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THE ROLE OF INTRODUCED DISEASES IN THE EXTINCTION OF THE ENDEMIC HAWAIIAN AVIFAUNA*

By Richard E. Warner

...This report examines first the historical evidence of changes in the indigenous avifauna, especially as related to the effects of introduced diseases. Then it presents experimental evidence clearly demonstrating the high susceptibility of existing drepaniid species to avian malaria and birdpox. Other ecological data are presented that substantiate the theory of extinction and restriction of range by exotic pathogens, which in turn are spread by introduced mosquitoes. Some predictions, based on the evidence derived from field studies and controlled experiments, are offered regarding the future of the Drepaniidae and the endemic Hawaiian avifauna in general.

PRIMEVAL AND EARLY HISTORICAL CONDITIONS

Distribution: ...At the time of discovery the native forests, together with their bird populations, extended from the high mountain slopes to the ocean....Some species were very limited in their distribution. For example, the Grosbeak Finch (Psittirostra kona) was restricted to the Kona district of Hawaii where it inhabited an area of a few square miles. In contrast, the 'I'iwi (Vestiaria coccinea) and the 'Apapane (Himatione sanguinea) were ubiquitous, ranging from the coastal lowlands to the upper limits of the high forests on all the high islands.

Movement Patterns: There is considerable historical evidence of seasonal migrations, both altitudinally and from one forest area to another. Prolonged winter storms would apparently induce movement of highland forms into the lower forests and often to the seashore itself. Some of these winter altitudinal movements may, however, have been regular seasonal migrations to the lowlands....I believe that these long-established movement patterns had an important role in the decline of the endemic avifauna.

Use of Introduced Plants: Despite a widely held current view to the contrary, some species of drepaniids were not restricted in their feeding habits to the native flora. For example, the 'O'u (Psittirostra psittacea), which normally fed on the fruit of the native 'Ie'ie (Freycinetia arborea), mountain apple (Eugenia malaccensis) and the berries of the lobelias (family Lobeliaceae), was observed by Munro (1944:124) to feed on guavas (Psidium guajava) on Kauai and on mulberries (Morus sp.), both introduced plant species. Henshaw (1902:44) reported of the Hawaii 'Amakihi (Loxops virens): "It has learned also that the imported nasturtium (Tropaeolum sp.) secretes a fine quality of honey and, however close to the house the flowers may grow, it pays them regular morning and evening visits." He also reported that the Hawaii

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'Amakihi regularly utilized the blossoms of the banana (Musa spp.)...On Oahu the 'Amakihi was reported during earlier times (Perkins 1903:409) to be very partial to the nectar of the introduced lantana (Lantana camara). The Maui 'Amakihi was seen in great numbers visiting the flowers of the introduced canna (Canna indica and C. edulis) in the Iao Valley (ibid); and Baldwin (1953:362) has reported observations of E. Y. Hosaka wherein: ...hundreds of Vestiaria and Himatione are attracted to the flowering groves of introduced tree alfalfa in upland pastures of Haleakala, Maui.

Thus the replacement of native plants by exotics did not necessarily leave the drepaniids without food.

THE PATTERN OF CHANGE AND ITS IMPLICATIONS

By the late 1800's it was apparent that drastic changes were taking place in the endemic bird populations. Cattle, sheep, and goats introduced by Cook, Vancouver, and others at the beginning of the 19th century had multiplied and were causing widespread damage to the native forests. Trees were being cut for commercial purposes, and fires had increased in severity. Suitable lowland areas were being cleared for agricultural purposes....Exotic plant species were already spreading in the disturbed areas, and to a lesser extent into the still-intact native forests. In addition, various predators, such as the feral housecat and the introduced mongoose (Herpestes javanicus auropunctatus), were well established on several islands....

The avifauna of Oahu seems to have experienced an especially rapid decline. By 1900, six of the 11 endemic passerine species were believed to be extinct.... The Oahu 'O'u (Psittirostra olivacea) was among the species that vanished during this period. It was known to be present on the island in 1893 and 1899, but was practically extinct by 1901. Henshaw (1902:66) wrote: The cause of the extinction of the 'o'u upon Oahu seems to be very obscure. The fruit of the 'ie'ie vine is the particular food of the bird, and there are considerable tracts of timber on the mountains of the island where this vine still abounds. So too, there are sections where the introduced guava and the mamaki are still plentiful, and the 'o'u is very fond of the fruit and berries. There apparently being no scarcity of food and shelter, why should the 'o'u have disappeared from Oahu, and yet persist upon other islands where the timbered areas are even more restricted?

