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The importance of the dog (*Canis lupus familiaris*) in cocoa farms as carriers of helminths potentially transmissible to humans and wildlife in the Southern Bahia, Brazil[1]

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ABSTRACT.- da Silva S.K.S.M., Cassano C.R., Sousa S.D., Campos-Júnior D.A. & Catenacci L.S. 2022. **The importance of the dog (*Canis lupus familiaris*) in cocoa farms as carriers of helminths potentially transmissible to humans and wildlife in the Southern Bahia, Brazil**. *Pesquisa Veterinária Brasileira 42:e06940, 2022.* Departamento de Ciências Agrárias e Ambientais, Universidade Estadual de Santa Cruz, Campus Prof. Soane Nazaré de Andrade, Rod. Jorge Amado Km 16, Ilhéus, BA 45662-900, Brazil. E-mail: kellysouzabiovet@gmail.com

Domestic dogs (*Canis lupus familiaris*) can be considered an invasive species as they have been introduced by humans in different parts of the world and represent a risk to wildlife conservation. Large extensions of agroforestry systems, where cocoa is grown under the shade of native trees, contribute to wildlife conservation in southern Bahia, Brazil. However, this system can increase contact between species of the native fauna and domestic dogs, which are frequently taken to the fields by rural workers. The aims of this study were to investigate the presence of domestic dogs inside cocoa agroforestry systems and the occurrence of helminths in dogs from cocoa farms near two protected areas: the Una Biological Reserve (REBIO-Una) and the Serra das Lontras National Park in Una, Bahia. We also investigated general characteristics of the dogs such as age, sex, breed, feeding frequency, vaccination, deworming and others, and evaluated possible risks of wildlife and human contamination by the domestic dog parasites. Camera traps were set up on eight cocoa agroforestry systems and three adjacent forest fragments. For parasitological investigation, fecal samples were collected from domestic dogs that lived on the eight cocoa farms. A total of 539 photos of 12 mammals were registered, of which 15% were of domestic dogs. The parasitological research was carried out with fecal samples from 32 of the 39 dogs that lived in the cocoa farms. We found one genus of cestode, *Dipylidium* sp. (7.7%), and five genera of nematodes, *Ancylostoma* sp. (80.7%), *Strongyloides* sp. (38.4%), *Toxocara* sp. (30.7%), *Spirocerca* sp. (15.4%) and *Trichuris* sp. (11.5%). Regarding animal care, all dogs were in poor body condition, 49% were fed twice a day, 90% defecated in the forest or cocoa agroforestry systems, only 33% were periodically dewormed, 64% were vaccinated against rabies in less than 12 months, and only one dog was vaccinated against other viruses. The results showed that domestic dogs share the same environment as wild animals yet lack some basic health care, increasing the possibility of parasitic transmission between domestic dogs, wildlife and humans from environmental contamination. We highlight the need for responsible pet ownership and the monitoring the health of wild animals and the human population living in this region.

INDEX TERMS: Dogs, *Canis lupus familiaris*, cocoa farms, helminths, Brazil, cabruca, canids, Atlantic Forest, gastrointestinal parasites, animal conservation.

