

## Prevalence of avian pox virus and effect on the fledging success of Laysan Albatross

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**ABSTRACT.** Avian pox virus (*Poxvirus avium*) is a mosquito-borne disease that occurs worldwide in a variety of bird species, but little is known about its prevalence or effect on seabirds. We monitored prevalence of pox virus and its effect on fledging success of Laysan Albatross (*Phoebastria immutabilis*) on Oahu, Hawaii, from 2003 to 2007. Pox prevalence in albatross chicks averaged 88% in years with high rainfall and 3% in years with low rainfall. Diagnosis of pox virus was clinically confirmed in two birds by Muscovy Duck (*Cairina moschata*) fibroblast cultures. Severity of infection ranged from small wart-like nodules and lesions on the bill, face, eyes, tarsus, and feet, to large tumorous growths that completely covered both eyes and caused deformation of the bill and skull. Most chicks recovered from infection, and the fledging rate in pox epizootic years (82%) did not differ from that in years with low pox prevalence (80%) or the average fledging rate on Midway Atoll (86%). Three chicks with severe infections were resighted as healthy adults on Kauai and Oahu in 2007, confirming postfledging survival of at least some birds. The high recovery rate, fledging success, and postfledging survival indicate that Laysan Albatross have strong immunity to avian pox virus.

### **SINOPSIS. Prevalencia de viruela aviar y su efecto en volantes de *Phoebastria immutabilis***

La viruela aviar (*Poxvirus avium*) es una enfermedad que afecta muchas especies de aves a nivel mundial. La enfermedad es transmitida por mosquitos y se sabe poco de su prevalencia y efecto en aves acuáticas. Monitoreamos la prevalencia de este virus y su efecto en volantes de albatros (*Phoebastria immutabilis*) en Oahu, Hawaii, en trabajo que se llevo a cabo desde el 2003–2007. Encontramos una prevalencia de 88% en pichones de albatros en años lluviosos y de 3% en años de poca lluvia. Se diagnosticó el virus, clínicamente, en dos patos comunes (*Cairina moschata*) mediante la técnica de cultivo fibroblástico. La severidad de la infección varió desde leve con algunas lesiones en el pico, cara, ojos, tarso y patas, hasta casos severos con grandes tumores que cubrían los ojos y causaron malformación de pico y craneo. La mayoría de los pichones se recuperaron de la infección. La tasa de pichones que dejaron el nido (82%) en años de alta incidencia (82%) fue similar (80%) a los años de pocas infecciones y al promedio de volantes (86%) en el Atolón de Midway. Tres individuos observados como pichones con infecciones severas fueron avistados posteriormente como adultos saludables en Kauai y Oahu en el 2007, lo que confirma la sobrevivencia post-volante de al menos algunas aves. La tasa tan alta de recobro, éxito en dejar el nido y sobrevivencia post-volante indican que en el Albatros de Laysan hay una alta inmunidad hacia la viruela aviar.

*Key words:* avian disease, Hawaii, Laysan Albatross, pox virus, seabirds

Avian pox virus (*Poxvirus avium*) occurs virtually worldwide and most species of birds are susceptible to at least some of the 13 described strains (Tripathy 1993, van Riper and Forrester 2007). Prevalence of pox virus varies with a variety of environmental and host-specific factors, and its effects vary among bird species (Kirmse 1967). Birds endemic to isolated islands may face increased risks from introduced diseases, with diminished natural immunity due to a

lack of exposure compared to continental species (Warner 1968, VanderWerf 2001, Kleindorfer and Dudaniec 2006). For many endemic Hawaiian forest birds, pox is often crippling or fatal (Warner 1968, van Riper et al. 2002, Atkinson et al. 2005, VanderWerf et al. 2006).

There are two forms of avian pox virus infections. The cutaneous form is characterized by wart-like nodules and tumorous lesions on unfeathered body areas, including the feet, legs, face, and around the bill and eyes (Tripathy 1993). Symptoms of the less common diphtheritic form, or wet pox, include soft, yellowish cankers and lesions on membranes of the upper respiratory and digestive tracts and in the mouth

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(Tripathy 1993, Hansen 2004, van Riper and Forrester 2007).