The changes were no less drastic on the small island of Lanai, although they occurred later than on most other islands. George Munro spent many years on Lanai and was able to watch the process of extinction there. In 1923, according to his reports, the forest birds were at least holding their own, and some species may have been increasing. But by 1932, although the forest was still intact, the native birds were rapidly declining in number....As a consequence of his observations, Munro was convinced that introduced diseases were playing a major role in the destruction of the native bird fauna.

Those species of native Hawaiian birds that still persist today are found, with the exception of the 'Elepaio (an Old World flycatcher: Muscicapinae), only in the upper forests, above elevations of approximately 600-900 m, depending upon local climatic and geographic circumstances, and on the low, isolated, and mosquito-free leeward islands of Nihoa and Laysan. The more ubiquitous species, such as the 'I'iwi and 'Apapane, still range over large areas of the high forests of the main islands. Others, such as the Kauai 'O'u, are for reasons as yet undetermined now confined to quite small portions of the relatively undisturbed high forests.

INTRODUCTION OF POTENTIAL AVIAN PATHOGENS AND THEIR VECTORS

Avian Malaria: The potential for avian malaria has probably existed in the Hawaiian Islands for thousands of years. Each autumn over a million migrating shorebirds and ducks pass from Alaska, Siberia, Canada, the United States, and possibly Mexico, to the Hawaiian Islands....A variety of blood parasites, including the one causing avian malaria, have been reported in North American shorebirds and ducks....It is therefore safe to assume that a reservoir of Haemoproteus and

Plasmodium existed in the Hawaiian Islands even before the arrival of Europeans. The random introduction of domestic and jungle fowl, domestic ducks, turkeys, game birds, and other avian stock without doubt was important in augmenting and maintaining the reservoir of blood parasites during spring and summer seasons when the migratory birds were absent.

The Night-flying Mosquito: Nevertheless, in the absence of a suitable vector, avian malaria could not be passed on to the native birds; and it is known that Hawaii was free of mosquitoes before the arrival of Europeans. This "deficiency" was satisfied when the tropical and subtropical form of the night-flying mosquito Culex pipiens fatigans (= quinquefasciatus Say), now known to be the principal vector of avian malaria, was accidentally introduced onto Maui in 1826....Investigation back-tracked the trail to...the ship Wellington, whose watering party had drained dregs alive with wrigglers into a pure stream, and thereby to blot one more blessing from the Hawaii that had been Eden. Apparently no attempt was made to isolate and destroy the hatchery, nor to prevent spread of the pest throughout the archipelago....The coastal areas of Hawaii are sufficiently tropical that the species quickly became established, and in time spread to the lowlands of all the major islands. Since Culex breeds in ground water and is known to have a flight range of at least 14 miles, its spread to other habitable parts of an island, once an initial colonization was accomplished, was no doubt very rapid. Culex also is able to complete normal development in 30 per cent sea water, enabling it to breed in the numerous coral holes along coastlines and thus to penetrate even the drier districts.

While this mosquito has been found breeding sporadically at altitudes higher than 1525 m,...the population densities drop precipitously when elevations above approximately 600± 150 m are reached, the variation being dependent upon local conditions....The ecologically determined upper limit of spread of the Culex populations was to have a profound effect on the events that followed....

Birdpox Virus: The birdpox virus, long a bane of domestic poultry, was without doubt carried to the Hawaiian Islands soon after their discovery by Europeans. The virus (or viruses) has been found in both the Old and New Worlds, and has been reported in a variety of passerines and other bird groups. Birdpox is known to be transmissible by mosquitoes and other biting flies such as the hippoboscids, the virus being carried on the proboscis of the insect after it feeds on an infected bird. It is reported that mosquitoes are able to infect susceptible birds for two months after a single feeding on an infected bird....

