

THE CONDOR

VOLUME 65

JANUARY-FEBRUARY, 1963

NUMBER 1

RECENT HISTORY AND ECOLOGY OF THE LAYSAN DUCK

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The Laysan Duck (*Anas laysanensis*) may have occurred originally on several islands of the Leeward Hawaiian chain, but in recent years it has persisted only on Laysan Island. I conducted field studies on Laysan in the summers of 1957, 1958, 1959, and 1961, each visit being of one to two weeks' duration. The earliest date of arrival on the island was May 27; the latest departure date was September 10. The seasonal span of observation of the duck is thus limited. Conclusions presented here regarding the ecology of the bird will necessarily stress the summer situation, although inferences regarding the situation at other seasons will be drawn.

HISTORY OF LAYSAN ISLAND

Laysan Island is the eroded remnant of a once-high island of the Hawaiian Archipelago, built up initially during an extended period of volcanic activity which began perhaps as early as the Miocene period. It was one of the first of the islands to be formed along the fissure or zone of weakness that extends across the floor of the Pacific Basin over 1500 miles, from Hawaii to Kure and Midway. The continued outpourings of lava from this great fracture eventually produced the Hawaiian chain or Archipelago. The string of shoals, reefs, and sand islands of the leeward portion of the chain represents the flattened tops of massive volcanic peaks whose exposed portions have been removed by subaerial and marine erosion. The Laysan Island peak, for example, at a depth of 100 fathoms, has an approximate area of 210 square miles; at sea level, however, its total area is only 1.56 square miles (Bryan, 1954). Separated from its neighbors in the chain by ocean depths averaging 1800 fathoms, it is located in a portion of the Pacific Basin whose floor lies approximately 2500 fathoms (15,000 feet) below the surface of the ocean. The recent interglacial rise in ocean level has inundated the platform to a depth of about 100 feet (Stearns, 1946; Zimmerman, 1948).

These flat-topped submarine mountains ultimately give way toward the southeast to fragments of basalt still protruding above the ocean's surface (for example, La Perouse Pinnacle; Nihoa) and terminate with the still-growing island of Hawaii. Geographically Laysan Island is 790 nautical miles WNW of Honolulu; latitude 25° 46' N, longitude 171° 44' W. It is due south of the Pribilof Islands, and its position is roughly equivalent in latitude to that of Miami, Florida.

PHYSIOGRAPHY

The immediate subsurface stratum of Laysan is coralline rock. The topography suggests that the island was at one time a small atoll with a central lagoon which is now nearly filled with sand and coral fragments. The island's present configuration is that of a great ringed sand dune of about forty feet maximal elevation (see fig. 1) heaped upon the coralline rock base whose surface is approximately five feet above mean high water mark. The total land area is 709 acres. The central lake is one mile long by half

a mile wide; its maximum depth was recorded in 1858 by Captain N. C. Brooks as 30 feet with coral bottom (Brooks, 1859). By 1920, disturbances of the island's flora resulted in complete loss of the plant cover with consequent large-scale sand movement. Before being stabilized once again by the regrowth of the vegetation, the drifting sand

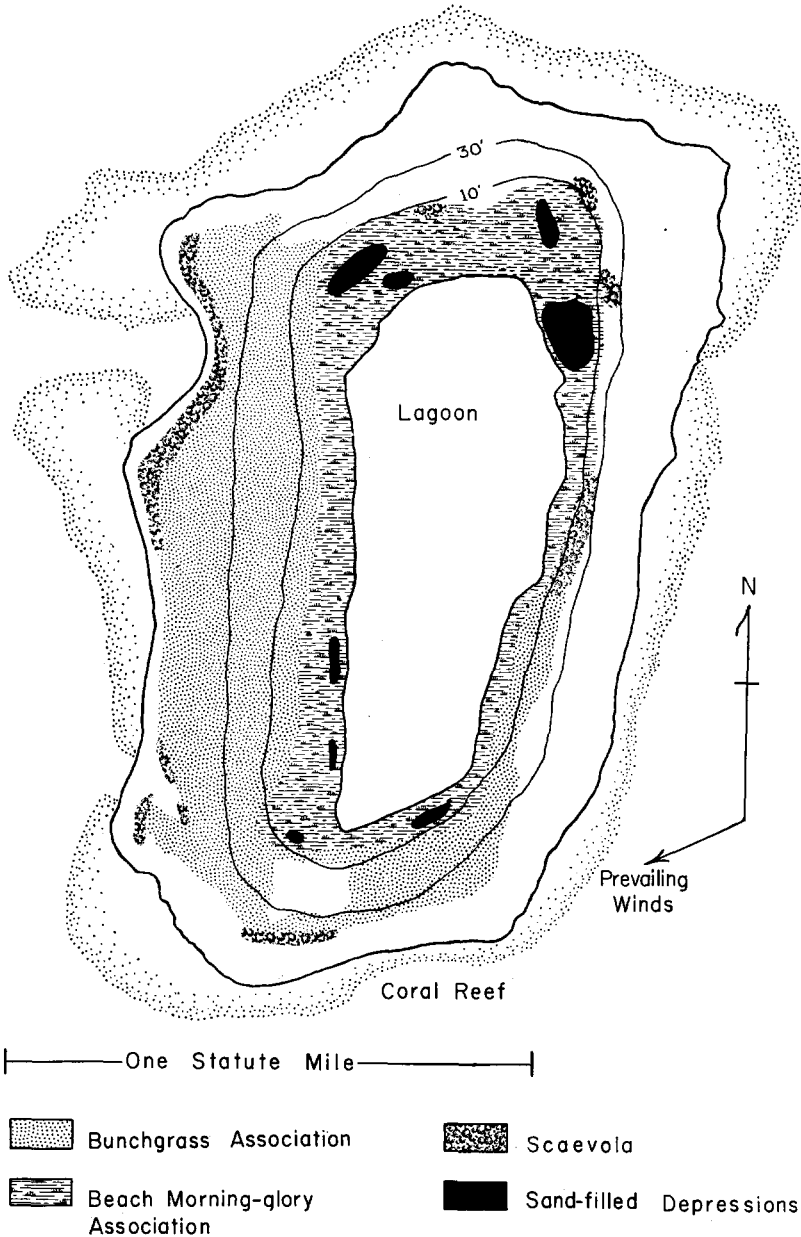


Fig. 1. Map of Laysan Island. Topographic data in part from "Tanager" Expedition, 1923. Beach morning-glory association includes the entire plant species complex found on and adjacent to the lake flat. The sand-filled depressions are believed to be former fresh water ponds.

filled in the eastern portion of the lake and the island was, in essence, "moved" several feet to the west or leeward side. Our most recent soundings indicate a maximum lake depth of 15 feet with sand bottom, immediately offshore of the eastern edge of the lake. The western shore line is also at variance with earlier maps. Previously prominent shore-line rock outcrops are now buried under extensive sand dunes with concomitant changes in the shore-line configuration.

Each winter during stormy periods volumes of ocean water are driven up and over the seaward east slope of the island, to flow down into the lake. Quantities of glass balls and other jetsam are left deposited on the lake flats. This periodic addition of salt water with its subsequent evaporation during the summer months more than offsets the dilution effect of any rains the island receives, so the central lake is much more saline than the ocean.

