds

Second Revision

Eric VanderWerf/USFWS

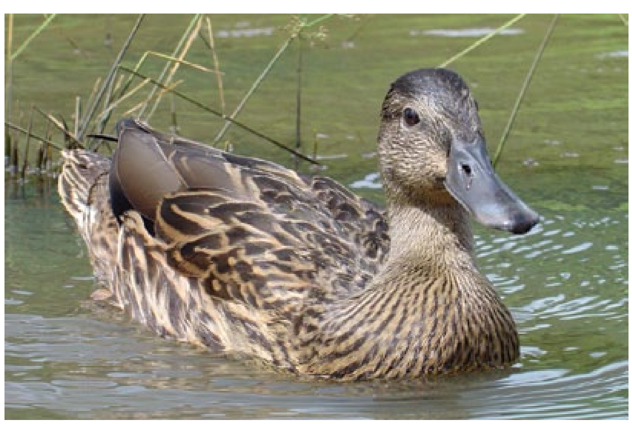
A'eo
Hawaiian stilt

Eric VanderWerf/USFWS

'Alae 'ula
Hawaiian moorhen

Eric VanderWerf/USFWS

'Alae ke'oke'o
Hawaiian coot



Brenda Zaun/USFWS

Koloa maoli
Hawaiian duck

Recovery Plan

for

Hawaiian Waterbirds,

Second Revision

Original plan approved 1978

First revision approved 1985

Region 1

U.S. Fish and Wildlife Service

Portland, Oregon

Approved: ______________________________

Regional Director, Region 1
U.S. Fish and Wildlife Service

Date: October 28, 2011

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Recovery plans delineate reasonable actions that are believed to be required to recover and protect listed species. We, the U.S. Fish and Wildlife Service, publish recovery plans, sometimes with the assistance of recovery teams, contractors, State agencies, Tribal agencies, and other affected and interested parties. Objectives will be attained and any necessary funds made available subject to budgetary and other constraints affecting the parties involved, as well as the need to address other priorities. Recovery plans do not obligate other parties to undertake specific actions and may not represent the views nor the official positions or approval of any individuals or agencies involved in recovery plan formulation, other than our own. They represent our official position only after they have been signed by the Regional Director or Director as approved. Recovery plans are reviewed by the public and submitted for peer review before we adopt them as approved final documents. Approved recovery plans are subject to modification as dictated by new findings, changes in species status, and the completion of recovery actions.

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Acknowledgments

Parts I and II of this recovery plan were drafted in 1997 for the U.S. Fish and Wildlife Service by Andrew Engilis, Jr. (then of Ducks Unlimited, currently with the University of California, Davis) and Dr. Frederic A. Reid of the Western Regional Office of Ducks Unlimited. Modifications were made by Dr. Ann Marshall and Colleen Henson of the U.S. Fish and Wildlife Service, which resulted in the Draft Revised Recovery Plan for Hawaiian Waterbirds Second Revision, published in May 1999. Substantial revisions to the draft plan were made by Leilani Takano and Dr. Eric VanderWerf of the U.S. Fish and Wildlife Service, including the addition of figures illustrating the population trend of each species and maps showing their abundance and distribution on each island. The primary authors of the second draft revised plan, which was published in August 2005, were Andrew Engilis, Jr., Dr. Ann Marshall, Dr. Frederic A. Reid, Leilani Takano, and Dr. Eric VanderWerf. This second revised plan was finalized by Dr. Ann Marshall and Joy Hiromasa, also of the U.S. Fish and Wildlife Service.

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Executive Summary

Current Species Status: This recovery plan addresses four species of Hawaiian waterbirds: the Hawaiian duck or koloa maoli (*Anas wyvilliana*), Hawaiian coot or `alae ke`oke`o (*Fulica alai*), Hawaiian common moorhen or `alae `ula (*Gallinula chloropus sandvicensis*), and Hawaiian stilt or ae`o (*Himantopus mexicanus knudseni*), all federally listed as endangered under the Endangered Species Act. Historically, these four species were found on all of the main Hawaiian Islands except Lāna`i and Kaho`olawe. Currently, Hawaiian ducks are found on the islands of Ni`ihau, Kaua`i, O`ahu, Maui, and Hawai`i; Hawaiian coots and Hawaiian stilts are found on all of the main Hawaiian Islands except Kaho`olawe; and Hawaiian common moorhens are found only on the islands of Kaua`i and O`ahu. Population counts based on biannual waterbird surveys, which are considered to be most accurate for the Hawaiian coot and Hawaiian stilt, indicate that the numbers of birds fluctuate among years. Trend data collected over the past three decades show that Hawaiian coot, Hawaiian common moorhen, and Hawaiian stilt populations are either stable or increasing. However, in recent years only the Hawaiian coot has commonly shown population counts near or above 2,000 individuals. The status of the Hawaiian duck is difficult to judge due to the difficulty of distinguishing between Hawaiian ducks, feral mallards (*Anas platyrhynchos*), and hybrids. Hawaiian common moorhen numbers are difficult to estimate due to their secretive habits and use of densely vegetated wetland habitats.

Habitat Requirements and Limiting Factors: These endangered Hawaiian waterbirds are currently found in a variety of wetland habitats including freshwater marshes and ponds, coastal estuaries and ponds, artificial reservoirs, kalo or taro (*Colocasia esculenta*) lo`i or patches, irrigation ditches, sewage treatment ponds, and in the case of the Hawaiian duck, montane streams and marshlands. The most important causes of decline for all four species were loss and degradation of wetland habitat and predation by introduced animals. Other factors that have contributed to waterbird population declines, and that continue to be detrimental, include modification of hydrology, alteration of habitat structure and vegetation composition by invasive non-native plants, loss of riparian vegetation and water quality degradation due to grazing, disease, and possibly environmental contaminants. In addition, hunting in the late 1800s and early 1900s took a heavy toll on Hawaiian duck populations, and to a lesser extent on

populations of the other three endemic waterbirds (Swedberg 1967). Currently, predation by introduced animals may be the greatest threat to the Hawaiian coot, Hawaiian common moorhen, and Hawaiian stilt, and hybridization with feral mallards is the most serious threat to the Hawaiian duck.

Recovery Priority Number: The recovery priority number for the Hawaiian duck is 2, on a scale of 1C (highest) to 18 (lowest) (see Appendix C) reflecting a high degree of threat, a high potential for recovery, and the Hawaiian duck's taxonomic rank as a full species. The Hawaiian common moorhen and Hawaiian stilt each have a recovery priority number of 9, reflecting a moderate degree of threat, a high potential for recovery, and their taxonomic rank as a subspecies. The recovery priority number of 8 for the Hawaiian coot reflects a moderate degree of threat, a high potential for recovery, and taxonomic rank as a full species. The Hawaiian coot was considered a subspecies of the American coot (*Fulica americana*) at the time it was listed, but it has been split from the American coot and is now regarded as a distinct species (*Fulica alai*; American Ornithologists' Union 1993).

Recovery Goal: The ultimate goal of the recovery program for Hawaiian waterbirds is to restore and maintain multiple self-sustaining populations within their respective historical ranges, which will allow them to be reclassified to threatened status (downlisted) and eventually removed from the Federal List of Endangered and Threatened Wildlife and Plants (delisted).

Recovery Objectives: Recovery of the four endangered waterbirds focuses on the following objectives:

1) ensuring that population numbers are large enough to persist into the foreseeable future in the face of stochastic demographic variability;

2) establishing multiple, self-sustaining breeding populations broadly distributed throughout each species' historical range to insure against population declines from localized demographic stresses;

3) establishing and protecting a stable network of both core and supporting wetlands that are managed as habitat suitable for waterbirds, including the maintenance of appropriate hydrological conditions and control of invasive non-native plants;

4) eliminating or controlling the threats posed by introduced predators, conditions that promote avian diseases, and contaminants to a sufficient degree for populations to be self-sustaining; and

5) specifically for the Hawaiian duck, removing the threat of hybridization with feral mallards.

Recovery Criteria: To consider downlisting the four species to threatened status, the following conditions must be met. The population target of 2,000 birds for the Hawaiian stilt is based on a population viability analysis conducted for that species (Reed *et al*. 1998a); population targets for the Hawaiian duck, Hawaiian coot, and Hawaiian common moorhen are provisional pending completion of population viability analyses for these species as discussed in section II.B. Recovery Strategy.

Hawaiian duck downlisting criteria

Criterion 1: All core wetlands on the islands of Kaua`i/Ni`ihau, O`ahu, Maui, and Hawai`i are protected and managed in accordance with the management practices outlined in this recovery plan (Table 11);

Criterion 2: Of the supporting wetlands on the islands of Kaua`i, O`ahu, Maui, and Hawai`i), at least 50 percent are protected and managed in accordance with the management practices outlined in this recovery plan (Table 12);

Criterion 3: A population viability analysis has been conducted, incorporating survey data from both montane streams and lowland wetlands, to determine the population size necessary for long-term viability of the species. The statewide surveyed number of Hawaiian ducks has shown a stable or increasing trend and has not declined below 2,000 birds (or an alternative target based on the population viability analysis) for at least 5 consecutive years;

Criterion 4: There are multiple self-sustaining breeding populations, including multiple populations present on at least Kaua`i/Ni`ihau, O`ahu, Maui, and Hawai`i; and

Criterion 5: The threat of hybridization with feral mallards is removed from all islands.

Hawaiian coot downlisting criteria

Criterion 1: All core wetlands on the islands of Kaua`i/Ni`ihau, O`ahu, Maui/Moloka`i, and Hawai`i are protected and managed in accordance with the management practices outlined in this recovery plan (Table 11);

Criterion 2: Of the supporting wetlands on the islands of Kaua`i, O`ahu, Maui/Moloka`i/Lāna`i, and Hawai`i, at least 50 percent are protected and managed in accordance with the management practices outlined in this recovery plan (Table 12);

Criterion 3: A population viability analysis has been conducted to determine the population size necessary for long-term viability of the species. The statewide surveyed number of Hawaiian coots shows a stable or increasing trend and has not declined below 2,000 birds (or an alternative target based on the population viability analysis) for at least 5 consecutive years; and

Criterion 4: There are multiple self-sustaining breeding populations, including multiple populations present on at least Kaua`i/Ni`ihau, O`ahu, Maui/Moloka`i/Lāna`i, and Hawai`i.

Hawaiian common moorhen downlisting criteria

Criterion 1: All core wetlands on the islands of Kaua`i and O`ahu are protected and managed in accordance with the management practices outlined in this recovery plan (Table 11);

Criterion 2: Of the supporting wetlands on the islands of Kaua`i and O`ahu, at least 50 percent are protected and managed in accordance with the management practices outlined in this recovery plan (Table 12);

Criterion 3: A population viability analysis has been conducted, incorporating surveys that can effectively detect secretive individuals in dense vegetation, to determine the population size necessary for long-term viability of the species. The statewide surveyed number of

Hawaiian common moorhen shows a stable or increasing trend and has not declined below 2,000 birds (or an alternative target based on the population viability analysis) for at least 5 consecutive years;

Criterion 4: There are multiple self-sustaining breeding populations, including multiple populations present on Kaua`i and O`ahu and on at least two additional islands (Maui, Moloka`i, Lāna`i, or Hawai`i); and

Criterion 5: An improved survey technique has been developed and implemented.

Hawaiian stilt downlisting criteria

Criterion 1: All core wetlands on the islands of Kaua`i/Ni`ihau, O`ahu, Maui/Moloka`i, and Hawai`i are protected and managed in accordance with the management practices outlined in this recovery plan (Table 11);

Criterion 2: Of the supporting wetlands on the islands of Kaua`i, O`ahu, Maui/Moloka`i/Lāna`i, and Hawai`i, at least 50 percent are protected and managed in accordance with the management practices outlined in this recovery plan (Table 12);

Criterion 3: A population viability analysis has been conducted to update the findings of Reed *et al*. (1998a) and reassess the population size necessary for long-term viability of the species. The statewide surveyed number of Hawaiian stilts shows a stable or increasing trend and has not declined below 2,000 birds (or an alternative target based on the updated population viability analysis) for at least 5 consecutive years; and

Criterion 4: There are multiple self-sustaining breeding populations, including multiple populations on at least Kaua`i/Ni`ihau, O`ahu, Maui/Moloka`i/ Lāna`i, and Hawai`i.

To consider delisting the four species, the downlisting criteria above must be met as well as the following criteria:

Hawaiian duck delisting criteria

Criterion 1: Of the supporting wetlands on the islands of Kaua`i, O`ahu, Maui, and Hawai`i, at least 85 percent are protected and managed in accordance with the management practices outlined in this recovery plan (Table 12); and

Criterion 2: The statewide surveyed number of Hawaiian ducks shows a stable or increasing trend and has not declined below 2,000 birds (or an alternative target based on the population viability analysis) for at least 10 consecutive years.

Hawaiian coot delisting criteria

Criterion 1: Of the supporting wetlands on the islands of Kaua`i, O`ahu, Maui/Moloka`i/Lāna`i, and Hawai`i, 85 percent are protected and managed in accordance with the management practices outlined in this recovery plan (Table 12); and

Criterion 2: The statewide surveyed number of Hawaiian coots shows a stable or increasing trend and has not declined below 2,000 birds (or an alternative target based on the population viability analysis) for at least 10 consecutive years.

Hawaiian common moorhen delisting criteria

Criterion 1: Of the supporting wetlands on the islands of Kaua`i and O`ahu, at least 85 percent are protected and managed in accordance with the management practices outlined in this recovery plan (Table 12); and

Criterion 2: The statewide surveyed number of Hawaiian common moorhens shows a stable or increasing trend and has not declined below 2,000 birds (or an alternative target based on the population viability analysis) for at least 10 consecutive years.

Hawaiian stilt delisting criteria

Criterion 1: Of the supporting wetlands on the islands of Kaua`i, O`ahu, Maui/Moloka`i/Lāna`i, and Hawai`i, at least 85 percent are

protected and managed in accordance with the management practices outlined in this recovery plan (Table 12); and

Criterion 2: The statewide surveyed number of Hawaiian stilts shows a stable or increasing trend and has not declined below 2,000 birds (or an alternative target based on the updated population viability analysis) for at least 10 consecutive years.

We believe that the downlisting and delisting criteria of protecting and managing 50 and 85 percent (respectively) of supporting wetlands represents reasonable proportions of important wetland habitat that would provide for both survival and long-term recovery of these waterbirds; the criteria also allow for needed flexibility, particularly when planning and managing for long-term recovery.

Selected Recovery Actions Needed:

1) Protect and manage core and supporting wetland habitats in order to maximize productivity and survival of endangered waterbirds. This would include the following actions: develop written management plans; secure water sources; manage water levels; manage vegetation; control predation; monitor waterbird populations and reproductive success; remove the threat of mallard-Hawaiian duck hybridization; minimize human disturbance; and monitor and control avian diseases and environmental contaminants (Tables 11 and 12). Some of these wetland habitat areas already have protected status but need to be more actively managed. The Fish and Wildlife Service and Hawaii Division of Forestry and Wildlife can provide technical assistance to private landowners to develop wetland management plans. Technical assistance may also be provided by waterbird biologists and/or through formation of a recovery coordination group(s).

2) Conduct research to better understand factors limiting Hawaiian waterbird population numbers, refine recovery objectives, and improve management techniques.

3) Remove the threat of hybridization to Hawaiian duck populations on Kaua`i/Ni`ihau, O`ahu, and Hawai`i, and reestablish Hawaiian duck populations on Maui and Moloka`i. Reestablish Hawaiian common

moorhen populations on at least two additional islands (Maui, Moloka`i, Lāna`i, or Hawai`i).

4) Plan and implement a public awareness program to increase landowner and land manager knowledge of waterbird needs and increase public support for waterbird recovery.

5) Re-evaluate recovery objectives as additional information warrants.

Date of Recovery: Downlisting to threatened status could be initiated in 2016 and delisting could be initiated in 2021, if recovery criteria are met.

Total Cost of Recovery: The total estimated cost to implement all recovery actions for all four species as described in the Recovery Actions Narrative over the next 10 years is $19,063,000. This figure may be substantially reduced with the development of more effective methods to address threats such as predator control. Certain costs, such as for some research actions, have yet to be determined. The estimated cost for the first 5 years of recovery implementation is $12,273,000; a detailed breakdown of these costs is provided in the Implementation Schedule.

As well as benefiting the four species of waterbirds addressed in this plan, the recovery actions described should also aid in the recovery of the endangered Laysan duck (*Anas laysanensis*) and the nēnē or Hawaiian goose (*Branta sandvicensis*). Fossil records indicate that the Laysan duck was formerly found throughout the main Hawaiian Islands. However, during historic times it was restricted to Laysan and Lisianski Islands (now extirpated from the latter) in the Northwestern Hawaiian Islands until recent successful introductions (2004-2005) to Midway (U.S. Fish and Wildlife Service 2009). Management of wetlands in the main islands, particularly control of introduced predators, could make these wetlands suitable sites for reintroduction of Laysan ducks. Similarly, nēnē are currently found primarily in mid-elevation to upland areas on most islands, with the exception of Kaua`i, but fossil evidence suggests that nēnē were once abundant in lowland habitats on low islands (Olson and James 1991). Nēnē have been reestablished in low-elevation wetlands at Hanalei National Wildlife Refuge on Kaua`i. Management and control of predators could provide suitable sites for nēnē in other low elevation wetlands; although this species does not require wetlands, the lush vegetation found at such sites may contribute to breeding success.

Table of Contents

List of Figures

List of Tables

I. Introduction and Overview

A. INTRODUCTION

Hawai`i accounts for less than 1 percent of the total land mass of the United States, yet it is home to approximately 27 percent of all animal and plant species federally listed as threatened or endangered (U.S. Fish and Wildlife Service [USFWS] 2011). A total of 109 endemic (*i.e.*, found only in Hawai`i) species and subspecies of birds have been described in the Hawaiian Islands, less than 30 of which are still extant (Scott *et al*. 2001, Pyle and Pyle 2009). Reasons for losses of many Hawaiian birds have been well documented, including destruction and alteration of habitat, hunting, introduced predatory mammals and nonnative birds, and diseases (Warner 1968; Atkinson 1977; van Riper *et al*. 1986; Cuddihy and Stone 1990; Engilis and Pratt 1993; Scott *et al*. 2001).

The Hawaiian Islands historically supported a diverse array of waterbirds in both wetland and forest habitats. At least 30 waterbird species are known from historical and fossil records (Scott *et al*. 2001). During the past 2,000 years of human presence, all of Hawai`i's endemic rails, flightless waterfowl, and an ibis have become extinct (Olson and James 1991). This massive extinction is attributed to the impacts of humans and the plants and animals they introduced to Hawai`i. Both Polynesian and European settlers have played significant roles in the alteration of Hawaiian ecosystems and the resulting extinctions of species (Kirch 1982, 1983; Olson and James 1992).

The six endemic species of waterbirds that persist today are the Hawaiian duck or koloa maoli (*Anas wyvilliana*), Laysan duck (*A. laysanensis*), Hawaiian coot or `alae ke`oke`o (*Fulica alai*), Hawaiian common moorhen or `alae `ula (*Gallinula chloropus sandvicensis*), Hawaiian stilt or ae`o (*Himantopus mexicanus knudseni*), and the Hawaiian goose or nēnē (*Branta sandvicensis*). All of these species, with the exception of nēnē, require wetlands for their survival, and all are listed as endangered. Recovery actions for the Laysan duck and nēnē are outlined in separate recovery plans (USFWS 2004, 2009). In this document, unless otherwise noted, the term "endangered waterbirds" refers to the four species addressed by this plan: the Hawaiian duck, Hawaiian coot, Hawaiian common moorhen, and Hawaiian stilt. These four species are currently found on various "main Hawaiian Islands" (Figure 1). The term "main Hawaiian Islands" refers to the following eight islands: Ni`ihau, Kaua`i, O`ahu, Maui, Moloka`i, Lāna`i,

The Main Hawaiian Islands

Figure 1. Map of the main Hawaiian Islands, with locations of major cities.

Kaho`olawe, and Hawai`i (also known as "the Big Island"). "Maui Nui" comprises the islands of Maui, Moloka`i, Lāna`i, and Kaho`olawe.

The Hawaiian duck and Hawaiian common moorhen were added to the Federal List of Endangered and Threatened Wildlife in 1967 (USFWS 1967), and the Hawaiian coot and Hawaiian stilt were added to this list in 1970 (USFWS 1970). Recovery priority numbers ranging from 1C to 18 (1C being highest priority) are assigned to each listed species based on degree of threat, recovery potential, taxonomic status, and conflict with human activities (USFWS 1983a, 1983b). Recovery priority numbers with a letter designation of "C" indicate conflict with human economic activity. The recovery priority number of 2 for the Hawaiian duck reflects a high degree of threat, a high potential for recovery, and its taxonomic status as a full species, which is given a higher priority than a subspecies. The Hawaiian common moorhen and Hawaiian stilt each have a recovery priority number of 9, reflecting a moderate degree of threat, a high potential for recovery, and their taxonomic status as subspecies. The recovery priority number of 8 for the Hawaiian coot reflects a moderate degree of threat, a high potential for recovery, and its taxonomic status as a distinct species. The Hawaiian coot was considered a subspecies of the American coot (*Fulica americana*) at the time it was listed, but it has been split from the American coot and is now regarded as a distinct species (*Fulica alai*; American Ornithologists' Union [AOU] 1993). Critical habitat has not been designated for any of these species.

B. SPECIES ACCOUNTS

1. Hawaiian Duck or Koloa Maoli

(a) Taxonomy

The Hawaiian duck or koloa maoli (*Anas wyvilliana*) was first described in 1851. At the time, it was considered to be a subspecies of the mallard (*Anas platyrhynchos*). However, genetic studies indicate that while the Hawaiian duck is closely related to the mallard, it is a distinct species (AOU 1983; Browne *et al*. 1993; Rhymer 2001). Allozyme data indicate there has been extensive hybridization between Hawaiian ducks and feral mallards on O`ahu, with the near disappearance of Hawaiian duck alleles from the population on that island

(Browne *et al*. 1993). The Maui population also includes a large number of hybrids (Engilis *et al*. 2002). Subsequent analyses of nuclear and mitochondrial DNA (Fowler *et al*. 2009) have confirmed these results, finding no pure koloa among 21 individuals sampled from the O`ahu and Maui populations. On Kaua`i and Hawai`i, Hawaiian duck-mallard hybrids have been documented but occur in apparently low numbers (Engilis *et al*. 2002; Hawai`i Division of Forestry and Wildlife [HDOFAW] 1976-2008; Fowler *et al.* 2009). The term "feral mallard" as used in this Recovery Plan refers to escaped domesticated mallards and subsequent generations that now breed in the wild. Domesticated mallards are non-native ducks that were brought to Hawai`i by humans.

(b) Species Description

The Hawaiian duck is a small (mean weight of males 604 grams [19 ounces], females 460 grams [15 ounces]), drab-brown duck (Griffin and Browne 1990). Both sexes are mottled brown and similar in appearance to a female mallard (Figure 2). Adult males are dark brown, variably spotted and mottled, with distinctive dark brown chevrons on the breast, flank, and back feathers, and an olive bill (Engilis *et al*. 2002). Adult females are similar but are slightly smaller than males on average, and slightly lighter in color, with plainer, buff-colored chin and back feathers (Engilis *et al*. 2002). Both sexes have emerald green to blue speculums (brightly colored areas on the wings), bordered both in front and back by white, with orange to yellow-orange legs and feet. The

Figure 2. Hawaiian duck male and female. Photo by Eric VanderWerf.

Figure 3. Hawaiian ducklings. Photo by Brenda Zaun.

plumage of first-year male Hawaiian ducks resembles the eclipse (non-breeding) plumage of male mallards, with a subdued green head and black upper and under-tail coverts (the short feathers covering the base of the tail feathers).

Where hybridization occurs with feral mallards, it may be difficult to distinguish between Hawaiian ducks, female mallards, and hybrids. Hawaiian ducks and mallards differ in size, behavior, voice, and coloration. The extent of the differences between these two species and hybrids depends upon the extent of hybridization at the location, the plumage at that time of year, and the variation among individuals and islands, making it difficult to distinguish Hawaiian ducks and hybrids based on phenotypic (visible) characteristics alone. Research combining morphological measurements and genetic identification, partly funded by the U.S. Fish and Wildlife Service, is currently being conducted to develop reliable criteria for distinguishing between Hawaiian ducks, female mallards, and hybrids (A. Engilis, pers. comm. 2003, 2008; Fowler *et al*. 2009). Hawaiian ducklings resemble mallard ducklings, but are smaller, a little more olive above and buffier, less yellow below and on the face (Delacour 1956; Figure 3).

(c) Historical Range and Population Status

Hawaiian ducks were known historically from all of the main Hawaiian Islands except Lāna`i and Kaho`olawe. There are no population estimates prior to 1940, but in the 1800s they were fairly common in natural and farmed wetland

habitats (Engilis *et al*. 2002). Hawaiian ducks were noted to occur on the hottest coasts with suitable ponds as well as in the mountains as high as 2,100 meters (7,000 feet) (Perkins 1903, cited in Banko 1987b). The arrival of the Polynesian people in Hawai`i about 1,600 years ago (Kirch 1982) and their cultivation of kalo or taro (*Colocasia esculenta*), an agricultural crop grown in a pond-like environment, considerably changed wetland habitat in the islands, including plant composition, water levels, and human disturbance (B. Zaun, USFWS, *in litt*. 2005). Rice (*Oryza sativa*) cultivation from the late 1800s to the 1940s continued to affect wetland habitat availability for the Hawaiian duck. A decline in flooded agriculture had occurred by 1900, but there were still about 7,700 hectares (19,000 acres) of taro and 6,500 hectares (16,000 acres) of rice at that time (Bostwick 1982). Although some authors have suggested that such agricultural practices increased the amount of wetland habitat in the islands (Swedberg 1967), the truth of this is not known (B. Zaun, *in litt*. 2005). Nor do we know how historical agriculture, such as taro farming, affected waterbird population sizes (J.M. Reed, Tufts University, *in litt*. 2005), and since farmers historically scared birds away from their agricultural fields, the impacts may well have been negative (B. Zaun, *in litt*. 2005).

A variety of factors, including predation of eggs and chicks by rats (*Rattus* spp.), mongooses (*Herpestes auropunctatus*), domestic dogs (*Canis familiaris*), domestic cats (*Felis catus*), introduced fish, and birds; habitat reduction due to agricultural practices and urban development; and local hunting pressure, brought about a significant population decline of the Hawaiian duck early in the 20th century. Cats and dogs prey on adult Hawaiian ducks, and introduced ungulates such as pigs (*Sus scrofa*) and goats (*Capra hircus*) have significantly affected Hawaiian duck nesting habitat along Kaua`i's montane streams (T. Telfer and A. Engilis, pers. comm. 1992). Pigs also destroy nests (Berger 1981). In 1949, an estimated 500 Hawaiian ducks remained on Kaua`i, and about 30 on O`ahu. By that time, Hawaiian ducks were considered only an occasional visitor to the island of Hawai`i, and were presumed extirpated on Maui and Moloka`i (Schwartz and Schwartz 1949). By 1960, they were apparently extirpated on O`ahu when Ka`elepulu Pond in Kailua, the last Hawaiian duck stronghold on O`ahu, was modified as part of a housing development. By the 1960s, Hawaiian ducks were found in small numbers only on Kaua`i and probably on Ni`ihau.

From the late 1950s through the early 1990s, Hawaiian ducks were reintroduced to O`ahu, Maui, and Hawai`i (Paton 1981; Bostwick 1982; Engilis *et*

al. 2002) through captive propagation and release (see Federal and State Actions under Section E, Conservation Measures, for details). Although populations of Hawaiian ducks still exist on each of these islands, these populations are affected by hybridization with feral mallards to varying degrees. Lewin (1971) suggested that the release of mainland mallards might pose a genetic threat to the Hawaiian duck through hybridization (Berger 1981). Mallards and Hawaiian ducks have been observed to interbreed and produce fertile offspring in captivity, and in 1980 this hybridization was confirmed to occur in the wild (Bostwick 1982).

(d) Current Range and Population Status

Engilis *et al*. (2002) estimated the statewide population of pure Hawaiian ducks to be 2,200 birds, with 2,000 on Kaua`i and 200 on Hawai`i. Biannual waterbird counts[1] have yielded lower numbers (averaging 360 based on winter counts from 2000 through 2007) primarily because this survey currently does not include montane streams that are believed to harbor much of the Hawaiian duck population on Kaua`i and Hawai`i (Swedberg 1967; Paton 1981). In addition, Engilis *et al*. (2002) noted that Hawaiian duck-like birds occur on O`ahu (estimated population approximately 300 individuals) and Maui (approximately 50); some of these may be Hawaiian ducks, with the remainder being mallard-Hawaiian duck hybrids. The total Hawaiian duck population appears to be increasing based on the biannual waterbird count, due primarily to increases in the Hawaiian duck population on Kaua`i, but Hawaiian ducks are declining on other islands (Figures 4 and 5) due to hybridization (Engilis and Pratt 1993; see also discussion of hybridization in section I.D.4.a and Figures 33 to 44 below). To address these issues we are incorporating efforts to conduct stream surveys, determine which streams are most important for the recovery of the Hawaiian duck, and protect those streams. On Kaua`i, seasonal movement of birds occurs from lowland wetlands to more secluded habitats in summer. Differences between the summer and winter bird surveys could represent altitudinal movements, dispersal up stream valleys, or possibly a reclusive post-breeding molt period.

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[1] See Section F. Monitoring for a description of the biannual waterbird counts.

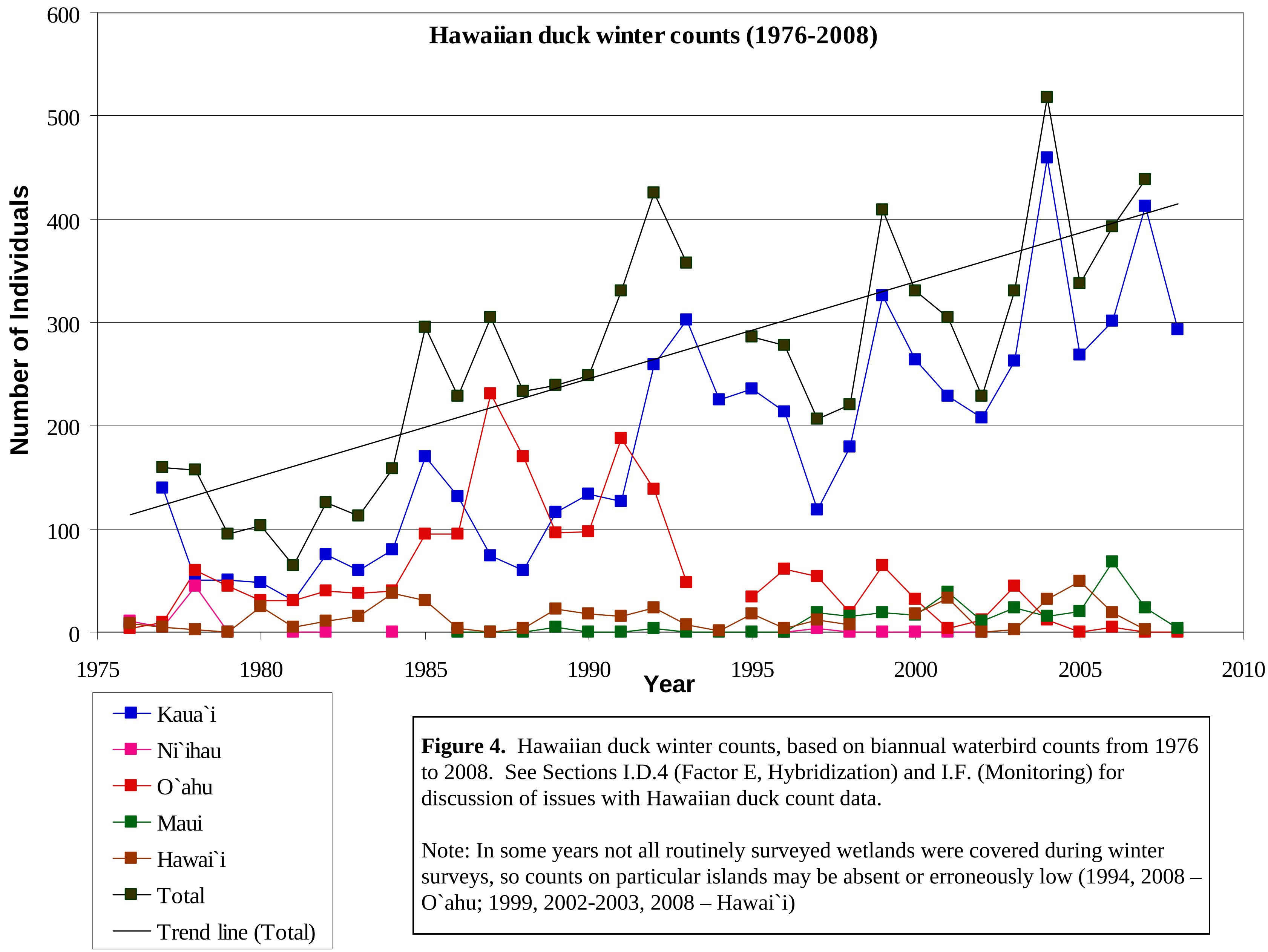

Figure 4. Hawaiian duck winter counts, based on biannual waterbird counts from 1976 to 2008. See Sections I.D.4 (Factor E, Hybridization) and I.F. (Monitoring) for discussion of issues with Hawaiian duck count data.

Note: In some years not all routinely surveyed wetlands were covered during winter surveys, so counts on particular islands may be absent or erroneously low (1994, 2008 – O`ahu; 1999, 2002-2003, 2008 – Hawai`i)

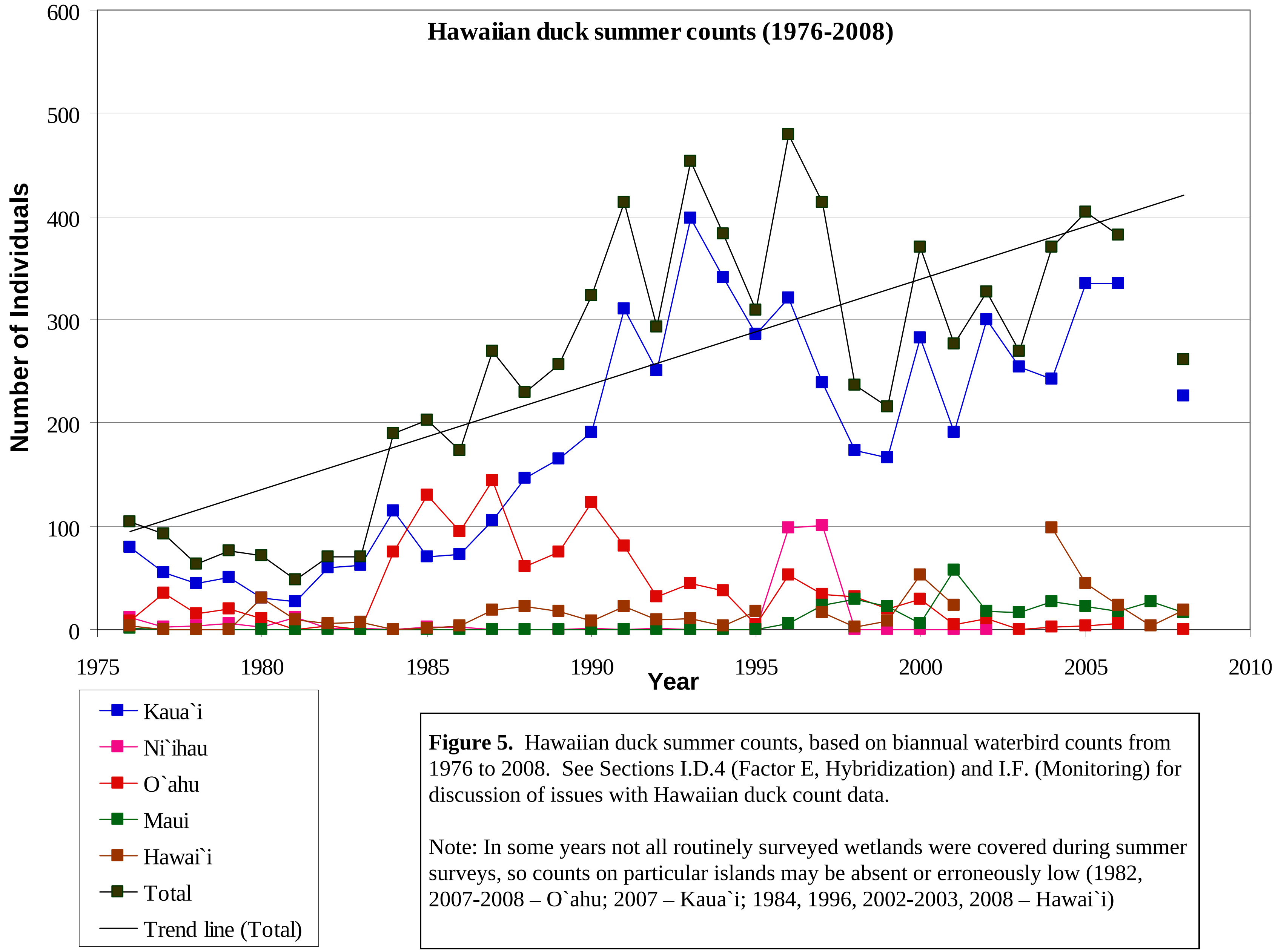

Figure 5. Hawaiian duck summer counts, based on biannual waterbird counts from 1976 to 2008. See Sections I.D.4 (Factor E, Hybridization) and I.F. (Monitoring) for discussion of issues with Hawaiian duck count data.

Note: In some years not all routinely surveyed wetlands were covered during summer surveys, so counts on particular islands may be absent or erroneously low (1982, 2007-2008 – O`ahu; 2007 – Kaua`i; 1984, 1996, 2002-2003, 2008 – Hawai`i)

i. Kaua`i Population

The Hawaiian duck population on Kaua`i (Figure 6) has maintained itself without the release of captive-bred birds. Lowland surveys during the 1940s and 1950s estimated the population at 500 birds. Surveys in the 1960s estimated a population of 3,000 Hawaiian ducks (Swedberg 1967), mostly in remote montane streams and valleys. This apparent increase was probably a result of the underestimation of birds in the mountainous stream habitat by earlier observers. The Kaua`i population was estimated to be between 1,500 and 2,000 Hawaiian ducks in 1988 (T. Telfer, pers. comm. 1988), and was estimated to be around 2,000 birds by Engilis *et al*. (2002). The Hawaiian duck population on Kaua`i is substantially larger than on all other islands combined, probably because of the lack of an established population of mongooses and very low occurrence of hybridization up to this time. However, the threat of hybridization with mallards and its potential to increase on Kaua`i is of great concern. In addition, there have been mongoose sightings on Kaua`i and it is likely that the establishment of a mongoose population there would place the Hawaiian duck at increased risk. The earliest report of a mongoose sighting on Kaua`i occurred in 1968 and there has been at least one confirmed road-killed mongoose that was recovered in 1976 (Tomich 1986). Between 1968 and 1977, 18 unconfirmed sightings of mongooses were made on Kaua`i (T. Telfer, HDOFAW, *in litt*. 1977). Mongoose sightings continue to be reported on Kaua`i; for example, 12 were reported in 2003-2004 (K. Gundersen, Kaua`i Invasive Species Committee, *in litt*. 2004) and 4 were reported in 2008 as of July (S. Williamson, USDA-APHIS Wildlife Services, *in litt*. 2008). The decades-long history of mongoose sightings on Kaua`i provides strong support for the likelihood that mongoose are now established on the island. Mongoose predation on native waterbirds could be occurring at very low levels on Kaua`i; the still-low density of mongoose and their prey-rich environment would make mongoose predation events difficult to detect (K. Swift, USFWS, *in litt*. 2008). Furthermore, predation events are notoriously difficult to document unless individual birds and/or nests are monitored.

Many Hawaiian ducks on Kaua`i use lowland ponds and wetlands primarily for feeding and loafing, and nest along montane streams. Hawaiian ducks use the Hanalei National Wildlife Refuge and nearby taro fields throughout the year. They feed primarily in the managed wetlands and also

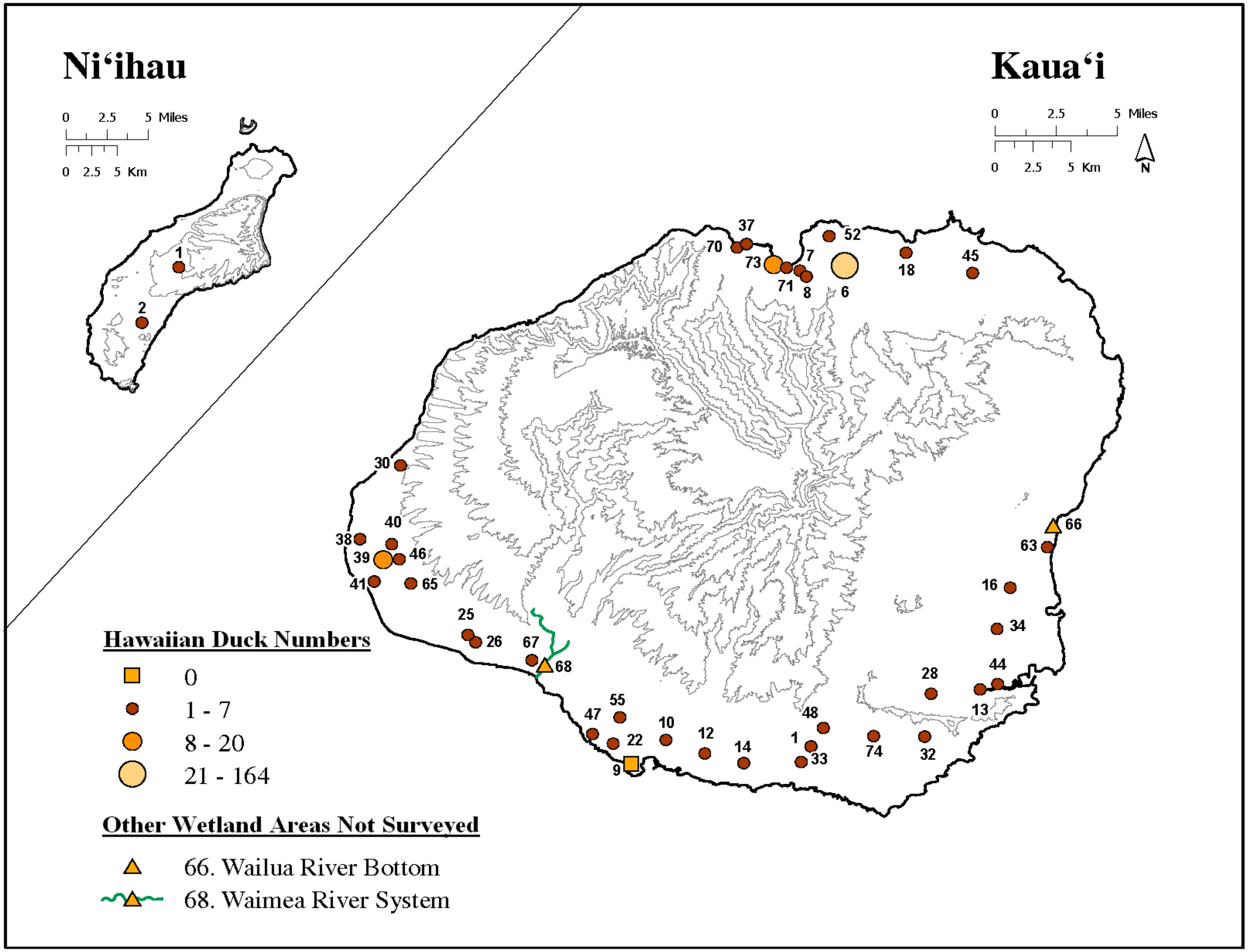

Figure 6. Koloa numbers at surveyed wetlands on Kaua`i and Ni`ihau based on the average from winter counts of adults from 1999-2003 for Kaua`i and 1993, 1995, 1996, 1997, and 1999 for Ni`ihau. The name for each wetland numbered in this figure, as well as whether it is a core or supporting wetland, is listed in Table 1.

the taro lo`i (ponds) and use the taro and wetland dikes extensively for roosting, with a small number of ducks breeding in the area. Also, many Hawaiian ducks have been seen utilizing the upper reaches of the Hanalei River watershed as a roosting area, and this region probably also provides foraging opportunities. A study of the temporal and spatial movements of these birds would be extremely beneficial for effective management of this population (B. Zaun, *in litt*. 2008). Numbers of Hawaiian ducks increased at the Refuge with the creation of impoundments in the 1980s and 1990s, which initially provided additional loafing areas. Modifications to the impoundments in 1999 and 2005 provided additional roosting, foraging, and nesting habitat. Hawaiian ducks also use artificial reservoirs, particularly near Līhu`e and on the Mānā Plain.

Seasonal movement of Hawaiian ducks to ephemeral wetlands on Ni`ihau has been reported (Munro 1939, Engilis *et al*. 2002). It is thought that these ephemeral wetlands (the 760-hectare (1,900-acre) Playa Lakes) are important habitat (Engilis *et al*. 2002; Ducks Unlimited 2006), but the unreliability of aerial counts (1970-1981) (Banko 1987b) and the ephemeral nature of the wetlands make it difficult to accurately determine the use of wetlands on Ni`ihau by Hawaiian ducks or to judge their importance to the species.

ii. O`ahu Population

Hawaiian ducks were reintroduced to O`ahu through a captive propagation and release program between 1958 and 1982. During this period, a total of 326 Hawaiian ducks were released by State biologists at Kawainui Marsh (177 birds), Nu`upia Ponds (45), Waimea Valley (66), and Ho`omaluhia Botanical Garden (38). The status of Hawaiian ducks on O`ahu, however, is questionable due to the apparent abundance of mallard-Hawaiian duck hybrids. A genetic study by Browne *et al*. (1993) found that all birds sampled on O`ahu were hybrids, although the sample of birds tested was small. Biannual waterbird surveys indicate a decreasing population trend for the Hawaiian duck on O`ahu (Figures 4 and 5), while the number of mallard-Hawaiian duck hybrids has increased (see Figure 42 below). Hawaiian ducks are still reported from wetlands on O`ahu's windward coast (Kawainui, Hāmākua, and He`eia Marshes, Ka`elepulu and Nu`upia Ponds, and Ho`omaluhia Botanical Garden), north shore (James Campbell National

Wildlife Refuge, Kahuku aquaculture ponds, Punaho`olapa, Hale`iwa), Pearl Harbor area (Pearl Harbor National Wildlife Refuge, Pouhala Marsh), and Lualualei (Figure 7), but whether these individuals are actually Hawaiian ducks or hybrids is not clear.

iii. Maui Population

A release of captive-bred Hawaiian ducks was conducted on Maui by the State of Hawai`i between 1989 and 1990 (Engilis *et al*. (2002). From these birds, a small breeding population was established (F. Duvall, pers. comm. 2004). Currently, the Hawaiian duck population probably numbers fewer than 20 birds, which occur primarily at Kanahā Pond (Figure 8). Mallards were not eradicated from Maui prior to the release of Hawaiian ducks, and hybridization is now occurring. Biannual waterbird counts indicate the number of hybrids has increased (HDOFAW 1976-2008; see Figure 43 below) and they may outnumber Hawaiian ducks.

iv. Hawai`i Population

The number of Hawaiian ducks on Hawai`i was estimated to be 200 by Engilis *et al*. (2002). The number of Hawaiian ducks counted on the biannual waterbird surveys is much lower (Figure 9), but these surveys do not include montane stream habitat in Kohala and Mauna Kea where many ducks occur. Hawaiian ducks were reestablished on the island of Hawai`i between 1976 and 1982, when captive-bred birds were released in the Kohala Mountains. Some birds have dispersed from release sites and have been recorded up to 32 kilometers (20 miles) away (Giffin 1983). They have been observed using stock ponds in the Kohala Mountains and the Wailuku River, stream habitats of Pololū, Waimanu, and Waipi`o Valleys, and on Mauna Kea in stock ponds and larger montane streams. Successful breeding in the wild has been documented in the Kohala Mountains and at Hakalau Forest National Wildlife Refuge.

Engilis *et al*. (2002) considered the Hawaiian duck population at higher elevations of Hawai`i to be genetically pure, but noted that hybrid individuals had been observed in Waipi`o Valley and the vicinity of Waimea. Pair bonds between Hawaiian ducks and mallards have been observed in the Hilo area, and hybrid birds have been documented to occur in Hawai`i's lowland wetlands (A. Engilis, pers. comm. 2003; see Figure 39 below).

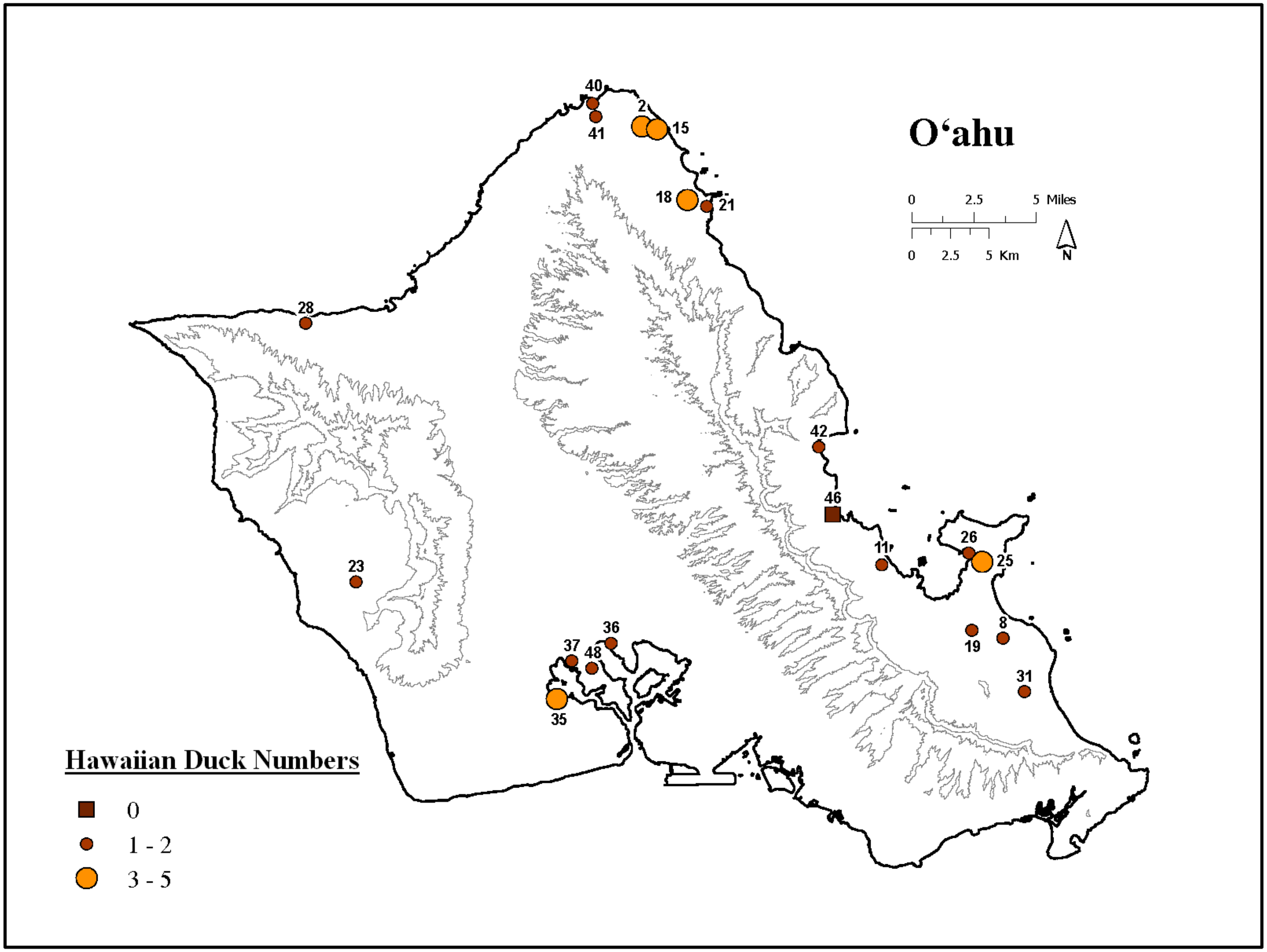

Figure 7. Koloa numbers at surveyed wetlands on O`ahu based on the average from winter counts of adults from 1999-2003. The name for each wetland numbered in this figure, as well as whether it is a core or supporting wetland, is listed in Table 2.

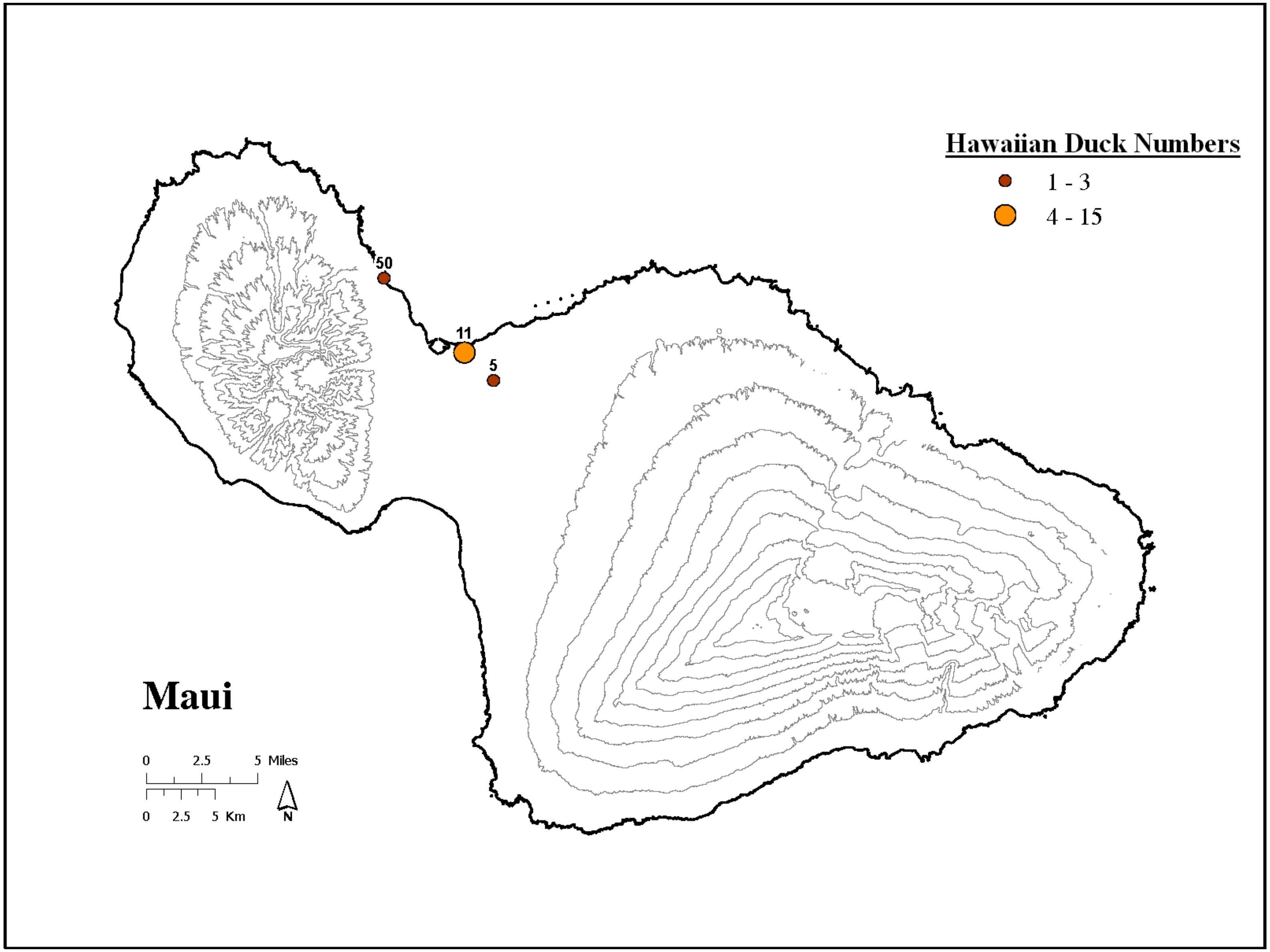

Figure 8. Koloa numbers at surveyed wetlands on Maui based on the average from winter counts of adults from 1999-2003. The name for each wetland numbered in this figure, as well as whether it is a core or supporting wetland, is listed in Table 3.

