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Combining camera-trapping and noninvasive genetic data in a spatial capture–recapture framework improves density estimates for the jaguar

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ABSTRACT

Abundance and density are key pieces of information for questions related to ecology and conservation. These quantities, however, are difficult to obtain for rare and elusive species, where even intensive sampling effort can yield sparse data. Here, we combine data from camera-trapping and noninvasive genetic sampling (scat surveys) of a jaguar population in the Caatinga of northeastern Brazil, where the species is threatened and little studied. We analyze data of both survey types separately and jointly in the framework of spatial capture–recapture. Density estimates were 1.45 (±0.46) for the camera-trap data alone, 2.03 (±0.77) for the genetic data alone, and 1.57 (±0.43) and 2.45 (±0.70) for the two methods, respectively, in the joint analysis. Density and other parameters were estimated more precisely in the joint model. Particularly the differences in movement between males and females were estimated much more precisely when combining both data sources, especially compared to the genetic data set alone. When compared to a previous non-spatial capture–recapture approach, present density estimates were more precise, demonstrating the superior statistical performance of spatial over non-spatial capture recapture models. The ability to combine different surveys into a single analysis with shared parameter allows for more precise population estimates, while at the same time enabling researchers to employ complementary survey techniques in the study of little known species.

1. Introduction

Knowledge of population abundance and density is of fundamental importance for many questions related to ecology, conservation and management. For most organisms, but especially for rare and cryptic species, we cannot census entire populations but have to rely on estimation techniques that account for our imperfect ability to detect individuals (Williams et al., 2002). Capture–recapture models have been a standard tool in estimating wildlife population parameters for decades. More recently, traditional capture–recapture models have been extended to spatial capture–recapture (SCR) models. SCR models combine a detection process describing how animals are detected by an array of traps, conditional on an ecological process describing individual distribution and movement in space (Efford, 2004; Efford et al., 2004; Gardner et al., 2009; Royle and Young, 2008). Contrary to traditional capture–recapture, these models fully account for heterogeneity in detection probability resulting from different exposure of individuals to the trap array. Further, they explicitly link abundance to a specific area, so that density estimation is straight forward, whereas traditional capture–recapture relies on ad hoc approaches to determine the area sampled and transform abundance into density estimates.

Rare and cryptic species, though often of particular conservation concern, are generally challenging to study, and even considerable survey effort may only yield sparse data. Sparse data limit our ability to obtain precise parameter estimates and to include potentially important covariates into an analytical model. Approaches that allow us to combine data from multiple surveys are therefore of prime importance in the study of rare and elusive species. In the context of SCR, combining data from several surveys using the same technique (for example, camera-trapping) either at several sites, or repeatedly over time, has enabled researchers to estimate density of little studied species such as leopard cats (Mohamed et al., 2013) and Sunda clouded leopards (Wilting

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et al., 2012). Recently, Gopalaswamy et al. (2012) developed an SCR model that combines data from a camera-trapping and a scat survey of a tiger population and showed that using both data sources led to a more precise estimate of population density.

Monitoring populations using different techniques allows researchers and managers to draw upon the specific advantages of each approach. For example, camera-traps are indisputably the most efficient tool to monitor populations of individually identifiable large cats such as tigers or jaguars (e.g., Karanth and Nichols, 1998; Wallace et al., 2003): camera-traps can be operated over large areas and extended periods of time with comparably little effort and work continuously once they are set up. Surveys can easily be standardized and plenty of ancillary data on the local mammal community is collected without additional effort (Silveira et al., 2003). On the other hand, the collection and subsequent genetic analysis of scats can provide insight into feeding ecology, genetic structure and diversity and aspects of health of the population under study (Kohn and Wayne, 1997; Schwartz et al., 2007; Waits and Paetkau, 2005). Clearly, both methods complement each other in studying a species' ecology.

The jaguar remains one of the less studied large felids (Brodie, 2009). It is the largest cat of the Americas and with a loss of approximately 40% of its original range in the past century (Zeller, 2007) it is one of the large mammals with the largest absolute range contraction in the past 500 years (Morrison et al., 2007). Although the species' stronghold is the Amazon rainforest (Sanderson et al., 2002), it occurs in a variety of habitats, including the semi-arid Caatinga biome of northeastern Brazil. A recent regional evaluation of the jaguar's conservation status in the Caatinga placed it at Critcally Endangered; habitat loss and especially high degrees of habitat fragmentation threaten the species' persistence in this biome (Paula et al., 2012).

