Pathogens and parasites: an increasing threat to the conservation of Galapagos avifauna

Sharon L. Deem[1,2,4], Marilyn Cruz[3], Gustavo Jiménez-Uzcátegui[2], Birgit Fessl[2], R. Eric Miller[1] & Patricia G. Parker[1,4]

1 Saint Louis Zoo, University of Missouri – Saint Louis
2 Charles Darwin Foundation
3 Genetics, Epidemiology, and Pathology Laboratory – Darwin Initiative Project – Galapagos National Park
4 Department of Biology, University of Missouri - St. Louis

Introduction

Today there is much interest in the impacts of disease on wildlife conservation in general, on island populations, and more recently on the avifauna of Galapagos. Diseases, both non-infectious and infectious/parasitic, have been shown to cause illness and death in Galapagos birds. Furthermore, the expanding poultry industry poses a threat to wild bird populations through the introduction of poultry pathogens, which may be highly infectious for the immunologically naïve native birds. In addition to the disease agents currently present in Galapagos, many new pathogens and parasites may soon arrive. Preventive measures to minimize their introduction are imperative.

Invasive pathogens and parasites can arrive in Galapagos by the same routes as other invasive species (plants, vertebrates, and invertebrates): on boats and planes or hidden in food items and materials (Causton, 2007) or via vertebrate species intentionally imported, which may harbor pathogens (e.g., day-old chicks). The true threat of these introduced pathogens in Galapagos is unknown. However, in other island systems, such as Hawaii, we know that introduced pathogens have caused avian extinctions.

There are 88 species of birds registered in Galapagos, 56 of which breed in the islands and 45 of which are endemic (Wiedenfeld, 2006). Fifteen of the native avian species have populations of less than 1500 individuals and/or are restricted to a single island. Both of these factors put these species at increased risk of disease-related extirpations or extinctions.

Avian pathogens and parasites of concern for Galapagos birds

Of 16 pathogenic and parasitic agents considered of high concern for conservation of wild birds in Galapagos, nine are already present and seven have

not yet arrived (Table 1). Eleven pathogens to which wild birds are susceptible have already been found in domestic poultry in the archipelago (Table 2).

Avian pathogens and parasites currently in Galapagos

Avian pox virus

Avian pox virus is mechanically transmitted by a number of vectors (e.g., mosquitoes and biting flies) or by contact through any break in the skin. Disease associated with this virus can be mild to highly pathogenic depending on virus strain and host species. In Galapagos, nine species of wild birds exhibit symptoms consistent with pox virus infection (Jiménez-Uzcátegui *et al.*, 2007). Mockingbirds appear to be the most severely affected (Figure 1) and can experience high mortality. The results of a recent molecular analysis indicate the presence of at least two strains of canary poxvirus present in wild birds in Galapagos and a third poxvirus, fowl poxvirus, present in chickens (Thiel *et al.*, 2005).

Philornis downsi

In 1997, an obligate dipteran bird parasite *Philornis downsi* was documented in nestling Darwin's finches on Santa Cruz Island (Fessl and Tebbich, 2002). The life cycle of this fly includes a parasitic larval stage (Figure 2a), which feeds on nestling birds (Figure 2b), and a free-living adult. Small broods suffer higher parasite loads per nestling than larger broods and therefore higher nestling mortality (Dudaniec and Kleindorfer, 2006). In addition to direct nestling mortality (up to 97%), studies have confirmed that some surviving nestlings of Darwin's finches have reduced growth rates, anemia, and may suffer permanent physical damage (Dudaniec *et al.*, 2006; Fessl *et al.*, 2006).

Poultry diseases

The poultry industry in Galapagos has rapidly expanded in recent years in response to the increasing human population. An estimated 143 000 day-old chicks were imported from the mainland to the archipelago in 2005; with an increase to 320700 in 2007 (SESA, unpub data). These imported chicks represent a frequent potential route for pathogens to enter the islands. However, in one study it was shown that free-living "backyard" chickens harbor more pathogens than the day-old chicks and adult broiler chickens (Soos *et al.*, 2008). The first indication of the threat posed by imported poultry was a 1995-96 Marek's epidemic (Vargas and Snell, 1997), a viral infection of high pathogenicity for both domestic and wild birds. More recently, two studies have documented a number of pathogens in both enclosed and free-roaming chickens (Table 2) (Gottdenker *et al.*, 2005; Soos *et al.*, 2008).

Introduced vectors

Many species of mosquitoes, flies, and ticks serve as mechanical and biological vectors for the transmission of avian pathogens. The recent establishment of the mosquito *Culex quinquefasciatus*, a good mechanical vector of avian pox and a vector for two important pathogens that have not yet been recorded in Galapagos, West Nile Virus (WNV) and *Plasmodium relictum* (avian malaria), is one example of an invasive invertebrate with potential significant impacts on avian health (Whiteman *et al.*, 2005).