Hippoboscid Flies: It is likely that hippoboscid flies, known as vectors for several blood parasites including several species of Haemoproteus, were introduced at an early date with the domestic fowls....Perkins (1893:106) reported hippoboscids on an 'I'iwi captured near Kona in the 1890's. I found heavy infestations of hippoboscids on lowland Kauai populations of the introduced House Finch (Carpodacus mexicanus)...in 1961. We may thus conclude that the vector is well established today.

EARLY EVIDENCE OF DISEASE IN THE NATIVE AVIFAUNA

Birdpox: Numerous descriptions of birdpox or "bumblefoot" in lowland populations of the endemic avifauna are found in the early literature....Available evidence indicates that in the second half of the 19th century the lowland populations of the native avifauna on all the major islands experienced severe infestations by birdpox. These epizootics were so numerous and extreme that large numbers of diseased and badly debilitated birds could be observed in the field. The epizootics were heaviest in the wetter portions of the lowland forests and increased in severity during the rainy season. The disease is present to some extent today both in introduced and endemic bird species.

Avian Malaria: There is no direct historical evidence of the effects of avian malaria on the endemic avifauna, principally owing to ignorance of the nature of the disease and its causative organism during the early period....There is, however, considerable circumstantial evidence suggesting that this pathogen was of profound importance in the extinction of the endemics.

In this regard the report of Henshaw (1902:20) is of great significance: "...I am not aware that the birds of the Hawaiian Islands are more subject to fatal diseases than those of other lands. Dead birds are, however, found rather frequently in the woods on the island of Hawaii, especially the 'i'iwi and 'apapane. There is no doubt that sudden and marked changes of temperature affect Hawaiian birds unfavorably, especially the two species just mentioned and, after heavy and prolonged storms, many individuals of both species are driven into sheltered valleys and even along the sea shore far from their woodland haunts. Under such circumstances scores of the above named species are picked up dead or dying, and the mortality among other birds is, perhaps, unusually great." Henshaw was, of course, unaware of the possible presence of avian malaria in the lowlands. I am convinced that the mass mortality of birds driven into the lowland areas by winter storms or other causes and exhibiting no birdpox lesions can be directly attributed to massive infections of one or more species of Plasmodium, the organism causing avian malaria. Evidence...established the extreme susceptibility of the drepaniids to avian malaria. What had been in primeval times a retreat from inclement weather had become, with the advent of the Culex mosquito, a death trap for the native birds.

Plasmodium has to date not been reported in wild drepaniids, and I searched in vain for it in these birds on both Kauai and Hawaii....However, Baldwin (1941) and Fisher and Baldwin (1947) reported Plasmodium in the introduced Pekin Nightingale (Leiothrix lutea) and the White-eye (Zosterops japonica) in the Hawaii National Park area of Hawaii. In addition, Alicata (1947) and Kartman (1949) have demonstrated Haemoproteus columbae in pigeons from the Honolulu area. I found several species of Plasmodium and another blood parasite, possibly Haemoproteus, in lowland Kauai populations of the introduced White-eye and House Finch in August 1961. Of seven White-eyes examined, all had mild infections of avian malaria; of 10 House Finches examined, all had avian malaria, and three possibly contained Haemoproteus.

There is little doubt that other introduced passerines will eventually be found to carry the disease....Nevertheless, major responsibility for establishment and spread of avian malaria andother debilitating diseases cannot be assigned to the introduced passerines of the Hawaiian Islands. The migratory shorebirds and waterfowl, the numerous domestic fowl, and the introduced upland game birds...all without doubt played, and continue to play, significant roles in the spreading of these pathogens.

EXPERIMENTAL EVIDENCE OF DREPANIID SUSCEPTIBILITY TO BIRDPOX AND MALARIA

General Plan of Experimentation: In 1958 a series of studies on disease susceptibility in the Drepaniidae was begun....The problem ultimately resolved itself into four partially independent components including: (1) susceptibility of the Laysan Finch (Psittirostra cantans) to birdpox virus; (2) susceptibility of the Laysan Finch to avian malaria; (3) susceptibility of the high-forest drepaniid populations to birdpox virus; and (4) susceptibility of the high-forest drepaniid populations to avian malaria.