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RESUMO.- [**A importância do cão (*Canis lupus familiaris*) nas fazendas de cacau como portador de helmintos potencialmente transmissíveis ao homem e à vida selvagem no sul da Bahia, Brasil.**] Cães domésticos (*Canis lupus familiaris*) podem ser considerados espécies invasoras introduzidas pelo ser humano em diversos lugares do mundo, representando risco para a conservação da fauna. Grandes extensões de sistemas agroflorestais, onde o cacau é cultivado sob a sombra de árvores nativas, contribuem para a conservação da vida selvagem no sul da Bahia, Brasil. Entretanto, esse sistema pode aumentar o contato entre espécies da fauna nativa e cães domésticos, frequentemente levados para o campo por trabalhadores rurais. Os objetivos deste estudo foram investigar a presença de cães domésticos em sistemas agroflorestais de cacau e a ocorrência de helmintos em cães de fazendas de cacau nas proximidades de duas áreas protegidas: a Reserva Biológica de Una (REBIO-Una) e o Parque Nacional da Serra das Lontras, em Una, Bahia. Também foram investigadas as características gerais dos cães como idade, sexo, raça, frequência de alimentação, vacinação, vermifugação e outros, e avaliados os possíveis riscos de contaminação da vida selvagem e seres humanos por parasitas de cães domésticos. Armadilhas fotográficas foram instaladas em oito sistemas agroflorestais de cacau e três fragmentos florestais adjacentes. Para investigação parasitológica, foram coletadas amostras fecais de cães domésticos que viviam nas oito fazendas de cacau. Foram registradas 539 fotos de 12 mamíferos, onde 15% das fotos pertenciam à cães domésticos. A pesquisa parasitológica foi realizada com amostras fecais de 32 dos 39 cães que viviam nas fazendas de cacau. Encontramos um gênero de cestóide: *Dipylidium* sp. (7,7%), e cinco gêneros de nematóides: *Ancylostoma* sp. (80,7%), *Strongyloides* sp. (38,4%), *Toxocara* sp. (30,7%), *Spirocerca* sp. (15,4%) e *Trichuris* sp. (11,5%). Em relação aos cuidados com os animais, todos estavam com score corporal baixo, 49% dos cães eram alimentados duas vezes ao dia, 90% defecam na floresta ou em sistemas agroflorestais de cacau, apenas 33% foram vermifugados periodicamente, 64% vacinados contra a raiva em menos de 12 meses e apenas um cão foi vacinado contra outros vírus. Os resultados mostram que os cães domésticos compartilham o mesmo ambiente que os animais silvestres e carecem de alguns cuidados básicos de saúde, aumentando a possibilidade de trânsito parasitário entre cães domésticos, animais silvestres e humanos por contaminação ambiental. Destaca-se a necessidade de atividades de posse responsável de animais de estimação e o monitoramento da saúde dos animais silvestres e da população humana que vive nesta região.

TERMOS DE INDEXAÇÃO: Cães, *Canis lupus familiaris*, fazendas de cacau, helmintos, Brasil, cabruca, canídeos, Mata Atlântica, parasitas gastrointestinais, preservação animal.

INTRODUCTION

Biological invasions are considered one of the five direct causes of change in nature, with the greatest global impact in the last 50 years (IPBES 2019). The proliferation of species outside their natural environments can promote changes in ecosystems through predation, parasitism or competition with native species, and generate hybrids and changes in local genetic diversity (Verona & Nava 2014). These processes may have direct impacts on native species and cascade down through food webs, indirectly affecting other species or physicochemical characteristics of the environment (Vitule & Prodocimo 2012).

Many invasive species were introduced by humans for a variety of purposes such as consumption, commercialization, production and to be used as companion animals as with the domestic dog (*Canis lupus familiaris)* (Schüttler & Karez 2009, Santos et al. 2018). When dogs share the same areas used by wild animals, they might represent a risk for the conservation of fauna, through hunting pressure, competition for resources, and pathogen introduction into the environment (Whiteman et al. 2007, Curi et al. 2010, Santos 2013, Otranto et al. 2015). In addition, the accentuated habitat loss and the consequent decrease of resource availability for fauna can reduce the immunity of wild animals, making parasitic infections, which are otherwise typically asymptomatic, a risk factor for free-living populations (Gillespie & Chapman 2008, Püttker et al. 2008, Silva 2014).

Parasitoses in the gastrointestinal tract might cause morbidity and mortality in their hosts, decreasing nutrient absorption with consequent weight loss, mechanical injuries, coat failure, and intestinal obstruction (Kohek Jr. 1998, García et al. 2007, Monteiro 2017). They can also reduce reproductive performance, with delay in the beginning of the breeding season and changes in the size and survival of the brood (Zuk 1990, Gustafsson et al. 1994, Sheldon & Verhulst 1996). Furthermore, depending on the intensity of parasitic spoliation, the host may have reduced ability to compete for food, territories or mates and escape from predators (Thompson 1999, Tompkins & Begon 1999, Thomas et al. 2000).

The Brazilian Atlantic Forest is recognized as a biome that hosts a significant number of rare and endemic species, many of which are threatened with extinction (Costa et al. 2005, ICMBio & MMA 2018). In the northeastern state of Bahia, Brazil, only 14% of the original area remains covered by forest that is already a small and isolated fragment (INPE 2018). In the middle of the 19th century, the agroforestry system regionally known as cabruca, was established as the main economic activity in this region. In this system, native trees from the original forest promote shade to the cocoa tree (*Theobroma cacao*) plantation, but the canopy layer is tinned, and the smaller trees are replaced by cocoa trees (Sambuichi et al. 2012, Faria et al. 2021). As a human managed system, cabrucas are known to contribute to the conservation of the regional biota by maintaining part of the forest cover, harboring native species and acting as corridors between forest remnants (Cassano 2014). However, cabrucas allow for the proximity of domestic and wild animals due to the frequent presence of rural workers and their dogs in these areas (Cassano et al. 2012, Frigeri et al. 2014). This contact may facilitate the spread of parasitic agents and pathogens to new environments (Daszak et al. 2000, Brandão et al. 2009, Curi et al. 2010).