THE HABITAT

Although the lake is perhaps the outstanding topographic feature of the island, the available evidence suggests that it may have had little to do with the evolution of the Laysan Duck. The lake waters, tested for salinity as early as 1858 (Brooks, 1859) and on several subsequent occasions (see, for example, Elschner, 1915), were found to be strongly hypersaline; concentrations of NaCl ranged from 10 to 15 per cent. Most recently the NaCl concentration was found in June, 1958, to be 12 per cent, and in July, 1959, 14 per cent. Only two species of invertebrates are known to thrive in its waters: a brine shrimp, *Artemia* sp., and the larva of a dipteran fly, *Neoscatella sexmaculata* (Butler, personal communication). The latter lives in the ooze of the shallow waters.

Utilization of the lake by the duck during the summer months is insignificant. Adult flies along the water's edge are occasionally taken as food. The high salt content of the lake's waters precludes the growth of any vegetation or animal life other than that just mentioned.

Although no significant tidal fluctuation of the lake was noted, in 1958 several small springs were discovered along the shallow northeast portion of the lake floor. The *Artemia* collected along these inlets in great numbers, attracted presumably by reduced salinity.

Observations by McKernan (personal communication) indicate that occasionally during the winter months a lens of fresh water may develop over the hypersaline lake waters as seasonal rains and ground water seepage contribute to the lake contents. The development of such a surface-covering fresh water lens would make the lake available, at least temporarily, to the ducks for bathing and courtship activities. Captive birds use fresh water ponds for bathing. While the evidence against use of the ocean or lake for breeding activities is inconclusive, the aversion of the species to ocean or hypersaline waters observed during the study intervals strongly supports this idea.

Perhaps one of the most important factors contributing to the maintenance of an isolated population of the progenitor of the Laysan Duck was a series of ponds of fresh or brackish water around the periphery of the lake (see fig. 1). Their formation resulted from the impermeability of the island's coralline rock base discussed earlier. Rain waters, percolating through the highly permeable sands heaped upon the basal rock, are restrained upon reaching the solidified coral. The result is a substantial retention of ground water in the lower sand layers. When local depressions in the sand occur, the water stratum is exposed forming small ponds. During historic times only one of these ponds was functional throughout the year, although several are still used when the water table is sufficiently high. Early records and photographs (for example, Dill and Bryan, 1912)

clearly reveal that this pond was permanent in nature. Located at the southwest corner of the lake, it was lined with sedges and had a cluster of rocks in the center upon which the adjacent portion of the duck population spent considerable time loafing and sunning. Dill found in 1911 that the few remaining ducks had concentrated in the vicinity of the pond, and Bailey in 1912 (Bailey, 1956) was able to photograph a pair swimming in its waters. The distribution of these depressions, most of which are filled with drifted sand, suggest that during the evolutionary development of the species considerably larger areas of fresh water habitat were available than is the case at present.

PROGENITOR

The Koloa, or Hawaiian Duck, *Anas platyrhynchos wyvilliana*, is intermediate in many respects between the Laysan Duck and the mainland form of the Mallard, *Anas platyrhynchos platyrhynchos*. Like the Laysan Duck, it does not migrate, but nests on the main Hawaiian Islands and several of the smaller offshore islets of the main group. Unlike its smaller Laysan Island relative, the Koloa is a strong and active flier capable of considerable island hopping; it is possible that the Koloa served as the archetype for the still more diminutive, highly inbred and sedentary Laysan Duck.

A number of other anatid species are known to visit Laysan. Schauinsland in 1896 (Schauinsland, 1899) and Bailey in 1912 (Bailey, 1956) reported the Mallard during the winter months. The Green-winged Teal (*Anas crecca carolinensis*), and the American Widgeon (*Mareca americana*) have been seen in winter, and I recorded a lone Pintail drake (*Anas acuta*) on the lake flat on June 1, 1958. However, it is noteworthy that no interspecific pairing has ever been reported, and extensive field observations during three spring and summer periods failed to indicate any evidence of hybridization.

The Laysan Duck was reported to have occurred originally on Lisiansky Island, Laysan's nearest neighbor which is 140 miles to the northwest. Herr Isenbeck, ship's surgeon for the Russian ship "Moller" when it visited the area during the spring of 1828, reported the Laysan Duck living in small flocks on both islands (von Kittlitz, 1834). Palmer, the next recorded visitor to Lisiansky, in 1891 found no trace of ducks (Rothschild, 1900). The presence of a dry lake bed lends some credence to Isenbeck's report, since a lake would have created a habitat similar to that on Laysan. But the thread of evidence ends here. The duck, if it occurred on Lisiansky, apparently disappeared at an early date.

The high degree of endemism of the flora of Laysan, seven endemic varieties of twenty-six recorded species (Christophersen and Caum, 1931), and of the insect life strongly suggests that a rather protracted period of stability preceded the island's invasion by white men. The unusual nature of the vegetation, which included groves of endemic sandalwood trees (*Santalum cuneatum* var. *laysanicum*) and several prichardia palms, *Prichardia* sp? (Paty, MS, journal of a voyage in the schooner "Manuokawai" in April and May, 1857; Munro, 1930), both plants now extinct, further distinguished Laysan from the rest of the sand and coral islands at the northwest end of the chain. These generally have a rather simple flora with fewer endemics.

DESTRUCTION OF ORIGINAL HABITAT

The nearly complete annihilation of the flora of Laysan Island followed the introduction of domestic rabbits in 1903. Originally introduced as a commercial meat venture by members of a guano mining firm which had leased the island for a period of twenty years, the rabbits quickly multiplied to fantastic numbers. In less than two decades they had completely denuded the island of every green plant they could reach

except three moderate-sized patches of sesuvium (*Sesuvium portulacastrum*) at one end of the lake flat. Guinea pigs and domestic swine were introduced at the same time as the rabbits, as well as either a cow or goat. The guinea pigs developed only a small local population at the south end of the lake flat, but the swine fared well for the relatively short time they were permitted to forage about the island. They fed on bird carcasses, rooted for tubers produced by one of the native plants, and no doubt took eggs, young, and possibly adult birds as well (Schlemmer, personal communication; Munro, MS; Walker, 1909). Despite the contribution of these latter animals to the island's degradation, the record indicates that the introduced rabbits were the immediate and principal cause.

As early as 1911 the rabbit population was substantial. Dill (*in* Dill and Bryan, 1912:10) observed in April of that year that, "in the latter part of the afternoon they [the rabbits] may be seen feeding. They are very fond of the green juncus that grows near the lagoon, and, while they are eating, their bodies are concealed among the thick growth and only their ears show. At times there are so many ears protruding that they resemble a vegetable garden." And W. A. Bryan, who was there at the same time, lamented (*in* Dill and Bryan, 1912:28): "Rabbits now literally swarm over the islands by thousands. The amount of damage done by them can better be imagined than told. They are exterminating first one species of plant then another. Several species that were common everywhere eight years ago have entirely gone, others are already doomed. Unless some drastic measures are resorted to within a very short time, not a bush or spear of grass will be alive."

One unsuccessful attempt to eradicate the rabbits was made in 1912 by the United States Biological Survey. When Alexander Wetmore visited the island in April, 1923, he found the vegetation completely destroyed. He wrote (Wetmore, 1925:103): "On every hand extended a barren waste of sand. Two coconut palms, a stunted hau tree and an ironwood or two, planted by the former habitants" were the only living plants save the three patches of sesuvium on the lake flat. He continued: "Of the vast army of destroyers, only a few hundred remained. . . . We had come prepared to eliminate the rabbits, so, with camp established, the work began at once. The destruction of the majority was simple, but the survivors became wary and it was necessary to hunt them out one at a time. . . . Pursuit, therefore, was relentless and effective. A party sent to Laysan a year after our visit reported no sign of a single survivor."

