

Hawaii's Endangered Waterbirds: A Resource Management Challenge

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Abstract: Four endemic waterbird species recorded by early naturalists still survive in the main Hawaiian Islands, including the black-necked (Hawaiian) stilt (*Himantopus mexicanus knudseni*), American (Hawaiian) coot (*Fulica americana alai*), common (Hawaiian) moorhen (*Gallinula chloropus sandvicensis*), and Hawaiian duck (*Anas wyvilliana*). All four are believed derived from North American colonist species and are classified as endangered. The long history of modifications to Hawaii's wetlands by Hawaiian and European cultures has left only remnants of former natural wetlands. More recently, urbanization of lowland areas, particularly on Oahu, has accelerated the conversion or alteration of wetlands. Taro fields, fish ponds, cane waste silting basins, and reservoirs have replaced natural wetlands and are now of primary importance for Hawaii's waterbirds. Of the nearly 4100 ha of wetlands identified as essential habitat for waterbirds, only 800 ha are in some form of refuge status. Sport hunting and introduction of exotic mammals have also affected waterbird populations. Hybridization with feral mallards (*Anas platyrhynchos*) presents a major threat to the integrity of the Hawaiian duck. Survival of endemic Hawaiian waterbirds depends on a multifaceted approach that will maximize their production and survival. At the core of a long-term conservation program is the need to secure, maintain, and enhance suitable habitat. Effective habitat enhancement programs become more important as unprotected wetlands continue to diminish in extent and quality. Financial constraints and increasing land use competition make it imperative that Hawaii's wetland managers become more aware of critical habitats and management options and, in effect, learn how to do more with less.

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INTRODUCTION

The wetlands of ancient Hawaii provided habitat for migratory shorebirds and waterfowl. Some vagrant species successfully reproduced and, in geographic isolation from their continental relatives, evolved over time into new forms. At least one species, the Hawaiian goose or nene (*Branta sandvicensis*) abandoned the wetland habitat of its ancestors. This endemic goose, similar in many respects to the Canada goose (*Branta canadensis*), now inhabits vegetated high-elevation lava flows on the islands of Maui and Hawaii (Fig. 1). As is characteristic of other island endemics, some waterbird colonists in Hawaii lost their ability to fly. Included in this group were geese, rails, and ibises. The flightless geese, ibises, and seven rails are known only from fossils (Olson and James, 1982); two other species of rails, the Hawaiian rail (*Porzana sandwichensis*) and Laysan rail (*Porzana palmeri*), became extinct during the late 19th and mid 20th centuries, respectively (Berger, 1981).

Today, five endemic waterbird species recorded by early naturalists still survive. One of these, the Laysan duck (*Anas laysanensis*) is confined in distribution to Laysan Island (400 ha), nearly 1500 km northwest of Honolulu. The other four waterbird species occur only in the main Hawaiian Islands (Niihau to Hawaii) (Fig. 1). This group includes the black-necked (Hawaiian) stilt (*Himantopus mexicanus knudseni*), American (Hawaiian) coot (*Fulica americana alai*), common (Hawaiian) moorhen (*Gallinula chloropus sandvicensis*), and Hawaiian duck (*Anas wyvilliana*). All four are believed derived from North American colonist species, but only the Hawaiian duck is classified as an endemic species. However, Pratt (1987) recently argued that the Hawaiian coot should be accorded full species status. All are included on the U. S. Fish and Wildlife Service (USFWS) Endangered Species List (USFWS, 1986).

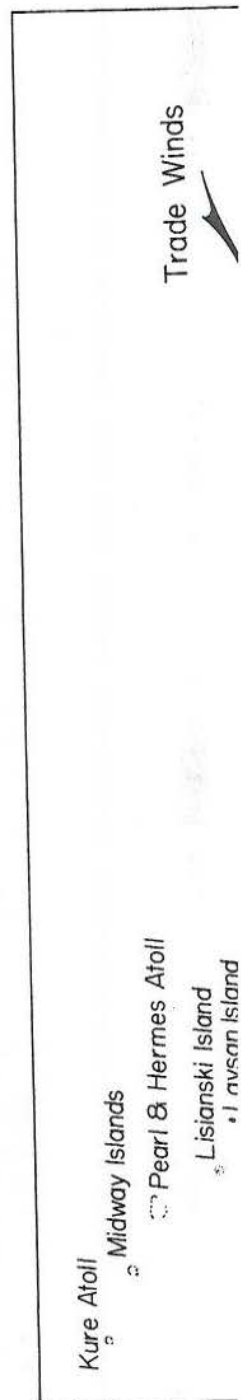
In this paper, we present an overview of the status and distribution of the four endemic waterbird species in the main Hawaiian Islands and review the conservation problems facing Hawaiian waterbirds.