In the present study we aim to investigate the presence of domestic dogs inside cocoa agroforestry systems and forest remnants, and the occurrence of helminths in dogs from eight cocoa farms located nearby to two Protected Areas: the Una Biological Reserve (REBIO-Una) and the Serra das Lontras National Park in Una, Bahia. We also collect information about the basic health care that owners have provided their dogs and aim to evaluate possible risks of wildlife and human contamination by the domestic dog's parasites.

MATERIALS AND METHODS

Study area. The study was carried out on eight cocoa agroforestry systems (cabrucas) and three forest fragments adjacent to them, belonging to eight rural properties located in the municipality of Una in Bahia, Brazil. These farms are located between two protected areas: the Una Biological Reserve (REBIO-Una) and the Serra das Lontras National Park (PARNA Lontras) (Fig.1). The farms had five to 200 ha of cocoa plantations and the three fragments measure 34,320 and 1,250 ha.

The study region presents hot and humid climate, with an average annual temperature of 24ºC, humnidity of 84%, and rainfall of 1,800mm/year (Mori et al. 1983). The vegetation consists of Hygrophilous Forest in the South of Bahia, characterized by the dense ombrophilous forest (Thomas 2003). Around REBIO-Una, 33 to 37% of the land is covered by ombrophilous forest, and the rest is occupied by cocoa agroforestry and syringe plantations (*Hevea brasiliensis*); cocoa cultivation corresponds to about 60% of the planted areas (Araújo et al. 1998).

Data collection. The records of wild animals and domestic dogs in the cabrucas and forest sites were obtained by camera traps (Trapa Câmera®), with one trap placed at each sampling site. The camera traps were positioned at 30cm from the ground, tied to trees at least 100m from the edge between environments. Cameras were placed facing a bait on the ground, containing banana and sardine. The camera traps were active during the day and night and were programmed to shoot every 90 seconds when triggered by the presence of an animal. The traps remained in the field for three one-month campaigns, from July 2007 to October 2008, resulting in approximately 84 days of sampling effort per site.

For parasitological investigation of domestic dogs, fecal samples were collected from individuals that lived in the eight rural properties where the camera traps were installed. All the owners of the dogs agreed to participate in the academic research and signed a consent form. One sample per animal was collected during the study period. The feces were collected by the owners of the animals as soon as they defecated and were immediately stored in plastic pots containing 10% formaldehyde solution. At the Veterinary Parasitology Laboratory of the "Universidade Estadual de Santa Cruz", Ilhéus/BA, the feces were processed using the centrifugal-sedimentation-Ritchie method (Santos 1999).

Finally, we investigated general characteristics of the dogs: age, sex, breed, body condition score, contact with other domestic animals, feeding frequency, if they enter cabrucas and forest areas (for hunting or other activities), vaccination, deworming and the place where they used to defecate. The distance between the houses where the dogs lived, and the nearest forest fragment were estimated by plotting each house location in a land use map.

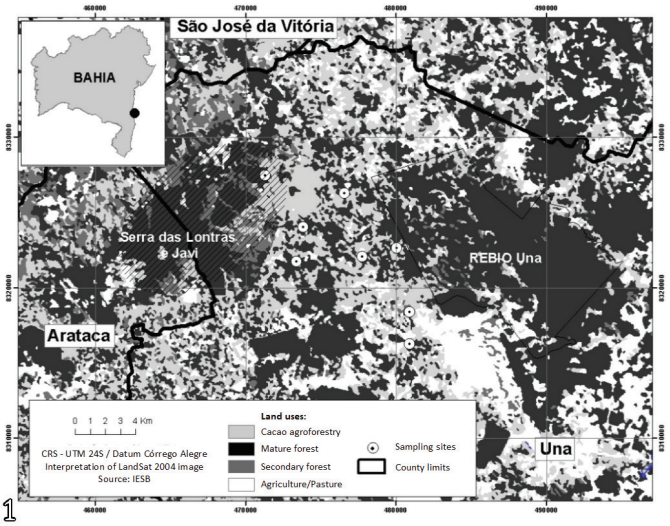

Fig.1. Location of the study sites in southern Bahia, Brazil. Rural properties are identified by white dots.