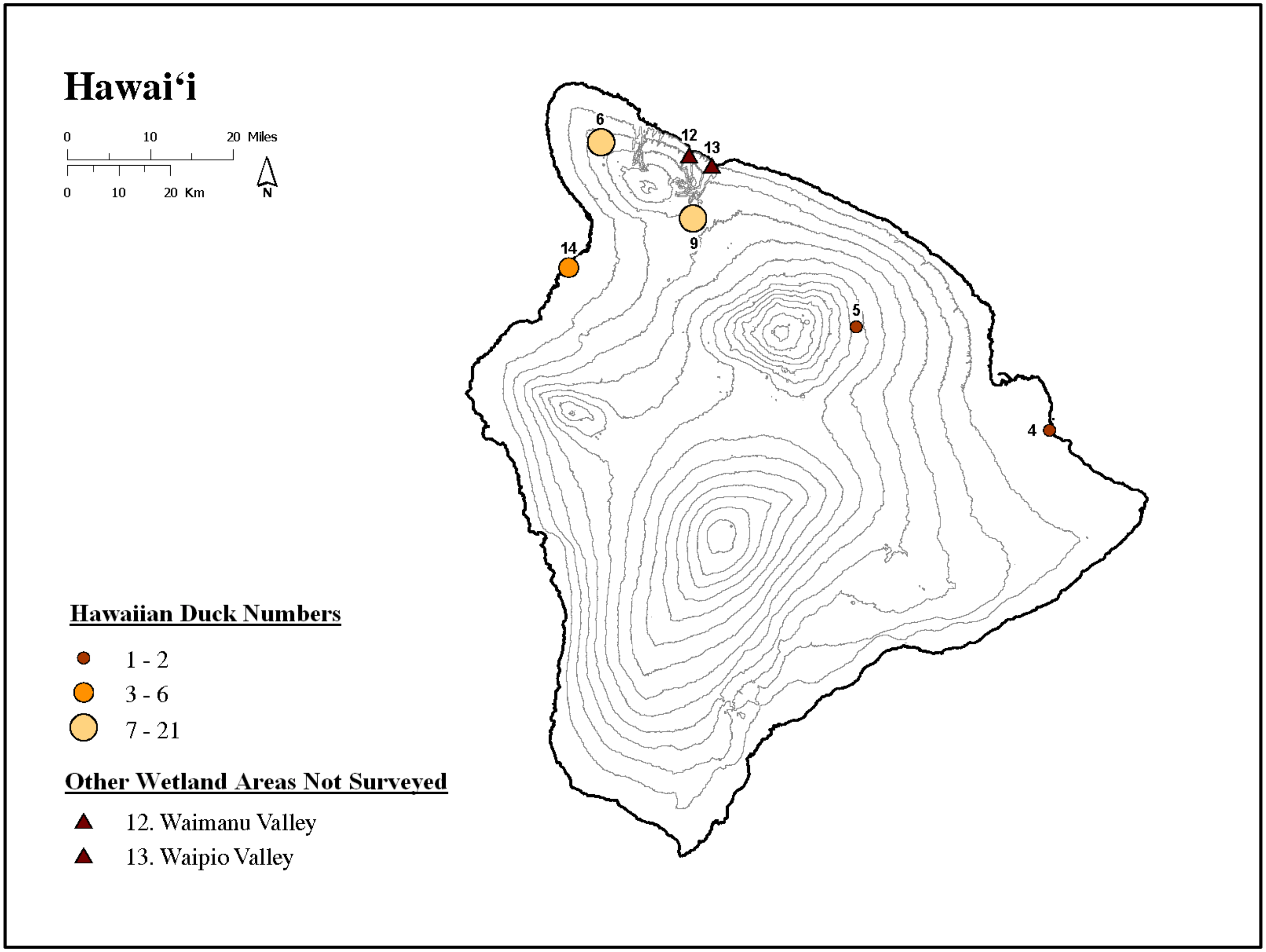

Figure 9. Koloa numbers at surveyed wetlands on Hawai`i based on the average from winter counts of adults from 1999-2003. The name for each wetland numbered in this figure, as well as whether it is a core or supporting wetland, is listed in Table 5.

(e) Life History

Hawaiian ducks breed year-round, but the majority of nesting records is from March through June (Giffin 1983). In Kaua`i lowlands, Hawaiian ducks form pair bonds between November and May, with pairs dispersing to montane nesting localities. Hawaiian duck numbers have been reported to fluctuate seasonally at Hanalei National Wildlife Refuge (Engilis and Pratt 1993; A. Asquith, pers. comm. 1999). This pattern of seasonal fluctuation was supported by a recent study (Gee 2007) demonstrating high use of the Refuge by Hawaiian ducks in the winter and declining use in the summer. These seasonal changes may reflect dispersal into montane areas during the breeding season, perhaps indicating a later breeding period for these Kaua`i birds. Some pairs find suitable nesting habitat in lowland wetlands. Gee (2007) also found that Hawaiian duck abundance at the Refuge was positively correlated with rainfall.

Nests are on the ground near water, but little else is known of specific nesting habits. There have been few documented records of nesting in areas populated by humans, particularly where cats, dogs, or mongooses are common. Clutch size ranges from 2 to 10 eggs (mean = 8.3) (Swedberg 1967). Incubation lasts approximately 30 days, with most chicks hatching from April to June.

Hawaiian ducks are usually found alone or in pairs and are wary, particularly when nesting or molting. Hawaiian ducks may congregate in substantially larger numbers when loafing or exploiting rich food sources. Concentrations of 200 or more Hawaiian ducks have been observed at Hanalei National Wildlife Refuge. They are strong flyers and usually fly at low altitudes. Hawaiian ducks exhibit intra-island movement but timing and dispersal tendencies are not understood (Engilis *et al*. 2002). Hawaiian ducks are capable of large daily movement but there is little data on dispersal from the natal site (Engilis *et al*. 2002). There is no information on the lifespan or survivorship of Hawaiian ducks from wild or captive flocks (Engilis *et al*. 2002).

Hawaiian ducks, like mallards, apparently are opportunistic feeders. Foods consumed include snails, insect larvae, earthworms, tadpoles, crayfish, mosquito larvae, mosquito fish (*Gambusia affinis*), aquatic invertebrates including water boatmen (family Corixidae), grass seeds, rice, green algae, and seeds and leaf parts of wetland plants (Swedberg 1967; B. Zaun, *in litt*. 2005). Feeding in

wetlands and streams typically occurs in water less than 24 centimeters (9.4 inches) deep (Engilis *et al*. 2002).

(f) Habitat Description

The Hawaiian duck historically used a wide variety of natural wetland habitats for nesting and feeding, including freshwater marshes, flooded grasslands, coastal ponds, streams, montane pools, and forest swamplands at elevations ranging from sea level to 3,000 meters (9,900 feet). Agricultural and artificial wetlands such as taro, lotus (*Nelumbo nucifera*), shrimp, fish, and sewage treatment ponds supplement natural wetland habitats and are also utilized as feeding habitat by the Hawaiian duck. They may also use irrigation ditches, flooded ephemeral fields, reservoirs, and the mouths of larger streams for feeding or nesting. Wetlands that are relatively small, isolated, or close to houses are less likely to be occupied (Uyehara *et al*. 2008).

Swedberg (1967) estimated that 90 percent of the Hawaiian duck population on Kaua`i lives along that island's extensive upland stream system, between 300 and 1,200 meters (1,000 to 4,000 feet) elevation. A typical stream used by the Hawaiian duck on Hawai`i Island is 7 meters (23 feet) wide, swiftly flowing, strewn with boulders, and has heavily vegetated banks (Paton 1981). However, little information is available on habitat use of stream systems by the Hawaiian duck. It is important to protect Hawaiian duck habitat in both coastal and upland habitats to promote recovery of the species.

Ephemeral wetlands are important habitat for the Hawaiian duck, although how they are used beyond foraging is unknown (Engilis *et al*. 2002). Hawaiian ducks move regularly between Ni`ihau and Kaua`i in response to periods of above-normal precipitation and the flooding and drying of Ni`ihau's ephemeral wetlands (Engilis 1988; Engilis and Pratt 1993). More information is needed on movements of the Hawaiian duck in response to the availability of seasonal and permanent wetland habitats between the summer (dry) and winter (wet) seasons.

(g) Species-specific threats

Hybridization with feral mallards is currently the primary threat to the recovery of the Hawaiian duck. Extensive hybridization has occurred on O`ahu and Maui, with limited hybridization on Kaua`i and Hawai`i. Hybridization is unlikely to occur with wild migratory mallards that winter or pass through the

islands because migrants occur in Hawai`i during their non-breeding season. Damage to watersheds by pigs, goats, and other feral ungulates may pose direct impacts to nesting habitat. Other limiting factors that threaten all of Hawai`i's waterbirds are covered in the "Reasons for Decline and Current Threats" section of this recovery plan.

2. Hawaiian Coot or `Alae ke`oke`o

(a) Taxonomy

The Hawaiian coot or `alae ke`oke`o (*Fulica alai*) is endemic to the Hawaiian Islands. In the past the Hawaiian coot was considered a subspecies of the American coot (*Fulica americana*) and was originally listed under the Endangered Species Act as such, but it is now regarded as a distinct species (AOU 1993). The Hawaiian coot is nonmigratory and presumably originated from stray migrants from continental North America that remained as residents in the islands (Brisbin *et al*. 2002).

(b) Species Description

The Hawaiian coot is smaller in body size than the American coot, and the bulbous frontal shield above the bill is distinctly larger than that of the American coot and is usually completely white (Shallenberger 1977; Pratt *et al*. 1987). From 1 to 3 percent of the total Hawaiian coot population has a red lobe at the top of the frontal shield and deep maroon markings at the tip of the bill, similar to the American coot (Engilis and Pratt 1993; Pratt *et al*. 1987; Figure 10). Adult Hawaiian coots are dark, slate-gray in color, with white undertail feathers. Male and female Hawaiian coots are similar in color. Hawaiian coots have large feet with lobed toes, unlike the webbed feet of ducks. Immature Hawaiian coots are a lighter gray with buff-tipped contour feathers, have smaller, dull white bills, and lack a well-developed frontal shield (Figure 11). Downy chicks have red skin and a bill with a yellow tip, similar to that of the American coot (Brisbin *et al*. 2002).

(c) Historical Range and Population Status

Hawaiian coots historically occurred on all of the main Hawaiian Islands except Lāna`i and Kaho`olawe, which lacked suitable wetland habitat. Hawaiian coots have always been most numerous on O`ahu, Maui, and Kaua`i (Shallenberger 1977). They were likely once fairly common in large natural

Figure 10. Color variation in frontal shield and bills of Hawaiian coots. Photo by Eric VanderWerf.

Figure 11. Hawaiian coot male, female, and chick. Photo by Michael Silbernagle.

marshes and ponds in addition to using wetland habitats created by Hawaiians for taro cultivation and large-scale fish production.

No population estimates are available prior to the 1950s; however, Schwartz and Schwartz (1949) identified a decline and potential threat of extinction in the first half of this century. Censuses from the late 1950s to the late 1960s indicated a population of fewer than 1,000 individuals (USFWS 1978), which contributed to the Federal listing of the Hawaiian coot as endangered in 1970.

Henshaw (1902) reported that Hawaiians often took eggs from nests. Hawaiian coots were on the Hawai`i gamebird list until 1939, and after that time were sometimes still killed by taro farmers (Berger 1981). Such activities are unlikely to still be occurring today (Brisbin *et al*. 2002). Hawaiian coots are preyed on by a large number of introduced predators, including cats, dogs, mongooses, rats, fish such as the large-mouth bass (*Micropterus* sp.), bullfrogs (*Rana catesbeiana*), and possibly cattle egrets (*Bubulcus ibis*) (Shallenberger 1977, Berger 1981, Brisbin *et al*. 2002). The indigenous black-crowned night heron (*Nycticorax nycticorax*) may also be a serious predator of Hawaiian coot chicks (Brisbin *et al*. 2002).

(d) Current Range and Population Status

Hawaiian coots currently inhabit all of the main Hawaiian Islands except Kaho`olawe. Their recent presence on Lāna`i is due to artificial “wetlands,” such as water treatment sites. Although data are missing on some islands in certain years, winter counts from biannual waterbird surveys from 1997 through 2006 generally indicate the Hawaiian coot population averages approximately 2,000 birds, fluctuating between approximately 1,500 and 2,800 birds (HDOFAW 1976-2008; Figure 12). Summer counts were generally more variable than winter counts, possibly due to the variability in hatch-year bird survival. As Hawaiian coots are conspicuous and often use open water areas, they are relatively easy to census, so these data are considered fairly accurate minimum population estimates, although not all wetlands are surveyed. Kaua`i, O`ahu, and Maui collectively support 80 percent of the birds detected in these surveys (HDOFAW 1976-2008). Engilis and Pratt (1993) reported the statewide Hawaiian coot population to range from 2,000 to 4,000 birds.

Survey data from 1976 through 2007 reveal short-term population fluctuations, with a long-term slightly increasing population trend overall (Figures 12 and 13). Hawaiian coots are known to disperse readily and exploit seasonally flooded wetlands; thus their populations will naturally fluctuate according to climatic and hydrologic conditions (Engilis and Pratt 1993). The large playa lakes on Ni`ihau have supported large numbers of Hawaiian coots in wet years.

i. Kaua`i and Ni`ihau Populations

On Kaua`i, Hawaiian coots occur primarily in lowland valleys, such as Hanalei, Lumaha`i, and `Opaeka`a, and in reservoirs, but they have occasionally been observed in plunge pools at elevations above 1,500 meters (4,950 feet) (HDOFAW 1989). Over a 10-year period (1998-2007), counts of Hawaiian coots on Kaua`i averaged about 500 birds, fluctuating between approximately 50 and 1,500 birds (HDOFAW 1976-2008; Figure 14). Some of this variation is due to dispersal of Hawaiian coots to Ni`ihau in wet years. Several authors have speculated that annual migration occurs between Kaua`i and Ni`ihau, but statewide surveys indicate that these movements are less frequent, usually occurring when annual precipitation is above normal and Ni`ihau's ephemeral lakes become flooded (Engilis and Pratt 1993). Numbers of Hawaiian coots counted on Ni`ihau during wet winters include 949 birds in 1986 and 803 birds in 1989; Ni`ihau has not been surveyed since 1999, a dry year when no Hawaiian coots were detected.

ii. O`ahu Population

On O`ahu, the Hawaiian coot population has fluctuated between approximately 500 and 1,000 birds in recent years (HDOFAW 1976-2008). O`ahu's extensive coastal wetlands provide excellent habitat for Hawaiian coots, and the species occurs less frequently on interior reservoirs such as Lake Wilson and Nu`uanu Reservoir. Large concentrations of Hawaiian coots occur at the Ki`i Unit of James Campbell National Wildlife Refuge, the Kahuku aquaculture ponds, the Kuilima wastewater treatment plant, the Ka`elepulu Pond in Kailua, the Honouliuli Unit of Pearl Harbor National Wildlife Refuge, and the Hawai`i Prince Golf Course (Figure 15).

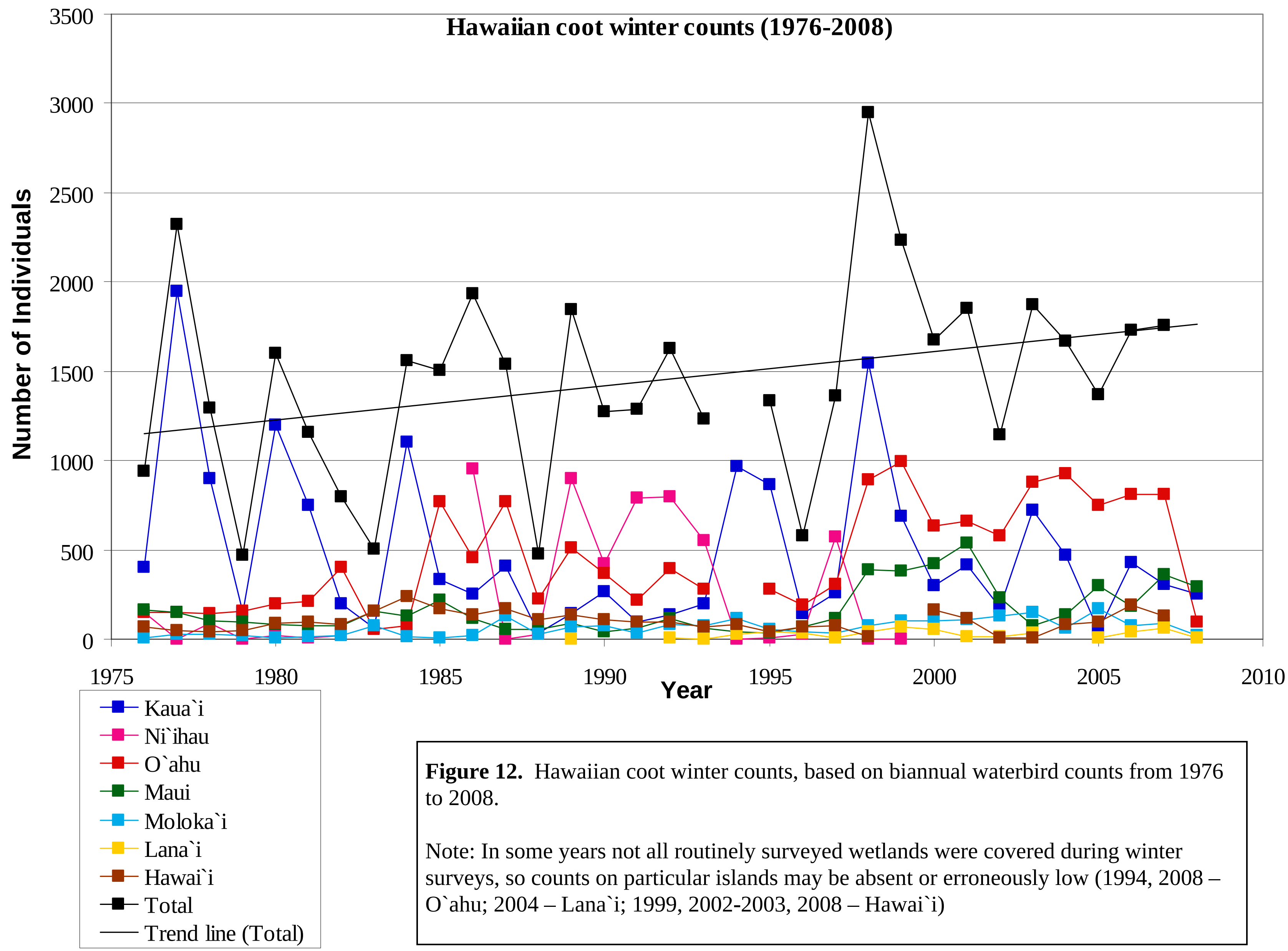

Figure 12. Hawaiian coot winter counts, based on biannual waterbird counts from 1976 to 2008.

Note: In some years not all routinely surveyed wetlands were covered during winter surveys, so counts on particular islands may be absent or erroneously low (1994, 2008 – O`ahu; 2004 – Lana`i; 1999, 2002-2003, 2008 – Hawai`i)

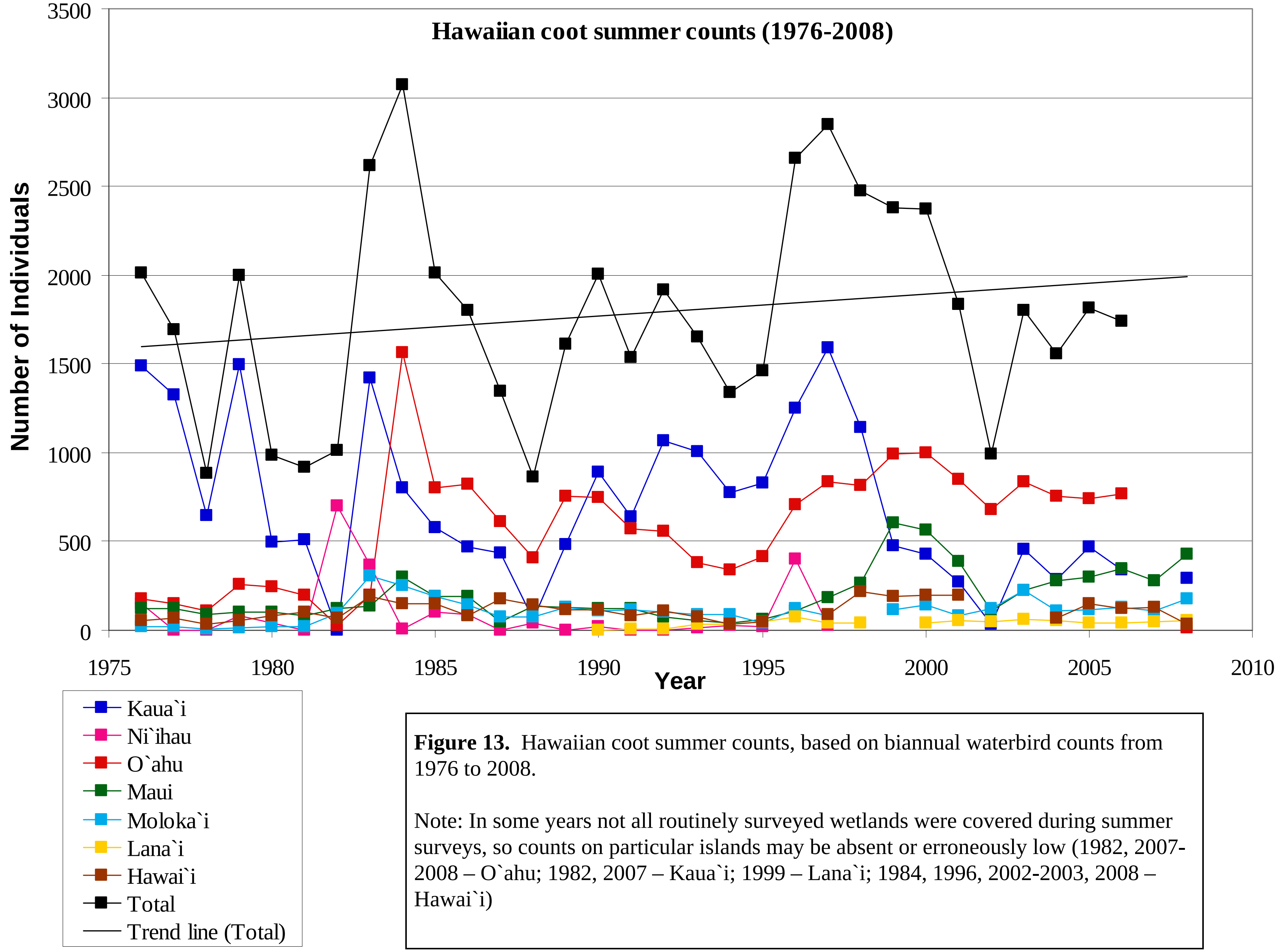

Figure 13. Hawaiian coot summer counts, based on biannual waterbird counts from 1976 to 2008.

Note: In some years not all routinely surveyed wetlands were covered during summer surveys, so counts on particular islands may be absent or erroneously low (1982, 2007-2008 – O`ahu; 1982, 2007 – Kaua`i; 1999 – Lana`i; 1984, 1996, 2002-2003, 2008 – Hawai`i)

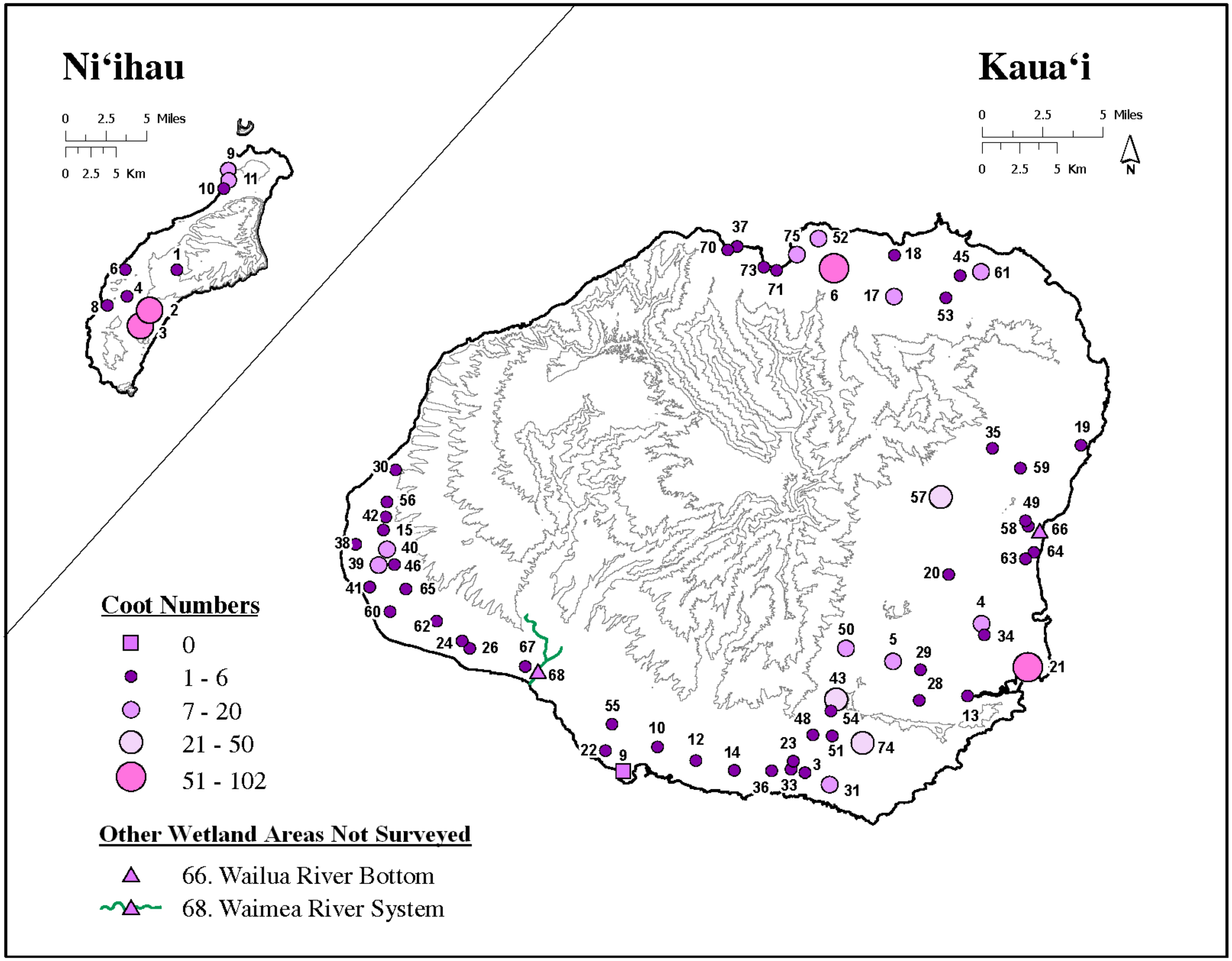

Figure 14. Hawaiian coot numbers at surveyed wetlands on Kaua`i and Ni`ihau based on the average from winter counts of adults from 1999-2003 for Kaua`i and 1993, 1995, 1996, 1997, 1999 for Ni`ihau. The name for each wetland numbered in this figure, as well as whether it is a core or supporting wetland, is listed in Table 1.

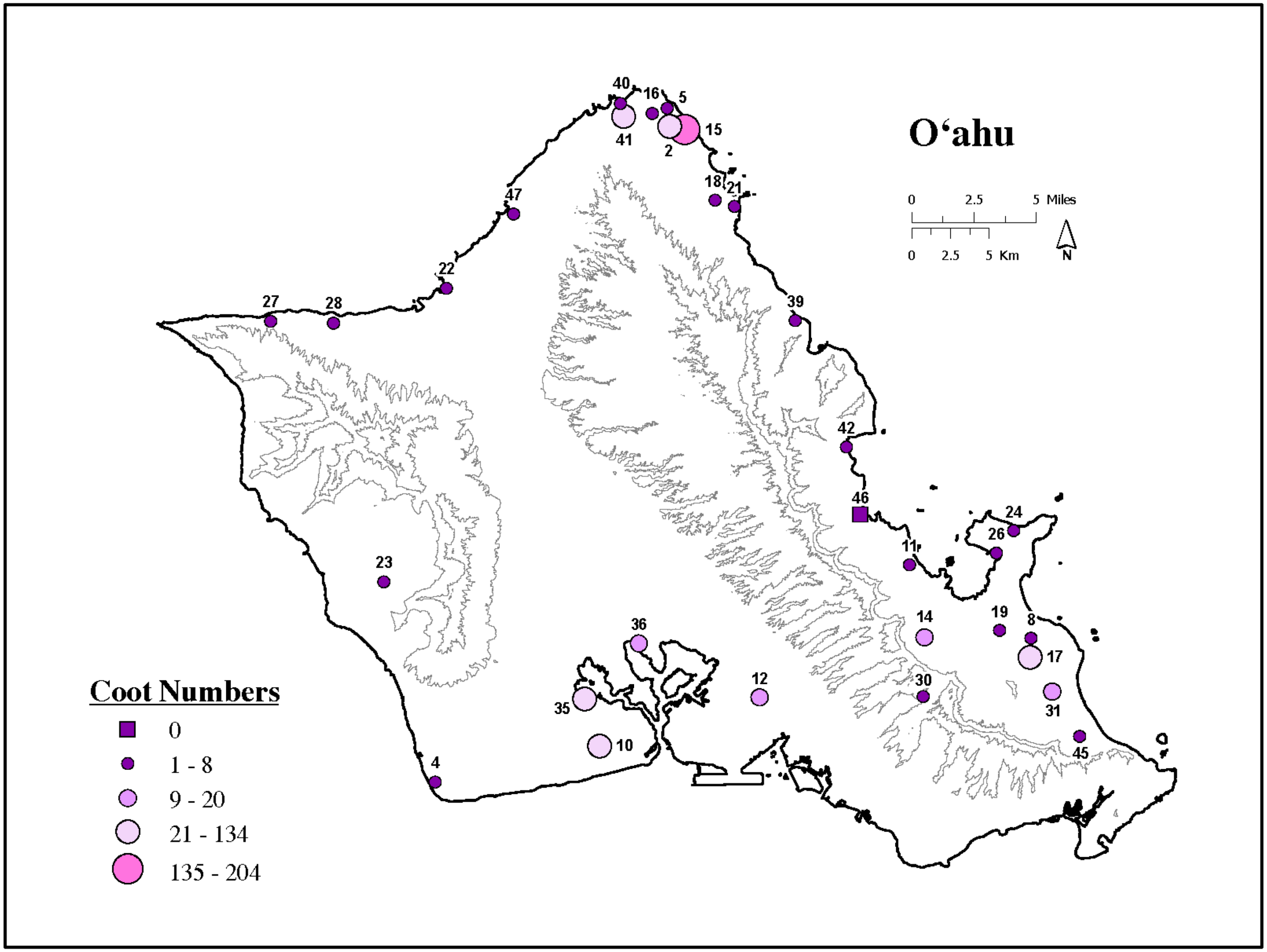

Figure 15. Hawaiian coot numbers at surveyed wetlands on O`ahu based on the average from winter counts of adults from 1999-2003. The name for each wetland numbered in this figure, as well as whether it is a core or supporting wetland, is listed in Table 2.

Aquaculture ponds for shrimp and fish production provide year-round foraging habitat for Hawaiian coots; however, nesting opportunities are limited on these ponds as vegetation is generally controlled along the banks and predators (dogs, cats, and mongooses) can readily find nests around these ponds.

iii. Maui, Moloka`i, and Lāna`i (Maui Nui) Populations

The Hawaiian coot population on Maui Nui varies from approximately 200 to 600 birds (HDOFAW 1976-2008). The largest concentrations of Hawaiian coots occur at Kanahā and Keālia Ponds on Maui, the Kaunakakai Sewage Treatment Ponds on Moloka`i, and the Lāna`i Sewage Treatment ponds (Figures 16 and 17). Waterbird survey data suggest that annual movements occur between Kanahā and Keālia Ponds, and also possibly between islands within Maui Nui. Monthly surveys of Kanahā and Keālia Ponds from 1995 to 1999 suggest that increased Hawaiian coot numbers at Keālia Pond are the result of influxes from other populations. This assumption is supported by counts at Keālia Pond which exceed the combined total of Keālia and Kanahā Ponds from the previous monthly count (M. Nishimoto, pers. comm. 2004). In addition to these wetlands, many of the remaining reservoirs associated with former sugar cane (*Saccharum officinarum*) production are frequented by Hawaiian coots.

The largest concentrations of Hawaiian coots on Moloka`i occur at the Kaunakakai Sewage Treatment Ponds and Kualapu`u Reservoir, but Hawaiian coots also occur on Moloka`i's coastal ponds and playa wetlands, particularly Paialoa Pond. There is some evidence from statewide waterbird surveys that Hawaiian coots move between Maui and Moloka`i. These movements are not seasonal, but are sporadic and seem to correlate with periods of heavy rainfall (Engilis and Pratt 1993). The playa habitats on Moloka`i are usually dry, but flood in wet winters. Hawaiian coots have become permanent residents at the Lāna`i City wastewater treatment ponds since 1989 when these ponds became operational. During the 2002 summer waterbird counts, 45 birds were observed using this area. Hawaiian coots have also been observed nesting at the wastewater treatment facility (HDOFAW 1976-2008).

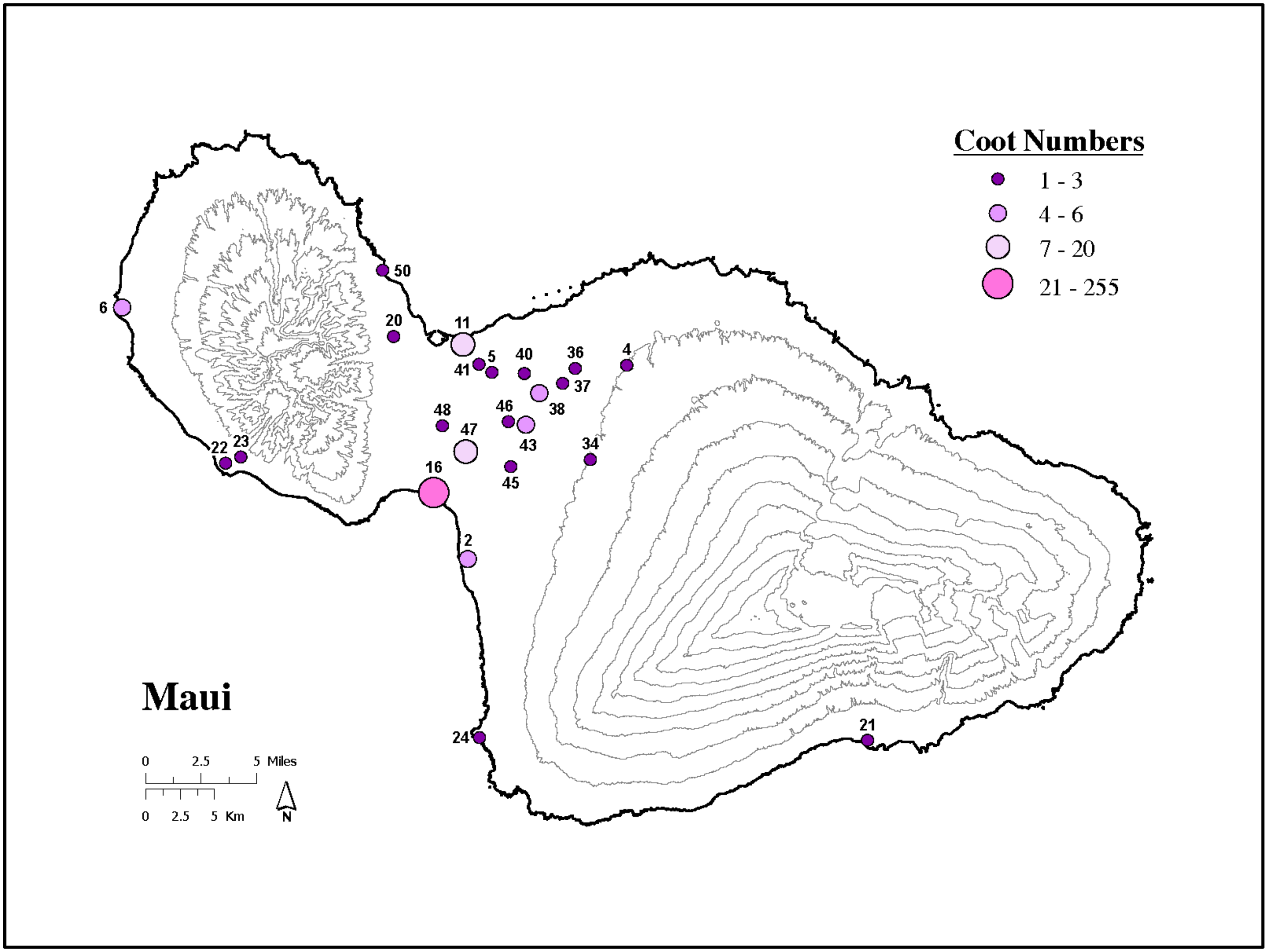

Figure 16. Hawaiian coot numbers at surveyed wetlands on Maui based on the average from winter counts of adults from 1999-2003. The name for each wetland numbered in this figure, as well as whether it is a core or supporting wetland, is listed in Table 3.

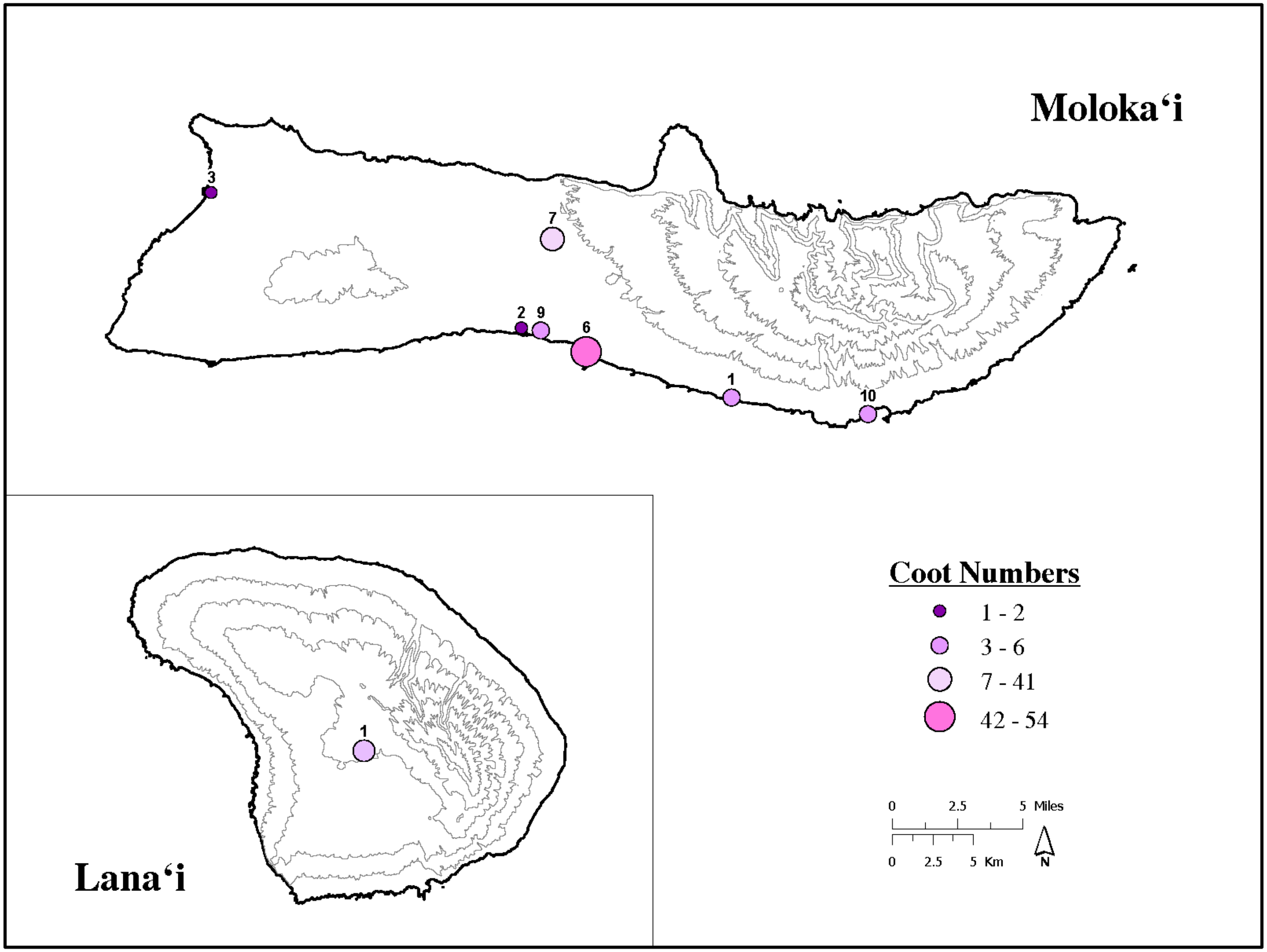

Figure 17. Hawaiian coot numbers at surveyed wetlands on Moloka`i and Lāna`i based on the average from winter counts of adults from 1999-2003. The name for each wetland numbered in this figure, as well as whether it is a core or supporting wetland, is listed in Table 4.

iv. Hawai`i Population

Hawai`i Island, with its limited wetlands, supports only a small Hawaiian coot population, generally fewer than 100 birds (HDOFAW 1976-2008; Figure 18). Four ponds on the island support the majority of these birds: `Aimakapā and `Ōpae`ula Ponds on the Kona Coast, and Waiakea and Loko Waka Ponds in Hilo. The latter two ponds are in urban areas. The Hawaiian coot population on Hawai`i Island shows little seasonal fluctuation. Numbers vary from year to year, suggesting birds disperse to and from other islands.

(e) Life History

Hawaiian coots nest on open fresh water and brackish ponds, taro ponds, shallow reservoirs, irrigation ditches, and in small openings of marsh vegetation (Udvardy 1960; Shallenberger 1977). They construct floating nests of aquatic vegetation in open water, or semi-floating nests anchored to emergent vegetation or in clumps of wetland vegetation (Byrd *et al*. 1985). Open-water nests typically are anchored on semi-floating mats of vegetation, usually constructed from water hyssop (*Bacopa monnieri*) and Hilo grass (*Paspalum conjugatum*). Nests in emergent vegetation are platforms constructed from buoyant stems of nearby vegetation, such as bulrush (*Scirpus* spp.) (Byrd *et al*. 1985). Hawaiian coots appear to be adaptive and opportunistic; cattail (*Typha* spp.), bulrush, and sprangletop (*Leptochloa uninervia*) are plants regularly utilized for nesting at the O`ahu National Wildlife Refuge Complex (S. Pelizza, *in litt*. 2005). Nests have also been documented on shorelines or rocky islets (M. Morin, pers. comm. 1994). Additional "false nests" may be constructed near the actual nest and are often used as loafing or brooding platforms.

Early naturalists considered the breeding season to be early spring through fall, but recent information suggests year-round breeding is more common than previously thought and active nests have now been found in all months (Shallenberger 1977; S. Pelizza, *in litt*. 2005). Nesting occurred at `Aimakapā Pond, Hawai`i, in all months except November and January (Morin 1998). The timing of nesting does appear to be opportunistic and correspond with seasonal weather conditions (Byrd *et al*. 1985; Engilis and Pratt 1993). Due to the drying cycle at Keālia Ponds, there is little to no Hawaiian coot nesting during the summer/fall period (M. Nishimoto, USFWS, *in litt*. 2008). Water levels are

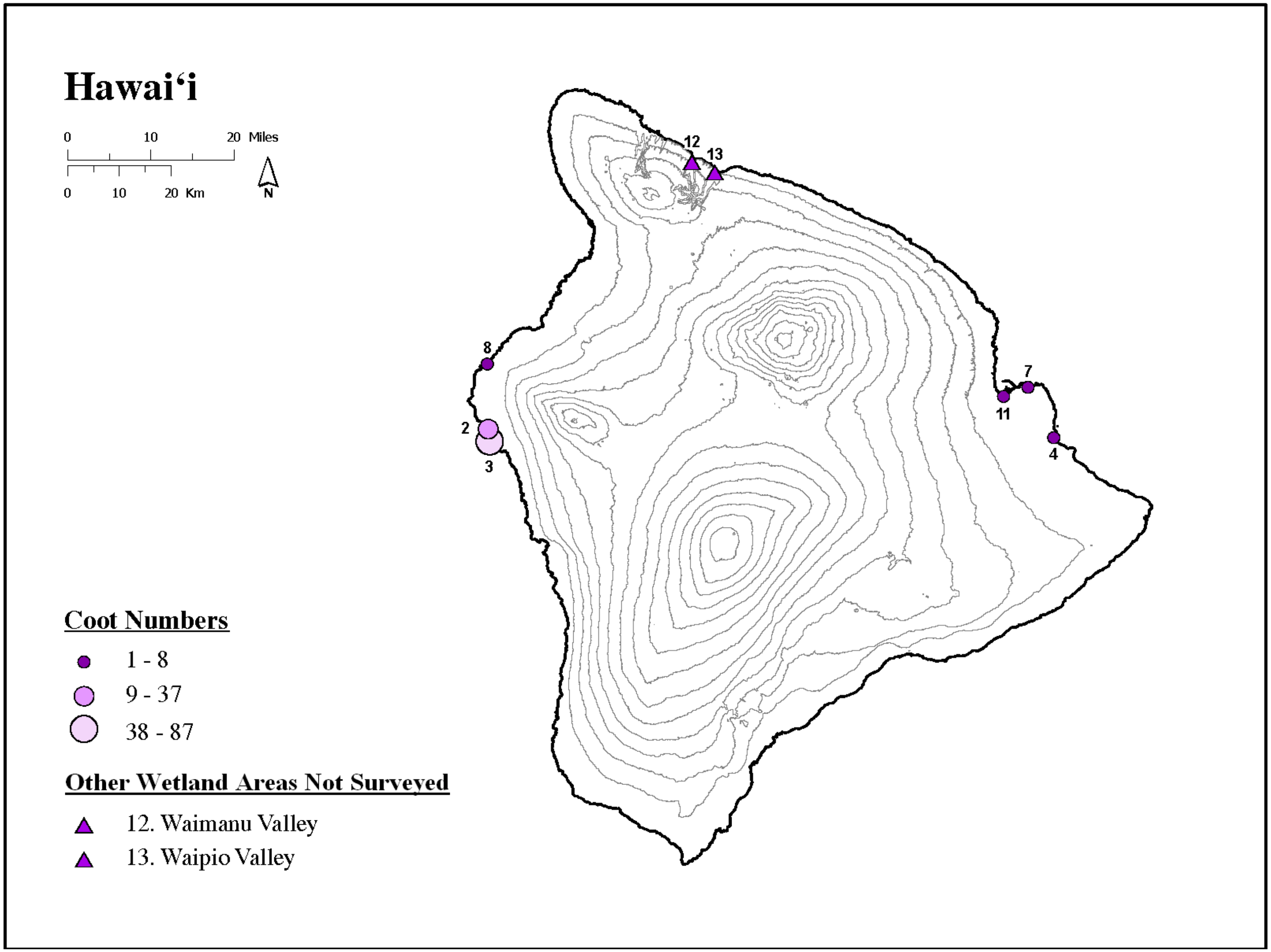

Figure 18. Hawaiian coot numbers at surveyed wetlands on Hawai`i based on the average from winter counts of adults from 1999-2003. The name for each wetland numbered in this figure, as well as whether it is a core or supporting wetland, is listed in Table 5.

critical for nest initiation and success. Taro ponds can provide good nesting and foraging habitat because they generally have limited water fluctuation compared to other unmanaged sites, though many taro farmers periodically drain, dry, and reflood their ponds, both of which (draining and flooding) can lead to waterbird nest failure (B. Zaun, *in litt*. 2005). Managed wetlands also provide excellent habitat, especially if water depth and flow are managed for successful nesting (S. Pelizza, *in litt*. 2005). Clutch size ranges from 3 to 10 eggs, with an average of 5 eggs (Byrd *et al*. 1985). The incubation period is about 25 days (Shallenberger 1977; Byrd *et al*. 1985), and chicks are able to swim as soon as their down has dried (Brisbin *et al*. 2002).

Hawaiian coots are generalist feeders, obtaining food near the surface of the water, diving, or foraging in mud or sand. They also graze on upland grassy sites such as golf courses that are adjacent to wetlands, especially during times of drought and when food is unavailable elsewhere (T. Telfer, pers. comm. 1999). Food items include seeds and leaves of aquatic plants, various invertebrates including snails, crustaceans, and aquatic or terrestrial insects, tadpoles, and small fish (Schwartz and Schwartz 1949). Hawaiian coots typically feed close to their nesting areas but will travel long distances when food is not locally available (Shallenberger 1977; Brisbin *et al*. 2002). Intra-island movements occur when water levels are low and food sources become concentrated. Hawaiian coots also disperse away from their natal sites (inter-or intra-island) due to density dependent factors (S. Pelizza, *in litt*. 2005).

The Hawaiian coot is an active and at times gregarious species. Like its North American relative, the Hawaiian coot sometimes forms large flocks. This usually occurs in the summer, but some localities do not show a seasonal flocking pattern, such as the Hanalei National Wildlife Refuge and the O`ahu National Wildlife Refuge Complex where large Hawaiian coot flocks have been observed during all months. There is no information on the lifespan and survivorship of the Hawaiian coot; however, the oldest reported American coot was at least 22 years old based on banding records (Klimkiewicz and Futcher 1989, cited in Brisbin and Mowbray 2002; Pratt and Brisbin 2002).

Hawaiian coot population fluctuations may be explained by inter-island dispersal in relation to rainfall patterns and are not the result of American coots migrating to the Hawaiian Islands (Engilis and Pratt 1993). Statewide waterbird

surveys from 1977 to 1986 indicate that Hawaiian coots migrate between islands in response to precipitation patterns. Periodic increases in Hawaiian coot numbers on Ni`ihau and Moloka`i presumably are the result of movement of birds from Kaua`i and Maui, respectively (Engilis and Pratt 1993). Population increases on Ni`ihau are correlated with the intermittent availability of wetlands resulting from high rainfall.

(f) Habitat Description

The Hawaiian coot is typically a species of the coastal plain, ranging from sea level to 260 meters (850 feet), rarely to 1,067 meters (3,500 feet), preferring lowland wetland habitats with suitable emergent plant growth interspersed with open water (Brisbin *et al*. 2002). However, some birds have been observed in mountain streams and stock ponds at higher elevations (Perkins 1903) on Hawai`i. Hawaiian coots prefer freshwater wetlands, but will use brackish wetlands, and rarely, saline habitats. Hawaiian coots forage in water less than 30 centimeters (12 inches) deep, but can dive in water up to 120 centimeters (48 inches) deep. They utilize more open water areas than do Hawaiian common moorhens, particularly for feeding. Optimum nesting habitat for the North American coot is generally in a 50:50 to 75:25 mix of dense emergent vegetation and open water. Hawaiian coots may utilize a similar mix but research on nesting habitat is limited. Large, deep ponds appear to provide only limited habitat for Hawaiian coots, particularly in areas where strong winds can cause the formation of wavelets. At `Aimakapā Pond on Hawai`i Island, Morin (1998) found 18 of 46 nests on a small islet (less than 1 m diameter) and 6 of 46 nests on human-made fishpond walls. Fifteen of 46 nests were either floating freely or were located on top of pre-existing floating vegetation (Morin 1998). Interspersion of robust emergent vegetation can help to reduce wave action by minimizing the distance over which wind blows (wind fetch).

Water salinity appears to be important to coots in general, and both Hawaiian coots and American coots apparently prefer fresh water areas for nesting (Byrd *et al*. 1985). Fredrickson (1977) suggested that nesting American coots may be restricted to freshwater areas because of their inability to excrete excess salt at an efficient rate. Hawaiian coots are not restricted to fresh water, however, and are often found in brackish water (Berger 1981).

Loafing sites include logs, rafts of vegetation, narrow dikes, mud bars, artificial islands, and “false nests.” Hawaiian coots also loaf on open bodies of water such as reservoirs. Because of Hawaiian coots’ ability to disperse to find suitable foraging habitat, ephemeral wetlands play an important part in their annual life cycle. Ephemeral wetlands may support large numbers of Hawaiian coots during the nonbreeding season (*e.g.*, up to 25 Hawaiian coots per hectare [10 per acre] year-round on Moloka`i wetlands [Coleman 1978; Engilis 1988], and concentrations of 600 or more Hawaiian coots on Ni`ihau in winter [HDOFAW 1976-2008]).

3. Hawaiian Common Moorhen or `Alae `ula

(a) Taxonomy

The Hawaiian common moorhen or `alae `ula (*Gallinula chloropus sandvicensis*) is an endemic subspecies of the common moorhen (*Gallinula chloropus*) (AOU 1998). The Hawaiian subspecies is non-migratory and has occurred on Hawai`i for an unknown length of time (Berger 1981). Nagata (1983) suggested that the Hawaiian birds originated from stray migrant birds that colonized Hawai`i from North America.

(b) Species Description

The Hawaiian common moorhen is recognized as a distinct subspecies, differing from other races in having a red blush on the front and sides of the tarsus (Taylor 1998). However, there are no evident plumage or measurement differences from forms in North America (Wilson and Evans 1890-1899; Rothschild 1900). Hawaiian common moorhens superficially resemble the related Hawaiian coot, but they are noticeably smaller, possess a red shield over their red and yellow bill, and have a white flank stripe (Schwartz and Schwartz 1949; Bannor and Kiviat 2002). They are black above and slate blue below, with underwing coverts mostly white (Figure 19). Their legs and feet are yellowish green, and the feet are not lobed as are the Hawaiian coot’s. The sexes are similar in appearance. Immature birds are olive-brown to grayish brown, with a pale yellow or brown bill.

Figure 19. Hawaiian common moorhen juvenile and adult. Photo by David DesRochers.

(c) Historical Range and Population Status

The Hawaiian common moorhen was found on all of the main Hawaiian Islands except Lāna`i (presumably due to the lack of wetlands there) and probably Ni`ihau (hardly known) in 1891 (Munro 1960; Banko 1987a). However, by the late 1940s their status was considered "precarious," especially on O`ahu, Maui, and Moloka`i (Schwartz and Schwartz 1949). Hawaiian common moorhens disappeared from Moloka`i sometime after the 1940s and were reintroduced in 1983 (Dibben-Young 2010), but the population did not persist and the species currently is not known to occur on the island. Hawaiian common moorhens disappeared after the late 1940s on Maui and an attempt to reestablish them at Kanahā Pond in 1959 was unsuccessful (Berger 1981; Banko 1987a). On Hawai`i Island, Hawaiian common moorhens were last reported from Hilo and Ka`ena (Puna) in 1887 and at the same time were disappearing from localities where they were formerly abundant. Attempts made to reestablish them in Ka`ena (around 1928 to 1930) and Waipi`o Valley (1950s) were unsuccessful (Banko 1987a). Like the Hawaiian coot, the Hawaiian common moorhen is predominantly a

species of the lowlands, using natural ponds, marshes, streams, springs or seeps, lagoons, grazed wet meadows, taro and lotus fields, shrimp aquaculture ponds, reservoirs, sedimentation basins, sewage ponds, and drainage ditches (Bannor and Kiviat 2002, Banko 1987a; Shallenberger 1977, Nagata 1983).

The Hawaiian common moorhen is quite secretive and difficult to census, and even rough population estimates were lacking until the 1950s, so the long-term population trend is difficult to determine. Surveys in the 1950s and 1960s estimated no more than 57 individuals (Engilis and Pratt 1993). Around the same time as the spread of aquaculture on O`ahu in the late 1970s and 1980s, several National Wildlife Refuges were established in Hawai`i; both are likely to have contributed to an increase in Hawaiian common moorhen numbers (S. Pelizza, *in litt*. 2005). The decline of taro farming as early as the 1850s and the passing of rice cultivation in 1963 apparently contributed to a decline of Hawaiian common moorhens (Nagata 1983; Bannor and Kiviat 2002). Agricultural development, along with residential and recreational development, adversely affected the Hawaiian common moorhen through modifications of channel and shorelines, increased siltation, filling of wetlands, stabilizing water levels in some areas and causing fluctuations or flooding in other areas (Berger 1981; Bannor and Kiviat 2002). Aquaculture projects continue to support Hawaiian common moorhens in the State; however, wetlands specifically managed for waterbirds (*e.g.*, National Wildlife Refuge lands) have the potential to support higher concentrations of Hawaiian common moorhens (S. Pelizza, *in litt*. 2005) than farmed lands.