Birdpox Induced in the Laysan Finch: ...Studies...had established that Culex was absent from the remote and isolated leeward Hawaiian island of Laysan. This small sand island hosts one species of drepaniid, the Laysan Finch, which is present in considerable numbers and is easily captured....In June 1958, 24 specimens of the Laysan Finch were ...transferred to Honolulu...in cages tightly wrapped with several layers of cheesecloth. Upon arrival they were placed in a large cage in the basement of the Board of Agriculture andForestry Building in downtown Honolulu. The cage remained swathed in cheesecloth to prevent entry of insects, especially mosquitoes....Hence, this first experimental effort was an attempt: (1) to maintain

the species in an apparently hostile environment by eliminating potential contact with possible arthropod disease vectors, and (2) subsequently to induce and then to diagnose any avian disease that might manifest itself in the caged Laysan Finches.

The caged finches were fed mixed bird seed, abundant greens, and fruit. Raw eggs and chopped hard-boiled eggs were occasionally provided. A supply of coral sand had been obtained from Laysan Island, and was available ad libitum. The birds consumed substantial quantities of this, much more than the usual gravel consumption by seed-eating birds. Standard canary gravel and water were also supplied ad libitum. The finches remained very partial to raw eggs, a taste acquired during their more predatory, egg-eating days on Laysan.

The birds were maintained in the tightly screened cage for two months, with no mortality and no evidence of any disease. There was much singing, molted feathers were properly replaced, and a minimal amount of agonistic behavior was exhibited. Interesting elements of their Laysan-adapted behavior were observed regularly, for example, their proclivity to bathe among wet spinach greens placed in the cage as food (Laysan has no standing fresh water supplies). The general impression obtained from the captive group was of a hardy and gregarious finch, capable of living comfortably in crowded conditions.

After two months of this cloistered existence, the cheesecloth cover was removed from the cage. The windows of the unscreened room were opened wide to permit entry by mosquitoes and other insects. All other conditions, including diet, remained unchanged. It is important to note that the mosquito population in Honolulu had, largely through the continued vigorous efforts of the then Territorial Board of Health, been reduced to the merest fraction of its earlier size. This was especially true in the downtown Honolulu area where the experiment was being conducted; in the peripheral and mauka (upland) regions of the city adjacent to forested areas, mosquito populations remained relatively high.

Within two weeks after removal of the protecting cheesecloth, indurated swellings typical of the first stage of birdpox virus infection had appeared on lores, tarsal, and wing joints (bend of wing) of six of the finches. These swellings increased in size, then erupted as granular, tumorlike lesions, and finally became necrotic with accompanying secondary bacterial infections. A bacterial examination was made on one of the more severe foot lesions....Smears and cultures were made, which subsequently demonstrated cocci of mixed types typical of secondary infection with necrosis.

By the end of one month virtually every finch had at least one lesion, and several had as many as three or four at different exposed points, such as the corner of the mouth, forehead, eyelid, or foot. As the tumors progressed in severity bleeding occurred, particularly from the foot lesions. The afflicted birds gradually weakened, and death occurred after a variable period, generally after the lesions had become granular and necrotic.

It is well known that domestic fowl and many passerines have genetically inherited immunological capacities against the pox virus....To test whether the Laysan Finch, despite its long isolation from the virus, had some degree of immunogenetic capacity that was being masked by death due to secondary bacterial infections, three birds suffering from acutely severe tumors were treated with the antibiotic Auromycin. These birds remained active after all others had succumbed, despite an increase in tumor size to grotesque proportions. The initial pox lesion was above the right eye; the tumor had become very large and was physically delibitating. At the termination of the experiment there was no sign whatsoever of regression in any of the lesions. On this basis I conclude that the Laysan Finch has altogether lost--or never acquired during its evolutionary history--a functional immunogenetic capacity against the birdpox virus.