SPECIES ACCOUNTS

Hawaiian Duck

The Hawaiian duck or koloa is one of at least three close relatives of the mallard (*Anas platyrhynchos*) found in the Pacific Basin. This species, along with the Laysan duck and Mariana mallard (*A. oustaleti*), is a monochromatic, insular endemic that apparently evolved from stray migratory mallard stock (Weller, 1980).

Formerly, the range of the Hawaiian duck included all main islands except Lanai and Kahoolawe (Fig. 1). Reports of early naturalists indicated that ducks were numerous. Numbers began to decline noticeably, however, after the turn of the present century (Swedberg, 1967). On Kauai, the duck population was large until the 1920s but then began to decline rapidly. An estimated 500 remained on Kauai and about 30 on Oahu in 1949. At this time, they were considered occasional visitors to the island of Hawaii and presumed extirpated on Maui and Molokai (Schwartz and Schwartz, 1949). By



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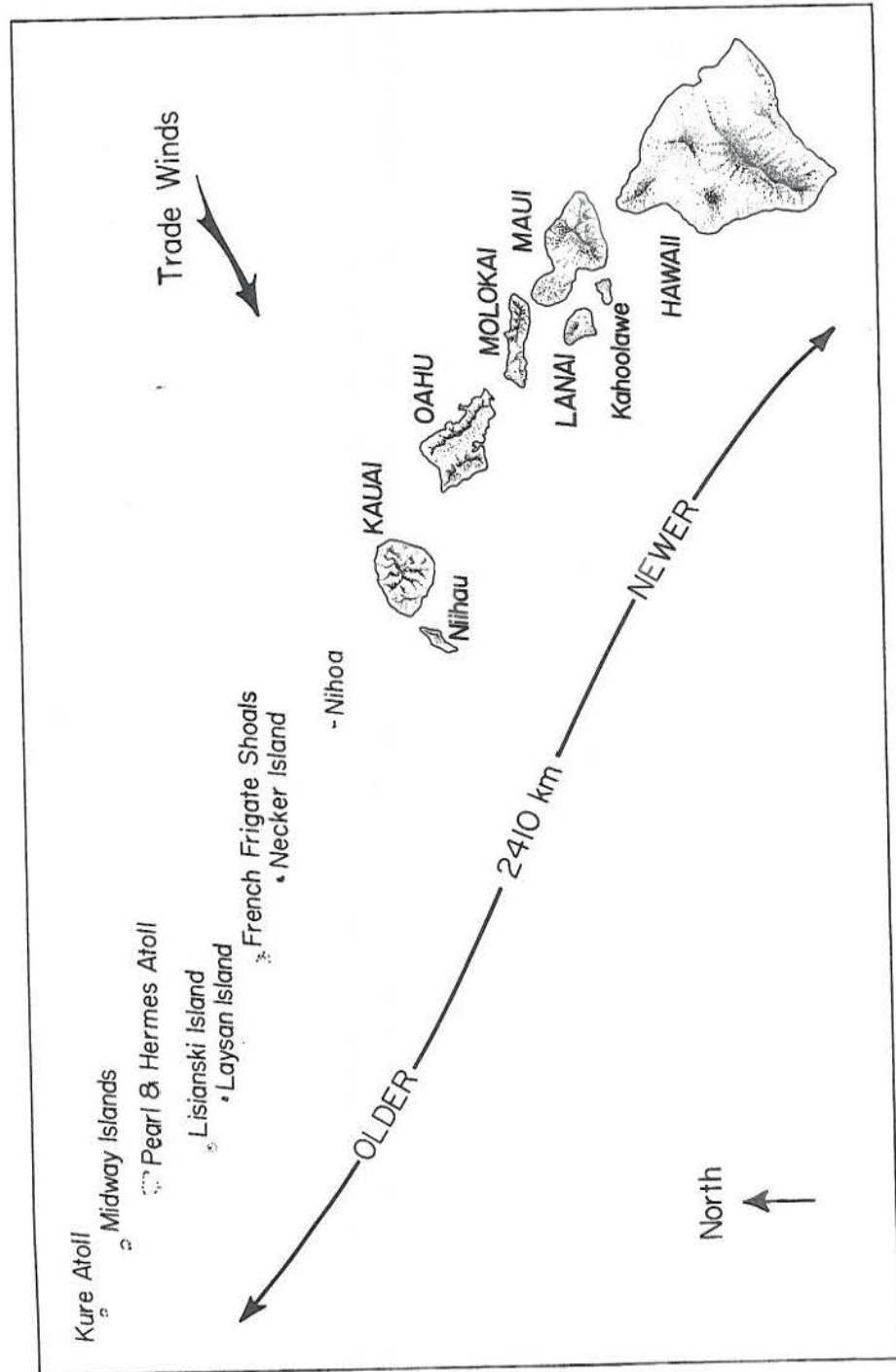


