



Barriers, corridors or suitable habitat? Effect of monoculture tree plantations on the habitat use and prey availability for jaguars and pumas in the Atlantic Forest



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ABSTRACT

Large carnivores are key elements of natural ecosystems and most of them are declining due to the impacts of human activities. Jaguars and pumas are the largest felids of the American continent, and particularly jaguars are critically endangered in the Atlantic Forest of South America. As with other tropical forests, the Atlantic Forest has been converted to human land uses including forest tree plantations with exotic species. We assessed jaguars and pumas habitat use in a productive landscape of exotic pine plantations and forest areas in the Atlantic Forest of Argentina. We estimated the availability of their main preys in this landscape and evaluated the variables that affect their occupancy pattern. We developed large scale camera traps surveys between 2013 and 2014 in an area that includes pine plantations, protected areas, and unprotected areas covered by native forest and small rural properties. In total, we sampled 274 sampling stations with an effort of 13,347 camera-trap days. We used single-species single-season occupancy models to evaluate the effect of the proportion of pine plantation around the sampling station, the cost of human access, and the distance to the edge of the continuous forest block on the occupancy of the felids and its main prey species. For felids, we also evaluated the effect of the availability of their prey species. With a few exceptions, the occupancy probabilities of most prey were affected by one or two of the landscape variables tested. Habitat use by jaguars and pumas was affected by this anthropogenic landscape change. Even though the relative proportion of plantation to forest around camera stations did not affect the habitat use of either of the two feline species, other factors associated with this anthropic land-use, as human accessibility and distance to the continuous forest, did show an effect on these big cat species. According to our results, relatively small and well-managed areas of exotic tree plantations interspersed with forest areas do not constitute barriers for jaguars and pumas in the Atlantic Forest and can function as potential corridors. Forest plantations as such, do not appear to constitute optimal habitats for these felids. The role of tree plantations as potential corridors or supplementary habitat for pumas, jaguars and their prey relies, to different degrees, on the maintenance of a high proportion of native forest among the plantations, on a good connectivity with the large patches of protected forest, and on the control of poaching.

1. Introduction

Large carnivores are considered keystone species that affect the provision of ecological services, including the maintenance of biodiversity (Estes et al., 2011; Ripple et al., 2014). With a few exceptions (e.g., Chapron et al., 2014), most large carnivore populations are

dwindling, and many of them are endangered as a result of human activities that in many cases cause habitat loss, prey depletion and human-carnivore conflicts (Loveridge et al., 2010; Ripple et al., 2014). The persistence of large carnivore populations in a landscape is highly dependent on the presence of large and connected areas of suitable habitat (Crooks, 2002), with a good prey base (Karanth et al., 2004)

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and free of major edge effects and persecution (Woodroffe and Ginsberg, 1998).

The jaguar (*Panthera onca*) and the puma (*Puma concolor*) are the largest felids of the Americas. They are generalized hyper-carnivores highly dependent on a good prey base of medium to large sized mammals (Currier, 1983; Seymour, 1989). Their trophic position determines that their population densities are naturally low (for jaguars generally < 4 individuals/100 km², Jędrzejewski et al., 2018; for pumas usually < 8 individuals/100 km², Caso et al., 2008; Kelly et al., 2008). As is the case with most other large carnivores, their densities are mostly regulated by habitat productivity and prey density (Di Bitetti et al., 2008a, 2008b; Karanth et al., 2004; Miquelle et al., 2010). Their dependency on good prey availability base also means that they require large home ranges and, consequently, large expanses of suitable habitat relatively free of human pressures to persist in a landscape (Herfindal et al., 2005; Jędrzejewski et al., 2007; Morato et al., 2016).

Their preference for large mammal prey usually bring jaguars and pumas into conflict with cattle raisers, which have habitually persecuted and killed them (Caselli de Azevedo, 2008; Inskip and Zimmermann, 2009; Loveridge et al., 2010; Quiroga et al., 2016; Zimmermann et al., 2005). Even in areas where human-jaguar/puma conflicts are not important, poaching has a negative effect on their populations, either as a result of large cat trophy hunting or as a result of prey depletion (Paviolo et al., 2008, 2009a). Thus, the puma and, particularly, the jaguar, have mostly disappeared from areas of high human population densities, particularly where poaching is common or the alteration of the original landscape has been severe (De Angelo et al., 2011; Jędrzejewski et al., 2018; Woodroffe, 2000). However, the negative impact of human activities on these large felids range from nil or mild, as in well managed logging concessions (Tobler et al., 2018), to drastic, as in landscapes where the original environment has been mostly replaced by annual crops or cattle raising grasslands (De Angelo et al., 2011, 2013; Paviolo et al., 2016).