Birdpox Induced in High-Island Drepaniids: In 1961, in the course of experiments with wild-trapped drepaniids from the mountain forests of Kauai, additional evidence of susceptibility to the birdpox virus was obtained. Eight specimens of the 'Amakihi (Loxops virens), Lesser 'Amakihi (Loxops parva) and 'Apapane from the

Koke'e region of Kauai (elevation approximately 1100 m) were trapped alive and transferred to the lowlands near Lihue, Kauai. While under observation for residual effects of avian malaria, which all eight had contracted during an experimental exposure to the lowland mosquitoes, the mosquito-bitten legs, feet, and lores of these birds developed large numbers of the indurated swellings typical of the first stage of birdpox. Unfortunately, the study had to be terminated before the possibility of immunogenetic resistance to the virus was determined. However, it is quite clear that the extant drepaniid populations of the high forests of Kauai are still susceptible to the birdpox virus. Future studies must determine whether exposure to the pathogen over the last century and a half has conferred on the high-island drepaniids some measure of resistance not currently shared by the isolated Laysan Finch.

Avian Malaria Induced in the Laysan Finch: ...Thirty-six Laysan Finches were trapped alive on Laysan Island in July 1959. The birds were brought to Lihue, Kauai, again in cages tightly shrouded with several layers of cheesecloth, and then placed in hardware cloth cages in a mosquitoproof room for one month before the start of the exposure experiment....On 22 September 1959 the birds were separated into three groups, consisting of two lots of 13 birds each for experimental and control groups, and the remainder for other studies. Peripheral blood smears made from all birds before the start of the experiment were negative for malaria or other blood parasites. One group of 13 birds was...placed outside but under a sheltering canopy to protect it from inclement weather and direct sun. The other group remained in the mosquito-proof room as a control.

The first death occurred in the experimental group after five nights of exposure to the lowland Kauai environment. After 12 nights of exposure five more birds of the experimental group were dead, and the remainder were showing signs of severe debility. By the end of the 16th night of exposure the last of the outside group had died. The control group remained in excellent condition throughout, with no deaths or visible signs of debility....Peripheral blood smears from several debilitated birds of the experimental group contained massive infections of Plasmodium; in one specimen, 97 per cent of the erythrocytes contained schizonts in various stages of maturation.

It is likely that anemia resulting from direct loss of blood to the feeding mosquitoes also played a role in debilitating the exposed finches. Evidence obtained in subsequent experiments...has established that the drepaniids are more likely to be bitten by mosquitoes than are other, better-adapted passerine groups. Thus, the combined action of mosquito attack per se and malaria-induced erythrocyte destruction with toxaemia was fatal to the susceptible birds.

Having established that the lowland malaria potential was great enough to cause mass mortality in the Laysan Finch, further tests were conducted to determine the minimum exposure necessary to induce a severe malarial infection....It is clear that (1) the Laysan Finch, and probably the Drepaniidae in general, are extremely susceptible to avian malaria; and (2) three nights of exposure to the night mosquito were sufficient to produce lethal infections of Plasmodium, given the Culex density present at that time. In all likelihood, lethal infection of malaria could have been achieved with but one night of exposure in earlier times, before the advent of mosquito-control programs.

Avian Malaria Induced in High-island Drepaniids: An opportunity arose in 1961 to pursue further the question of susceptibility of the high-island remnant populations of drepaniids to Plasmodium. A month was spent on the island of Kauai during July and August of that year conducting the necessary experiment....It is clear that (1) avian malaria is not present in the Kauai high-forest drepaniids or in populations of White-eyes with which they are in contact; (2) the drepaniids exhibit a far greater susceptibility to avian malaria than do the White-eyes; and (3) under the conditions of this cage experiment the pathogenicity of Plasmodium to the drepaniids is still great enough to be potentially lethal, despite exposure

of at least the lower fringes of the drepaniid populations to the pathogen for perhaps 100 years (the exact date of the Culex introduction onto Kauai is unknown).

NONIMMUNOGENETIC FACTORS INFLUENCING SUSCEPTIBILITY

Observations of the birds sleeping at night yielded several significant points. (1) The sleeping posture of the White-eye differs in important ways from that of the drepaniids. The White-eye would almost invariably tuck bill and face into the fluffed back feathers. It also fluffed the breast feathers, and crouched down with belly nearly touching the perch. These actions materially reduced the ability of Culex to find exposed soft parts to bite. None of the drepaniids, including the Laysan Finches observed 1959, slept in this posture. As a consequence the corner of the bill, the forehead, and the tarsi were exposed to mosquito attack when the birds were asleep. Mosquitoes could be observed regularly feeding at these exposed points on the drepaniids throughout the night hours....(2) The number of mosquitoes attracted to the sleeping drepaniids was markedly greater than for the White-eyes. Counts of Culex resting on the body feathers, perched near the birds' feet, or actually feeding on the drepaniids were five to ten times greater than in White-eyes. On rare occasions a mosquito would be observed feeding on a White-eye, usually on the foot. The mechanism responsible for this subtantial difference in attractiveness has not been determined.