However, living rabbits were reportedly seen on Laysan by a visitor to the island in 1926. This report has not been verified, but it suggests that the last of the species may have escaped the extermination effort of 1923 and died out from natural causes.

It is of considerable interest to note that the neighboring island of Lisiansky experienced the same sort of devastation as did Laysan. Rabbits were introduced there about 1903 by the same individuals responsible for the introduction on Laysan. By 1914 the vegetation had been almost completely destroyed, although a few rabbits were still in evidence (Elschner, 1915). By 1923 the last of the rabbits had perished naturally, and the island was showing the first signs of vegetative recovery (Ball, MS, notebooks on Tanager Expedition, 1923, in B. P. Bishop Museum). It is possible that rabbits would have died out on Laysan even without deliberate efforts at control.

The denudation of Laysan brought the duck perilously close to extinction. In 1923 the "Tanager" expedition found the single remaining pond filled in with wind-blown sand and no longer usable (Ball, MS). The three remaining patches of sesuvium were apparently of considerable importance in maintaining the remnant population over the critical period. Both Bailey in 1912 and Wetmore in 1923 reported considerable utiliza-



Fig. 2. Laysan Island vegetation, beach morning-glory association. Adjacent to lake are mats of heliotrope and sesuvium; extensive areas of sedge may also be seen lying between the beach morning-glory (foreground) and the lake. Photograph taken at northwest corner of lake flat looking southeast, July 26, 1958.

tion of this plant by the ducks. Today, with vegetative recovery well along, the sesuvium is completely ignored as a food source.

PRESENT HABITAT CONDITIONS

As can be discerned from figures 2 and 3, a large portion of the island has been revegetated in some manner in the intervening post-rabbit years. The distribution of major plant species is similar to that noted at the time of the island's discovery, although several species have disappeared altogether and those which have become re-established have yet to spread to all available growth areas. A large expanse of the northeast sector of the island is yet devoid of plant life.

But there has now developed a distinct vegetative zonation as one moves from the lake flat up the sand slopes toward the summit of the encircling dune ridge. The lagoon flat is covered with alternating (rarely mixed) stands of sedge (*Sicyos* sp.), heliotrope (*Heliotropium curassavicum*), and sesuvium (*Sesuvium portulacastrum*). These species extend from the barren edge of the salt flats for a varying number of yards, to be replaced by a tangled, knee-deep mat of beach morning-glory (*Ipomoea pes-caprae*) which, except in a few places, completely surrounds the lake flat. As one progresses up the gradual slope and rises above the water table, the morning-glory is replaced by a dense belt of bunch grass (*Erogrostis variabilis*) or by mixed stands of bunch grass, tribulus or puncture vine (*Tribulus cistoides*), and boerhaavia (*Boerhaavia diffusa*).

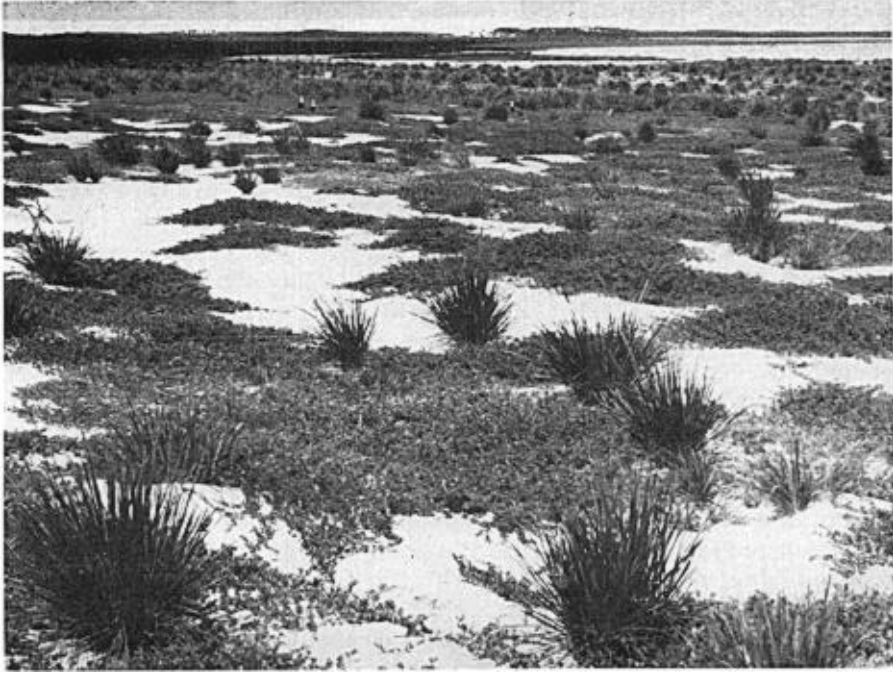


Fig. 3. Laysan Island vegetation, bunch grass association. Prostrate boerhaavia is interspersed with bunch grass. Photograph taken at northwest corner of lake flat looking northeast, July 26, 1958.

Still farther up the slope the plant cover thins to scattered mats of the prostrate, succulent boerhaavia, interspersed with bunch grass and tribulus; between these various species are areas of bare, still-exposed coral sand. The substrate is extensively undermined with shearwater and petrel burrows, which are utilized almost constantly through the year by one species or another. Occasional clumps of scaevola (*Scaevola frutescens*) are scattered about the island, principally on the high ridges.

PRESENCE AND UTILIZATION OF WATER

During the first three study periods, only one source of fresh or brackish water was found on the entire island. This consisted of a small, sand-bottomed depression about one foot in diameter in the coralline rock of the western ocean shore of the island; it was present only in 1957. Surrounded by large wave-tossed rock fragments, the pothole was filled only during the high tide, either by ground water seepage or by the elevation of a fresh-water lens possibly underlying the entire island. The water tasted mildly brackish. It was, however, sufficiently fresh to attract a local group of four ducks which could be found almost constantly in the area during the day. Continued observations revealed only this one small group to be using the water supply. Turbid water, feathers, and numerous tracks indicated extensive use of the basin for bathing; on occasion a duck could be disturbed from its bath, and it would go off shaking water from its feathers and preening.

In September, 1961, there were numerous indications of increased amounts of fresh

water, presumably the result of greater rainfall during the preceding months. The vegetation was green and luxuriant, and a thin but persistent stand of nama (*Nama sandwicensis*, var. *laysanicum*) had developed over most of the previously barren northeast portion of the island. The lake was conspicuously higher than in previous years, covering a considerably greater area. Ducks were congregated in substantial numbers at the west shore water hole and at several small ponds along the east and southeast shore of the lake (see fig. 1). Their behavior suggested that the water of these ponds might be potable. Subsequent salinity tests have verified that the water was only slightly brackish.

It appears that at present the abundance and availability of fresh water is dependent upon the weather patterns of the area. During dry years there is virtually no available fresh water; wetter years produce potholes and local seepages of essentially fresh water, even during the dry summer months. The fact that the ducks survive dry periods when fresh water is unavailable suggests that it is not essential to existence.

Preliminary field studies on possible salt excretion by the nasal glands of the species were conducted in September, 1961. Four Laysan Ducks were given 4 to 10 cc. doses of sea water using a syringe with a rubber stomach tube. Two birds exhibited considerable nasal dripping 15 to 30 minutes following administration of the sea water. The excretions are presently being analyzed. It is well known that many anatid species have nasal gland salt excretion mechanisms. Such a device would be eminently useful to the Laysan Duck.

