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Research Letters

Dog invasion in agroforests: The importance of households, roads and dog population size in the surroundings

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ABSTRACT

Dogs are considered an invasive species, whose presence in natural habitats adversely affects wildlife. We investigate the effects of household and road proximity, and of dog population size in the surroundings on the invasion of cacao agroforest by dogs, and evaluate if dogs raised in the vicinity are more likely to invade agroforests than dogs of unknown origin. The study was conducted in a landscape dominated by agroforests, within the cacao growing region of Southern Bahia, Brazil. Dogs were recorded by camera-traps in 15 agroforest sites, and we identified dogs inhabiting the vicinity of each sampled agroforest site by visiting all households up to 800 m from sampling sites. We obtained 115 photographic records of 47 individuals, and identified 213 dogs inhabiting the site surroundings. The number of individuals and frequency of visit of dogs tend to be higher in agroforests located nearer a household, but were not associated with the distance to the nearest road or the dog population size in the surroundings. The frequency of visits in agroforests did not differ between dogs residing in the surroundings and dogs of unknown origin. Our results indicate that the surroundings are not the main source of dogs invading agroforests, most likely because dogs perform long-distance movements in association to humans. Strategies to reduce the impacts of dogs on wildlife will gain from studies on movement ecology and should include practices to restrict dogs' home range.

Introduction

After more than 15,000 years interacting with humans (Vila et al., 1997), dogs (*Canis familiaris*) stand as the most abundant and widely distributed Canidae in the world (Ferreira et al., 2011; Wandeler et al., 1993). Current global dog population exceeds 700 million individuals (Hughes and Macdonald, 2013). These animals can use different types of environment and a large territory, especially in rural areas, where they enter agricultural systems and pastures, as well as remnants of native vegetation, and interact with wildlife (Vanak and Gompper, 2010). In rural areas the dog/human rate is generally higher than in urban areas and the number of dogs exceeds the number of humans (Wandeler et al., 1993).

Biological invasions are increasing around the world and are currently considered the second largest threat to biodiversity, after habitat loss (Baillie et al., 2004; Hulme, 2009). Introduced in all environments where man has settled, dogs have been considered an invasive species whose presence in natural habitats can negatively affect wildlife. Dogs may function as competitors, predators and/or pathogen reservoirs (Young et al., 2011; Hughes and Macdonald, 2013; Doherty et al., 2017). Through these interactions, they affect several levels of biological organization. For instance, behavioral changes have been reported in pudu (*Pudu puda*) and chilla foxes (*Lycalopex griseus*), with individuals of these species avoiding areas used by dogs (Silva-Rodríguez et al., 2010; Silva-Rodríguez and Sieving, 2012); Manor and Saltz (2004) report a negative relationship between gazelle (*Gazella gazella gazella*) recruitment and dog records; and Randall et al. (2006) indicate the high suscetibility of Ethiopian wolves (*Canis simensis*) to generalist pathogens transmitted from domestic dogs, specially rabies and canine distemper virus. Dog invasion of natural environments are

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also likely to change ecosystem processes through negative effects on key species, such as medium-sized mammals responsible for seed dispersal (Galetti and Sazima, 2006).

Agroforestry landscapes are rural areas with great potential for species conservation. Agroforestry systems might provide habitat or act as corridors between habitat patches, increasing the chances of (meta)population persistence (Cassano et al., 2009; Schroth and Harvey, 2007). As other human-modified landscapes, agroforestry mosaics are subjected to dog invasion (Cassano et al., 2014; Frigeri et al., 2014). In cacao agroforests in northeastern Brazil, the occurrence and detectability of some native species are negatively related to the frequency of dogs (Cassano et al., 2014) and invasion by dogs occur predominantly during days and times of greatest human activity (Frigeri et al., 2014). In other words, rural workers may be mediating the presence and the use of space by dogs in agroforestry mosaics.

Several factors are likely to influence the frequency of free-ranging dog (*sensu* Vanak and Gompper, 2009) visits in agricultural or natural environments, the proximity to human settlement figuring among the most important. Soto and Palomares (2014) detected a higher abundance of dog signs near the edges of a protected area (*i.e.* edges close to human settlements) compared to sites far away from these edges. Through camera trapping, Srbek-Araujo and Chiarello (2008) also found a high number of dog records in forest edges next to human residences. In a rural landscape, Odell and Knight (2001) reported that dogs were detected more frequently closer to human residences than farther away (considering the distance classes of 30, 180, and 330 m), while wild canids (*Vulpes vulpes* and *Canis latrans*) showed the opposite pattern. Roads and trails may also influence invasion of agricultural and natural environments by facilitating dog displacement in rural landscapes (Sepúlveda et al., 2015).