Pox virus infects a bird through a break in unfeathered skin or in the oral or respiratory mucous membranes, and can be transmitted by arthropod bites, direct contact with a contaminated surface, and by aerosol transmission (Tripathy 1993, Mete et al. 2001, Hansen 2004). At least 11 species of flies (Diptera) have been reported as vectors of avian pox (Akey et al. 1981), but the principal vector in Hawaii is believed to be the introduced mosquito, *Culex quinquefasciatus* (Warner 1968, van Riper et al. 1986, Atkinson et al. 1995).

Little is known about the effects of pox virus on some bird taxa, particularly for seabird species. Seabirds often congregate into small areas for breeding or foraging (Schreiber and Burger 2001), making them vulnerable to diseases. Examples include emerging infectious diseases in a wide range of colonial seabirds, such as West Nile Virus in White Pelicans (*Pelecanus erythrorhynchos*; Rocke et al. 2005), Exotic Newcastle's Disease in cormorants (*Phalacrocorax auritus*; Glaser et al. 1999), and periodic outbreaks of avian pox in several albatross species (Hansen 2004). Long-term data on the prevalence and effect of diseases is needed to assess their impact on seabird populations, but such information is largely lacking. Here we report on the prevalence of pox in Laysan Albatross (*Phoebastria immutabilis*) chicks on Oahu and the effects of the disease on their fledging rates and postfledging survival over a 5-yr period.

## METHODS

**Study sites.** Laysan Albatross nest at Kaena Point Natural Area Reserve and Kuaokala Game Management Area on Oahu, Hawaii. Kaena Point (21.58N, 158.27W) is located at the northwestern tip of Oahu, and Kuaokala (21.56N, 158.23W) is located 5 km to the east. Kaena Point is a coastal site with sandy soil and supports a relatively intact native dry shrubland and grassland community dominated by naupaka (*Scaevola taccada*), ilima (*Sida fallax*), ohai (*Sesbania tomentosa*), and several introduced plant species. Kuaokala is an upland site (350 m asl) where albatrosses nest on steep bluffs dominated by alien plants, particularly ironwood (*Casuarina equisetifolia*), christmasberry

(*Schinus terebinthifolius*), and various invasive grasses. Kaena Point and Kuaokala are both relatively dry, with an average annual rainfall of less than 80 cm (Giambelluca et al. 1986). There is usually little or no standing water at either site, but winter rains can form temporary pools that serve as breeding sites for mosquitoes, including *Culex quinquefasciatus*.

**Field techniques.** Laysan Albatross chicks were inspected for pox-like symptoms at approximately weekly intervals from hatching (February) until fledging (July) in 2004–2007 at both Kaena Point and Kuaokala. Hatching date, initial infection date, disease progression, and either fledging or mortality date were recorded for each individual. The status of four individuals was not determined in 2004 because they were either taken by predators or swept away by flooding during the period when pox emerged in the colony. We classified birds as having active pox if there were soft swellings, warty growths, open sores, or crusty scabs on the toes, feet, legs, or face. Anecdotal information on vector presence was collected by visually inspecting pools of standing water for mosquito larvae.

**Laboratory confirmation.** We collected a small (less than 2 by 2 mm) sample of sloughing epithelial tissue from lesions on two chicks. Clinical confirmation of the avian pox diagnosis was conducted at the United States Geological Survey Pacific Island Ecosystems Research Center in Volcano, Hawaii, using protocols outlined in Jarvi et al. (2008). The strain of virus infecting the Laysan Albatross chicks in our study was canary pox, the same strain found in Hawaiian forest birds (Jarvi et al. 2008).

