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STATUS AND POPULATION TRENDS OF HAWAII'S NATIVE WATERBIRDS, 1977–1987

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ABSTRACT.—Status and population trends of Hawaii's native waterbirds were examined from 1977 through 1987. Waterbird population fluctuations were analyzed in relation to rainfall and land use dynamics. Numbers of Hawaiian Duck (Koloa) (*Anas wyvilliana*) and Hawaiian Common Moorhen (*Gallinula chloropus sandvicensis*) appeared stable over time; however, surveys were limited. Increase in Black-crowned Night-Heron (*Nycticorax nycticorax*) abundance appeared linked to expansion of aquaculture, particularly on Oahu, and not to climatic events. Annual rainfall patterns help explain and predict population fluctuations and anomalous distribution patterns involving Hawaiian American Coots (*Fulica americana alai*), moorhens, and Hawaiian Black-necked Stilts (*Himantopus mexicanus knudseni*). Coot, stilt, and moorhen populations fluctuated with climatic events, and intra-island dispersal to ephemeral wetlands occurred. Stilts exhibited regular inter-island migratory behavior, but coots dispersed in relation to major rainfall events. Seasonal fluctuation recorded for coots by past observers is the result of survey techniques not accounting for seasonal dispersal patterns. *Received 10 Jan. 1992, accepted 28 Sept. 1992.*

The Hawaiian Islands probably have lost, as a result of human activity, more species of birds than any other locality in the world. Extinctions during the first 2000 years of human habitation (Olson and James 1982a) resulted in the loss of 50% of native avian species. Unfortunately this process has accelerated during the past 200 years, and of the remaining 40 endemic species, 70% currently are endangered. Recognizing these trends, resource managers and conservation organizations have attempted to develop and implement essential habitat inventories and management programs. Critical to the success of these programs is information concerning species' biology, population trends, and distribution.

Hawaii's wetlands are diverse, ranging from salt water lagoons to freshwater marshes and montane bogs. These wetlands support a small fauna of waterbirds, including five endemic forms, one indigenous form, two recently colonized species, and several alien species. Several other waterbird species once occurred but have become extinct due to the colonization of Hawaii by humans (Olson and James 1982b). Although there have been many publications treating occurrence records for migratory and native waterbirds (Shallenberger 1977, Paton and Scott 1985, USFWS 1985, Pyle et al. 1988), only Griffin et al. (1989) and Engilis (1988) present discussions of the distribution and status of Hawaii's native waterbirds.

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Shallenberger (1977) also documented species occurrence for individual wetlands as known in the 1970s. An in-depth examination of population trends and reasons for their fluctuations is needed for all of Hawaii's wetland birds. In this paper, we present a summary of the current status and population trends for all endemic and indigenous waterbirds in the main Hawaiian Islands, excluding the northwestern chain islands, from 1977–1987.

METHODS

Regular waterfowl surveys were initiated in Hawaii in the 1940s as part of a nationwide attempt by federal and state wildlife agencies to count breeding migratory waterfowl in North America. By the mid-1950s most of the major wetlands on Oahu, Maui, and Kauai were counted annually. In the late 1960s, state biologists adapted the survey to monitor Hawaii's four resident waterbirds: the Hawaiian Duck (Koloa) (*Anas wyvilliana*), Hawaiian Common Moorhen (*Gallinula chloropus sandvicensis*), Hawaiian American Coot (*Fulica americana alai*), and Hawaiian Black-necked Stilt (*Himantopus mexicanus knudseni*) (AOU 1983). This approach spawned two separate surveys involving coots and stilts. In the 1970s, Molokai and Niihau were added to the survey. Lanai and Kahoolawe were not counted due to their small wetland acreage. By 1978, state biologists moved to a semi-annual survey format to document some of the unique problems associated with Hawaii's waterbirds, e.g., inter-island movements, dispersal, and hybridization. In 1985, the Hawaiian Waterbirds Recovery Plan was finalized, and it called for continued monitoring of waterbird numbers and wetland habitat in Hawaii. All of these developments resulted in the evolution of the waterfowl count into a multifaceted waterbird survey and inventory.

In this paper, we analyze waterbird survey data from 1977 through 1987. Data from previous years are fragmentary and were not used to examine statewide trends. In addition, because of past inconsistency of survey data gathering, e.g., poor observer training, lack of tide information, and poor documentation of weather conditions, we chose to limit statistical treatments to trend analysis only. The Hawaii Division of Forestry and Wildlife (DOFAW) coordinated the above surveys in January and July of each year. All significant waterbird habitat was censused by DOFAW personnel, U.S. Fish and Wildlife personnel, and other experienced observers using binoculars and low-power telescopes. Mountain streams were omitted from the survey. Ground surveys were conducted on Kauai, Oahu, Maui, Molokai, and Hawaii. Niihau was surveyed from a fixed-wing aircraft flying approximately 200 feet (65 m) elevation at a speed of 50 knots. Summer data were used to examine population trends for Koloa. Using summer counts eliminated the problem associated with separating Koloa from migratory ducks wintering in the islands.

American and Hawaiian Coots were distinguished for five winters (1983–1987) by frontal shield color and size. The Hawaiian Coot has a large, white frontal shield (nominate form) or a large, red shield (color morph). American Coot (*Fulica americana*) has a small, red shield. A shield was scored as large if it protruded above the crown of the head, a characteristic not found in winter American Coots (Pratt 1987). Coots were not scored for frontal shield size when seen at a distance or during aerial counts.

