Plasmodium relictum 简体中文 正體中文 **System:** Terrestrial

Kingdom	Phylum	Class	Order	Family
Protista	Apicomplexa	Aconoidasida	Haemosporida	Plasmodiidae

Common name avian malaria (English), Vogelmalaria (German), paludisme des oiseaux (French)

Synonym *Haemamoeba relicta* , Grassi and Feletti 1891
Plasmodium inconsta , Hartman 1927
Plasmodium capistrani , Russell 1932

Similar species

Summary The protozoa, Plasmodium relictum, is one of the causative parasites of avian malaria and may be lethal to species which have not evolved resistance to the disease (e.g. penguins). It may be devastating to highly susceptible avifauna that has evolved in the absence of this organism, such as native Hawaiian birds. The parasite cannot be transmitted directly from one bird to another, but requires a mosquito to move from one bird to another. In Hawaii, the mosquito that transmits Plasmodium relictum is the common house mosquito, Culex quinquefasciatus. Passerine birds are the most common victims of avian malaria.

view this species on IUCN Red List

Species Description
Histopathological examination may reveal numerous intraendothelial schizonts in spleen, lung, liver, heart and kidney (Fix *et al*. 1988). Schizonts may be 16 to 28 micron by 11 to 16 micron large and contain merozoites of two distinct sizes (macromerozoites, nuclei 1.0 micron; micromerozoites, nuclei 0.5 micron) (Fix *et al*. 1988).\r\n
The clinical signs of disease are caused by the tissue phase, causing tissue damage (Cranfield *et al*. Undated). There may not be enough destruction within the red blood cells to cause clinical anemia. The clinical signs in penguins are paleness, anoxia, dyspnea, inappetence, regurgitation, and death. The gross pathology reveals a very enlarged spleen, swollen liver, and congested and extremely edematous lungs. Impression smears from these tissues often reveals schizonts. Schizonts are present in several tissues throughout the body. Histologically, the lungs have acute severe interstitial pneumonia with schizonts present. Post mortem blood samples from major vessels or the heart can be extremely useful in the diagnosis, even up to 48 hours after death (Cranfield *et al*. Undated). \r\n
Plasmodium pathology observed in native Hawaiian honeycreepers includes: extremely high blood parasitemias (infection in up to 50% of circulating red blood cells), extensive damage to the liver and spleen, weight loss and inappetance and high mortality rates (Trouble in Paradise Undated).

Lifecycle Stages
This disease causing agent is carried and transmitted by a mosquito vector. The mosquito takes a blood meal from the reservoir host and ingests micro and macro gametocytes. These develop into oocysts in the gut of the mosquito. The oocysts then produce numerous sporozoites, which migrate to the salivary gland of the mosquito. These are infectious agents of malaria and are injected into the blood stream of the bird when the mosquito is taking its next blood meal. The cycle through the mosquito takes approximately 13 days (Cranfield *et al*. Undated).\r\n
The sporozoites, on entering the blood stream of the bird, are picked up by macrophages and reticuloendothelial cells where they develop into merozoites and then further on to schizonts (Cranfield *et al*. Undated). It is the merozoites with accompanying toxins that cause the chills and fever of malaria (SPREP Undated).The schizonts break apart shedding several more merozoites, which sets up the asexual tissue phase of the infection (Cranfield *et al*. Undated). After several cycles through the tissue, the merozoites are picked up by the red blood cells and develop into trophozoites and then on to either the sexual stage of the gametocytes or the asexual stage of schizonts (Cranfield *et al*. Undated). Therefore avians have two cycles going - a tissue phase and a blood phase. Within the blood phase, there is a sexual cycle and an asexual cycle (Cranfield *et al*. Undated). Fully developed erythrocytic schizonts cause rupturing of the red blood cells to release merozoites (to continue the blood cycle in the host) and gametocytes (capable of initiating sexual development if ingested by a mosquito) (SPREP Undated).\r\n
It is the merozoites with accompanying toxins that cause the chills and fever of malaria (SPREP Undated). Exponential growth every 36 hours while in circulating blood cells (SPREP Undated).