Fig. 1 The Hawaiian Islands.

1960, the species was found only on Kauai. Swedberg (1967) estimated about 3000 ducks on Kauai in the mid-1960s. The apparent increase from 500 to 3000 probably resulted from underestimation of birds in the montane stream habitats in the 1940s and 1950s. A captive propagation and release program for the Hawaiian duck was initiated in 1958. Birds have been released and reestablished on Hawaii and Oahu (Paton, 1981; USFWS, 1986).

Semiannual statewide counts (January and July) of Hawaiian ducks from 1980 through 1985 averaged 132 (range: 67 to 299) (Table 1). These counts do not reflect actual statewide numbers because there were no counts in montane stream habitats. Further, it is difficult to distinguish accurately between migratory or resident mallards and Hawaiian ducks during winter counts. While no accurate statewide counts are available, current population estimates are believed to be about 3000 birds on Kauai and 100 birds each on Hawaii and Oahu.

Common (Hawaiian) Moorhen

The common (Hawaiian) moorhen or 'alae 'ula was prominent in early Hawaiian legends and considered "common in swampy taro patches" on all the main islands (except Lanai and Kahoolawe) in 1891 (Munro, 1960). By 1947, moorhens were considered rare on Maui, Molokai, and Oahu (Schwartz and Schwartz, 1949) (Fig. 1). Today, the species is absent on Maui and Hawaii. Six marked birds were transplanted from Oahu to Molokai in May 1983 (USFWS, unpublished data).

Moorhens are difficult to census accurately. No more than 57 birds were counted in the 1950s and 1960s (Hawaii Department of Land and Natural

TABLE 1
Semiannual Statewide Hawaiian Waterbird Counts, 1980 to 1985*

| Year | Hawaiian duck | Common moorhen | American coot | Black-necked stilt | Black-crowned night-heron | Cattle egret |
|--------|---------------|----------------|---------------|--------------------|---------------------------|--------------|
| 1980 | | | | | | |
| Winter | 106 | 212 | 1753 | 881 | 155 | 619 |
| Summer | 84 | 100 | 1000 | 1012 | 297 | 1235 |
| 1981 | | | | | | |
| Winter | 67 | 204 | 1243 | 1185 | 342 | 1097 |
| Summer | 68 | 78 | 997 | 1217 | 322 | 1481 |
| 1982 | | | | | | |
| Winter | 128 | 194 | 785 | 694 | 245 | 823 |
| Summer | 85 | 109 | 1213 | 695 | 327 | 1901 |
| 1983 | | | | | | |
| Winter | 126 | 314 | 1425 | 633 | 394 | 1167 |
| Summer | 119 | 134 | 4466 | 1044 | 510 | 1516 |
| 1984 | | | | | | |
| Winter | 184 | 334 | 2823 | 1352 | 577 | 1649 |
| Summer | 191 | 69 | 2998 | 1360 | 497 | 656 |
| 1985 | | | | | | |
| Winter | 299 | 194 | 1537 | 829 | 371 | 1216 |

*Data from Hawaii Department of Land and Natural Resources, Division of Forestry and Wildlife, Honolulu, Hawaii.