Dr. Miklos Udvardy reported an interesting observation in 1959 of a Laysan Duck bathing in salt water. On July 27, he came upon a female duck squatting on the sand on the western (lee) shore of the island. When first seen, the bird was pecking at something at the water's edge. Then, as the wavelets washed up to her feet she stopped pecking and commenced bathing; tail down, wings down, ducking the head and bobbing and splashing. At the arrival of the third wavelet, she floated out from the water's edge about a foot and a half while continuing to bathe. The waters then receded and left her on the sand. This was repeated four or five times. To determine whether the duck would escape to land or water, Dr. Udvardy circled above it about ten yards distant. As he approached down the slope of the beach, the duck ran not into the water but diagonally up into the cover.

There is some evidence to suggest that moisture which collects on the vegetation from intermittent thundershowers is used for bathing purposes. On nights when the vegetation is so dampened ducks quickly become water-soaked. However, no actual instances of bathing in this manner have been observed in the duck. The writer has noted on several occasions such behavior by the endemic passerine Laysan Finch (*Psittirostra cantans*). It is possible that both species have learned to utilize the water source for bathing.

The probability of opportunistic use of temporarily available water supplies is further indicated by observations reported by D. L. McKernan (personal communication), who visited Laysan on February 10, 1955. He noted: "I found them [the ducks] feeding along the shore of the lagoon and, in a sense, in little potholes and side channels of the lagoon on what, as I recall, was the south side of the lagoon. They were obviously feeding on roots, and perhaps grass, because they stuck their heads down under the water in the shallow water and were rooting around in the mud." Probably ground water seepage, combined with an elevated lake level, created the temporary aquatic feeding area. The ease with which captive Laysan Ducks return to using fresh water ponds attests to their appreciation of fresh water when it is available.

DISTRIBUTION AND HOME RANGE

Although the species has been observed on all parts of the island, most individuals spend the daylight hours hidden in the dense tangle of beach morning-glory surrounding the lake. A few small groups have been seen consistently inhabiting scaevola thickets where they have taken up residence.

In 1958, 58 ducks inhabiting the northwest sector of the island between the lake flat and the northwest ridge were banded (FWS band numbers 535-15201 to 535-15258); there were 38 males and 20 females. At least eight pairs were included in the banded population. In 1959, color neck bands were devised for distance identification and used with considerable success. It is evident from these studies that the home range of any individual is generally very limited, usually being approximately two acres in size. Daily, or nightly movements followed a regular pattern and indicated favored routes for feeding activities. The birds were very active and moved about with alacrity as they sampled insects first of one boerhaavia patch then another. Nocturnal feeding commenced at or shortly before nightfall, with large numbers of ducks emerging from the beach morning-glory simultaneously.

During the summer flightless molting period, total movement was more restricted. For example, one female, in full molt and flightless, emerged from precisely the same point in the beach morning-glory-bunch grass interphase at or shortly before sundown each evening. After an interval of quiet watching she would move slowly in a westerly direction for fifty yards, while feeding among the boerhaavia plants. She would then double back in a narrow loop to the south, and by 9 p.m. again would be at the beach morning-glory-bunch grass interphase. After a period of casual feeding at the border she returned to the seclusion of the tangled beach morning-glory vines. This highly restricted feeding activity was typical of birds in flightless condition.

The data are not complete enough to determine whether feeding territories had been established. No intraspecific rivalry or territorial behavior was noted with certainty, but this could be due to the difficulty of observation at night or to the fact that territories if any may already have been well established at the time of observation (latter part of May on).

Of considerable interest is the fact that when Kramer in April, 1959, briefly examined the northwest sector of the island where we had conducted the saturation-banding program in 1958, he counted a total of 11 banded birds but no unbanded ones. In contrast to this, he found in the southwest sector only two banded birds out of a total of 152 individuals seen (Kramer, MS). It is not known precisely where the banded birds in the latter instance were found, and it is quite possible that Kramer's southwest sector slightly overlapped our banding area of 1958. These data agree completely with those obtained by the writer several months later (July), when an examination of the previous year's banding area produced no evidence that banded birds had moved to different sectors of the island.

The ducks were never observed utilizing the innumerable shearwater burrows which honeycomb the island, except in the evening when the entrances and occasionally the depths of the burrows were searched for insects. No doubt the occupation of these holes by various species of shearwaters and petrels over most of the year contributed to this abstinence.

POPULATION NUMBERS

For over a decade at the turn of the century, duck shooting provided sport and food for members of the guano mining firm which at that time inhabited the island (Schlem-

mer, personal communication). The excited interest of occasional visiting ornithologists over the state of the species finally aroused the superintendent to measures of protection, although the duck had been sorely decimated before conservation was considered. Fisher in 1902 estimated the population at considerably below one hundred, although at this time the flora was still intact (Fisher, 1903).

That same year W. A. Bryan (1906) visited Midway Island for a short while and discovered that Japanese feather hunters were destroying thousands of sea birds for the millinery trade. He reported finding carcasses left by the poachers over the length of the island. The alarming nature of Bryan's observations combined with the pressure of conservationists induced President Theodore Roosevelt on February 3, 1909, to set aside the leeward islands, including Laysan but not Midway, as the Hawaiian Islands Refuge. Despite this declaration of refuge status for Laysan, a party of Japanese plumage hunters landed on the island in 1909, and while busily engaged in slaughtering an estimated 200,000 sea birds—principally Laysan Albatrosses—for their feathers, they killed large numbers of the Laysan Duck for food. Dill and Bryan (1912) in 1911 found feathers and other parts of the ducks which the poachers had dressed and used for food. Figure 4 illustrates the profound effect of the plumage hunters on the duck population and removes any doubt as to the fate of the species had the poachers not been interrupted in their activities. After that episode Dill was able to count only six individuals, although Bryan in the same period estimated approximately a dozen pairs probably remaining.

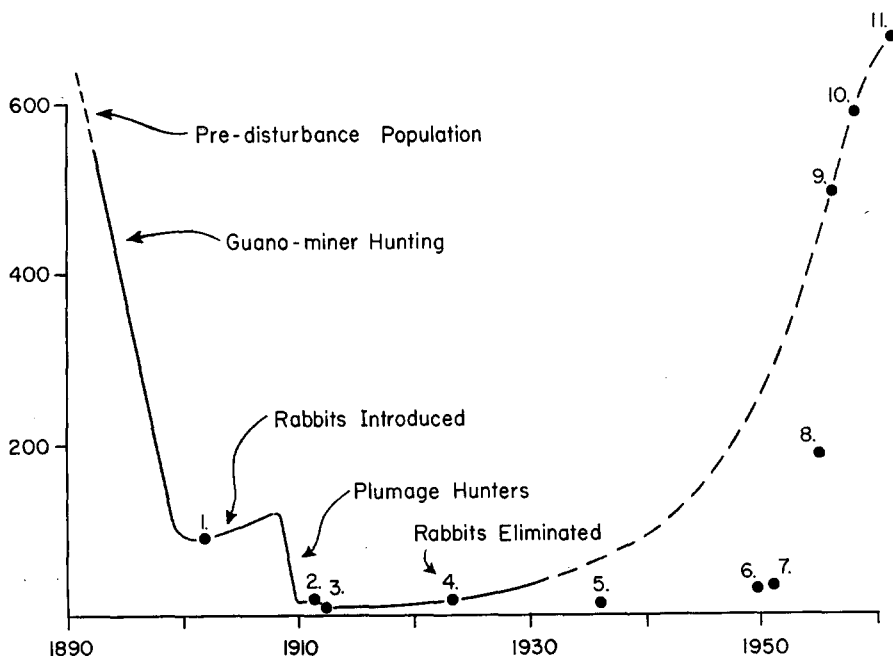


Fig. 4. Graph showing estimated population size of the Laysan Duck during historical times, based on published records and transect censuses. Precise nature of growth curve since 1923 speculative. Authorities and year of census as indicated by numbers on graph: 1, Fisher, 1902; 2, Dill and Bryan, 1911; 3, Bailey, 1912; 4, Wetmore, 1923; 5, Coultas, 1936; 6, Brock, 1950; 7, Brock, 1951; 8, McKernan, 1955; 9, Warner and Woodside, 1957; 10, Warner and Rice, 1958; 11, Warner and party, 1961.