Habitat Description
Presence of the disease is linked with the presence of a suitable vector species. In the case of Hawaii this is the range of the house mosquito *Culex quinquefasciatus* (USDI and USGS 2005), a primary carrier of the disease causing agent. Studies by researchers at the Pacific Islands Ecosystem Science Center have revealed a lot about the ecology of the bird malaria in Hawaii including the link between the vector range and disease prevalence. Because this species of mosquito is more numerous at lower elevations, avian malaria is found mainly in birds of the lowland forests (USDI and USGS 2005), however, recent evidence suggests the range of the vector and thus disease could be moving into high land areas.

Reproduction
Undergoes sexual and asexual reproduction at different stages in both the vertebrate (bird) and invertebrate (mosquito) hosts.\r\n

\r\nSporozoites are the infectious stage of the *Plasmodium* protozoan parasite and are transmitted to a vertebrate host through blood feeding by a mosquito. The disease to the host is caused by the parasite protozoan attacking red blood cells to continue its development. Fully developed erythrocytic schizonts cause rupturing of the red blood cells to release merozoites (to continue the blood cycle in the host) and gametocytes (capable of initiating sexual development if ingested by a mosquito). It is the merozoites with accompanying toxins that cause the chills and fever of malaria (SPREP, 2000).
Exponential growth every 36 hours while in circulating blood cells.

Nutrition
This organism is an intracellular parasite that acquires most of its essential nutrients directly from the host cells.

General Impacts
Several species of the filarial parasite Plasmodium are the causal organism for avian malaria. *Plasmodium relictum capistranoae* Russell is the parasite found in infected Hawaiian birds (USDI and USGS 2005). In birds, *P. relictum* reproduces in red blood cells. If the parasite load is sufficiently high, the bird begins losing red blood cells causing anemia (USDI and USGS 2005). Because red blood cells are critical for moving oxygen about the body, loss of these cells can lead to progressive weakness and, eventually, death (USDI and USGS 2005). Malaria mainly affects birds in the order Passeriformes (perching birds). In Hawaii, this includes most of the native honeycreepers and the Hawaiian crow. Susceptibility to the disease varies between species, for example, the iiwi is very susceptible to malaria while the apapane less so (USDI and USGS 2005). Native Hawaiian birds are more susceptible than introduced birds to the disease and exhibit a higher mortality rate (Van Riper *et al*. 1982; Atkinson *et al*. 1995). This has serious implications for native bird faunas (SPREP) with *P. relictum* being blamed for the range restriction and extinctions of a number of bird species in Hawaii, primarily forest birds of low-land forests habitats where the mosquito vector is most common (Warner 1968; Van Riper 1991; USDI and USGS 2005). \r\n
Recent evidence indicates that some native Hawaiian lowland forest birds have developed some tolerance to *P. relictum*. For example, the Amakihi are once again breeding in remaining lowland forest habitat although they show a incidence of malaria (60-70%) (Trouble in Paradise Undated). Although this appears encouraging Freed and colleagues (2005) point out that as more of the common species evolve tolerance they increase reservoirs of the disease, which in turn increases the risk of transmission to rarer species that are vulnerable to avian malaria. Most honeycreepers, especially endangered species, now persist only in forests above 1500m elevation, where cool temperatures prevent effective malaria development in mosquitoes (Freed *et al*. 2005). The prevalence of malaria in Hawaiian forest birds at 1900m on the island of Hawaii has more than doubled over a decade. This increase is associated with breeding of mosquitoes and warmer summertime air temperatures. Tolerance to malaria in native birds is adding to a reservoir of malaria at upper elevations even while vectors are rare and air temperatures are too low for complete development of the parasite in the vector. Freed and colleagues argue that malaria is becoming an emergent infectious disease at upper elevations and that the spread of avian malaria can be partly attributed to climate change and increasing temperatures.\r\n
The parasite does not appear to be pathogenic in birds that have evolved with the parasite, often causing no signs. However, it causes varying degrees of pathology and can cause high mortalities in species of birds that have not evolved with the parasite. These susceptible species may come from areas without the vector, such as very cold, dry, or windy environments. This is why avian malaria is so lethal to penguins (in which it is caused by *Plasmodium relictum* and *P. Elongatum*), as illustrated by the 1986 outbreak of the disease in wild-caught Magellanic penguins (see [*Spheniscus magellanicus* in IUCN Red List of Threatened Species]) at the Blank Park Zoo in Des Moines, Iowa, USA (Fix *et al*. 1988). It is the highest cause of mortality in outdoor penguin exhibits and causes 50% or greater mortality in untreated juvenile and adult penguins when first exposed to the vector (Cranfield *et al*. Undated). For more detailed information of the impacts of *P. relictum*, click here