A separate Pittman-Robertson project was created to examine Hawaiian Stilt recruitment. From 1981–1987, stilts were recorded by three age classes: adult, subadult and unknown age. Ground surveys were conducted in September and October. Observers were trained to separate subadults from adults using plumage and vocalization differences, as recommended by Coleman (1981).

Rainfall data were compared with bird counts to identify trends that might be associated with climatic variation. Previous studies of Hawaiian waterbird populations failed to evaluate the effects of rainfall on waterbird populations in Hawaii. Annual rainfall totals of 1977–1986 were obtained for the Kanaha Watershed, from the Hawaii Dept. of Water and Land (DOWALD). This station is significant because of its importance to state water managers in predicting water use and precipitation patterns in Hawaii.

RESULTS

Engilis (1988) examined annual rainfall patterns from 1977 through 1986 using thirteen weather stations on Kauai, Oahu, Maui, and Hawaii and found that weather patterns generally correlated among stations; 1980 and 1982 were especially wet years, and 1977 and 1983 were dry. We noted a drop in rainfall from 1983 to 1985 which was the result of Southern Oscillation weather patterns (El Niño) (Haraguchi and Matsunaga 1985). During El Niño, winter precipitation in Hawaii is low. Southern Oscillations affected Hawaiian weather in 1957, 1963, 1965, 1969, 1972–1973, 1975–1976, 1979, 1983–1985 (DOWALD, unpubl. data). Hurricane Iwa was the most prominent weather event to affect the Hawaiian Islands in over a decade. Hurricane Iwa made landfall on Kauai in November 1982, causing considerable damage, and torrential rain resulted in flooding on Kauai, Oahu, and other islands.

SPECIES ACCOUNTS

Black-crowned Night-Heron.—Surveys showed a steady statewide increase in populations of night-herons through 1985 (Fig. 1), but counts dropped sharply in 1986. Nearly two-thirds of Oahu's night-herons were counted at Kahuku aquaculture ponds, and Oahu accounted for over half the annual statewide night-heron total (Fig. 1). Night-herons were documented in a variety of habitats including lagoons, reefs, and lava benches exposed during low tide. However, 90% of night-herons surveyed were in permanent freshwater wetlands, lowland streams, and man-made wetlands.

Hawaiian Duck (Koloa).—Survey results show an increase in Koloa counted in lowland wetlands (Fig. 2). Population trends of Koloa were not linked to rainfall patterns. Koloa increased on Oahu, but hybridization between feral Mallard (*Anas platyryhnchos*) and Koloa complicated counts. Waterbird surveys also documented seasonal fluctuations in Koloa numbers, with winter counts averaging 36% higher than summer counts (Engilis 1988).

Hawaiian Common Moorhen.—Hawaiian Moorhens are secretive and occur in densely vegetated wetlands, consequently, surveying moorhens is difficult. Nonetheless, winter counts suggest a relatively stable population that increased in 1978, 1982, and 1983 (Fig. 3). These peaks cor-

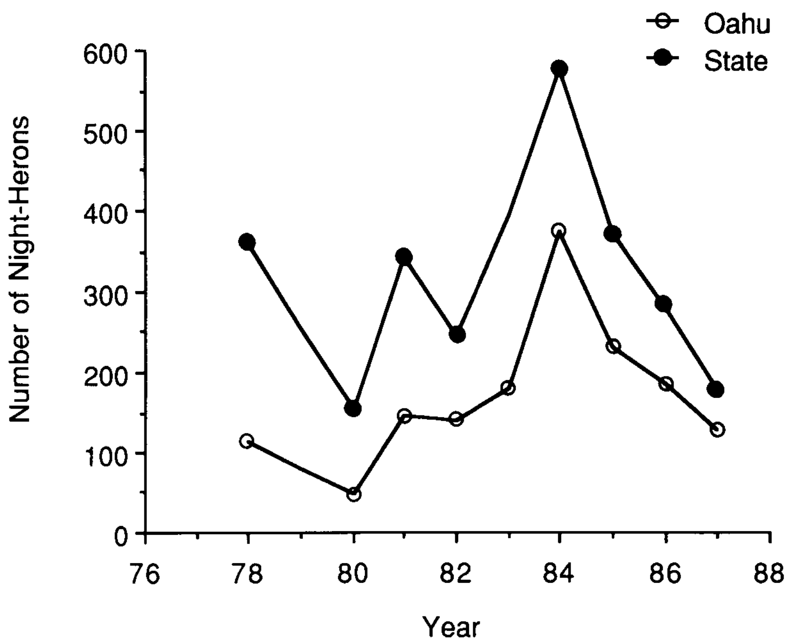

FIG. 1. Annual summer count totals of Black-crowned Night-Herons.

respond with increased rainfall during 1978 and 1982. A smaller peak in 1986 also corresponds with the return of normal weather patterns in that year following an El Niño. Winter counts ranged from 109 to 334 birds, summer counts 72 to 134 birds. Counts in Haleiwa lotus farms, Oahu, averaged 48% of the state total.