In 1912, Bailey (1956) concluded that there were not over seven individuals left, and he did not collect any specimens for fear it would cause the extinction of the species. Wetmore in 1923 counted 20 individuals which, owing to the degree of visibility permitted by the loss of plant cover, probably represents the total population of the species at that time. He collected six, leaving a breeding stock of fourteen (Phillips, 1923; Delacour, 1956). Coultas of the 1936 "Zaca" expedition counted 11 birds, but the brevity of his visit likely precluded a thorough survey (Munro, 1944).

Vernon Brock visited the island briefly in June, 1950, and counted 26 adults and seven young during the course of a walk about the central lake (Brock, 1951*a*). In 1951 he conducted a more thorough census but found only 39 birds (Brock, 1951*b*). According to his report the beach morning-glory had become re-established around the periphery of the lake, thus offering a considerable opportunity for the ducks to conceal themselves. Judging from the behavior of the species at the time of our recent visits, it is probable that only a small portion of the population was counted in 1950 and 1951. Curiously enough, the only sign of the once-common beach morning-glory found by the "Tanager" expedition upon its visit in 1923 were two seeds lying among the rocks at the south end of the island. All other evidence of the plant had been consumed by the voracious rabbits. This vine was one of the first components of the vegetation to re-establish itself after the last of the rabbits were killed or died off. No doubt it was very important in providing shade as well as nesting and feeding grounds for the Laysan Duck during the ensuing period of recovery.

In February, 1955, the research vessel "Hugh M. Smith" stopped at Laysan for one day. Donald McKernan made a special attempt to evaluate the duck population and wrote: "my opinion is that there were less than 200 [ducks], although I have no illusions about being able to count every bird. Conditions were, however, excellent for making the counts and there is no reason why a large number of birds were overlooked." (Personal communication.)

In 1957 the writer, together with David Woodside of the Hawaii Board of Agriculture and Forestry, made a cursory transect census of the western portion of Laysan Island. From it the duck population was estimated at between 400 and 600 birds. The following year, on May 28 and 29, Dale Rice and I made an extensive transect census over the entire island. On this second occasion twelve transects were run from the ocean edge to the lake shore at intervals around the island. Distances and directions traversed were recorded, as well as numbers of Laysan Ducks, young of the Black-footed Albatross (*Diomedea nigripes*), young of the Laysan Albatross (*Diomedea immutabilis*), and Laysan Finches which passed beneath the fifty-foot cord stretched between us. Based on a dry land island area of 1.56 square miles, a population of 594 adult ducks was calculated. Such censuses are by nature conservative, because rarely are all the birds flushed or counted; but due to the sparse nature of most of the habitat the count is believed to be over 90 per cent accurate. The fact that the nesting season was well underway at the time of the census further biased the count, as incubating birds would be more difficult to flush than those not so occupied.

The surprisingly large population was further demonstrated when, in the course of one night's activity, our party of 1958 was able to capture and band 94 individuals within a study area of one-quarter square mile.

In September, 1961, a careful transect census was made using the same transect pattern as in 1958. Ronald Walker and David Woodside censused the northern half of the island; Starker Leopold and I censused the southern half. This census yielded a population of 688 ducks.

The secretive nature of the species during daylight hours presents an illusory picture of a very sparse population. In reality it approaches one bird per vegetated acre of the island, a very high density. This secretiveness and nocturnal activity has no doubt tended to make all population estimates of recent years very conservative. The population of about 600 ducks that has prevailed for the past four years is presumably approaching that which the island will support in its present condition. The response of this once endangered species to the recovery of the island's flora is heartening.

MORTALITY AND PREDATION

Despite the relatively dense population of ducks and the lack of scavenging species, no adult duck carcasses were ever found. The only possible case of adult mortality was seen in 1957. A female, disturbed by my approach while she was loafing on the western beach slope, flushed and flew about fifty yards out over the calm inshore waters of the lee side of the island, alighting on the surface of the ocean. She then paddled about in seemingly aimless fashion for perhaps fifteen minutes, gradually moving seaward toward the encircling reef which lay several hundred yards offshore. Suddenly she vanished from view and did not reappear, although the area was scrutinized for a considerable period. Perhaps she was taken by a passing shark, although no disturbance was noted.

In 1961 two dead ducklings were found, one approximately one week of age, the other about two weeks old: The progressive reduction of brood size with age, which dropped from an average of three at hatching to about one (or less) at one month, strongly suggests that population growth may be limited by juvenal mortality.

Dill in 1911 reported seeing Man-o'-War Birds (*Fregata minor*) persistently pursuing the ducks, but he did not see any successful predation. They may, however, be able to capture ducklings occasionally, as the Man-o'-War has been observed taking juvenal terns as well as young from the nests of other members of their own species. The denuded state of the vegetation during the period of Dill's visit no doubt greatly increased the duck's vulnerability to such predation and may in part account for the lack of successful reproduction in the interval from 1910 to 1920 when the number of ducks remained practically stationary.

T. M. Blackman and others have reported occasional visits to Laysan by unidentified species of hawks, and on one occasion by the Black-crowned Night Heron, *Nycticorax nycticorax* (Bryan and Greenway, 1944). It is unlikely, however, that predation by these occasional visitants would have any appreciable effect on the duck population.

One of the three endemic land birds which was unable to withstand the enormous habitat destruction was the Laysan Rail (*Porzana palmeri*) which became extinct between 1903 and 1911. While still abundant it was reported to have destroyed the eggs of the Wedge-tailed Shearwater (*Puffinus pacificus*), which are similar in size to those of the Laysan Duck. In all likelihood it destroyed the eggs of the latter as well.

The Laysan Finch is also known to destroy the eggs of several species of ground-nesting seabirds, and it may cause losses to the duck. However, the shell thickness of the duck eggs would render them less vulnerable than those of the various species of terns whose eggs are successfully broken open by the finch with great regularity, albeit with some difficulty. (Udvardy has reported several instances of Laysan Finches successfully opening eggs of Wedge-tailed Shearwaters.) Should the finch experience any appreciable success in marauding duck nests, its ubiquity—our 1958 and 1961 censuses yielded an estimated population of over 10,000 finches—would make it a considerable nuisance to the Laysan Duck at certain times of the year and especially during the period of nesting prior to the arrival of the Sooty Tern (*Sterna fuscata*) in May.