Management Info
Preventative measures: Because *P. relictum* presence is linked to mosquito populations malaria is very hard to eradicate. To effectively eliminate malaria from a habitat either the vector (mosquito) must be eliminated or prevented from feeding on the bird (USDI and USGS 2005). This is difficult particularly in remote areas in the wet forests of Hawaii where wallows from feral pigs and hollowed out logs of the native apuu ferns provide ample areas of standing water where the mosquito breeds (USDI and USGS 2005). One effective procedure is to reduce the number of potential water catchment containers in order to reduce the mosquito breeding sites available (SPREP Undated). However, in Hawaii attempts to control the mosquitoes by larval habitat reduction and larvicide use have been largely unsuccessful.
\r\nChemical: Captive bird populations may be treated with pharmaceuticals such as chloroquine and primaquine to cure the disease (Cranfield *et al*. Undated). To see more detailed information of the management and control of *P. relictum*, click here

Pathway
Introduction of game species. Infective birds not detected by standard diagnostics.

Principal source:

Compiler: Carter T. Atkinson, Ph.D. and Dennis A. LaPointe, Ph.D., USGS-BRD Pacific Island Ecosystems Research Center, Volcano, Hawaii & IUCN/SSC Invasive Species Specialist Group (ISSG)

Review: Carter T. Atkinson, Ph.D. and Dennis A. LaPointe, Ph.D., USGS-BRD Pacific Island Ecosystems Research Center, Volcano, Hawaii

Pubblication date: 2005-07-14

ALIEN RANGE

[1] AUSTRALIA
[1] BERMUDA
[1] BULGARIA
[1] COOK ISLANDS
[1] FRANCE
[3] FRENCH POLYNESIA
[1] JAPAN
[1] KOREA, DEMOCRATIC PEOPLE'S REPUBLIC OF
[1] KOREA, REPUBLIC OF
[1] LESSER ANTILLES
[1] MAURITANIA
[1] NEW ZEALAND
[1] NIGERIA
[1] NORTHERN EUROPE
[1] PAPUA NEW GUINEA
[1] SOUTHERN EUROPE
[1] SPAIN
[1] SWEDEN
[1] UNITED KINGDOM
[9] UNITED STATES
[1] VENEZUELA

Red List assessed species 36: EW = 1; CR = 12; EN = 8; VU = 12; LC = 3;