Hawaiian American Coot.—Coot populations were related inversely to rainfall (Fig. 4). Winter counts ($\bar{x}$ = 1447 birds, range = 422–2823) were lower than summer counts ($\bar{x}$ = 1872 birds, range = 915–4466) (Fig. 5). All islands reflected similar population fluctuations, indicating no annual, corresponding shift of numbers between islands that might indicate regular population movements. A corresponding shift of numbers in coots counted between Niihau (692 birds) and Kauai (13 birds) occurred in summer 1982. Another population shift between Niihau (949 birds) and Kauai (254 birds) was documented in winter 1986. Coot numbers increased four-fold in 1983, but declined thereafter, stabilizing in 1985–1986 (Fig. 4). Molokai showed an increase in coot numbers following the 1982 wet year; summer counts went from 37 birds (1982) to 321 (1983) and finally dropped back to 72 birds in 1987. Populations on Niihau and Molokai varied dramatically during the 10-year period, sometimes eclipsing counts

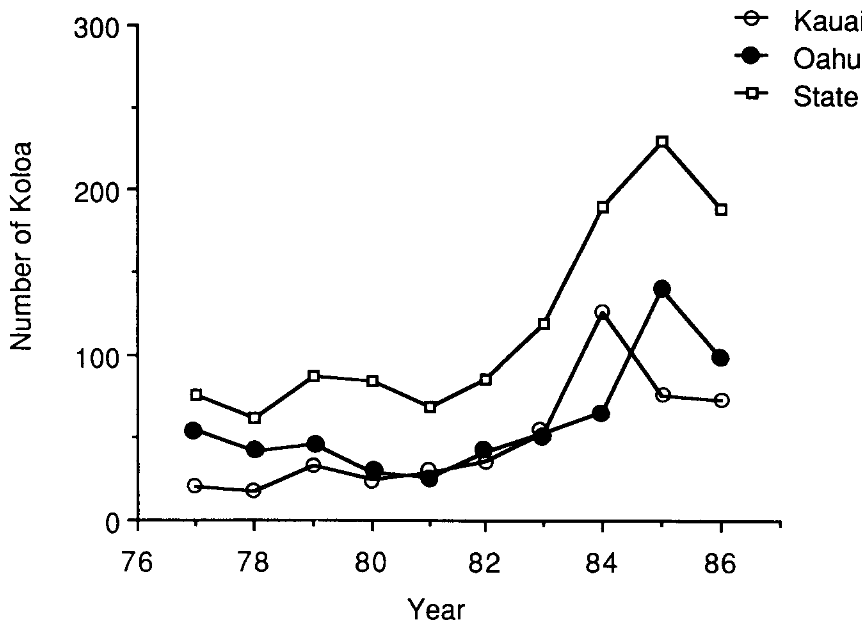

FIG. 2. Annual summer count totals of Koloa.

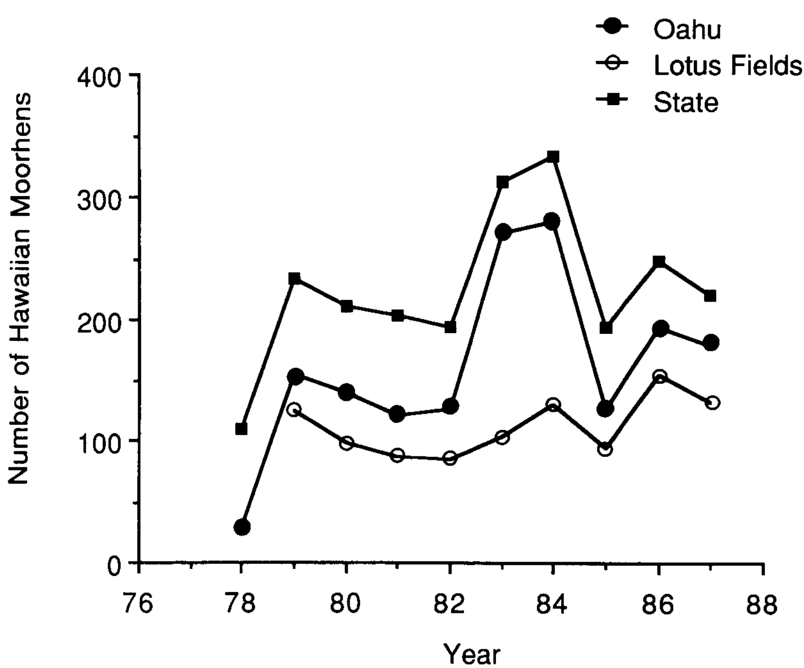

FIG. 3. Annual winter count totals of Hawaiian Moorhens.

