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Dog overpopulation and burden of exposure to canine distemper virus and other pathogens on Santa Cruz Island, Galapagos

Nicole M. Diaz[a], Gabriella S. Mendez[a], C. Jaime Grijalva[a], Heather S. Walden[a], Marilyn Cruz[b], Eduardo Aragon[c], Jorge A. Hernandez[a,*]

[a] College of Veterinary Medicine, University of Florida, Gainesville, FL 32610-0136, USA
[b] Agencia de Regulación y Control de la Bioseguridad y Cuarentena para Galápagos, Santa Cruz, Galápagos, Ecuador
[c] Facultad de Medicina Veterinaria y Zootecnia, Universidad Central del Ecuador, Quito, Ecuador

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ABSTRACT

Dog overpopulation and diseases are hazards to native island species and humans on the Galapagos. Vaccination and importation of dogs are prohibited on the Galapagos. Risk management of these hazards requires the use of science-based risk assessment and risk communication. The objectives of the study reported here were (i) to estimate the human:dog ratio and (ii) the prevalence of and identify exposure factors associated with positive antibody titers to canine distemper virus (CDV) and other pathogens, as well as infection with intestinal parasites in owned dogs on Santa Cruz Island, Galapagos in September 2014. The observed human:dog ratio was 6.148:1 which extrapolates to 2503 dogs (two times more than a recent dog count conducted by Galapagos Biosecurity Agency in March 2014). The proportion of spayed female dogs (50%) was higher, compared to neutered male dogs (30%) ($p = 0.04$). Prevalence of dogs with positive antibody titers to CDV was 36% (95% CI = 26, 46%), to canine parvovirus was 89% (95% CI = 82, 95%), and to canine adenovirus was 40% (95% CI = 30, 51%). The frequency of seropositive dogs to CDV was lower in urban dogs (26%), compared to rural dogs (53%) ($p < 0.05$). A positive interaction effect between rural residence and spay/neuter status on seropositivity to CDV was observed, which we discuss in this report. Because vaccination is prohibited, the dog population on Santa Cruz is susceptible to an outbreak of CDV (particularly among urban dogs) with potential spill over to marine mammals. Dog's age (1–2 or 3–14 years old, compared to younger dogs), and residence (rural, urban) were associated with positive antibody titers to parvovirus, adenovirus, *Ehrlichia* spp., or *Anaplasma* spp., as well as infection with *Ancylostoma* spp., an intestinal parasite in dogs that can be transmitted to humans, particularly children. These results provide the most comprehensive assessment of dog overpopulation and exposure to CDV and other pathogens on the Galapagos to date.

1. Introduction

Introduced species are a threat to the biodiversity of the Galapagos archipelago via predation, selection pressure, infectious diseases, and habitat destruction (Kaiser, 2001) (Levy et al., 2008a). Galapagos marine iguanas (*Amblyrhynchus cristatus*) have lived virtually without predation for 5–15 million years until some populations were first confronted with feral cats and dogs about 150 years ago (Berger et al., 2007). In 1979, observational studies concluded that feral dogs could prey on a population of about 4900 marine iguanas on Isabela Island, harvesting approximately 27% per year and preferentially targeting the largest individuals and males (Kruuk and Snell, 1981). Because marine iguanas remain threatened by free-roaming cats and dogs illegally imported by humans, Galapagos authorities have implemented local and international partnerships to control reproduction of introduced cats and dogs. In 2004, the Galapagos National Park Service started a pilot program on Isabela to control cat and dog populations by neutering; the program was deemed a success and expanded to other islands on the archipelago in subsequent years (Levy et al., 2008a). However, published data on neutering and resulting cat and dog population trends (e.g., baseline and annual number of dogs or cats in following years) on the archipelago are lacking.

* Corresponding author at: PO Box 100136, Gainesville, FL 32610-0136, USA. Fax: +1 352 392 7551.
E-mail address: hernandezja@ufl.edu (J.A. Hernandez).

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Table 1
Frequency-distribution of study dogs and people. Santa Cruz, Galapagos: September 2014.

Parish	Barrio	Residence	Dog pop'n n[a]	Dog pop'n %	Calculated sample size	No. of dogs in the study	No. of people in the study	Calculated human:dog ratio
Puerto Ayora	La Cascada	Urban	72	12.26	14	14	51	3.6
	La Union		30	5.11	6	8	66	8.2
	Miraflores		80	13.62	15	16	104	6.5
	Alborada		41	6.98	8	8	30	3.7
	Arrayanes		39	6.64	7	6	42	7.0
	El Edén		68	11.58	13	5	67	13.4
	Pelikambay		12	2.04	2	2	42	21.0
	Punta Estrada		5	0.85	1	1	1	1.0
Bellavista	Bellavista	Rural	137	23.33	27	16	103	6.4
Santa Rosa	Santa Rosa		103	17.54	20	25	115	4.6
Total	587	100.00	113	101	621	6.1		

[a] Galapagos Biosecurity Agency's census data: March 2014.