Henshaw (1902) mentioned the extirpation of Hawaiian common moorhen populations in some localities and diminishing numbers of birds in all districts. Hunting was considered a major limiting factor prior to 1939, and despite a ban on hunting and the unpalatability of the Hawaiian common moorhen to many people, illegal hunting continued to be a problem after 1941 (Berger 1981; Nagata 1983; Bannor and Kiviat 2002). Predation by introduced species also had and continues to have a large impact on this ground-nesting species. Most unsuccessful nesting attempts fail as the result of predation (Byrd and Zeillemaker 1981). A large number of species prey on Hawaiian common moorhens, including mongooses, cats, dogs, and bullfrogs (Berger 1981; Byrd and Zeillemaker 1981; Viernes 1995). Human vandals have destroyed nests in recent times (Byrd and Zeillemaker 1981).

(d) Current Range and Population Status

Hawaiian common moorhens are currently found only on the islands of Kaua`i and O`ahu. Reestablishing populations on additional islands is a high priority. Biannual waterbird surveys provide a rough idea of recent population trends, but an accurate population estimate is not available due to the secretive nature of this species and its use of densely vegetated wetland areas. Counts of Hawaiian common moorhens have been stable, but remain low, with average totals of 287 birds over 10 years from 1998 to 2007 (Figures 20 and 21) (HDOFAW 1976-2008). The inaccuracy of current methodology used in the biannual waterbird count, which involves relatively brief visits to each wetland (Griffin *et al*. 1989), is demonstrated by the extreme differences in numbers between summer and winter waterbird surveys of lotus fields on O`ahu. In the winter, after fields have been harvested and visibility is greater, numbers may be two to three times higher than the numbers seen during the summer survey of the same areas. A more time-intensive point count method can provide accurate assessments of Hawaiian common moorhens at a given site (Chang 1990), but this method requires a substantial commitment of resources. For example, the number of Hawaiian common moorhens detected at Hāmākua Marsh during waterbird counts is low (average of 3.8 Hawaiian common moorhens from 2000 to 2002), but repeated careful observations by Smith and Polhemus (2003) for longer periods revealed 10 Hawaiian common moorhen pairs at the same site. Another survey method that may enhance detection of Hawaiian common moorhens during surveys is the use of tape playbacks, which have been used successfully for other moorhen species and subspecies and other cryptic waterbirds (Brackney and Bookhout 1982; Ribic *et al*. 1999; Takano and Haig 2004a, Conway and Gibbs 2005). Recent research on the Hawaiian common moorhen found that playing calls of the Hawaiian common moorhen increased detections of birds by 30 percent on Oahu and 56 percent on Kauai, and more individuals were detected responding to calls at wetlands with larger populations of Hawaiian common moorhens (DesRochers *et al*. 2008). Gee (2007) also found that playbacks can increase Hawaiian common moorhen detections. This information can be used to update and increase the accuracy of surveys for the Hawaiian common moorhen during the biannual waterbird surveys.

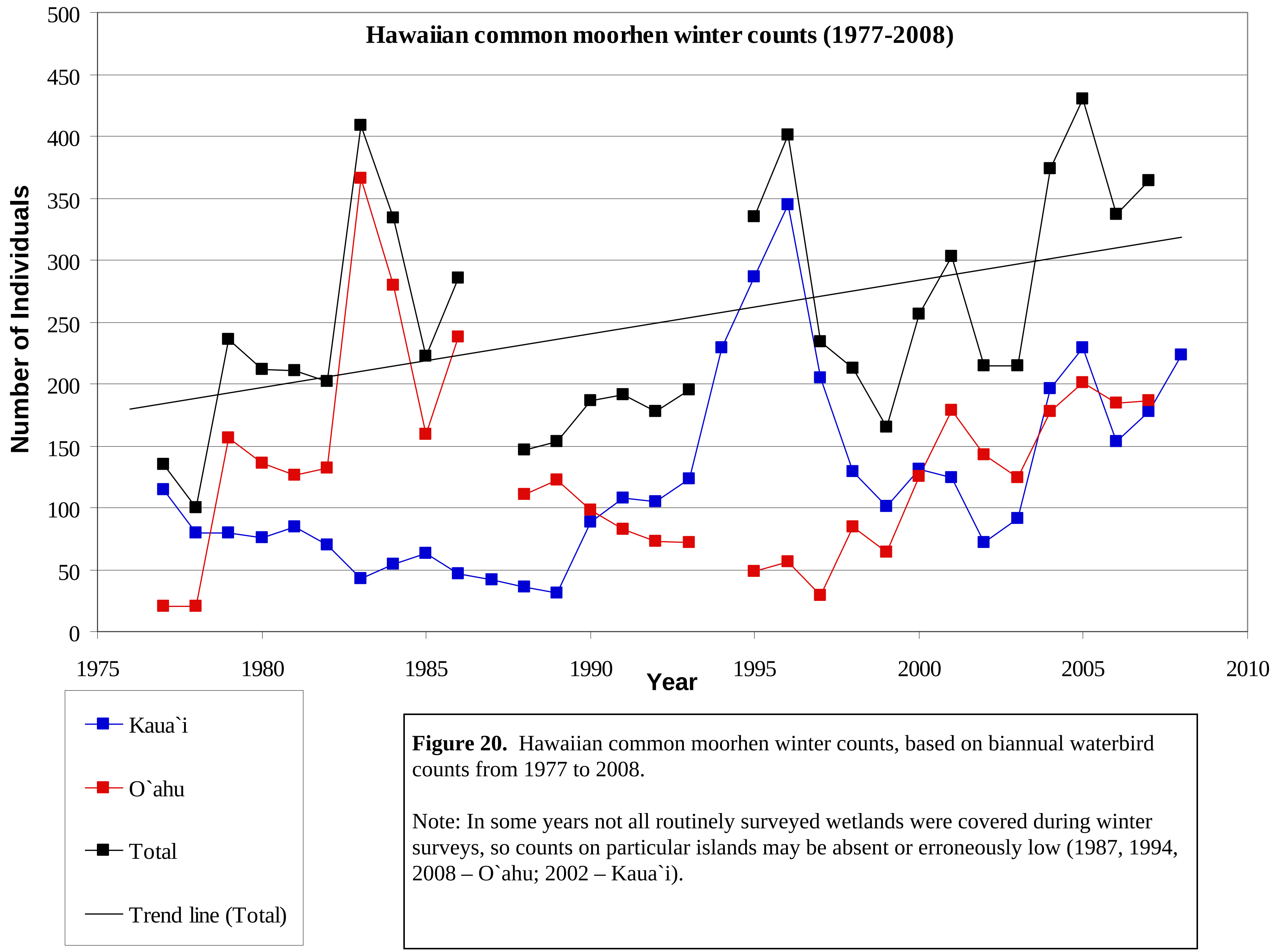

Figure 20. Hawaiian common moorhen winter counts, based on biannual waterbird counts from 1977 to 2008.

Note: In some years not all routinely surveyed wetlands were covered during winter surveys, so counts on particular islands may be absent or erroneously low (1987, 1994, 2008 – O`ahu; 2002 – Kaua`i).

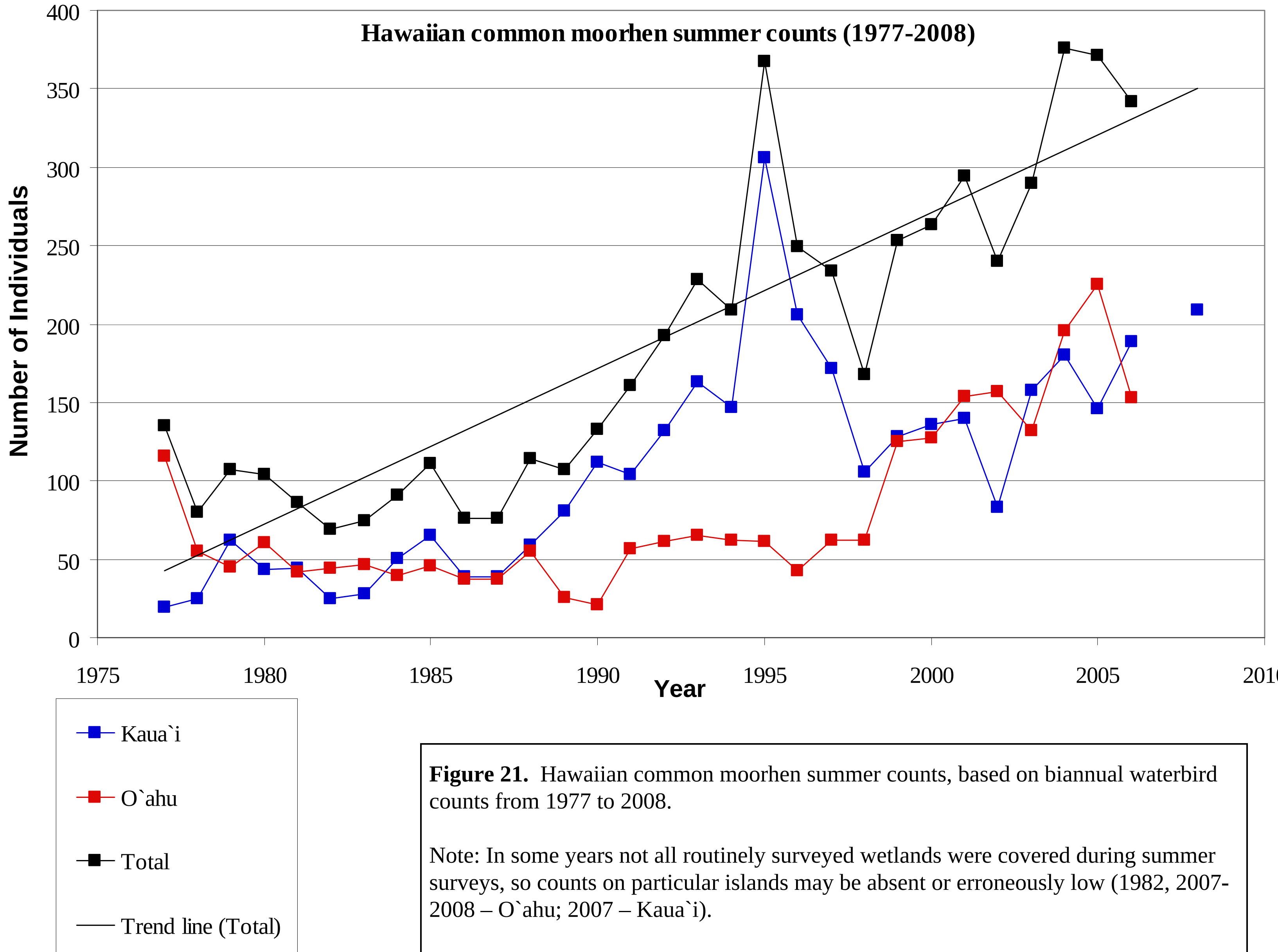

Figure 21. Hawaiian common moorhen summer counts, based on biannual waterbird counts from 1977 to 2008.

Note: In some years not all routinely surveyed wetlands were covered during summer surveys, so counts on particular islands may be absent or erroneously low (1982, 2007-2008 – O`ahu; 2007 – Kaua`i).

i. Kaua`i Population

Hawaiian common moorhens are widely distributed in lowland wetlands and valleys on Kaua`i (Figure 22). Sizable populations exist in the Hanalei and Wailua River valleys, Waiakalua Reservoir, and Wilcox Ponds. The irrigation canals on the Mānā Plain of western Kaua`i also support birds. (HDOFAW 1976-2008). Dense vegetation around lowland reservoirs may also support Hawaiian common moorhens, but nesting is limited by deep water and severe water level fluctuations. Hawaiian common moorhens are also found in wetland agricultural areas such as taro fields. Hawaiian common moorhens also commonly utilize artificially created ponds, such as those at Kaua`i Lagoons where Hawaiian common moorhens are very common, but the significance of such populations to recovery has not been studied.

ii. O`ahu Population

Hawaiian common moorhens are widely distributed on O`ahu, but are most prevalent on the northern and eastern coasts between Hale`iwa and Waimānalo (Figure 23). Small numbers exist in Pearl Harbor, where foraging occurs in semi-brackish water. The population on the leeward coast is limited to Lualualei Valley. Based on biannual waterbird surveys, O`ahu holds approximately half of the State's total population of Hawaiian common moorhens (Figures 20 and 21).

iii. Maui and Moloka`i Populations

In the past, Hawaiian common moorhens were observed regularly on Maui, with unsubstantiated reports of Hawaiian common moorhen from the Ke`anae Peninsula (Shallenberger 1977). Six marked birds were released by Fish and Wildlife Service staff at Kakahai`a National Wildlife Refuge on Moloka`i in June 1983. At least two birds were present in January 1984, but there have been no confirmed sightings since 1985 (USFWS, unpubl. data).

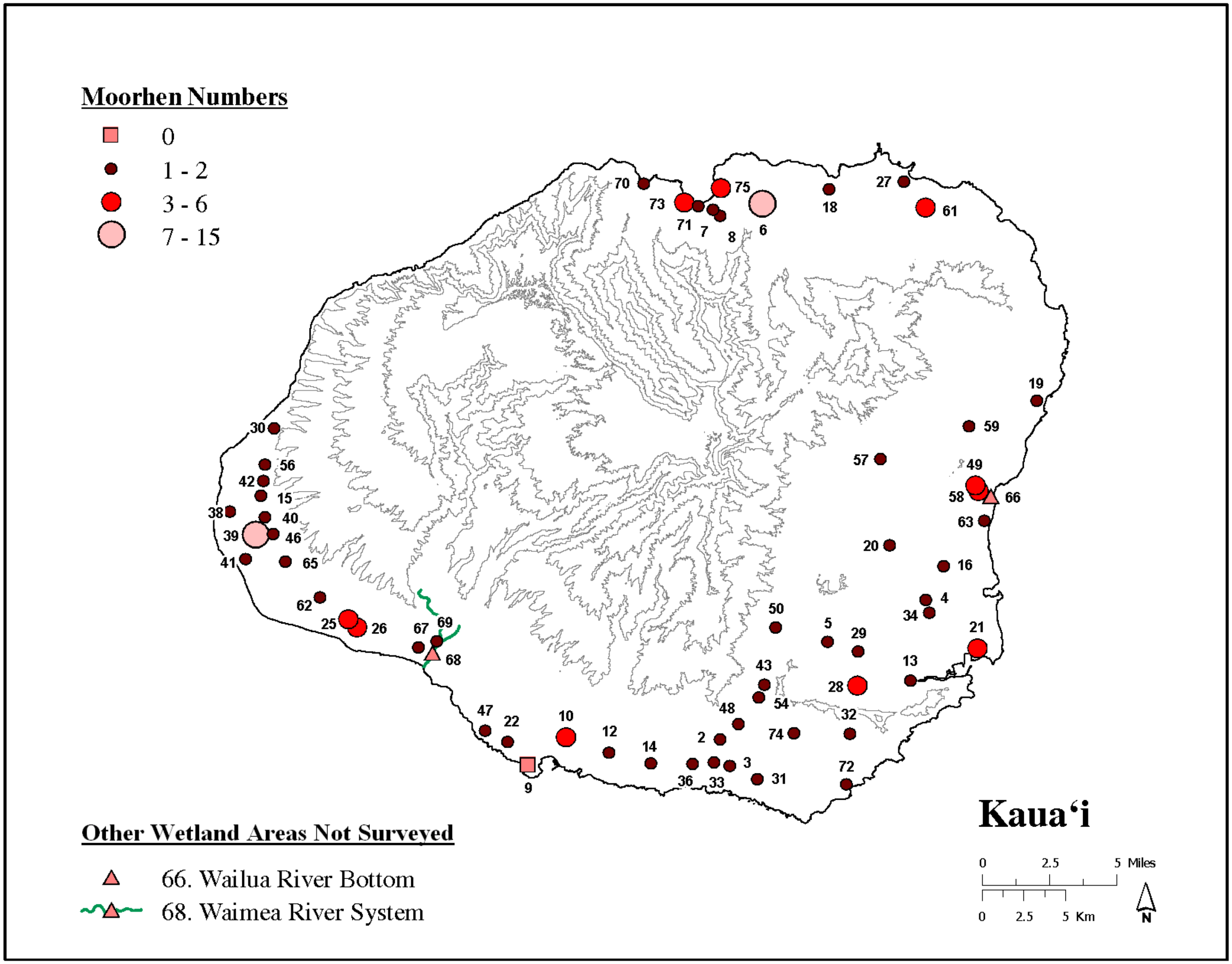

Figure 22. Hawaiian common moorhen numbers at surveyed wetlands on Kaua`i based on the average from winter counts of adults from 1999-2003. The name for each wetland numbered in this figure, as well as whether it is a core or supporting wetland, is listed in Table 1.

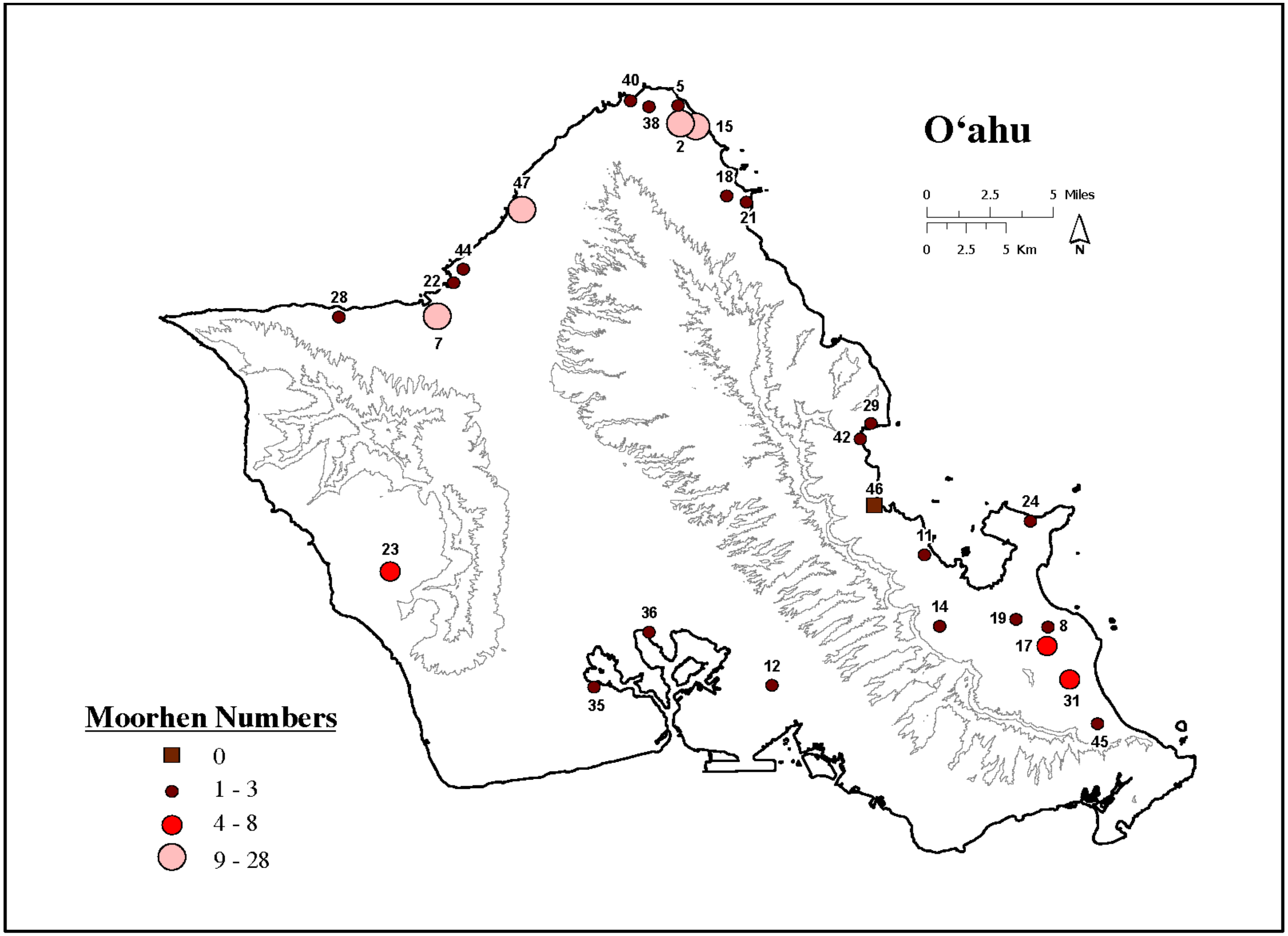

Figure 23. Hawaiian common moorhen numbers at surveyed wetlands on O`ahu based on the average from winter counts of adults from 1999-2003. The name for each wetland numbered in this figure, as well as whether it is a core or supporting wetland, is listed in Table 2.

iv. Hawai`i Population

There are unsubstantiated reports of Hawaiian common moorhen observed on Hawai`i Island (HDOFAW, unpubl. data), but no confirmed reports.

(e) Life History

Little is known of the Hawaiian common moorhen's breeding biology. Most nests are inconspicuously placed within dense emergent vegetation over shallow water. Hawaiian common moorhens generally nest in areas with standing freshwater less than 60 centimeters (24 inches) deep. The emergent vegetation is folded over into a platform nest (Shallenberger 1977). Where emergent aquatic vegetation is insufficient, nests may be placed on the ground, but most have tall cover nearby. Apparently, the particular species of emergent plant used for nest construction by Hawaiian common moorhens is unimportant as long as it is a robust emergent (Weller and Fredrickson 1973).

Like other common moorhen subspecies, the Hawaiian common moorhen is territorial. Territory size of nesting pairs at Hāmākua Marsh on O`ahu ranged from 853 to 2,416 square meters (9,182 to 26,006 square feet) (Smith and Polhemus 2003). Nesting occurs year-round, but most activity extends from March through August and is influenced by water levels and vegetation growth (Shallenberger 1977; Byrd and Zeillemaker 1981; Chang 1990). Clutch size differed among 2 island investigations, averaging 4.9 eggs on Kaua`i (n = 87 nests) (Chang 1990) and 5.6 eggs on O`ahu (n = 64 nests; Byrd and Zeillemaker 1981). An average clutch size of 8.4 eggs was reported from 7 North American moorhen sites (Byrd and Zeillemaker 1981). The incubation period ranges from 19 to 22 days (Byrd and Zeillemaker 1981). Hawaiian common moorhens are a precocial species; chicks are covered with down and are able to walk, but are dependent on the parents for several weeks. Renesting and multiple broods during one season have been observed (Byrd and Zeillemaker 1981). Brood sizes have been observed to range from 2 to 7 chicks (mean of 4.4 chicks per brood) at Hāmākua Marsh, O`ahu (Smith and Polhemus 2003). Flooding is a major cause of nest failure (Byrd and Zeillemaker 1981).

Little information is available on the feeding habits of the Hawaiian common moorhen. Food items consumed by this subspecies may include algae,

aquatic insects, and mollusks (Schwartz and Schwartz 1949). Telfer (unpubl. data) found remains of snails, guava seeds, algae, and other plant material in stomachs of road-killed Hawaiian common moorhens on Kaua`i. Seeds of grasses, parts of various plants, and other types of invertebrates are probably also included in the Hawaiian common moorhen's diet. These birds are apparently opportunistic feeders, so the diet may vary with the particular habitat (Shallenberger 1977).

Hawaiian common moorhens are the most secretive of the native Hawaiian waterbirds, generally foraging in dense emergent vegetation. Most birds feeding along the edge or in the open quickly seek cover when disturbed. Hawaiian common moorhens are good swimmers and often cross open water to reach foraging sites. They are generally sedentary; however, they readily disperse in spring, presumably to breed (Nagata 1983). Dispersal may occur in relation to dry and wet periods (Engilis and Pratt 1993). This pattern also occurs in a similar island common moorhen subspecies, the Mariana common moorhen (*Gallinula chloropus guami*), where moorhens exhibited reduced breeding and natal site fidelity during the dry period. This pattern was presumably in response to resource shifts caused by flooded habitat and creation of new seasonal habitat, and possibly behavioral changes as juveniles dispersed to other wetlands (Takano 2003). Mariana common moorhens have also been documented to move between islands in response to high rainfall during the wet season and creation of new habitat (Worthington 1998; Takano and Haig 2004b). Whether the Hawaiian common moorhen is capable of inter-island movement is unknown.

There is no information on the lifespan or survivorship of Hawaiian common moorhen; however, a banded common moorhen (*Gallinula chloropus*) was recaptured at an age of approximately 10.5 years (Clapp *et al*. 1982).

(f) Habitat Description

Hawaiian common moorhen habitat consists of freshwater marshes, taro patches, lotus fields, reedy margins of water courses (streams, irrigation ditches, etc.), reservoirs, wet pastures, and occasionally saline and brackish water areas. They appear to prefer lowland freshwater habitats. The conversion of aquaculture ponds in Kahuku, O`ahu, from fresh to salt water resulted in an observed decline in Hawaiian common moorhen numbers (Engilis and Pratt 1993) apparently due to a preference for freshwater. High numbers of nesting Hawaiian common

moorhens are found at the Hanalei National Wildlife Refuge and taro fields on the island of Kaua`i, and at the Ki`i Unit of James Campbell National Wildlife Refuge, Kahuku and `Uko`a wetlands, and Waialua lotus fields on O`ahu.

The key features of habitat areas for Hawaiian common moorhens are: 1) dense stands of robust emergent vegetation near open water, 2) floating or barely emergent mats of vegetation, 3) water depth less than 1 meter (3.3 feet), and 4) fresh water (as opposed to saline or brackish water). Interspersion of robust emergent vegetation and open water is important for common moorhens on the mainland, and presumably is also for the Hawaiian subspecies. For North American common moorhens, Weller and Frederickson (1973) found that the optimal overall ratio of emergent vegetation to open water was 50:50. Continued management of wetland areas is necessary to maintain these habitat conditions.

4. Hawaiian Stilt or Ae`o

(a) Taxonomy

The Hawaiian stilt or ae`o (*Himantopus mexicanus knudseni*) is part of a cosmopolitan superspecies complex including the black-necked stilt (*Himantopus mexicanus*) of North and South America, the black-winged stilt (*H. himantopus*) of Eurasia and Africa, and pied stilt (*H. leucocephalus*) and black stilt (*H. novazelandiae*) from Australasia (Mayr and Short 1970, AOU 1998, Robinson *et al*. 1999). The Hawaiian stilt is clearly allied with the black-necked stilt and is considered a distinct subspecies (AOU 1998). Colonization of Hawai`i by stilts probably resulted from North American vagrants.

(b) Species Description

The Hawaiian stilt is a slender wading bird, black above (except for the forehead) and white below with distinctive long, pink legs (Figure 24). The Hawaiian stilt differs from North American black-necked stilts by having black coloration extending lower on the forehead as well as around the sides of the neck, and by having a longer bill, tarsus (lower leg), and tail (Coleman 1981; Robinson *et al*. 1999). Sexes are distinguished by the color of the back feathers (brownish in females, black in males) as well as voice (lower in females). Downy

Figure 24 (left). Hawaiian stilt female and male. Photo by Eric VanderWerf.

Figure 25 (right). Hawaiian stilt nest with chicks. Photo by Leila Gibson.

chicks are well camouflaged, tan with black speckling (Figure 25). Immature birds have a brownish back and more extensive white on the cheeks and forehead (Coleman 1981). Immature birds produce a sharp peeping call. The total length of adult Hawaiian stilts is about 40 centimeters (16 inches).

(c) Historical Range and Population Status

Hawaiian stilts were historically known from all of the major islands except Lāna`i and Kaho`olawe (Paton and Scott 1985). Prior to 1961, documented records of Hawaiian stilts on the island of Hawai`i were limited to three collected by S. B. Wilson in the late 1800s and possibly one collected by Collett prior to 1893 (Banko 1979). As with the other Hawaiian waterbirds, there are no estimates of historical numbers, although Henshaw (1902) wrote that Hawaiian stilts were common on O`ahu in the late 1800s, but were scarce by 1900. Extensive wetlands historically provided a fair amount of habitat, and lands under aquatic agriculture were also used by Hawaiian stilts. Loss of natural wetland habitat as well as the previously noted decline in aquatic agriculture lands undoubtedly caused a decrease in Hawaiian stilt numbers. It has been suggested that the population had declined to approximately 200 birds by the early 1940s (Munro 1960). This number, however, may have been an underestimation of the

population, as other estimates from the late 1940s place the population at approximately 1,000 birds (Schwartz and Schwartz 1949). This number may still be a low estimate, as a sizable number of Hawaiian stilts can be found seasonally on Ni`ihau, which was not surveyed in the 1940s.

The Hawaiian stilt was a popular game bird, and hunting contributed to local population declines until waterbird hunting was prohibited in 1939 (Henshaw 1902; Schwartz and Schwartz 1949). Handy and Handy (1972) indicated that Hawaiians had a tradition of hunting Hawaiian stilts, though the flesh was apparently of little value for food (Henshaw 1902). Predation has also affected Hawaiian stilt populations historically (also see section I.B.4.e, Life History, below).

(d) Current Range and Population Status

Hawaiian stilts are currently found on all of the main Hawaiian Islands except Kaho`olawe. The first Hawaiian stilts on Lāna`i were documented in 1989 at the Lāna`i City wastewater treatment ponds (Engilis and Pratt 1993; M. Ueoka, pers. comm. 1993). Based on biannual Hawaiian waterbird surveys from 1998 through 2007, the Hawaiian stilt population averaged 1,484 birds, but fluctuated between approximately 1,100 and 2,100 birds (HDOFAW 1976-2008; Figure 26). The census method used during these surveys appears to provide a reasonably accurate picture of the number of Hawaiian stilts at a site; Hawaiian stilts are undercounted the least of the Hawaiian waterbirds because they do not usually evade observers and their contrasting colors allow for high detectability (Chang 1990). Summer counts were not averaged because these counts are generally more variable than winter counts due to the variability in hatch-year bird survival (Reed and Oring 1993).

Long-term census data indicate statewide populations have been relatively stable or slightly increasing for the last 30 years (Reed and Oring 1993; Figures 26 and 27). As with Hawaiian coots, census data show year-to-year variability in the number of Hawaiian stilts observed. This variability can be partially explained by rainfall patterns and reproductive success (Engilis and Pratt 1993). Hawaiian

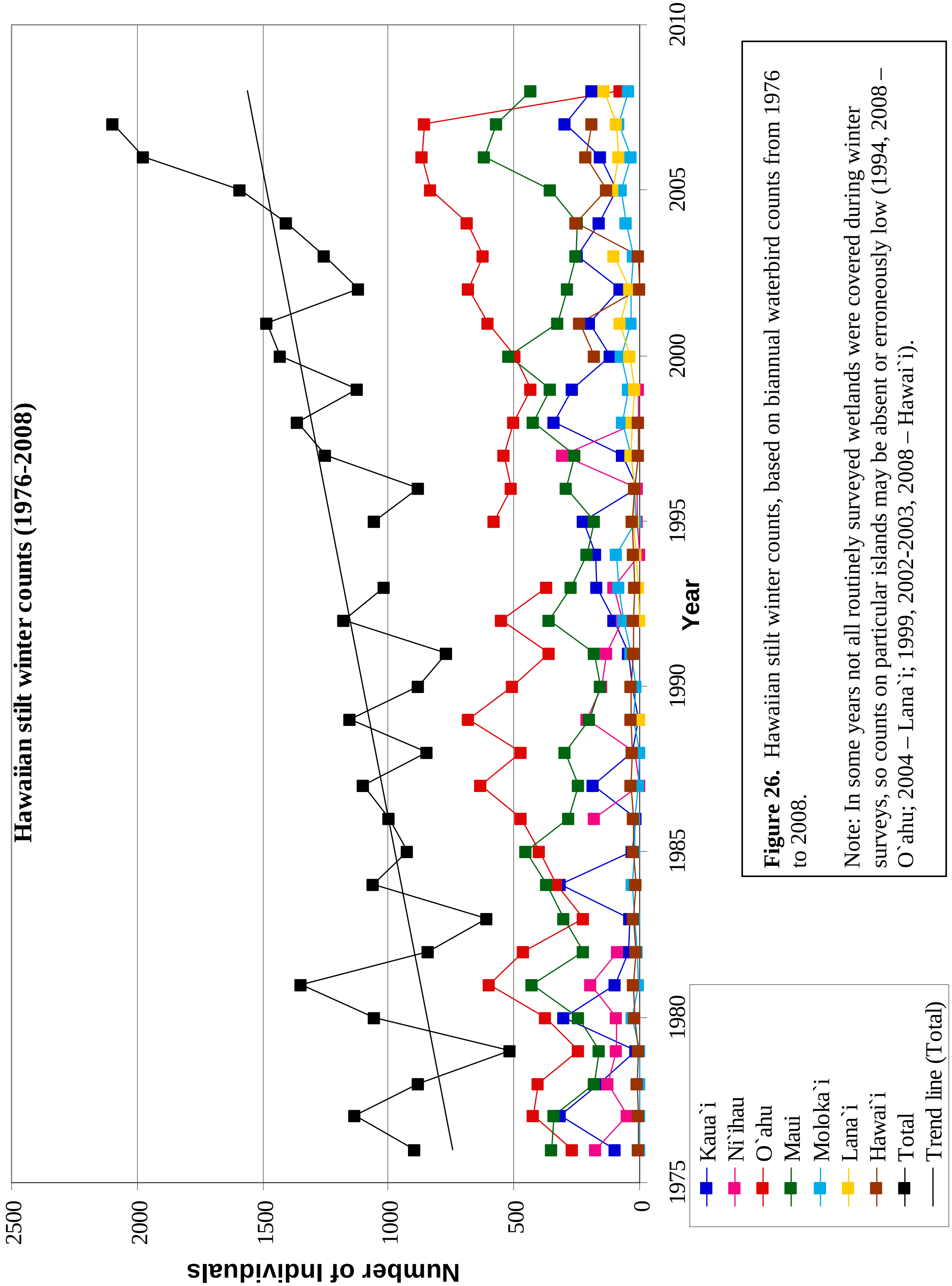

Figure 26. Hawaiian stilt winter counts, based on biannual waterbird counts from 1976 to 2008.

Note: In some years not all routinely surveyed wetlands were covered during winter surveys, so counts on particular islands may be absent or erroneously low (1994, 2008 – O`ahu; 1999, 2002-2003, 2008 – Hawai`i; 2004 – Lana`i).

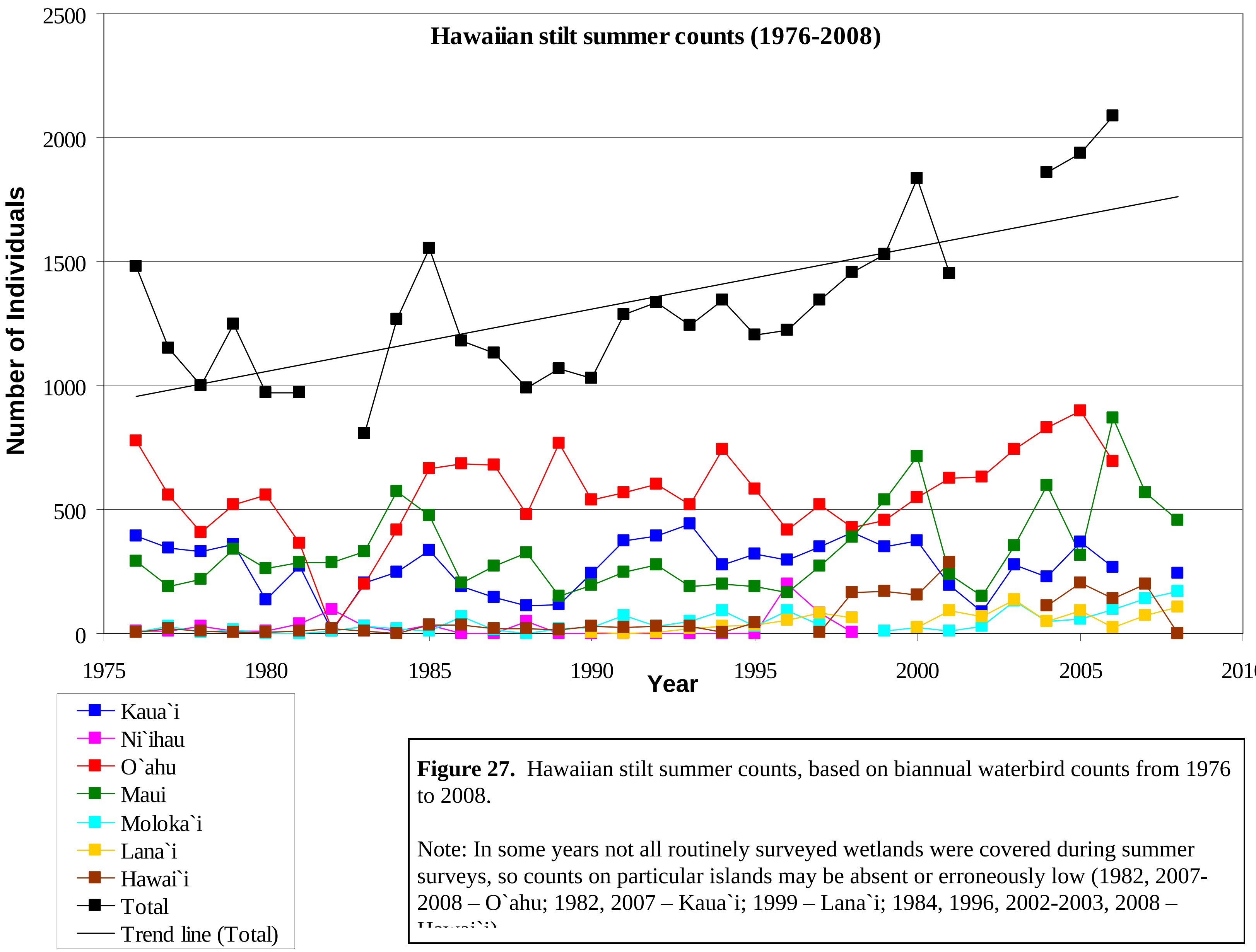

Figure 27. Hawaiian stilt summer counts, based on biannual waterbird counts from 1976 to 2008.

Note: In some years not all routinely surveyed wetlands were covered during summer surveys, so counts on particular islands may be absent or erroneously low (1982, 2007-2008 – O`ahu; 1982, 2007 – Kaua`i; 1999 – Lana`i; 1984, 1996, 2002-2003, 2008 – Hawai`i)

stilts readily disperse between various islands, and collectively the Hawaiian island subpopulations constitute one population (Reed *et al*. 1994, 1998b). The population viability assessment (PVA) conducted by Reed *et al*. (1998a) indicated that (given their model assumptions), the Hawaiian stilt population will not decline over 200 years and should increase to fill available habitat. Available habitat is thought to be crucial as it limits carrying capacity, and models suggest that if currently available habitat is maintained through management (particularly predator control and regulation of water level fluctuations), they are adequate for self-sustaining populations of Hawaiian stilts for 200 years (Reed *et al*. 1998a).

i. Kaua`i and Ni`ihau Populations

Considerable movement of Hawaiian stilts occurs between these two islands, apparently in response to rainfall patterns and the flooding and drying of Ni`ihau's ephemeral lakes (Engilis and Pratt 1993). On Kaua`i, Hawaiian stilts are numerous in large river valleys such as Hanalei, Wailua, and Lumaha`i, and on the Mānā Plain (Figure 28). Hawaiian stilts also frequent Kaua`i's reservoirs, particularly during drawdown periods, as well as sugarcane effluent ponds in Līhu`e and Waimea.

Over 5 years (excluding 2002 because of missing data), the Hawaiian stilt population on Kaua`i has fluctuated between approximately 125 to 350 birds (HDOFAW 1976-2008). Ni`ihau can potentially support a large number of Hawaiian stilts when the extensive ephemeral lakes are flooded. In 1939, Munro reported several hundred Hawaiian stilts on Ni`ihau (Hawai`i Audubon Society 1999) and numbers in the hundreds have occasionally been recorded there during biannual waterbird counts (HDOFAW 1976-2008).

ii. O`ahu Population

O`ahu supports the largest number of Hawaiian stilts in the Hawaiian Islands (Engilis 1988; HDOFAW 1976-2008). Large concentrations of Hawaiian stilts can be found at the James Campbell National Wildlife Refuge, the Kahuku aquaculture ponds, the Honouliuli and Waiawa units of the Pearl Harbor National Wildlife Refuge, and on Nu`upia Ponds in Kāne`ohe. Populations also exist at the Chevron Refinery, the fishponds at Kualoa Beach Park, at Salt Lake District Park, and at scattered locations along the northern and eastern coasts. Over the past 5 years, O`ahu accounted for 35 to 50

percent of the State's Hawaiian stilt population, with approximately 450 to 700 birds counted during any single year (HDOFAW 1976-2008; Figure 29).

iii. Maui, Moloka`i, and Lāna`i (Maui Nui) Populations

Maui's two large coastal wetlands, Kanahā and Keālia, support a significant number of Hawaiian stilts, with important nesting habitat at Keālia. Monthly counts indicate that birds freely move between these two wetlands, apparently in search of optimal foraging habitat (Ueoka 1979). A small number of Hawaiian stilts also frequent aquaculture areas on Maui. Over the past 5 years, Hawaiian stilt numbers have ranged from approximately 250 to 530 birds (HDOFAW 1976-2008; Figure 30).

Moloka`i's south coastal wetlands and playa lakes are, at times, important habitats for Hawaiian stilts, with large concentrations at the Kaunakakai Wastewater Reclamation Facility (Figure 31). There is some evidence of periodic movements of birds between Maui and Moloka`i, again probably in response to available foraging habitat (Engilis and Pratt 1993). Since 1968, statewide waterbird surveys have shown a significant increase in Hawaiian stilts on Moloka`i (Reed and Oring 1993). On Moloka`i, the Hawaiian stilt population has fluctuated between approximately 25 to 90 birds over the past 10 years (HDOFAW 1976-2008).

Hawaiian stilts are now permanent residents at the Lāna`i City wastewater treatment pond. They have been recorded there annually since the ponds became operational in 1989, and numbers sometimes exceed 100 birds (HDOFAW 1976-2008).

iv. Hawai`i Population

The Kona Coast from Kawaihae Harbor south to Kailua supports the largest number of Hawaiian stilts on Hawai`i Island, with `Ōpae`ula and `Aimakapā Ponds being key breeding areas (Figure 32). These two ponds anchor the continuous network of wetlands along the Kona Coast and together have maintained 95 percent of the Hawaiian stilts and 90 percent of the Hawaiian coots for Hawai`i Island (Paton *et al*. 1985; M, Morin, *in litt*. 2005). Until 2003, the Cyanotech Ponds were a key breeding area because management focused on providing adequate breeding habitat for Hawaiian

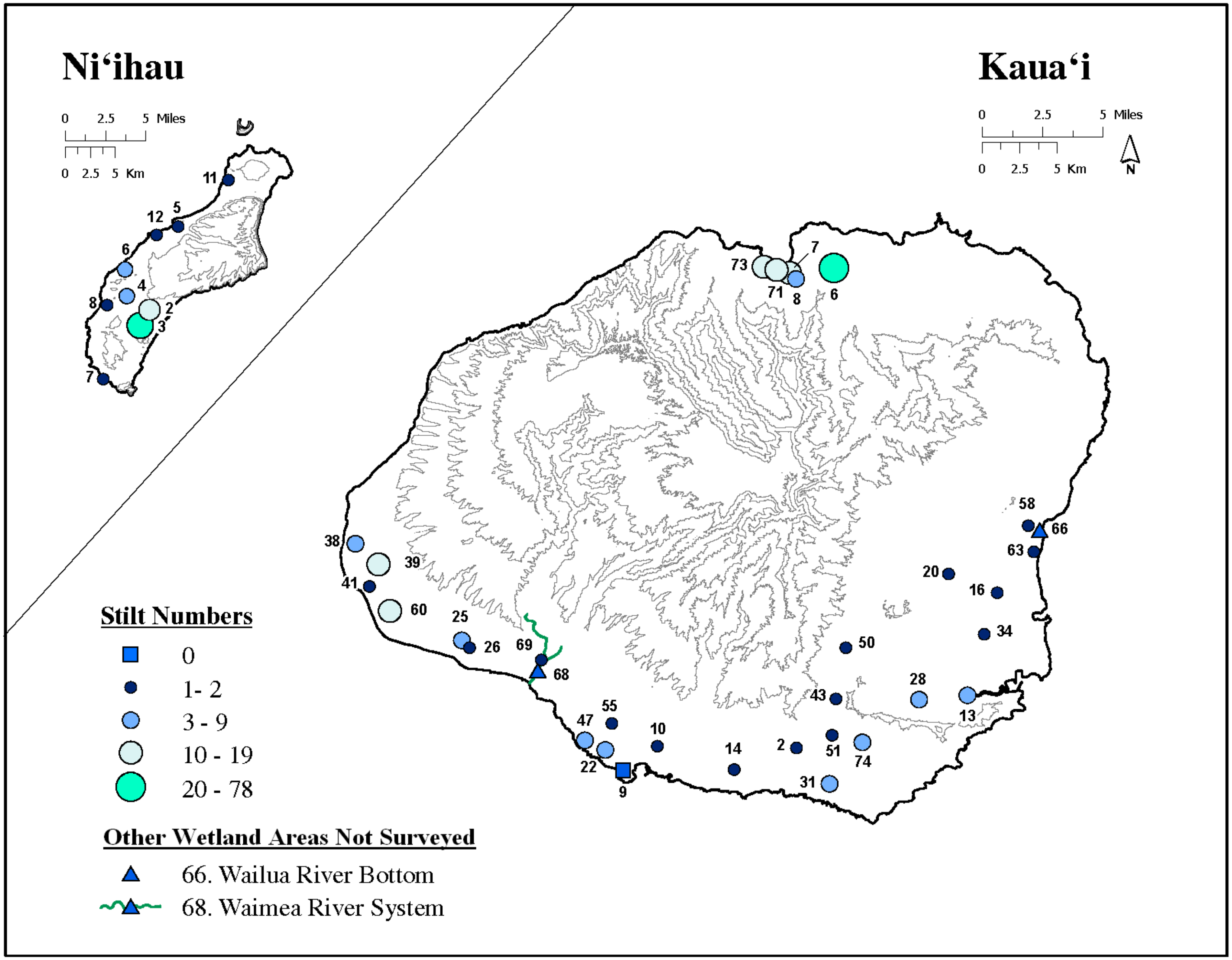

Figure 28. Hawaiian stilt numbers at surveyed wetlands on Kaua`i and Ni`ihau based on the average from winter counts of adults from 1999-2003 for Kaua`i and 1993, 1995, 1996, 1997, 1999 for Ni`ihau. The name for each wetland numbered in this figure, as well as whether it is a core or supporting wetland, is listed in Table 1.

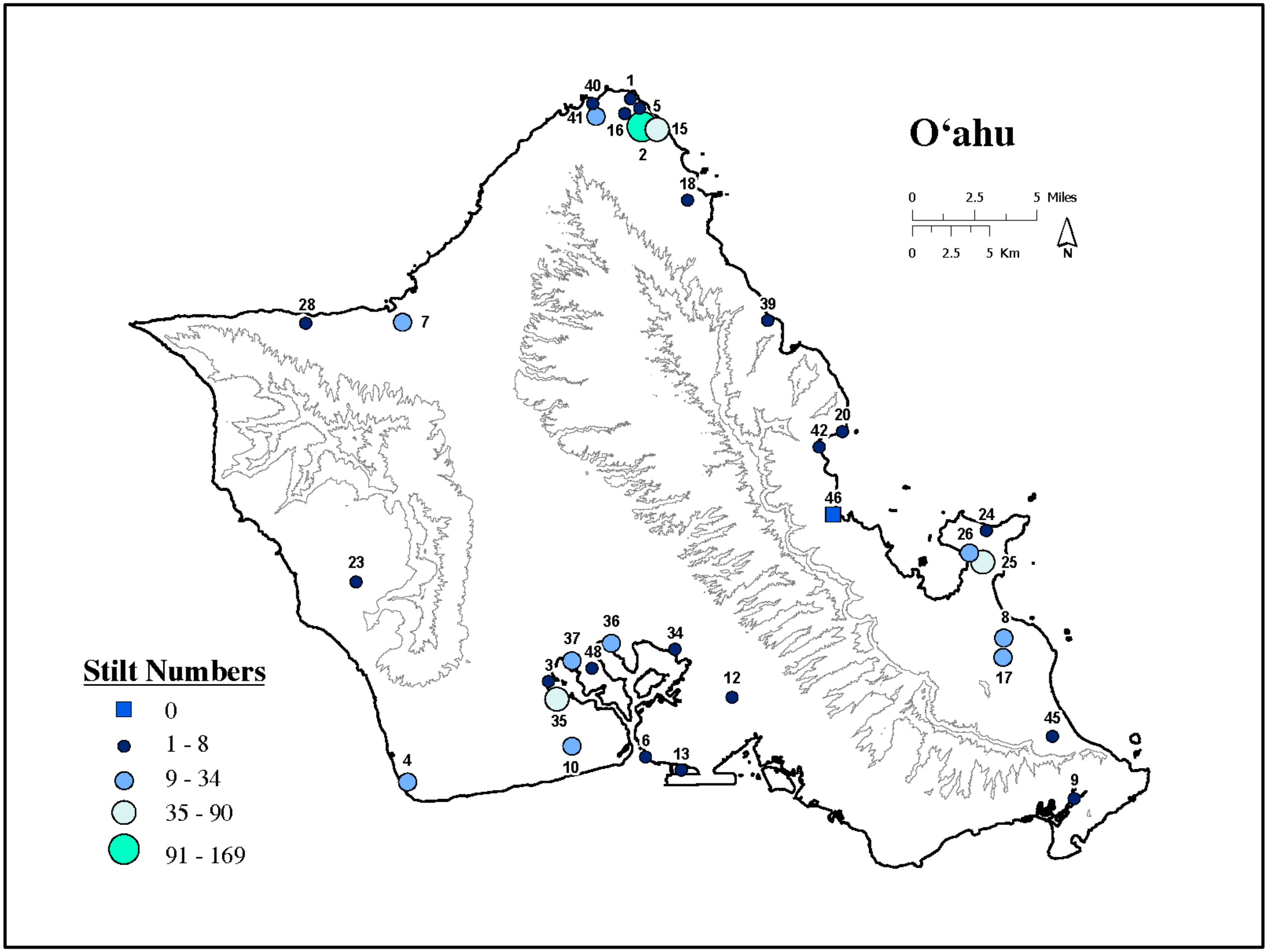

Figure 29. Hawaiian stilt numbers at surveyed wetlands on O`ahu based on the average from winter counts of adults from 1999-2003. The name for each wetland numbered in this figure, as well as whether it is a core or supporting wetland, is listed in Table 2.

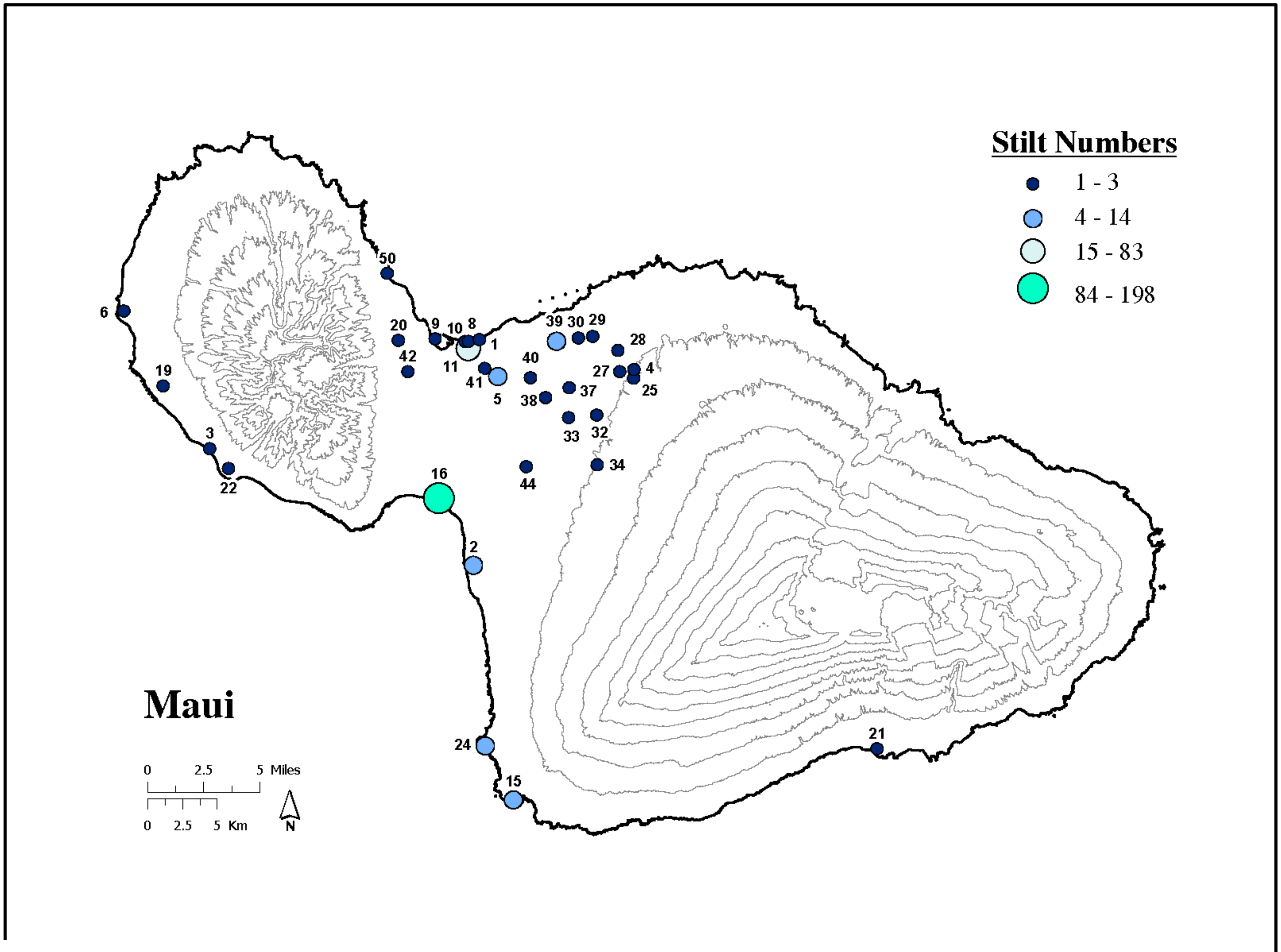

Figure 30. Hawaiian stilt numbers at surveyed wetlands on Maui i based on the average from winter counts of adults from 1999-2003. The name for each wetland numbered in this figure, as well as whether it is a core or supporting wetland, is listed in Table 3.

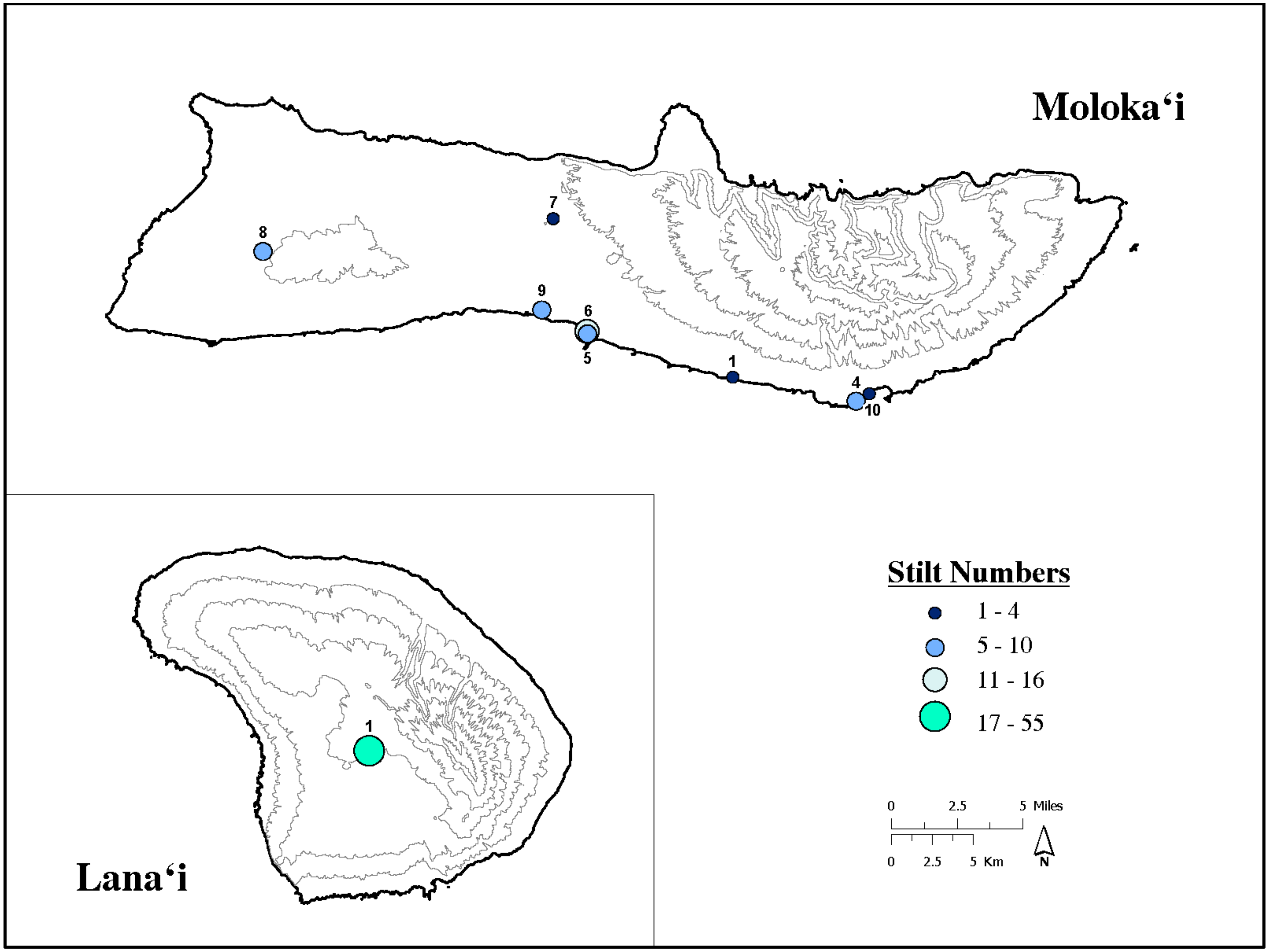

Figure 31. Hawaiian stilt numbers at surveyed wetlands on Moloka`i and Lāna`i i based on the average from winter counts of adults from 1999-2003. The name for each wetland numbered in this figure, as well as whether it is a core or supporting wetland, is listed in Table 4.