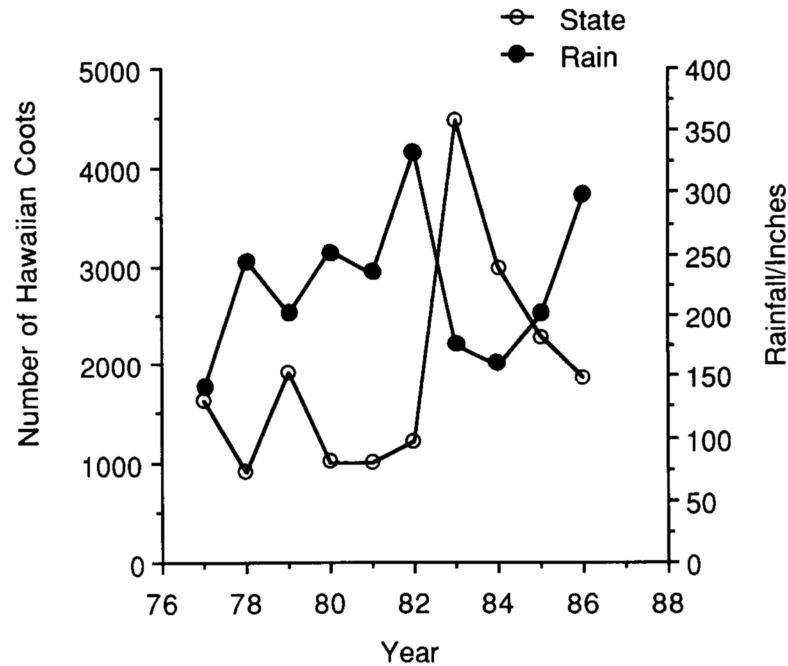

FIG. 4. Annual statewide summer count totals of Hawaiian Coots in relation to rainfall.

on Kauai and Maui. Coots are now regularly observed at the Lanai City sewer ponds and the Manele flats on Lanai (R. Walker, pers. comm.).

Engilis (1988) calculated the five-year mean for ratios of coot frontal shield color and determined that only 1–3% of coots surveyed had red shields. Of those, less than 0.6% exhibited shields small enough to be considered American Coot.

Hawaiian Black-necked Stilt.—Hawaiian Stilt population fluctuations appeared linked to climatic changes. When compared, stilt numbers were inversely related to rainfall (Fig. 6). Stilt numbers increased 114% from 1982 to 1985, peaking at 1492 birds. Counts in 1986 showed the population maintaining a level above 1200 birds. Stilt summer counts were higher ($\bar{x}$ = 1144 birds, range = 695–1492) than winter counts ($\bar{x}$ = 934 birds, range = 523–1354). A corresponding shift in stilt population was evident between Kauai and Niihau. Data do support a pattern consistent with that expected for an annual winter movement of birds from Kauai to Niihau (Fig. 7). Over the 10-year period, summer counts on Kauai averaged 84% higher than winter counts. In 1982, an exceptionally wet year, winter counts on Niihav were lower than summer counts (66 vs 109 birds, respectively). The 109 stilts recorded on Niihau represented the highest total recorded for summer counts; the second highest summer

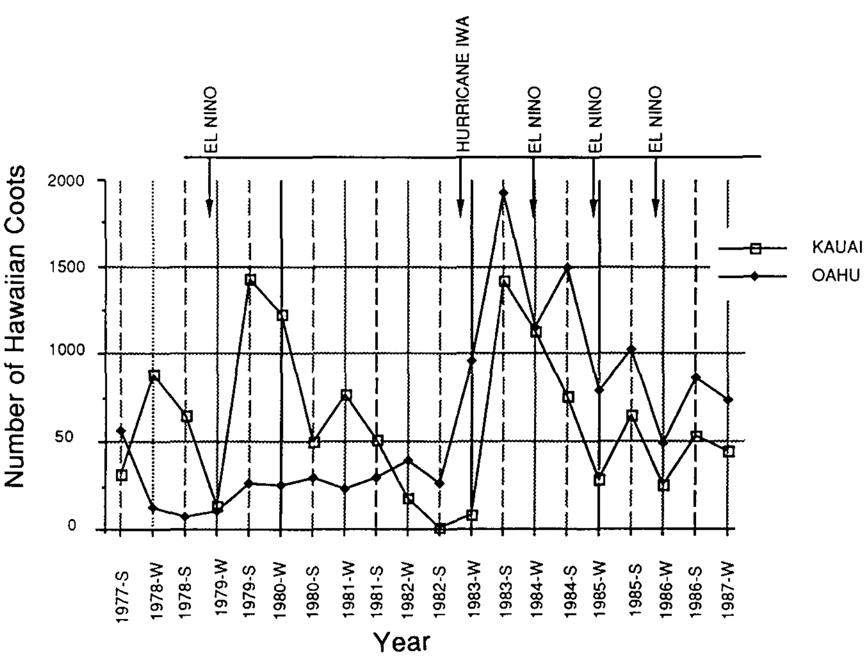

FIG. 5. Annual winter and summer count totals for Hawaiian Coots on Kauai and Oahu in relation to severe climatic events.

count was 46 birds in 1983 (Engilis 1988). Nineteen percent of stilts counted in 1981 were fledged subadults. In 1982, recruitment jumped to 34.3%, but declined thereafter (33.5% in 1983, 22.5% in 1984, and 21.7% in 1985).