**Analyses.** We defined pox prevalence as the proportion of birds with active pox lesions. We calculated pox prevalence each year to provide a measure of annual variation, and examined temporal patterns in pox prevalence with a chi-square analysis of the numbers of birds with and without active infections in years of high versus low rainfall. Rainfall data were taken from the National Weather Service gauge at Camp Mokuleia (National Weather Service 2007) that is the closest gauge to the two sites where Laysan Albatross breed on Oahu. Rainfall data from January to April were used each year because that was when pox infections were initially recorded. The relationship between pox prevalence and rainfall was investigated with a regression of annual pox prevalence on annual rainfall. We

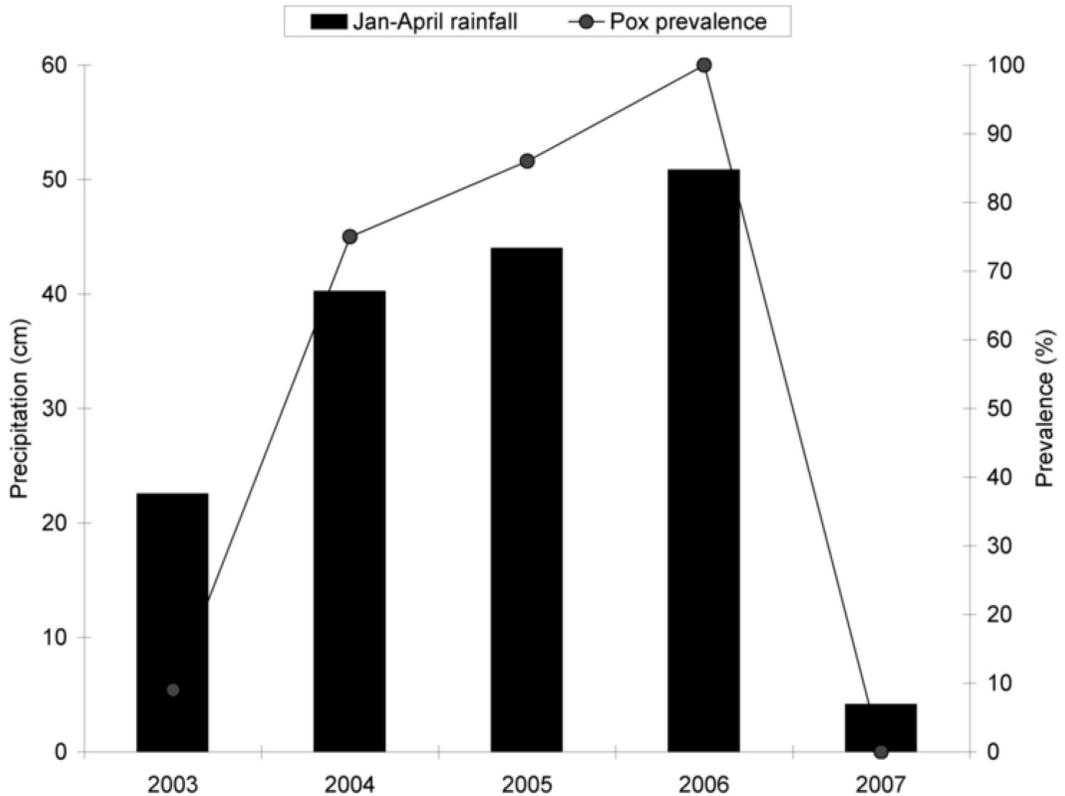


Fig. 1. Annual avian pox virus prevalence in Laysan Albatross chicks on Oahu and annual January–April rainfall.

compared albatross fledging success during high and low rainfall years with a chi-square test, and against the average fledging rate on Midway Atoll in the northwestern Hawaiian Islands where 69% of Laysan Albatross breed (Naughton et al. 2007) with a one-sample  $t$  test. All statistical tests were conducted using Minitab (Minitab Inc. 2003).