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Resources, unpublished data). Semiannual statewide counts from 1980 through 1985 averaged 176 (range: 69 to 334) (Table 1). Again, these counts do not reflect actual statewide population numbers. The total population is estimated at 750 birds with most (about 500) occurring on Kauai and the remainder (about 250) on Oahu (Shallenberger, 1977). However, these estimates are speculative and better census methods need to be developed.

American (Hawaiian) Coot

The American (Hawaiian) coot or 'alae ke'o ke'o is smaller in body size and has a distinctly larger white frontal shield than the continental form (Shallenberger, 1977). Some birds are similar to continental birds with a red bulbous lobe at the top of the frontal shield and black markings at the tip of the bill. Another form in Hawaii has a full red frontal lobe (Pratt, 1978, 1987).

Coots historically occurred and are still present on all the major islands except Lanai and Kahoolawe (Fig. 1). They have always been most numerous on Oahu, Maui, and Kauai (Shallenberger, 1977). A decline in coot numbers was reported during the first half of this century (Schwartz and Schwartz, 1949) which contributed to listing the species as endangered.

Semiannual statewide counts from 1980 through 1985 averaged 1840 (range: 785 to 4466) (Table 1). These counts probably reflect actual statewide population numbers. Further, interisland movement of coots may explain the occasional sightings of large concentrations of coots on a single water area that exceeds the entire estimated population on an island. Coots are known to move from Niihau to Kauai during drought conditions (T. Telfer, personal communication). Udvardy (1960) and Pratt (1987) indicate there is little evidence to support the occurrence of large influxes of migrant coots from North America as suggested by Pratt (1978).

Black-Necked (Hawaiian) Stilt

The black-necked (Hawaiian) stilt or ae'o occurred on all the major islands except Lanai and Kahoolawe (Fig. 1). By the early 1940s, Munro (1960) estimated the population at about 200 birds; however, Schwartz and Schwartz (1949) estimated about 1000 birds in the late 1940s. Paton and Scott (1985) documented the apparent absence of stilts on Hawaii Island from 1896 to 1961.

Stilts still occur on all islands in their historic range. Population counts have fluctuated widely during the last 25 years, ranging from a low of 253 in 1960 to a high of 1484 in 1976. Semiannual statewide counts from 1980 through 1985 averaged 991 (range: 633 to 1360) (Table 1). These counts probably reflect actual statewide population numbers, and the islands of Maui and Oahu account for 60 to 70% of the present population. Stilts regularly move between Kauai and Niihau and less often between other islands (USFWS, 1983).

Other Waterbird Species in Hawaii

There are only three other resident waterbirds in the main Hawaiian Islands, including the black-crowned night-heron (*Nycticorax nycticorax*), cattle egret (*Bubulcus ibis*), and fulvous whistling-duck (*Dendrocygna bicolor*).

Nearly 30 species of migratory ducks and geese and more than 30 species of migratory shorebirds also have been recorded in the Hawaiian Islands (Pyle, 1977, 1979).

The black-crowned night-heron is indigenous to the islands and is considered a relatively new colonist. The species is resident on all main islands, except possibly Kahoolawe. The largest heron concentrations occur on Maui and Oahu. Semiannual statewide counts between 1980 and 1985 averaged 367 (range: 155 to 577) (Table 1). Heron population numbers have increased greatly during the past decade.

The cattle egret was introduced to Hawaii from Florida in 1959 (Breese, 1959). The population has increased dramatically since their introduction and egrets now occur on all the main islands. Semiannual statewide counts between 1980 and 1985 averaged 1214 (range: 619 to 1901) (Table 1).

The fulvous whistling-duck was first observed in Hawaii in 1982, and adults with recently hatched chicks were observed in July 1984 (Leishman, 1986). Since this time, we have recorded over 20 breeding attempts by whistling-ducks on Oahu between January 1985 and February 1986. Whether the arrival of this species in Hawaii occurred naturally or from escaped domestic stock is not known.

WATERBIRD CONSERVATION PROBLEMS

Numerous factors, both historical and modern, have been suggested as causing the decline of native Hawaiian birds (Warner, 1968; Atkinson, 1977; Berger, 1981). The loss of wetland habitat, hunting and predation, and interbreeding and competition have been identified as factors detrimental to Hawaiian waterbirds. These factors are examined below.