DISCUSSION

Black-crowned Night-Heron.—There appears to be no correlation of night-heron population trends with rainfall patterns. Instead, this species' recent population increase appeared linked with expansion of the aquaculture industry, particularly in the Kahuku region of Oahu. Two hypotheses may explain these increases in Kahuku: (1) the aquaculture ponds serve as concentrated food sources drawing night-herons from other localities to feed, and (2) concentrated food sources have enhanced breeding success and survivability of young, thus increasing the population of night-herons. Night-herons have increased so dramatically that aquaculture farmers, concerned about depredation of shrimp and fish, have, in the past, successfully petitioned for their control. The sharp decline noted in 1985 coincides with the institution of a control program administered by

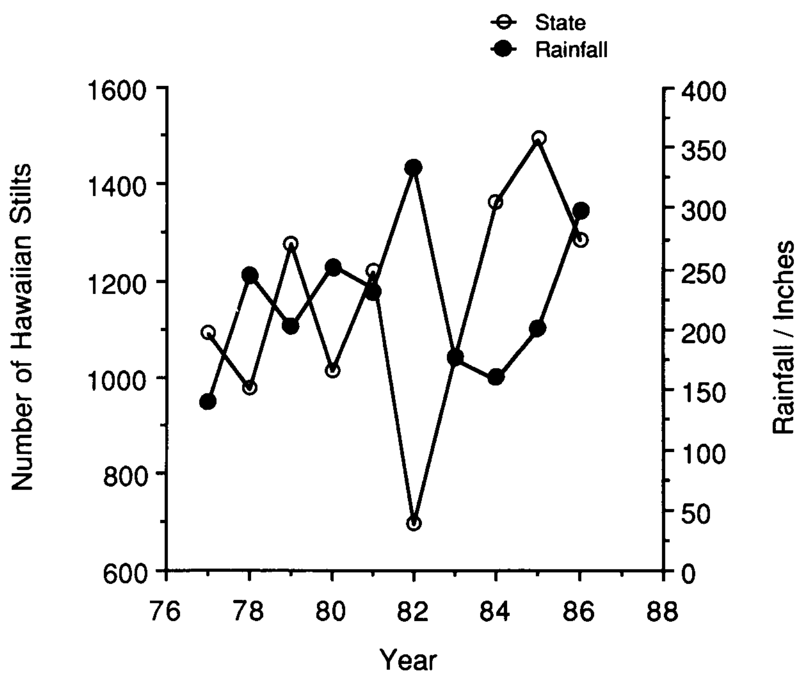

FIG. 6. Annual statewide summer count totals of Hawaiian Stilts in relation to rainfall.

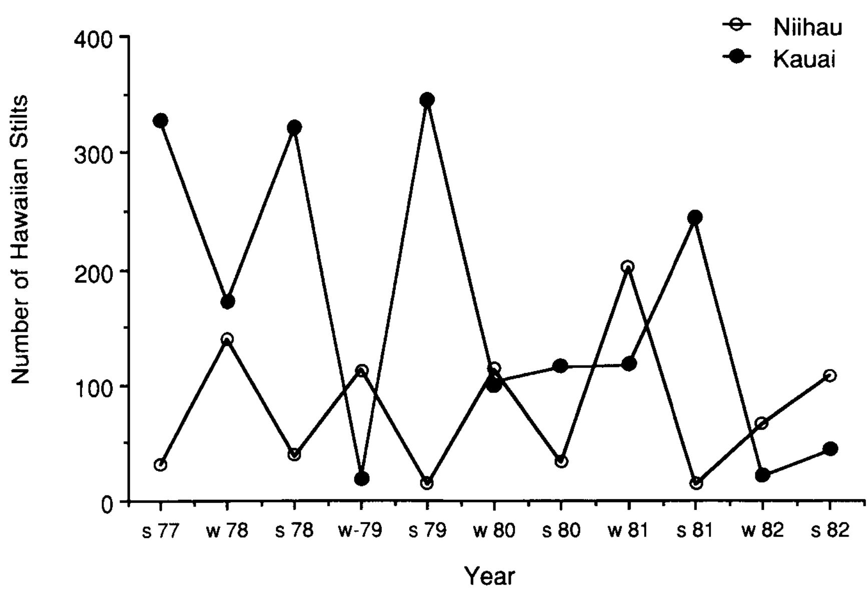

FIG. 7. Annual winter and summer count totals for Hawaiian Stilts on Kauai and Niihau

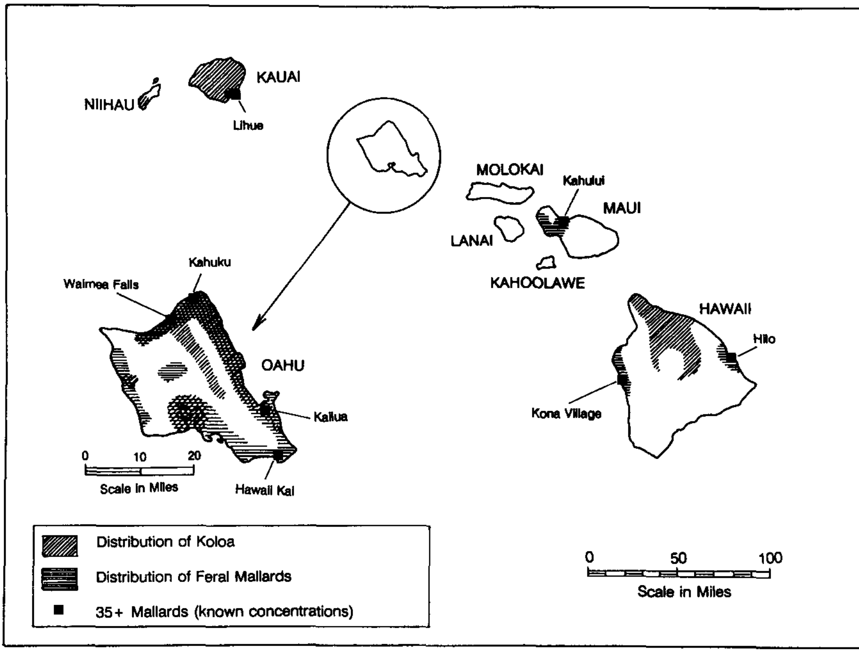

FIG. 8. Distribution of Koloa and feral Mallards in Hawaii.