## RESULTS

Pox prevalence among Laysan Albatross chicks varied among years (Fig. 1), and was associated with annual rainfall ( $R^2 = 94\%$ ,  $F = 45.7$ ,  $P = 0.007$ ). More birds than expected were infected during years of high rainfall (2004–2006, 88%;  $N = 92$ ) than during years of low-to-intermediate rainfall (2003 and 2007, 3%,  $N = 70$ ;  $\chi^2_1 = 115$ ,  $P < 0.001$ ). After periods of rain, we observed pools of water with mosquito larvae on the surface. We observed only the

cutaneous form of pox, and observed pox in only a few adults. However, the absence of adults from the colony for long periods made it more difficult to detect infections.

Fledging success of albatross chicks in years with high pox prevalence (82%,  $N = 95$ ) did not differ ( $\chi^2_1 = 0.12$ ,  $P = 0.73$ ) from that in years with low prevalence (80%,  $N = 70$ ). In addition, fledging success on Oahu for all years combined ( $81\% \pm 6\%$ ) did not differ ( $t = -0.75$ ,  $P = 0.49$ ) from the average fledging rate at Midway Atoll (86%; Whittow 1993).

Infections were first observed in chicks ranging in age from 7 d to 2 mo. Most infected chicks eventually recovered and showed no apparent disabilities (Fig. 2). Pox may have contributed to death of two chicks that had obvious and severe deformations of the bill and skull (Fig. 3), but the cause of death was not confirmed by necropsy. Three chicks with severe infections (two in 2004 and one in 2005) were resighted



Fig. 2. Two Laysan Albatross chicks with moderate-to-severe avian pox virus infections on 17 April 2004 (left two photos), and the same chicks on 22 May 2004 (right two photos).

as apparently healthy adults on Kauai and Oahu in 2007, confirming their postfledging survival. The individual hatched in 2005 is one of only a handful of Laysan Albatross ever observed to return to a breeding colony in its second year (Rice and Kenyon 1962).

### DISCUSSION

Prevalence of avian pox virus in Laysan Albatross on Oahu was high in some years and was related to rainfall, with wetter conditions likely creating more mosquito breeding habitat. Disease prevalence also has been correlated with rainfall and mosquito abundance in Hawaiian forest birds (van Riper et al. 2002, VanderWerf et al. 2006). Albatross chicks are large, sedentary targets and virtually defenseless against mosquitoes. Many chicks in our study had nu-

merous growths on their feet and face, suggesting multiple mosquito bites.

Despite the severity of infection in some chicks, avian pox did not reduce overall fledging success. Albatross chicks continued to be fed by their parents well beyond the duration of infection, possibly contributing to the high recovery rates and fledging success. The low prevalence of pox in adult albatrosses may be due to a more mature immune system, or previous exposure to the virus as nestlings.

The postfledging survival of three Laysan Albatross chicks in our study indicates that even severely infected birds can survive, but questions remain about the long-term survival of infected birds and their ability to reproduce. Lesions on the feet, wings, bill, and eyes may have a variety of negative effects, including impaired flight, reduced foraging efficiency, impaired vision, and physiological trade-offs associated with an immune response (Pearson et al. 1975, Docherty et al. 1991, Rodriguez et al. 1997). Lifetime



Fig. 3. Two Laysan Albatross chicks with severe pox infections that did not survive. Pox may have contributed to the death of these chicks.

fitness costs may be difficult to quantify because the virus can remain latent in individuals for long periods and be reactivated due to environmental stress (Montgomery and Chowdhury 1980, Tripathy 1993, Oros et al. 1997). Continued monitoring of return rates and nesting success of Laysan Albatross on Oahu will permit documentation of any long-term effects of pox virus on survival and fitness.

The unknown effects of avian pox on long-term survival and productivity of albatrosses highlights the need to reduce the threat from introduced diseases. Because Kaena Point is a small area and mosquito breeding sites tend to be spatially concentrated, it may be possible to reduce or eliminate mosquito breeding habitat by controlling erosion caused by off-road vehicles that creates pools of standing water and by treating natural pools with a mosquito larvicide.

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