MALARIA IN INTRODUCED BIRD SPECIES IN THE LOWLANDS

While the drepaniid lowland exposure experiment was in progress (August 1961) some lowland passerine forms were sampled for blood parasites. Birds captured in nets near Lihue, Kauai, were bled for peripheral blood smears, examined for ectoparasites and evidence of birdpox lesions, banded, and then released.

Seven White-eyes and 10 House Finches were taken. All had light infections of Plasmodium. Three House Finches exhibited blood forms suggestive of Haemoproteus. These same finches were found to be carrying numbers of parasitic pupiparous flies of the family Hippoboscidae....These same birds exhibited considerable evidence of present and former birdpox lesions. Toes were missing, and primary indurated swellings were found on feet, legs, bend-of-wings, and head.

MALARIA IN AN ENDEMIC NONPASSERINE SPECIES

During the summer of 1961 large numbers of the endemic Dark-rumped Petrel (Pterodroma phaeopygia sandwichensis) were observed and reported grounded along the windward beaches of Kauai. Birds were frequently seen along the roadways, usually dead but on occasion alive yet unable to fly. It was at first presumed that occasional birds were being attracted into collision with automobiles at night by the glare of headlamps. However, the number of dead birds found off the roadways and along beaches defied explanation....

I made blood smears from a fledged juvenile Dark-rumped Petrel and found a serious case of avian malaria. The bird, although alert, was unable to fly, even when launched into the air by hand.

The Dark-rumped Petrel is endemic to the Hawaiian Islands, and during earlier times nested on all the major islands. It is now known to nest only locally on the higher volcanic slopes of Maui and Hawaii, and probably on Kauai. It is possible that this species and the endemic Newell's Shearwater (Puffinus newelli), which is also believed to be virtually extinct, have suffered the same fate as the drepaniids. The Newell's Shearwater, once abundant, was known to nest in burrows on the lower slopes of most or all of the high islands. Thus those portions of the shearwater and petrel populations that had nesting burrows within the "mosquito belt" were in locations eminently suited for exposure to the introduced night mosquito and its various pathogens. The nestlings would be especially vulnerable to mosquito attack owing to their lack of a dense feather covering and their sedentary behavior. It remains, however, for further studies to clarify the role, if any, of mosquitoes in the reduction of petrel populations.

PRESENT DISTRIBUTION OF THE DREPANIIDS

Surveys conducted in recent years...definitely established that the Drepaniidae are now confined to regions above 600 m, and in some instances considerably higher elevations....It is my conclusion, in view of the recent evidence, that the principal reason that the more ubiquitous drepaniids remain strictly in the regions above 600 m is to be found in their continued susceptibility to introduced diseases, principally avian malaria and birdpox. Any protracted visit to the lowland mosquito belt would mean immediate death from infections of Plasmodium. Even if some survived the malaria, onset of birdpox would complete the extermination.

SELECTION PRESSURES TOWARD IMMUNOGENETIC CAPACITIES IN THE REMNANT AVIFAUNA

Given the conditions of a high-mountain sanctuary, an interface of host-disease interaction at about 600-m elevation, and occasional forays by the host species into the lowlands, it is significant to ask if some degree of immunogenetic capacity might be developing in the remnant populations....

There is some indication that the Oahu 'Amakihi may be recolonizing certain lowland habitats. However, the present lack of evidence makes it impossible to tell whether this extension of range is resulting from an historically developed immunogenetic capacity against introduced diseases, a reduction in arthropod disease vectors to subcritical densities, or both.

While certain aspects of the general problem will no doubt remain obscure, many of the specifics can now be explained. The hitherto enigmatic abandonment of intact lowland forests and the concomitant extinction of forms having strong altitudinal migration patterns or fixed lowland habitats is clarified. The early and exceptionally rapid extinction of most of the endemic avifauna of Oahu, when viewed in this light, also is explained. This island has extensive areas of low elevations suitable for propagation of Culex, a situation compounded by the lack of adequate high-forest sanctuary areas. According to the survey conducted by the Territorial Board of Health, Oahu has the greatest acreage of major actual breeding sites of Culex of any of the islands. Despite continued control efforts, parts of the island are still plagued with enormous numbers of Culex.