U.S. Dept. of Agriculture's Animal Damage Control and the Hawaii Division of Forestry and Wildlife (Fig. 1). During a one-year period, nearly 300 night-herons were taken at Kahuku (R. Saito, pers. comm.). If night-heron populations have increased, and control culled those individuals dependent upon the farms, then this action may not be detrimental to the Oahu population. If however, these farms act as magnets luring night-herons away from other localities, then continued culling may seriously impact Oahu's night-heron population.

Hawaiian Duck (Koloa).—Historically, the Koloa was found on all main islands except Lanai and Kahoolawe. The species was not extirpated on Kauai and has been reintroduced on Oahu and Hawaii (Fig. 8). In the early 1900s, the Koloa was heavily exploited as a game bird (Schwartz and Schwartz 1953). However, habitat loss and predation by introduced predators have been assumed to be the most significant causes of the decline of this species (Swedberg 1967, Griffin et al. 1989). The Oahu population was thought extirpated by the early 1960s (Shallenberger 1977). The State of Hawaii initiated a captive breeding program and made its first releases on Oahu in 1968. Subsequent releases continued until 1982 and were expanded to encompass the island of Hawaii. Five hundred Koloa were released (350 on Oahu) during this period (DOFAW records).

Altitudinal movements may help explain seasonal fluctuations revealed by winter and summer surveys. Some Koloa may move to the lowlands during early winter to exploit ephemeral wetlands and return to montane breeding areas in early spring. Richardson and Bowles (1964) found Koloa nesting in montane streams during their summer survey. Their observation of a flightless adult suggested that at least part of the population undergoes post-breeding molt prior to moving into the lowlands. Apparently the entire Kauai population does not move to the lowlands in winter. Forest bird surveys in mid-winter have regularly documented Koloa in very remote regions of the Alakai Swamp (Engilis and Pratt, pers. obs.). The dynamics of these altitudinal movements are not understood and require further investigation.

Because of potential competition and interbreeding with native Koloa, monitoring feral Mallards has become a paramount issue in Hawaii. During the 1930s and 1940s, Mallards were commercially farmed in the Kahuku region of Oahu, and escapes to the wild occurred (P. Chang, pers. comm.). Figure 8 shows the location of known nuclei of 35 or more Mallards. The dispersal of Mallards from these nuclei has been well documented by state and federal biologists, particularly on Oahu, on the west coast of Hawaii Island, and on Kauai (unpublished DOFAW records). The state survey was modified in 1989 to survey Mallards more accurately. The Mallard also occurs in the state as an accidental migrant (Pyle 1988). These birds usually associate with migratory Northern Pintail (*Anas acuta*) and Northern Shoveler (*A. clypeata*) (pers. obs.).

Although wild Mallards are normally monogamous, multiple copulation has been suggested as a secondary means for maximized breeding success (Evarts and Williams 1987). It is now clear that domesticated Mallards adopt multiple copulations as their primary reproductive strategy (Kear 1990).This behavioral shift has implications for survival of genetically pure populations of Koloa. As males become established in the wild they successfully seek mates, including Koloa, resulting in increased hybridization. This same phenomenon has been documented in Mallard and American Black Duck (*A. rubripes*) populations (Heusmann 1974, Ankney et al. 1986) and Mallard and Australian Black Duck (*A. superciliosa*) populations (Frith 1967). Because the Koloa is a morphologically variable species and shares several character traits with Mallard (Perkins 1903, Schwartz and Schwartz 1953, Swedburg 1967), Koloa × Mallard hybrids in the wild may resemble either species and means other than visual identification are needed to address the problem.

Recent genetic studies have shown that a high percentage of Oahu's Koloa are hybrids (Griffin and Browne 1990). However, their conclusion that genetically pure Koloa persist only on Kauai is tenuous. The Koloa population on Hawaii Island is derived from known pure genetic stock and thrives in remote montane stock ponds and river valleys (J. Giffin, pers. comm.). They enjoy the same degree of isolation from feral Mallards as do their counterparts on Kauai. Feral Mallards do occur on the island, mostly in urban or hotel ponds where Koloa are absent. If Koloa numbers increase and birds disperse to lowlands, hybridization may become a problem. In the mean-time, state wildlife officials should identify sources of Mallards on Hawaii and push for their eradication.

On Oahu, Koloa continue to frequent mountain streams where Mallards are unlikely to occur (pers. obs.). Specimens taken on Oahu by Griffin and Browne were specifically biased towards suspected Koloa × Mallard hybrids. Therefore it was not surprising that they found a high incidence of hybridization at James Campbell National Wildlife Refuge, at Kahuku. Hybridization is a problem on Oahu and was probably compounded by the state's choice of release sites. The two Oahu sites chosen were Kawainui Marsh and Waimea Falls State Park; both support substantial feral Mallard populations. The first documented Mallard × Koloa mating was at Waimea Falls State Park in 1977 (DOFAW, unpubl. data). Further research is necessary to identify the degree of hybridization on Kauai, Oahu, and Hawaii so that management actions can be taken.