Calidris minuta **LC**
Charadrius pecuarius **LC**
Charmosyna diadema **CR**
Charmosyna palmarum **VU**
Chasiempis ibidis **EN**
Chasiempis sandwichensis **VU**
Chasiempis sclateri **VU**
Corvus hawaiiensis **EW**
Hemignathus flavus **VU**
Hemignathus kauaiensis **VU**
Hemignathus lucidus **CR**
Hemignathus munroi **EN**
Hemignathus parvus **VU**
Loxioides bailleui **CR**
Loxops caeruleirostris **CR**
Loxops coccineus **EN**
Megadyptes antipodes **EN**
Melamprosops phaeosoma **CR**
Mimus melanotis **EN**
Myadestes lanaiensis **CR**
Myadestes obscurus **VU**
Myadestes palmeri **CR**
Oreomystis bairdi **CR**
Oreomystis mana **EN**
Palmeria dolei **CR**
Paroreomyza maculata **CR**
Paroreomyza montana **EN**
Progne modesta **VU**
Pseudonestor xanthophrys **CR**
Psittirostra psittacea **CR**
Ptilinopus insularis **VU**
Spheniscus mendiculus **EN**
Telespiza cantans **VU**
Tringa glareola **LC**
Vestiaria coccinea **VU**
Vini stepheni **VU**

BIBLIOGRAPHY

51 references found for **Plasmodium relictum**

Managment information

Cranfield, M.R., Graczyk, T., McCutchan, T., Shaw, M., Beall, F., Skjoldager, M. and Ialeggio, D. Undated. *Avian Malaria in the African Penguin (Spheniscus demersus).*
Summary: Available from: http://www.veterinaria.uchile.cl/publicacion/congresoxi/prafesional/exo/4.doc [Accessed 6 April 2006]

Gleeson, Dianne, and Tompkins, Dan, Manaaki whenua-Landcare Research. Avian malaria in New Zealand � Hawaii all over again? Centre for Biodiversity and Biosecurity Seminar Series, University of Auckland.

Grim, K.C., McCutchan, T., Li, J., Sullivan, M., Graczyk, T.K., McConkey, G. & Cranfield, M. 2004. Preliminary results of an anticircumsporozoite DNA vaccine trial for protection against avian malaria in captive African black-footed penguins (*Spheniscus demersus*). *Journal of Zoo and Wildlife Medicine 35*(2): 154-161.

Kilpatrick, A.M. 2006. Facilitating the evolution of resistance to avian malaria in Hawaiian birds. *Biological Conservation 128*: 475-485.
Lounibos, L.P. 2002. Invasions by Insect Vectors of Human Disease, Annual Review of Entomology 47. Mandal, S.K., Ghosh, A., Bhattacharjee, I. & Chandra, G. 2008. Biocontrol efficiency of odonate nymphs against larvae of the mosquito, *Culex quinquefasciatus* Say, 1823. *Acta Tropica 106*: 109-114.
Mosha, F.W., Lyimo, I.N., Oxborough, R.M., Malima, R., Tenu, F., Feston, E., Mndeme, R., Magesa, S.M. & Rowland, M. 2008. Experimental hut evaluation of the pyrrole insecticide chlorfenapyr on bed nets for the control of *Anopheles arabiensis* and *Culex quinquefasciatus*. *Tropical Medicine and International Health 13*(5): 644-652.
Nishida, G. M. and Evenhuis, N. L. 2000. Arthropod pests of conservation significance in the Pacific: A preliminary assessment of selected groups. In Invasive Species in the Pacific: A Technical Review and Draft Regional Strategy. South Pacific Regional Environment Programme, Samoa: 115-142.
Summary: Discusses over a dozen of the worst arthropod pests in the South Pacific, with particular emphasis on ants and their control and management.
U.S. Department of the Interior (USDI) and U.S. Geological Survey (USGS). 2005. *Avian Malaria.*
Summary: Available from: http://www.nwhc.usgs.gov/hfs/Malaria.htm [Accessed 6 April 2006]
Vanderwerf, E.A. & Smith, D.G. 2002. Effects of alien rodent control on demography of the O ahu Elepaio, an endangered Hawaiian forest bird. *Pacific Conservation Biology 8*(2): 73-81.
Varnham, K. 2006. Non-native species in UK Overseas Territories: a review. JNCC Report 372. Peterborough: United Kingdom.
Summary: This database compiles information on alien species from British Overseas Territories.
Available from: http://www.jncc.gov.uk/page-3660 [Accessed 10 November 2009]
Wirth, M.C., Walton, W.E. & Federici, B.A. 1999. Cyt1A from *Bacillus thuringiensis* restores toxicity of *Bacillus sphaericus* against resistant *Culex quinquefasciatus* (Diptera: Culicidae), *Journal of Medical Entomology 37*(3).