Wetland Loss

Prior to the arrival of the first Polynesian canoes nearly 1500 years ago, Hawaii's natural wetlands provided habitat for resident and migratory waterbirds. Among the natural wetlands were forested bogs, streams, estuaries, and a few lakes and low elevation marshes. The few freshwater marshes present were less than 200 ha in size. There were also few natural mud flats, especially by continental standards (USFWS, 1983).

The paucity of natural wetlands in Hawaii is due to the volcanic origin of the islands. The land area of the islands is small, less than 17,000 km², and the island chain is relatively young. Of the main islands, Kauai is geologically the oldest at 4 to 5 million years, while the island of Hawaii, which is still volcanically active and growing, is less than 0.7 million years (Decker and Decker, 1980). The topography of the main islands is very steep. Fifty percent of the state lies above an elevation of 600 m and 10% is above 2100 m (Blumenstock and Price, 1972). Thus, there is relatively little acreage in lowland areas and virtually no shallow coastal areas. Further, the basalt substrate of the islands is very porous, providing maximum infiltration of water (Sherman, 1972).

We can only speculate on the overall impact of early Hawaiian culture on waterbirds and their habitats. All species were captured for food and feathers (Malo, 1951). However, Hawaiians probably provided additional wetland

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habitat for waterbirds through their agricultural development and construction of fishponds in coastal waters. To support a population believed to be as high as 300,000 Hawaiians, most lowland areas with adequate water were converted to cultivated taro (*Colocasia esculenta*) (Kirch, 1982). Taro is irrigated in shallow ponds and produces an edible corm which is used as a staple food throughout Polynesia. Over 10,000 ha are believed to have been in taro production (USFWS, 1983). Further, saltwater ponds unique to the Hawaiian culture were constructed as holding areas for fish. They were constructed of stone in shallow waters and fluctuated with the tides. Over 200 fishponds once lined the shorelines and lowland drainages on the five main islands (Summers, 1964). While these man-made wetlands undoubtedly provided habitat for endemic and migratory waterbirds, to what extent this effect was balanced by the conversion of natural wetlands and the harvest of waterbirds is unknown.

In the two centuries since the first European ship reached the islands, most of the major natural and man-made wetlands of significance to Hawaiian waterbirds have been eliminated or radically altered. As early as the 1850s, significant losses in wetland habitat began with conversion of taro fields to other agricultural activities, such as sugarcane (*Saccharum officinarum*) and pineapples (*Ananas comosus*). As recently as 1900, taro in the state was estimated at nearly 8000 ha. Today, less than 200 ha remain in taro production. Further, a short-lived rice industry that in 1860 covered about 6500 ha was virtually nonexistent by 1963 (Shallenberger, 1977). While expansion of other forms of agriculture destroyed some wetlands, the associated irrigation reservoirs and cane waste silting basins created some new waterbird habitat. However, the conditions of these artificial waterbird habitats are subject to the water demands of these industries and are managed without consideration of requirements of waterbirds.

More recently the urbanization of lowland areas, particularly on Oahu, has accelerated the conversion or alteration of wetlands. Many wetlands have been filled or modified and are now occupied by hotels, housing developments, golf courses, shopping centers, landfills, military installations, highways, agricultural fields, and industrial sites. Further, most of the original fishpond walls have disappeared or the ponds have filled with silt. Introduced plants such as California grass (*Brachiaria mutica*), water hyacinth (*Eichhornia crassipes*), pickleweed (*Batis maritima*), and red mangrove (*Rhizophora mangle*) present serious problems in many wetlands by out-competing more desirable species and eliminating the interspersed open water and vegetated areas. The long history of extensive modifications to wetlands by Hawaiian and European cultures has left only remnants of former natural marshlands and mud flats. Man-made or altered sites (such as taro and other wetland agriculture, fishponds, cane waste silting basins, reservoirs, drainage and irrigation ditches, sewage ponds, aquaculture facilities, and ephemerally flooded pastures) have replaced natural wetlands and are now of primary importance to waterbirds.