The global jaguar population is continuously declining and its range is shrinking (Quigley et al., 2017). Although a large population still exists in the Amazon, the jaguar range outside this region has been highly reduced, and most of the remaining populations are small and isolated (de la Torre et al., 2018; Jędrzejewski et al., 2018). In Argentina, the jaguar has been categorized as Critically Endangered (Aprile et al., 2012). It is estimated that about 300 individuals remain in three small and relatively isolated subpopulations in the north of the country (Di Bitetti et al., 2017; Jędrzejewski et al., 2018), with the Misiones province population estimated at around 90 individuals (Paviolo et al., 2016). The non-endangered puma has a much wider distribution and a much larger population, both globally, in Argentina, and in Misiones; and is more resilient than the jaguar to human impacts and landscape transformations (Aprile et al., 2012; Caso et al., 2008; De Angelo et al., 2011; Paviolo et al., 2009b).

Tropical and subtropical forests concentrate high levels of biodiversity (Myers et al., 2000). At the same time, they provide good conditions for forestry production. As a consequence, large expanses of tropical and subtropical forests are being replaced by fast-growing short-rotation plantations that usually contain lower levels of biodiversity (Barlow et al., 2007). In the Atlantic Forest of South America, one of the most endangered biodiversity hotspots on Earth (Ribeiro et al., 2009), *Pinus* and *Eucalyptus* monoculture plantations constitute an important productive activity. In the Atlantic Forest of Misiones province, Argentina, monoculture plantations, totaling about 4058 km² (MA, 2015), have replaced large expanses of native forests in the last few decades (Izquierdo et al., 2008). Most of these plantations are localized in the northern sector of this province, which is one of the last strongholds of the jaguar in the whole Atlantic Forest (Paviolo et al., 2008, 2016). Even though these plantations have negative effects on some taxonomic groups (small felids, Cruz et al., 2018; anurans, Gangenova et al., 2018; small terrestrial mammals, García, 2018; medium-large terrestrial mammals and understory birds, Iezzi et al.,

this issue; spiders, Munévar et al., this issue; birds, Zurita et al., 2006) there have been no assessment of their effects on the wide-ranging large felids, the jaguar and the puma.

Using camera-trap records in combination with occupancy models (MacKenzie et al., 2006; Wearn and Glover-Kapfer, 2017), we investigated jaguar and puma habitat use in a productive landscape that includes pine plantations and forest areas in northern Misiones province. We estimated the availability of their main preys in this landscape and evaluated the variables that affect their occupancy pattern. For jaguars, pumas and prey species, we predicted a lower probability of use and occupancy of camera-trap sites with higher relative percentage of plantations vs. native forest in their surroundings. We also predicted a positive effect of the cost of human access to a site (a proxy variable negatively related to poaching intensity) on the probability of it being used by these large felids and in the probability of occupancy of the commonly-poached species in the region. We also expected the probability of use of a site by these felids and the probability of occupancy of the prey species to decrease with the distance to the large and better-protected forest block, under the assumption that it constitutes the main population source for these species. Finally, we predicted a positive relation between prey abundance and the large cats' probability of use of a site.

2. Materials and methods

2.1. Study area

We conducted this study in northern Misiones province, Argentina (Fig. 1; 54°15'30.60"W, 25°55'52.32"S). The study area contains one of the largest continuous remnants of Atlantic Forest (AF) in the World. The natural vegetation of this region is a semi-deciduous subtropical forest and the study area still holds the complete regional native mammal assemblage (Galindo-Leal and de Gusmão Câmara, 2003; Giraud and Abramson, 2000). This study area comprises a central portion with several contiguous public and private protected areas (Iguazú National Park, Urugua-í Provincial Park, San Jorge Forest Reserve, Urugua-í Wildlife Reserve, etc.) that together constitute a large block of continuous native forest of more than 2700 km² (Fig. 1). To the West, the landscape is dominated by pine (*Pinus taeda*) plantations and native forest remnants of different sizes and degree of connectivity with the continuous native forest. Pine monoculture plantations have a high density of trees (1670 individuals per ha), and the stands are neither pruned nor thinned. This western portion of the study area has an extensive network of dirt roads that provide access to the pine plantation stands. Some of these roads are closed to public traffic, but others have no restricted access. To the East, the study area contains a matrix of small-scale (10–200 ha) rural properties with agricultural production (yerba mate, tobacco, maize), and small pastures with cattle and swine. There are also small (usually < 100 ha) forest fragments in these properties and medium-sized (100–5000 ha) public and private protected areas (Fig. 1).

2.2. Data collection

For this study, we joined data from two overlapping (both in space and time) large-scale camera-trap surveys developed in the area between 2013 and 2014. In total, we developed 274 sampling stations with an effort of 13,347 camera-trap days. Mean distance between nearest camera-trap stations was 1.8 km. The minimum convex polygon that included all the cameras was of 5089 km² including 66% of native forest, 17% of pine plantations and 17% of other land uses such as pastures, cities, water, etc. (Fig. 1). One of the surveys was developed between February and July 2014 with the main objective of estimating jaguar densities (Paviolo et al. 2016). During this survey, 90 camera trap stations were deployed on infrequently used unpaved roads (2–6 m wide). Each station consisted of two camera traps facing each other on

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