General information

Apperson, C.S., Harrison, B.A., Unnasch, T.R., Hassan, H.K., Irby, W.S., Savage, H.M., Aspen, S.E., Watson, W., Rueda, L.M., Engber, B.R. & Nascif, R.S. 2002. Host-feeding habits of *Culex* and other mosquitoes (Diptera: Culicidae) in the borough of Queens in New York City, with characters and techniques for identification of *Culex* mosquitoes. *Journal of Medical Entomology 39*(5).
Atkinson, C.T. 2008. Avian Malaria. In C.T. Atkinson, N. Thomas and D.B. Hunter (Eds.). *Parasitic Diseases of Wild Birds* (pp. 35-53). Blackwell Publishing.
Atkinson, C.T., Lease, J.K., Dusek, R.J. & Samuel, M.D. 2005. Prevalenceof pox-like lesions and malaria in forest bird communities on leeward Mauna Loa volcano, Hawaii. *The Condor 107*: 537-546.
Atkinson, C. T., Woods, K. L., Dusek, R. J., Sileo, L. S. and Iko, K. W. 1995. Wildlife disease and conservation in Hawaii: pathogenicity of avian malaria (*Plasmodium relictum*) in experimentally infected I�iwi (*Vestiaria coccinea*). Parasitology 111 Suppl.: S59�S69.
Bennett, G.F., Bishop, M.A. & Peirce, M.A. 1993. Checklist of the avian species of *Plasmodium* Marchiafava & Celli, 1885 (*Apicomplexa*) and their distribution by avian family and Wallacean life zones. *Systematic Parasitology 26*: 171-179.
Centers for Disease Control and Prevention (CDC). 2005.
Summary: Available from: http://www.cdc.gov/ncidod/dvbid/arbor/culex.htm [Accessed 12 September 2006]
Cornel, A.J., Mcabee, R.D., Rasgon, J., Stanich, M.A., Scott, T.W. and Coetzee, M. 2002. Differences in extent of genetic introgression between sympatric *Culex pipiens* and *Culex quinquefasciatus* (Diptera: Culicidae) in California and South Africa. *Journal of Medical Entomology 40*(1).
Cosgrove, C.L., Wood, M.J., Day, K.P. & Sheldon, B.C. 2008. Seasonal variation in *Plasmodium* prevalence in a population of blue tits *Cyanistes caeruleus*. *Journal of Animal Ecology 77*: 540-548.
DuPonte, M.W. & Larish, L.B. September 2003. Livestock Management Insect Pests LM-10.2. Southern House Mosquito. Cooperative Extension Service College of tropical Agriculture and Human Resources University of Hawaii at Manoa.
Summary: Available from: http://www2.ctahr.hawaii.edu/oc/freepubs/pdf/LM-10-2.pdf [Accessed 12 September 2006]
Dusek, R.J. & Forrester, D.J. 2002. Blood parasites of American crows (*Corvus brachyrhynchos*) and fish crows (*Corvus ossifragus*. *Comparative Parasitology 69*(1): 92-96
