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Spatial patterns of mammal occurrence in forest strips surrounded by agricultural crops of the Chaco region, Argentina

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ABSTRACT

Deforestation is a major cause of biodiversity loss, and the predominant factor driving deforestation is expansion of agriculture. A key step toward successful conservation in agricultural areas is maximizing biodiversity value of remaining forest. In subtropical and tropical regions, forest often is left in narrow strips between agricultural fields under the assumption that biodiversity is sustained. We examined use of forest strips and continuous forest by medium and large-sized mammals in Argentine Chaco with camera trapping and hierarchical Bayesian zero-inflated occupancy models and assessed how use related to ecological traits of species. Almost 70% of the species cited for our study area were not detected or were detected in less than 10% of the sampling units. Ten of the 23 species that occurred in the area were absent from strips or were detected most frequently in continuous forest, including all large-bodied species and forest interior specialists. Low occurrence of mammals in strips and in continuous forest raises major concerns related to long-term persistence of mammals in Chaco. Under current development policies, agriculture will continue to expand in this region, further threatening the second largest forest in South America. Alternative configurations for the forest-agriculture landscape, as well as synergism between landscape configuration and other threats, need to be evaluated and incorporated into policy if the rich mammalian fauna of this region is to be conserved.

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1. Introduction

Because of massive conversion of forested habitats to agriculture, many previously forested landscapes comprise large expanses of crops interspersed with forest patches and strips (Hawes et al., 2008). Understanding and predicting how wildlife responds to different configurations of forest in agricultural landscapes is essential for development of effective conservation policy. Deforestation is a major cause of loss of biological diversity, and the largest factor driving deforestation is expansion of agriculture to supply an increasing demand for food, biofuels, and other agricultural products (FAO, 2012). Forest buffers are often left along rivers and streams to reduce agricultural run-off and protect water quality (Naiman and Descamps, 1997), and upland forest strips are frequently retained around agricultural fields as windbreaks and to prevent soil erosion and spread of pests and fire (Eriksson et al., 2001). Although upland forest strips likely are not as widespread as riparian buffers, these forest strips occur in agricultural landscapes in tropical and subtropical regions across the planet [e.g., Argentina (Seghezzo et al., 2011), Bolivia (L. Branch, pers. obs.), India (Sreekar et al., 2013), and Paraguay (Eriksson et al., 2001)]. Forest strips and their configuration (e.g., width) historically have been dictated by government policy to benefit agriculture and, more recently, with the additional assumption that these strips maintain biodiversity (Eriksson et al., 2001; Seghezzo et al., 2011). This pattern of land conversion thus represents a deliberate landscape design, albeit often a design with little consideration of conservation outcomes (Fig. 1).

Despite the widespread distribution of forest strips in production landscapes, the assumption that maintaining forest strips around crops allows forest biodiversity to persist in agricultural landscapes remains largely untested (Laurance and Laurance, 1999; Baudry et al., 2000). Forest strips have been evaluated in a limited range of ecological systems, principally temperate systems and to a lesser degree in wet tropical forests, and most studies have focused on small vertebrates, particularly birds (Hawes et al., 2008;

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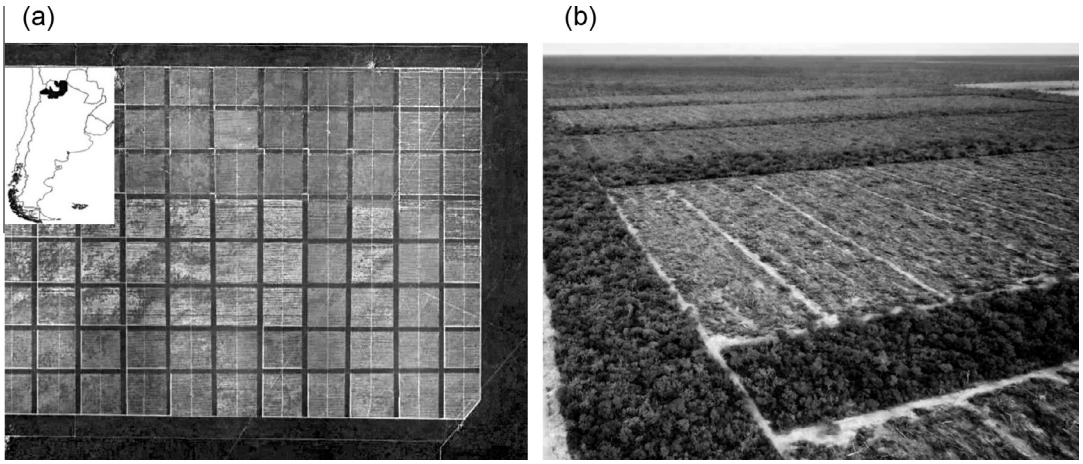

Fig. 1. (a) Province of Salta, Argentina, and satellite image of modified Chaco forest including remnant forest strips (dark strips) imbedded in ~34,000 ha of agricultural land (light squares, each ~200 ha), and adjacent continuous Chaco forest in Salta, Argentina. Satellite image downloaded from Google Earth. (b) Aerial photograph of forest strips in a recently deforested area in the Chaco region. Aerial photograph courtesy of Greenpeace Argentina.

