Preventive Veterinary Medicine 157 (2018) 99–104

Contents lists available at ScienceDirect

Preventive Veterinary Medicine

journal homepage: www.elsevier.com/locate/prevetmed

Dog overpopulation and diagnosis of intestinal parasites on Santa Cruz Island, Galapagos 2016

Nicole M. Diaz[a,1], Heather S. Walden[a], Andrew Yoak[d], Antoinette McIntosh[a], Viviana Duque[e], Marilyn Cruz[e], Jorge A. Hernandez[a,b,c,*]

[a] College of Veterinary Medicine, University of Florida, Gainesville, FL, 32610-0136, USA
[b] College of Public Health and Health Professions, University of Florida, Gainesville, FL, 32610-0136, USA
[c] Center for Latin American Studies, University of Florida, Gainesville, FL, 32610-0136, USA
[d] Otterbein University, Westerville, OH, 43081, USA
[e] Agencia de Regulación y Control de la Bioseguridad y Cuarentena para Galápagos, Santa Cruz, Galápagos, Ecuador

ARTICLE INFO

Keywords:
Galapagos
Dog overpopulation
Canine ecology
Intestinal parasites

ABSTRACT

Dog overpopulation and diseases are hazards to native island species and humans on the Galapagos. The main objective of the study reported here was to estimate the observed human:dog ratio on Santa Cruz Island, Galapagos in September 2016. In addition, dog demographic data were used to model the expected annual dog population growth in the next 10 years. A secondary objective was to measure the burden of dogs infected with intestinal parasites. The observed human:dog ratio was 964:202 (or 4.77:1), which extrapolates to 3290 dogs; an increase of 31% in the dog population on Santa Cruz from 2014 to 2016. Study results show that current spay-neuter efforts (about 300 dogs per year; 60% females, 40% males) are not enough to keep the population stable (i.e., current baseline of 3290 dogs). The frequency of dogs infected with *Ancylostoma* spp., an intestinal parasite in dogs that can cause cutaneous larval migrans in humans, was 18/44 or 41% (95% CI = 27%, 55%). These results provide the most complete assessment of the dog overpopulation on the Galapagos to date.

1. Introduction

The consequences of dog overpopulation and diseases on conservation marine mammal programs on the Galapagos are significant. Currently, although there are no feral dogs on the Galapagos, owned dogs that range freely can be a threat to native species because they can colonize remote areas of inhabited islands and establish new feral dog populations (Reponen et al., 2014). In the past, observational studies concluded that feral dogs can prey on marine iguanas on the Galapagos (Kruuk and Snell, 1981). In addition, the risk of potential outbreaks of canine distemper virus in dogs on the Galapagos (which can potentially spill over to marine mammals and cause mortality) is not negligible (Levy et al., 2008; Diaz et al., 2016; Denkinger et al., 2017). In 2001, an outbreak of CDV killed more than 600 dogs on Santa Cruz and Isabela Islands, Galapagos (Levy et al., 2008; Diaz et al., 2016). On both islands, the suspected cause of the outbreak was the illegal introduction of infected dogs. In a recent study (Denkinger et al., 2017), lung and placenta tissue samples from Galapagos sea lions tested positive for CDV by PCR; the source of exposure was not confirmed. 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.

Information about dog population growth on the Galapagos is very limited. In 2014, the observed human:dog (H:D) ratio on Santa Cruz Island was 6.14:1, which extrapolated to 2503 dogs (Diaz et al., 2016). To our knowledge, no other published research reports have estimated the dog population or measure dog population trends on the Galapagos. Accurate dog population data are important for policy makers to justify and allocate adequate resources to manage the dog population on the archipelago (personal communication: Dr. Marilyn Cruz, Director, Galapagos Biosecurity Agency).

The Galapagos Biosecurity Agency (ABG) is responsible for regulating, controlling and preventing the introduction and dissemination of introduced species that represent a hazard to native species and their habitat—and humans on the archipelago. The ABG advocates for responsible pet ownership. In addition to promotion of spay-neuter procedures to control dog reproduction, another element is education to the public to avoid dog defecation in public spaces, and the use of

* Corresponding author at: College of Veterinary Medicine, University of Florida, Gainesville, FL, 32610-0136, USA.
E-mail address: hernandezja@ufl.edu (J.A. Hernandez).
[1] Current address: Friendship Hospital for Animals, 4105 Brandywine Street, NW Washington, DC 20016, Washington D.C., USA.

https://doi.org/10.1016/j.prevetmed.2018.06.003
Received 12 February 2018; Received in revised form 30 May 2018; Accepted 11 June 2018

deworming products to reduce the burden of dogs infected with intestinal parasites. Two studies have investigated the burden of dogs infected with intestinal parasites on the Galapagos. In one study (Gingrich et al., 2010), fecal samples were collected from dogs presented during neutering campaigns on Santa Cruz, San Cristobal, and Isabela Islands and examined for intestinal parasites; *Ancylostoma* spp., an intestinal parasite in dogs that can be transmitted to humans, was the most frequent parasite identified (56/97 or 57%). In 2014, a dog population study on Santa Cruz (Diaz et al., 2016), the most common parasite was *Ancylostoma* spp. (21/56 or 38%; 95% CI = 25, 50%). To our knowledge, no follow-up studies have been conducted to measure and detect changes on the burden of dogs infected with intestinal parasites on the Galapagos.