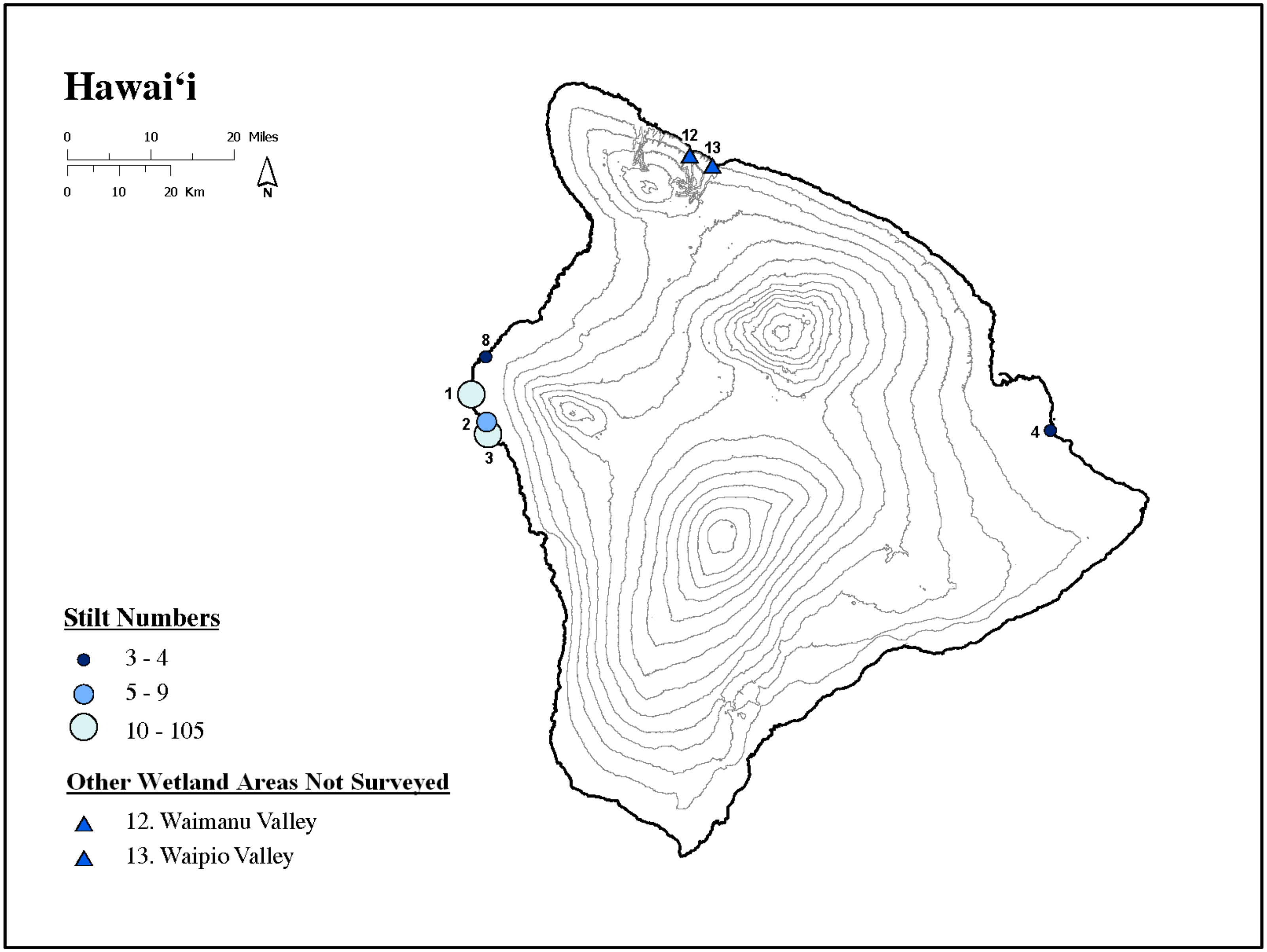

Figure 32. Hawaiian stilt numbers at surveyed wetlands on Hawai`i i based on the average from winter counts of adults from 1999-2003. The name for each wetland numbered in this figure, as well as whether it is a core or supporting wetland, is listed in Table 5.

stilts to minimize nesting attempts in hazardous areas (Evans and Uyehara 2001; Waddington 2003). For a variety of reasons, these ponds are no longer managed as breeding habitat for Hawaiian stilts. However, we are working with Cyanotech and the State to provide suitable nesting habitats for Hawaiian stilts displaced from the site, and Cyanotech is funding predator control actions at `Ōpae`ula Pond (J. Kwon, pers. comm. 2008, Waddington 2010). The anchialine[2] pools north of the harbor in Kona are also important Hawaiian stilt as well as Hawaiian coot habitat (M. Morin, *in litt*. 2005).

Hawaiian stilts can also be found along the Hāmākua Coast and in the Kohala River valleys of Waipi`o, Waimanu, and Pololū. The scattered anchialine ponds along the Kona Coast are important feeding sites. Hawaiian stilts have become numerous at the Kona (Kealakehe) wastewater treatment plant. The County of Hawai`i has designed wildlife habitat for Hawaiian stilts to fit within the 12-hectare (30-acre) perimeter around the Kona Wastewater Treatment Plant. Comprehensive surveys on Hawai`i have placed the Kona Coast population at 130 birds (Ducks Unlimited 1993 to 1997). Based on biannual waterbird surveys (2000 to 2007), there are approximately 200 birds islandwide (HDOFAW 1976-2008; Figure 26).

(e) Life History

Hawaiian stilts generally nest on freshly exposed mudflats interspersed with low-growing vegetation. The nest itself is a simple scrape on the ground. They have also been observed using grass stems and rocks for nesting material (Coleman 1981; M. Morin, pers. comm. 1994). Nesting also occurs on islands (natural and manmade) in freshwater or brackish ponds (Shallenberger 1977). Higher nesting densities are found on large mudflat expanses interspersed with vegetation. Hawaiian stilts have also been observed successfully using manmade floating nest structures on Kaua`i (T. Telfer, pers. comm. 1988) and floating wooden platforms at `Aimakapā Pond in Kona, Hawai`i (Morin 1994; M. Morin, pers. comm. 1999). Coleman (1981) found that 80 percent of 438 nests located on O`ahu were placed on islands ranging in size from 20 centimeters to 20 meters (8 inches to 66 feet) in diameter. Hawaiian stilts are territorial, with average inter-nest distances varying from 16 to 80 or more meters (53 to 262 feet) (Coleman 1981, Robinson *et al*. 1999). Coleman (1981) found that the overall average distance between active nests in a "colony" ranged from 21

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[2] Land-locked brackish-water pools adjacent to the ocean, lacking surface connection to the ocean but with a subterranean connection and showing a damping tidal fluctuation in water level.

meters (69 feet) at Salt Lake to 70 meters (230 feet) at Nu`upia; 38 percent of 366 active nests had no active nests within 50 meters (164 feet), 35 percent of nests had one active nest, and 19 percent of nests had two active nests within 50 meters (164 feet).

The nesting season normally extends from mid-February through August, but varies among years, perhaps depending on water levels. Hawaiian stilts usually lay 3 to 4 eggs that are incubated for approximately 24 days (Coleman 1981; Chang 1990). Chicks are precocial, leaving the nest within 24 hours of hatching. Young may remain with both parents for several months after hatching (Coleman 1981). Parents are extremely aggressive toward unrelated young (Robinson *et al*. 1999).

A hatching success of 54 percent (n = 243 nests, 833 eggs) was reported for Hawaiian stilts at the Ki`i Unit of the James Campbell National Wildlife Refuge (Chang 1990). Of the 243 total nests observed at Ki`i, during a period when predators were being controlled (A. Nadig, USFWS, pers. comm. 2011), 61 (25 percent) were lost to predation and 42 (17 percent) were lost to flooding or abandonment (Chang 1990). Robinson *et al*. (1999) estimated long-term means of 2.18 Hawaiian stilt chicks hatched per nest (n = 982) and 0.93 fledged per brood (n = 131). Evans and Uyehara (2001) summarized Hawaiian stilt reproductive success at eight locations on O`ahu, Hawai`i, and Maui; the highest percent nesting success occurred at Cyanotech and fledging success was highest at Cyanotech and Chevron. In a study at the James Campbell National Wildlife Refuge, bullfrogs were found to be an important predator of young Hawaiian stilts based on tracking of birds fitted with radio transmitters (Eijzenga 2004). It should be noted that many other predators on the Refuge (*e.g.*, dogs, cats, and mongooses) were controlled during this study.

Other predators of Hawaiian stilts include mongooses, black rats (*Rattus rattus*), feral cats, feral dogs, black-crowned night herons, cattle egrets, Hawaiian short-eared owl or pueo (*Asio flammeus sandwichensis*), and common mynas (*Acridotheres tristis*) (Coleman 1981, Robinson *et al*. 1999). Hawaiian stilts have a variety of antipredator behaviors, including mobbing aerial predators, a "popcorn display" (birds hopping and flapping around a ground predator), and striking ground predators from behind with their legs (Dougherty *et al.* 1978; Robinson *et al*. 1999). Because of their exposed nest sites, Hawaiian stilts appear to be more susceptible to avian predators than are other Hawaiian waterbirds.

Hawaiian stilts are opportunistic feeders. They eat a wide variety of invertebrates and other aquatic organisms as available in shallow water and mudflats. Specific organisms taken include water boatmen (insects in the family *Corixidae*), beetles (order *Coleoptera*), possibly brine fly (*Ephydra riparia*) larvae, polychaete worms, small crabs, fish (*e.g.*,

Mozambique tilapia [*Oreochromis mossambica*] and mosquito fish [*Gambusia affinis*]), and tadpoles (*Bufo* spp.) (Shallenberger 1977; Robinson *et al*. 1999). Midges are an important food source for Hawaiian stilts; in taro patches at Hanalei National Wildlife Refuge, silt and midge abundance were positively related and Hawaiian stilt and mosquito fish abundance were negatively related; mosquito fish, not Hawaiian stilts, were limiting midge populations (Broshears 1979).

Feeding typically occurs in shallow flooded wetlands. These types of wetlands are ephemeral in nature and may appear at any time of year, but are primarily available in winter. Hawaiian stilts require specific conditions (water depths of 13 centimeters [5 inches] or less) for optimal foraging (Telfer 1973; Gee 2007). Thus, intra- and inter-island movement is an important strategy for exploiting food resources; movement between O`ahu and Maui has been documented by statewide waterbird survey data and banding studies (Ueoka 1979; Engilis and Pratt 1993; Reed *et al*. 1994; 1998b).

Little is known about the lifespan or survivorship of the Hawaiian stilt. From two Hawaiian stilt cohorts, Reed *et al*. (1998a) determined first-year survival to be 0.53 and 0.6, and second-year survival for one cohort was 0.81. Hawaiian stilts have survived 15 years in captivity, and several banded wild Hawaiian stilts survived 15 to 17 years (Robinson *et al*. 1999).

(f) Habitat Description

Hawaiian stilts use a variety of aquatic habitats, primarily at lower elevations, but are limited by water depth and vegetation cover. Hawaiian stilts require early successional marshlands with water depth less than 24 centimeters (9 inches), and utilize areas of sparse, low-growing perennial vegetation or exposed tidal flats. Hawaiian stilts appear to select sites with little or even no cover surrounding the nest (Coleman 1981), presumably so their ability to spot predators is not affected (Morin 1998). In many wetlands, the predominant vegetation is invasive and introduced, including non-native pickleweed (*Batis maritima*) and California grass (*Brachiaria mutica*), and must be controlled by active management (Robinson *et al*. 1999). Nesting occurs almost exclusively on human-maintained wetlands as others are too overgrown (Robinson *et al*. 1999). Hawaiian stilts use taro ponds in the wet fallow and early stages of planting before the plants form a canopy (Broshears 1979; Gee 2007). However, Hawaiian stilts do not frequent closed canopy taro patches (K. Uyehara, University of California, Davis, *in litt*. 2005), and harvest and flooding of the taro patches often adversely affects reproduction (Robinson *et al*. 1999).

Ephemeral wetlands on Moloka`i, Maui, and Ni`ihau are important for Hawaiian stilts. Management techniques that mimic seasonal inundation and evaporation of freshwater mudflats are beneficial to nesting Hawaiian stilts and provide invertebrate forage for their young. Insular mudflats that are isolated from terrestrial predators are still susceptible to avian and amphibian predation. On the island of Hawai`i, anchialine ponds provide important foraging habitat for the Hawaiian stilt. Prawn farms, which have numerous ponds with changing water levels, provide excellent foraging habitat for adult birds.

During the nesting season, incubating pairs may move between the nest site and a foraging area. Adults with 3-day-old chicks have been observed to move 0.5 kilometer (0.3 mile) from the nest site to foraging sites (Reed and Oring 1993). Coleman (1981) observed that within a few hours of the last chick hatching, parents lead their brood to a shallow feeding area that may be the same feeding site used by the adults during incubation. Coleman (1981) also observed that adults will carve out nesting territories and foraging areas which they actively defend. Nesting sites are adjacent to or on low-relief islands within bodies of fresh, brackish, or salt water. These include irrigation reservoirs and settling basins, natural or manmade ponds, marshes, taro patches, silted ancient fish ponds, salt evaporation pans, and other wetlands.

Feeding habitat consists of shallow water that may be fresh, brackish, or saline. Freshwater sites include managed wetlands, irrigation ditches, reservoirs, settling basins, taro patches, sewage ponds, and marshes. Brackish-water feeding habitat consists of coastal ponds, fish ponds, and estuaries. Saltwater feeding habitat includes inshore reefs, beach areas, and tidal flats. Ephemeral ponds provide an immediate and short term food supply with the emergence of invertebrates (S. Pelizza, *in litt*. 2005). Loafing areas include open mudflats, sparsely vegetated pickleweed flats, and pasture lands. Such areas may be utilized because of good visibility in open habitat. Pasture lands appear to be used on an opportunistic basis following wet weather (S. Pelizza, *in litt*. 2005).

C. WETLAND IDENTIFICATION TABLES

The tables below identify wetlands that provide habitat for the four endangered Hawaiian waterbirds. Certain sites are identified as "core" or "supporting" wetlands. As described below in section II.B (Recovery Strategy), core wetlands provide habitat essential for the larger populations of Hawaiian waterbirds that comprise the bulk of the numbers prescribed for recovery, while supporting wetlands are additional areas that may not support the bulk of waterbird populations but provide habitat important for smaller waterbird populations or that provide habitat needed seasonally by segments of the waterbird populations during part of their life cycle. Both core and supporting wetlands may contribute to meeting recovery criteria for the endangered Hawaiian waterbirds if appropriately managed.

Wetlands identified as "protected" (whether core, supporting, or neither) are those that we consider secure from development. In general these are National Wildlife Refuges, State-owned wildlife sanctuaries, or mitigation wetlands, where the primary purpose of management is wildlife conservation or does not conflict with that goal. While all protected wetlands have at least some value to waterbirds, those that are not considered core or supporting wetlands may not be of sufficient size or quality to play a large role in recovery.

All core and supporting wetlands, as well as other sites included in the biannual waterbird surveys conducted by the Hawaii Division of Forestry and Wildlife, are sequentially numbered in each table, corresponding to the site labels on the species maps (Figures 6 to 9, 14 to 18, 22 to 23, and 28 to 40). Sites that were not included in the surveys and are neither core nor supporting wetlands are listed subsequently, but are not numbered and do not appear on the maps; these sites are typically small and individually constitute relatively minor elements of waterbird habitat.

Table 1. Key to names, locations, and core, supporting, or protected status for wetlands on Kaua`i and Ni`ihau. Numbering key refers to maps in Figures 6, 14, 22, 28, 33, and 34. Unnumbered wetlands, generally relatively minor elements of waterbird habitat, were not included on regular waterbird surveys and are not shown on maps.

Wetland	Island	Number on Map	Core or Supporting Wetland	Protected
Aeopoalua Reservoir	Kaua`i	1		
Aepo Reservoir	Kaua`i	2		
Aepoeha Reservoir	Kaua`i	3		
De Mello Reservoir	Kaua`i	4		
Halenānahu Reservoir	Kaua`i	5		
Hanalei National Wildlife Refuge	Kaua`i	6	Core	X
Hanalei Post Office Taro Fields (Hanalei River and Taro fields that are not part of Hanalei National Wildlife Refuge)	Kaua`i	7	Supporting	
Hanalei Trader Taro Fields (Hanalei River and Taro fields that are not part of Hanalei National Wildlife Refuge)	Kaua`i	8	Supporting	
Hanapēpē Salt Ponds	Kaua`i	9	Supporting	
Hanapēpē Taro Fields	Kaua`i	10		
Hanini Reservoir	Kaua`i	11		
Hukiwai Reservoir	Kaua`i	12		
Hulē`ia National Wildlife Refuge	Kaua`i	13	Core	X
Ioleau Reservoir	Kaua`i	14		
Kahelu Nui Reservoir	Kaua`i	15		
Kailiiliainale (Okinawa) Reservoir	Kaua`i	16		
Kalihiwai Reservoir	Kaua`i	17		
Kalihiwai River Estuary	Kaua`i	18		
Kapa`a Stream Estuary	Kaua`i	19		
Kapaia Reservoir	Kaua`i	20		
Kaua`i Lagoons Westin	Kaua`i	21		
Kaumakani Gulch Pond	Kaua`i	22		
Kaupale Reservoir	Kaua`i	23		
Kekaha Landfill (Leachate) Pond	Kaua`i	24		
Kekaha Slaughter House Reservoir	Kaua`i	25		
Kekaha Sugar Company Settling Basin	Kaua`i	26		

Table 1 (continued). Key to names, locations, and core, supporting, or protected status for wetlands on Kaua`i and Ni`ihau.

Wetland	Island	Number on Map	Core or Supporting Wetland	Protected
Kīlauea Stream Estuary	Kaua`i	27		
Kīpū Reservoirs 1-4	Kaua`i	28		
Kīpū Road Reservoir	Kaua`i	29		
Kolo Reservoir	Kaua`i	30		
Kōloa (Kukui`ula) Sewage Pond	Kaua`i	31		
Kōloa Kapohu Reservoir	Kaua`i	32		
Kumano Reservoir	Kaua`i	33		
Līhu`e Settling Basin	Kaua`i	34		
Lono Reservoir	Kaua`i	35		
Luawai Reservoir	Kaua`i	36		
Lumaha`i Valley Wetlands	Kaua`i	37	Core	
Mānā Base Pond and Wetlands (Part of Mana Plain)	Kaua`i	38	Supporting	Mānā Base Pond only
Mānā Ditches and Drains (Part of Mana Plain)	Kaua`i	39		
Mānā House Reservoir (Part of Mana Plain)	Kaua`i	40		
Mānā Plains Forest Reserve (formerly Kawai`ele Wild Bird Sanctuary)	Kaua`i	41	Core	X
Mānā Ridge Reservoir (Part of Mana Plain)	Kaua`i	42		
Mauka Reservoir	Kaua`i	43		
Menehune Fish Pond	Kaua`i	44		
Morita Reservoir	Kaua`i	45		
Niu Valley Reservoir	Kaua`i	46		
Olokele Settling Basin Reservoir	Kaua`i	47		
`Ōma`o Reservoir	Kaua`i	48		
`Ōpaeka`a Marsh	Kaua`i	49	Supporting	
Pāpua`a Reservoir	Kaua`i	50		
Pia Mill Reservoir	Kaua`i	51		
Princeville Golf Course Ponds	Kaua`i	52		
Pu`u Ka Ele Reservoir	Kaua`i	53		
Pu`u O Hewa Reservoir	Kaua`i	54		
Pu`u O Papai Reservoir	Kaua`i	55		
Saki Mana Reservoir	Kaua`i	56		

Table 1 (continued). Key to names, locations, and core, supporting, or protected status for wetlands on Kaua`i and Ni`ihau.

Wetland	Island	Number on Map	Core or Supporting Wetland	Protected
Sloggett Reservoir	Kaua`i	57		
Smith's Tropical Paradise	Kaua`i	58	Supporting	
Twin Reservoir	Kaua`i	59		
U.S. Navy Sewage Treatment Pond	Kaua`i	60		
Waiakalua Reservoir	Kaua`i	61		
Waiawa Reservoir	Kaua`i	62		
Wailua Golf Course Pond	Kaua`i	63		
Wailua Jail Swamp	Kaua`i	64		
Wailau Siphon Reservoir	Kaua`i	65		
Wailua River Bottoms	Kaua`i	66	Supporting	
Waimea Heights Reservoir	Kaua`i	67		
Waimea River System	Kaua`i	68	Supporting	
Waimea Taro Fields	Kaua`i	69		
Wainiha Valley River and Taro Fields	Kaua`i	70	Supporting	
Waioli Taro Fields/Streams	Kaua`i	71		
Waiopili Spring Quarry	Kaua`i	72		
Waipa Taro Fields	Kaua`i	73		
Waitā Reservoir	Kaua`i	74	Supporting	
Wilcox Ponds	Kaua`i	75		
`A`aka Reservoir	Kaua`i	--		
Aepoekolu Reservoir	Kaua`i	--		
Ahukini Reservoir	Kaua`i	--		
Aii Reservoir	Kaua`i	--		
Alexander Reservoir	Kaua`i	--		
Fern Grotto Reservoir	Kaua`i	--		
Grove Farm Settling Basin (new)	Kaua`i	--		
Grove Farm Settling Basin (old)	Kaua`i	--		
Hā`ena Marsh	Kaua`i	--		
Hanamā`ulu Air Strip Reservoir	Kaua`i	--		
Huinawai Reservoir	Kaua`i	--		
Hule`ia Stream Valley	Kaua`i	--		
Ipuolono Reservoir	Kaua`i	--		
Kaloko Reservoir	Kaua`i	--		
Kanaele Swamp	Kaua`i	--		

Table 1 (continued). Key to names, locations, and core, supporting, or protected status for wetlands on Kaua`i and Ni`ihau.

Wetland	Island	Number on Map	Core or Supporting Wetland	Protected
Kanehu Reservoirs	Kaua`i	--		
Kaneha Reservoir	Kaua`i	--		
Kapa Reservoir	Kaua`i	--		
Kawailoa Flats	Kaua`i	--		
Kekaha Pasture (dried up)	Kaua`i	--		
Kekaha Settling Basins (dried up)	Kaua`i	--		
Kuhumu Reservoir	Kaua`i	--		
Lāwa`i Kai Estuary	Kaua`i	--		
Māhā`ulepū Ponds	Kaua`i	--		
Manuhonuhonu Reservoir	Kaua`i	--		
Niumalu Reservoir	Kaua`i	--		
Nonopahu Reservoir	Kaua`i	--		
Pila`a Wetlands	Kaua`i	--		
Poa Marsh	Kaua`i	--		
Po`ipū Ponds /Area	Kaua`i	--		
Po`opueo Reservoir	Kaua`i	--		
Pukaki Reservoir	Kaua`i	--		
Pu`u Ainako	Kaua`i	--		
Pu`u Opae Reservoir	Kaua`i	--		
Pu`uhi Crater Reservoir	Kaua`i	--		
Pu`ulani Reservoir	Kaua`i	--		
Reservoir 429	Kaua`i	--		
Rodriques Reservoir 296 (defunct)	Kaua`i	--		
`Umi Reservoir	Kaua`i	--		
Waikai Reservoir	Kaua`i	--		
Waikoloi Reservoir	Kaua`i	--		
Wakai Reservoir	Kaua`i	--		
`Āpana Reservoir	Ni`ihau	1		
Halāli`i Ditches (Part of Playa Lakes wetland complex)	Ni`ihau	2	Core	
Halāli`i Lake (Part of Playa Lakes wetland complex)	Ni`ihau	3	Core	
Halulu Lake (Part of Playa Lakes wetland complex)	Ni`ihau	4	Core	
Kaununui Ponds	Ni`ihau	5		
Ki`eki`e Ponds	Ni`ihau	6		

Table 1 (continued). Key to names, locations, and core, supporting, or protected status for wetlands on Kaua`i and Ni`ihau.

Wetland	Island	Number on Map	Core or Supporting Wetland	Protected
Lē`ahi Pond	Ni`ihau	7		
Nonopapa Lake (Part of Playa Lakes wetland complex)	Ni`ihau	8	Core	
Palikoa`e Ponds	Ni`ihau	9		
Pōhueloa Valley Pond	Ni`ihau	10		
Pu`u `Alala Pond	Ni`ihau	11		
Pu`u Wai Pond	Ni`ihau	12		
Hā`ao Dam	Ni`ihau	--		
Kahino Pond	Ni`ihau	--		
Kamalino Pond	Ni`ihau	--		
Keanauhi Dam	Ni`ihau	--		
Makahau`ena Pond	Ni`ihau	--		

Table 2. Key to names, locations, and core, supporting, or protected status for wetlands on O`ahu. Numbering key refers to maps in Figures 7, 15, 23, 29, 35, and 36. Unnumbered wetlands, generally relatively minor elements of waterbird habitat, were not included on regular waterbird surveys and are not shown on maps.

Wetland	Number on Map	Core or Supporting Wetland	Protected
Airstrip Ponds, Kahuku	1		
Amorient Aquafarm (includes Romey's + Ming Dynasty) (Part of Kahuku Aquaculture Farms)	2		
Apoka`a Ponds 1 and 2	3		
Chevron Refinery Ponds	4		
Coconut Grove Marsh	5		
Fort Kamehameha Reef Flats	6		
Hale`iwa Lotus and Taro Fields/Waialua Lotus Fields	7	Supporting/ Supporting	
Hāmākua Marsh Waterbird Sanctuary	8	Core	X
Hawai`i Kai	9		
Hawai`i Prince Golf Course Ponds	10		
He`eia Marsh	11	Supporting	X
Honolulu Country Club, Salt Lake	12		
Honolulu International Airport Reef Runway Wetlands	13		
Ho`omaluhia Botanical Garden Ponds	14		
James Campbell National Wildlife Refuge, Ki`i Unit	15	Core	X
James Campbell National Wildlife Refuge, Punamanō Unit	16	Core	X
Ka`elepulu Mitigation Pond (Enchanted Lake)	17	Supporting	
Kahuku Prawn Farm (Part of Kahuku Aquaculture Farms)	18	Supporting	
Kawainui Marsh	19	Core	X
Kualoa State Park (`Āpua Pond)	20		X
Lā`ie Wetlands	21	Supporting	
Loko Ea Pond	22		
Lualualei RTF, Niuli`i Ponds	23	Supporting	X
Marine Core Base Hawai`i, Klipper Golf Course	24		X
Marine Core Base Hawai`i, Nu`upia Ponds	25	Core	X

Table 2 (continued). Key to names, locations, and core, supporting, or protected status for wetlands on O`ahu.

Wetland	Number on Map	Core or Supporting Wetland	Protected
Marine Core Base Hawai`i, Water Reclamation Facility	26		
Mokulē`ia Quarry Pond	27		
Mokulē`ia Ranch (Crowbar)	28		
Mōli`i Fish Pond	29		
Nu`uanu Reservoirs 1-4	30		
Olomana Golf Course	31		
Oneawa Canal	32		
Paikō Lagoon Wildlife Sanctuary	33	Supporting	X
Pearl City Watercress Farm (Sumida)	34		
Pearl Harbor National Wildlife Refuge, Honouliuli Unit	35	Core	X
Pearl Harbor National Wildlife Refuge, Waiawa Unit	36	Core	X
Pouhala Marsh Waterbird Sanctuary	37	Core	X
Punaho`olapa Marsh	38	Supporting	
Punalu`u Prawn Farm	39		
Turtle Bay, Golf Course Ponds	40		
Turtle Bay, Kuilima Wastewater Treatment Plant	41	Supporting	
UH Mariculture Research Center	42		
UH Waiale`e Agricultural Research Station	43		
`Uko`a Marsh	44	Supporting	
Unisyn Biowaste site	45		
Waihe`e Marsh	46	Supporting	
Waimea Valley	47		X
Waipi`o Soccer Field Wetlands	48		
Barber's Point Golf Course Ponds	--		
Upper Waimanalo Stream Wetland	--		X
Lower Waimanalo Stream Wetland	--		X
Diamond Head Marsh	--		
Dillingham Ranch Ponds	--		
Halekou Wetland	--		
Helemano Reservoirs	--		
Honouliuli Golf Course Ponds	--		
Ka`alaea Aquafarm Ponds	--		

Table 2 (continued). Key to names, locations, and core, supporting, or protected status for wetlands on O`ahu.

Wetland	Number on Map	Core or Supporting Wetland	Protected
Ka`a`awa Wetlands	--		
Kahana Marsh (Huilua Pond)	--		
Kalou Marsh (University of Hawai`i Waiale`e Station Pond)	--		
Kaneshiro's Lotus Fields	--		
Kapolei Golf Course Ponds (Ewa Ponds)	--		
Ke`ehi Lagoon (Mudflats)	--		
Ko Olina Golf Course Ponds	--		
Kualoa Aquafarm (University of Hawai`i Mariculture Research Center)	--		
Kuapa Pond, Hawaii Kai	--		
Laulaunui Island Fish Pond (Naval Reservation)	--		X
Lualualei Rubber-lined Pond	--		X
Makaha Golf Course Ponds	--		
Makaha Sewage Pond	--		
Marine Corps Base Hawai`i Hale Koa Wetland	--		X
Marine Corps Base Hawai`i Motor Pool Wetlands	--		X
Marine Corps Base Hawai`i Percolation Ditch Wetland	--		X
Marine Corps Base Hawai`i Sag Harbor Wetland	--		X
Marine Corps Base Hawai`i Salvage Yard Wetlands	--		X
Marine Corps Base Hawai`i Temporary Lodging Facility Wetland	--		X
Nakatani Watercress Farm	--		
`Opae`ula Reservoirs 1-5	--		
Ranch Camp Ponds	--		
Steamer's Lotus	--		
Sumida Watercress	--		
Wahiawa Reservoir	--		
Waikane Aquaculture Ponds	--		

Table 2 (continued). Key to names, locations, and core, supporting, or protected status for wetlands on O`ahu.

Wetland	Number on Map	Core or Supporting Wetland	Protected
Waikele Harbor Mudflat	--		
Waimānalo Reservoirs	--		
Waipi`o Peninsula, Pearl Harbor Shoreline	--		
Waipi`o Settling Basins	--		
Walker's Bay Wetlands, Waipi`o Peninsula	--		

Table 3. Key to names, locations, and core, supporting, or protected status for wetlands on Maui. Numbering key refers to maps in Figures 8, 16, 30, 37, and 38. Unnumbered wetlands, generally relatively minor elements of waterbird habitat, were not included on regular waterbird surveys and are not shown on maps.

Wetland	Number on Map	Core or Supporting Wetland	Protected
Airport Drainage Ditch	1		
Azeka Ponds 1 and 2	2		
Cut Mountain Settling Ponds	3		
Hāli`imaile Wastewater Stabilization Ponds	4		
Hansen Road Ponds (Reservoirs 70 and 71)	5		
Kā`anapali Golf Course Ponds	6		
Kahului Fairgrounds Drainage	7		
Kahului Oxidation Pond (HC&S Settling Pond)	8		
Kahului Settling Pond	9		
Kahului Sewage Treatment Plant Ponds	10		
Kanahā Pond Wildlife Sanctuary	11	Core	X
Kapalua Bay Golf Course	12		
Kapalua Reservoir	13		
Kapalua Village Golf Course	14		
Kauhiolokini Pond	15		
Keālia Pond National Wildlife Refuge	16	Core	X
Ke`anae Point	17	Supporting	
K-mart Settling Pond	18		
Lahaina Aquatic Center	19		
Mill Pond	20		
Nu`u Pond	21		X
Olowalu Reservoir 1	22		
Olowalu Reservoir 2	23		
Pāniaka Pond	24		
Reservoir 20	25		
Reservoir 21	26		
Reservoir 22	27		
Reservoir 23	28		
Reservoir 26	29		
Reservoir 29	30		
Reservoir 32	31		
Reservoir 33	32		

Table 3 (continued). Key to names, locations, and core, supporting, or protected status for wetlands on Maui.

Wetland	Number on Map	Core or Supporting Wetland	Protected
Reservoir 35	33		
Reservoir 40	34		
Reservoir 42	35		
Reservoir 50	36		
Reservoir 51	37		
Reservoir 52	38		
Reservoir 60	39		
Reservoir 61	40		
Reservoir 72 (Ōma`opio)	41		
Reservoir 73 (Wai`ale)	42		
Reservoir 80	43		
Reservoir 81	44		
Reservoir 82	45		
Reservoir 84	46		
Reservoir 90 (Airport Village)	47		
Reservoir 92	48		
Ukumehame Settling Pond and Reservoirs (1 and 2)	49		
Waihe`e Coastal Dunes and Wetlands (Waihe`e Refuge)	50	Supporting	X
Ahihikinau Natural Area Reserve	--		X
Cement House	--		
Crater Reservoir	--		
Crater Village	--		
Hale Nanea Drainage Pond	--		
Halua Pond	--		
Kaneaka Pond	--		
Lahainaluna Pond	--		
Lahaina Settling Ponds	--		
Laniapoku Pond	--		
Little Pond	--		
Longs Ponds	--		
Mākena Golf Course	--		
Maluaka Pond	--		
Mauna Lani Golf Course	--		
Paia Settling Pond	--		

Table 3 (continued). Key to names, locations, and core, supporting, or protected status for wetlands on Maui.

Wetland	Number on Map	Core or Supporting Wetland	Protected
Pioneer Crater Reservoir	--		
Pu`u Ali`i Pond	--		
Pu`u Kolii Reservoir 1 - 3	--		
Pu`u Nēnē Settling Basin (70,71)	--		
Ukumehame Target Range	--		
`Ulupalakua Ranch Pond	--		X
VIP Drainage Ditch	--		
Waine`e Settling Ponds	--		

Table 4. Key to names, locations, and core, supporting, or protected status for wetlands on Moloka`i and Lānа`i. Numbering key refers to maps in Figures 17 and 31. Unnumbered wetlands, generally relatively minor elements of waterbird habitat, were not included on regular waterbird surveys and are not shown on maps.

Wetland	Island	Number on Map	Core or Supporting Wetland	Protected
Kakahai`a National Wildlife Refuge	Moloka`i	1	Core	X
Kalua`apuhi Fish Pond	Moloka`i	2		
Kaluako`i Golf Course	Moloka`i	3		
Kamalō Flats	Moloka`i	4		
Kaunakakai Stream	Moloka`i	5		
Kaunakakai Wastewater Reclamation Facility Ponds	Moloka`i	6	Supporting	X
Kualapu`u Reservoir	Moloka`i	7	Supporting	
Maunaloa Sewage Treatment Ponds	Moloka`i	8		
`Ōhi`apilo Pond Bird Sanctuary	Moloka`i	9	Core	X
Paialoa Fish Ponds	Moloka`i	10	Supporting	
Hālawa River Estuary	Moloka`i	--		
Hawai`i Research Flats	Moloka`i	--		
Kamahuehue Fish Pond	Moloka`i	--		
Kupeke Fish Pond	Moloka`i	--		
Moloka`i Playas	Moloka`i	--		
Mo`omi	Moloka`i	--		
O` ō`ia Fish Pond	Moloka`i	--		
Oliwai Sewage Treatment Pond	Moloka`i	--		
One Ali`i Fish Pond	Moloka`i	--		
Pālā`au Flats	Moloka`i	--		
Lāna`i Sewage Treatment Ponds	Lāna`i	1	Supporting	
Hulopo`e Mud Flats	Lāna`i	--		
Mānele Oxidation Ponds	Lāna`i	--		
Mānele Road Reservoir	Lāna`i	--		
Manele Mud Flats	Lāna`i	--		
Kō`ele Golf Course Ponds	Lāna`i	--		

Table 5. Key to names, locations, and core, supporting, or protected status for wetlands on Hawai`i. Numbering key refers to maps in Figures 9, 18, 32, 39, and 40. Unnumbered wetlands, generally relatively minor elements of waterbird habitat, were not included on regular waterbird surveys and are not shown on maps.

Wetland	Number on Map	Core or Supporting Wetland	Protected
Cyanotech	1		
Kaloko-Honokōhau, National Historic Park, `Aimakapā and Kaloko Ponds	2	Core	X
Kealakehe (Kona) Sewage Treatment Plant	3	Supporting	
Ke`anae Pond (Kea`au/Shipman)	4	Supporting	
Keanakolu Road Stock Ponds (Part of Kohala-Mauna Kea Ponds and Streams)	5	Supporting	
Kehena Reservoir and Ponds (1-5) (Part of Kohala-Mauna Kea Ponds and Streams)	6	Supporting	
Loko Waka Ponds	7	Core	
`Ōpae`ula Pond	8	Supporting	
Pāi`akuli Reservoir (Part of Kohala-Mauna Kea Ponds and Streams)	9	Supporting	
Punalu`u Pond	10		
Waiākea Pond	11	Supporting	X
Waimanu Valley	12	Supporting	X
Waipi`o Valley	13	Supporting	
Waipuhi Ponds (1 and 2)	14		
Ahn's Pond	--		
`Anaeho`omalu Pond	--		
Baker Paddock Ponds	--		
Honoapu	--		
Honokōhau Reef	--		
Ka`alu`alu	--		
Kapulehu Ponds	--		
Kealakekua Bay Pond	--		
Kokoiki Reservoir	--		
Lahuipuaa Ponds	--		
Lālākea Reservoir	--		
Lālākea Stream	--		
Nakagawa Pond	--		
Old Kahua Pond	--		

Table 5 (continued). Key to names, locations, and core, supporting, or protected status for wetlands on Hawai`i.

Wetland	Number on Map	Core or Supporting Wetland	Protected
Pololū River Valley	--		
Puakea Reservoir	--		
Pu`u Iki Pond	--		
Pu`u Kapu Reservoir	--		
Pu`u Lio`lio Pond	--		
Pu`u Mauna Pond	--		
Pu`u O`o Ranch Stock Ponds	--		
Pu`u Pūlehu Reservoir	--		
Raley's Pond	--		
Slatter Pond	--		
Tribble Pond	--		
Umikoa Ranch Ponds	--		X
Waikoloa Golf Course Pond	--		
Wailoa	--		

D. REASONS FOR DECLINE AND CURRENT THREATS

Historically, the most important cause of decline for these four species of endangered Hawaiian waterbirds was loss of wetland habitat. Other factors that have contributed to population declines, and which continue to be detrimental, include predation by introduced animals, altered hydrology, alteration of habitat by invasive non-native plants, disease, and possibly environmental contaminants. Hunting in the late 1800s and early 1900s took a heavy toll on Hawaiian duck populations, and to a lesser extent on populations of the other three species (Swedberg 1967). Currently, predation by introduced animals may be the greatest threat to the Hawaiian coot, Hawaiian common moorhen, and Hawaiian stilt, and hybridization with feral mallards is the most serious threat to the Hawaiian duck.

The identified threats to the Hawaiian waterbirds are each classified according to the five factors identified under section 4(a)(1) of the Endangered Species Act in consideration for listing, delisting, and reclassification decisions. These five factors are as follows:

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; and

E - Other natural or manmade factors affecting its continued existence.

1. Factor A – Present or Threatened Destruction, Modification, or Curtailment of Habitat or Range

(a) Loss and Degradation of Wetland Habitat

A significant amount of Hawai`i's wetlands have been filled or otherwise modified and are now occupied by hotels, housing developments, golf courses, shopping centers, landfills, military installations, highways, former sugarcane fields, and industrial sites. Hawai`i currently contains approximately 44,320 hectares (110,800 acres) of wetlands and deep freshwater habitats, of which 81

percent are classified as palustrine scrub-shrub forest habitats, which are not used by Hawai`i's four endangered waterbirds. This wetland class is located at mid- to high elevations and occurs as bogs and rainforest ecosystems. The waterbirds addressed in this recovery plan (except for the Hawaiian duck) primarily utilize wetlands that exist within the coastal plains of Hawai`i, of which an estimated 8,990 hectares (22,475 acres) existed around 1780 (USFWS 1990). By 1990, however, only an estimated 6,190 hectares (15,474 acres) of these wetlands remained, a decrease of 31 percent (Dahl 1990). Wetlands in Hawaii have been delineated and characterized by vegetation and hydrology in National Wetlands Inventory data (see http://www.fws.gov/wetlands/Data/Mapper.html).

Waterbirds utilize wetlands where agriculture (taro, lotus, and rice) has been practiced since the arrival of the first Polynesians (Stone 1989a). The impact of this practice on waterbird species is unknown; while it maintained wetlands that might have otherwise been lost, and perhaps increased acreage (*e.g.*, fish ponds and irrigated fields), it also changed the nature of the wetlands and affected the ability of waterbirds to utilize them. Such impacts included human disturbance (especially during the nesting season), clearing of vegetation, and manipulation of water levels for crops (Stone 1989a). However, these changes may have also allowed colonization of some areas previously unused by Hawaiian waterbirds. As early as the 1850s, significant losses of this type of habitat began with the partial replacement of taro by other agricultural crops (*e.g.*, sugarcane) and by development for an expanding industrial society (Bostwick 1982). This gradual loss of natural and agricultural wetlands has continued to the present. Sugar plantations provided a limited amount of habitat in the form of settling basins and reservoirs. The collapse of the sugarcane industry since the 1980s has resulted in the draining of many of these reservoirs and basins, which were widely utilized by resident waterbirds, migratory waterfowl, and migratory shorebirds.

In some areas, Hawaiian common moorhens heavily utilize modern aquaculture wetlands (used for raising, for example, taro or shrimp) (Engilis and Pratt 1993), and many other bird species also use these wetlands. The majority of aquaculture wetlands occur on O`ahu. The industry reached its peak in the mid-1980s, then declined, but is currently increasing (F. Mencher, Hawaiian Marine Enterprises, *in litt*. 2005). Waterbirds are occasionally implicated as a cause of depredation on taro (USFWS 1999b) and may have an impact on prawn farm production. Suspected depredation may result in efforts by farmers to place exclusion devices around ponds that would effectively eliminate some habitat

presently utilized by waterbirds. It is important that there are sufficient wetlands managed to provide for the recovery of Hawaiian common moorhens, as agricultural lands cannot be relied upon (S. Pelizza, *in litt*. 2005).

Many of Hawai`i's wetlands occur in coastal areas that are highly valued for development and are becoming increasingly urbanized. This urban encroachment raises concerns regarding human disturbance, urban runoff impacts on water quality, and an increased incidence of domestic cats and dogs in wildlife areas (Brown and Dinsmore 1986; Reid 1993). Development pressure in wetland areas has been most prevalent on the islands of O`ahu and Maui, but is increasing on all islands. Urban development has encroached upon both Kanahā and Keālia Ponds on Maui, and the Honouliuli Unit of Pearl Harbor National Wildlife Refuge is now surrounded by urban development. If hotels and golf courses on the Kahuku Plain of O`ahu expand, ephemeral wetlands that are utilized by waterbirds will be lost to development.

Grazing by feral animals has also had an impact on wetlands in Hawai`i, especially along streams. Large numbers of hoofed animals ate native plants, reduced plant populations, and introduced weeds (Stone 1989b). Feral animals remove streamside plant cover that provide shade, change temperature and light conditions which stream animals have adapted to, increase nutrients and soil in the water, effectively degrading or destroying habitat for aquatic organisms (Stone 1989a). Wetland loss can also be attributed to invasive species (see c. Invasions of Habitat by Non-native Plants), even in protected wetlands (Morin 1998). Loss of wetlands to invasive species ranks with predation as a reason for waterbird endangerment, and management to control invasive species is also very costly (M. Morin, *in litt*. 2005).

The majority of Hawai`i's 366 perennial streams (on 5 major islands) have had some form of water diversion or alteration; by 1989 less than 14 percent were pristine, and fewer were biologically intact (Parrish *et al*. 1978 cited in Stone 1989a; Stone 1989a). These changes almost certainly affected the Hawaiian duck, which unlike the other three endangered waterbirds heavily utilizes mountain stream habitat, particularly on Kaua`i (Swedberg 1967).

(b) Alteration of Hydrology

Hydrologic alterations of wetlands, such as flood control and channelization, often make habitat less suitable or unusable for native waterbirds

by altering both water depth and timing of water level fluctuations. Hawai`i's waterbirds may be unable to adjust their breeding behavior to accommodate these modifications, possibly resulting in decreased reproductive success. For example, in years when water was pumped into Keālia Pond during the dry months, Hawaiian coots nested year-round, but when water was not pumped in, no nests were located (M. Nishimoto, pers. comm. 2008). In addition, the depletion of freshwater aquifers causes salt water intrusion into coastal ground water, altering the salinity levels in associated wetlands. Although Hawaiian stilts and Hawaiian coots will use brackish/salt water (Coleman 1981; Morin 1998; Robinson *et al*. 1999; Brisbin *et al*. 2002), Hawaiian coots may prefer freshwater (Morin 1998) and Hawaiian common moorhens and Hawaiian ducks will use brackish/salt water only rarely (Engilis and Pratt 1983; Engilis *et al*. 2002). In addition, fluctuations in salinity level alters the species composition of the vegetation and arthropod communities, which might affect food availability for the waterbirds (M. Silbernagle, pers. comm. 2008). At Nu`upia Ponds on O`ahu, mean salinity varied from 35 to 64 ppt (parts per thousand) (HDOFAW 1978) and salinity measured during a study on Hawaiian stilts, also on O`ahu, ranged from a low of 0 ppt to a high of 116 ppt (Coleman 1981). Though such fluctuations in salinity may have limited impact on Hawaiian stilts and Hawaiian coots, it could have a greater impact on Hawaiian duck and Hawaiian common moorhen. Thus the availability of secure water sources is crucial for both the core and supporting wetlands identified in this recovery plan (see Recovery Strategy). Analysis and management of hydrology are vital to managing waterbird habitat.

(c) Invasion of Habitat by Nonnative Plants

The alteration of wetland plant communities due to invasion by non-native plants can greatly reduce the usefulness of wetland areas for native waterbirds. Therefore, non-native plant control is a key problem facing wetland managers in the State of Hawai`i. Managers are constantly faced with the challenge of developing techniques and then securing enough staff and funding to implement management. Species such as California grass, pickleweed, water hyacinth (*Eichornia crassipes*), Indian fleabane (*Pluchea indica*), and mangrove (*Rhizophora mangle*) present serious problems in most Hawaiian wetlands by outcompeting native species and eliminating open water, exposed mudflats, or shallows (Shallenberger 1977).

Morin (1996, 1998) also concluded that non-native plants (especially pickleweed and mangroves on the Kona Coast) are a main reason for wetland loss, even in protected wetlands. Efforts to remove such invasive species are expensive and require ongoing vegetation management as well as periodic sweeps for removing seedlings. Many of the anchialine pools along the Kona Coast are overgrown with invasive non-natives and are no longer much used by waterbirds (M. Morin, *in litt*. 2005). Rauzon and Drigot (2002) discussed the problem of mangrove and pickleweed in Hawaiian stilt habitat and documented the increase in Hawaiian stilt population achieved through intensive vegetation management. Rauzon and Drigot (2002) also suggested that the establishment of red mangrove (*Rhizophora mangle*) facilitated the use of wetlands by introduced cattle egrets and the indigenous black-crowned night-heron, thereby increasing the threat of predation on Hawaiian stilts.

In addition, hydrological alteration (*e.g.,* channelization) changes the flow of water to wetlands resulting in habitat modification. Wetlands may become wetter or drier increasing the need to control both native and non-native plants in order to maintain suitable habitat for the recovery of a suite of waterbirds (S. Pelizza, *in litt*. 2005).

2. Factor B - Overutilization

(a) Hunting

Indiscriminate hunting of migratory waterfowl in the late 1800s and early 1900s took a heavy toll on Hawaiian duck populations. During this period, as habitat size and quality decreased, direct pressure on waterbird populations increased. When bag limits were introduced, they were generous (25 ducks, including both Hawaiian ducks and mainland duck migrants, per day over a 4-month season) and difficult to enforce. In 1925, the Territorial Fish and Game Commission closed the Hawaiian duck season, but because of their similarity to female mallards and pintails, Hawaiian ducks probably received little protection (Swedberg 1967). A total ban on waterfowl hunting was initiated in 1939, although hunting continued up to 1941 (Schwartz and Schwartz 1949). The ban, still in effect today, provided important protection for the remaining Hawaiian ducks (Bostwick 1982). Although overhunting contributed to the historical decline of the Hawaiian duck, it is not considered a current threat.

As mentioned previously, hunting also adversely affected the Hawaiian common moorhen, Hawaiian stilt, and Hawaiian coot, though perhaps to a lesser extent than the Hawaiian duck. Henshaw (1902) mentioned that Hawaiian coots were indiscriminately hunted. Hawaiian coots were also on the gamebird list and were legally hunted until at least 1939 and perhaps illegally after that (Berger 1981). Shallenberger (1977) suggested that hunting was a factor in keeping Hawaiian stilt populations low even though they were apparently not used as food (Henshaw 1902).

3. Factor C – Disease or Predation

(a) Predators

The introduction of alien predators has had a negative impact on populations of these four endangered waterbirds (Griffin *et al*. 1989). Birds on the Hawaiian Islands evolved in the absence of mammalian predators, and are consequently highly vulnerable to these introduced animals. Mongooses were first introduced to the island of Hawai`i in 1883, and subsequently to Maui, Moloka`i, and O`ahu; they may not be established on Kaua`i, although sightings continue to be reported (K. Gundersen, pers. comm. 2004, S. Williamson *in litt*. 2008). Mongooses have become a serious threat to waterbirds throughout these islands, taking eggs, young birds, and nesting adults. Feral cats became established in Hawai`i shortly after European contact and were common in O`ahu forests as early as 1892 (Tomich 1986). Feral cats range from sea level to at least 2,900 meters (9,500 feet) on Hawai`i Island (Hu *et al*. 2001) and 3,055 meters (10,000 feet) on Maui (Hodges and Nagata 2001). The proliferation of feral cat feeding stations near parks and other areas that support waterbirds may have a significant effect on waterbird recovery in these areas. Dogs have become a serious problem in some wetlands, particularly near urban areas. Rats are known to prey on eggs and young of Hawaiian stilts and possibly Hawaiian ducks as well (Atkinson 1977, Robinson *et al*. 1999, Engilis *et al*. 2002); they are known to be one of the primary predators on the eggs and goslings of the endangered nēnē (USFWS 2004).

Other introduced species, such as the cattle egret, bullfrog, and barn owl (*Tyto alba*), have also had negative impacts on waterbirds. The introduced bullfrog is a voracious predator of all small animals, and is known to eat young Hawaiian ducks (R. Walker, pers. comm. 1982), Hawaiian stilts (Robinson *et al*.

1999; Eijzenga 2004), Hawaiian coots (Berger 1981), and Hawaiian common moorhen (Viernes 1995). Barn owls have been observed taking adult Hawaiian stilts and are presumed to take chicks as well (K. Viernes, pers. comm. 1994). Cattle egrets play an unquantified role as a predator of nestling birds; however, there are several documented incidents of cattle egrets taking Hawaiian stilt, Hawaiian coot, and Hawaiian common moorhen chicks as well as Hawaiian ducklings at the O`ahu National Wildlife Refuge Complex (S. Pelizza, *in litt*. 2005). Other predators include the native Hawaiian short-eared owl or pueo, which preys on adult stilts, and the introduced common myna (Robinson *et al*. 1999).

In addition, both native and non-native fish may prey upon endangered waterbirds. It is suspected that large fish in the `Aimakapā Fishpond in Kona may be a source of mortality for Hawaiian coot chicks (Morin 1994). It is believed introduced tilapia degrade waterbird feeding habitats by depleting the invertebrate prey base used by these birds (C. Swenson, pers. comm. 2004). Native barracuda (*Sphyraena barracuda*) in Nu`upia Ponds on O`ahu are suspected of eating young Hawaiian stilts (C. Swenson, pers. comm. 2004). Largemouth bass eat Hawaiian ducklings (Swedberg 1967).

The problems posed by these predators are magnified by a severe shortage of protected nesting areas. The importance of core wetland areas, permanent habitat that supports substantial numbers of Hawaiian waterbirds, is most evident during drought periods when waterbird populations become concentrated. During drought periods, nesting, foraging, and loafing sites become limited and overcrowding can result. Predator numbers then rapidly increase in response to this concentrated food source. This type of predator response has been well documented in North America and is summarized by Sargeant and Raveling (1992).

(b) Avian Disease

The most prevalent disease affecting waterbirds is avian botulism, which has been documented at, for example, Ohi`apilo Pond on Moloka`i, Hanalei National Wildlife Refuge, Kaua`i, `Ōpae`ula Pond and `Aimakapā Pond on Hawai`i, Keālia Pond National Wildlife Refuge and Kanahā Pond Wildlife Sanctuary on Maui, and at the lake on Laysan Island. It is caused by a toxin produced by anaerobic bacteria (*Clostridium botulinum* type C_a) in stagnant

water. The disease may reappear annually and can affect all native and migratory waterbirds, causing flaccid paralysis which is evidenced by staggering and the eventual loss of use of legs. Tracking of the location and timing of avian botulism outbreaks might reveal patterns that could be used to avoid environmental conditions that lead to outbreaks. Hydrologic conditions and weather are also important factors to monitor in management of botulism (S. Pelizza, *in litt*. 2005). Once an outbreak occurs, the primary response is intense field surveillance to find and remove dead birds from the field (M. Silbernagle, *in litt*. 2008). Preventive and treatment measures include: being observant for "unusual" behavior, increasing surveillance, regulating water levels before and during outbreaks (botulism often occurs during warmer months when evaporation lowers water levels), maintaining water movement through impoundments, removing all carcasses from the site (including fish and other animals), and removing sick birds for treatment (M. Silbernagle, *in litt*. 2008).

Two emerging avian diseases pose a significant threat to native waterbirds. West Nile virus (WNV) has spread throughout much of mainland North America since its introduction in 1999, but has not been detected in Hawai`i or Alaska (Kilpatrick *et al.* 2007). Transmitted by mosquito species common in Hawai`i, its potential to affect passerine birds is known to be high, and the introduction of WNV would probably lead to extinctions of several native forest birds. There is no practical way to protect wild bird populations from infection. In general the vulnerability of continental waterbirds to the virus is apparently relatively low (Kilpatrick *et al.* 2007), but vulnerability is known to vary substantially between closely related species and has not been assessed for Hawaiian waterbirds, so it remains a potential threat. Currently no capability exists to eradicate WNV if it were to be detected (J. Burgett, USFWS, *in litt*. 2008).

Highly pathogenic avian influenza H5N1, or "bird flu," is established in many areas of Europe, Asia, and Africa, but not yet in North or South America. It is suspected to be spread globally mainly through commercial trade in poultry and poultry products, but apparently is maintained in populations of asymptomatic ducks. Long-distance migration of infected but healthy ducks or shorebirds is a likely route by which highly pathogenic H5N1 might reach Hawai`i. A surveillance program for this disease has also been conducted. Introduction of highly pathogenic H5N1could result in mortalities of birds visiting infected water

bodies, but the potential for long-term, major impacts to populations is lower than for WNV (J. Burgett, *in litt*. 2008).