Miscellaneous avian pathogens and parasites

A number of studies in Galapagos have confirmed the presence of avian pathogens (Table 1) but the current threat to Galapagos birds is unknown (reviews in Parker *et al.*, 2006; Padilla and Parker, 2007). There have also been many studies on the ectoparasites of Galapagos birds (reviews in Parker *et al.*, 2006; Padilla and Parker, 2007). Many of these parasites have health costs, best exemplified by the Galapagos hawk in which decreased immunologic status and higher parasite loads have been demonstrated for the

smaller populations residing on small islands (Whiteman *et al.*, 2006).

Avian pathogens and parasites that may soon arrive to Galapagos

Avian influenza (H5N1)

The threat of spread of H5N1 from the epidemic in the Old World to the Americas is of international concern due to its human pandemic potential, huge economic costs, and pathogenic effects on wild birds. Today over 30 wild bird species have been confirmed positive with H5N1 avian influenza (Redrobe, 2007). If H5N1 were to arrive in Galapagos, it would likely be devastating for both the endemic and commercial avian species, as well as for the tourism trade.

Avian malaria

Plasmodium relictum is an avian malarial parasite that can induce severe anemia and death in many avian species and has been a key factor in Hawaiian bird extinctions (Warner, 1968). It has yet to be identified in any Galapagos avian species. However, there is grave concern as a number of birds in the archipelago are thought to be highly susceptible and the mosquito *C. quinquefasciatus*, a known vector for this parasite, is now established in the archipelago. Additionally, the finding of a *Plasmodium* parasite in the Galapagos penguin is another recent concern. This parasite appears to be distinct from other *Plasmodium* species, including *P. relictum*, known to cause avian malaria, but studies are currently underway to identify this parasite and its impact more precisely.

West Nile Virus

West Nile Virus (WNV), which is spread by mosquitoes and pathogenic to birds, humans, and horses, has caused significant loss of life in the United States since arriving in New York City in 1999. In less than 10 years it has spread west across North America and south into the Caribbean and Latin America. In the New World, WNV has been detected in over 200 avian species (Komar, 2003). A risk analysis for WNV introduction to Galapagos found that infectious mosquitoes, transported on airplanes, represent the highest risk of arrival (Kilpatrick *et al.*, 2006).

Miscellaneous avian pathogens

There are a number of pathogens that have significant impacts on wild bird health. In Galapagos, there is continual concern about avian diseases such as *Toxoplasma gondii*, *Salmonella* spp., cholera, and botulism (Wikelski *et al.*, 2004).

Current research and management efforts for the health of avifauna in Galapagos

Many dedicated scientists are working in Galapagos to better understand and minimize the disease threats to the avifauna. Studies include: (i) baseline data collection; (ii) population health monitoring; (iii) specific pathogen studies; (iv) vector studies; (v) necropsy database of all submitted dead birds; and (vi) health studies related to specific conservation efforts such as the re-introduction of the Floreana mockingbird (*Nesomimus trifasciatus*) to Floreana. A number of Galapagos avian health workshops have been held during the past decade and a disease risk analysis workshop, which will provide an objective prioritization of diseases threatening Galapagos avifauna, is scheduled for the coming year.

Preventive measures have been implemented to halt the introduction of new pathogens, including spraying of incoming airplanes for vector control and control of domestic animals coming to Galapagos. Stronger measures are warranted, including increased biosecurity and proper husbandry/veterinary care for poultry farms, the elimination of cock fighting, backyard poultry operations and all domestic Anatidae. Veterinary diagnostic capabilities for wild bird species are available at the Galapagos Genetics, Epidemiology, and Pathology Laboratory (GGEPL) but current capacity has been exceeded and there is little capacity for agricultural (e.g., poultry) veterinary needs.

The conservation of the avifauna of Galapagos is imperative for ecosystem health, as birds serve many ecological roles. Additionally birds are one of the most popular attractions drawing tourists to Galapagos. Lastly many avian pathogens are zoonotic (affecting humans and birds) and cross the wildlife (free-ranging birds) - domestic (poultry) animal "divide": these pathogens have ecologic, human health, and economic impacts. Therefore we must strive to minimize infectious diseases in the avifauna of Galapagos to ensure not only the health of the ecosystem and the avian species, but also that of the humans.