The Hawaiian Waterbirds Recovery Plan, approved in 1978 and revised in 1985, identified 64 wetland habitats essential for the long-term habitat security for Hawaiian waterbirds (USFWS, 1978, 1985). Ten of these areas are now in some form of refuge status, totaling 800 ha of the nearly 4100 ha

identified. These protected wetland areas serve the pivotal role in the state-wide, multiagency endangered waterbird program. Nevertheless, all ten of these important wetland areas currently are producing and maintaining endangered waterbirds at levels far below their potential (USFWS, 1983). Thus, not only are there relatively few wetlands in Hawaii, all are small and most are afforded little protection. Further, all Hawaiian wetland areas suffer from encroachment by exotic vegetation.

Hunting and Predation

Simultaneous to the loss of wetlands, Hawaii's waterbirds have suffered from a host of other man-related influences. Migratory waterfowl were regularly hunted for sport and food. Bag limits for ducks, including the Hawaiian duck, were as high as 25 birds per day in the early part of this century. In 1925, the Territorial Fish and Game Commission closed the Hawaiian duck hunting season, but because of its similar appearance to female mallards and northern pintails (*A. acuta*), Hawaiian ducks probably received little protection (Swedberg, 1967). Hunting for other ducks and waterbirds continued until 1939.

In addition to sport hunting, introduction of exotic mammalian predators has also affected waterbird populations. The mongoose (*Herpestes auropunctatus*), first introduced to Hawaii Island in 1883 and subsequently to Maui, Molokai, and Oahu to control rats in sugarcane fields, has been implicated as a serious predator on native waterbirds (Tomich, 1969). Feral cats (*Felis domesticus*), dogs (*Canis familiaris*), and rats (*Rattus* spp.) also have an undetermined negative effect on waterbirds. Although indigenous to the islands, black-crowned night-herons are known to eat young waterbirds. Heron populations have increased greatly and may pose a potential threat to waterbird populations. The problems posed by these predators are exacerbated by a severe shortage of suitable protected nesting areas. As waterbirds retreat to marginal habitats, their nesting success and survival decline.

Interbreeding and Competition

A major threat to the Hawaiian duck is hybridization with increasing numbers of resident feral mallards. Mixed Hawaiian duck/mallard pairs have been observed on Oahu and interbreeding has occurred. With the noticeable increase in feral mallards over the last 20 years and the severe reduction in wetland habitat, especially on Oahu, opportunities for a significant amount of hybridization now present a real and major threat to the integrity of the Hawaiian duck species.

Only two migrant waterfowl species have been recorded breeding in the Hawaiian Islands, the blue-winged teal (*A. discors*) and the fulvous whistling-duck. There is only one record of blue-winged teal breeding (Paton et al., 1984); however, as discussed earlier, the fulvous whistling-duck population is increasing rapidly. Although currently small, the fulvous whistling-duck population has the potential to adversely affect endemic waterbird populations through competition for nesting sites and feeding areas.

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CONCLUSIONS AND RECOMMENDATIONS

The primary management goal for endangered Hawaiian waterbirds is to provide and maintain as much optimum nesting and maintenance habitat as possible. A critical step in this process is further acquisition and development of wetland areas. This may include cooperative agreements with private landowners, similar to those that are now in effect at the U. S. Marine Corps and Navy installations in Hawaii. Incentives for the aquaculture industry, whose prawn farms provide important waterbird foraging areas, should also be explored.

Enhancement of waterbird habitats already protected is also critically important. To date, most refuge management efforts have been directed at securing water sources, constructing impoundments and water control structures, and initiating predator and noxious plant control programs. Stilt nesting islands have been constructed on several refuges, and considerable efforts have been made to manage waterbird habitats. However, little is known about specific mechanisms regulating both the structure and function of Hawaiian wetlands and their influence on production and maintenance of waterbirds. The concepts and practices of moist-soil management offer opportunities to enhance wetland habitats in Hawaii and increase their contribution in meeting the goals of the Hawaiian Waterbirds Recovery Plan (USFWS, 1978, 1985). The potential to seasonally flood basins with the use of moist-soil management techniques has resulted in positive responses by wildlife at many sites in the midwestern United States. By manipulating water levels and controlling undesirable vegetation in impoundments, managers produce desired hydrophytes, seed abundances, and stem densities that provide cover and food for waterbirds. Diverse populations of macroinvertebrates also regularly occur in moist-soil impoundments and comprise important foods of many wetland bird species (Fredrickson and Taylor, 1982). Although moist-soil management techniques were developed in temperate areas of the continental U. S., their ecological and management principles may be of great value in tropical wetlands of Hawaii.