Here we investigate the invasion of an agroforestry mosaic by dogs, addressing two inter-related hypotheses: (1) whether invasion of agroforests by dogs is negatively associated with the distance from the nearest household and distance from the nearest road, and positively associated with dog population size in the surroundings; and (2) if dogs residing in the vicinity are more prone to invade agroforests than dogs whose origin is unknown.

Material and methods

Study area

The study was conducted in the municipalities of Ilhéus and Uruçuca, Southern Bahia, Brazil, in a landscape of ~400 km^2 (between 14°26′–14°50′ S and 39°03′–39°44′ W; Fig. 1). The study area is a typical landscape of the cacao growing region of southern Bahia, with a few small native forest fragments (10–200 ha) immersed in a matrix predominantly composed of cacao plantations (*Theobroma cacao*), mainly under the agroforestry system locally known as cabruca. Cabrucas were historically set through native forest thinning and the removal of understory for cacao tree cultivation (Johns, 1999). The studied landscape is largely covered by cacao plantations (nearly 59% of landscape), with approximately

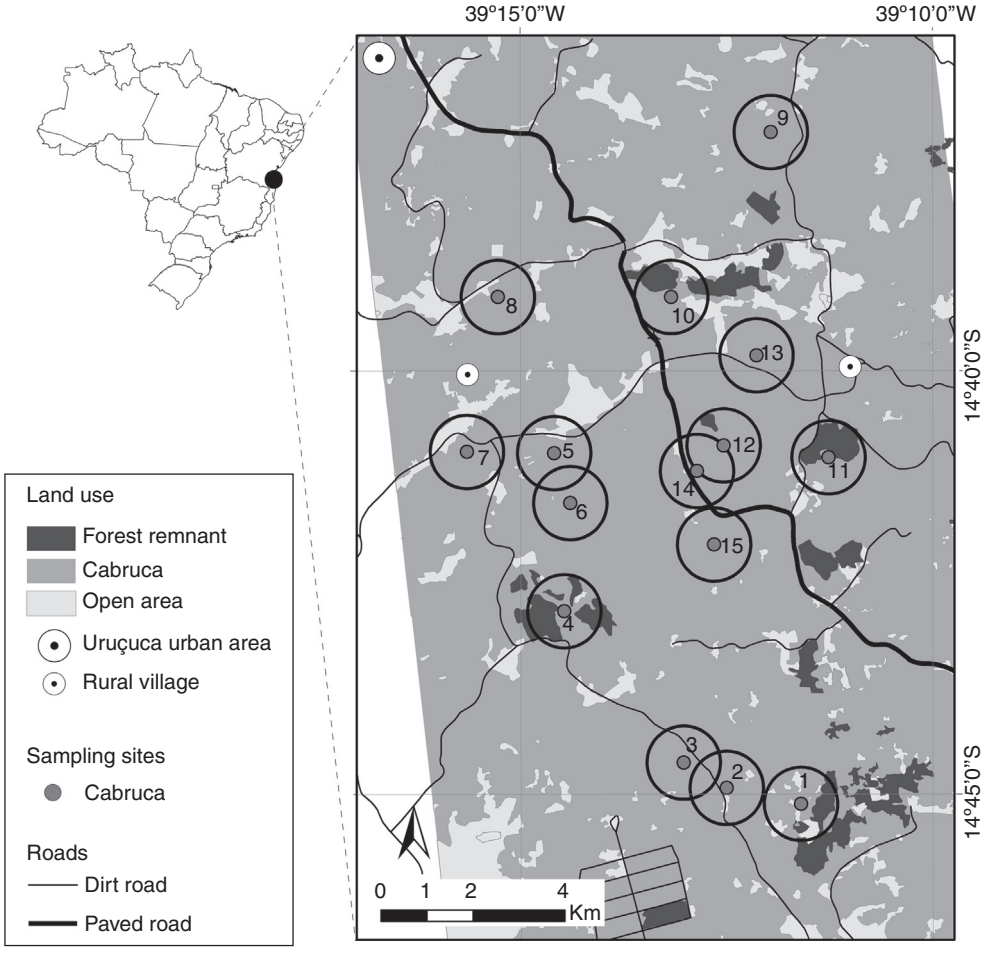

Fig. 1. Map of the study area showing the sampling sites in cabrucas and circular areas of 800-m radius where households and size of dog populations were quantified. Site identification according to Table S1.