Based on a current law and regulations for control of introduced species on the Galapagos (Libro VII del Regimen Especial: Galapagos, Capítulo III, Artículo 6 http://bioseguridadgalapagos.gob.ec/lista-de-productos-2/), vaccination of dogs is prohibited on the archipelago. Local authorities do not approve the use of dog vaccines because dogs are not native island species, and because the use of vaccines in introduced species requires vaccination guidelines supported by a risk assessment that must be approved by local authorities. In 2001, an outbreak of CDV killed more than 600 dogs on Santa Cruz and Isabela Islands, Galapagos. The disease was first diagnosed in dogs on Santa Cruz; one month later, dogs began to die of distemper on Isabela (Levy et al., 2008a). On both islands, the suspected cause of the outbreak was the illegal introduction of infected dogs. Because dogs have access to the beaches, there is potential exposure and risk of CDV transmission to beach-dwelling sea lions, although CDV transmission to sea lions on the archipelago has not been confirmed. During the outbreak of CDV in dogs, sea lions were sampled and tested for CDV antibodies, but laboratory results were negative (Alava et al., 2014). In 2011, unusual sea lion pup mortality was observed on San Cristobal Island, Galapagos; laboratory test results ruled out CDV as the cause of mortality in sea lion pups (Galapagos Conservancy, 2015).

Knowledge of disease burden in dogs on the Galapagos is limited to two studies. In May 2004, as part of neutering project of 95 dogs on Isabela Island, a study revealed positive antibody titers against parvovirus (100%), parainfluenza virus (100%), adenovirus (67%), and distemper virus (22%), as well as *Dirofilaria immitis* (34%), *Wolbachia pipiens* (22%), *Bartonella* sp. (13%), *Ehrlichia*/*Anaplasma* spp. (1%), and *Mycoplasma haemocanis* (1%) (Levy et al., 2008a). In another study (Gingrich et al., 2010), fecal samples were collected from 97 dogs presented during neutering campaigns on Santa Cruz ($n = 51$), San Cristobal ($n = 17$), and Isabela ($n = 29$) Islands and examined for intestinal parasites; *Ancylostoma caninum* (57%) was the most frequent instetinal parasite identified followed by *Toxocara canis* (16%), *Giardia* spp. (5%), *Isospora canis* (4%), *Sarcocystis canis* (3%), and *Cryptosporidium* spp. (1%). Although the study sample used in these two studies was not random and could not be used to estimate an accurate seroprevalence of selected pathogens in dog populations on the Galapagos, they were the first published reports that provided evidence of infectious diseases that can impact dog or human health.

In October 2012, Ecuador's Ministry of the Environment established the Agencia de Regulación y Control de la Bioseguridad y Cuarentena para Galápagos (Galapagos Biosecurity Agency) (ABG). An important mandate of the ABG is to regulate, control and prevent the introduction and dissemination of introduced species that represent a hazard to Galapagos native species and their habitat. An issue of concern is dog overpopulation and dog diseases that represent a health hazard to dogs, people, and native island species. The objectives of the study reported here were (i) to estimate the human:dog ratio and (ii) the prevalence of and identify exposure factors associated with a positive diagnosis of antibody titers to CDV and other pathogens, as well as infection with intestinal parasites in owned dogs on Santa Cruz Island, Galapagos in September 2014. Other pathogens of interest included parvovirus, adenovirus, as well as *D. immitis*, *Borrelia burgdorferi*, *Ehrlichia* spp., *Anaplasma* spp., and intestinal parasites. These pathogens were selected because they can spill over to native wildlife (CDV), can impact dog health, or human health (*Ancylostoma* spp.). Other pathogens (i.e., influenza virus, which can spill over to native wildlife) were not targeted because of funding limitations. The Galapagos is free of dog rabies. Investigated factors included dog's age, sex, spay-neuter status, and residence (rural, urban). It is expected that study results will support ABG education and health policy efforts aimed at controlling the dog population and diseases that represent a health hazard to dogs, people, and native island species on the Galapagos.

2. Materials and methods

This study was approved by the Universidad Central del Ecuador's ethics committee (Memorandum No. 106-CE-UCE-2014), the University of Florida's Institute of Animal Care and Use Committee (protocol # 201408313) and Institutional Review Board (protocol # 2014-U-0486).

2.1. Study site and study population

The study was conducted on Santa Cruz, Galapagos, during 8–26 September 2014. Santa Cruz is the second largest island on the archipelago; it is the main tourismhub for all of Galapagos, and has the largest human population. In 2010, the estimated human population was 15393 (11,974 people distributed on 16 *barrios* (neighborhoods) and 2468 households in the urban parish of Puerto Ayora and 3419 people in the two rural *barrios* of Bellavista and Santa Rosa) (Concejo de Gobierno del Regimen Especial de Galápagos, 2015). The surface area on Santa Cruz Island is 30.31 km^2 (Puerto Ayora: 2.59 km^2; Bellavista and Santa Rosa: 27.72 km^2) (Concejo de Gobierno del Regimen Especial de Galápagos, 2012–2013). Puerto Ayora is the urban center of Santa Cruz and most populous town in the Galapagos. The Santa Cruz Island was selected for this study because of its history of CDV in dogs, and the interest, communication support, as well as laboratory capacity available in ABG's headquarters at the port of Puerto Ayora. In March 2014, a house-to-house survey conducted by ABG personnel counted 1247 dogs on Santa Cruz (666 dogs in urban

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