State surveys may not accurately estimate Koloa numbers because many individuals reside in unsurveyed mountain streams, dense emergent cover, and montane bogs and ponds, particularly on Kauai and Hawaii. Swedberg (1967) estimated the Koloa's population on Kauai at 3000 birds. Telfer (in Kato 1981) believes this estimate to be high and that the population is probably stable between 1500 to 2000 ducks. Based on these figures, and results from the waterbird survey, we estimate the state population near 2500 birds (2000 on Kauai, 300 on Oahu, 200 on Hawaii).

Increase of the number of Koloa since the 1960s can be attributed to the Hawaii Division of Forestry and Wildlife's captive propagation and release programs and to wetland habitat acquisition and management by state and federal agencies. Eradication of feral Mallards and known Koloa × Mallard hybrids, a ban on Mallard importation to Hawaii, acquisition and development of additional wetlands, maintenance of existing wetlands, and continued monitoring of birds on Kauai, Oahu, and Hawaii will be required to fulfill recovery goals outlined for Koloa in the Hawaiian Waterbirds Recovery Plan. More detailed life history information should be gathered to identify limiting factors that affect the species. In 1989, DOFAW released a small number of Koloa on Maui that will probably not establish a viable population, but establishing a captive-release program on Maui and Molokai should be carefully considered.

Hawaiian Common Moorhen.—The Hawaiian Moorhen is an endangered subspecies endemic to the main Hawaiian Islands. Its current range is Kauai and Oahu, where it is fairly widespread and locally common. DOFAW released six moorhen on Molokai in 1983; these birds and their offspring may still survive. The last observation of a moorhen on Molokai 1985 (R. Pyle, pers. comm.).

The Common Moorhen is a secretive species, preferring freshwater marshes and grassy wetlands and is not tolerant of brackish water (Hawaii Audubon Society 1989). In 1983, Kahuku aquafarms changed shrimp production from freshwater to saltwater species. The conversion of ponds to saltwater resulted in a decline in moorhens observed there (R. Pyle and D. Woodside, pers. comm.). The Hawaiian Moorhen has responded well to man-made wetlands and lives in close association with humans.

Moorhen numbers appear stable on Kauai and Oahu, but the species' dependency on agricultural wetlands makes its status precarious. The highest concentrations in the state are documented at Paradise Pacifica, Kauai, and Oahu lotus farms, both man-made wetlands. Nagata (1983) compared moorhen densities at lotus farms on Oahu with those of a natural wetland and found densities to be 17.2 birds/ha and 4.6 birds/ha, respectively.

Differences in counts during winter and summer appear related to count biases on lotus fields on Oahu. Indian lotus is grown as a food crop and requires flooded fields or slow moving streams for cultivation (Neal 1965). Fields are harvested from October through December, and planting of new lotus takes place in January. During this time, fields are bare, and loose flocks of moorhen can be easily observed scurrying for cover or feeding. Rapid foliage growth follows planting, and by mid-June umbrella-like leaves reach an average height of 120 cm. During this time few moorhens are observed. The 1982 statewide population peak was not correlated to counts in lotus fields, indicating numbers increased in other regions of Oahu and Kauai. Dispersal and an attenuated breeding season caused by increased ephemeral wetlands during wet years may account for the increase in birds. Nagata (1983) has shown that moorhens disperse seasonally into ephemeral wetlands during spring. This seasonal dispersal may also contribute to declines documented during summer surveys. The very low total for 1978 is the result of the lotus fields not being surveyed (Fig. 3).

The recovery of this species is dependent upon protecting and managing wetland habitats, thus reducing the species' dependence on aquacultural habitats. Easements can be established on critical aquaculture projects that provide habitat for moorhens. An ideal situation for easements exists at the Haleiwa lotus fields on Oahu. One estimate placed the moorhen state population at 750 birds (500 on Kauai and 250 on Oahu) (USFWS 1985). Based on the number of habitat areas missed during surveys, it would be reasonable to think this number too low. Due to their reclusive nature, an accurate population estimate cannot be made from available data. For a discussion of methodology required to census moorhens accurately, see Chang (1990). In 1991, population estimates from James Campbell NWR, alone, stand near 100 birds (P. Chang, pers. comm.).

Hawaiian American Coot.—Several authors (Udvardy 1960; Shallenberger 1977; USFWS 1985; Pratt 1978, 1987; Griffin et al. 1989) have commented on the perplexing population fluctuations of Hawaiian Coots. Various reasons for these fluctuations have been suggested, but two main hypotheses prevail: (1) the influx of mainland American Coots during the winter (USFWS 1985), and (2) the inter-island movements of Hawaiian Coots (Udvardy 1960, Pratt 1987, Griffin et al. 1989).

A major flaw in past analyses of coot population fluctuations has been the use of fragmentary data from past waterbird surveys. The most reliable information available on changes in Hawaiian Coot numbers is from 1977 through 1986 summer waterbird survey data when all islands were surveyed.

Udvardy (1960) and Pratt (1987) independently concluded that American Coots constitute an insignificant portion of coots in Hawaii. The very low percentages of small shielded coots observed from 1983 to 1987 confirm their conclusion. Thus, the recent data indicate that fluctuations of coot populations in Hawaii are not the result of periodic eruptions of American Coots to the islands.