4. Factor E – Other Natural or Manmade Factors

(a) Hybridization

The most serious threat specifically affecting Hawaiian ducks is genetic introgression (the introduction of genes from one species into the gene pool of another) through interbreeding with feral mallards. Wild, migratory mallards also occur in Hawai`i (Pyle 2002) but generally leave the islands before the breeding season starts and thus are not thought to interbreed with Hawaiian ducks. Reduction of wetland habitat may increase opportunities for hybridization as populations of Hawaiian ducks and feral mallards are forced to share smaller wetland areas. The distribution and abundance of Hawaiian ducks and mallard-Hawaiian duck hybrids is not clear in some areas, particularly O`ahu and Maui, due to difficulties in identification and inconsistency in attempting to distinguish hybrids. Determination of the population status of Hawaiian ducks and whether there are any pure Hawaiian ducks left on O`ahu will require simultaneous genetic testing and morphological characterization to develop reliable morphological criteria for distinguishing Hawaiian ducks, female mallards, and hybrids. Once such criteria are available they can be used to identify birds for removal in order to reduce interbreeding and introgression. The number of hybrids apparently has increased rapidly on some islands in recent years (Figures 33 through 44); however, it is possible that hybridization has been occurring for some time and the apparently rapid increase is due to greater realization of the hybridization problem and more careful identification of Hawaiian duck-like birds.

Kaua`i has by far the largest Hawaiian duck population and is thought to be largely free of hybrids, making it extremely valuable as a potential source of individuals for translocation or captive breeding and reintroduction to other islands. However, hybridization appears to be beginning on Kaua`i, and a few Hawaiian duck-mallard hybrids have been recorded at Smith's Tropical Paradise (Paradise Pacific) in the Wailua River bottoms, and possibly at Hanalei National Wildlife Refuge (Figures 6 and 33).

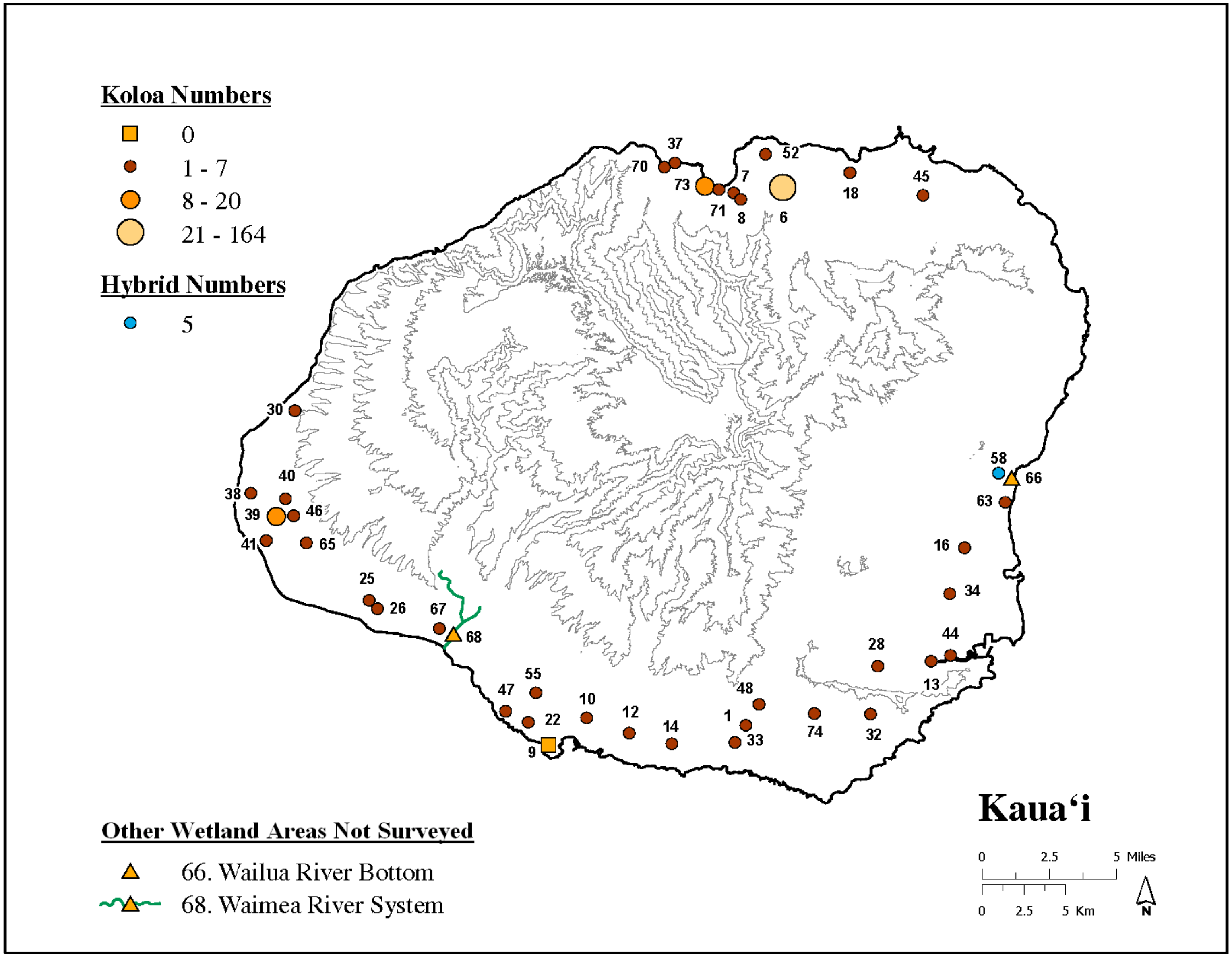

Figure 33. Distribution and abundance of Hawaiian ducks and mallard-Hawaiian duck hybrids on Kaua`i, based on winter counts from 1999-2003. The name for each wetland numbered in this figure, as well as whether it is a core or supporting wetland, is listed in Table 1.

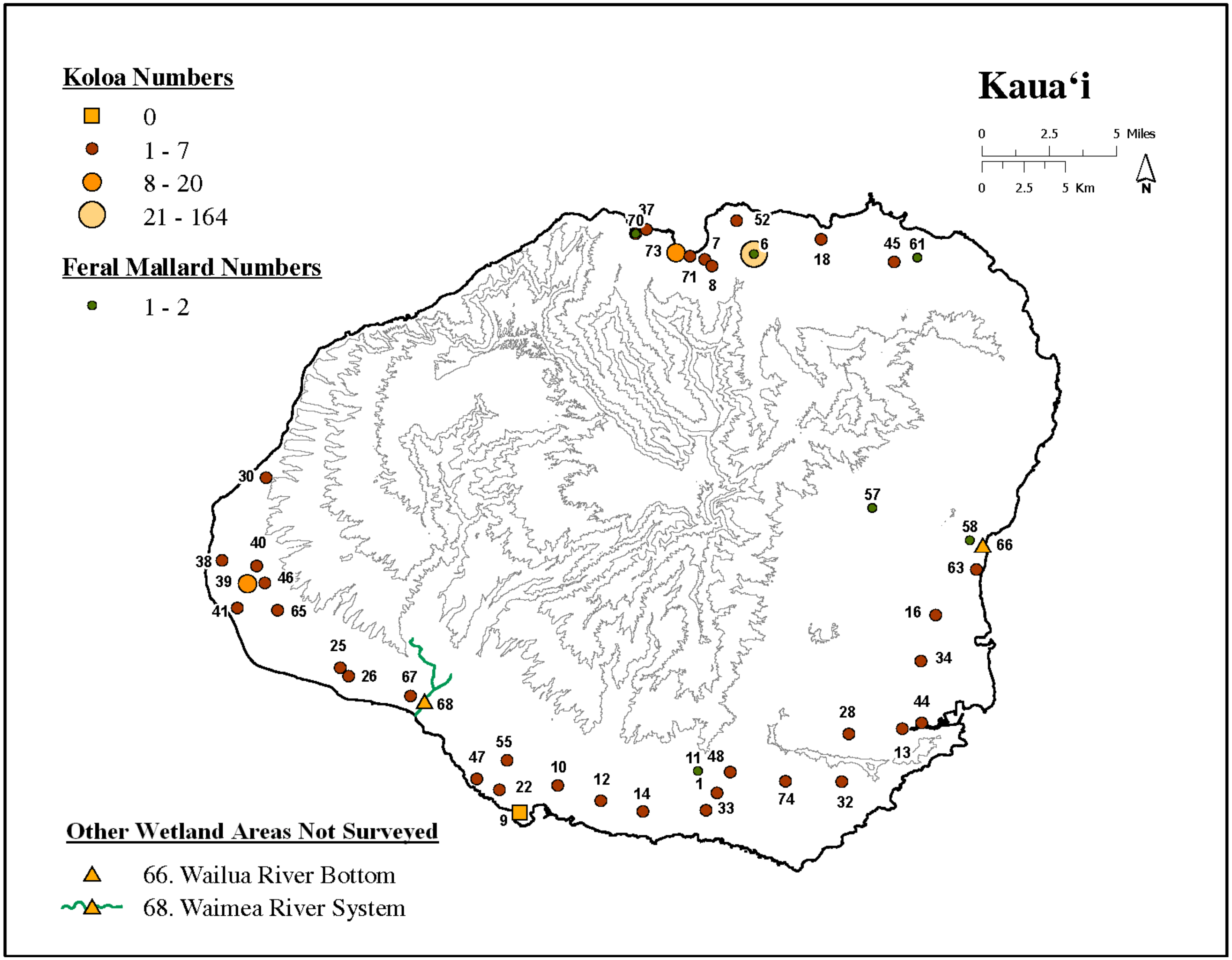

Figure 34. Distribution and abundance of Hawaiian ducks and feral mallards on Kaua`i, based on winter counts from 1999-2003. The name for each wetland numbered in this figure, as well as whether it is a core or supporting wetland, is listed in Table 1.

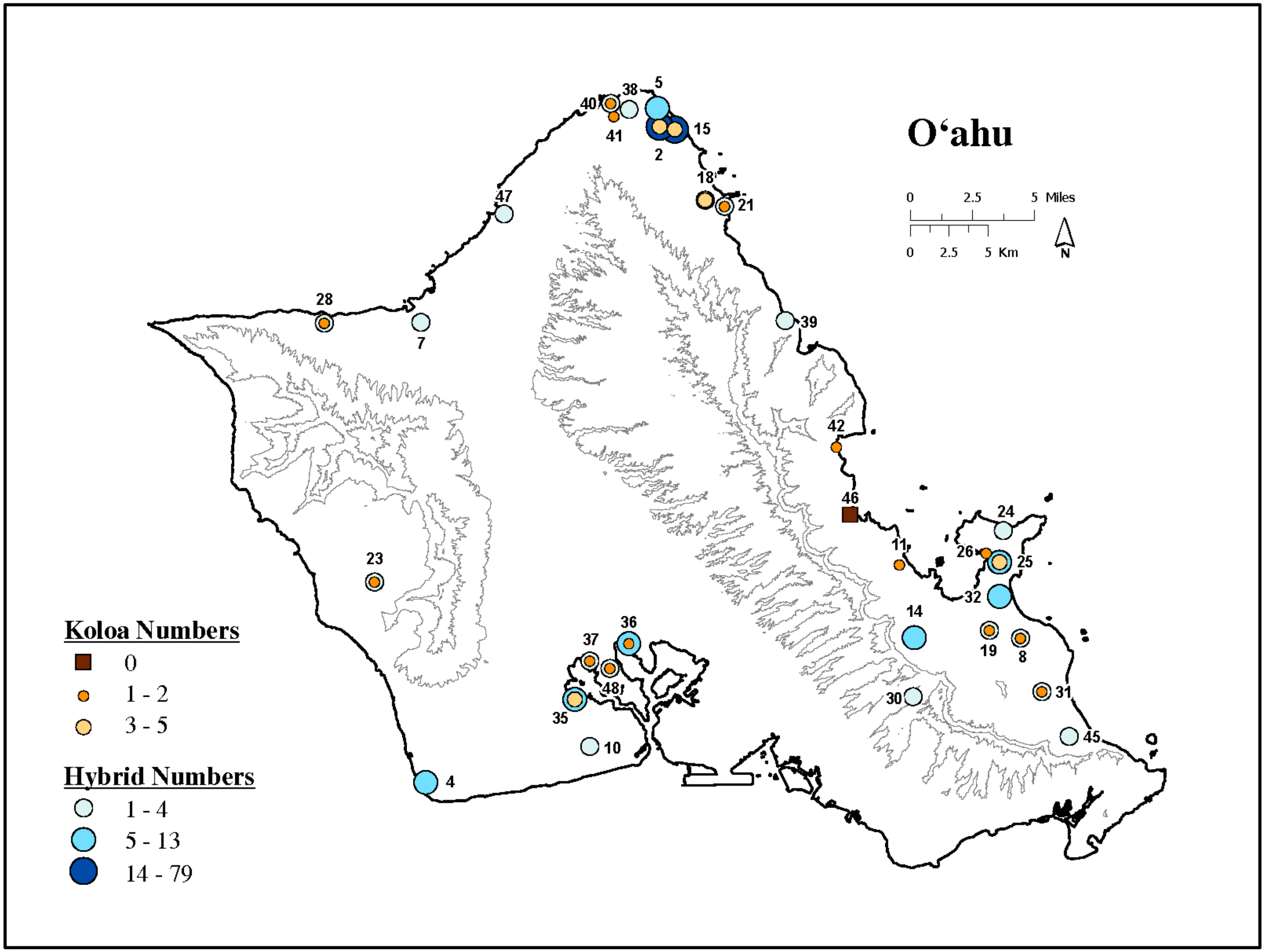

Figure 35. Distribution and abundance of Hawaiian ducks and mallard-Hawaiian duck hybrids on O`ahu, based on winter counts from 1999-2003. The name for each wetland numbered in this figure, as well as whether it is a core or supporting wetland, is listed in Table 2.

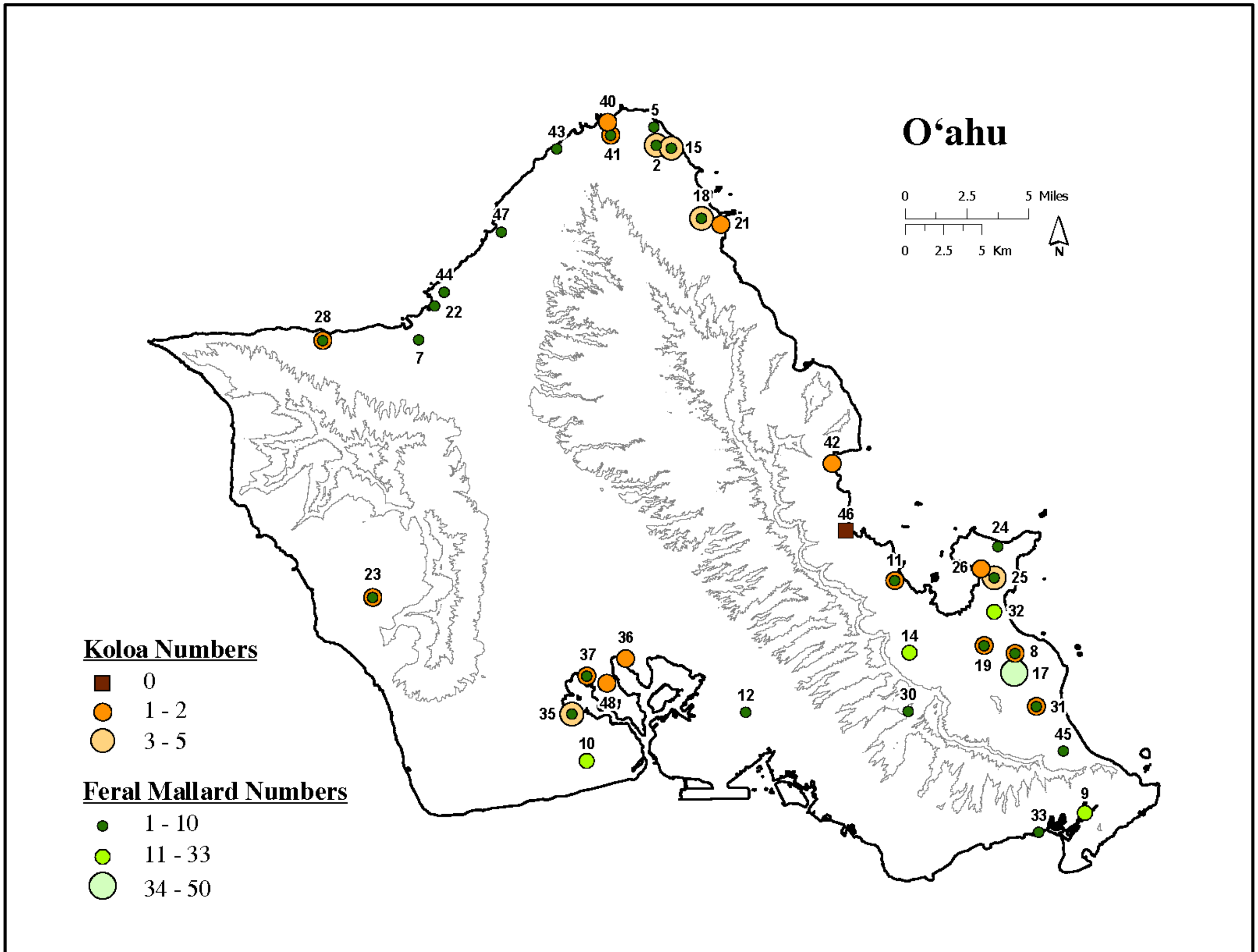

Figure 36. Distribution and abundance of Hawaiian ducks and feral mallards on O`ahu, based on winter counts from 1999-2003. The name for each wetland numbered in this figure, as well as whether it is a core or supporting wetland, is listed in Table 2.

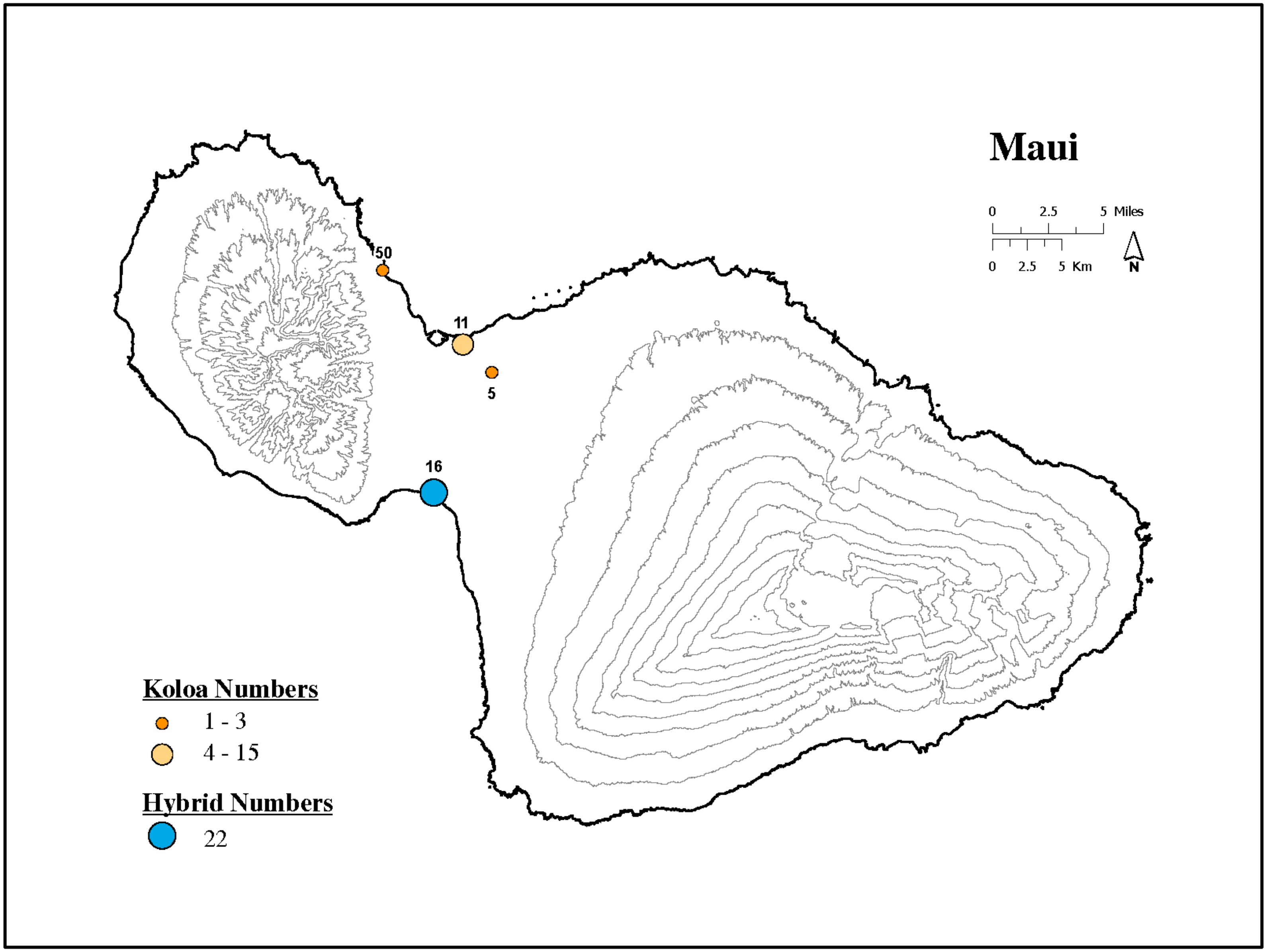

Figure 37. Distribution and abundance of Hawaiian ducks and mallard-Hawaiian duck hybrids on Maui, based on winter counts from 1999-2003. The name for each wetland numbered in this figure, as well as whether it is a core or supporting wetland, is listed in Table 3.

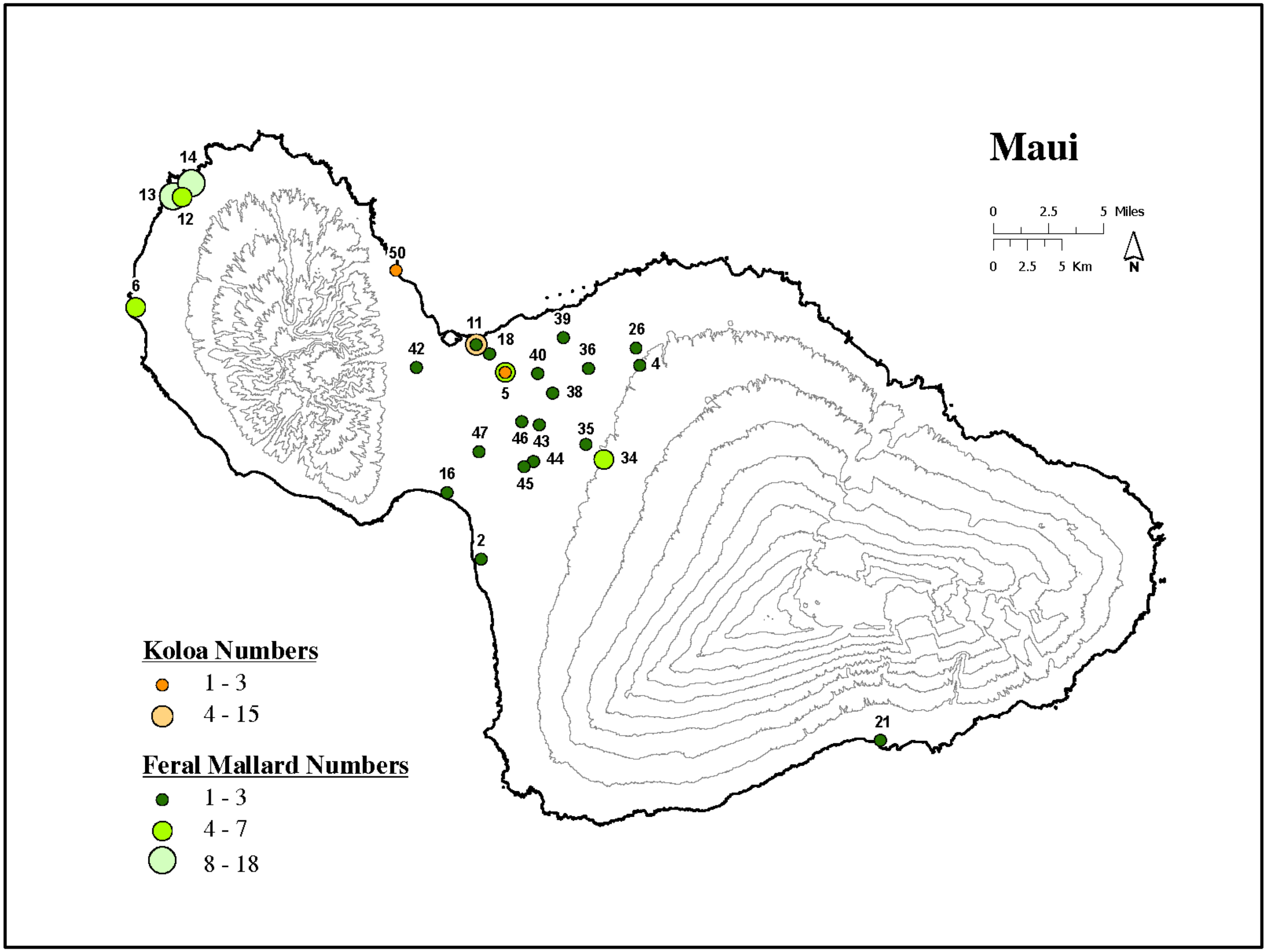

Figure 38. Distribution and abundance of Hawaiian ducks and feral mallards on Maui, based on winter counts from 1999-2003. The name for each wetland numbered in this figure, as well as whether it is a core or supporting wetland, is listed in Table 3.

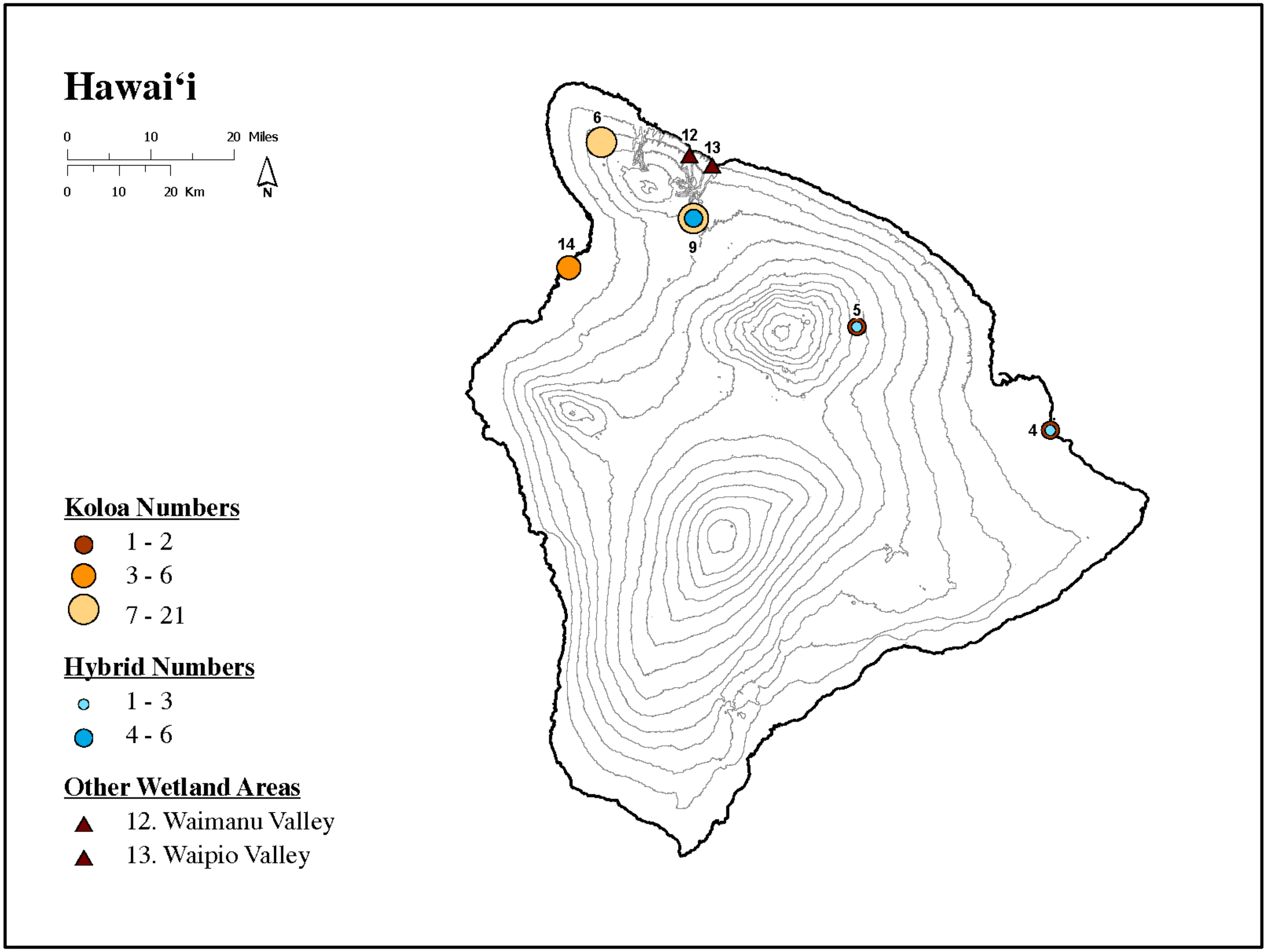

Figure 39. Distribution and abundance of Hawaiian ducks and mallard-Hawaiian duck hybrids on Hawai`i, based on winter counts from 1999-2003. The name for each wetland numbered in this figure, as well as whether it is a core or supporting wetland, is listed in Table 5.

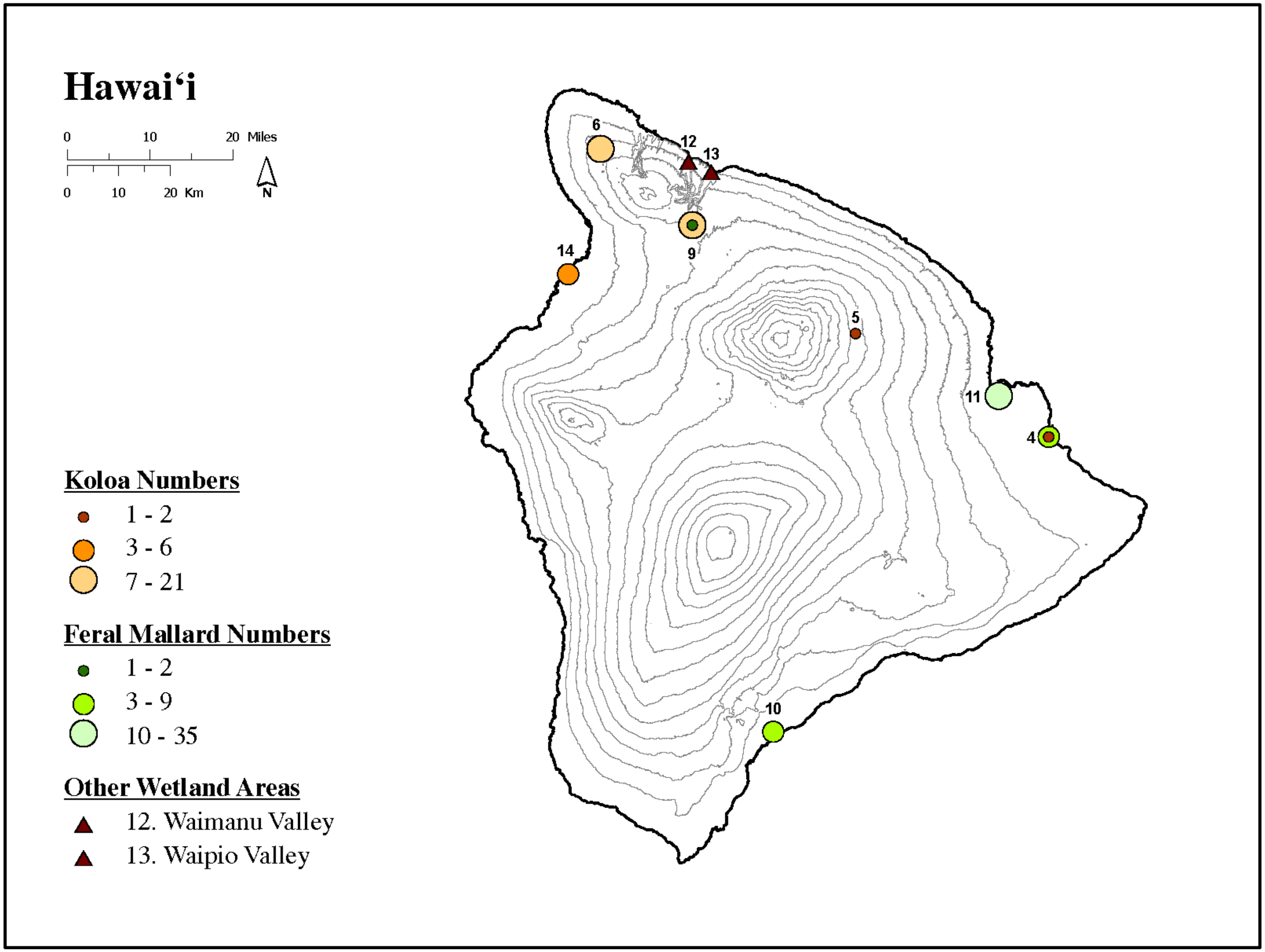

Figure 40. Distribution and abundance of Hawaiian ducks and feral mallards on Hawai`i, based on winter counts from 1999-2003. The name for each wetland numbered in this figure, as well as whether it is a core or supporting wetland, is listed in Table 5.

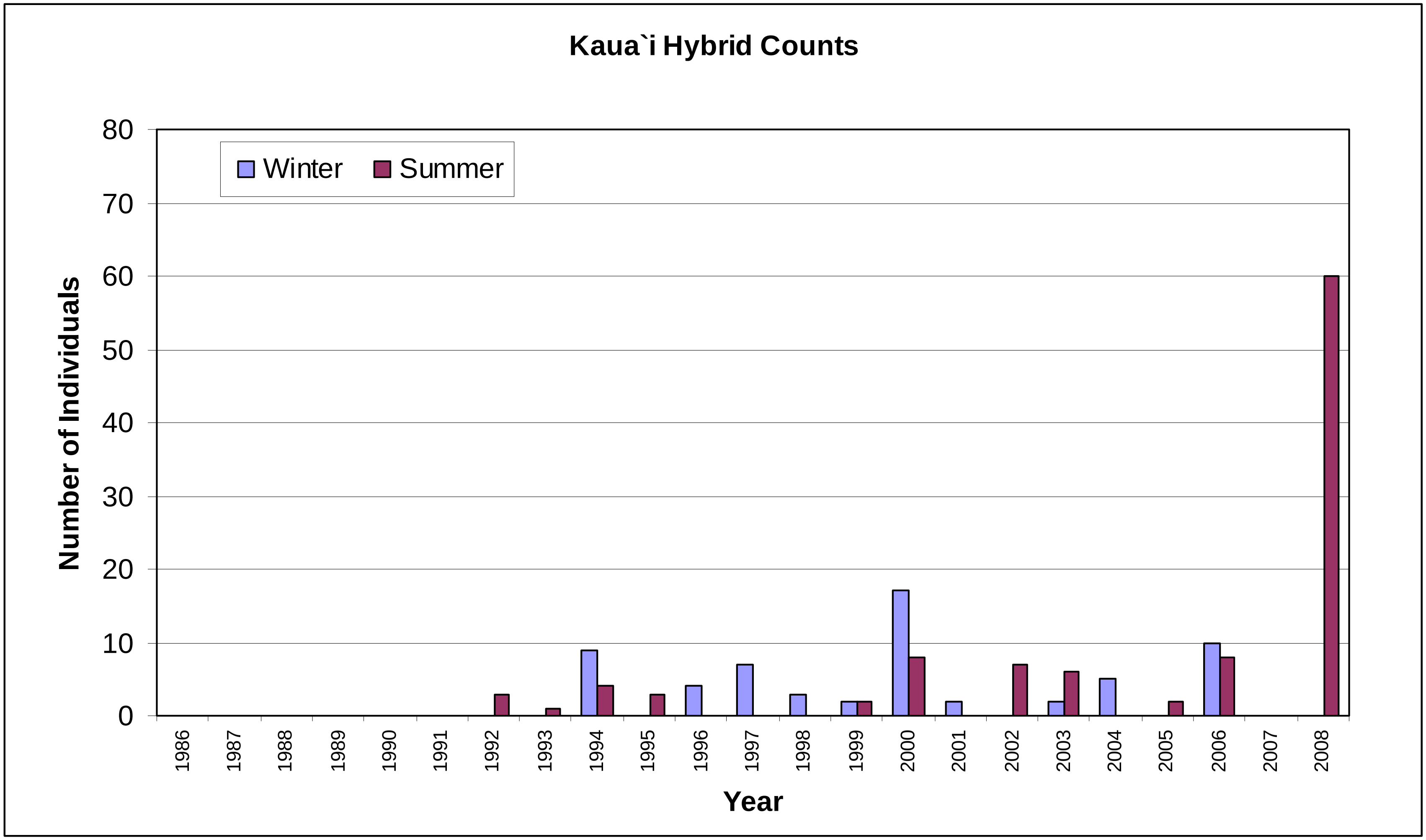

Figure 41. Winter and summer counts of Mallard/Hawaiian duck hybrids on Kaua`i, based on biannual waterbird counts from 1986 to 2008.

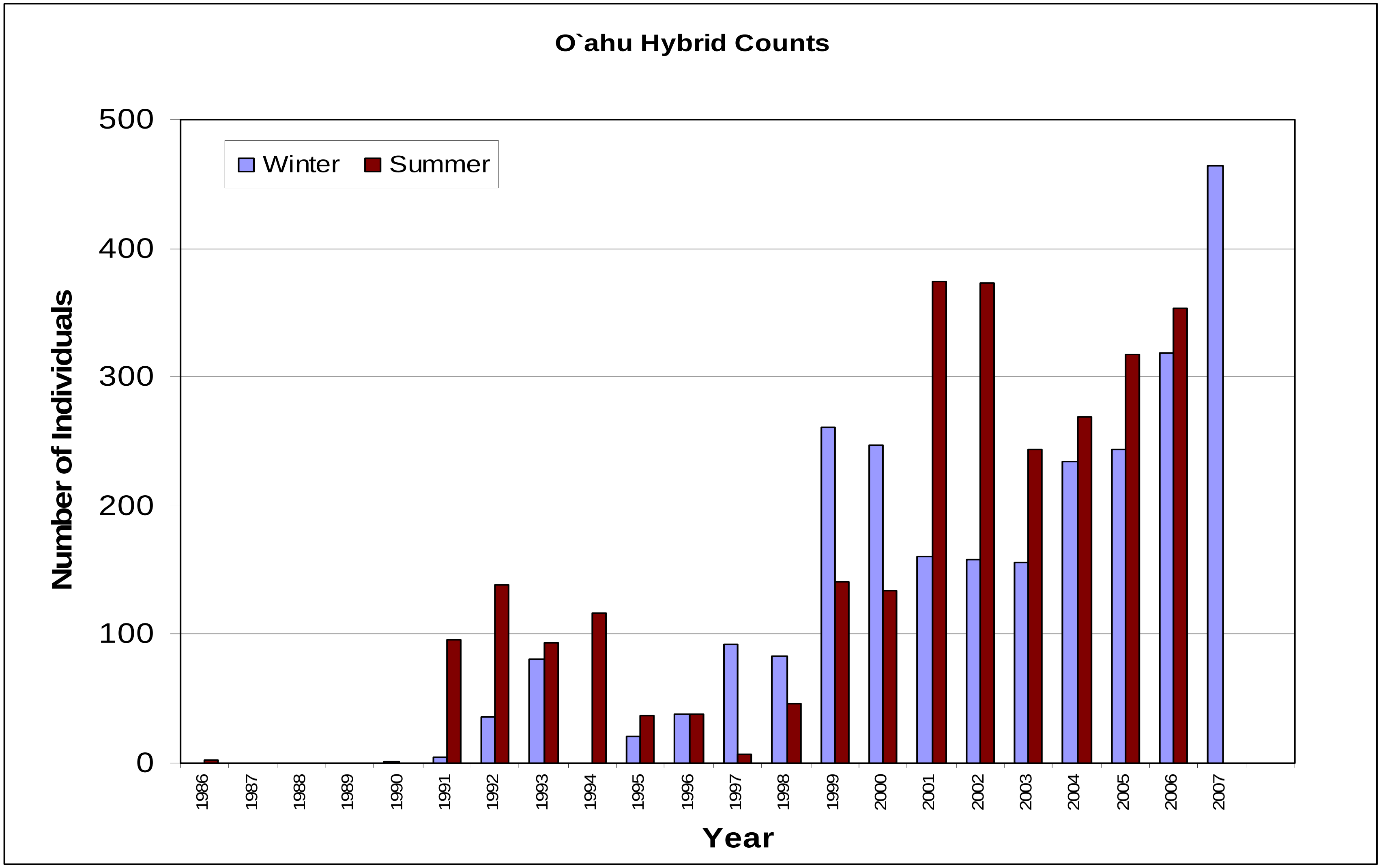

Figure 42. Winter and summer counts of Mallard/Hawaiian duck hybrids on O`ahu, based on biannual waterbird counts from 1986 to 2008.

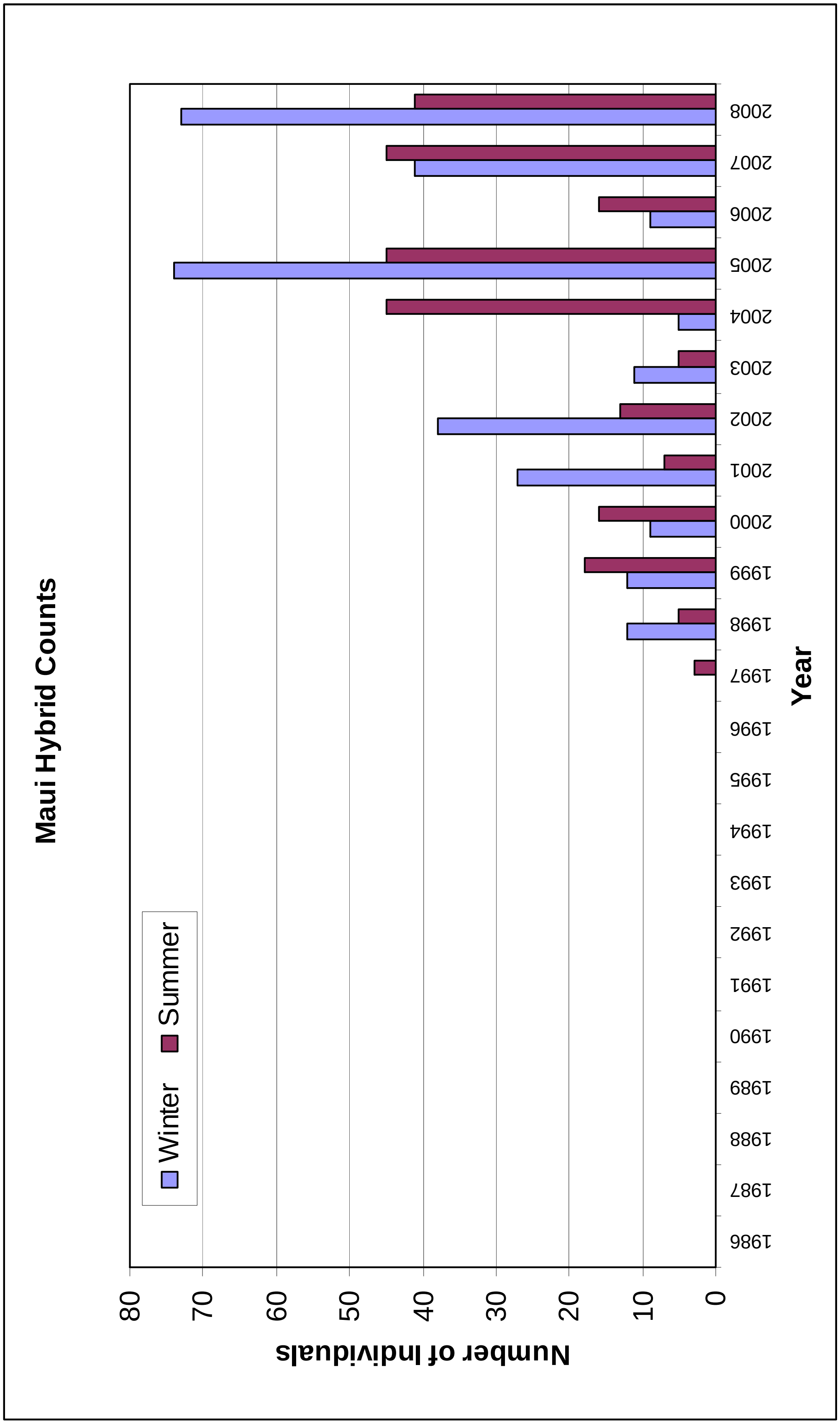

Figure 43. Winter and summer counts of Mallard/Hawaiian duck hybrids on Maui, based on biannual waterbird counts from 1986 to 2008.

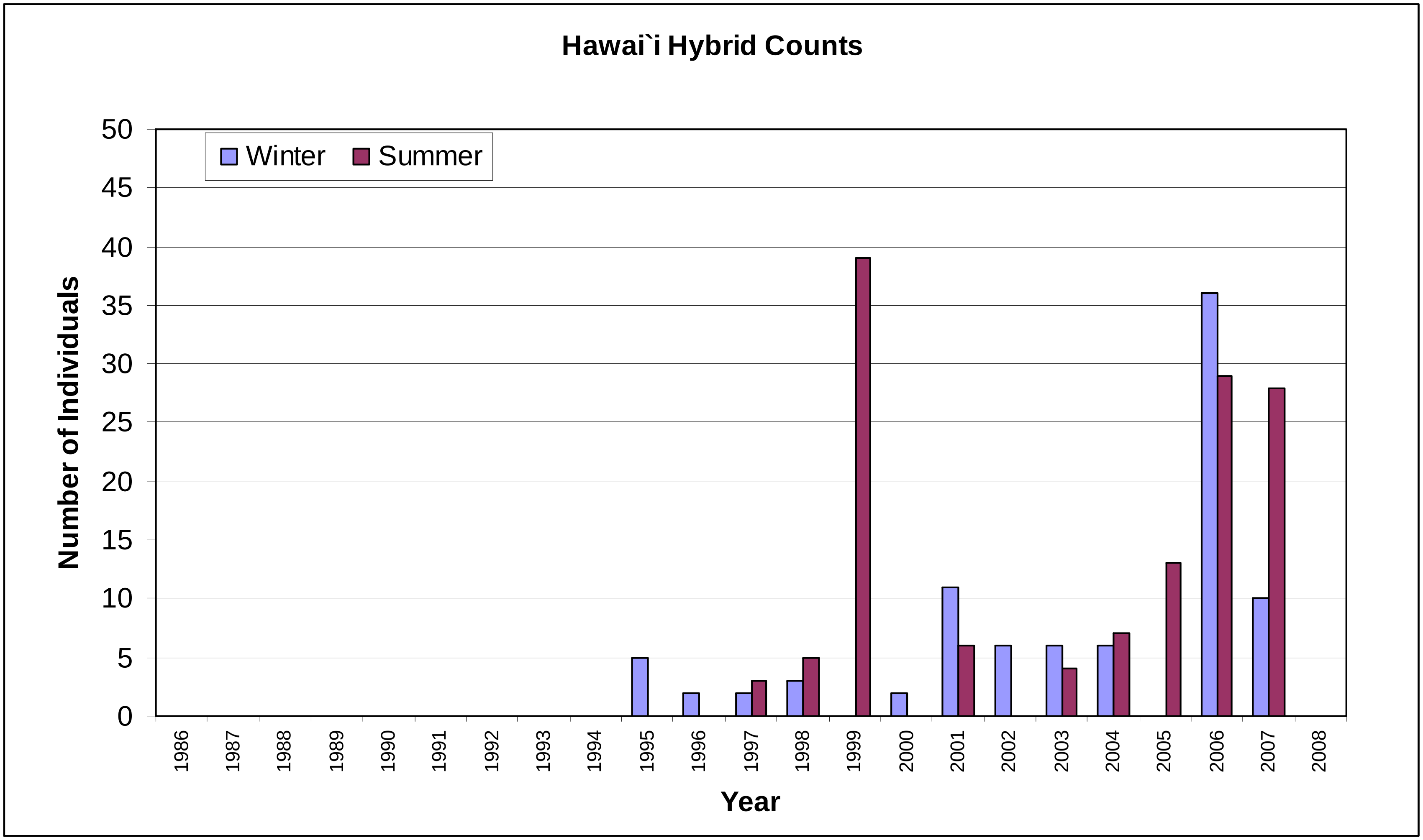

Figure 44. Winter and summer counts of Mallard/Hawaiian duck hybrids on Hawai`i, based on biannual waterbird counts from 1986 to 2008.

On O`ahu, Hawaiian ducks are still reported in small numbers at some sites (Figures 7, 35, 36, and 42), but whether these birds are actually Hawaiian ducks or hybrids is not clear. Hybridization appears to be most severe on O`ahu and many areas on O`ahu now have numerous feral mallards and mallard-Hawaiian duck hybrids, with the largest concentrations in Kawainui Marsh, Oneawa Canal, Ka`elepulu Pond (Enchanted Lake), Ho`omaluhia Botanical Garden, and the Hawai`i Prince Golf Course.

On Maui, most feral mallards are found in the Ka`anapali area, with smaller numbers in the numerous reservoirs of the central valley (Figure 38). All Hawaiian duck-like birds on Kanahā Pond recently have been recorded as Hawaiian ducks, while all those at Keālia Pond have been recorded as hybrids, but it seems unlikely that this apparent segregation is real. Ducks could move easily between these sites, and the difference is probably due to the difficulty of identification in the field. Feral mallards have not been reported on Lāna`i.

On the island of Hawai`i, the largest concentration of feral mallards is at Waiakea Pond in Hilo, which also supports many other exotic waterfowl and may serve as a source of feral mallards that disperse across the island (Figure 40). Substantial numbers of Hawaiian ducks exist in the Kohala area, but hybrids have been reported recently in stock ponds on Kohala and Mauna Kea (Figure 40; K. Uyehara, pers. comm. 2003). At this time, hybridization appears to be increasing on Hawai`i.

An additional conflict has arisen due to the fact that many taro farmers in the State want to use domestic ducks (mallard varieties such as the Cayuga) for the control of apple snails (*Pomacea canaliculata*), an introduced pest species that consumes all parts of taro plants. Domestic ducks may be capable of hybridization with the native Hawaiian duck. Hawaiian ducks have been considered for control of the snail, but they only eat the smaller snails.

Public outreach efforts are currently underway through cooperative efforts between many agencies concerned about conserving the Hawaiian duck, including the University of California, Davis (UC Davis), U.S. Geological Survey (USGS), the Hawai`i Cooperative Studies Unit at University of Hawai`i, Hilo, Hawaii Division of Forestry and Wildlife (HDOFAW), and the U.S. Fish and Wildlife Service. For example, USGS and UC Davis have published a brochure about the Hawaiian duck and the threat of hybridization (Uyehara *et al*. 2007). Malama

Hawai`i, Outside Hawai`i (TV magazine), UC Davis, and The Wildlife Society, through grants from the Hawai`i Invasive Species Council, Pacific Coast Joint Venture, and U.S. Fish and Wildlife Service, joined forces to develop public service announcements and a public education and outreach action plan to heighten awareness about the Hawaiian duck and its importance as an endemic species in Hawai`i. USDA Natural Resources Conservation Service sponsored a Hawai`i Conservation Alliance white paper about the threats of feral mallards to the Hawaiian duck and other Hawaiian waterbirds.

(b) Environmental Contaminants

Environmental contaminants in wetlands are of concern to waterbird recovery because the general diet of these birds makes them susceptible to toxins accumulated in the food chain (Ratner 2000). In 1988, a fuel spill in Pearl Harbor caused direct mortality and nest abandonment of native waterbirds at the Honouliuli Unit of Pearl Harbor National Wildlife Refuge (J. Leinecke, pers. comm. 1993). In 1996, an oil spill in Pearl Harbor imperiled the Hawaiian stilt as well as marine fisheries (Pearl Harbor Natural Resource Trustees 1999). Urban encroachment has the potential to negatively affect waterbirds' habitats via flushing of household and industrial products into water-collecting systems (storm drains and roadside ditches) which lead to streams, wetlands, and the ocean. Currently, little is done to survey for toxicants at wetlands.

(c) Human Disturbance

Human disturbance in this section refers specifically to impacts humans have on waterbirds in wetlands created and managed by humans for a specific use. Agricultural/aquacultural wetlands provide habitat for waterbirds and can assist in their recovery, although the lands are managed for profit, rather than waterbirds. Their ability to assist in recovery would be determined by timing specific crop cycles with waterbird breeding, soil type and water availability at the site (Nagata 1983), water type (fresh or saline) (M. Silbernagle, pers. comm. 2008), and other biological and commercial factors. However, human disturbance in these wetlands can be detrimental, especially during breeding season. For example, flooding or draining of taro fields may destroy nests located in the area and the presence of humans working in the wetlands can negatively affect the species (Nagata 1983). Human disturbance during the early stages of incubation

has been shown to cause nest abandonment and altered behavior in non-breeding waterfowl (Korschgen and Dahlgren 1992).

Waterbirds also utilize other human-made habitats such as golf course water features, sewage treatment facilities, agricultural and roadside ditches, and other areas where water can pond and collect. However, as in agricultural/ aquacultural wetlands, the impacts of human disturbance in these habitats can be detrimental, especially during the breeding season. Because conflicts may arise in areas utilized by both humans and waterbirds (*e.g.*, birds on golf courses, birds in ditches along roads), we need to understand how to address use of these areas and their significance to recovery of these species.

(d) Global Warming and Sea Level Rise

The wetlands utilized most frequently by these species (with the exception of the Hawaiian duck) are coastal wetlands. Therefore they are vulnerable to a rise in sea level. Estimates of sea level rise due to global warming by the end of the 21st century range from 20 to 190 centimeters (8 to 75 inches) with the rate of rise accelerating later in the century (Intergovernmental Panel on Climate Change 2007; Pfeffer *et al*. 2008; Vermeer and Rahmstorf 2009). Dynamic changes in ice sheet outflow may substantially affect sea level rise but remain poorly understood. Such a rise may result in the loss of some wetland habitat and negatively impact the habitat quality of other wetlands for waterbirds. Increased salinity in the groundwater may result in increasing salinity levels of wetlands, which may especially affect species that prefer fresh water such as the Hawaiian duck and Hawaiian common moorhen.

E. CONSERVATION MEASURES

A variety of conservation measures have been implemented to protect Hawai`i's endangered waterbirds. These efforts include a long-term hunting ban, protection of habitat through establishment and management of refuges and sanctuaries, population monitoring, research projects, release of captive-bred Hawaiian ducks, and restrictions on importation of mallards. Federal, State, and private entities have all contributed to Hawaiian waterbird recovery. The major contributions of these entities are summarized below.

1. Federal and State Actions

Indiscriminate hunting of migratory waterfowl in the late 1800s and 1900s took a heavy toll on Hawaiian waterbird populations, especially the Hawaiian duck because of its similarity in appearance to mallards and pintails. When bag limits were introduced they were generous and difficult to enforce. All Hawaiian waterbird species continued to be hunted for several more decades. In 1925, the Territorial Fish and Game Commission closed the Hawaiian duck season, but because of their similarity to female mallards and pintails, Hawaiian ducks probably received little protection (Swedberg 1967). A total ban on waterfowl hunting in 1939, which is still in effect today, provided important protection for the remaining Hawaiian ducks (Bostwick 1982).

In 1952, the State designated Kanahā Pond on Maui as the first State wildlife sanctuary. The following year, Keālia Pond, now a National Wildlife Refuge, was also designated a sanctuary through a cooperative agreement with the landowner (USFWS 1978). Other State sanctuaries include Kawai`ele on Kaua`i, and Hāmākua Marsh, Paiko Lagoon Wildlife Sanctuary, and Pouhala Marsh on O`ahu. In 1964, the U.S. Fish and Wildlife Service and the Hawai`i Department of Land and Natural Resources (HDLNR) became involved in studies (*e.g.*, nesting and surveys) of Hawaiian stilts and other waterbirds at Kanahā Pond.

Additional legal protection was afforded these waterbirds with the passage of Federal legislation for endangered species, including the Endangered Species Preservation Act of 1966, the Endangered Species Conservation Act of 1969, and the Endangered Species Act of 1973. The Hawaiian duck and the Hawaiian common moorhen were declared Federal endangered species in 1967 (USFWS 1967). The Hawaiian coot and Hawaiian stilt were added to the Federal endangered species list in 1970 (USFWS 1970).