Fix, A.S., Waterhouse, C., Greiner E.C., and Stoskopf M.K. 1988. *Plasmodium relictum* as a Cause of Avian Malaria in Wild-caught Magellanic Penguins (Spheniscus magellanicus), *J Wildl Dis. 24*(4): pp 610-9.
Foster, J.T., Woodworth, B.L., Eggert, L.E., Hart, P.J., Palmer, D., Duffy, D.C. & Fleischer, R.C. 2007. Genetic structure and evolved malaria resistance in Hawaiian honeycreepers. *Molecular Ecology 16*: 4738-4746.
Freed, L.A., Cann, R.L., Goff, M.L., Kuntz1, W.A., Bodner, G.R. 2005. Increase in Avian Malaria at Upper Elevation in Hawaii, *The Condor 107*(4): pp 753�764.
Harding, J.S., Brown, C., Jones, F. & Taylor, R. 2006. A preliminary assessment of the distribution of mosquitoes in the kingdom of Tonga: potential threats to biodiversity through invasive pathogens. University of Canterbury. School of Biological Sciences Research Report
Summary: Report of a study which involved a preliminary survey of mosquito species and larval habitat preferences in the kingdom of Tonga in order to assess the possible risk to indigenous wildlife from mosquito-borne diseases.
Hartup, B.K. Oberc, A., Stott-Messick, B., Davis, A.K & Swarthout, E.C.H. 2008. Blood Parasites of House Finches (*Carpodacus mexicanus*) from Georgia and New York. *Journal of Wildlife Diseases 44*(2): 469-474.
Hewitt, R. I. 1940. Bird malaria. American Journal of Hygiene, Monograph Series, no. 15: xvii + 228 pp.
Illera, J.C., Emerson, B.C & Richardson, D.S. 2008. Genetic characterization, distribution and prevalence of avian pox and avian malaria in the Berthelot�s pipit (*Anthus berthelotii*) in Macaronesia. *Parasitology Research 103*: 1435-1443.
Jarvi, S.I., Farias, M.E.M. & Atkinson, C.T. 2008-A. Genetic characterization of Hawaiian isolates of Plasmodium relictum reveals mixed-genotype infections. *Biology Direct 3*(25).
Jarvi, S.I., Farias, M.E.M., Baker, H., Freifeld, H.B., Baker, P.E., Gelder, E.V., Massey, G. & Atkinson, C.T. 2003. Detection of avian malaria (*Plasmodium* spp.) in native land birds of American Samoa. *Conservation Genetics 4*: 629-637.
Jarvi, S.I., Triglia, D., Giannoulis, A., Farias, M., Bianchi, K. & Atkinson, C.T. 2008-B. Diversity, origins and virulence of *Avipoxviruses* in Hawaiian forest birds. *Conservation Genetics 9*: 339-348.