In trying to attribute coot population fluctuations to inter-island movement we examined trends for corresponding high and low counts between islands. The data show that an increase in the state coot population is usually reflected by increases on all islands. These patterns are not consistent with those expected for inter-island movements. There are eruptive movements of coots to Niihau, presumably from Kauai. But Shallenberger's (1977) statement that most of Kauai's coots annually migrate to Niihau to nest is not supported by available data. Eruptive events have occurred twice during the period examined, in the summer of 1982 and in the winter of 1986. These events can be correlated to intermittent availability of wetlands on Niihau that resulted from unusually high rainfall.

The American Coot disperses during periods of greater habitat availability and attenuates its breeding season accordingly (Fredrickson et al. 1977, Sugden 1979, Weller and Spatcher 1965). This pattern is also apparent for the Hawaiian Coot. Hawaiian Coots normally breed from March through September (Berger 1981), although nesting year-round has been reported (Shallenberger 1977, Byrd et al. 1985, Chang 1990). We suspect that past reports of winter breeding probably came during high rainfall years. Wet winters occurred in 1988 and 1989 and Hawaiian Coots were observed nesting by mid-December (USFWS and DOFAW records).

Based on available data, it appears that Hawaiian Coot population fluctuations may be related to two other phenomena: intra-island dispersal and breeding success. Seasonal flocking in mainland American Coots is well documented (Fredrickson et al. 1977, Bartlet 1977), but differs from that of Hawaiian Coot. American Coots congregate in winter and disperse in late spring and summer to breed. In general, Hawaiian Coots disperse in late winter and spring to breed, and congregate in summer for the nonbreeding period. This dispersal accounts for the lower numbers documented in winter censuses. Waterbird survey data indicate that coot populations change relative to climatic events and that intra-island dispersal and associated counting bias are the primary causes of the "perplexing fluctuations" noted by past observers.

Although the waterbird survey was not designed to address breeding success, there is evidence that increased nesting may have resulted in the 1983 population peak. Coot counts were low in 1982, presumably because birds had dispersed. By summer 1982, small increases were seen on Maui and Molokai, and coots erupted to Niihau. The following year, Hawaiian weather was influenced by an El Niño, resulting in winter drought that impacted seasonal wetlands. By winter 1983, the counts of coots increased on Oahu, the result of an increasing number of adults and their progeny forced to congregate on permanent wetlands. By summer 1983, even major wetlands dried throughout the state, forcing coots to congregate further, and all islands reported increases in coots. The sharp population decline in 1983 may have been the result of mortality due to limited wetland habitat. Coot populations stabilized as rainfall patterns returned to normal in 1986.

The current statewide population of Hawaiian Coots probably fluctuates between 2000 and 4000 birds, with Kauai, Oahu, and Maui supporting 80% of these birds (Engilis 1988). The number of coots in the state can be increased with the increase of properly managed wetlands and control of mammalian predators.

Hawaiian Black-necked Stilt.—Data show that Hawaiian Stilt population fluctuations may be related to rainfall patterns. The pattern of correlation between rainfall and bird numbers was similar to that observed for coots. Winter rains create suitable seasonal habitat (shallow pools and flooded fields) that stilts are quick to locate and exploit. Winter surveys generally report fewer stilts than summer surveys, possibly because of dispersal. As seasonal habitat dries during summer, adults with progeny stage on permanent ponds, leading to higher counts. Unpublished DOFAW life history studies, from 1977 to 1979, suggest that Hawaiian Stilts require specific conditions (water depths of 13 cm or less) for optimal foraging, and they freely move to find such conditions. Studies of feeding behavior suggest that stilts seek these temporary pools because much of their prey items are concentrated, thus facilitating feeding by the adults and young (Coleman 1981).

Correspondingly, annual count fluctuations between Kauai and Niihau suggest that migration does occur (Fig. 7). Telfer (pers. comm.) suggests that many stilts migrate to Niihau after onset of winter rains to exploit the large ephemeral wetlands at the center of the island. After breeding, they migrate back to Kauai in late summer, by which time much of Niihau's wetland areas have dried. The only summer where a substantial number of stilts remained on Niihau was in 1982, a heavy rainfall year.

The increase of stilt population documented for 1983 to 1985 was the result of increased reproductive success. In the late 1970s, Coleman (1981) found the mean fledgling success rate on Oahu to be 23%. Fledgling success rates as high as 34.3% were recorded during the population peak of 1983–1985. The drop in numbers in 1986 was reflected by a decrease in fledglings. The decrease was probably linked to a return to normal rainfall patterns, resulting in decreased wetland habitat.

Because Hawaiian Stilts are restricted to open wetlands and are highly visible, the annual statewide totals can be accepted as estimates of population size. Statewide populations probably fluctuate between 1200 and 1600 birds, with Oahu, Kauai, and Maui supporting 92% of the birds. Stilts are annually counted on Niihau, Molokai, and Hawaii. In 1989, a pair was observed on Lanai at the new sewer treatment facility near Lanai City (DOFAW, unpubl. obs.). Stilt populations on Oahu and Maui have shown a steady increase since 1982. This increase can be attributed to active management and creation of optimal nesting habitat by state and federal agencies. Areas managed primarily for stilts include: Kanaha Pond (Maui), Nuupia Ponds, Pearl Harbor NWR, and James Campbell NWR (Oahu). The continued management of these core areas is crucial to the existence of stilts in Hawaii.

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