The danger of rats becoming established on the island is ever present. Were this to happen they would undoubtedly wreak great destruction on many of the nesting species. Quite likely such an unwelcome introduction would bring about the complete extinction of both the duck and the finch. The fate of two endemic Laysan land birds gives some indication of the possible consequences. The drepaniid Laysan Finch and the flightless Laysan Rail had both been successfully introduced on to the Midway Islands in the early 1900's. Murid rats were accidentally released there during the early part of World War II, and within a few years both the finch and the rail had vanished entirely from the island. I made a thorough search of both Sand and Eastern islands of the Midway group in 1958 and failed to find either species, and they are no doubt gone. There is scant possibility that the duck would fare any better on Laysan should rats become established there. With the increasing amount of visitation which Laysan is receiving from passing military, fishing, and pleasure vessels, this potentiality may be the greatest threat to the survival of the duck.

FOOD HABITS

The nightly search for lepidopterous larvae was so universally and extensively practiced as to be by far the dominant food-gathering activity of the species during the periods of observation. As illustrated in figure 3, large portions of the inner slopes of the island are covered by clumps of the prostrate, succulent boerhaavia plant, which spread mat-like over the coral sand. Interspersed among the boerhaavia are scattered clumps of bunch grass and at higher elevations intermingling expanses of bare sand. The ducks would move into the boerhaavia areas en masse at sundown, often in pairs or occasionally in family groups, and continue feeding until near midnight, at which time a distinct drop in the number of feeding birds was regularly noted. The object of this widespread search was the cutworm larva of a noctuid moth (*Agrotis* sp.) which was very abundant during the spring and summer months. The larvae buried themselves in the sand beneath the boerhaavia plants during the day, emerging in the night hours to feed on the succulent leaves of the host plant. The sand beneath the plants was searched systematically by the ducks. It was sifted through with quick exploring bill movements until one of the cutworms was located, the insect then being avidly seized and swallowed. This behavior and the nature of the boerhaavia mat are shown in figure 5. A drake, taken shortly after midnight while apparently still feeding had a total of seventy-five larvae in the crop, as well as a quantity of sand. Twenty-five of the larvae were still intact, the remainder had been deprived of their contents, leaving only empty skins.

The ubiquity of this habit, the liquid condition of the feces, and the obvious succulence of the larvae strongly suggest that this is both a food and water source of fundamental significance to the duck. A displacement pseudo-worm-catching behavior mechanism, exhibited both in the wild and in captivity when the birds are under stress, further suggests that this food source may have been of important consequence to the species over a considerable period of time. The feigned searching among the ground vegetation for cutworms, all the while watching the disturbance and working away from it, was observed commonly.

During the late spring and summer months roughly 5 per cent of the feeding occurs during daylight hours. Although most of the population is quiescent during these hours, occasional individuals or pairs may be seen puddling in the mud along the lake's edge or pursuing the myriad flies (presumably *Neoscatella sexmaculata*) which collect on the damp sand of the lake's periphery. The duck's method of capture is peculiar but seem-



Fig. 5. Laysan Duck in search of cutworm larvae beneath a patch of boerhaavia. This male was photographed while feeding at 9 p.m.

ingly reasonably effective. The bird slowly approaches an area of fly concentration, then runs briskly through it with bill open and working rapidly about an inch above the sand. The flies are so abundant as to swarm up in little clouds around the duck as it rushes down the beach. At the end of a run, it is often possible to observe the bird vigorously swallowing, suggesting some degree of success. Fisher (1903:32) reported that the stomach of a male collected near the pond was "gorged with small flies resembling the common housefly." The infrequency of this particular feeding behavior is such, however, as to indicate an incidental contribution to the diet.

Somewhat more common is the practice of searching the sand around albatross and other seabird carcasses for the larvae and pupae of flies and beetles. While this activity was not observed with any regularity, the presence of numerous pupae in the sand around the carcasses suggested a relatively profitable food-producing technique for those ducks practicing it.

Crustaceans and other littoral forms were taken from the shallow tide and spray pools on occasion, particularly along the rocky south coast of the island. While under the present conditions this type of food gathering can be considered incidental, it may have provided a significant portion of the species' diet during the critical transitional period of the 1920's. There is nothing to indicate that the vegetative changes had any appreciable effect on the littoral and spray zones of the shores of the island, except on the western side where extensive sand drifting has occurred. The ducks were very adept at using this food supply, and energetically worked over the spray pools for small mollusks and other invertebrates inhabiting the rocky holes. Their feeding behavior when

so engaged strongly resembled that of the Harlequin Duck (*Histrionicus histrionicus*) in which the head is submerged beneath the water's surface while the bird vigorously rummages about after some snail or crab.

A high incidence of diurnal and crepuscular feeding by the ducklings was noted throughout the period of study. Activity during daylight hours concentrated on the many species of flies, moths, and other insects which inhabited the lower vegetation. Feeding groups of juveniles, often of several sizes, indicating components of more than one family group, were led by a female over sizable areas of the island. Plant materials were taken, if at all, only incidentally with the arthropods which were actively sought.

Munro (1944:44) observed during a visit in 1891 that: "The wild ones [ducks] ran around the buildings in the evenings and early mornings chasing moths which furnished food for all the land birds on the island at that time. They also fed on caterpillars and maggots." This pursuit of moths was not observed during the recent studies, suggesting that the insect fauna may have been markedly altered by the changes in the vegetation.

It can therefore be concluded that the species is at present terrestrial, insectivorous and largely nocturnal, and in addition it has adapted to a life (neglecting the exceptions discussed earlier) independent of fresh water.

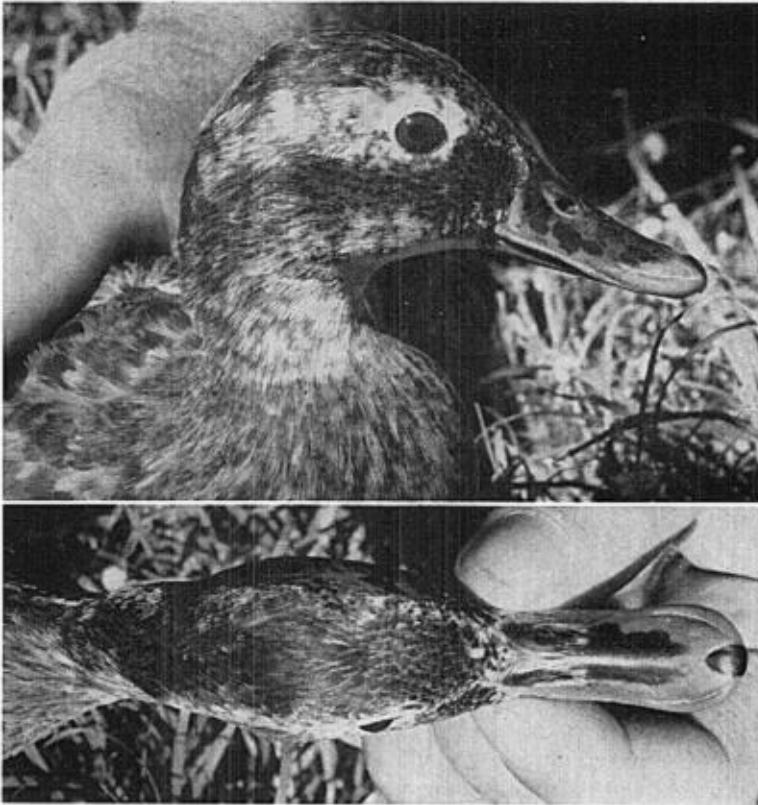


Fig. 6. Sexual dimorphism in bill marking. Female (above) shows heavy splotching on lateral surfaces, the ground color dull yellow-brown. Male (below) with black markings limited to the central ridge, the ground color greenish-blue.