Wetland birds are typically long-lived species that are adapted to exploiting dynamic wetland resources within annual and long-term cycles. Varying water regimes provide the conditions that promote production of plant and macroinvertebrate foods. Because waterbirds typically require several types of wetlands during their annual cycle, a single wetland cannot provide all the habitat needs for all species. Ideally, several refuge areas should be managed as a complex of wetlands with several impoundments at each area that can be manipulated to promote production of different foods and covers to attract the different waterbird species. Optimum waterbird survival and recruitment depend on good juxtaposition of refuges and availability of resources during critical periods of their annual cycle.

Research efforts need to be expanded. Most research efforts to date have centered on Oahu. While a variety of wetland types is represented on Oahu, primary waterbird habitat on Kauai is provided by taro farms. Very little is known about the dynamics of this important wetland habitat for waterbirds. Further, it is essential that research on the hybridization of Hawaiian ducks and mallards be initiated.

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To conclude, survival of endemic Hawaiian waterbirds depends on a multifaceted approach that will maximize their production and survival. At the core of a long-term conservation program is the need to secure, maintain, and enhance suitable habitat. Understanding the role of each wetland type within the annual cycle will enhance management efforts. Effective habitat enhancement programs become more important as unprotected wetlands continue to diminish in extent and quality. Financial constraints and increasing land use competition make it imperative that Hawaii's wetland managers become more aware of critical habitats and management options.

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LITERATURE CITED

- Atkinson, I. A. E., 1977, A Reassessment of Factors, Particularly *Rattus rattus* L., That Influenced the Decline of Endemic Forest Birds in the Hawaiian Islands, *Pacific Science*, 31: 109-133.
- Berger, A. J., 1981, *Hawaiian Birdlife*, University Press of Hawaii, Honolulu.
- Blumenstock, D. I., and S. Price, 1972, Climates of the States: Hawaii, *A Natural History of the Hawaiian Islands*, E. A. Kay (Ed.), University Press of Hawaii, Honolulu, pp. 155-204.
- Breese, P., 1959, Information on Cattle Egret, A Bird New to Hawaii, *Elepaio*, 20: 33-34.
- Decker, D. W., and B. Decker, 1980, *Volcano Watching*, Hawaii Natural History Association, Hawaii Volcanoes National Park, Hawaii.
- Fredrickson, L. H., and T. S. Taylor, 1982, *Management of Seasonally Flooded Impoundments for Wildlife*, U. S. Fish and Wildlife Service Resource Publication No. 148, Washington, D. C.
- Kirch, P. V., 1982, The Impact of Prehistoric Polynesians on the Hawaiian Ecosystem, *Pacific Science*, 36:1-14.
- Leishman, N. J., 1986, Fulvous Whistling-Ducks Breeding in Hawaii: A New Indigene or Another Exotic?, *Elepaio*, 46: 75-76.
- Malo, D., 1951, *Hawaiian Antiquities*, Bishop Museum Special Publication 2, 2nd ed., Bishop Museum Press, Honolulu.
- Munro, G. C., 1960, *Birds of Hawaii*, Charles E. Tuttle Co., Rutland, Vermont.
- Olson, S. L., and H. F. James, 1982, Fossil Birds from the Hawaiian Islands: Evidence for Wholesale Extinction by Man Before Western Contact, *Science*, 217: 633-635.
- Paton, P. W. C., 1981, The Koloa (Hawaiian Duck) on the Island of Hawaii, *Elepaio*, 41: 131-133.
- , and J. M. Scott, 1985, Water Birds of Hawaii Island, *Elepaio*, 45: 69-76.
- , A. Taylor, and P. Ashman, 1984, Blue-Winged Teal Nesting in Hawaii, *Condor*, 86: 219.
- Pratt, D., 1978, Do Mainland Coots Occur in Hawaii?, *Elepaio*, 38: 73.
- , 1987, Occurrence of the North American Coot (*Fulica americana americana*) in the Hawaiian Islands, with Comments on the Taxonomy of the Hawaiian Coot, *Elepaio*, 47: 25-28.
- Pyle, R. L., 1977, Preliminary List of the Birds of Hawaii, *Elepaio*, 38: 110-121.
- , 1979, Preliminary List of the Birds of Hawaii, Amendment No. 1, *Elepaio*, 40: 55-58.
- Schwartz, C. W., and E. R. Schwartz, 1949, *The Game Birds in Hawaii*, Division of Fish and Game, Board of Commissioners of Agriculture and Forestry, Honolulu.
- Shallenberger, R. J., 84-77-C-0036, U. S. Sherman, G. D., 19 *Hawaiian Islands*, Summers, C. C., 1964, Swedberg, G. E., 196 of Fish and Game, Tomich, Q. P., 1969, Bishop Museum S Udvardy, M. D. F., 1: Oahu, *Elepaio*, 21: U. S. Fish and Wildlife Service, F —, 1983, *Master P Wildlife Service, F —, 1985, Hawaiian land, Oregon. —, 1986, Endangere 17.12, U. S. Fish a Warner, R. E., 1968, Avifauna, *Condor*, Weller, M. W., 1980, 1*