RESULTS

We recorded a total of 539 photos of mammals: 461 photos (85%) of wild mammals, belonging to 11 species and 78 photos (15%) of domestic dogs. Marmosets (33.6%, n=127), foxes (20.6%, n=78) and domestic dogs were the species most recorded (19%, n=72) in the cabrucas. In forests, the golden-headed lion tamarins (39.7%, n=64), marmosets (25.5%, n=41) and big-eared opossums (16%, n=10) were the most common species, and only six photos of dogs were recorded (Table 1). We found 39 dogs living in the eight cocoa farms, and fecal samples were collected from 32 (82%) of them. Of these, 13 were females and 19 were males. All were adults and mixed breed. All animals showed thin body condition, and 84.4% (26/32) of the samples were observed at least one gastrointestinal parasite. Eggs of one genus of cestode and five genera of nematodes were found, with *Ancylostoma* sp. being the most frequent (Table 2). Of the 26 parasitized dogs, 54% (14/26) presented with only one genus of helminths, 23% (6/26) with two genera, 12% (3/26) with three, 8% (2/26) with four, and 4% (1/26) with five.

Most of the 39 dogs (49%, n=19) were fed twice a day, followed by those fed three times a day (33%, n=13) and once a day (18%, n=7). Approximately 90% (35/39) of the dogs defecated in cabrucas and forest remnants, and about 10% (n=4) defecated only around the farmhouses. Most dogs (64%, n=25) followed the workers into the cocoa plantations, and 26% (n=10) hunted for food. In addition, only 33% (n=13) of dogs were dewormed annually and 64% (n=25) had been vaccinated against rabies less than a year ago. Only one of the animals was vaccinated against other viruses that can affect dogs. The approximate distance between the house and the nearest forest ranged from 20 to 2000m. Sighting of wild animals circulating nearby the farmhouse were common.

DISCUSSION

The results showed a high prevalence of helminths in domestic dogs living in cocoa farms near REBIO-Una and PARNA-Serra das Lontras, and that most of these dogs are not vaccinated nor dewormed, contradicting the Manual of Surveillance, Prevention and Control of Zoonoses' recommendations (Ministério da Saúde 2016). Also, dogs often shared environments with wild animals, especially in cabrucas, verified by the high proportion of domestic dog photos taken by our camera traps. These findings show that domestic dogs and wild animals share the same environments and that dogs may likely facilitate environmental contamination with parasites.

Our data corroborate results presented by Frigeri et al. (2014) and Santos et al. (2018), who reported that domestic dogs explored cabruca areas, and although these animals spend the same amount of time in agroforestry and open

areas, the area used in the former was roughly 10 times greater. Moreover, by tracking 10 domestic dogs for 312 h and 48 min, Santos et al. (2018) recorded 800 urination and 82 fecal deposition events. These widespread and frequent events should be particularly harmful for wild species that have terrestrial behavior and those that practice coprophagy or visit latrines or burrows (Livingston et al. 2005, Leuchtenberger et al. 2012), as observed in the majority of mammal species recorded by the camera traps in the present study. Santos et al. (2018) also proved the close contact between dogs and wildlife when agoutis (*Dasyprocta iacki*), armadillos (*Dasypus novemcinctus*), golden-headed lion tamarins (*Leontopithecus chrysomelas*) and marmosets (*Callithrix khulii*) were chased by dogs in cocoa agroforestry systems.

Parasites registered in the present study are likely to circulate between wild and domestic animals. Nematodes of the genus *Strongyloides* sp., *Ancylostoma* sp., *Toxocara* sp. and *Trichuris* sp. have been recorded in wild and captive wild carnivores and in callitrichids in several states in Brazil (Diniz 1997, Freitas et al. 2001, Carmo & Salgado 2003, Santos et al. 2003, Curi 2005). According to Okulewicz et al. (2012), the genus *Toxocara* and Toxascaris occurs in wild canids and felids, as well as in domestic cats. Furthermore, except for the genus *Spirocerca*, all the parasites found also have zoonotic characteristics and may parasitize workers from cabrucas causing symptoms such as infections, enteritis, colic, diarrhea, liver damage and even loss of vision (Monteiro 2017).