The Serra da Capivara National Park (SCNP) holds an important jaguar population for the Caatinga (Paula et al., 2012). Using camera-trapping and non-spatial capture–recapture models, Silveira et al. (2009) estimated jaguar density in SCNP at 2.67 individuals/100 km^2. In the year following this camera trap effort, a jaguar scat collection survey was carried out at the SCNP. Here, we modify the approach by Gopalaswamy et al. (2012) to estimate separate population densities of jaguars in the SCNP in two subsequent years, by combining data from both the camera-trapping and the scat collection survey within a single SCR model. Using an improved analytical tool, the density estimates we produce are more reliable than earlier estimates from non-spatial capture–recapture models. Further, we demonstrate how combining data from complementary survey methods can improve inference about population density and other ecological parameters. Since the ability to detect changes in populations depends strongly on the ability to estimate population size precisely, the approach we demonstrate is useful for many monitoring programs of rare and elusive species.

2. Methods

2.1. Study site

The Serra da Capivara National Park (SCNP) is located in the south of the state of Piauí, north-east Brazil (Fig. 1). It protects 129,140 ha of the Caatinga, a semi-arid biome contained entirely within Brazil. Temperatures can reach as high as 45 °C, the rainy season is from October to April (Emperaire, 1985), and mean total annual precipitation is 644 mm (SMAPR, 1994). A 6 to 10-m-tall shrubby vegetation predominates the vegetation of the park (Emperaire, 1985). Altitude ranges from 280 to 600 m and the topography consists of a main plateau bounded by 50- to 200-m cliffs and dissected by valleys and canyons. There is no natural permanent water within the Park but a system of artificial waterholes has been constructed over the past 15 years.

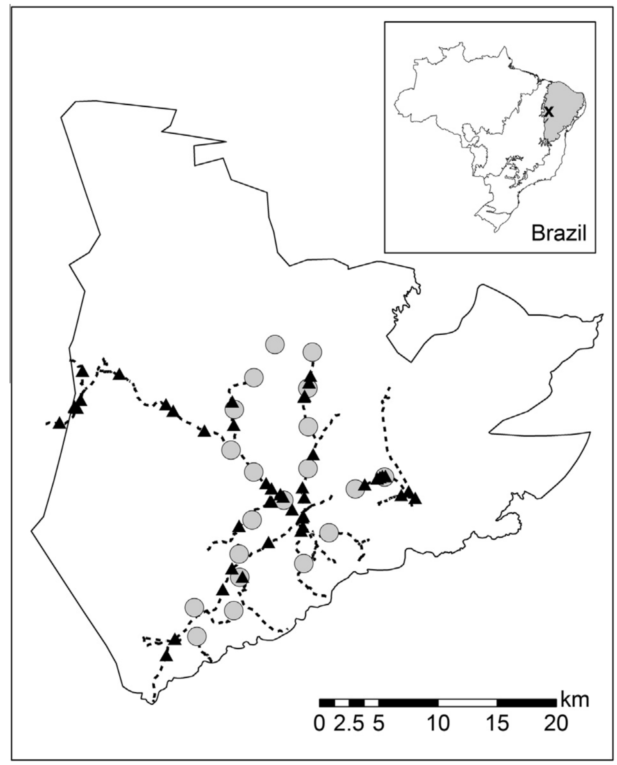

Fig. 1. Camera-traps (grey circles) operated in 2007 and scat surveys (dashed lines) walked in 2008 to study the jaguar population of the Serra da Capivara National Park (cross) in the Caatinga (grey), northeastern Brazil (inset map); triangles mark the locations of jaguar scats collected in 2008.

2.2. Field surveys and data preparation

From August to October 2007, we set up 20 camera-trap stations along the roads of the southern and central part of SCNP, covering an area of approximately 205 km^2 (Fig. 1), as described in detail by Silveira et al. (2009). Each station consisted of two passive-sensor Camtrakker (CamTrack South Inc., Watkinsville, USA) camera traps, model Original 35 mm, facing each other to capture both flanks of a passing animal. Stations were spaced at approximately 3 km and checked every 15 days over 92 days. From the photographs we constructed individual and trap station specific detection histories, containing the number of times each individual was photographed at each trap. To account for occasional camera trap failure we also recorded the number of days each camera trap station was functional over the total survey period.

Between November 10 and December 3 2008 we collected scats in SCNP with the help of scat detector dogs (Long et al., 2007; Smith et al., 2001), trained to search for scats from jaguar and puma. One dog-handler team walked 180.94 km during 21 transects along the roads of SCNP, covering an area of approximately 506 km^2. The scat survey area overlapped largely with the camera trap survey area (Fig. 1). The largest portion of each scat was stored frozen for dietary analysis, and a small portion was stored in 96% ethanol for subsequent genetic analysis. DNA was extracted using protocols based on the GuSCN/silica method (Boom et al., 1990; Höss and Pääbo, 1993; Frantz et al., 2003). Posterior species identification was carried out using an optimized PCR-based protocol as described in Roques et al. (2011). Sex was identified using the method proposed by Pilgrim et al. (2005) based on the size