As regards the critical high-forest sanctuary areas, Oahu has only one mountain over 1000 m (Mt. Kaala, elevation 1228 m) and but two over 900 m....This ecological vulnerability was compounded by the early establishment of domestic fowl populations associated with a large and widespread human population. It is therefore not surprising that so few of Oahu's endemic forms survived the onslaught.

PORTENTS OF THE FUTURE

There is nothing man can do to re-establish a species, once it is extinct.... Hope persists for those species that now exist as remnant populations in the sanctuaries of the high forests....As selection toward disease-resistant forms continues, the remnant populations will become progressively more able to penetrate into the pestilent lowlands. We may thus witness, within a few decades, the return of more endemic species into the disturbed but potentially habitable lowland forests. Many such potential habitats exist on all the islands, especially in the 150- to 600-m zone at the bases of the mountains.

Unfortunately, this possibility is clouded by the continued introduction of exotic game-birds and other disease carriers into Hawaii....Several esotheric pathogens have already been brought in by wild turkeys, francolins, and pheasants, including a gapeworm (probably Syngamus trachea) and a coccidium....With a few notable exceptions, the Hawaii Department of Fish and Game has in recent years tried to minimize establishment of exotic pathogens through quarantine and prerelease checks. However, current knowledge of avian disease is rudimentary; adequate diagnostic procedures for many pathogens have yet to be developed.... New diseases are continually being found in game birds....This problem is further amplified by the flow of commercial avian stock into the islands.

The other major latent threat to the remnant endemic avifauna is believed to be the temperate-zone subspecies of the night mosquito, Culex pipiens pipiens.

This form, while not yet established in the Hawaiian Islands, is abundant in the lowlands of coastal California from Stockton northward. Should it be accidentally introduced into Hawaii before the development in the existing populations of a sufficient immunogenetic capacity against malaria and birdpox, then the high forests will no longer be the ecological sanctuaries they now are. Culex pipiens pipiens would very likely be able to invade and reproduce in all but the very highest portions of the wetter forest regions, carrying the seeds of debility and death. Such an event could very well herald the extinction of one of the world's most extraordinay avifaunas.

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"MANU PAPALAGI" OF WESTERN SAMOA
Notes by Richard A. Goodman

(A letter was received at the Pacific Scientific Information Center, Bishop Museum, giving an interesting account of a bird known in Western Samoa as "manu papalagi" (which means foreigner's bird) and which Richard A. Goodman, the writer of the letter, believes to be a Red-vented Bulbul, Pycnonotus cafer bengalensis Blyth. The letter was prompted by the statement made by Mrs. Myrtle J. Ashmole in her "Guide to the Birds of Samoa," that "further records would be of considerable interest." This species appears to be a recent introduction to Samoa, and the note concerning its present abundance, at least on Upolu, is of special interest. E.H. Bryan, Jr.)

This letter was written from Leone Village, Apia, Upolu, Western Samoa.

On the morning of 16 January 1969, one of the children in the village arrived at the house with a live manu papalagi fledgling, which he found beneath a mango tree near the house. Evidently the bird came from one of the two manu papalagi nests in the tree, neither of which at this time contained any eggs.

About 1,000 yards from this tree, in another mango tree, there is a third manu papalagi nest, which fledglings were leaving approximately two months ago, in mid-November. Two days ago the same nest had in it three eggs, white with brownish-purple spots, but a child destroyed them.

The Samoans with whom I was staying described the manu papalagi as being the commonest bird in this area, and in the morning and early afternoon I usually can hear its whistling creaks. Often the call consists of a pair of whistles, followed by a brief pause, and then a third whistle.

The vegetation in this area consists mostly of banana, mango, coconut, and a few breadfruit trees. There is rather more vegetation than in many villages, but human habitations are common; the manu papalagi nests close to houses. There are some isolated clumps of sugar cane and a few papaya trees, also, with much open, close-cropped malae.