SEXUAL DIMORPHISM

Although plumage pattern is similar in the sexes, several characteristics were found to be useful in distinguishing males from females: (1) the legs and feet of males are markedly more orange than those of the females; (2) male plumage is richer and darker in color, with more iridescence and gloss; (3) some, but less than 50 per cent, of the males have some suggestion of upturned upper tail coverts; (4) the male speculum is of richer coloration; (5) generally there is more white on the heads and necks of females; (6) bill coloration is markedly different, the males having a blue-green ground color with black spots along the dorsal midline whereas females have a dull brownish-yellow ground color with black spots on the lateral borders of the upper mandible. This latter is the most distinctly dimorphic feature and is illustrated in figure 6.

BREEDING HABITS

Practically nothing is known of the courtship and early breeding behavior of the species. One of the intriguing problems yet to be solved is how courtship is accomplished in the probable absence of fresh water.

Nests are built in a variety of places, for example, in patches of *Cyperus laevigatus* (Kramer, MS), under chenopodium bushes (Fisher, 1903), and amongst clumps of scaevola bushes as is shown in figure 7. The distribution of birds over the island in May

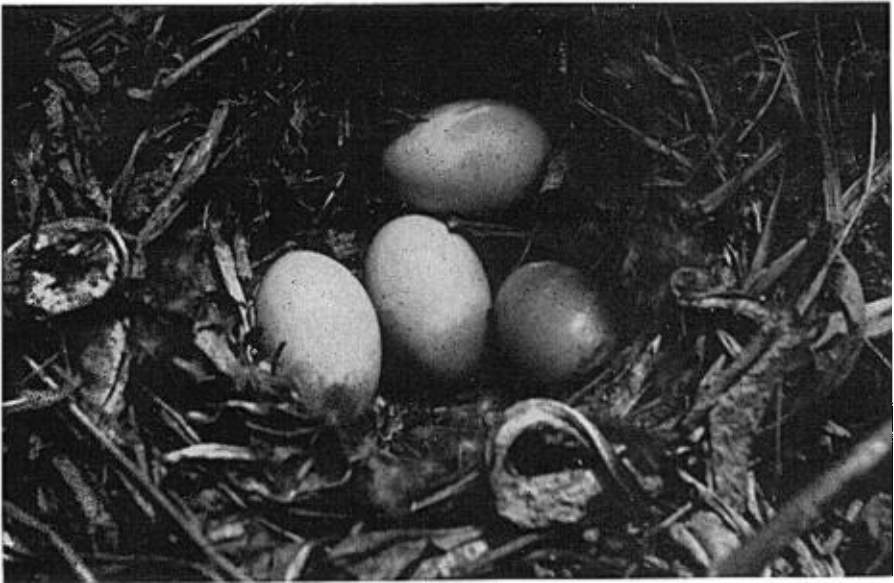


Fig. 7. Nest of Laysan Duck among clumps of scaevola on top of west ridge of island. July 1, 1957.

of 1958, with the great majority concentrated in the beach morning-glory and with feeding in the boerhaavia at night would indicate a strong preference for the beach morning-glory zone during the breeding season. However, no nests were found in this area despite concentrated efforts. It is not possible to say whether this lack of success was due to the density of the vegetation or to a paucity of nests.

Copulation was observed only once. On June 28, 1957, a pair was observed loitering about the northern end of the lake flat in an area of scattered shrubs at midday. There

was no apparent pre-copulatory activity; the male moved up to and mounted the female who submitted, the activity taking less than a minute. Afterward the pair stood quietly side by side, then moved slowly off together.

Pairing continued at least until midsummer, but it was particularly noticeable during spring and early summer. Kramer observed that during the latter part of April an estimated 90 to 95 per cent of the birds were paired. We found no evidence of birds remaining paired after the onset of the molt. However, the observations in September, 1961, indicated many firm pairs in fresh plumage. Aggressive male hostility toward possible interloping males was commonly observed. Presumably, then, there is a relatively brief solitary period during the molt, with pairing occurring very shortly thereafter.

The young were in the majority of cases attended by the female, but at least two exceptions to this were noted. On June 26, 1957, a female was observed with three yellow-brown downy young on the west portion of the lake flat. A male suddenly flew in, alighted, and drove the hen away. The young subsequently followed the drake for the remainder of the 30-minute observation period. The following day a drake being followed by three very young ducklings was seen at the northwest corner of the lake flat. The young appeared to be less than one week old. The group was very tame, permitting approach to within three feet before becoming agitated.

It was rather common to find elements of two broods cared for by a single bird.

EFFECTS OF INSULARITY ON BEHAVIOR

As is true of many species of wildlife evolving in insular environments, the Laysan Duck exhibits greatly reduced fear responses. Curiosity or its avian equivalent is hence expressed to a markedly greater degree than in mainland forms, resulting in almost exaggerated quizzical behavior whenever a new feature, such as a man, is added to the environment. There is a great deal of neck-craning and prolonged examination whenever such a strange stimulus is presented. Birds can on occasion be decoyed into walking up to the observer by playing on this curiosity.

One excerpt from my field notes of June 25, 1957, illustrates the three basic responses to man: "5:50 p.m.—four drakes seen at edge of brush (*Scaevola*) along crest of west ridge 200 yards south of camp. When approached closely two ran into the shrubs, the other two remaining watching me. When I was within ten feet the remaining two flew off to a distance of twenty feet, then walked slowly away. At that moment a pair (male and female) walked out of the same clump of shrubs and, being suddenly alarmed at my presence, flew off [strongly] toward the lake."

Strong, rather swift flights from one end of the island to the other or across the lake have been observed, but not commonly. The ducks usually act as though they are reluctant to take wing and when flushed rise slowly as if preferring to remain on the ground. Certainly flight under normal circumstances is at best a convenience and likely is unnecessary to the economy of the species. The possibility of being blown to sea during periods of heavy winds is also considerably increased with any proclivity for flight.

It was noted that in contrast to most duck species, the resistance to water soaking was reduced in the Laysan Ducks. On nights when thundershowers occurred the birds quickly became drenched (because they were bathing in the wet vegetation?) and required several hours to dry out completely. The feathers when dry also lacked the oily sheen typical of most ducks, appearing dull and lusterless as though inadequately oiled. Such a condition would have a marked negative survival value for any individual blown to or lost at sea and having to alight on the ocean. However, those birds which were captured and placed on inert food developed what seemed to be the characteristic duck-like sheen and had an increased resistance to wetting.

It would be reasonable to expect modifications in the familiar puddle-duck home range and breeding territory patterns. The establishment of feeding territories, especially during the breeding season, might be anticipated in such a sedentary form. Data indicate seasonal reuse of the same area but otherwise are at present too incomplete for further conclusions.

TRANSPLANTING OF SPECIES

Concern for the welfare and possible extinction of the Laysan Duck has grown over the years. Since the size and status of the wild population were unknown, the 1957 expedition was organized to make field investigations and, if possible, to live-capture a limited number of birds for a breeding nucleus at the Honolulu Zoo. Accordingly, eight ducks were subsequently captured in 1957 and transported to the zoo; all survived there under the skilled supervision of director Paul Breese.



Fig. 8. Female captured in June, 1957, and photographed in September, 1959, after two years of captivity in the Honolulu Zoo. Shows increase of white on head and neck.