The State Division of Forestry and Wildlife (then called the Division of Fish and Game) initiated Hawaiian duck restoration efforts in 1956 when they brought Hawaiian ducks from Kaua`i into captivity at Pohakuloa, Hawai`i, to create a captive breeding population for use in reestablishing the species on other islands. The first release of 26 captive-bred Hawaiian ducks occurred in 1958 at Kahua Ranch, Hawai`i (Engilis *et al*. 2002). Releases of captive-bred birds continued on Hawai`i from 1968 through 1979, with 361 birds released at Kahua Ranch and 58 released in the Hilo Forest Reserve. On O`ahu, 350 Hawaiian

ducks were released from 1968 through 1982 (Engilis and Pratt 1993). Feral mallards were not removed from the reintroduction sites on O`ahu prior to the releases, however, resulting in extensive hybridization and genetic introgression of mallards into the reestablished Hawaiian duck population on that island. Hawaiian ducks were also released on Maui from 1989 to 1990, resulting in the establishment of a small population, although hybridization with feral mallards has proven problematic there as well (Ducks Unlimited 1998).

In 1970, State and Federal biologists published an assessment of wetland habitats for endangered waterbirds (USFWS and HDLNR 1970). An important summary of the status of Hawai`i's wetlands followed this assessment (Shallenberger 1977). Since 1972, six National Wildlife Refuges have been established for the protection of waterbirds and their habitats: Hanalei and Hulē`ia on Kaua`i, James Campbell and Pearl Harbor on O`ahu, Kakahai`a on Moloka`i, and Keālia Pond on Maui. Two sanctuaries have also been designated on military lands for the conservation of Hawaiian waterbirds: Niuli`i Ponds in Lualualei Naval Magazine and Nu`upia Ponds on Kane`ohe Marine Corps Base, both on O`ahu. State and Federal efforts now protect 1,711 hectares (4,230 acres) or 27 percent of the remaining 6,190 hectares (15,475 acres) of coastal wetlands in Hawai`i.

Over the past decades, State and Federal land managers have tested a number of experimental management techniques that increase waterbird productivity, including development of artificial nesting islets, floating nest structures, and eradication of the invasive red mangrove using mechanical clearing and herbicide treatments (Rauzon and Drigot 2002; Smith and Polhemus 2003). These experiments show promise for increasing productivity of endangered waterbirds in habitats currently lacking adequate nesting and foraging habitat. Use of windmills for water manipulation, fencing and trapping to control predators (Morin 1998), and controlling human disturbance are additional successful management techniques that have increased waterbird numbers.

Managers have also studied connectivity between wetland habitats, such as the study commissioned by the Marine Corps Base Hawai`i as part of the implementation of their Integrated Natural Resources Management Plan. This study (Rauzon *et al*. 2002) described wetland use by the Hawaiian stilt in the windward O`ahu Ko`olaupoko District. The goal of this study was to increase understanding of current and potential habitat enhancements for the Hawaiian stilt

on windward O`ahu and distribute this information to help regional stakeholders improve programs and activities that might improve Hawaiian stilt recovery efforts there. Reed *et al*. (1998b) also studied wetland connectivity, showing that Hawaiian stilts move between wetlands but that movement declines with increasing distance between wetlands. Over the past two decades, Marine Corps Base Hawai`i has worked to maintain Hawaiian stilt habitat on its properties and facilitated events that promote Hawaiian stilt conservation and involve both the public and military personnel. Their overall goal is to contribute to regional recovery efforts of the Hawaiian stilt, with a view to building regional partnerships and strengthening the Hawaiian stilt population outside of the core habitat on the Marine Corps Base.

Additional research is needed to develop appropriate census techniques, determine those parameters that characterize a viable self-sustaining breeding population, and to understand the behavior and biology of these endangered waterbirds to allow us to effectively manage for these species.

2. Private Actions

Significant research on the endemic waterbirds of Hawai`i began in 1962 with a study of Hawaiian ducks on Kaua`i supported by the World Wildlife Fund. From 1980 to the present, research has been conducted to improve our biological knowledge of Hawai`i's endangered waterbirds (*e.g.*, Coleman 1981; Nagata 1983; Griffin *et al*. 1989; Chang 1990; Engilis and Pratt 1993; Browne *et al*. 1993; Reed and Oring 1993; Reed *et al*. 1994, 1998a,b; Eijzenga 2004; Smith and Polhemus 2003; and Gee 2004). Research on anchialine pools has been conducted by the Oceanic Institute. These research projects and data summaries have enhanced our knowledge of Hawai`i's waterbirds; however, many gaps still exist.

A variety of non-governmental organizations have also been instrumental in protecting Hawai`i's wetlands and endangered waterbirds. Ducks Unlimited, a private wetlands conservation organization, works cooperatively with State and Federal agencies, as well as with private landowners and local corporations, on wetlands conservation and habitat restoration and protection efforts. In 1997, Ducks Unlimited developed a comprehensive, cooperative plan to protect and restore wetlands used by native waterbirds in Hawai`i. Ducks Unlimited continues some work on wetland projects statewide with various partners.

A variety of other conservation organizations are contributing to the recovery of Hawai`i's endangered waterbirds. The Nature Conservancy manages several ecological preserves in the State. The Maui Coastal Land Trust is restoring a dune system on Maui. The Hawai`i Audubon Society and the Sierra Club advocate on behalf of wetland protection. The National Audubon Society organizes the annual Christmas Bird Count, which provides another tool for monitoring waterbird populations. `Ahahui Mālama I Ka Lōkahi and Kawai Nui Heritage Foundation are watchdog organizations that oversee the future of Kawainui Marsh on O`ahu. They sponsor and lead educational tours and coordinate plant restoration projects at Na Pohaku o Hauwahine. The Nature Center, The Wildlife Society, and The University of Hawai`i's Pacific Cooperative Studies Unit all work on waterbird recovery issues. Private landowners that also contribute to waterbird recovery include Kamehameha Schools, Midler Family Trust**,** Kaelepulu Wetland Preserve, `Ulupalakua Ranch, Hana Ranch, Moloka`i Sea Farms, New Moon Foundation, Hawaiian Cloud Forest Coffee, Kohala Preserve Conservation Trust, and Kukio Resort.

3. Partnerships

The recovery of Hawai`i's endangered waterbirds requires strong partnerships among Federal, State, local, and private groups. A variety of partnerships have been formed to protect and manage waterbird habitat. Examples of such partnership opportunities include our Pacific Coast Joint Venture, Partners for Fish and Wildlife Program, Coastal Program, and Habitat Conservation Plan and Safe Harbor Agreement Programs; the multi-agency Coastal America program; restoration plans for hazardous materials spills that target waterbird habitat; and the Natural Resources Conservation Service's wetland restoration programs. Partnerships aim to encourage landowners and private citizens to protect and preserve waterbirds and their habitats through cooperative agreements, and funding for habitat restoration and creation. Partnerships with private landowners and conservation groups can assist land managers in acquiring and maintaining wetland habitats and developing and implementing public awareness programs.

Examples of ongoing partnerships are agreements with Chevron Refinery on O`ahu and `Umikoa Ranch on the island of Hawai`i. From 1993 to 2004, Chevron Refinery and the U.S. Fish and Wildlife Service implemented terms specified in a Cooperative Agreement to manage Rowland's Pond as temporary

nesting habitat for Hawaiian stilts. Activities included predator control and vegetation management at Rowland's Pond, the Impounding Basin, and Oxidation Ponds. Chevron Refinery continues to manage the refinery grounds today for the benefit of the Hawaiian stilt and Hawaiian coot under a Safe Harbor Agreement. As a result of these agreements, a total of 419 Hawaiian stilt chicks fledged at Chevron Refinery Hawai`i over the 14-year period (L. Gibson, pers. comm. 2004, J. Hiromasa, USWFS, pers comm. 2008). The Safe Harbor Agreement for `Umikoa Ranch included the creation and maintenance (*e.g.*, fencing to exclude cattle and predator control) of 10 ponds for the Hawaiian duck and Hawaiian goose over a period of 20 years (J. Kwon, pers. comm. 2008). Another potential partnership could be developed with the Kaua`i Lagoons landowners. Hawaiian coots, Hawaiian common moorhens, and Hawaiian ducks are common at Kaua`i Lagoons water features. With such a partnership in place, Kaua`i Lagoons could play a role in advancing the recovery of these species.

4. Summary of Accomplishments

Recovery efforts for these four species have been underway since hunting was first banned in 1939. Although much work is still needed to recover all four species, there have been major accomplishments. For example, the numbers of wetlands that are now protected and under consistent management have increased; over 50 percent of the core wetlands are protected. Management at many of the wetlands has increased and is more consistent, including predator control, vegetation control, and management of water levels. Wetlands without consistent management fare much worse. For example, when predator control of cats and mongooses was implemented at `Aimakapā Pond on Hawai`i Island (1993-1994) 18 to 22 Hawaiian stilts and 6 to 18 Hawaiian coots were fledged (Morin 1998). However, since predator control was discontinued in 1995, no Hawaiian stilts have been recruited and on average only two Hawaiian coots are recruited yearly (K. Uyehara, pers. comm. 2008). Survey methodologies for the biannual waterbird counts have been improved and implemented several times, most recently in 2005 (USFWS 2005a), and information on using playbacks during surveys to increase Hawaiian common moorhen detections may be added in the near future (Conway and Gibbs 2005; DesRochers 2006; Gee 2007). Several private landowners are working in partnership with other entities to improve conditions of wetlands on their lands. The University of Hawai`i offers Sea Grant extension services on aquaculture and coastal conservation. Research on anchialine pools has been conducted by the Oceanic Institute. The University of

Hawai`i also administers the Hawai`i Biodiversity and Mapping Program (formerly the Hawai`i Natural Heritage Program) as part of the Center for Conservation and Training. The Hawai`i Biodiversity and Mapping Program maintains a database of natural communities and rare and endangered species and have been instrumental in summarizing biannual waterbird counts for the State.

Through the years, many researchers, as well as managers, have studied and observed waterbirds and their work has lead to suggestions for management of wetlands (*e.g.*, Chang 1990; Gee 2007; Wirwa 2007), a better understanding of population biology (*e.g.*, Coleman 1981; Engilis and Pratt 1993; Morin 1998; Reed *et al*. 1998b), and measures to reduce or remove the threat of hybridization to Hawaiian ducks (*e.g.*, Uyehara *et al*. 2007). Because of the efforts of many people involved in waterbird recovery, the number of waterbirds appears to be increasing (Figures 4, 5, 12, 13, 20, 21, 26, and 27) toward the stated recovery population goal number (HDOFAW 1976-2008). Hawaiian coots and Hawaiian stilts are the closest to reaching the minimum counted population size of 2,000, one of several criteria for considering downlisting. Although Hawaiian common moorhen counts appear considerably lower than the population goals, their secretive nature has made it difficult to accurately assess their population. Efforts to continue improving the opportunity for Hawaiian common moorhens to reach the minimum population goals in the near future (by increasing the number of protected and managed wetlands and predator control) along with improving our ability to adequately survey for Hawaiian common moorhens are both important for meeting population targets. The biannual survey data for Hawaiian ducks show total counts well below the current population target. However, our ability to accurately survey for Hawaiian ducks is impaired by the difficulty in distinguishing between hybrids and Hawaiian ducks. In addition, montane stream habitats are poorly surveyed and, as noted, observations indicate Hawaiian ducks are prevalent in these areas. Efforts are currently underway to resolve these issues which compromise our ability to accurately assess the population of Hawaiian ducks.

F. MONITORING

After World War II, State biologists, with Federal assistance, began an investigation of migratory waterfowl in the belief that wintering populations might support a continued hunting program. Although hunting was never reopened, this early study became the foundation of a continuing program of biannual statewide waterfowl surveys, which was later expanded to include all endemic and migratory waterbirds.

Biannual counts, organized by the HDOFAW, have been conducted statewide since the mid-1950s, but coverage of certain areas was somewhat inconsistent until about 1976. Data from these surveys were recently compiled by the Hawai`i Biodiversity and Mapping Program (under contract from the State of Hawai`i) and by the U.S. Fish and Wildlife Service, making it possible to examine a comprehensive data set of waterbird abundance for population trends from 1976 through 2007.

The biannual waterbird surveys consist of visits to wetlands on all islands on a single day each winter and summer, reducing the possibility of counting birds more than once as they move among sites. In addition to recording the number of individuals of all waterbird species at each wetland, surveyors collect information on water level, vegetation cover, weather conditions, and human disturbance. These surveys include the majority of wetlands on each island, but do not cover several locations that support waterbirds, such as streams and newer reservoirs on private lands. The numbers resulting from these surveys are thus minimum values and likely underestimate the actual population by an unknown amount. These counts are probably fairly accurate population estimates for Hawaiian coots and Hawaiian stilts in most years because these species are relatively conspicuous and often use open water areas. Hawaiian common moorhens and Hawaiian ducks, however, are likely seriously undercounted; they are secretive and often hide in densely vegetated areas, in the case of the Hawaiian common moorhen, or use montane stream habitats that are not covered in the biannual survey, in the case of the Hawaiian duck. No method currently exists to accurately census Hawaiian common moorhens, but the data from the biannual waterbird surveys are useful for population trend analysis. Ni`ihau has not been surveyed since 1999, but presumably supports many Hawaiian coots and Hawaiian stilts in wet years. Reinitiating Ni`ihau surveys would increase the overall accuracy and usefulness of waterbird surveys. Limitations of access,

personnel (people available to survey) and lack of knowledge contribute to the reason some wetlands are not included in the surveys. Because the data are used as an index to indicate trend (rather than absolute numbers), not all wetlands need to be surveyed, but an effort should be made to survey wetlands that reflect utilized habitat as much as possible. Wetlands should also periodically be evaluated for removal (no longer functioning as a wetland after some years of survey efforts) or addition (newly discovered wetlands, or new access to a site) to survey efforts to ensure this is the case.

The biannual waterbird count is the best tool available for estimating the relative abundance of waterbirds and is extremely valuable for monitoring their populations. The overall goal and methodology of the count are sound, but improvements could include greater standardization and consistency among islands in the identification of Hawaiian ducks, mallards, and hybrids; more consistent coverage of wetlands each year to increase comparability over time; development of more accurate methods of surveying Hawaiian common moorhens, possibly including playbacks; and inclusion of montane stream habitats to provide a more thorough estimate of the Hawaiian duck population. The count protocol was revised in 2005 (see http://www.state.hi.us/dlnr/dofaw/pubs), improving its utility for monitoring populations of migratory shorebirds (Engilis and Naughton 2004) and including more thorough instructions for counters and a photographic guide (http://www.state.hi.us/dlnr/dofaw/pubs /WaterbirdCount_photoguide.pdf). Additional needs could include maps delineating survey points/routes for each wetland surveyed, extent of wetland, justifications for non-surveyed lands, why it was not surveyed, GPS coordinates for each wetland, and synonyms for the site (S. Pelizza, *in litt*. 2005). Additionally, data from other monitoring efforts such as at National Wildlife Refuges may be used for in-depth knowledge of resource status (S. Pelizza, *in litt*. 2005).

Population values presented in maps in this plan (Figures 6 to 9, 14 to 18, 22 to 23, 28 to 32, and 33 to 40) are based on 5-year averages of winter counts from the biannual waterbird survey. In most cases data from 1999 to 2003 were used to calculate this 5-year average, but in a few cases data from 1998 to 2003 were used because data from 2002 were missing. Although the population trend graphs in this plan (Figures 4, 5, 12, 13, 20, 21, 26, and 27) present data from both summer and winter counts, we have primarily used the winter counts to assess

trends because summer counts tend to be more variable due to annual variation in survival of hatch-year birds.

When compiling these data, we found numerous differences between the numbers recorded on the original data sheets obtained from the State and the summary values reported in previous versions of the recovery plan for Hawaiian waterbirds (USFWS 1999a). The population data reported in this plan are based on the original data recorded wetland by wetland on each island, are verifiable, and are therefore regarded as correct. Some values in the previous draft plan could not be verified, and were not consistently higher or lower. Researchers and managers using previously available data are urged to confirm that the information they have is correct.

II. Recovery

A. RECOVERY PLANNING HISTORY

In 1975, we established the Hawaiian Waterbird Recovery Team. The mission of this team was to evaluate available data and develop a plan for the recovery of the Hawaiian coot, Hawaiian common moorhen, and Hawaiian stilt (the Hawaiian duck was not included in this original recovery plan). Limited information was available to the team due to the lack of statewide surveys and research on each of the species.

The team recognized that the availability of optimum habitat for the waterbirds was crucial to maintaining self-sustaining populations of these species. Past population target levels were based on expected habitat carrying capacity and best professional judgment. The first Hawaiian Waterbirds Recovery Plan was completed in 1978 (USFWS 1978). The primary objective of that recovery plan, as defined by the team, was to maintain self-sustaining populations of at least 2,000 individuals of the coot, stilt, and moorhen throughout their known distribution and habitat as it existed in 1976. Upon the accomplishment of this objective, downlisting and then delisting of the waterbirds could be considered if the birds maintained these target population sizes and distributions for 3 and then 6 years, respectively. Specific recommendations discussed in the original recovery plan included: 1) providing optimum habitat throughout the State for each endangered species to complete their life cycle (accomplished through preservation and enhancement of primary habitat and development and enhancement of secondary and former habitats); 2) reducing adverse factors affecting waterbirds and their habitat, such as predation by alien species and/or encroachment of wetlands by invasive non-native plants, to the lowest possible level; 3) preventing or moderating disasters adversely affecting the species in primary habitats, including habitat management to avoid disease; 4) monitoring populations to determine numbers, status, and distribution and to determine the progress of the statewide recovery program; 5) fostering public awareness and support of recovery plan implementation through an education and information program; and 6) investigating the possibility of captive rearing and release of Hawaiian common moorhens on Maui, Moloka`i, and Hawai`i (USFWS 1978).

The recovery plan was revised and updated in 1985 to include the Hawaiian duck (USFWS 1985). While the primary recovery objectives and time

frames remained the same, there were some modifications in the primary habitats identified as needing protection or management, based on changes in habitat status. Specific recommendations of the first revised recovery plan included: 1) providing protection of suitable habitat in sufficient abundance and distribution throughout the State for each of the four taxa of waterbirds; 2) maximizing productivity and survival of adults and young; 3) conducting management-related research to fill the gaps in required information; 4) continuing monitoring of all populations of waterbirds; 5) maintaining pure genetic stocks of Hawaiian ducks; 6) supplementing existing or historical populations of waterbirds, as needed; and 7) generating public awareness and support for the waterbird recovery program through education and information.

This recovery plan builds upon previous efforts. The goal of this second revised recovery plan is to identify actions needed to downlist these four endangered Hawaiian waterbirds from endangered to threatened status and, ultimately, to remove them from the Federal List of Endangered and Threatened Wildlife (delisting). The following sections outline the strategy and criteria for recovery leading to the downlisting and eventual delisting of these endangered species.

Studies initiated since the first recovery plan was published have allowed us to modify population target levels and identify more specific recommendations for each species. The time frame for achieving recovery objectives has been modified in this revision of the plan from 3 and 6 years for downlisting and delisting, respectively, to 5 and 10 years. In this recovery plan, population target levels are based on State waterbird biannual survey data collected from 1976 through 2007, as well as a population viability analysis for the Hawaiian stilt. While the statewide survey data provides information about population trends and can be used as starting points for establishing recovery targets, population viability analyses are needed for all four of these species (includes updating the Hawaiian stilt analysis) (Reed *et al*. 1998a) to help us develop population targets that may serve as more accurate predictors of long-term recovery.

B. RECOVERY STRATEGY

The recovery of Hawai`i's endangered waterbirds focuses on attaining adequate population sizes and distribution of multiple self-sustaining populations throughout the historical range of each species. These objectives are based upon

two widely recognized and scientifically accepted goals for promoting viable self-sustaining populations: 1) the creation or maintenance of multiple populations so that a single or series of catastrophic events will not result in the extinction of the species; and 2) increasing the population size of each species throughout its range to a level where the threats of genetic, demographic (population dynamics), and normal environmental uncertainties are diminished (Mangel and Tier 1994; National Research Council 1995; Tear *et al*. 1995; Meffe and Carroll 1996). Furthermore, for these population and distribution goals to ensure the long-term viability of the species, they will require the successful control or elimination of the threats identified in this plan. By maintaining minimum population numbers and self-sustaining breeding populations at multiple sites on multiple islands, the endangered waterbirds have a greater likelihood of achieving long-term survival and recovery.

The population size and distribution prescribed for recovery of the Hawaiian stilt are based on a projection for a basic single-population model conducted by Reed *et al*. (1998a). This model estimated that Hawaiian stilts would increase in number to a long-term mean of 1,901 (SD = 89) individuals, with a 0 percent chance of extinction over 200 years, given observed parameter values for reproductive success and mortality and assuming ongoing predator control. (However, modifying reproductive and mortality parameters to reflect cessation of predator control resulted in a 100 percent chance of extinction over 200 years, with a mean time to extinction of 32 years.) Carrying capacity for the entire population was estimated at 1,929, the total of the maximum winter counts for each island. Sensitivity analysis showed that the long-term mean population closely tracked the carrying capacity estimate used in the model. We have used the best estimate of carrying capacity, conservatively rounded to 2,000, as the basis for the population size required for recovery.

Population viability analyses or other quantitative means of establishing population requirements have not yet been developed for the Hawaiian duck, Hawaiian coot, or Hawaiian common moorhen, although sufficient information may exist for such analyses to be developed (M. Morin, *in litt*. 2005; A. Engilis, pers. comm. 2008). For these species, current and historical population counts from the biannual statewide waterbird survey suggest that a similar population size may be roughly appropriate as a long-term target for a stable, self-sustaining population. Based on this and on the above estimated carrying capacity for the Hawaiian stilt (USFWS 2005), the population targets in these species' recovery

criteria are provisionally set at 2,000 individuals; these targets should be viewed as starting points that are subject to revision based on future research and statistical analyses (*e.g.*, more detailed criteria reflecting species-specific resilience to perturbations), as recommended in this recovery plan. Before downlisting or delisting the Hawaiian duck, Hawaiian coot, or Hawaiian common moorhen, a population viability analysis must be conducted to quantitatively assess what population level will be viable to assure the recovery of the species. Data collected with updated survey methodologies that can more effectively detect secretive Hawaiian common moorhens in dense vegetation and survey montane stream habitat for Hawaiian ducks should be incorporated into such analyses. Before downlisting or delisting the Hawaiian stilt, a new population viability analysis should be conducted to update the findings of Reed *et al*. (1998a) and confirm whether a population of 2,000 will be adequate for the recovery of the species.

Wetland protection and management is crucial to maintain self-sustaining breeding populations of waterbirds. This recovery plan identifies a number of actions for important wetlands used by the Hawaiian coot, Hawaiian duck, Hawaiian common moorhen, and Hawaiian stilt. The recovery strategy for the endangered waterbirds relies on a combination of core and supporting wetlands, as defined below:

Core Wetlands are areas that provide habitat essential for the larger populations of Hawaiian waterbirds that comprise the bulk of the numbers prescribed for recovery. It is crucial for wetlands at these sites to be secure from conversion to non-wetland condition and to have sufficient enduring management to recover Hawai`i's waterbirds. Appendix A provides a brief description of the core wetlands identified in this plan.

Supporting Wetlands are additional areas that may not support the bulk of waterbird populations but provide habitat important for smaller waterbird populations or that provide habitat needed seasonally by segments of the waterbird populations during part of their life cycle. Protection and management of these wetlands is required to recover Hawai`i's waterbirds, but there is more flexibility with regard to which sites must be managed, as it is possible that other sites may fulfill the same needs as those listed here. Appendix B provides a brief description of the supporting wetlands listed in this plan.

Protected Wetlands are any wetlands (core, supporting, or neither) that are secure from development.

The core and supporting wetlands identified in Tables 6 through 9 are currently thought to be the sites on each island that provide the greatest potential for recovery of Hawaiian waterbirds. All core wetlands and a portion of supporting wetlands (50 percent for downlisting and 85 percent for delisting) should be protected and managed in accordance with the management practices outlined in this recovery plan. This approach is designed to ensure persistence of Hawaiian waterbird populations across a reasonably broad distribution of their range, which should also allow for periodic fluctuations in population numbers and site conditions. However, it is possible that in the future some of these sites, particularly those on private land, may become unsuitable for waterbirds due to changes in land use practices. Similarly, additional sites that are not currently suitable for endangered Hawaiian waterbirds may become so, following restoration efforts. The implementation of recovery actions for Hawaiian waterbirds must be flexible and often depends on opportunities provided by interested parties. The recovery criteria for these species thus also should be somewhat flexible, so that future changes in land use and unexpected opportunities for recovery can be accommodated. Therefore, it may be possible to substitute other wetlands for core or supporting wetlands, as long as they provide a similar amount of habitat that can be expected to support a similar number of birds. We will use the best available information and update the core and supporting wetland list as necessary.

For core wetlands it will generally be difficult to substitute an alternate site that provides the same function because they are among the largest wetlands and support the greatest abundance of each species. An exception among the core wetlands may be the Playa Lakes on Ni`ihau, which in some years provide seasonally important habitat for large numbers of Hawaiian stilts and Hawaiian coots, but are located on private land where it may be difficult to ensure protection of the habitat. If similar habitat can be restored in a supporting location, such as the Mānā Plain of Kaua`i, which once contained extensive seasonal wetlands, then that site could be substituted for the Playa Lakes as a core wetland.

Table 6. Core and supporting wetlands on Kaua`i and Ni`ihau identified for protection and management in order to recover the Hawaiian duck, Hawaiian coot, Hawaiian common moorhen, and Hawaiian stilt.

Island	Wetland	Status	Ownership*
Ni`ihau	Playa Lakes (including Halāli`i Lake and Ditches, Nonopapa Lake, and Halulu Lake)	Core[1]	Private
Kaua`i	Hanalei National Wildlife Refuge	Core	USFWS[2]
Kaua`i	Hulē`ia National Wildlife Refuge	Core	USFWS[2]
Kaua`i	Lumaha`i Valley Wetlands	Core	Private
Kaua`i	Mānā Plain Forest Reserve (formerly Kawai`ele Wild Bird Sanctuary)	Core	HDOFAW[3]
Kaua`i	Hanalei River and Taro Fields (that are not part of Hanalei National Wildlife Refuge)	Supporting	Private/State[4]
Kaua`i	Hanapēpē Salt Ponds	Supporting	Private/HDOFAW[3]
Kaua`i	Mānā Base Pond (Part of Mānā Plain)	Supporting	Private/HDOFAW[3]
Kaua`i	Mānā Wetlands (Part of Mānā Plain)	Supporting	Private/State[4]
Kaua`i	Ōpaeka`a Marsh	Supporting	Private/HDOFAW[3]
Kaua`i	Smith's Tropical Paradise	Supporting	Private/State[4]
Kaua`i	Wailua River Bottoms	Supporting	Private/State[4]
Kaua`i	Waimea River System	Supporting	Private/State[4]
Kaua`i	Wainiha Valley River and Taro Fields	Supporting	Private/County
Kaua`i	Waitā Reservoir	Supporting	Private

* In some areas, entities may have partial ownership

[1] See Section II.A Recovery Strategy

[2] USFWS = U.S. Fish and Wildlife Service

[3] HDOFAW = Hawai`i Division of Forestry and Wildlife

[4] State = Other State departments/agencies

Table 7. Core and supporting wetlands on O`ahu identified for protection and management in order to recover the Hawaiian duck, Hawaiian coot, Hawaiian common moorhen, and Hawaiian stilt.

Wetland	Status	Ownership*
Hāmākua Marsh Waterbird Sanctuary	Core	HDOFAW[1]
James Campbell National Wildlife Refuge, Ki`i and Punamanō Units	Core	USFWS[2]
Kawainui Marsh	Core	HDOFAW[1]
Marine Core Base Hawaii, Nu`upia Ponds	Core	MCBH[3]
Pearl Harbor National Wildlife Refuge, Honouliuli and Waiawa Units	Core	USFWS[2]
Pouhala Marsh Waterbird Sanctuary	Core	HDOFAW[1]
Halei`wa Lotus and Taro Fields	Supporting	Private/County
He`eia Marsh	Supporting	HDOFAW[1]
Ka`elepulu Mitigation Pond (Enchanted Lakes)	Supporting	Private
Kahuku Aquaculture Farms (Includes Amorient Aquafarm and Kahuku Prawn Farm)	Supporting	Private
Lā`ie Wetlands	Supporting	Private
Lualualei RTF, Niuli`i Ponds	Supporting	USN[4] /USFWS[2]
Paikō Lagoon Wildlife Sanctuary	Supporting	HDOFAW[1]
Punaho`olapa Marsh	Supporting	Private
Turtle Bay, Kuilima Wastewater Treatment Plant	Supporting	Private
`Uko`a Marsh	Supporting	Private
Waialua Lotus Fields	Supporting	Private
Waihe`e Marsh	Supporting	Private

* In some areas, entities may have partial ownership

[1] HDOFAW = Hawai`i Division of Forestry and Wildlife

[2] USFWS = U.S. Fish and Wildlife Service

[3] MCBH = Marine Core Base Hawai`i

[4] USN = U.S. Navy

Table 8. Core and supporting wetlands on Maui, Moloka`i, and Lāna`i identified for protection and management in order to recover the Hawaiian duck, Hawaiian coot, Hawaiian common moorhen, and Hawaiian stilt.

Island	Wetland	Status	Ownership*
Maui	Kanahā Pond Wildlife Sanctuary	Core	HDOFAW[1]
Maui	Keālia Pond National Wildlife Refuge	Core	USFWS[2]
Maui	Ke`anae Point	Supporting	State[3]
Maui	Waihe`e Coastal Dunes and Wetlands (Waihe`e Refuge)	Supporting	Private
Moloka`i	Kakahai`a National Wildlife Refuge	Core	USFWS[2]
Moloka`i	`Ōhi`apilo Pond Bird Sanctuary	Core	County
Moloka`i	Kaunakakai Wastewater Reclamation Facility Ponds	Supporting	County
Moloka`i	Kualapu`u Reservoir	Supporting	State[3]
Moloka`i	Paialoa Fish Ponds	Supporting	Private
Lāna`i	Lāna`i Sewage Treatment Ponds	Supporting	County

* In some areas, entities may have partial ownership

[1] HDOFAW = Hawai`i Division of Forestry and Wildlife

[2] USFWS = U.S. Fish and Wildlife Service

[3] State = Other State departments/agencies

Table 9. Core and supporting wetlands on Hawai`i Island identified for protection and management in order to recover the Hawaiian duck, Hawaiian coot, Hawaiian common moorhen, and Hawaiian stilt.

Wetland	Status	Ownership*
Kaloko-Honokōhau National Historic Park, `Aimakapā and Koloko Ponds	Core	NPS[1]
Loka Waka Ponds	Core	Private/State[2]
Kealakehe (Kona) Sewage Treatment Plant	Supporting	County
Ke`anae Pond (Kea`au/Shipman)	Supporting	Private
Kohala-Mauna Kea Ponds and Streams	Supporting	Private
`Ōpae`ula Pond	Supporting	Private
Waiākea Pond	Supporting	State[2]/County
Waimanu Valley	Supporting	County
Waipi`o Valley	Supporting	County/Private

* In some areas, entities may have partial ownership

[1] NPS = National Park Service

[2] State = Other State departments/agencies

Core and supporting wetlands include Federal, State, and private lands. Most sites are natural wetlands, but some are of human origin, such as aquaculture ponds, agricultural areas, sewage treatment ponds, and reservoirs. While these sites generally are not managed for waterbirds, resource management and regulatory agencies should seek the development of cooperative agreements, habitat conservation plans, Safe Harbor Agreements, conservation easements, or other protective measures to restore, enhance, or create wetland sites that provide important habitat for waterbirds. Such actions may provide long-term protection of these sites or encourage habitat improvements.

The distribution of core and supporting habitat allows for multiple breeding localities on the main Hawaiian Islands within each species' historical distribution. Such a distribution should enhance recovery by minimizing the impact of random environmental events and catastrophes that can adversely affect the viability of these endangered waterbirds (Meffe and Carroll 1996; Shaffer 1996).

Actions identified in this plan to protect and manage both core and supporting wetlands include efforts to directly address many of the threats identified for the endangered waterbirds, as detailed below. Some of the recommended actions are site-specific, such as establishing protected land status and writing management plans, while other actions, such as population monitoring, assessing reproductive success, and increasing public awareness should be implemented on a statewide basis.

The basic steps detailed in this recovery plan are as follows:

1) Protect and manage (including habitat restoration) core and supporting wetland habitats in order to maximize productivity and survival of endangered waterbirds. This management would include the following actions: develop written management plans; secure water sources; manage water levels; manage vegetation; control predation; monitor waterbird populations and reproductive success; remove the threat of mallard-Hawaiian duck hybridization; minimize human disturbance; and monitor and control avian diseases and environmental contaminants (Tables 11 and 12, pp. 162-168 below). Some of these wetland habitat areas already have protected status but need to be more actively managed. The U.S. Fish and Wildlife Service and HDOFAW

can provide technical assistance to private landowners to develop wetland management plans. Technical assistance may also be provided by waterbird biologists and/or through formation of a recovery coordination group(s).

2) Conduct research to better understand factors limiting Hawaiian waterbird population numbers, refine recovery objectives, and improve management techniques.

3) Remove the threat of hybridization to Hawaiian duck populations on Kaua`i/Ni`ihau, O`ahu, and Hawai`i; and reestablish Hawaiian duck populations on Maui and Moloka`i.  Reestablish Hawaiian common moorhen populations on at least two additional islands (Maui, Moloka`i, Lāna`i, or Hawai`i).

4) Plan and implement a public awareness program to increase landowner and land manager knowledge of waterbird needs and increase public support for waterbird recovery.

5) Reevaluate recovery objectives as additional information warrants.

The key to the success of this general recovery strategy will be the formation of productive partnerships among Federal, State and local agencies, private organizations, and individuals. Partnerships have been instrumental in achieving past conservation efforts and are essential to protect and manage existing wetlands. Such partnerships also result in greater community support to insure long-term wetland and waterbird protection. Each of the basic steps identified above will succeed only with the active participation of a variety of entities.

C. GOAL AND OBJECTIVES

The ultimate goal of the recovery program is to restore and maintain multiple self-sustaining populations of these Hawaiian waterbirds within their historical ranges, which will allow them to be reclassified to threatened status (downlisted) and eventually removed from the Federal List of Endangered and Threatened Wildlife and Plants (delisted).

The recovery of the endangered waterbirds focuses on the following objectives:

1) increasing population numbers to statewide baseline levels (consistently stable or increasing with a minimum counted population size of 2,000 birds for each species);

2) establishing multiple, self-sustaining* breeding populations broadly distributed throughout each species' historical range;

3) establishing and protecting a stable network of both core and supporting wetlands that are managed as habitat suitable for waterbirds, including the maintenance of appropriate hydrological conditions and control of invasive non-native plants;

4) eliminating or controlling the threats posed by introduced predators, human disturbance, avian diseases, and contaminants to a sufficient degree for populations to be self-sustaining*; and

5) specifically for the Hawaiian duck, removing the threat of hybridization with feral mallards.

D. RECOVERY CRITERIA

Downlisting or delisting is warranted when a listed species no longer meets the definition of threatened or endangered under the Endangered Species Act (Box 1). We set recovery criteria to serve as objective, measurable guidelines to assist us in determining when a species has recovered to the point that the protections afforded by the Endangered Species Act are no longer necessary. However, the actual change in listing status is not solely dependent upon achieving the recovery criteria set forth in a recovery plan; it requires a formal rulemaking process based upon an analysis of the same five factors considered in the listing of a species (see Reasons for Decline and Current Threats). The recovery criteria presented in this recovery plan thus represent our best assessment of the conditions that would likely result in a downlisting or delisting determination in a formal status review.

* Self-sustaining means a population that is large enoughto make extirpation from stochastic forces unlikely, and that is able to remain stable or grow with little human intervention except for predator control and vegetation management.

Box 1. Definitions according to section 3 of the Endangered Species Act.

Endangered Species
Any species that is in danger of extinction throughout all or a significant portion of its range.

Threatened Species
Any species that is likely to become endangered within the foreseeable future throughout all or a significant portion of its range.

1. Downlisting Criteria

To consider downlisting the four species to threatened status, the following criteria must be met:

(a) Hawaiian duck downlisting criteria

Criterion 1: All core wetlands on the islands of Kaua`i/Ni`ihau, O`ahu, Maui, and Hawai`i are protected and managed in accordance with the management practices outlined in this recovery plan (Table 11, p. 162);

Criterion 2: Of the supporting wetlands on the islands of Kaua`i, O`ahu, Maui, and Hawai`i, at least 50 percent are protected and managed in accordance with the management practices outlined in this recovery plan (Table 12, p. 165);

Criterion 3: A population viability analysis has been conducted, incorporating survey data from both montane streams and lowland wetlands, to determine the population size necessary for long-term viability of the species. The statewide surveyed number of Hawaiian ducks has shown a stable or increasing trend and has not declined below 2,000 birds (or an alternative target based on the population viability analysis) for at least 5 consecutive years;

Criterion 4: There are multiple self-sustaining breeding populations, including multiple populations present on at least Kaua`i/Ni`ihau, O`ahu, Maui, and Hawai`i; and

Criterion 5: The threat of hybridization with feral mallards is removed from all islands.

(b) Hawaiian coot downlisting criteria

Criterion 1: All core wetlands on the islands of Kaua`i/Ni`ihau, O`ahu, Maui/Moloka`i, and Hawai`i are protected and managed in accordance with the management practices outlined in this recovery plan (Table 11);

Criterion 2: Of the supporting wetlands on the islands of Kaua`i, O`ahu, Maui/Moloka`i/Lāna`i, and Hawai`i, at least 50 percent are protected and managed in accordance with the management practices outlined in this recovery plan (Table 12);

Criterion 3: A population viability analysis has been conducted to determine the population size necessary for long-term viability of the species. The statewide surveyed number of Hawaiian coots shows a stable or increasing trend and has not declined below 2,000 birds (or an alternative target based on the population viability analysis) for at least 5 consecutive years; and

Criterion 4: There are multiple self-sustaining breeding populations, including multiple populations present on at least Kaua`i/Ni`ihau, O`ahu, Maui/Moloka`i/Lāna`i, and Hawai`i.

(c) Hawaiian common moorhen downlisting criteria

Criterion 1: All core wetlands on the islands of Kaua`i and O`ahu are protected and managed in accordance with the management practices outlined in this recovery plan (Table 11);

Criterion 2: Of the supporting wetlands on the islands of Kaua`i and O`ahu, at least 50 percent are protected and managed in accordance with the management practices outlined in this recovery plan (Table 12);

Criterion 3: A population viability analysis has been conducted, incorporating surveys that can effectively detect secretive individuals in dense vegetation, to determine the population size necessary for long-term viability of the species. The statewide surveyed number of Hawaiian common moorhen shows a stable or increasing trend and has not declined below 2,000 birds (or an alternative target based on the population viability analysis) for at least 5 consecutive years;

Criterion 4: There are multiple self-sustaining breeding populations, including multiple populations present on Kaua`i and O`ahu and on at least two additional islands (Maui, Moloka`i, Lāna`i, or Hawai`i); and

Criterion 5: An improved survey technique has been developed and implemented.

(d) Hawaiian stilt downlisting criteria

Criterion 1: All core wetlands on the islands of Kaua`i/Ni`ihau, O`ahu, Maui/Moloka`i, and Hawai`i are protected and managed in accordance with the management practices outlined in this recovery plan (Table 11);

Criterion 2: Of the supporting wetlands on the islands of Kaua`i, O`ahu, Maui/Moloka`i/Lāna`i, and Hawai`i, at least 50 percent are protected and managed in accordance with the management practices outlined in this recovery plan (Table 12);

Criterion 3: A population viability analysis has been conducted to update the findings of Reed *et al*. (1998a) and reassess the population size necessary for long-term viability of the species. The statewide surveyed number of Hawaiian stilts shows a stable or increasing trend and has not declined below 2,000 birds (or an alternative target based on the updated population viability analysis) for at least 5 consecutive years; and

Criterion 4: There are multiple self-sustaining breeding populations, including multiple populations on at least Kaua`i/Ni`ihau, O`ahu, Maui/Moloka`i/ Lāna`i, and Hawai`i.

2. Delisting Criteria

To consider delisting the four species, the downlisting criteria above must be met as well as the following criteria:

(a) Hawaiian duck delisting criteria

Criterion 1: Of the supporting wetlands on the islands of Kaua`i, O`ahu, Maui, and Hawai`i, at least 85 percent are protected and managed in accordance with the management practices outlined in this recovery plan (Table 12); and

Criterion 2: The statewide surveyed number of Hawaiian ducks shows a stable or increasing trend and has not declined below 2,000 birds (or an alternative target based on the population viability analysis) for at least 10 consecutive years.

(b) Hawaiian coot delisting criteria

Criterion 1: Of the supporting wetlands on the islands of Kaua`i, O`ahu, Maui/Moloka`i/Lāna`i, and Hawai`i, 85 percent are protected and managed in accordance with the management practices outlined in this recovery plan (Table 12); and

Criterion 2: The statewide surveyed number of Hawaiian coots shows a stable or increasing trend and has not declined below 2,000 birds (or an alternative target based on the population viability analysis) for at least 10 consecutive years.

(c) Hawaiian common moorhen delisting criteria

Criterion 1: Of the supporting wetlands on the islands of Kaua`i and O`ahu, at least 85 percent are protected and managed in accordance with the management practices outlined in this recovery plan (Table 12); and

Criterion 2: The statewide surveyed number of Hawaiian common moorhens shows a stable or increasing trend and has not declined below 2,000 birds (or an alternative target based

on the population viability analysis) for at least 10 consecutive years.

(d) Hawaiian stilt delisting criteria

Criterion 1: Of the supporting wetlands on the islands of Kaua`i, O`ahu, Maui/Moloka`i/Lāna`i, and Hawai`i, at least 85 percent are protected and managed in accordance with the management practices outlined in this recovery plan (Table 12); and

Criterion 2: The statewide surveyed number of Hawaiian stilts shows a stable or increasing trend and has not declined below 2,000 birds (or an alternative target based on the updated population viability analysis) for at least 10 consecutive years.

We believe that the downlisting and delisting criteria of protecting and managing 50 and 85 percent (respectively) of supporting wetlands represent reasonable proportions of important wetland habitat that would provide for both survival and long-term recovery of these waterbirds; the criteria also allow for needed flexibility, particularly when planning and managing for long-term recovery.

3. Recovery Criteria and Threats

The successful elimination or control of the threats that originally led to the need for protection under the Endangered Species Act is a key component of recovery. The recovery criteria identified above describe conditions that must be met to adequately mitigate these threats and recover the species. Table 10 below summarizes how specific recovery criteria and recovery actions address threats to these species.

Several of the major threats that affect all four of the endangered waterbirds (loss and degradation of wetland habitat, alteration of hydrology, invasion of habitat by nonnative plants, and predation), as well as some comparatively minor threats (avian disease, environmental contaminants, and human disturbance), must be addressed through site-specific management of wetland habitat. For each species, Downlisting Criteria #1 and #2 and Delisting Criterion #1 address these threats by calling for protection and management of

wetlands in accordance with the management practices outlined in this recovery plan. Specific actions needed to implement these practices are described below in the Stepdown Narrative of Recovery Actions (section II.F). Our recommendations for application of these actions to specific sites are summarized in Table 11 (for core wetlands) and Table 12 (for supporting wetlands) (pp. 162-168 below).

Because hybridization with feral mallards is a threat unique to the Hawaiian duck, this threat is addressed separately in Downlisting Criterion #5 for this species. Recovery actions addressing this criterion include elimination of feral mallards and hybrids and quarantine measures to prevent new introductions of mallards.

In addition to the above criteria, which address specific threats, for each species Downlisting Criteria #3 and #4 and Delisting Criterion #2 describe the population levels and the distribution of self-sustaining populations among islands that will be necessary to achieve recovery. Failure to achieve the population size and distribution in these criteria would be evidence that threats have not been mitigated sufficiently to recover the species. Adequate population size and distribution also protect against loss of genetic diversity through inbreeding and help provide the redundancy and resiliency to recover from demographic fluctuations, seasons with adverse weather, or localized catastrophic events. Recovery actions addressing these criteria include monitoring, population biology research, and (for Hawaiian common moorhen and Hawaiian duck) reintroduction efforts. Because survey protocols are currently inadequate to assess population levels of the Hawaiian common moorhen, Downlisting Criterion #5 for this species specifically addresses the need to develop improved survey methods.

Table 10. Crosswalk relating threats to the recovery criteria and recovery actions that address them.

Species	Listing Factor	Threats	Recovery Criteria	Recovery Actions
All	A	Loss and degradation of wetland habitat	Downlisting #1; Downlisting #2; Delisting #1	1.1, 1.2, 1.3.1, 1.3.2, 4.3.1, 4.3.2,
All	A	Alteration of hydrology	Downlisting #1; Downlisting #2; Delisting #1	1.1, 1.2, 1.3.1
All	A	Invasion of habitat by nonnative plants	Downlisting #1; Downlisting #2; Delisting #1	1.1, 1.2, 1.3.2, 4.1.3
All	B	Hunting	Not current threat	1.3.5.1
All	C	Predators	Downlisting #1; Downlisting #2; Delisting #1	1.1, 1.2, 1.3.3, 1.3.4, 4.1.1, 4.1.2
All	C	Avian Disease	Downlisting #1; Downlisting #2; Delisting #1	1.1, 1.2, 1.3.6
Hawaiian Duck	E	Hybridization	Downlisting #5	2.1, 2.2
All	E	Environmental Contaminants	Downlisting #1; Downlisting #2; Delisting #1	1.1, 1.2, 1.3.7
All	E	Human Disturbance	Downlisting #1; Downlisting #2; Delisting #1	1.1, 1.2, 1.3.5
All	E	Small Population Size/Genetic Diversity Loss/ Stochastic Vulnerability	Downlisting #3; Downlisting #4; Delisting #2; Delisting #5 (moorhen)	1.4, 2.3 (duck), 3 (moorhen), 4.2, 4.3 (duck)
All	E	Global Warming and Sea Level Rise	Beyond scope of direct management; see previous row	

E. STEP-DOWN OUTLINE OF RECOVERY ACTIONS

The following actions are those needed to achieve the recovery of Hawaiian waterbirds, presented in the form of a step-down outline and a narrative outline following. Suggested responsible parties and estimated costs for each action are provided, as numbered below, in the Implementation Schedule.

1. Protect (including securing from development) and manage all core (100%) and supporting wetlands (50% for downlisting and 85% for delisting) as described in Tables 11 and 12. Once montane streams are identified through action 4.3.3, they should be added as core or supporting wetlands for koloa recovery.

    1.1 Develop management plans for core and supporting wetlands.

    1.2 Coordinate management of core and supporting wetlands with other agencies and organizations. Provide technical assistance to private landowners to develop wetland management plans. Consider forming a recovery coordination group for Hawaiian waterbirds consisting of State and Federal resources agencies, interested researchers, cooperators, and stakeholders.

    1.3 Implement management plans for core and supporting wetlands.

        1.3.1 Secure water sources and manage water levels to maximize nesting success, brood survival, food availability, and recruitment of waterbirds.

        1.3.2 Manage vegetation to maximize nesting success, brood survival, food availability, and recruitment of waterbirds.

            1.3.2.1 Encourage desirable plant species.

            1.3.2.2 Control undesirable plant species.

            1.3.2.3 Prevent introduction of invasive non-native plants.

        1.3.3 Eliminate or reduce and monitor predator populations.

1.3.3.1 Prevent predator access.

1.3.3.2 Control mongooses.

1.3.3.3 Control feral cats.

1.3.3.4 Control feral dogs.

1.3.3.5 Control rats.

1.3.3.6 Control cattle egrets.

1.3.3.7 Control tilapia.

1.3.3.8 Control bullfrogs.

1.3.4 Prevent introduction of new non-native predators, such as the brown treesnake (*Boiga irregularis*).

1.3.5 Minimize human disturbance to waterbirds and their habitats.

1.3.5.1 Assess and if necessary prevent intentional or accidental shooting of waterbirds.

1.3.5.2 Control human access to waterbird habitats during the breeding season.

1.3.5.3 Resolve conflicts from actual or perceived depredation of aquaculture or agriculture products by waterbirds.

1.3.5.4 Minimize the influence of urban encroachment.

1.3.6 Monitor and control avian disease.

1.3.6.1 Monitor waterbird populations to detect disease outbreaks as soon as possible.

1.3.6.2 Take immediate action to restrict the spread of disease outbreaks.

1.3.7 Minimize contamination of waterbird habitat by toxic substances/contaminants.

1.3.7.1 Monitor water quality.

1.3.7.2 Restrict introduction of contaminants into wetland systems.

1.3.7.3 Assess nutrient levels and other parameters that influence core and supporting wetland productivity for waterbirds.

1.4 Monitor all populations of endangered waterbirds.

1.4.1 Continue standardized, biannual, statewide surveys for all endangered waterbirds and include wetlands designated as core and supporting wetlands for waterbirds in the surveys.

1.4.2 Develop and implement improved survey techniques for the Hawaiian duck and Hawaiian common moorhen.

1.4.2.1 Survey techniques for the Hawaiian duck.

1.4.2.2 Survey techniques for the Hawaiian common moorhen.

1.4.3 Monitor reproductive success on core and supporting wetlands.

1.4.4 Monitor aquatic invertebrate prey species used by waterbirds and fish to determine whether they compete with waterbirds for aquatic invertebrates.

2. Remove the threat of mallard-Hawaiian duck hybridization on all islands where Hawaiian ducks occur and establish a self-sustaining population of Hawaiian ducks on Maui and/or Moloka`i.

2.1 Eliminate feral mallards and hybrid ducks in the State.

2.1.1 Develop and test methods for differentiating between Hawaiian ducks and mallard-Hawaiian duck hybrids.

2.1.2 Conduct a public information and awareness program regarding the mallard-Hawaiian duck interbreeding problem and the need for a feral and hybrid duck removal program.

2.1.3 Develop and implement a statewide program to humanely remove feral mallards and mallard-Hawaiian duck hybrids.

2.2 Ensure new stocks of mallards and closely related ducks are not brought into the State.

2.2.1 Strengthen quarantine rules and regulations to restrict in-state production and commerce of mallards and closely-related ducks that threaten the persistence of Hawaiian ducks.

2.3 Establish a self-sustaining population of Hawaiian ducks on Maui and/or Moloka`i.

2.3.1 Identify sites for reintroduction of the Hawaiian duck on Maui and Moloka`i.

2.3.2 Assess the utility of captive propagation versus translocation for establishing additional Hawaiian duck populations and develop a reintroduction plan that includes the preferred method.

2.3.3 Reintroduce either captive-bred or translocated Hawaiian ducks to protected and managed sites on Maui and Moloka`i and monitor their survival, dispersal, and reproduction.

3. Establish a self-sustaining population of Hawaiian common moorhen on two additional islands (Maui, Moloka`i, Lāna`i, or Hawai`i).

3.1 Continue surveys of wetland areas on Maui, Moloka`i, and Hawai`i to confirm that a Hawaiian common moorhen population does not already exist.

3.2 If a population of Hawaiian common moorhen is found on Maui, Moloka`i, or Hawai`i, protect and manage its wetland habitat.

3.3 Evaluate potential reintroduction sites for Hawaiian common moorhen on Maui, Moloka`i, Lāna`i, and Hawai`i.

3.4 Assess the utility of captive propagation versus translocation for establishing additional Hawaiian common moorhen populations and develop a reintroduction plan that includes the preferred method.

3.5 Reintroduce Hawaiian common moorhens to a protected and managed site on two additional islands (Maui, Moloka`i (if there is enough habitat on Moloka`i), Lāna`i, or Hawai`i) and monitor their survival, dispersal, and reproduction.

4. Conduct research to better understand population biology and limiting factors, evaluate recovery objectives, and improve management techniques.

4.1 Increase understanding of Hawaiian waterbird population limiting factors.

4.1.1 Investigate the effects of different predators on endangered waterbirds.

4.1.2 Research improved predator control methods.

4.1.3 Research improved methods to control non-native plants and restoration of native plants.

4.2 Conduct research to better understand Hawaiian waterbird population biology and recovery needs.

4.2.1 Analyze existing survey data and estimate current population size and population trends.

4.2.2 Determine carrying capacity of wetland habitats.

4.2.3 Estimate reproductive parameters.

4.2.4 Estimate mortality rates.

4.2.5 Conduct research on movement of adults and natal dispersal.

4.2.6 Determine the sex and age structure of populations.

4.2.7 Investigate genetic population structure and potential inbreeding depression.

4.2.8 Before downlisting or delisting, population viability analyses (PVA) should be conducted for the Hawaiian duck, Hawaiian coot, and Hawaiian common moorhen, and the Hawaiian stilt PVA should be updated.

4.3 Research Hawaiian waterbird habitat needs.

4.3.1 Research habitat needs for Hawaiian waterbirds.

4.3.2 Research Hawaiian waterbird habitat manipulation including the role of "created wetlands" in waterbird recovery.

4.3.3 Research and survey montane stream habitat for Hawaiian duck.

5. Plan and implement a public information and awareness program to increase public awareness and support for waterbird recovery.

5.1 Prepare and distribute television and radio spots, written information, slide programs, videos, films, posters, and displays.

5.2 Coordinate with the Hawai`i Department of Education and private schools to incorporate wetland and waterbird information into school curricula.

5.3 Develop and maintain interpretive displays of endangered waterbirds and wetlands.

6. Develop post-delisting monitoring plans for each species when appropriate.

6.1 Coordinate with relevant partners managing for waterbirds to work on developing agreements for maintaining waterbird habitat post-delisting.

F. NARRATIVE OUTLINE OF RECOVERY ACTIONS

1. Protect (including securing from development) and manage all core (100%) and supporting wetlands (50% for downlisting and 85% for delisting) as described in Tables 11 and 12 (pp. 163-169 below). Once montane streams are identified through action 4.3.3 they should be added as core or supporting wetlands for koloa recovery.

A network of protected and managed wetland habitats is the key element in the recovery strategy for all four taxa. Loss and degradation of habitat has been and continues to be a primary threat; thus maintenance and management, especially including habitat restoration, of suitable habitat distributed over all the main islands is imperative for recovery of these waterbirds. Most core wetlands are protected except the Playa Lakes (Ni`ihau), Loko Waka Ponds (Hawai`i), and Lumaha`i Wetlands (Kaua`i). Agreements with the landowners should be developed to ensure protection of these wetlands. Some of these areas are sufficiently managed, but most need increased levels of management to maximize waterbird production and survivability.

Supporting wetlands are additional areas that provide habitat important for smaller waterbird populations or that provide habitat needed seasonally by segments of the waterbird population during part of their life cycle. Protection and management of these or similar wetlands is required to recover Hawai`i's waterbirds, but there is room for some flexibility in which sites must be managed, and it is possible that other sites may fulfill the same needs as those listed here (see wetlands listed in Tables 1 to 5 that are not identified as core or supporting wetlands). Tools available to work with private landowners to provide habitat management and protection include habitat conservation plans, Safe Harbor Agreements, Partners for Fish and Wildlife and Coastal program projects, and conservation easements.

We believe montane streams on Kaua`i and Hawai`i need to be protected and managed in order to recover koloa. Once these streams are identified (action 4.3.3) we can add them as core or supporting wetlands (Tables 6, 9, 11, and 12). Montane stream habitat that is privately owned may be protected through cooperative agreements with watershed partnerships.

1.1 Develop management plans for core and supporting wetlands.

Management of the core and supporting wetlands is required to realize their full potential for providing waterbird nesting and/or feeding habitat. Management plans should be developed for core and supporting wetlands, and actions to be implemented on these habitats will include, but are not limited to, the recommended recovery actions in Tables 11 and 12 (pp. 163-169 below).

1.2 Coordinate management of core and supporting wetlands with other agencies and organizations. Provide technical assistance to private landowners to develop wetland management plans. Consider forming a recovery coordination group for Hawaiian waterbirds consisting of State and Federal resources agencies, interested researchers, cooperators, and stakeholders.

Managers charged with the stewardship of refuges and sanctuaries have developed numerous methods of habitat management. These techniques vary among sites. Interagency management workshops, such as the Wetland and Predator Control Workshops organized by The Wildlife Society and the Hawai`i Department of Land and Natural Resources, or other forums for exchanging information have been held and should continue to be regularly conducted in Hawai`i. These meetings provide a professional forum for the presentation of management methodology practiced in Hawai`i and allow managers to present published and unpublished research results, develop new methods, and find solutions to shared management problems. A statewide approach to wetland stewardship is important for successful management of core and supporting wetlands. Establish cooperative agreements on private lands through Safe Harbor Agreements/habitat conservation plans/conservation easements using private lands funding to achieve this (*e.g.*, Partners for Fish and Wildlife, Landowner Incentive Programs).