Table 1. Pathogenic and parasitic agents currently known, or feared to soon arrive, in wild birds in the Galapagos.*

Parasite	Species**	Islands**	Risk rating***
Philornis downsi	CA, CM, COA, CPA, CPL CPS, GFA, GS, MP, PR, GFT	CHP, DM, FER, FL, GBF, ISA, MAR, PZ, SCB, SC, STO	High
Avian pox virus	CPA, CPL, DP, GFA, GFT, GG, GMS, GS, MP, PCS	CHP, FL, ISA, SCB, SC	High
West Nile Virus	NONE****	NONE	High
Plasmodium relictum	NONE	NONE	High
H5N1	NONE	NONE	High
Chlamydophila psittaci	NPH, SMS, ZGS	ESP, FER, ISA	Medium
Adenovirus	DIT, NPH	ESP, FER, ISA	Medium
Microfilariae	NPH, SMS	FER, ISA	Medium
Botulism	NONE	NONE	Low-Medium
Avian cholera	NONE	NONE	Low-Medium
Trichomonas gallinae	CL, ZGS	SCB, SC	Low-Medium
Hemoproteus	FM, SS, CFS, SMS, ZGS	ESP, GEN, SC, SFE, STO, SC	Low
Trypanosome sp.	BGS	STO	Low
Isospora spp.	GFA, GFT	FL, SC	Low
Toxoplasma gondii	NONE	NONE	Low
Salmonella spp.	NONE	NONE	Low

*This is not an exhaustive list but highlights disease agents currently believed to be of highest overall conservation concern.
**Galapagos species and islands are based on current data but this does not preclude the potential for the presence of disease agents in other species or islands.
Species: BGS - *Buteo galapagoensis* (Galapagos hawk); CA - *Crotophaga ani* (Smooth-billed ani); CFS - *Creagrus furcatus* (Swallow-tailed gull); CL - *Columbia livia* (Rock dove); COA - *Certhidea olivacea* (Warbler finch); CM - *Coccyzus melacoryphus* (Dark-billed cuckoo); CPA - *Camarhynchus psittacula* (Large tree finch); CPL - *Camarhynchus pallidus* (Woodpecker finch); CPS - *Camarhynchus parvulus* (Small tree finch); PBI - *Phoebastria irrorata* (Waved albatross); DP - *Dendroica petechia* (Yellow warbler); FM - *Fregata minor* (Great frigatebird); GG - *Gallus gallus* (Domestic chicken); GFA - *Geospiza fuliginosa* (Small ground finch); GMS - *Geospiza magnirostris* (Large ground finch); GFT - *Geospiza fortis* (Medium ground finch); GS - *Geospiza scandens* (Cactus finch); MP - *Nesomimus parvulus* (Galapagos mockingbird); NPH - *Nannopterum harissi* (Flightless cormorant); PCS - Platyspiza crassirostris (Vegetarian finch); PR - Pyrocephalus rubinus (Vermillion flycatcher); SMS - *Sphieniscus mendiculus* (Galapagos penguin) ; ZGS - *Zenida galapagoensis* (Galapagos dove); SS - *Sula sula* (Red-footed booby).

Islands: CHP - Champion; DM - Daphne Major; ESP - Española; FER - Fernandina; FL - Floreana; GBF - Gardner by Floreana; GEN - Genovesa; ISA - Isabela; MAR - Marchena; PZ - Pinzón; SCB - San Cristóbal; SC - Santa Cruz; SFE - Santa Fe; STO - Santiago.

***Risk rating is based on a subjective assessment of known virulence, susceptible species, transmission dynamics, and epidemiology in Galapagos and elsewhere. All the pathogens in this table are in the "highest overall conservation concern" category with the risk rating a comparison of these pathogens/parasites with each other.

**** NONE – indicates that the pathogen or parasite has not yet been identified as present.

Table 2. Pathogens and parasites detected in domestic poultry in Galapagos.

Pathogen/ Parasite	Risk Rating*
Avian paramyxovirus-1	High
Mycoplasma gallisepticum	High
Marek's disease virus	High
Adenovirus-1	Medium
Chlamydophila psittaci	Medium
Infectious laryngotracheitis virus	Medium
Infectious bronchitis virus (Mass)	Medium
Infectious bronchitis virus (Conn)	Medium
Infectious bursal disease virus	Medium
Reovirus (infectious tenosynovitis virus)	Low
Avian encephalomyelitis virus	Low

*Risk rating is based on a subjective assessment of known virulence, susceptible species, transmission dynamics, and epidemiology in domestic and wild birds world-wide.

Figura 1a. Juvenile Galapagos mockingbird (*Mimus parvulus*) on Santa Cruz Island with severe pox lesions (photo courtesy of Sharon Deem).

Figura 1b. Figure 1b. Galapagos mocking-bird with severe pox lesions on its head (photo courtesy of Andrew Hendry).

Figure 2a. *Philornis downsi* larvae in a Darwin's finch nest (photo courtesy of Andrew Hendry).

Figura 2b. Dead Darwin's finch nestling with *Philornis downsi* larvae-induced deformation to nares (photo courtesy of Sarah Huber).