Landau, I., Chabaud, A.G., Bertani, S. & Snounou, G. 2003. Taxonomic status and re-description of *Plasmodium relictum* (Grassi et Feletti, 1891), *Plasmodium maior* Raffaele, 1931, and description of *P. bigueti* n. sp. in sparrows. *Parassitologia 45*: 119-123
Lapointe, D.A., Goff, M.L. & Atkinson, C.T. 2005. Comparative susceptibility of introduced forest-dwelling mosquitoes in Hawai�i to avian malaria, *Plasmodium relictum*. *Journal of Parasitology 91*(4): 843-849.
Liu, H., Xu, Q., Zhang, L. and Liua, N. 2005. Chlorpyrifos Resistance in Mosquito *Culex quinquefasciatus*. *Journal of Medical Entomology 42*(5).
Marzal, A., Bensch, S., Reviriego, M., Balbontin, J. & De Lope, F. 2008. Effects of malaria double infection in birds: one plus one is not two. *Journal of Evolutionary Biology 21*: 979-987.
McCutchan, T.F. Grim, K.C., Li, J., Weiss, W., Rathore, D., Sullivan, M., Graczyk, T.K., Kumar, S. & Cranfield, M.R. 2004. Measuring the effects of an ever-changing environment on malaria control. *Infection and Immunity 72*(4): 2248-2253.
Mendes, L., Piersma, T., Lecoq, M., Spaans, B. and Ricklefs, R.E. 2005 Disease-limited Distributions? Contrasts in the Prevalence of Avian Malaria in Shorebird Species Using Marine and Freshwater Habitats, *Oikos 109*(2): 396.
Mendes, L., Piersma, T., Lecoq, M., Spaans, B. & Ricklefs, R.E. 2005. Disease-limited distributions? Contrasts in the prevalence of avian malaria in shorebird species using marine and freshwater habitats. *Oikos 109*: 396-404.
Savidge, J. A. 1985. The role of disease and predation in the decline of Guam�s avifauna. PhD dissertation, University of Illinois, Urbana. 79pp.
Shurulinkov, P. & Golemansky, V. 2003. *Plasmodium* and *Leucocytozoon* (Sporozoa: Haemosporida) of Wild Birds in Bulgaria. *Acta Prozoologica 42*: 205-214.
Steadman, D. W., Geiner, E. C. and Wood, C. S. 1990. Absence of blood parasites in indigenous and introduced birds from the Cook Islands, South Pacific. Conservation Biology 4: 398�404.
Tompkins, D.M. & Gleeson, D.M. 2006. Relationship between avian malaria distribution and an exotic invasive mosquito in New Zealand. *Journal of the Royal Society of New Zealand 36*(2): 51-62.
Trouble in Paradise: Avian malaria in the Hawaiian islands. Undated.
Summary: Available from: http://mentor.lscf.ucsb.edu/course/winter/eemb111/lecture/Lect26_Avian_Malaria.pdf [Accessed 6 April 2006]
Van Riper, III C. S. 1991. The impact of introduced vectors and avian malaria on insular passeriform bird populations in Hawaii. Bulletin of the Society of Vector Ecologists 16: 59�83.
Van Riper, III C. S., Van Riper, S. G., Goff, M. L. and Laird, M. 1982. The impact of malaria on birds in Hawai i Volcanoes National Park. Cooperative National Park Resources Studies Unit Technical Report, no. 47: iii + 74.
Van Riper III, C. S., Van Riper, S. G., Goff, M. L. and Laird, M. 1986. The epizootiology and ecological significance of malaria in the Hawaiian land birds. Ecological Monographs 56: 327�44.
Van Riper, S. G. and Van Riper, III C. S. 1985. A summary of the known parasites and diseases recorded from the avifauna of the Hawaiian Islands. pp. 298�371 in Stone, C. P.; Scott, J. M. (eds) Hawai�i�s terrestrial ecosystems: preservation and management. Proceedings of a symposium held June 5�6, 1984 at Hawaii Volcanoes National Park. Cooperative National Park Resources Studies Unit, University of Hawaii, Honolulu. xxviii + 584 pp.
Warner, R. E. 1968. The role of introduced diseases in the extinction of the endemic Hawaiian avifauna. Condor 70: 101�20.
Whitman, N.K., Goodman, S.J., Sinclair, B.J., Walsh, T., Cunningham A.A., Kramer, L.D. & Parker, P.G. 2005. Establishment of the avian disease vector *Culex quinquefasciatus* Say, 1823 (Diptera: Culicidae) on the Gal�pagos Islands, Ecuador. *Ibis 147*(4).
Woodworth, B.L., Atkinson, C.T., LaPointe, D.A., Hart, P.J., Spiegel, C.S., Tweed, E.J., Henneman, C., LeBrun, J., Denette, T., DeMots, R., Kozar, K.L., Triglia, D., Lease, D., Gregor, A., Smith, T. & Duffy, D. 2005. Host population persistence in the face of introduced vector-borne diseases: Hawaii amakihi and avian malaria. *Proceedings of the National Academy of Sciences 102*(5): 1531-1536.
Zinser, M., Ramberg, F. & Willott, E. 2004. *Culex quinquefasciatus* (Diptera: Culicidae) as a potential West Nile virus vector in Tucson, Arizona: Blood meal analysis indicates feeding on both humans and birds. *Journal of Insect Science 4*(20).