1.3 Implement management plans for core and supporting wetlands.

Wetland habitats in Hawai`i, including wildlife sanctuaries and refuges, have been altered or influenced to a varying extent by a number of factors (see section Reasons for Decline and Current Threats). Providing these areas with the habitat components that allow waterbirds to survive and reproduce successfully requires active management. The steps necessary for enhancing habitat for Hawai`i's endangered waterbirds are outlined below. A number of these are already being implemented on protected wetland areas.

1.3.1 Secure water sources and manage water levels to maximize nesting success, brood survival, food availability, and recruitment of waterbirds.

Understanding hydrology, and managing it as necessary, is crucial to ensuring the suitability of wetland habitat for these endangered waterbirds. An adequate water source must be ensured, and water levels must be managed so as to enhance productivity of wetland food sources and to provide suitable vegetative cover.

1.3.2 Manage vegetation to maximize nesting success, brood survival, food availability, and recruitment of waterbirds.

The composition and distribution of vegetation in a wetland ecosystem determines the habitat's value for waterbirds. Most of Hawai`i's wetlands have been extensively altered such that vegetation management is required to provide habitat for waterbirds.

1.3.2.1 Encourage desirable plant species.

Certain types of vegetation provide better feeding and nesting conditions for waterbirds. Habitat management should aim to develop the optimum distribution and density of these

species, with an emphasis on enhancing native species. Desirable native plant species include, but are not limited to, *Bolboschoenus maritimus* (kaluha, bulrush); *Cyperus javanicus*, *C. laevigatus*, *C. polystachyos*, and *C. trachysanthos* (ahu`awa, makaloa, or umbrella sedge); *Eleocharis obtusa* (kohekohe, spikerush); *Ludwigia octovalvis* (primrose willow); *Ruppia maritima* (ditchgrass, widgeongrass); *Schoenoplecus juncoides* and *S. lacustris* (`aka`akai).

In some cases, naturalized non-native plants can provide important habitat components for waterbirds as well, serving as a source of food, cover, nesting material, and habitat for invertebrate prey. Non-native plants that serve these functions should not be eradicated before a suitable native plant species is identified that would provide equivalent resources. Non-native plants that may provide beneficial resources for waterbirds include *Cyperus difformis* (variable flatsedge), *Echinochloa* spp. (cockspur, barnyard grass), *Eleocharis geniculata* (spikesedge), *Fimbristylis ferruginea* (West Indian fimbry), *Lemna* spp. (duckweed), *Leptochloa uninervia* (sprangletop), *Paspalum distichum* (knotgrass), and *Typha* spp. (cattails).

1.3.2.2 Control undesirable plant species.

Undesirable plants, mainly introduced species such as *Brachiaria mutica* (California grass), *Batis maritima* (pickleweed), *Eichornia crassipes* (water hyacinth), *Pluchea indica* (Indian fleabane), and *Rhizophora mangle* (red mangrove), make wetlands less useful or unusable for waterbirds (Morin 1996, 1998;

Rauzon and Drigot 2002; Chimner *et al*. 2006). These plants should be eliminated, where feasible, or controlled. In many cases, water level management can be used to control noxious species. In particular, pickleweed and mangrove both grow in areas frequently used by waterbirds for nesting and feeding and need to be controlled. In some situations indigenous plants may also pose problems for waterbird habitat if changes in hydrology cause them to overgrow wetlands and form monocultures. Control methods that do not introduce environmental contaminants and that can be sustained over the long-term should be employed.

1.3.2.3 Prevent introduction of invasive non-native plants.

Non-native plants, particularly invasive species, can decrease wetland suitability for waterbirds. Measures should be taken to prevent accidental introduction of non-native plants by people or equipment used in the management of wetlands and to prevent these plants from becoming established in wetland habitats. For example, equipment used on wetlands should be thoroughly cleaned before being used at a site, especially if equipment is moved between sites.

1.3.3 Eliminate or reduce and monitor predator populations.

Predation is a major cause of waterbird mortality and nest failure. Introduced mammals such as mongooses, cats, dogs, and rats are the primary predators, but depredation by birds and bullfrogs has also been documented. Adult waterbirds are occasionally taken, but most depredation is of eggs and young. Long-term predator management at

nesting sites is needed and may be more effective when control methods are used in conjunction with exclusion devices such as fences. Predation control should incorporate monitoring of predator populations so methods can be assessed for cost-effectiveness (Recovery Action 4.1.2); the most efficient techniques should be implemeted more widely, as appropriate.

1.3.3.1 Prevent predator access.

One means of controlling predators is preventing their access to nesting habitat. This can be accomplished by the use of barriers, moats, or fences. Moats can be constructed around nesting habitat if sedimentation and vegetation are adequately controlled. Where appropriate and feasible, barriers and/or fences should be installed around important breeding sites to exclude as many species of predators as possible. All of these methods have pros and cons. Moats do not exclude mongoose, rats, or dogs, which can all swim, and moats provide seasonal habitat for bullfrogs. Barriers and fences can impede waterbird movement and predator-proof fences are very expensive. All access deterrents must be carefully thought out and applied with an individual wetland in mind (S. Pelizza, *in litt*. 2005).

1.3.3.2 Control mongooses.

Mongooses are thought to be the most serious predator of Hawai`i's waterbirds in many areas. Removal of mongooses has been proven to increase waterbird reproduction and should be actively pursued using trapping and/or toxicants. At the O`ahu National Wildlife Refuge, trapping

and removal has worked best (S. Pelizza, *in litt*. 2005).

1.3.3.3 Control feral cats.

Feral cats are known to be predators of waterbirds and should be controlled. Feral cat feeding stations near waterbird habitat should be removed or relocated. Public education about the detrimental effects of feral cats is also important. The American Bird Conservancy launched a Cats Indoors! campaign in 1977, and has developed brochures for public outreach, including information on indoor cats living longer and the devastating impacts outdoor cats can have on native birds (American Bird Conservancy 2008). Trapping for cats needs to be improved.

1.3.3.4 Control feral dogs.

Dogs are known to kill waterbird adults and young and should be removed. Dogs often can be effectively excluded by fences. It may be possible to work with lawmakers to develop stronger ordinances requiring that pets be kept inside or on a leash and for stronger enforcement of existing ordinances (K. Gifford, USFWS, *in litt*. 2005).

1.3.3.5 Control rats.

Rats have been known to prey on waterbird chicks and eggs. The importance of rat predation should be assessed and control measures implemented as necessary.

1.3.3.6 Control cattle egrets.

Predation and competition for food resources by cattle egrets is poorly understood in Hawai`i, but we do know that cattle egrets prey upon Hawaiian stilt chicks. Modified habitats and exposed nesting areas make young waterbirds more vulnerable to predation. Fragmented wetlands and high-density waterbird breeding sites also attract predators (S. Pelizza, *in litt*. 2005). These areas should be identified and improved as possible. Control of cattle egrets in rookeries near, or in, refuges has proven effective and should be continued.

1.3.3.7 Control tilapia.

Tilapia modify the bottom of wetlands by creating circular nests and are suspected of depleting the invertebrate prey base used by endangered waterbirds, thereby degrading waterbird feeding habitats. Tilapia should be controlled, possibly by manipulating water levels. It may be possible to work with the State to develop fishing incentives and have the public fish tilapia from desired wetlands, ensuring disturbance to waterbirds is minimized (K. Gifford, *in litt*. 2005). Tilapia control is difficult, water level manipulations may be ineffective unless the entire area is drained and dried, and even then they may reestablish themselves as they are common in Hawai`i's waters. In addition, it should be noted that currently available alternative methods of control (*e.g.*, pesticide application) may negatively impact waterbirds and other wildlife (F. Mencher, *in litt*. 2005). Other fish, such as bass are predators (K. Uyehara, *in litt*. 2005).

Preventive measures for excluding all invasive fish from wetlands should be incorporated. Though fish may occasionally be food for waterbirds, they also compete with them for food resources (Broshears 1979).

1.3.3.8 Control bullfrogs.

Bullfrogs are known to prey on juvenile Hawaiian ducks and Hawaiian stilts, and were identified as an important predator on radio-tracked Hawaiian stilt chicks at James Campbell National Wildlife Refuge (Eijzenga 2004). It may be possible to control bullfrogs by direct removal, or by strategic manipulation of water levels. Salinity can also be used to control bullfrogs, but care must be taken that salinity levels don't disrupt the wetland ecosystem (S. Pelizza, *in litt*. 2005).

1.3.4 Prevent introduction of new non-native predators, such as the brown treesnake (*Boiga irregularis*).

Non-native predators are causing severe problems for native waterbirds. Introductions of new predators, such as the brown treesnake, must be prevented in the entire State. Special attention is needed to prevent the establishment of mongooses on Kaua`i, Lāna`i, and Ni`ihau.

1.3.5 Minimize human disturbance to waterbirds and their habitats.

Disturbance or loss of adult and young waterbirds is occasionally attributed to people. Although such losses are usually restricted to isolated incidents, measures should be taken to minimize this threat.

1.3.5.1 Assess and, if necessary, prevent intentional or accidental shooting of waterbirds.

The occurrence of shooting of waterbirds should be assessed and control measures taken as necessary to prevent such events through law enforcement and/or public education.

1.3.5.2 Control human access to waterbird habitats during the breeding season.

Certain habitats and birds are more sensitive to human disturbance, especially during the breeding season. Restricting human access to sensitive habitat areas during certain times of the year may be needed.

1.3.5.3 Resolve conflicts from actual or perceived depredation of aquaculture or agriculture products by waterbirds.

Some waterbird habitat is also used for agriculture and aquaculture. This can result in conflicts due to actual and/or perceived depredation problems attributed to endangered waterbirds. Wildlife agencies need to respond to potential problems associated with waterbirds and minimize conflicts. Problems not associated with waterbirds can be explained and solutions to problems associated with waterbirds can be sought before birds or nests are harmed. Open communication between agricultural and waterbird managers is necessary to minimize conflicts.

1.3.5.4 Minimize the influence of urban encroachment.

Urban encroachment is a significant threat to wetland areas in Hawai`i. Urban encroachment has increased because of the recent shift in land use from agriculture to housing developments. Issues such as predator control, water quality, and harassment are magnified in an urban setting. Refuges that were once surrounded by cane fields are now surrounded by housing tracts or resort developments. The establishment of buffer lands around protected wetlands through cooperative agreements or other measures is critical to the protection of these habitats. Buffer lands can also provide corridors between wetland refuges within a large complex.

1.3.6 Monitor and control avian disease.

Waterbirds and their habitat should be monitored for potential disease problems. When avian diseases are detected, control measures must be employed rapidly. Diseases that may affect endangered waterbirds include, but may not be limited to, avian botulism, cholera, malaria, pox, avian influenza, and West Nile virus.

1.3.6.1 Monitor waterbird populations to detect disease outbreaks as soon as possible.

Disease monitoring should be a part of wetland area management. A disease monitoring protocol should be developed, made available for wide use, and incorporated into management plans. Wildlife health professionals should be consulted to develop monitoring techniques (USFWS 1987). Being observant of “unusual” behavior is a key to early detection, regulating

water levels, maintaining water movement through impoundments, and removal of carcasses (including fish and other animals) are important preventive measures.

1.3.6.2 Take immediate action to restrict the spread of disease outbreaks.

When a disease outbreak is identified, managers need to take immediate action to restrict the disease's spread and severity. Disease response protocols should be developed and incorporated into management plans. Measures to help contain the disease include removal and treatment of sick birds, removal of dead birds, and regulating water levels.

1.3.7 Minimize contamination of waterbird habitat by toxic substances/contaminants.

Contamination of wetlands with toxic substances from human development or from agricultural/aquacultural practices (*e.g.*, oil, pesticides, herbicides) is a potential threat. Because waterbirds are often concentrated in small areas, the localized contamination of water or food can affect a large number of birds.

1.3.7.1 Monitor water quality.

To minimize exposure of waterbirds to contaminants, environmental contaminant monitoring should be incorporated into management plans.

1.3.7.2 Restrict introduction of contaminants into wetland systems.

To minimize potential impacts to waterbirds, the introduction of chemicals to wetland areas,

either directly or via water supplies, should be restricted as much as possible.

1.3.7.3 Assess nutrient levels and other parameters that influence core and supporting wetland productivity for waterbirds.

Wetland productivity for waterbirds varies annually. Measuring nutrient levels, food availability, water turbidity, salinity, temperature, and other parameters that influence productivity of wetlands for waterbirds will enhance our understanding of waterbird populations.

1.4 Monitor all populations of endangered waterbirds.

Monitoring populations of waterbirds is important for assessing the success of management activities. The biannual statewide data are the best information we have on status of the four species in this plan, but as previously mentioned the summary counts are an index at best. As such, it is important to ensure that the wetlands surveyed reflect utilized habitat as much as possible, but not all wetlands in the entire State need to be surveyed. Accounting for differences in summary counts should also take into consideration other factors, including the number of sites surveyed in a year. Adding new locations can be considered. In fact, there should be an evaluation process for addition or removal of survey sites as new locations are found, or can be accessed, or as other locations no longer function as habitat (M. Laut, pers. comm. 2008).

1.4.1 Continue standardized, biannual, statewide surveys for all endangered waterbirds and include wetlands designated as core and supporting wetlands for waterbirds in the surveys.

The biannual statewide surveys provide valuable information for gauging the status of endangered waterbirds, particularly Hawaiian coots and Hawaiian stilts.

These surveys should be continued to provide a long-term data set for examining population trends. However, the data need to be analyzed for comparison of wetland quality and waterbird use, and particularly better analyses of waterbird numbers, information that will help manage waterbirds better. Wetlands that have been designated as core and supporting wetlands should be included in these surveys to ensure they continue to function as important habitat for waterbirds.

1.4.2 Develop and implement improved survey techniques for the Hawaiian duck and Hawaiian common moorhen.

Existing survey techniques are adequate for assessing Hawaiian coot and Hawaiian stilt populations, but improved methods are needed to accurately survey Hawaiian ducks and Hawaiian common moorhens.

1.4.2.1 Survey techniques for the Hawaiian duck

Because Hawaiian ducks use montane stream habitats that are not surveyed during the bi-annual waterbird surveys, the Hawaiian duck is believed to be undercounted (see section I.F). As montane stream habitat important to the Hawaiian duck is identified, efforts should be made to incorporate these areas into the surveys. In addition, surveyors have generally not distinguished between Hawaiian ducks and Hawaiian duck-mallard hybrids. A new key is in preparation that will use morphological and genetic information to help surveyors better distinguish between Hawaiian ducks and Hawaiian duck-mallard hybrids (A. Engilis, pers. comm. 2009).

1.4.2.2 Survey techniques for the Hawaiian common moorhen

As discussed in section I.F, the secretive behavior of this species has made them difficult to census. However, there is new information on improving Hawaiian common moorhen detections using playbacks that should be incorporated in the waterbird surveys (Conway and Gibbs 2005; DesRochers 2006; Gee 2007, DesRochers et al. 2008).

1.4.3 Monitor reproductive success on core and supporting wetlands.

Surveys are needed to determine the reproductive success of endangered waterbirds. Hawaiian stilt recruitment survey techniques have already been developed, but methods for monitoring the reproductive success of the other species should be developed and implemented on core and supporting wetlands.

1.4.4 Monitor aquatic invertebrate prey species used by waterbirds and fish to determine whether fish compete with waterbirds for aquatic invertebrates.

Monitoring seasonal densities of aquatic invertebrates that occur in the diets of waterbirds may identify periods when food sources are scarce. Fish should also be monitored to determine if they are competitors of aquatic invertebrate prey used by waterbirds, although controlled experiments are more effective at answering such questions. If non-native fish such as bass, poeciliids, cyprinids, etc. are determined to be competitors, control measures and/or eradication of fish should be developed and implemented.

2. Remove the threat of mallard-Hawaiian duck hybridization on all islands where Hawaiian ducks occur and establish a self-sustaining population of Hawaiian ducks on Maui and/or Moloka`i.

Hybridization between Hawaiian ducks and mallards has resulted in a large population of hybrids and a scarcity of pure Hawaiian ducks on the island of O`ahu. This threat also occurs on Kaua`i, Maui, and Hawai`i, although to a lesser extent. Hybridization of the Hawaiian duck with mallards or other related waterfowl should be prevented.

Self-sustaining Hawaiian duck populations should be established on Maui and/or Moloka`i. Although a small population (fewer than 15 individuals) of Hawaiian ducks exist on Maui (F. Duvall, pers. comm. 2004), augmentation may be needed to increase the likelihood of its sustainability.

2.1 Eliminate feral mallards and hybrid ducks in the State.

2.1.1 Develop and test methods for differentiating between Hawaiian ducks and mallard-Hawaiian duck hybrids.

Methods for identifying mallard-Hawaiian duck hybrids are currently being developed to insure that the correct birds are removed from the population. The development of such identification criteria requires the simultaneous collection of genetic and morphological data. Genetic information is being used to confirm field identification of birds, thus protecting Hawaiian ducks. Genetic methods developed using nuclear DNA markers are now capable of distinguishing Hawaiian ducks from hybrids with high reliability (Fowler et al. 2009). An identification guide that outlines physical characteristics differentiating pure Hawaiian ducks from hybrids, validated against the genetically identified categories, is currently under development (A. Engilis, pers. comm. 2009.)

2.1.2 Conduct a public information and awareness program regarding the mallard-Hawaiian duck interbreeding

problem and the need for a feral and hybrid duck removal program.

Eliminating hybridization will be controversial unless the public becomes aware of its importance. The public may be more supportive of programs to remove mallards, other closely related feral ducks, and mallard-Hawaiian duck hybrids from the islands if the program's role in preserving the native species is better understood. This task needs to be accomplished in coordination with the public information and awareness program.

2.1.3 Develop and implement a statewide program to humanely remove feral mallards and mallard-Hawaiian duck hybrids.

A Hawaiian duck recovery implementation group that includes various resource agencies and researchers was recently established to address this problem. The group is working on developing a comprehensive statewide approach to the mallard-Hawaiian duck hybridization problem. Efforts to remove mallards and related waterfowl should be accomplished through approved duck trapping techniques and other humane methods to be developed in the program planning process.

Because Kaua`i represents the core of the species distribution and is the only island that likely could provide birds for reintroduction to other islands, removal of feral mallards and hybrids on Kaua`i is of the highest priority. Feral mallards and known hybrids should be removed immediately to stop hybridization and prevent introgression into the Hawaiian duck gene pool on Kaua`i. Although hybridization is most severe on O`ahu, removal of feral mallards from O`ahu is a lower priority than on other islands because few or no pure Hawaiian ducks may be left. Because no feral mallards have been reported on Lāna`i, efforts should be made to prevent their arrival, including

control of inter-island shipping by humans. Management of feral mallards and known hybrids is also a high priority on Hawai`i Island as hybridization appears to be increasing there.

2.2 Ensure new stocks of mallards and closely related ducks are not brought into the State.

Stricter control is needed over the importation of additional domesticated mallards or closely related ducks into Hawai`i. Coordination with the Hawai`i Department of Agriculture will be necessary to maintain or improve importation controls.

2.2.1 Strengthen quarantine rules and regulations to restrict in-state production and commerce of mallards and closely related ducks that threaten the persistence of Hawaiian ducks.

Strengthening rules and regulations will not prohibit responsible use of domestic ducks in agriculture. However, this action will help reduce the increasing numbers of ducks abandoned in wetlands and impacting Hawaiian ducks (K. Uyehara, *in litt*. 2005).

2.3 Establish a self-sustaining population of Hawaiian ducks on Maui and/or Moloka`i.

Techniques for breeding the Hawaiian duck in captivity have been developed; however, translocation might also prove to be a useful method of reestablishing or augmenting populations.

2.3.1 Identify sites for reintroduction of the Hawaiian duck on Maui and Moloka`i.

Core wetlands on Maui and Moloka`i that are protected and managed for waterbirds should be considered first as sites for Hawaiian duck reintroduction (Tables 3 and 4). If none of these areas are suitable, supporting wetlands on these islands should be considered before consideration of other

areas (wetlands listed in Tables 3 and 4 that are not identified as core or supporting wetlands).

2.3.2 Assess the utility of captive propagation versus translocation for establishing additional Hawaiian duck populations and develop a reintroduction plan that includes the preferred method.

The pros and cons of captive propagation versus translocation should be investigated to determine which method is likely to be more successful and efficient for reestablishing a Hawaiian duck population. A reintroduction plan should be developed using the preferred method.

2.3.3 Reintroduce either captive-bred or translocated Hawaiian ducks to protected and managed sites on Maui and Moloka`i and monitor their survival, dispersal, and reproduction.

Depending on the outcome of Recovery Actions 2.3.1. and 2.3.2, either captive propagation or translocation should be used to reestablish or, in the case of Maui, augment Hawaiian duck populations at protected and managed sites. Newly established Hawaiian duck populations should be monitored to evaluate the success of the reintroduction.

3. Establish a self-sustaining population of Hawaiian common moorhens on two additional islands (Maui, Moloka`i, Lāna`i, or Hawai`i).

Hawaiian common moorhens formerly occurred on all of the main Hawaiian Islands except Lāna`i and Kaho`olawe, but now occur only on Kaua`i and O`ahu. Captive propagation and release, or translocation of Hawaiian common moorhen should be conducted to help restore this species to its former range. Additional populations will help increase numbers of the Hawaiian common moorhen, which is rarer than other species in this plan, and will also reduce the impact to the population of local outbreaks of disease or stochastic events.

3.1 Continue surveys of wetland areas on Maui, Moloka`i, and Hawai`i to confirm that a Hawaiian common moorhen population does not already exist.

It is possible that a population of Hawaiian common moorhens already exists on the islands of Maui, Moloka`i, or Hawai`i. While this possibility is slim, all likely Hawaiian common moorhen habitat areas should be thoroughly searched, reasons for the disappearance of Hawaiian common moorhens identified, and the use of core and/or supporting wetlands for potential reintroduction sites assessed.

3.2 If a population of Hawaiian common moorhen is found on Maui, Moloka`i, or Hawai`i, protect and manage its wetland habitat.

Hawaiian common moorhen populations found on the islands of Maui, Moloka`i, or Hawai`i should be increased through permanent habitat protection and management.

3.3 Evaluate potential reintroduction sites for Hawaiian common moorhen on Maui, Moloka`i, Lāna`i, and Hawai`i.

Habitat criteria for the reintroduction of Hawaiian common moorhens need to be established. Core and supporting wetlands that are protected and managed (Tables 3 through 5) should be considered first for Hawaiian common moorhen reintroduction. Sites on Maui and Hawai`i are higher in priority given uncertainties about habitat availability on Moloka`i and Lāna`i. (Historical records of Hawaiian common moorhens are also lacking from Lāna`i, although this is more likely to have been because the historical quantity of wetland habitat on the island was insufficient to maintain a population rather than because of any inherent inter-island barriers to dispersal, since the species was otherwise well-distributed through the main islands). If none of these areas are suitable, additional wetlands (wetlands listed in Tables 3 through 5 that are not identified as core or supporting wetlands) that meet the habitat criteria should be considered.

3.4 Assess the utility of captive propagation versus translocation for establishing additional Hawaiian common moorhen populations and develop a reintroduction plan that includes the preferred method.

Captive propagation and translocation are both useful methods for reintroducing species; however, the method most appropriate in a particular case depends on the ease of capturing, breeding, and maintaining the species in captivity. A reintroduction plan should be developed using the preferred method.

3.5 Reintroduce Hawaiian common moorhens to a protected and managed site on two additional islands (Maui, Moloka`i [if there is enough habitat on Moloka`i], Lāna`i, or Hawai`i) and monitor their survival, dispersal, and reproduction.

Depending on the outcome of action 3.4, either captive propagation or translocation should be used to reestablish a Hawaiian common moorhen population on two additional islands (Maui, Hawai`i, Moloka`i, Lāna`i). It needs to be determined if there is currently enough habitat on Moloka`i to support a Hawaiian common moorhen population. Newly established Hawaiian common moorhen populations should be monitored to evaluate success of the reintroduction.

4. Conduct research to better understand population biology and limiting factors, evaluate recovery objectives, and improve management techniques.

Proper management requires the application of information obtained from research. Many of the successful waterbird management techniques currently in use were developed in response to research findings. Additional research is needed to better understand limiting factors, refine recovery objectives, and improve management techniques for Hawai`i's endangered waterbirds. Adaptive management should be implemented as management techniques evolve.

4.1 Increase understanding of Hawaiian waterbird population limiting factors.

A better understanding of the factors that limit the recovery of Hawai`i's waterbirds will allow more effective management techniques to be developed. Hawaiian common moorhens are particularly secretive, which contributes to the fact that we know very little about their biology and habitat use. Hawaiian duck utilize upland areas, particularly on Kaua`i, and their biology and movements are also less well understood. Such information would help us better manage and protect these birds.

4.1.1 Investigate the effects of different predators on endangered waterbirds.

Waterbirds may be preyed on by a variety of animals, including dogs, cats, mongooses, bullfrogs, black-crowned night-herons, cattle egrets, owls, and possibly others. The relative importance of these predators may differ among sites and waterbird species. The frequency of predation, demographic effects, and efficiency of potential control programs should be investigated for each predator and at different sites.

4.1.2 Research improved predator control methods.

The effectiveness of predator control methods should be evaluated and improved methods should be developed if possible.

4.1.3 Research improved methods to control non-native plants and restoration of native plants.

Improved methods for controlling non-native plants and outplanting native plants should be developed to improve habitat suitable for waterbird use. The emphasis here should be on providing the plant assemblage, structure, interspersion, and timing that benefits waterbirds and native plants may sometimes need to be controlled as well (S. Pelizza, *in litt*. 2005).

4.2 Conduct research to better understand Hawaiian waterbird population biology and recovery needs.

Scientific information is needed to better understand the population biology of these four species. This information can be used to more effectively manage the recovery program and support or modify the recovery criteria for the Hawaiian coot, duck, common Hawaiian common moorhen, and Hawaiian stilt.

4.2.1 Analyze existing survey data and estimate current population size and population trends.

Biannual surveys to monitor waterbird populations have been conducted for many years by the State. A great deal of information about the size and status of waterbird populations can be obtained by careful analysis of this data. For example, we can review waterbird use of different wetlands over the years and which wetlands are most important to which species.

4.2.2 Determine carrying capacity of wetland habitats.

Understanding the limits to the potential population density of the waterbird species at different types of wetlands will improve our ability to predict population sizes and whether additional management will allow for an increase in the population size.

4.2.3 Estimate reproductive parameters.

Collecting information on the reproductive parameters of all four of these waterbird species will increase our understanding of each species' biology. This research should focus on the following areas: age at first breeding, nest site and mate fidelity, length of nesting season, clutch size, hatching and feeding rates, and nesting attempts per pair.

4.2.4 Estimate mortality rates.

Determining the rates and sources of mortality will allow a better understanding of the threats and management needs for each species and facilitate a determination of the minimum reproductive rates needed to increase and stabilize populations.

4.2.5 Conduct research on movement of adults and natal dispersal.

Investigate the movement patterns of adults and natal dispersal of juveniles. Evidence from banding studies and population fluctuations indicates there is some movement of waterbirds among and within islands (Engilis and Pratt 1993; Reed *et al*. 1998b). More information of this kind will allow a better understanding of statewide population size and trends.

4.2.6 Determine the sex and age structure of populations.

Determine the sex and age structures of important populations (*e.g.*, waterbird populations that use core wetlands) of these four endangered waterbird species.

4.2.7 Investigate genetic population structure and potential inbreeding depression.

Determine the genetic population structure and the potential for inbreeding depression in these four endangered waterbird species.

4.2.8 Before downlisting or delisting, population viability analyses (PVA) should be conducted for the Hawaiian duck, Hawaiian coot, and Hawaiian common moorhen, and the Hawaiian stilt PVA should be updated.

Population viability analyses can identify the population numbers and time spans that may serve as useful predictors of long term recovery. Before downlisting or delisting, a

population viability analysis should be conducted for the Hawaiian duck, Hawaiian coot, and Hawaiian common moorhen to determine if 2,000 is an adequate population size for the recovery of each species. A population viability analysis was completed for the Hawaiian stilt (Reed *et al*. 1998a), but needs to be updated before downlisting or delisting the Hawaiian stilt. The PVA should use 1,000-year runs for each species to ensure a reasonable persistence (M. Morin, *in litt*. 2005). This exercise will also help identify those parameters that have the most impact on population viability through a sensitivity analysis.

4.3 Research Hawaiian waterbird habitat needs.

4.3.1 Research habitat needs for Hawaiian waterbirds.

Determine the habitat requirements of each species for foraging, nesting, and loafing and develop management techniques to produce these habitat conditions. Analyzing data collected on each species from the different wetlands will allow us to create better wetland management plans.

4.3.2 Research Hawaiian waterbird habitat manipulation including the role of "created wetlands" in waterbird recovery.

Habitat manipulation occurs at many wetlands statewide, including varying water levels, removing invasive plants, controlling predators, etc. These practices are known to improve reproduction and help support greater waterbird numbers. However, many of these practices have not been documented and if we were able to compile known information, it could help us to develop better management plans and improve habitat practices.

It will be useful to determine how created wetlands (*e.g.*, ponds created for mitigation connected to a development project, in association with Safe Harbor Agreements, or

storm drainage ponds at golf courses) may contribute to waterbird recovery.

4.3.3 Research and survey montane stream habitat for Hawaiian duck.

Research is needed on the use of montane stream systems by the Hawaiian duck, especially the use of these streams as nesting sites. It is thought that many Hawaiian ducks nest on the banks of upland streams near pools of water. Surveys of montane stream habitat should be conducted on Kaua`i and Hawai`i to obtain a more accurate population estimate of the Hawaiian duck. In the past, selected samples of streams in upland habitat were surveyed and the results were used to calculate an index of the number of Hawaiian ducks per linear mile of stream. This method, as well as other methods, should be evaluated to determine the best way to accurately estimate Hawaiian duck populations in montane stream habitats. In addition, the survey results and stream habitat characteristics should be used to assess which streams are most important for recovery of the Hawaiian duck.

5. Plan and implement a public information and awareness program to increase public awareness and support for waterbird recovery.

The waterbird recovery program cannot be fully successful without a well-informed and supportive public. Efforts need to be made to inform the public, increase public accessibility to waterbird areas, and provide information on the various programs outlined in this recovery plan.

5.1 Prepare and distribute television and radio spots, written information, slide programs, videos, films, posters, and displays.

Educational materials on waterbird conservation should be developed to implement a public awareness and information program to enhance recovery of endangered waterbirds.

5.2 Coordinate with the Hawai`i Department of Education and private schools to incorporate wetland and waterbird information into school curricula.

Efforts to teach wetland ecology and avian biology should be made within the public and private school systems. Wetland refuges and sanctuaries provide excellent opportunities for field trips and field studies.

5.3 Develop and maintain interpretive displays of endangered waterbirds and wetlands.

Interpretive displays should be developed and maintained at wetland habitat areas and at various community locations.

6. Develop post-delisting monitoring plans for each species when appropriate.

6.1 Coordinate with relevant partners managing for waterbirds to work on developing agreements for maintaining waterbird habitat post-delisting.

It is important to ensure waterbird habitat will be maintained post-delisting. Many wetlands currently managed for waterbirds are on private lands and will be as important to the persistence of Hawaiian waterbirds once they are delisted as they are now.

Table 11. Specific recovery actions recommended for core wetlands in the main Hawaiian Islands.

Core Wetlands	STATUS			RECOMMENDED RECOVERY ACTIONS								
	Hectares (Acres)	Responsibility[1]	Protected[2]	1.1	1.3.1	1.3.2	1.3.3	1.3.5	1.3.6	1.3.7	1.4	2
Ni`ihau												
Playa Lakes[3]	769 (1900)	Private	No	X			X		X	X		
Kaua`i												
Hanalei National Wildlife Refuge	371 (917)	USFWS	Yes	X	X	X	X	X	X	X	X	X
Hulē`ia National Wildlife Refuge	98 (241)	USFWS	Yes	X	X	X	X	X	X	X	X	X
Lumaha`i Valley Wetlands	51 (125)	Private	No	X		X	X	X				X
Mānā Plain Forest Reserve (formerly Kawai`ele Wild Bird Sanctuary)	14 (35)	HDOFAW	Yes	X		X		X	X	X	X	X
O`ahu												
Hāmākua Marsh Waterbird Sanctuary	35.6 (88)	HDOFAW/DU	Yes	X	X	X	X	X	X	X	X	X

[1] Responsibility: HDOFAW = Hawai`i Division of Forestry and Wildlife, DU = Ducks Unlimited, MCBH = Marine Core Base Hawai`i, NPS = National Park Service, USFWS = U.S. Fish and Wildlife Service, USN = U.S. Navy, Private = Private Landowner
[2] Protected refers to wetland habitats that are secure from development.
[3] See Section II.A Recovery Strategy

Table 11 (continued). Specific recovery actions recommended for core wetlands in the main Hawaiian Islands.

CORE WETLANDS	STATUS			RECOMMENDED RECOVERY ACTIONS								
	Hectares (Acres)	Responsibility[1]	Protected[2]	1.1	1.3.1	1.3.2	1.3.3	1.3.5	1.3.6	1.3.7	1.4	2
O`ahu (continued)												
James Campbell National Wildlife Refuge (Ki`i and Punamanō Units)	66 (164)	USFWS	Yes	X	X	X	X	X	X	X	X	X
Kawainui Marsh	304 (750)	HDOFAW	Yes	X	X	X	X	X	X		X	X
Marine Core Base Hawaii, Nu`upia Ponds	196 (483)	MCBH	Yes	X		X	X	X	X	X		
Pearl Harbor National Wildlife Refuge (Honouliuli and Waiawa Units)	25 (61)	USFWS	Yes	X		X	X	X	X	X	X	X
Pouhala Marsh Waterbird Sanctuary	28 (70)	HDOFAW	Yes	X		X	X	X	X		X	X
Moloka`i												
Kakahai`a National Wildlife Refuge	18 (45)	USFWS	Yes	X	X	X	X	X	X	X		X
`Ōhi`apilo Pond Bird Sanctuary	10 (25)	County	Yes		X					X		
Maui												
Kanahā Pond Wildlife Sanctuary	59 (145)	HDOFAW	Yes	X	X	X	X	X	X	X	X	X

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[2] Protected refers to wetland habitats that are secure from development.

Table 11 (continued). Specific recovery actions recommended for core wetlands in the main Hawaiian Islands.

CORE WETLANDS	STATUS			RECOMMENDED RECOVERY ACTIONS								
	Hectares (Acres)	Responsibility[1]	Protected[2]	1.1	1.3.1	1.3.2	1.3.3	1.3.5	1.3.6	1.3.7	1.4	2
Maui (continued)												
Keālia Pond National Wildlife Refuge	280 (692)	USFWS	Yes	X	X	X	X	X	X	X	X	X
Hawai`i												
Kaloko-Honokōhau Nattional Historic Park, `Aimakapā and Kaloko Ponds	22 (55)	NPS	Yes		X	X	X	X	X	X		
Loko Waka Ponds	10 (24.5)	Private/State	No	X	X	X	X	X	X		X	X

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[2] Protected refers to wetland habitats that are secure from development.

Table 12. Specific recovery actions recommended for supporting wetlands in the main Hawaiian Islands.

SUPPORTING WETLANDS	STATUS			RECOMMENDED RECOVERY ACTIONS								
	Hectares (Acres)	Responsibility[1]	Protected[2]	1.1	1.3.1	1.3.2	1.3.3	1.3.5	1.3.6	1.3.7	1.4	2
Kaua`i												
Hanalei River and Taro Fields (that are not part of Hanalei National Wildlife Refuge	40.4 (100)	Pvt/State	No	X		X	X	X	X		X	
Hanapēpē Salt Ponds	20 (50)	Pvt/DOFAW	No	X	X	X	X	X	X	X	X	
Mānā Base Pond and Mānā Wetlands	81 (200)	Pvt/State	No	X			X	X	X			X
`Ōpaeka`a Marsh	20 (50)	Pvt/DOFAW	No	X	X	X	X	X	X	X		X
Smith's Tropical Paradise	1.9 (4.7)	Pvt/State	No	X	X	X	X	X	X	X	X	
Wailua River Bottoms	20 (50)	Pvt/State	No	X			X	X	X		X	
Waimea River System	64 (158)	Pvt/State	No	X			X	X	X		X	
Wainiha Valley River and Taro Fields	44 (109)	Pvt/County	No	X	X	X	X	X	X		X	
Waitā Reservoir	151 (373)	Private	No	X		X	X	X			X	X

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[2] Protected refers to wetland habitats that are secure from development.

Table 12 (continued). Specific recovery actions recommended for supporting wetlands in the main Hawaiian Islands.

SUPPORTING WETLANDS	STATUS			RECOMMENDED RECOVERY ACTIONS								
	Hectares (Acres)	Responsibility[1]	Protected[2]	1.1	1.3.1	1.3.2	1.3.3	1.3.5	1.3.6	1.3.7	1.4	2
O`ahu												
Halei`wa Lotus and Taro Fields	4.2 (10.6)	Pvt/County	No	X			X	X	X		X	
He`eia Marsh	162 (400)	HDOFAW	Yes	X	X	X	X	X	X	X		X
Ka`elepulu Mitigation Pond (Enchanted Lakes)	2.2 (5.6)	Private	No	X	X	X	X		X	X	X	
Kahuku Aquaculture Farms (Includes Amoriant Aquafarm and Kahuku Prawn Farm)	41 (100)	Private	No	X		X	X	X	X			
Lā`ie Wetlands	81 (200)	Private	No	X								X
Lualualei RTF, Niuli`i Ponds	16 (40)	USN/USFWS	Yes	X	X	X	X	X	X	X	X	X
Paikō Lagoon Wildlife Sanctuary	13 (33)	HDOFAW	Yes	X	X	X	X	X	X	X	X	X
Punaho`olapa Marsh	41 (100)	Private	No	X	X	X	X	X	X	X	X	X
Turtle Bay, Kuilima Wastewater Treatment Plant	5 (12.4)	Private	No	X			X	X	X	X		
`Uko`a Marsh	122 (300)	Private	No				X	X	X			X

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[2] Protected refers to wetland habitats that are secure from development.

Table 12 (continued). Specific recovery actions recommended for supporting wetlands in the main Hawaiian Islands.

SUPPORTING WETLANDS	STATUS			RECOMMENDED RECOVERY ACTIONS								
	Hectares (Acres)	Responsibility[1]	Protected[2]	1.1	1.3.1	1.3.2	1.3.3	1.3.5	1.3.6	1.3.7	1.4	2
Oahu (continued)												
Waialua Lotus Fields	30 (75)	Private	No	X	X	X	X	X	X			X
Waihe`e Marsh	10 (25)	Private	No	X	X	X	X	X	X			X
Molokai												
Kaunakakai Wastewater Reclamation Facility Ponds	1.5 (3.7)	County	No	X		X	X	X	X	X		
Kualapu`u Reservoir	30 (74)	State	No	X		X	X	X	X	X		
Paialoa Fish Ponds	2 (5)	Private	No	X		X	X	X	X			X
Lāna`i												
Lāna`i Sewage Treatment Ponds	3 (7.4)	Pvt/County	No	X		X	X	X	X	X		
Maui												
Ke`anae Point	1.5 (3.7)	State	No	X	X	X	X	X	X	X	X	
Waihe`e Coastal Dunes and Wetlands (Waihe`e Refuge)	101 (250)	Private	Yes	X	X	X	X	X	X	X	X	

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[2] Protected refers to wetland habitats that are secure from development.

Table 12 (continued). Specific recovery actions recommended for supporting wetlands in the main Hawaiian Islands.

SUPPORTING WETLANDS	STATUS			RECOMMENDED RECOVERY ACTIONS								
	Hectares (Acres)	Responsibility[1]	Protected[2]	1.1	1.3.1	1.3.2	1.3.3	1.3.5	1.3.6	1.3.7	1.4	2
Hawai`i Island												
Kealakehe (Kona) Sewage Treatment Plant	12 (30)	County	No	X		X	X	X	X	X		
Ke`anae Pond (Kea`au/Shipman)	2.9 (7.2)	Private	No	X	X	X	X	X	X	X	X	
Kohala-Mauna Kea Ponds and Streams	18+ (45+)	Pvt/State	No	X	X	X	X	X	X			
`Ōpae`ula Pond	3 (7.5)	Private	No	X	X	X	X	X	X			
Waiākea Pond	16 (39.5)	State/County	Yes	X	X	X	X	X	X	X	X	X
Waimanu Valley	*	County	Yes	X	X	X	X	X	X	X	X	X
Waipi`o Valley	*	County	No	X	X	X	X	X	X	X	X	X

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[2] Protected refers to wetland habitats that are secure from development.

* Area undetermined.

III. Implementation Schedule

The Implementation Schedule outlines actions and estimated costs for the Hawaiian waterbirds recovery actions, as set forth in this recovery plan. It is a guide for meeting the recovery goals outlined in this plan. The Implementation Schedule includes the following elements:

A. ACTION PRIORITIES

The actions identified in the Implementation Schedule are those that, in our opinion, are necessary to bring about the recovery of these species. However, the actions are subject to modification as dictated by new findings, changes in species status, and the completion of recovery actions. The priority for each action is given in the first column of the Implementation Schedule, and is assigned as follows:

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.

B. ACTION NUMBER AND DESCRIPTION

The action number and action description are extracted from the stepdown narrative of recovery actions found in section II.F of this plan. Please refer back to this narrative for a more detailed description of each action.

C. LISTING/DELISTING FACTORS

As discussed earlier, we evaluate five major factors when considering listing, delisting, or reclassifying a species:

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 - Inadequacy of existing regulatory mechanisms; and

E - Other natural or man-made factors affecting its continued existence.

The Listing Factor column in the schedule indicates which of the five factors the recovery action addresses in order to meet the recovery goals for the endangered waterbirds. The majority of recovery actions in the Implementation Schedule address threats to habitat (factor A), disease and predation (factor C), and other factors such as hybridization (factor E).

D. RESPONSIBLE PARTIES

In this table, we have identified agencies and other parties that we believe are primary stakeholders in the recovery process for the Hawaiian waterbirds. Stakeholders are those agencies who may voluntarily participate in any aspect of implementation of particular actions listed within this recovery plan. Stakeholders may willingly participate in project planning, funding, provide technical assistance, staff time, or any other means of implementation. The list of potential stakeholders is not limited to the list below; other stakeholders are invited to participate. In some cases, the most logical lead agency (based on authorities, mandates, and capabilities) has been identified with an asterisk (*).

The listing of an agency in the Implementation Schedule does not require, nor imply a requirement or an agreement, that the identified agency implement that action(s) or secure funding for implementing action(s). However, agencies willing to participate may benefit by being able to show in their own budgets that their funding request is for a recovery action identified in an approved recovery plan and is therefore considered a necessary action for the overall coordinated effort to recover these four species. Also, section 7(a)(1) of the Endangered Species Act (Act) directs all Federal agencies to utilize their authorities in furtherance of the purposes of the Act by carrying out programs for the conservation of threatened and endangered species.

We, the U.S. Fish and Wildlife Service, have the statutory responsibility for implementing this recovery plan. Only Federal agencies are mandated to take part in the effort. Recovery actions identified in this plan imply no legal obligations of the State and local government agencies or private landowners. However, the recovery of the Hawaiian coot, Hawaiian duck, Hawaiian common moorhen, and Hawaiian stilt will require the involvement and cooperation of Federal, State, local, and private interests.

E. ACTION DURATION

The action duration column indicates the number of years estimated to complete the action if it is a discrete action, or whether it is a continual or ongoing action. Occasionally it is not possible to provide a reasonable estimate of either the time or cost to complete an action; these cases are denoted as To Be Determined (TBD). Continual and ongoing actions are defined as follows:

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 the action is no longer necessary.

F. COST ESTIMATES

The Implementation Schedule provides the estimated costs of implementing recovery actions for the first 5 years after the release of the recovery plan, the years 2012 through 2016. Estimates for recovery actions are based on average costs of similar actions implemented to date. For wetland management, these costs may vary considerably depending upon the condition of the wetland vegetation, hydrology, types of management actions, and actions already occurring in the area.

Annual cost estimates are as follows:

2012 = $2,594,000
2013 = $2,876,000
2014 = $2,667,000
2015 = $2,318,000
2016 = $1,818,000

The total estimated cost to implement this plan for years 2012 through 2016 is $12,273,000. The total estimated cost to implement this plan over the next 10 years is $19,063,000.

G. ACRONYMS USED IN THE IMPLEMENTATION SCHEDULE

BRD	U.S. Geological Survey, Biological Resources Discipline
DOCARE	Hawai`i Department of Land and Natural Resources, Division of Conservation and Resources Enforcement
DU	Ducks Unlimited
FWS-ES	U.S. Fish and Wildlife Service, Ecological Services, Honolulu, Hawai`i
FWS-LE	U.S. Fish and Wildlife Service, Law Enforcement, Honolulu, Hawai`i
FWS-R	U.S. Fish and Wildlife Service, Refuges, Honolulu, Hawai`i
HDOFAW	Hawai`i Division of Forestry and Wildlife
HDOA	Hawai`i Department of Agriculture
HDOE	Hawai`i Department of Education
NPS	National Park Service
USDA	U.S. Department of Agriculture
USMC	U.S. Marine Corps
USN	U.S. Navy
WS	U.S. Department of Agriculture, Wildlife Services

Implementation Schedule for the Recovery Plan for Hawaiian Waterbirds, Second Revision

Priority Number	Action Number	Listing Factor	Action Description	Action Duration (Years)	Responsible Party	Cost Estimates ($1,000s) FY 2012	FY 2013	FY 2014	FY 2015	FY 2016	Recovery Total
1	1.3.2.2	A	Control undesirable plant species.	C	HDOFAW	150	150	150	150	150	1,500
					FWS-R	150	150	150	150	150	1,500
					USMC	10	10	10	10	10	100
					USN	5	5	5	5	5	50
1	1.3.3.1	C	Prevent predator access.	C	FWS-R	80	80	80	80	80	800
					HDOFAW	80	80	80	80	80	800
					USMC	5	5	5	5	5	50
					USN	5	5	5	5	5	50
1	1.3.3.2	C	Control mongooses.	C	FWS-R	80	80	80	80	80	800
					HDOFAW	80	80	80	80	80	800
					USMC	10	10	10	10	10	100
					USN	2	2	2	2	2	20
1	1.3.3.3	C	Control feral cats.	C	FWS-R	40	40	40	40	40	400
					HDOFAW	40	40	40	40	40	400
					USMC	10	10	10	10	10	100
					USN	2	2	2	2	2	20

Implementation Schedule for the Recovery Plan for Hawaiian Waterbirds, Second Revision												
Priority Number	Action Number	Listing Factor	Action Description	Action Duration (Years)	Responsible Party	Cost Estimates ($1,000s)					
						FY 2012	FY 2013	FY 2014	FY 2015	FY 2016	Recovery Total
1	1.3.3.4	C	Control feral dogs.	C	FWS-R	10	10	10	10	10	100
					HDOFAW	10	10	10	10	10	100
					USMC	2	2	2	2	2	20
					USN	2	2	2	2	2	20
1	1.3.3.5	C	Control rats.	C	FWS-R	30	30	30	30	30	300
					HDOFAW	30	30	30	30	30	300
					USMC	5	5	5	5	5	50
					USN	2	2	2	2	2	20
1	1.3.3.8	C	Control bullfrogs.	C	FWS-R	10	10	10	10	10	100
					HDOFAW	10	10	10	10	10	100
					USMC	2	2	2	2	2	20
					USN	1	1	1	1	1	10
1	1.3.4	C	Prevent introduction of new non-native predators such as the brown treesnake (*Boiga irregularis*).	C	FWS-ES	10	10	10	10	10	100
					HDOFAW	10	10	10	10	10	100
					HDOA	10	10	10	10	10	100
					USMC	10	10	10	10	10	100
					USN	10	10	10	10	10	100

Implementation Schedule for the Recovery Plan for Hawaiian Waterbirds, Second Revision

Priority Number	Action Number	Listing Factor	Action Description	Action Duration (Years)	Responsible Party	Cost Estimates ($1,000s) FY 2012	FY 2013	FY 2014	FY 2015	FY 2016	Recovery Total
1	2.1.1	E	Develop and test methods for differentiating between Hawaiian ducks and mallard-Hawaiian duck hybrids.	2	FWS-ES	15	15				30
					FWS-R	15	15				30
					HDOFAW	20	20				40
1	2.1.2	E	Conduct a public information and awareness program regarding mallard-Hawaiian duck interbreeding problem and the need for a feral and hybrid duck removal program.	3	FWS-ES	20	20	20			60
					FWS-R	5	5	5			15
					BRD	10	10	10			30
1	2.1.3	E	Develop and implement statewide program to humanely remove feral mallards and mallard-Hawaiian duck hybrids.	3	FWS-R	50	50	50			150
					FWS-ES	20	20	20			60
					HDOFAW	50	50	50			150
					WS	50	50	50			150
1	2.2.1	E	Strengthen quarantine rules and regulations to restrict instate production and commerce of mallards and closely-related ducks that threaten the persistence of Hawaiian ducks.	C	*HDOA	5	5	5	5	5	50
					FWS-LE	5	5	5	5	5	50
1	4.1.1	C	Investigate the effects of different predators on endangered waterbirds.	4	FWS-R	20	20	20	20		80
					HDOFAW	20	20	20	20		80
					BRD	20	20	20	20		80

Implementation Schedule for the Recovery Plan for Hawaiian Waterbirds, Second Revision

Priority Number	Action Number	Listing Factor	Action Description	Action Duration (Years)	Responsible Party	Cost Estimates ($1,000s) FY 2012	FY 2013	FY 2014	FY 2015	FY 2016	Recovery Total
1	4.1.2	C	Research improved predator control methods.	3	FWS-R		40	40	40		120
					HDOFAW		40	40	40		120
					*BRD		40	40	40		120
					WS		40	40	40		120
2	1	A	Protect (including securing from development) and manage all core (100%) and supporting wetlands (50% for downlisting and 85% for delisting) listed in Tables 11 and 12. Once montane streams are identified through action 4.3.3 they should be added as core or supporting wetlands for koloa recovery (Tables 11 and 12).	5	FWS-R	100	100	100	100	100	500
					HDOFAW	100	100	100	100	100	500
2	1.3.1	A, C, E	Secure water sources and manage water levels to maximize nesting success, brood survival, food availability, and recruitment of waterbirds.	C	FWS-R	25	25	25	25	25	250
					FWS-ES	5	5	5	5	5	50
					HDOFAW	25	25	25	25	25	250
2	1.3.3.6	C	Control cattle egrets.	C	FWS-R	10	10	10	10	10	100
					HDOFAW	10	20	10	10	10	100
					USMC	2	2	2	2	2	20
					USN	1	1	1	1	1	10

Implementation Schedule for the Recovery Plan for Hawaiian Waterbirds, Second Revision											
Priority Number	Action Number	Listing Factor	Action Description	Action Duration (Years)	Responsible Party	Cost Estimates ($1,000s)					
						FY 2012	FY 2013	FY 2014	FY 2015	FY 2016	Recovery Total
2	1.3.3.7	C	Control tilapia.	C	FWS-R	30	30	30	30	30	300
					HDOFAW	30	30	30	30	30	300
					USMC	5	5	5	5	5	50
					USN	2	2	2	2	2	20
2	1.3.5.1	E	Assess and if necessary prevent intentional or accidental shooting of waterbirds.	C	FWS-R	5	5	5	5	5	50
					FWS-LE	5	5	5	5	5	50
					*DOCARE	10	10	10	10	10	100
2	1.3.5.2	E	Control human access to waterbird habitats during breeding seasons.	C	FWS-R	5	5	5	5	5	50
					HDOFAW	5	5	5	5	5	50
2	1.3.5.3	A, E	Resolve conflicts from actual or perceived depredation of aquaculture or agriculture products by waterbirds.	C	FWS-ES	2	2	2	2	2	20
					FWS-R	3	3	3	3	3	30
					HDOFAW	5	5	5	5	5	50
2	1.3.5.4	A	Minimize the influence of urban encroachment.	C	FWS-ES	5	5	5	5	5	50
					FWS-R	5	5	5	5	5	50
					HDOFAW	5	5	5	5	5	50
					USMC	1	1	1	1	1	10
					USN	1	1	1	1	1	10

Implementation Schedule for the Recovery Plan for Hawaiian Waterbirds, Second Revision

Priority Number	Action Number	Listing Factor	Action Description	Action Duration (Years)	Responsible Party	Cost Estimates ($1,000s)					
						FY 2012	FY 2013	FY 2014	FY 2015	FY 2016	Recovery Total
2	1.3.6.1	C	Monitor waterbird populations to detect disease outbreaks as soon as possible.	C	FWS-R	2	2	2	2	2	20
					HDOFAW	2	2	2	2	2	20
					USMC	1	1	1	1	1	10
					USN	1	1	1	1	1	10
2	1.3.6.2	C	Take immediate action to restrict the spread of the disease outbreaks.	C	FWS-R	TBD	TBD	TBD	TBD	TBD	TBD
					HDOFAW	TBD	TBD	TBD	TBD	TBD	TBD
					USMC	TBD	TBD	TBD	TBD	TBD	TBD
					USN	TBD	TBD	TBD	TBD	TBD	TBD
2	1.3.7.1	A, C	Monitor water quality.	O	HDOFAW	5	5	5	5	5	50
					FWS-R	5	5	5	5	5	50
					USMC	1	1	1	1	1	10
					USN	1	1	1	1	1	10
2	1.3.7.2	A	Restrict introduction of contaminants to wetland systems.	O	HDOFAW	2	2	2	2	2	20
					FWS-R	1	1	1	1	1	10
					USMC	1	1	1	1	1	10
					USN	1	1	1	1	1	10

Implementation Schedule for the Recovery Plan for Hawaiian Waterbirds, Second Revision

Priority Number	Action Number	Listing Factor	Action Description	Action Duration (Years)	Responsible Party	Cost Estimates ($1,000s) FY 2012	FY 2013	FY 2014	FY 2015	FY 2016	Recovery Total
2	1.4.1	E	Continue standardized, biannual, statewide surveys for all endangered waterbirds and include wetlands designated as core and supporting wetlands for waterbirds in the surveys.	O	*HDOFAW	25	25	25	25	25	250
					FWS-R	15	15	15	15	15	150
					FWS-ES	3	3	3	3	3	30
					USMC	2	2	2	2	2	20
					USN	2	2	2	2	2	20
2	1.4.2.1	E	Survey techniques for the Hawaiian duck.	2	BRD	50	50				100
2	1.4.2.2	E	Survey techniques for the Hawaiian common moorhen.	2	BRD	TBD	TBD				
2	1.4.3	E	Monitor reproductive success on core wetlands.	C	FWS-R	10	10	10	10	10	100
					HDOFAW	10	10	10	10	10	100
					USMC	5	5	5	5	5	50
					USN	1	1	1	1	1	10
2	2.3.1	E	Identify sites for reintroduction of the Hawaiian duck on Maui and Moloka`i.	1	HDOFAW		4				4
					FWS-R		2				2
					FWS-ES		2				2
					BRD		4				4

Implementation Schedule for the Recovery Plan for Hawaiian Waterbirds, Second Revision

Priority Number	Action Number	Listing Factor	Action Description	Action Duration (Years)	Responsible Party	Cost Estimates ($1,000s) FY 2012	FY 2013	FY 2014	FY 2015	FY 2016	Recovery Total
2	2.3.2	E	Assess the utility of captive propagation versus translocation for establishing additional Hawaiian duck populations and develop a reintroduction plan that includes the preferred method.	1	FWS-ES		5				5
					HDOFAW		5				5
2	2.3.3	E	Reintroduce either captive-bred or translocated Hawaiian ducks to protected and managed sites on Maui and Moloka`i and monitor their survival, dispersal, and reproduction.	2	HDOFAW			30	30		60
					BRD			30	30		60
					FWS-ES			30	30		60
					FWS-R			30	30		60
2	3.3	A, E	Evaluate potential reintroduction sites for Hawaiian common moorhen on Maui, Moloka`i, Lāna`i, and Hawai`i.	1	HDOFAW		4				4
					FWS-ES		2				2
					FWS-R		2				2
					BRD		2				2
					DU		2				2
2	3.4	E	Assess the utility of captive propagation versus translocation for establishing additional Hawaiian common moorhen populations and develop a reintroduction plan that includes the preferred method.	2	FWS-R		2	2			4
					HDOFAW		2	2			4
					BRD		2	2			4
					DU		2	2			4
2	4.2.1	E	Analyze existing survey data and estimate current population size and population trends.	3	*BRD	30	30	30			90
					HDOFAW	20	20	20			60
					FWS-ES	20	20	20			60

Implementation Schedule for the Recovery Plan for Hawaiian Waterbirds, Second Revision

Priority Number	Action Number	Listing Factor	Action Description	Action Duration (Years)	Responsible Party	Cost Estimates ($1,000s) FY 2012	FY 2013	FY 2014	FY 2015	FY 2016	Recovery Total
3	1.1	A	Develop management plans for core and supporting wetlands.	2	FWS-R	50	50				100
					HDOFAW	50	50				100
					USMC	10	10				20
					USN	5	5				10
3	1.2	A, E	Coordinate management of core and supporting wetlands with other agencies and organizations. Provide technical assistance to private landowners to develop wetland management plans. Consider forming a recovery coordination group for Hawaiian waterbirds consisting of State and Federal resources agencies, interested researchers, cooperators, and stakeholders.	C	FWS-ES	5	5	5	5	5	50
					HDOFAW	5	5	5	5	5	50
3	1.3.2.1	A	Encourage desirable plant species.	C	FWS-R	50	50	50	50	50	500
					HDOFAW	50	50	50	50	50	500
					USMC	10	10	10	10	10	100
					USN	5	5	5	5	5	50

Implementation Schedule for the Recovery Plan for Hawaiian Waterbirds, Second Revision

Priority Number	Action Number	Listing Factor	Action Description	Action Duration (Years)	Responsible Party	Cost Estimates ($1,000s) FY 2012	FY 2013	FY 2014	FY 2015	FY 2016	Recovery Total
3	1.3.2.3	A	Prevent introduction of invasive non-native plants.	C	FWS-R	5	5	5	5	5	50
					HDOFAW	5	5	5	5	5	50
					USMC	1	1	1	1	1	10
					USN	1	1	1	1	1	10
3	1.3.7.3	A	Assess nutrient levels and other parameters that influence core and supporting wetlands productivity for waterbirds.	3	HDOFAW	2	2	2			6
					FWS-R	2	2	2			6
					USMC	1	1	1			3
3	1.4.4	E	Monitor aquatic invertebrate prey species used by waterbirds and fish to determine whether they compete with waterbirds for aquatic invertebrates.	3	*BRD	10	10	10			30
					FWS-R	5	5	5			15
					USMC	1	1	1			3
					HDOFAW	5	5	5			15
3	3.1	E	Continue surveys of wetland areas on Maui, Moloka`i, and Hawai`i to confirm that a Hawaiian common moorhen population does not already exist.	1	HDOFAW	10					10
					BRD	10					10

Implementation Schedule for the Recovery Plan for Hawaiian Waterbirds, Second Revision											
						Cost Estimates ($1,000s)					
Priority Number	Action Number	Listing Factor	Action Description	Action Duration (Years)	Responsible Party	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016	Recovery Total
3	3.2	A, E	If a population of Hawaiian common moorhen is found on Maui, Moloka`i, or Hawai`i, protect and manage its wetland habitat.	C	HDOFAW		TBD	TBD	TBD	TBD	TBD
					FWS-ES		TBD	TBD	TBD	TBD	TBD
					BRD		TBD	TBD	TBD	TBD	TBD
3	3.5	A, E	Reintroduce Hawaiian common moorhens to a protected and managed site on two additional islands (Maui, Moloka`i, Lāna`i, or Hawai`i) and monitor their survival, dispersal, and reproduction.	2	FWS-ES				30	30	60
					FWS-R				30	30	60
					HDOFAW				30	30	60
					BRD				30	30	60
3	4.1.3	C	Research improved methods to control non-native plants and restore native plants.	3	FWS-R	40	40	40			120
					HDOFAW	40	40	40			120
					*BRD	40	40	40			120
3	4.2.2	E	Determine carrying capacity of wetland habitats.	3	*BRD			5	5	5	15
					FWS-ES			5	5	5	15
					HDOFAW			5	5	5	15
					FWS-R			5	5	5	15
3	4.2.3	E	Estimate reproductive parameters.	3	BRD			5	5	5	15
					FWS-ES			5	5	5	15
					HDOFAW			5	5	5	15
					FWS-R			5	5	5	15

Implementation Schedule for the Recovery Plan for Hawaiian Waterbirds, Second Revision											
						Cost Estimates ($1,000s)					
Priority Number	Action Number	Listing Factor	Action Description	Action Duration (Years)	Responsible Party	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016	Recovery Total
3	4.2.4	E	Estimate mortality rates.	3	BRD			5	5	5	15
					FWS-ES			5	5	5	15
					HDOFAW			5	5	5	15
					FWS-R			5	5	5	15
3	4.2.5	E	Conduct research on movement of adults and natal dispersal.	4	BRD	20	20	20	20		80
					HDOFAW	20	20	20	20		80
					FWS-R	20	20	20	20		80
					FWS-ES	20	20	20	20		80
3	4.2.6	E	Determine the sex and age structure of populations.	3	BRD	5	5	5			15
					FWS-ES	5	5	5			15
					HDOFAW	5	5	5			15
					FWS-R	5	5	5			15
3	4.2.7	E	Investigate genetic population structure and potential inbreeding depression.	4	*BRD		20	20	20	20	80
					FWS-ES		20	20	20	20	80
					HDOFAW		20	20	20	20	80
					FWS-R		20	20	20	20	80

Implementation Schedule for the Recovery Plan for Hawaiian Waterbirds, Second Revision											
Priority Number	Action Number	Listing Factor	Action Description	Action Duration (Years)	Responsible Party	Cost Estimates ($1,000s)					
						FY 2012	FY 2013	FY 2014	FY 2015	FY 2016	Recovery Total
3	4.2.8	E	Before downlisting or delisting, population viability analyses (PVA) should be conducted for the Hawaiian duck, Hawaiian coot, and Hawaiian common moorhen, and the Hawaiian stilt PVA should be updated.	2	BRD		10	10			20
					FWS-ES		10	10			20
3	4.3.1	E	Research habitat needs for Hawaiian waterbirds.	4	BRD	20	20	20	20		80
					FWS-ES	20	20	20	20		80
					HDOFAW	20	20	20	20		80
					FWS-R	20	20	20	20		80
3	4.3.2	A	Research Hawaiian waterbird habitat manipulation including the role of "created wetlands" in waterbird recovery	TBD	BRD						TBD
					FWS-ES						TBD
					HDOFAW						TBD
					FWS-R						TBD
3	4.3.3	A	Research and survey montane stream habitat for Hawaiian duck.	TBD	BRD						TBD
					FWS-ES						TBD
					HDOFAW						TBD
					FWS-R						TBD

Implementation Schedule for the Recovery Plan for Hawaiian Waterbirds, Second Revision

Priority Number	Action Number	Listing Factor	Action Description	Action Duration (Years)	Responsible Party	Cost Estimates ($1,000s) FY 2012	FY 2013	FY 2014	FY 2015	FY 2016	Recovery Total
3	5.1	E	Prepare and distribute television and radio spots, written information, slide programs, videos, films, posters, and displays.	2	FWS-ES	10	10				20
					HDOFAW	10	10				20
					FWS-R	10	10				20
3	5.2	E	Coordinate with the Hawai`i Department of Education and private schools to incorporate wetland and waterbird information into school curricula.	2	HDOFAW	20	20				40
					FWS-ES	20	20				40
					HDOE	20	20				40
3	5.3	E	Develop and maintain interpretive displays of endangered waterbirds and wetlands.	2	HDOFAW	20	20				40
					FWS-ES	10	10				20
					FWS-R	20	20				40
3	6.1	A, D	Coordinate with relevant partners managing waterbirds to work on developing agreements for maintaining waterbird habitat post delisting.	3	FWS-ES			TBD	TBD	TBD	TBD
					HDOFAW			TBD	TBD	TBD	TBD
					USMC			TBD	TBD	TBD	TBD
					USN			TBD	TBD	TBD	TBD
					Totals[2]	$2,594	$2,876	$2,667	$2,318	$1,818	$19,063

[1]An asterisk (*) denotes the lead agency. If no asterisk is present, the agencies share the lead equally. Refer to page 173 for a description of acronyms.