As to positive identification of this bird, I can only offer the following: First, a look at the checklist of Samoan birds presents no other bird which I think I would confuse with the Red-vented Bulbul. The adults of the manu papalagi were described to me as having "fulufulu mumu autafa olo muli" (red feathers near the anus). Thus, the Red-vented Bulbul would seem to be the correct identification.

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Excerpt from the minutes, Hawaii Audubon Society General Meeting, 17 March 1969:

...Charter member Edwin Bryan introduced another charter member Charles M. Dunn and recalled for us that it was exactly 30 years ago, on March 17, 1939, that the initial meeting of the Hawaii Audubon Society was held at the Library of Hawaii at the invitation of Charles M. Dunn.

The speaker of the evening was Dr. Charles H. Lamoureux, Botany Professor at the University of Hawaii. He told us about his very interesting course entitled, "The Natural History of the Hawaiian Islands" given at the University of Hawaii. It features geography, geology, climatology and biotic environment of the Pacific Basin and the Hawaiian Islands and the evolution of terrestrial biota of oceanic islands.

There are two one-hour classes a week, and field trips are scheduled throughout the semester. There are many guest lecturers and a lecture devoted to birds of Hawaii is given by Dr. Andrew Berger.

Footnote: I happened to look up the minutes of the initial meeting written by Ed. Bryan and among other interesting things was the following: "Various possible names for a Honolulu Audubon Society were discussed. Mr. Dunn favored a Hawaiian name such as 'Hui Makaala' (the Society with the wide awake eye), but for the time being 'Honolulu Audubon Society' was left as the official name."

A little more research revealed that the name was changed to Hawaii Audubon Society in May 1946, and it first appeared in THE ELEPAIO of Vol. 7, No. 1 in July 1946.

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21 April 1969: ...Hildegard Kaigler, wife of our field trip chairman, gave us a very informative account of our field trip to Ulupau Head on the Kaneohe Marine Base, on April 13, 1969....

Our speaker for the evening, Chapman Lam of KGMB News,...gave us an excellent talk on Hanauma Bay illustrated with both colored alides and a movie. He has been working on his own time to make a survey of Hanauma Bay as a wildlife preserve and living museum of sea life....

Leilani Pyle

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19 May 1969: ...Mr. Charles Kaigler reported on the Poamoho trail hike....A short ceremony was held honoring Dr. and Mrs. Robert Pyle who will be leaving the islands on the Oriana on 27 May 1969. Lei and the Bishop Museum publication, HAWAII: A PICTORIAL HISTORY were presented to them in gratitude for the great amount of work this couple has done for the Society...

Mr. Henry Yuen, our guest speaker,...is a student at the University of Hawaii, and has been making extensive observations of the Fairy Terns of Koko Head. He presented a series of slides and comments based on his paper, "Notes on the Fairy Tern, Gygis alba, Summer, 1968, on Koko Head, Oahu, Hawaii." He also showed slides of Shearwater chicks and Sooty Terns which were taken on the Audubon trip to Manana last August. The presentation and slides were thoroughly appreciated...

Mrs. Kaigler reported on the University of Hawaii natural history class trip to Ulupau Head. The class saw a male Frigatebird displaying the red gular pouch. They also saw Red-footed Booby nestlings. Employees of Sea Life Park were collecting some of these chicks, and Dr. Pyle explained that they were attempting to form a new colony of Red-footed Boobies at the Park....

Virginia Cone

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HAWAII'S BIRDS, a field guide, available for $2.00. Send in your orders to: Book Order Committee, Hawaii Audubon Society, P.O. Box 5032, Honolulu, Hawaii 96814.

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JULY ACTIVITIES:

July 13 - Field trip to Honouliuli fire-break trail to study the forest birds. Bring lunch, water, and if possible your car. Transportation cost ($1.00) to be paid to the drivers. Meet at the Library of Hawaii at 8:00 a.m. Leader: Alex L. MacGregor, telephone: 923-7122.

July 14 - No board meeting.

July 21 - General meeting at the Waikiki Aquarium Auditorium at 7:30 p.m. Speaker: Eugene Kridler, Federal Wildlife Administrator in Hawaii Topic: Hawaiian Islands National Wildlife Refuge (color slides).

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