waterbirds depends on a production and survival. At the need to secure, maintain, the role of each wetland type efforts. Effective habitat unprotected wetlands constraints and increasing Hawaii's wetland managers management options.

review of the manuscript. i Cooperative Fish and ies and Wildlife; Univer- Conservation; U. S. Fish itute, cooperating); Gay- uri-Columbia; and the 3, Journal Series 10136. ce Research Agreement issouri-Columbia.

Rattus rattus L., That Influ- Islands, *Pacific Science*, 31:

onolulu.
ii, *A Natural History of the*
onolulu, pp. 155-204.
Elepaio, 20: 33-34.
atural History Association.

Flooded Impoundments for
148, Washington, D. C.
waiian Ecosystem, *Pacific*

New Indigene or Another
cation 2, 2nd ed., Bishop

mont.
nds: Evidence for Whole-

ii, *Elepaio*, 41: 131-133.

3.
i, *Condor*, 86: 219.

na americana) in the
oot, *Elepaio*, 47: 25-28.

21.
vio, 40: 55-58.
Division of Fish and

- Shallenberger, R. J., 1977, *An Ornithological Survey of Hawaiian Wetlands*, Contract DACW 84-77-C-0036, U. S. Army Corps of Engineers District, Honolulu.
- Sherman, G. D., 1972, *Tropical Soils of the Hawaiian Islands, A Natural History of the Hawaiian Islands*, E. A. Kay (Ed.), University Press of Hawaii, Honolulu.
- Summers, C. C., 1964, *Hawaiian Fishponds*, Bishop Museum Press, Honolulu.
- Swedberg, G. E., 1967, *The Koloa*, Hawaii Department of Land and Natural Resources, Division of Fish and Game, Honolulu.
- Tomich, Q. P., 1969, *Mammals in Hawaii, a Synopsis and Notational Bibliography*, Bernice P. Bishop Museum Special Publication 57, Bishop Museum Press, Honolulu.
- Udvardy, M. D. F., 1960, Movements and Concentrations of the Hawaiian Coot on the Island of Oahu, *Elepaio*, 21: 20-22.
- U. S. Fish and Wildlife Service, 1978, *Hawaiian Waterbirds Recovery Plan*, U. S. Fish and Wildlife Service, Portland Oregon.
- , 1983, *Master Plan—Hawaiian Wetland NWR Complex*, (Draft), 2 vol., U. S. Fish and Wildlife Service, Honolulu.
- , 1985, *Hawaiian Waterbirds Recovery Plan* (revised), U. S. Fish and Wildlife Service, Portland, Oregon.
- , 1986, *Endangered and Threatened Wildlife and Plants, January 1, 1986*, 50 CRF 17.11 and 17.12, U. S. Fish and Wildlife Service, Washington, D. C.
- Warner, R. E., 1968, The Role of Introduced Diseases in the Extinction of the Endemic Hawaiian Avifauna, *Condor*, 70: 101-120.
- Weller, M. W., 1980, *The Island Waterfowl*, The Iowa State University Press, Ames, Iowa.