The main objective of the study reported here was to estimate the observed H:D ratio on Santa Cruz Island, Galapagos in September 2016. In addition, dog demographic data were used to model the expected annual dog population growth on Santa Cruz in the next 10 years. A secondary objective was to measure the burden of dogs infected with intestinal parasites.

2. Materials and methods

This study received approval from the University of Florida's Institute of Animal Care and Use Committee (protocol # 201609271).

2.1. Study site and study population

The study was conducted on Santa Cruz Island, Galapagos, during 19–30 September 2016. Santa Cruz is the main tourism hub for all of Galapagos, and has the largest human population. In 2015, the estimated human population was 15,701 (about 12,213 people distributed on 16 neighborhoods and 2,468 households in the urban parish of Puerto Ayora and 3,488 people in the two rural neighborhoods of Bellavista and Santa Rosa) (Ecuador's Instituto Nacional de Estadística y Censos, 2015). Santa Cruz was selected for this study to measure and compare H:D ratio estimates between 2014 (6.1:1) (Diaz et al., 2016) and 2016.

2.2. Sampling approach

This study targeted the same eight urban neighborhoods and blocks and one of two rural neighborhoods included in a dog survey conducted on Santa Cruz Island in September 2014 (Diaz et al., 2016). Briefly, eight of 16 urban neighborhoods and one of four blocks within each selected neighborhood were randomly selected. Within each selected block, all households inhabited by people were included. In this study, however, the rural neighborhood of Santa Rosa was not included because of time limitations.

2.3. Data collection

With the assistance of ABG, households were visited every day from 16.30 h to 19.30 h during a one-week period, and the following data were collected from each study household: neighborhood name, residence (rural, urban), block number, house number, current number of dogs and people who live in the household, number of dogs born or dead in the last 12 months, and number of dogs in 2015. In households with ≥1 dogs, the following additional data were collected from each dog: dog's name, age, gender, spayed/neutered (yes, no), and fecal sample collected (yes, no). Finally, additional collected data included the number of dogs that were spayed-neutered on Santa Cruz Island in 2014, 2015 and 2016 (Internal Report, *Agencia de Regulación y Control de la Bioseguridad y Cuarentena para Galápagos, 2017*).

2.4. Collection of fecal samples

During house-to-house visits, a local animal health technician facilitated communication with dog owners who participated in the study. On a first home visit, dog owners were instructed in sanitary collection of dog's fecal sample after normal defecation. The dog owner was provided with two or more new pairs of gloves and Whirlpack© plastic containers for collection of fecal samples. Plastic containers were labeled with the dog(s) name. Fecal samples were collected the following day and submitted to a designated laboratory at ABG for diagnosis of intestinal parasites. Fifteen of 237 (6%) study households with ≥1 dogs returned a fecal sample from 44 dogs.

2.5. Diagnosis of intestinal parasites

Fecal samples were collected and stored at 4 °C until processed. Approximately 1 g of feces from each sample was assayed by fixed angle bucket centrifugation using modified Sheather's sugar solution (specific gravity of 1.26) followed by microscopic examination at 40x and parasite stages were identified based on morphological characteristics (Zajac and Conboy, 2012; Diaz et al., 2016).

2.6. Data analysis

The null hypotheses that the proportions of households, households with ≥1 dogs, households with one, two, or ≥three dogs, and spayed/neutered dogs were not different in urban and rural neighborhoods were tested by using a chi-square test. Among female dogs and male dogs, the frequency of spayed and neutered dogs was compared between age groups (≤11 months old, 1–2 years old, 3–14 years old) by using a chi-square test. Values of $p < 0.05$ were considered significant.

The observed H:D ratio was calculated by dividing the total number of people by the total number of dogs in study households. The variable for number of dogs (at the neighborhood and block levels) was not normally distributed. However, the correlation between number of study people and study dogs was examined by constructing a scatter diagram (Diaz et al., 2016). Data included 34 paired observations of number of dogs (Y) and number of people (X) counted in all 34 study blocks (in eight urban and four rural neighborhoods). Two reference lines were drawn to estimate proportions of observations in positive quadrants (B and C) and negative quadrants (A and D) and to reflect the strength of association between number of people and number of dogs. Reference lines were based on the median distribution of number of dogs (Y) and of number of people (X). In addition, the association between number of study people and study dogs was examined by calculating the correlation coefficient (r). Although data for the variable of number of dogs were not normally distributed, simple linear regression was used to calculate a beta coefficient to produce an additional H:D ratio (i.e., 1 divided by the beta coefficient) and 95% confidence intervals (CI) derived from the regression results.

2.7. Expected annual dog population growth

2.7.1. Model's entities, variables and scale

A model was produced using Netlogo V6.0.2. A single agent type representing dogs was included. The agent had unique characteristics such as age, sex, and spay-neuter status. There was no spatial relationship or pre-defined carrying capacity for the dog population in the model. A single model time step was equivalent to one day.

2.7.2. Submodels

2.7.2.1. Reproduction. Sexually-intact adult (≥1 year old) females had a 30% probability of reproducing in any given year and if they were selected to reproduce in a given year by the model. The birth occurred on a random day of the year if they were still intact and alive on the date. This event triggered a normal distribution ($\mu = 5.62$, $\sigma = 1.0$) of