[2] Some of the above costs are yet to be determined and there are likely to be additional costs as well.

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C. *IN LITT*. COMMUNICATIONS

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V. Appendices

APPENDIX A. Core Wetlands

Core Wetlands: Areas that provide habitat essential for survival and recovery, supporting large populations of Hawaiian waterbirds. Wetlands at these sites must be secure from conversion to non-wetland condition and have reliable long-term management. Survival and recovery is dependent upon conserving these wetlands and securing long-term agreements to manage them for viable Hawaiian waterbird populations.

Ni`ihau

Playa Lakes (Sites 2, 3, 4, and 8 on Ni`ihau maps in text) - The Playa Lakes on Ni`ihau are seasonally some of the most important wetlands in the State. Three large lakes (Halāli`i, Halulu, and Nonopapa Lakes) dominate the 760-hectare (1,900-acre) wetland complex. Large numbers of Hawaiian coots, Hawaiian stilts, and Hawaiian ducks are regularly observed on these lakes. The long-term protection of these wetlands should be sought through a cooperative effort with the private landowner.

Kaua`i

Hanalei National Wildlife Refuge (Site 6 on Kaua`i maps in text) - The first National Wildlife Refuge established for waterbirds in Hawai`i was acquired in Hanalei Valley, on Kaua`i, in 1972. This 367-hectare (917-acre) refuge supports 49 species of birds. Taro is grown on the refuge by local farmers, a practice that dates back more than 1,000 years in the valley (Burney and Burney 2003). Management of wetland units for waterbird habitat is ongoing and has recently focused on providing additional foraging, nesting, and loafing habitats.

Hulē`ia National Wildlife Refuge (Site 13 on Kaua`i maps in text) - In 1973, Hulē`ia National Wildlife Refuge was established on Kaua`i, south of the town of Līhu`e. The Refuge encompasses 98 hectares (241 acres) of river bottom habitat along the Hulē`ia River. It was established to provide open,

productive wetlands for endangered Hawaiian waterbirds. Habitat improvement and management have been accelerated and waterbirds are responding positively to this work. Increased waterbird numbers and Hawaiian stilt breeding have occurred (S. Pelizza, *in litt*. 2005).

Mānā Plain Forest Reserve (Formerly Kawai`ele Waterbird Sanctuary) (Site 41 on Kaua`i maps in text) - The State, through a sand mining lease, has created several ponds totaling 14 hectares (35 acres). These ponds have been sculpted to provide nesting islands, sloped banks, and water depths suitable for the endangered waterbirds.

Lumaha`i Valley Wetlands (Site 37 on Kaua`i maps in text) - Lumaha`i Valley in Kaua`i covers approximately 121 hectares (300 acres) and is used by the four endangered waterbirds. The lower reaches of Lumaha`i Valley provide relatively undisturbed high quality feeding, loafing, and possibly nesting habitat. The land is owned by the Bishop Estate. Protection of this area is needed. A partnership should be pursued to protect and preserve Lumaha`i Valley through a cooperative agreement, funding, or habitat conservation plan with the landowner.

O`ahu

Hāmākua Marsh Waterbird Sanctuary (Site 8 on O`ahu maps in text) - Hāmākua Marsh recently increased from 9 to 35.6 hectares (23 to 88 acres) due to a section 6 Recovery Land Acquisition grant in 2008. This wetland is associated with Kawainui Marsh on the windward coast of O`ahu. Located along Hāmākua Drive in Kailua, it is utilized by the four endangered waterbirds and was purchased by Ducks Unlimited, which donated the land to the Hawai`i Department of Land and Natural Resources. The site has been partially restored but additional work is needed to further improve habitat for native waterbirds.

James Campbell National Wildlife Refuge (Includes Ki`i and Punamanō Units) (Sites 15 and 16 on O`ahu maps in text) - Established in 1976, this 105-hectare (260-acre) Refuge has become one of the State's most important sites for waterbirds. Approximately 28 hectares (70 acres) of managed wetlands occur on the Refuge. Year-long intensive management and location contribute to its importance. The Refuge contains a mix of naturally

occurring spring-fed marshes, modified natural wetlands, and artificial ponds and impoundments. From 1976 until 2005, the then 66.7-hectare (165-acre) Refuge was leased. In 2005, the leased acreage plus an additional 32 hectares (80 acres) were purchased in fee simple title by the U.S. Fish and Wildlife Service, providing greater protection to the lands. Some of the permanent wetlands on the site are supported by numerous seasonal wetlands not currently within Refuge boundaries. Under the James Campbell National Wildlife Refuge Expansion Act of 2005, the refuge boundary was expanded to 445 hectares (1,100 acres) and land acquisition within the area was authorized, making James Campbell NWR the largest managed wetland system on O`ahu and further adding to its value as a core waterbird and endangered species recovery location. The expansion enhanced the protective measures that support waterbirds throughout their annual cycle. Waterbird diversity and numbers of individuals are high on this Refuge; peak numbers of endangered waterbirds include 295 Hawaiian coots, 98 Hawaiian common moorhens, and 276 Hawaiian stilts. A maximum of 63 ducks have been recorded, but these are likely all hybrids (Silbernagle, *in litt*. 2008). This Refuge also supports international migratory species, including bristle-thighed curlews (*Numenius tahitiensis*), and other resident indigenous species, such as the Hawaiian short-eared owl (*Asio flammeus sandwichensis*).

Kawainui Marsh (Site 19 on O`ahu maps in text) - Historically, this 300-hectare (741-acre) marsh on windward O`ahu contained a 180-hectare (450-acre) fishpond used by native Hawaiians. It is fed primarily by Manauwili and Kahana Iki streams. The marsh feeds into a canal and then into Kailua Bay. Most of the marsh is densely vegetated; however, some open water exists near the center. Expansion of open water areas would facilitate use by the four endangered waterbirds, which now use the area in small numbers. Kawainui Marsh is currently owned by the Department of Land and Natural Resources (76 hectares [188 acres] around the marsh periphery) and the City and County of Honolulu (the remaining 224 hectares [553 acres]). The entire area is managed by the State of Hawai`i. In 1993, the State began extensive planning efforts for wetland restoration, habitat development, and long-term management.

Marine Core Base Hawai`i, Nu`upia Ponds (Site 25 on O`ahu maps in text) - An interagency agreement under the Sikes Act between the U.S. Marine

Corps, the U.S. Fish and Wildlife Service, the Hawai`i Department of Land and Natural Resources, and the National Marine Fisheries Service provides for management of this wetland area. Eight shallow ponds, totaling approximately 196 hectares (483 acres), comprise the Nu`upia Pond complex at the Kāne`ohe Marine Corps Base Hawai`i on the eastern side of O`ahu. The open water and extensive mudflats with stands of pickleweed (*Batis maritima*), provide valuable habitat for Hawaiian stilts. Over 20 years, the number of Hawaiian stilts at these ponds has doubled from about 60 to over 130 birds, approximately 10 percent of O`ahu's Hawaiian stilt population (Rauzon *et al*. 2002). Various management plans have been developed and implemented for this area, the most comprehensive being an Integrated Natural Resources Management Plan for the Marine Corps Base Hawai`i (Drigot *et al*. 2001).

<u>Pearl Harbor National Wildlife Refuge (Includes Honouliuli and Waiawa Units)</u> (Sites 35 and 36 on O`ahu maps in text) - This Refuge is composed of three units. Two are wetland units, Honouliuli (14.7 hectares [36.5 acres]) and Waiawa (9.9 hectares [24.5 acres]), totaling 24.7 hectares (61 acres). Both wetland units are managed under a cooperative agreement with the U.S. Navy. The Refuge wetland units were established in 1976 as mitigation for construction of the Honolulu International Airport Reef Runway. The Refuge is managed for a variety of waterbirds, including the four endangered waterbirds. Through intensive habitat management and water-level management the Honouliuli Unit has become a stronghold for Hawaiian coots. Coot numbers as high as 389 have been recorded, as well as a peak of 259 Hawaiian stilts and 13 Hawaiian common moorhens. Active water-level manipulation has the potential to benefit endangered and other waterbird species throughout the year. The wetlands of this refuge contribute significantly to both migratory and resident waterbirds, and at least 63 bird species have been documented using the wetlands at Pearl Harbor NWR (S. Pelizza, *in litt*. 2005).

<u>Pouhala Marsh Waterbird Sanctuary</u> (Site 37 on O`ahu maps in text) - This urban estuarine wetland, located adjacent to Waikele Stream, is the largest intact wetland (about 42 hectares [104 acres]) in the Pearl Harbor basin. The wetlands of Pearl Harbor have been degraded through filling, urban development, water pollution, and alien plant invasion. Tidal water-level

fluctuations provide ephemeral foraging and nesting habitats for the Hawaiian stilt, Hawaiian common moorhen, and Hawaiian coot. Funding from the North American Wetlands Conservation Act in 2002 helped to restore 28 hectares (70 acres) of degraded and non-functioning tidal wetland habitats by removing 50,000 cubic meters (66,000 cubic yards) of fill, clearing trash and debris that was dumped into the wetland.

Maui/Molokai

Kakahai`a National Wildlife Refuge (Site 1 on Moloka`i maps in text) - In 1977, Kakahai`a National Wildlife Refuge was established on Moloka`i's southern shore. The 18-hectare (45-acre) refuge protects a pond and artificial impoundment. Twelve species of birds, including the Hawaiian coot and Hawaiian stilt, use this area.

Kanahā Pond Wildlife Sanctuary (Site 11 on Maui maps in text) - In 1952, Kanahā Pond on Maui was designated as the first State wetland sanctuary. The sanctuary encompasses a 57-hectare (143-acre) wetland that is owned by the Hawai`i Department of Transportation and managed by the Hawai`i Department of Land and Natural Resources. It provides valuable nesting, loafing, and feeding habitat for Hawaiian coots and Hawaiian stilts.

Keālia Pond National Wildlife Refuge (Site 16 on Maui maps in text) - This very important 280-hectare (692-acre) wetland and pond is located near Kihei. Representing some of the last remaining natural wetland habitat in the State of Hawai`i, the area provides valuable nesting, loafing, and feeding habitat for Hawaiian coots and Hawaiian stilts. The area was acquired in 1992 and established as a National Wildlife Refuge. The U.S. Fish and Wildlife Service and Ducks Unlimited are currently developing a restoration and management plan that will improve habitat for waterbirds, provide secure water delivery to restored ponds, and provide for public use activities (*e.g.*, wildlife viewing and education).

`Ohi`apilo Pond Bird Sanctuary (Site 1 on Moloka`i maps in text) - This 10-hectare (25-acre) wetland is managed by the County of Maui and is an important area for endangered waterbirds (primarily Hawaiian stilts and Hawaiian coots) and migratory waterfowl. The wetland is part of the `Ohi`apilo Playa (approximately 25 hectares [60 acres]), a seasonal wetland

on the southern coast of Moloka`i near Kaunakakai. The wetland has become overgrown with pickleweed and other introduced plant species. As mitigation for wetland fill, the county worked with Ducks Unlimited to develop a wetland enhancement and management plan. Habitat enhancement was completed in November 1999, and provided open flats for nesting Hawaiian stilts, an additional 4 hectares (10 acres) of seasonally-flooded mudflat, an additional 1 hectare (3 acres) of semi-permanent ponds and channels for Hawaiian coot and Hawaiian stilt chick foraging habitat, and predator fencing. The 10-hectare (25-acre) wetland is surrounded by a 90-meter (300-foot) fenced buffer zone. The county is monitoring and conducting predator and vegetation control in the wetland.

Hawai`i Island

`Aimakapā and Kaloko Ponds (Site 2 on Hawai`i maps in text) - The National Park Service acquired these two ponds as part of Kaloko-Honokohau National Historical Park. `Aimakapā Pond is an important Kona Coast wetland that provides vital foraging and nesting habitat for Hawaiian coots and Hawaiian stilts in the region. The pond comprises approximately 5.3 hectares (13 acres) of open water and another 6.9 hectares (17 acres) of marsh. Kaloko Pond is located approximately 1 mile (1.5 km) from `Aimakapā Pond and, at approximately 4.5 hectares (11 acres) of open water, is somewhat smaller. Kaloko Pond supports many Hawaiian stilts in the Kona Coast region. The National Park Service is currently monitoring bird use on the ponds; however, there is no management plan for `Aimakapā Pond and management plans for Kaloko Pond emphasize restoration of the area as a demonstration fishpond for cultural resource preservation. Additionally, the area surrounding Kaloko-Honokohau National Historical Park is developing commercially and it will be important to ensure protection from the effects of nearby development.

Loko Waka Ponds (Site 7 on Hawai`i maps in text) - The Loko Waka Ponds, roughly 10 hectares (25 acres) in size, are located near Hilo. The privately owned portions of these ponds are managed for fish culture, while the public areas are managed for recreational fishing. They provide nesting and feeding habitat for Hawaiian coots. The use of pesticides should be closely coordinated with the Hawai`i Division of Aquatic Resources to prevent habitat damage. Agreements should be sought with the landowner to enhance habitat for waterbirds. Technical assistance to private land managers could allow

enhancement of waterbird habitat, especially for Hawaiian coots. Vegetation and water control management may increase the habitat value of the Loko Waka Ponds.

APPENDIX B. Supporting Wetlands

Supporting Wetlands: Areas that provide habitat important for survival and recovery, but may support only smaller waterbird populations or may be occupied only seasonally. Protection and management of these or similar wetlands is required to recover Hawai`i's waterbirds, but there is room for some flexibility in which sites must be managed, and it is possible that other sites may fulfill the same needs as those listed here.

Kaua`i

Hanalei River and Taro Fields (Sites 7 and 8 on Kaua`i maps in text) - Protection is needed for the additional taro acreage in Hanalei Valley that is not part of the Hanalei National Wildlife Refuge. These taro fields are occupied by the four endangered waterbirds. Waterbirds move between these fields and refuge lands, and between Hanalei Valley sites and other habitat on Kaua`i and Ni`ihau. Hawaiian ducks, Hawaiian coots, and Hawaiian common moorhens are also known to use areas of the Hanalei River. Thus, these areas provide stepping-stones of habitat between core wetland areas in Hanalei National Wildlife Refuge and the Lumaha`i Valley. Expanded farmer education is the most appropriate management tool for the Hanalei Taro Fields and predator control may also be possible.

Hanapēpē Salt Ponds (Site 9 on Kaua`i maps in text) - The Hanapēpē Salt ponds are located on the southern coast of Kaua`i. This area is made up of two ponding basins separated by a road, and covers about 20 hectares (50 acres). Hawaiian coots, ducks, and especially Hawaiian stilts are known to use these ponds. Hawaiian stilts find this site attractive during winter months when rainfall is abundant, and year-round use of these ponds could be encouraged with effective management. Hanapēpē is mid-way between two Hawaiian stilt nesting and feeding areas (Mānā and Līhu`e Settling Basins) and provides stepping-stones of habitat between these areas.

Mānā Base Pond and Mānā Wetlands (Part of Mānā Plain) (Site 38 on Kaua`i maps in text) - Mānā Plains was once an 810-hectare (2,000-acre) wetland expanse. The currently remaining 81 hectares (200 acres) is regularly used by

the four endangered waterbird species. Further habitat restoration and management of the area is necessary to realize its potential for waterbird recovery. Although a formal cooperative agreement between the State Department of Fish and Wildlife, Kekaha Sugar Company, and the Department of Hawaiian Homelands has declared the Mānā Plain a wildlife sanctuary, a more formal designation of specific areas for waterbird conservation should be made. The decline of the sugar industry in Hawai`i puts future land use in this area in question.

`Ōpaeka`a Marsh (Site 49 on Kaua`i maps in text) - Adjacent to the Wailua River, `Ōpaeka`a Marsh is a 20-hectare (50-acre) wetland that supports Hawaiian ducks, Hawaiian common moorhens, and Hawaiian coots. The State already owns portions of the land. Protection of additional private land, and restoration and enhancement of managed units, could create an important wetland refuge.

Smith's Tropical Paradise (Site 58 on Kaua`i maps in text) - The lowest flatland along the Wailua River, once a tidal marsh, was modified in the 1960s by construction as a tropical garden. This area contains seven shallow ponds and approximately four are used by endangered waterbirds, especially Hawaiian common moorhens. A cooperative agreement with the landowner should be developed to insure that this habitat is protected for waterbirds, and ideally to develop a restoration and management plan that will improve habitat for waterbirds. This site is unique in that it could also be an important area for education about waterbird conservation for the public (*e.g.*, wildlife viewing).

Wailua River Bottoms (Site 66 on Kaua`i maps in text) - This supporting wetland is associated with the Wailua Golf Course Ponds, Jail Swamp, and Siphon Reservoir (Sites 63-65). The Wailua River is located in the District of Kawaihau and runs parallel to the `Opaeka`a Stream, which joins Wailua River at a point approximately 0.8 kilometer (0.5 mile) west of the river mouth. Flat pasturelands border the downstream portion of Wailua River, although most of the sloping hillsides are heavily forested. Hawaiian ducks, Hawaiian common moorhens, and Hawaiian coots are known to forage along the river bottoms.

Waimea River System (Site 68 on Kaua`i maps in text) - This supporting wetland is associated with the Waimea Heights Reservoir and Waimea Taro fields (Sites 67 and 69). Waimea River is located in the southwestern region of Kaua`i. It is the island's largest river system, surrounded by dense vegetated land and on the

lower reaches, by taro patches or agricultural lands. Hawaiian ducks are thought to use upland portions of the river, and lower reaches may be good foraging habitat for Hawaiian coots and Hawaiian common moorhens, although surveys have not been conducted to quantify waterbird usage because access to agricultural lands are limited.

Wainiha Valley River and Taro Fields (Site 70 on Kaua`i maps in text) - Wainiha Valley is located in northern Kaua`i and provides a wide variety of wetland habitats for waterbirds, including a large estuarine area, flowing freshwater stream, ephemeral flooded pastures and taro fields. Hawaiian stilts and Hawaiian common moorhens are found in the taro fields and Hawaiian coots are found in the lower stream and estuarine area. Hawaiian ducks may also occur in the valley. A cooperative agreement with the landowner should be developed to insure maintenance of stream flow throughout its normal course in the valley. Predator trapping should also be considered as part of this agreement.

Waitā Reservoir (Site 74 on Kaua`i maps in text) - Waitā is the largest fresh water reservoir on Kaua`i. It is surrounded mostly by cane fields, although emergent grasses line the reservoir's edge when the water level is high. Large numbers of Hawaiian coots periodically use this reservoir for loafing and feeding. Hawaiian ducks, Hawaiian common moorhens, and Hawaiian stilts have also been recorded at this site. A cooperative agreement with the landowner should focus on measures to ensure that disturbance of foraging and loafing habitat for Hawaiian coots is avoided or minimized.

O`ahu

Hale`iwa Lotus and Taro Fields (Site 7, in part, on O`ahu maps in text) - The Hale`iwa lotus and taro fields are located primarily in the Hale`iwa lowlands between Anahulu and Kaukonahua streams. The taro and lotus fields are fed by springs, wells, and perennial streams. This area provides important habitat for waterbirds, particularly the Hawaiian common moorhen. Waterbird numbers for Hale`iwa Lotus and Taro Fields and Waialua Lotus Fields are lumped together during the biannual waterbird surveys because Waialua Lotus Fields are considered a subwetland of Hale`iwa Lotus and Taro Fields (see Table 2).

Waialua Lotus Fields (Site 7, in part, on O`ahu maps in text) - Relatively few taro and lotus fields remain in what was once a large wetland agriculture development

on the north shore of O`ahu. The lotus fields in Waialua support the State's highest concentration of Hawaiian common moorhens, which use the area to nest and feed. Hawaiian stilts, numerous shorebirds, and night-herons also feed in the wetland. Long-term protection of Waialua Lotus Fields could be reached through cooperative agreements between landowners and natural resource agencies. Waterbird numbers for Waialua Lotus Fields and Hale`iwa Lotus and Taro Fields are lumped together during the biannual waterbird surveys because Waialua Lotus Fields are considered a subwetland of Hale`iwa Lotus and Taro Fields (see Table 2).

He`eia Marsh (Site 11 on O`ahu maps in text) - This 160-hectare (400-acre) area was formerly a complex of tidal marshes and open-water areas. It has been substantially modified and presently consists of non-native mangroves, remnants of ponds, and wet pasture grazed by cattle. This wetland area should be restored and managed to provide enhanced habitat for the endangered waterbirds. The State secured this property through a land exchange in 1992. The Hawai`i Department of Land and Natural Resources is currently planning for enhancement and management of the site's upland and wetland resources.

Ka`elepulu Mitigation Pond (Enchanted Lakes) (Site 17 on O`ahu maps in text) - This privately-owned wetland is surrounded by a housing development but was once more than 200 acres in size (Shallenburger 1977). It is now approximately 1.2 hectares (3 acres) and supports nesting Hawaiian coots, as well as smaller numbers of nesting Hawaiian common moorhens and Hawaiian stilts. Vegetation management and predator control are carried out on the wetland.

Kahuku Aquaculture Farms (includes Kahuku Prawn Farm) (Site 18 on O`ahu maps in text) - This supporting wetland is associated with Amorient Aquafarm (Site 2). Kahuku area wetlands provide valuable foraging and marginal nesting habitats for all four endangered waterbirds. Prior to 1994, this area supported one of the largest aquaculture developments in the State. Much of the area is currently undergoing redevelopment by Ming Dynasty Aquaculture. The natural wetlands in the area have become overgrown with invasive species such as pickleweed (*Batis maritima*). Long-term protection is needed for the aquacultural and wetland ponds in this area.

Turtle Bay, Kuilima Wastewater Treatment Plant (Site 41 on O`ahu maps in text) - This site is located in northern O`ahu and is periodically used by large numbers

of Hawaiian stilts. Long-term protection should be encouraged through cooperative agreements between the landowner and natural resource agencies.

La`ie Wetlands (Site 21 on O`ahu maps in text) - This 81-hectare (200-acre) wetland complex comprises three natural ponds and several aquaculture ponds. All are linked hydrologically and these four endangered waterbird species use the site. This area is owned by the Church of Jesus Christ of Latter-day Saints and long-term protection is planned for the site. If restored and managed, the La`ie Wetlands would be an important addition to the available wetland habitat in the Kahuku area.

Lualualei RTF, Niuli`i Ponds (Site 23 on O`ahu maps in text) - Located at Naval Computer and Telecommunication Area Master Station Pacific Radio Transmitter Facility (RTF) Lualualei on O`ahu's leeward coast, this 35.7-hectare (88.4-acre) refuge was established by the Navy in 1972. The refuge is managed through a cooperative agreement between the Navy and the U.S. Fish and Wildlife Service. The refuge includes three small man-made ponds built for disposal and treatment of wastewater runoff effluent. Improvements to the ponds (*e.g.*, installation of a solar-powered groundwater pump to provide additional freshwater in the primary pond, periodic control of California grass and other invasive non-native plant species, and control of feral and non-native animals) facilitated the creation of wetland habitat that supported the four endangered waterbirds in addition to other waterfowl and shorebirds. However, recent realignment of Naval facilities has eliminated the majority of source water for the ponds and substantially reduced their size from 3.9 hectares (9.6 acres) to approximately 0.4 hectares (1 acre). An Integrated Natural Resources Management Plan for the area notes that Navy Region Hawai`i will maintain the remaining wetland as long as endangered waterbirds continue to populate the ponds (Navy Region Hawai`i 2001). We should work with the Navy to ensure this management plan commits to maintaining wetland habitat after delisting.

Paikō Lagoon Wildlife Sanctuary (Site 33 on O`ahu maps in text) - Purchased in 1974, Paikō Lagoon receives water from Kuliouou Stream through a channelized inlet. Water levels fluctuate as a direct result of tidal fluctuations which periodically expose extensive saline mudflats (Shallenberger 1977). Currently, predator control and native out-plantings are occurring.

Punaho`olapa Marsh (Site 38 on O`ahu maps in text) - This former pond and large marsh of over 40 hectares (100 acres) has been highly altered due to the development of a golf resort. The golf course surrounds the site, and a second planned resort will impact its coastal buffer. All four endangered waterbirds use this area. It has been suggested that incorporating Punaho`olapa Marsh into the refuge system as part of the James Campbell National Wildlife Refuge would ensure protection and management of this site. Mitigation requirements associated with this site as part of the approval for development of the golf course have not been fulfilled (S. Pelizza, *in litt*. 2005).

`Uko`a Marsh (Site 44 on O`ahu maps in text) - This is a 122-hectare (300-acre) freshwater marsh near Hale`iwa on the north shore of O`ahu. Much of this privately owned marsh has been overgrown by non-native plants, but still provides valuable waterbird habitat. A cooperative agreement with the landowner should be developed to ensure that this habitat is protected and managed for waterbirds.

Waihe`e Marsh (Site 46 on O`ahu maps in text) - This 10-hectare (25-acre) marsh is located along the windward coast of O`ahu near the town of Waiāhole and supports limited numbers of waterbirds. The site is adjacent to the main road and close to City and County of Honolulu parks that could be integrated with wetland habitat conservation for public environmental education opportunities. Protection and enhancement of Waihe`e Marsh could improve its value for endangered waterbirds.

Moloka`i/Lāna`i /Maui (Maui Nui)

Kaunakakai Wastewater Reclamation Facility Ponds (Site 6 on Moloka`i maps in text) - This site lies just north of the town of Kaunakakai, Moloka`i. Hawaiian stilts and especially Hawaiian coots in large numbers have been observed at this site. Artificial nesting platforms placed in the ponds have encouraged Hawaiian coot nesting. Long-term protection should be encouraged through cooperative agreements between the County of Maui and natural resource agencies.

Kualapu`u Reservoir (Site 7 on Moloka`i maps in text) - Located in north-central Moloka`i, this reservoir periodically supports relatively large numbers of Hawaiian coots. Monitoring of bird populations and protection of Kualapu`u Reservoir should be sought.

Paialoa Fish Ponds (Site 10 on Moloka`i maps in text) - This is a privately owned freshwater marsh on the southern coast of Moloka`i, about 2 hectares (5 acres) in size, used by Hawaiian coots and Hawaiian stilts. A cooperative agreement should be sought with the landowner to prevent habitat alteration.

Lāna`i Sewage Treatment Ponds (Site 1 on Lāna`i maps in text) - This sewage treatment plant is located southwest of Lāna`i City adjacent to Kaumalapau Highway. It provides habitat for the Hawaiian stilt and in several years, over 100 Hawaiian stilts were observed using this site (HDOFAW 1976-2008).

Ke`anae Point (Site 17 on Maui maps in text) - Waiokamilo and Palauhulu streams drain the upper Ke`anae Valley into an open ephemeral marsh. Below the marshland are extensive taro fields that are used by waterbirds. Long-term protection and management through cooperative agreements between the landowner and natural resource agencies should be encouraged.

Waihe`e Coastal Dunes and Wetlands (Waihe`e Refuge) (Site 50 on Maui maps in text) - The Waihe`e Refuge is part of 112 hectares (277 acres) of coastal dune and wetland complex on the northern shore of Maui that has been under imminent threat of development as a golf course. The Maui Coastal Land Trust holds the title of the properties acquired with funding from public and private sources. Maui County and the State of Hawai`i hold conservation easements on the properties to ensure perpetual protection of the land (Maui Coastal Land Trust 2008). The Maui Coastal Land Trust will restore and permanently protect 101 hectares (250 acres) of this wetland complex, which encompasses 9.7 hectares (24 acres) of wetlands, 41.7 hectares (103 acres) of buffering sand dunes, and approximately 3.2 hectares (8 acres) of riparian habitat (Maui Coastal Land Trust 2008). The Waihe`e Refuge provides habitat for the Hawaiian stilt and Hawaiian coot.

Hawai`i Island

Kealakehe (Kona) Sewage Treatment Plant (Site 3 on Hawai`i maps in text) - The County of Hawai`i has designed artificial wetlands for Hawaiian stilts at the Kealakehe (Kona) Wastewater Treatment Plant. Ponds will be constructed with predator fencing and nesting islands for Hawaiian stilts, and designed to allow public access, with a parking area and interpretive trails and signs. Technical support by resource agencies to the county should continue, and future projects

should be encouraged to incorporate wildlife habitat enhancement where compatible with the operations of the plant.

Ke`anae Pond (Kea`au/Shipman) (Site 4 on Hawai`i maps in text) - Ke`anae Pond, located in eastern Hawai`i, is a spring-fed pond with connection to the ocean that has been altered through construction of a shoreline rock wall and gate system. Hawaiian coots have been observed using the marsh edge and some areas of the pond are suitable for loafing and feeding. Long-term protection and management should be encouraged through cooperative agreements between the landowner and natural resource agencies. Vegetation management and predator control are needed to enhance habitat for waterbirds.

Kohala-Mauna Kea Ponds and Streams (Sites 5 and 6 on Hawai`i maps in text) - The highest density of perennial streams, depressional wetlands, and agricultural ponds occurs on the windward (northeastern) slopes of Kohala and Mauna Kea mountains. These wetlands are under State, Federal, and private ownership and encompass an area of about 700 square miles. Wetland complexes consisting of agricultural and natural wetlands, streams, and grasslands support a breeding population of Hawaiian ducks. Hawaiian coots are rarely observed in ponds and stream plunge-pools. These lands are under threat of conversion from agricultural to residential uses. Protection and enhancement of these wetlands should be accomplished through cooperative efforts between agencies and private landowners, including State watershed partnerships. Landowners, through USDA's Wetlands Reserve Program and other incentive programs, should be encouraged to protect core wetlands and streams and create or enhance wetlands suitable for the Hawaiian duck.

`Ōpae`ula Pond (Site 8 on Hawai`i maps in text) - This 3-hectare (7.5-acre) privately-owned coastal pond is located in the North Kona District. Water levels fluctuate with ocean tides, rainfall, and freshwater seepage (Ducks Unlimited 2006). This freshwater to brackish wetland is of primary importance to Hawaiian stilts and Hawaiian coots. Habitat for waterbirds on this site may be improved with continued vegetation management, predator control, and ungulate removal (Ducks Unlimited 2006).

Waiākea Pond (Site 11 on Hawai`i maps in text) - Waiākea Pond is an estuarine pond that drains into the Wailoa River, which then flows eastward about 0.5 miles into Hilo Bay. Waiākea Pond is one of the largest freshwater habitats for

endangered waterbirds and provides habitat for a large portion of the island's Hawaiian coot population. It also harbors a population of feral mallards, which should be removed.

Waimanu Valley (Site 12 on Hawai`i maps in text) - Waimanu Valley was inhabited and extensively used for rice and taro production prior to the tsunami of 1946 (Shallenberger 1977). Since then, the valley has remained undeveloped. This 1,456.9-hectare (3,600-acre) site in the Hāmākua District, is unique in that it is one of the few unaltered watersheds in Hawai`i. In its unmanaged state, however, it provides very little habitat for waterbirds.

Waipi`o Valley (Site 13 on Hawai`i maps in text) - Waipi`o Valley, located in Hawai`i's Hāmākua District, along the northeastern coastline of the Kohala Mountains. Several tributaries flow into Waipi`o Stream; however, some are diverted by smaller ditches that feed taro fields. The central valley is dominated by taro fields, while the lower valley is marshland. The taro fields and the large pond at the north edge of the lower valley provide waterbird habitat. The Hawaiian duck and Hawaiian coot utilize this site. Long-term protection and management should be encouraged through cooperative agreements between the landowner and natural resource agencies. Extensive management of wetlands in the lower valley is needed, particularly extensive clearing of invasive wetland vegetation, creation of water impoundment areas, and effective water level manipulation.

APPENDIX C. Endangered and Threatened Species Recovery Priority Guidelines*

Degree of Threat	Recovery Potential	Taxonomy	Priority
High	High	Monotypic genus	1
	High	Species	2
	High	Subspecies	3
	Low	Monotypic genus	4
	Low	Species	5
	Low	Subspecies	6
Moderate	High	Monotypic genus	7
	High	Species	8
	High	Subspecies	9
	Low	Monotypic genus	10
	Low	Species	11
	Low	Subspecies	12
Low	High	Monotypic genus	13
	High	Species	14
	High	Subspecies	15
	Low	Monotypic genus	16
	Low	Species	17
	Low	Subspecies	18

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* Adapted from Listing and Recovery Priority Guidelines (1983), Federal Register 48:43098-43105 (USFWS 1983a). In addition, a species' rank may be elevated by adding a C designation to its numerical rank to indicate that there is some degree of conflict between the species' conservation efforts and economic development associated with its recovery

APPENDIX D. Summary of the Comments on the Draft Revised Recovery Plan for Hawaiian Waterbirds (Second Draft of Second Revision)

In May 2005, we released the Draft Revised Recovery Plan for Hawaiian Waterbirds, Second Draft of Second Revision for review and comment by Federal agencies, the State of Hawai`i, and members of the public (U.S. Fish and Wildlife Service 2005a). The public comment period was announced in the Federal Register (70 FR 49668) on August 24, 2005, and closed on October 24, 2005 (U.S. Fish and Wildlife Service 2005b). Over 300 copies of the draft plan were sent out for review during the comment period, including distribution to scientific peer reviewers.

Fifteen letters/comments were received, 9 during the comment period and 6 shortly after the comment period closed. Comments were received from three peer reviewers, four agencies (including three letters from the Fish and Wildlife Service), one non-government organization, one private company, and four individuals. All comments received have been considered and incorporated into the approved recovery plan, as appropriate. A summary of the substantive comments received and our responses follows below.

<u>Issue 1: Recovery goals and criteria</u>

Comment: The minimum population size of 2,000 for downlisting/delisting for each of the species was not well justified in the recovery plan.

Response: Reasons for using the population target of 2,000 individuals are discussed in the Recovery Strategy (Section II.B). This population target is meant as a starting point for establishing recovery targets and is subject to future revision, since each of these species has different life histories and biological requirements. As described in Recovery Action 4.2.8, before decisions on downlisting/delisting are made a population viability analysis should be conducted for each species to confirm whether 2,000 individuals is an appropriate goal for each species.

Comment: Ephemeral wetlands are noted in the plan as being important to Hawaiian coots, but there was no specific mention of the need to protect these wetlands in the downlisting/delisting criteria.

Response: The large complex of ephemeral wetlands in the Playa Lakes area on Ni`ihau is a major waterbird habitat area during favorable years, and is identified as a core wetland area that should be protected. Elsewhere in the Hawaiian Islands, smaller ephemeral wetlands such as flooded fields can seasonally provide important habitat for waterbirds. However, because they are small, dispersed, and primarily managed for other purposes, we cannot rely on them for recovery. It is most important at this time to protect larger sites and wetlands that provide waterbird habitat year-round, especially with the limited resources currently available, but smaller ephemeral wetlands should also be protected where possible.

Comment: The recovery plan should be refocused on a few of the most important threats, especially predator control, followed by methods to address habitat loss (vegetation control, water levels, etc.). There should be more discussion of strategies to mitigate threats.

Response: We agree that predation is the most important threat currently facing waterbirds, with the exception of the threat of hybridization to the Hawaiian duck (See Habitat Requirements and Limiting Factors under Executive Summary). Control of introduced species preying upon Hawaiian waterbirds is a significant issue due to both the number of predators and the diversity of predator species (Recovery Action 1.3.3). Therefore, control of the major introduced waterbird predators is assigned the highest priority in the implementation schedule of this recovery plan. The action priorities in the implementation schedule should allow us to focus on the most important threats while ensuring that our long-term strategy addresses and mitigates the secondary threats.

Comment: Why should past distributions of the four species in this plan be the basis by which future recovery is defined?

Response: Although past distribution patterns may not need to be exactly replicated, as indicators of the overall potential for habitat availability they are an important consideration in assessing whether species populations have achieved recovery goals (see Section II.D.3).

Comment: The recovery plan does not provide justification for requiring a particular number of populations (*i.e.*, self-sustaining populations on four islands).

Response: Since wetlands are fairly scarce in the Hawaiian Islands, it is prudent to have populations of waterbirds on as many islands as possible for multiple reasons (see section II.D.1). Given the relatively small population sizes on some islands, having populations on multiple islands provides necessary redundancy to buffer against loss of genetic diversity or local population declines. Decline or extirpation of local populations may occur asynchronously among islands because islands vary in threats and management issues; catastrophic events such as disease outbreaks, weather events, or introgressive hybridization may be localized to a single island.

Comment: Habitat management is vital and securing wetland habitat for protection and management should be a priority for all remaining wetlands.

Response: We agree that these actions are important for recovery, and they are included as recovery actions in the plan.

Comment: How important is protection of habitat, since core and supporting wetlands do not include many of the sites that support large numbers of waterbirds? Predator control is more important in regulating population size.

Response: Habitat protection and predator control are complementary actions that are both important for increasing waterbird populations. Effective predator control is generally difficult to accomplish at sites that do not have plans for habitat protection and management (see section II.D.3.a). Protection of habitat can also open options for implementing various management actions that will increase the number of waterbirds that a wetland can support.

Comment: Maintaining minimum population numbers is a risky approach for a recovery strategy given the difficulty of incorporating environmental stochasticity (particularly catastrophes) in population viability analyses.

Response: In addition to the population-based recovery criteria, the recovery plan includes other requirements, such as wetland protection and management and spatial distribution of populations, that must be met before considering downlisting or delisting. Moreover, the population number must be maintained over a number of years to meet recovery criteria. This approach incorporates adequate time to demonstrate species resilience to stochastic events (*e.g.*, weather).

Issue 2: Waterbird survey data

Comment: The shortcomings of the waterbird survey data should be adequately discussed in the plan.

Response: There are several places in the recovery plan where we discuss the shortcomings of the waterbird survey data and their importance as an index of waterbird status rather than as an actual estimation of populations. These data continue to be our best resource for tracking waterbird populations across the State and the surveys should be continued. The recovery plan acknowledges that improvement of the surveys is an important recovery need for these species.

Comment: The recovery plan does not adequately explain how the survey data will be used to monitor recovery progress.

Response: The waterbird survey data are the best available comparative index of trends and regional variations in population levels for the four endangered waterbirds. Over multiple years, these data will be used as an index of abundance to assess whether species have met the recovery criteria described in this recovery plan. However, raw totals of survey data do not account for observer bias, area surveyed, or detection probability, and sampling biases; thus although they are useful as an abundance index to detect population trends, their estimates may systematically deviate from true abundance values. This issue is particularly significant for Hawaiian common moorhens and Hawaiian ducks, which may not be detected effectively by existing survey methods. The need to improve survey methodologies is discussed in the recovery plan in several locations.

Comment: Additional guidance on data collection protocols and measures to improve data collection are needed in the recovery plan.

Response: It is hoped that information presented in this plan will help update the waterbird survey data collection process. Updated guidance was incorporated into revisions of the waterbird survey protocols in 2005 (see http://www.state.hi.us/dlnr/dofaw/pubs) with the publication of the draft revised plan. A Photographic Identification Guide is also available to improve data collection (http://www.state.hi.us/dlnr/dofaw/pubs /WaterbirdCount_photoguide.pdf). Additional suggestions for improvement in survey protocols are included in this final revised plan, and should be reflected in subsequent versions of the protocols.

Issue 3: Hawaiian duck conservation

Comment: How should one view the existing duck populations on the islands, since the genetic material of Hawaiian ducks reintroduced over two decades ago is now extremely diluted by hybridization with mallards?

Response: In the past, Hawaiian ducks were introduced to O`ahu, Hawai`i, and Maui and have since then interbred with mallards. Once we can reliably distinguish between hybrids and pure Hawaiian ducks, hybrids from all islands must be removed to address the threat of hybridization for this species.

Comment: Core wetlands identified in the recovery plan do not include any streams used by the Hawaiian duck. Furthermore, none of the three core wetlands listed for Hawai`i support Hawaiian ducks, which strongly suggests that protection of core and supporting wetlands is an insufficient goal for downlisting or recovery of the Hawaiian duck.

Response: Additional information is needed on the use of upland streams by Hawaiian ducks as nesting habitat. In Recovery Action 4.3.3 we recommend conducting stream surveys on Kaua`i and Hawai`i to identify streams that are used by Hawaiian duck. When the most important streams for Hawaiian duck recovery have been identified, the lists of core and supporting wetlands on Kaua`i and

Hawai`i should be modified as appropriate. These streams should be protected through cooperative agreements with watershed partnerships. However, Hawaiian ducks are also expected to benefit from protection of core wetlands in coastal habitats, which have potential to function as foraging or loafing habitat.

Comment: The Hawaiian duck should be separated from the recovery plan for the Hawaiian stilt, Hawaiian coot, and Hawaiian common moorhen due to major differences in biology, especially in habitat use. Because of these differences, it should have its own recovery plan.

Response: Although we agree that the Hawaiian duck differs from the other three species in this plan in several respects, it does co-occur with them in a number of wetlands; moreover, most of the threats and many of the recovery actions are similar. Therefore we have retained the Hawaiian duck as a species addressed in this recovery plan.

<u>Issue 4: Recovery priority number</u>

Comment: What criteria were used to assign the recovery priority number to each species? There is limited reliable data for the Hawaiian common moorhen, and the Hawaiian coot should be upgraded to a higher priority number.

Response: Recovery priority numbers are assigned based on our assessment of degree of threat, recovery potential, and taxonomic rank, as described in our recovery priority guidelines (U.S. Fish and Wildlife Service 1983a, 1983b). We believe the recovery priority numbers are appropriate for the Hawaiian stilt, Hawaiian common moorhen, and the Hawaiian duck. We agree that the threats for Hawaiian coot are similar to those for the other species (moderate rather than low), and so we are changing its recovery priority number from 14 to 8.

<u>Issue 5: Agricultural lands and lands managed for waterbirds</u>

Comment: Discussion in the recovery plan that implies agricultural lands are of equal or higher quality than habitat specifically managed for waterbirds is misleading. The amount of habitat that agricultural lands historically provided is overstated.

Response: We have modified the language in various locations throughout the text to reflect the importance of wetlands that are managed or protected for waterbirds, in comparison to agricultural lands. Agricultural lands have, in the past, provided habitat for waterbirds and continue to do so, but we agree that, due to various factors (*e.g.*, human disturbance, habitat quality, economic considerations in utilizing the lands, and potential contaminant issues), they are unlikely to provide the same quality of habitat as do wetlands managed for waterbirds.

Issue 6: Water issues

Comment: Hawai`i's Public Trust Doctrine requires that before water is diverted from instream use, the needs of the stream's ecosystem and habitat protection must be taken into account. Any information the U.S. Fish and Wildlife Service obtains on instream water needs of Hawai`i's waterbirds should be forwarded to the State Water Commission.

Response: We will plan to pass along any information we obtain related to water stream diversions as requested.

Issue 7: Hawaiian access rights

Comment: Native Hawaiian traditional and cultural gathering and access rights should be taken into account in plans to designate critical habitat for these species.

Response: If critical habitat is designated for these species, this request will be taken into account during the designation process.

Issue 8: Habitat restoration

Comment: Although wetland loss is acknowledged in the recovery plan, there is no requirement for a specific amount of habitat restoration or creation for recovery of the species.

Response: Habitat restoration research is addressed as an important need in Recovery Action 4.3.1, and management of water levels and invasive weed problems to improve and restore waterbird habitat is recommended through Recovery Actions 1.3.1 and 1.3.2. While habitat restoration needs are site-specific and are not readily generalized to range-wide goals, we agree that habitat restoration is important for the recovery of Hawaiian waterbirds and it is an

important component of the protection and management of core and supporting wetlands recommended in the recovery criteria.

Issue 9: Native versus non-native plants

Comment: Because many wetlands now have predominantly non-native vegetation but presently support waterbirds, we should not let a bias toward native plant species get in the way of endangered species recovery.

Response: Under some circumstances altered hydrology and changes in plant communities can create a need for native plants to be controlled in order to improve waterbird habitat. In general, however, invasive non-native plants pose a more serious threat to waterbird habitat, and we recommend that native plants should be planted preferentially over non-native plants.

Issue 10: Core versus supporting wetlands issues

Comment: How are wetlands anked as "core" and "supporting"? Under the current definitions, we run the risk of having fewer and fewer core wetlands if core wetlands are downgraded to "supporting" due to lack of management. Revisions were suggested to some core/supporting wetland designations.

Response: Determination of a wetland as "core" or "supporting" in this recovery plan was based on several factors including wetland size, species supported in the wetlands, the location of the wetland, landowner (*e.g.*, National Wildlife Refuges, State, private), as well as whether it is protected or managed.

Comment: An updated inventory of each wetland listed as "core" and "supporting" on the order of Shallenberger (1977) is needed, although the cost of such an inventory would be high and the undertaking huge.

Response: While this information would be useful, we consider it of relatively low priority in comparison to other actions needed for recovery. Much of this information could be obtained in conjunction with the waterbird survey data collection (Recovery Actions 1.4.1, 4.2.1, 4.2.2).

Comment: Too few wetlands are listed as "supporting" All wetlands capable of being protected and managed should be included, especially in consideration of the mandate for "no net loss of wetlands."

Response: We agree that no net loss of wetlands is an important overall goal. However, because wetlands vary in their size, location, and other characteristics, not all of them are of equal value as waterbird habitat and some may not be necessary for the recovery of these species. Identifying core and supporting wetlands will allow us to focus management efforts on those wetlands that will contribute most to recovering endangered waterbirds, given limited funds.

<u>Issue 11: Downlisting and delisting criteria for supporting wetlands issues</u>

Comment: Are the protection goals in the Draft Revised Recovery Plan for Hawaiian Waterbirds (USFWS 2005a) intended to protect 25 percent of supporting wetland acres for downlisting or 25 percent of the total number of supporting wetlands? The metric used should be acres of habitat and not the number of places that are protected.

Response: This criterion was intended to be based on the percentage of individual wetlands protected rather than the percentage of total wetland acreage; we believe this metric is appropriate because it is readily quantified and reflects the importance of spatially well-distributed habitat. However, in order to provide for greater population stability across the species' range, we have increased the requirements for protection of supporting wetlands from 25 to 50 percent (for downlisting) and from 75 to 85 percent (for delisting).

Comment: We should be cautious in generalizing the 25 percent and 75 percent downlisting and delisting requirements for supporting wetlands in the Draft Revised Recovery Plan for Hawaiian Waterbirds (USFWS 2005a), as not all identified wetlands have equal value to waterbirds. We should rely on wetland habitat that has been dedicated to natural resource management and perpetuation for the downlisting and delisting of these species.

Response: We agree that not all wetlands have equal value to waterbirds, and in fact some wetlands may have high value to one species but not

to others. In addition, we agree that managed wetlands are likely to provide the greatest value to waterbirds. However, not all wetlands statewide are managed, and since the amount of wetland habitat in the State is limited, it is appropriate to target for protection some unmanaged wetlands that have good potential as waterbird habitat.

Issue 12: General recovery plan format and content issues

Comment: Inconsistencies in wetland names should be cleared up.

Response: We agree that the wetland names should be consistent and we attempted to make them so. The revised wetland names should be included in forthcoming versions of waterbird survey data instructions.

Comment: Removal actions for egrets, tilapia, and bullfrogs can be lumped together and given a lower priority and less emphasis in the plan.

Response: While we agree these species may pose less of a threat than some other species, we believe that the recovery actions oriented to these species should not be lumped as the removal methodology is likely to be developed and implemented differently for each species.

Comment: Too much emphasis is placed on research and monitoring, and the priorities placed on some research and monitoring actions are inappropriate.

Response: We believe research and monitoring are important to recovery and their emphasis in the plan is appropriate. Monitoring is necessary to accurately understand population status and trends for the endangered waterbirds, and research is critical to helping us prioritize management actions and effectively plan the recovery strategy.

Comment: References relevant to the issues discussed have been omitted, or are out of date.

Response: We have added a number of the references suggested and added several recently published references as well.

Comment: Given the overriding evidence about global warming and its current and future effects on weather and plant and animal

distribution, it would be prudent to incorporate some aspect of that uncertainty into the recovery plan.

Response: We agree with this comment and have included global warming in our discussion of threats to the Hawaiian waterbirds.

Comment: If contaminants are only a $5,000/year, priority 2 action, they should receive less attention earlier in the document.

Response: We believe that threats from contaminants are accurately described in the recovery plan. Adverse impacts on water quality have potential to affect waterbirds. Recovery Action 3.7.2 addresses preventative measures, but other management and monitoring actions identified in the plan will also contribute to reducing waterbird exposure to contaminants.

Comment: The recovery plan should include a better description of what is meant by “protected wetland” and what the value of a protected wetland is to waterbird recovery.

Response: Protected wetlands are described in the Recovery Strategy (section II.B) as wetlands that are secure from development. In general these are sites such as National Wildlife Refuges, State-owned wildlife sanctuaries, or mitigation wetlands, where the primary purpose of management is wildlife conservation or does not conflict with that goal. All protected wetlands have at least some value to waterbirds, but those that are not considered core or supporting wetlands may not be of sufficient size or quality to play a large role in recovering waterbird species.

Comment: Use of the term “population” in the plan is confusing in referring to “populations” on different islands because the species are capable of interisland flight and thus intermixing.

Response: We agree that some degree of population interchange among islands is likely, but we believe that the term "population" is still appropriate in the sense of a group of organisms of the same species occupying a particular area.

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