Wehling and Diekmann, 2009). Conclusions to date are mixed. For example, studies in Amazonia have found greater activity of large terrestrial mammals in strips than in adjacent forest (Barlow et al., 2010), similar abundances of frogs and small mammals in remnant forest strips and adjacent continuous forest (de Lima and Gascon, 1999), and depauperate communities of birds and primates in strips as compared to continuous forest (Lees and Peres, 2008). To inform policy and design agricultural landscapes that incorporate conservation goals, understanding of conservation value of strips needs to be expanded to a greater range of geographic regions/ecological systems and a broader set of taxa.

Research on forest strips, and forest fragmentation in general, suggests that species responses to the forest strips may be diverse and possibly idiosyncratic (Henle et al., 2004). Understanding of how species traits (e.g., life history attributes and dietary and habitat requirements) influence the ability of species to use forest strips may improve prediction of impacts of forest conversion to croplands surrounded by forest strips and facilitate design of landscapes that promote species persistence. Such trait-based approaches have provided insights into vulnerability of species to climate change, habitat fragmentation, and hunting (Devictor et al., 2008; Diamond et al., 2011; Thornton et al., 2011; Chessman, 2013). Reproductive rate, determined by traits such as age at first reproduction and litter size, influences ability of species to persist in the face of human-induced mortality factors such as hunting, as well as population recovery following a decline (Altrichter, 2005). Body size often correlates negatively with reproductive rate, but also can contribute to vulnerability because species with large body size require large quantities of food and space that may be not available in human-dominated landscapes (Thornton and Fletcher, 2014). Also, these species often are preferred as game (Peres, 2001). Hunting is a significant threat throughout tropics and subtropics, and exposure of species to hunting often increases where forests are fragmented (Peres, 2001). Vulnerability of species to conversion of continuous forest into remnant forest strips also may be inversely related to ability of species to exploit multiple habitats and food resources. A general pattern emerging from many studies is that specialist species are more likely to respond adversely to a variety of global changes than are generalist species (Devictor et al., 2008). Reduction in abundance or total loss of specialist species can result in a shift to communities dominated by generalist species, resulting in a decrease in functional diversity and biotic impoverishment in the form of functional homogenization of the community (Olden, 2006).

We examine the conservation value of forest strips for medium and large mammals in Argentine Chaco with the goal of informing on-going land use planning that will largely determine the future of forests in this region (Seghezzo et al., 2011; Piquer-Rodriguez et al., 2015). Tropical dry forests and savannas, such as Chaco, are a high conservation priority worldwide, because these regions have suffered extensive habitat conversion (Hoekstra et al., 2005). The Chaco forest of Argentina, Bolivia, and Paraguay is the second largest forest in South America after the Amazon forest, and 60 percent of this forest occurs in Argentina (Piquer-Rodrigez et al., 2015). Diversity of medium and large mammals in Chaco rivals that of tropical forests in South America, and endemism is high (Mares, 1992; Redford et al., 1990). Forest cover in Chaco remained relatively intact until recently with extensive land uses focused on cattle ranching, charcoal extraction, and selective logging (Gasparri and Grau, 2009). In the last two decades, expansion of modern agribusiness has rapidly accelerated forest conversion in this region (Hansen et al., 2013). In northern Argentina current environmental norms require that forest strips at least 100 m wide be left surrounding agricultural plots when forest is cut (~23–37 ha of forest strips for every 100 ha of deforested land), resulting in huge expanses of commercial crops, particularly soybeans (*Glycine max*), divided by a grid of forest strips (Fig. 1, Ginzburg et al., 2012). An increasing number of studies document patterns of land-cover change in Argentine Chaco, but field studies are scarce and very little is known about impacts of this process on biodiversity or, more specifically, the value of these modified landscapes for wildlife (Piquer-Rodriguez et al., 2015; Periago et al., 2015).

We evaluated use of forest strips in Argentine Chaco by medium and large mammals (body weight > 1 kg) and assessed how this use relates to their ecological traits. We expected composition of mammals to differ in forest strips and continuous forest, and that the most vulnerable species (i.e., species that are more likely to be absent from forest strips) would be those with low reproductive rate, large body mass, narrower habitat and dietary breadth, and species that are severely hunted. This work not only supports a broader understanding of effects of habitat loss and creation of forest strips, but also documents the critical situation for wildlife in Chaco, which has the world's highest deforestation rate (Hansen et al., 2013).