Considering the wildlife, the animals tend to develop resistance against parasitic diseases, showing a state of equilibrium between parasite and natural host that reduces harmful symptoms (Barbosa et al. 2020). However, when these infections become symptomatic, wild animals might show clinical signs such as diarrhea and, in severe cases, death (Levecke et al. 2007). In captivity, it was observed that the accumulation of animals in a small area increases the chances of parasitic infection or reinfection in wild species and this situation gets worse in cases of high population density, stress and favorable climatic conditions (Guerrero et al. 2012).

Some features of wild canid ecology such as close social contacts, foraging behaviour, scent communication with infectious material (urine and faces), and the genetic proximity to domestic dogs (*Canis lupus familiaris*) make them particularly susceptible to disease (Woodroffe et al. 2004). Probably the crab-eating fox (*Cerdocyon thous*) is the most fragile and susceptible between the animals in direct contact with domestic dogs in the study area.

It is also important to emphasize that helminth eggs can survive in the soil for about two years, with greater ability to survive in humid and shaded environments (Urquhart et al. 1990, EPA 2013, Monteiro 2017), as is the case with the Atlantic Forest biome. Thus, a high abundance of parasitic eggs and larvae in the environment can pose a threat to wild species and humans that share parasitic varieties with dogs. Moreover, due to their physiological and biochemical characteristics, many parasites have limited development in organisms other than their natural hosts. However, in accidental hosts, they may exhibit unpredictable behaviors, such as tissue migration and installation in non-parasitized organs (Urquhart et al. 1998). This is particularly important for wildlife populations living in fragmented areas and already experiencing other pressures, such as habitat and resource limitations (Püttker et al. 2008).

Table 1. Number (n) and frequency (%) of records of wild mammals and domestic dogs in cabrucas and forest sites, Una/Bahia, Brazil

Species	Common name	Cabruca		Forest		Total	
		N	%	N	%	N	%
Order Artiodactyla							
Mazama sp.	Deer	-	-	1	0.6	1	0.2
Order Carnivora							
Canis familiaris	Domestic dog	72	19.0	6	3.7	78	14.5
Cerdocyon thous	Forest fox	78	20.6	8	5.0	86	16.0
Eira Barbara	Tayra	5	1.3	1	0.6	6	1.1
Nasua nasua	South American coati	1	0.3	14	8.7	15	2.8
Procyon cancrivorus	South American raccoon	15	4.0	5	3.1	20	3.7
Order Marsupialia							
Didelphis aurita	Big-eared opossum	24	6.3	16	10.0	40	7.4
Order Pilosa							
Dasypus novemcinctus	Nine-banded	1	0.3	3	1.9	4	0.7
Euphractus sexcinctus	Yellow armadillo	3	1.0	-	-	3	0.5
Order Primates							
Callithrix kuhlii	Wied's marmoset	127	33.6	41	25.5	168	31.3
Leontopithecus chrysomelas	Golden-headed Lion Tamarin	51	13.5	64	39.7	115	21.3
Order Rodentia							
Agouti paca	Lowland paca	1	0.4	2	1.2	3	0.5
TOTAL		378	100	161	100	539	100

Table 2. Number (n) and percentage (%) of feces of domestic dogs with helminth parasites in feces

Helminths	N	%
Nematodes		
Ancylostoma sp.	21	80.7%
Strongyloides sp.	10	38.4%
Toxocara sp.	8	30.7%
Spirocerca sp	4	15.4%
Trichuris sp.	3	11.5%
Cestode		
Dipilidium sp.	2	7.7%

CONCLUSIONS

This study provides evidence of favorable conditions for the circulation of helminth parasites between domestic dogs, wild animals and humans, but it is not possible to conclude which parasites are shared or in what frequency. Such responses depend on evaluations of worms in domestic and wild animals and the human population living in the same region, which may be the target of future studies.

We emphasize that the lack of basic care regarding the health of dogs, such as periodic deworming and vaccination, indicates the need to reinforce the concept of responsible pet ownership for the residents. Changes to human behaviors toward their dogs are needed to mitigate the direct and indirect impacts of dogs on wildlife. In addition, the high loss of native habitats in the Atlantic Forest and the large number of species depending on fragmented landscapes to maintain viable populations enhance the need for knowledge of health aspects combined with fauna inventories and ecological studies. The one health approach must be included in the conservation strategies of species and their habitats.

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