In 1958, thirty-six ducks were live-trapped at night using a gasoline lantern and long-handled dip net. The birds were then transported to the Honolulu Zoo for acclimatization and ultimately shipped to selected aviculturists in America and Europe. Those receiving breeding stock included: Philadelphia Zoological Gardens, San Antonio Zoo, Dr. Jean Delacour, Dr. S. Dillon Ripley, Wildfowl Trust, San Diego Zoo, Tracy Aviary, and the Bronx Zoo. During the period of acclimatization at the Honolulu Zoo, nine of the birds died. Autopsies revealed no evidence of disease, but the ducks were in advanced states of malnutrition. By separating the birds into progressively smaller groups, Breese was able to stop the mortality, suggesting that there had been intensive intraspecific conflicts contributing to the starvation in addition to the problems of adjustment to new surroundings and diet. Of the adjustment to captivity Breese (personal communication) wrote: "The day these birds arrived we began providing in addition to the worms [corn ear worms and earth worms] wet mash and wet grain and lettuce in the pools. In the beginning their interest in artificial food centered on wet mash and

they consumed a great deal of this. Then they would take dry mash and grain also, but very little lettuce. As the months went by, they fed well on the lettuce but slacked off somewhat on the mash and grain intake. Knowing they were worm feeders, we wanted to supply the animal protein but couldn't get them interested in taking more mash."

One interesting response of the birds to captivity was a marked increase in the degree of whiteness of the head feathers, especially in females. This occurred within a season of confinement and is illustrated in figure 8. The phenomenon is progressive and appears directly related to length of time in captivity. The same kind of albinism has been reported in the Laysan Ducks being reared in the Philadelphia Zoo (Griswold, personal communication) and in the captive Koloas. One old female Koloa at the Honolulu Zoo has gradually developed nearly two-thirds white plumage, particularly around the head, neck, and breast. The cause of this is unknown.

The success achieved to date in rearing the Laysan Duck in captivity is most reassuring and demonstrates that the species can be preserved despite some catastrophic accident to the wild population. But because of this, I am compelled to stress most strongly the conviction that our success in preserving the bird under artificial conditions must not be a justification for relaxing vigilance in the protection of the wild population on Laysan Island. Any wild species loses much of its identity, its aesthetic value, and its ecologic significance when divorced from the habitat instrumental to its evolution.

PRESERVATION

We may expect ever-increasing dangers to the wild population in years to come. Typical of the threat to the integrity of Laysan Island and the whole of the fauna of the Leeward Islands is an incident which occurred less than two years ago. At that time the military was interested in establishing a new electronic facility in the leeward area. A team of investigators was sent to the various possible facility sites, including Laysan Island. No request to conduct such an investigation was received by the Hawaii Department of Land and Natural Resources which presently watches over the refuge. In fact, conservationists had no knowledge of this survey until well after it was completed.

Hawaii has many times in the past experienced the pressures induced by the hushed phrases of "secret" and "national defense" when a military project was planned. Often the activity following therefrom had little immediate relation to either secrecy or national defense. By nature such activities are difficult to analyze or rebutt, because conservationists are unable to evaluate the relevance of the claim due to the "classified" nature of the project. The situation can at times become extremely difficult. One wonders, for example, what would have happened had Laysan been found eminently suitable for the proposed facility.

It can be seen therefore that the future of the Laysan Duck, as is true of many other species inhabiting the Leeward Islands, is far from secure. The neglect of this refuge by the United States Fish and Wildlife Service for many years has recently been rectified, with that organization taking a greatly increased interest in proper administration and protective measures. Research teams have been sent into the area, and long term studies are planned. With continued supervision and inspection, with sustained alertness and interest by Hawaiian conservationists, and with a certain amount of luck the Laysan Duck may continue to lead for another millennium the unique, tranquil, and rather unduck-like existence which has until recently been its heritage.

ACKNOWLEDGMENTS

A number of persons and organizations participated in one or more aspects of the activities here reported, and without their combined assistance little would have been

accomplished. Nevertheless, all interpretations of data and opinions expressed are solely mine. The 14th Coast Guard District through Rear Admiral S. H. Evans and recently Rear Admiral R. M. Ross generously provided transport to Laysan Island on all four occasions. It was a pleasure to work with Dr. A. Starker Leopold on the 1961 investigations. Dr. Miklos Udvardy, University of British Columbia, and Dr. George Butler, University of Arizona contributed materially to the success of the 1959 expedition. The author owes a special debt of gratitude to Dale Rice who participated in the 1958 expedition and provided important assistance and many valuable suggestions and ideas. The continued support and assistance of Johnson Neff and the United States Fish and Wildlife Service made possible the very successful field activities of 1958. I am indebted to Ray Kramer, Hawaii Department of Land and Natural Resources, for the use of his very helpful observational notes made during April, 1959, to David Woodside of the same organization who participated in the 1957 and 1961 landings, and to Ronald Walker for his assistance in the 1961 census. Dr. Prentis Burtis, Dr. Ted Landers, and Lt. (jg) Dick Takahashi provided important assistance during the banding and live-trapping operations in 1958, and Charles Daniel helped in many ways during the study of 1959. Donald McKernan, director of the Bureau of Commercial Fisheries, United States Fish and Wildlife Service, generously provided details of the only known observations of the habits of the species during winter months. Dr. Harold J. Coolidge was instrumental in bringing about the 1961 expedition.

The assistance of Dr. Alden H. Miller and Dr. A. Starker Leopold, who read the entire manuscript and provided numerous helpful suggestions and criticisms is acknowledged with sincere appreciation.

Lastly, to Dr. Cyril Pemberton, who in 1957 introduced me to the Laysan Duck, I would like to dedicate this paper. It is hoped that the interest he aroused in this species has contributed something to the understanding and preservation of the native Hawaiian biota which this eminent conservationist has labored so diligently to protect.

SUMMARY

The Laysan Duck (*Anas laysanensis*) occurred originally on two of the Leeward Islands of the Hawaiian chain, namely Laysan and Lisiansky. It is completely non-migratory and essentially terrestrial in habit.

Sport hunting and killing for food reduced the population on Laysan to less than 25 individuals by 1909. The population on Lisiansky had apparently vanished by 1895 of unknown causes. Denudation of Laysan by domestic rabbits introduced in 1903 led to almost complete extinction of the species. During the critical years of 1911 to 1924, the surviving population was variously counted to be about a dozen birds, and on one occasion (1912) the species numbered seven individuals. The rabbits died off or were killed off in 1924 or shortly thereafter. The recovery of the Laysan flora in the ensuing 35 years has been accompanied by a progressive increase in the duck population, estimated at 400 to 600 in 1957, 594 in 1958, and 688 in September, 1961.

Courtship and early breeding behavior are still unknown. Pairing is evident in April and continues until midsummer. Banded birds were found to use the same area for breeding and nesting each year. The possibility of permanent home ranges was suggested, but needs confirmation. Proclivity for flight has been markedly reduced. The species is entirely terrestrial during spring and summer, largely nocturnal, insectivorous, and has adapted to a habitat devoid of standing fresh water.

Insular tameness, or loss of elements of wild behavior, was noted.

A total of 44 birds were live-captured and captive breeding populations are now being maintained at nine locations in America and England. The establishment of such

captive breeding populations should not be permitted to induce laxity in the protection of the wild population. The future of the species, in common with the rest of the fauna of the Leeward Islands, is far from secure. Continued supervision, alertness, and interest by conservationists are needed to assure its perpetuation.

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