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Regional scale effects of human density and forest disturbance on large-bodied vertebrates throughout the Yucatán Peninsula, Mexico

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ABSTRACT

The occupancy probability of 35 large-bodied bird and mammal species was examined in relation to patch- and landscape-scale habitat and disturbance variables in 147 forest patches distributed throughout the Mexican Yucatán Peninsula. Occupancy was assessed on the basis of interviews with local informants. The most important predictors of vertebrate species richness, composition, and patch occupancy were human population density and the extent and quality of forest cover. Most forest species responded positively to forest extent, while felids in particular were sensitive to human population density. However, the effects of human density on patch occupancy operated at extremely local scales. Effects were stronger at a smaller grain size, offering optimistic prospects for conservation strategies that incorporate human population effects. Three arboreal frugivores (*Ateles geoffroyi*, *Alouatta pigra*, and *Ramphastos sulfuratus*) were strongly associated with total basal area of trees bearing fleshy fruits. The degree of hunting pressure was not related to human population density, and affected the occupancy probability of three game species, two of which (*Mazama* spp., *Crax rubra*) are among the most preferred prey across the Yucatán Peninsula. Levels of patch occupancy across this region varied considerably among species, and were best explained by body size and degree of forest habitat specificity, large-bodied species and habitat specialists being the most vulnerable. This study provides a quantitative assessment of the conservation potential of large vertebrates in Mesoamerica and identifies disturbance-sensitive species. This can inform regional-scale conservation planning at a time when low deforestation in parts of the Yucatán Peninsula still provides a narrow window of conservation opportunity given the rapid human population growth.

1. Introduction

Land-use change is the single most important driver of biodiversity erosion in terrestrial ecosystems worldwide (Sala et al., 2000). However, the combined impacts of anthropogenic effects on the present distribution and abundance of large-bodied vertebrates remain poorly understood. This is particularly due to the variation in the extent and intensity of disturbance in most tropical forest regions, the differential ability of species to use a mosaic of human-modified habitats (Lawton et al., 1998), and the synergistic interactions between different disturbance processes, such as logging,

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surface fires, fragmentation, and hunting (Laurance and Peres, 2006).

Human population growth is considered a primary driver of environmental change and the underlying cause of most recent and ongoing species declines and extinctions (Meyer and Turner, 1992; Cardillo et al., 2004). Nevertheless, studies that have examined the relationship between human population density (HPD) and biodiversity have found both positive and negative relationships (see Luck, 2007a; Burgess et al., 2007). The correlation between HPD and species richness is scale-dependent, with a negative correlation at local scales, but a positive association at coarse (e.g. global and national) scales; the latter presumably because of the underlying covariation of both species richness and HPD with ecosystem productivity (Pautasso, 2007; Luck, 2007a,b). While the spatial co-occurrence of species-rich communities and humans represents a great challenge for conservation planning, little is known about how human population pressure affects species richness and assemblage composition at small spatial scales. Fewer than 1% of the studies reviewed by Luck (2007a) used a small grain size. Moreover, although relatively few studies have attempted to link HPD with extinction, most of these have found a positive correlation between HPD and extinction (e.g. Brashares et al., 2001; Parks and Harcourt, 2002; Woodroffe, 2000; Cardillo et al., 2004). Species extinction risk is not only determined by exposure to external threats but also by intrinsic biological traits. Between-species variation in the vulnerability to extinction can be largely explained by high trophic level, low population density, slow life history, and small geographical range size (Purvis et al., 2000; Cardillo et al., 2004). In order to mitigate the detrimental effects of habitat change and disturbance, it is crucial to better understand the causes — both external and intrinsic factors — behind persistence or decline of species in human-dominated landscapes (Daily et al., 2003; Pereira and Daily, 2006).

Here, we evaluate the combined effects of patch and landscape-scale forest habitat quality (i.e. status and extent of closed-canopy forest), human population density, and other structural (logging and fire severity) and non-structural (hunting) forms of habitat disturbance on the species richness, assemblage structure and incidence patterns of large-bodied vertebrates in forests ranging across a wide gradient of anthropogenic disturbance. We examine the species-specific variation in vulnerability to local extinction in terms of ecological and life history traits. The study was conducted throughout the Mexican Yucatán Peninsula, a region attracting high conservation interest within the framework of the Mesoamerican Biological Corridor project, which aims to retain biodiversity in one of the most heavily settled global biodiversity hotspots (Myers et al., 2000; Miller et al., 2001).

2. Methods

2.1. Study area

A total of 147 forest patches were surveyed from September 2002 to February 2003 across a wide disturbance gradient (ranging from nearly intact to highly degraded forests) within the tropical dry forest of the Yucatán Peninsula, Mexico (Fig. 1). Agricultural occupation of the Peninsula dates back to at least 4000 BP (Edwards, 1986), with up to 75% of the region modified by 1200 BP at the peak of the Maya classic period (Whitmore et al., 1990). Forest cover expanded c:a.760 BP after the Mayan collapse [1200–1000 BP] (Leyden, 2002). More recently, considerable forest degradation resulted from timber extraction (e.g. *Cedrela odorata*, *Swietenia macrophylla*) during the first half of the 20th century, followed by dramatic population growth resulting from government-sponsored colonization initiatives (1975–1982) favouring both smallholder subsistence and large-scale agriculture (Klepeis, 2003). Many existing even-aged stands result from past human disturbance events, such as fires and shifting cultivation (Bray et al., 2004; Urquiza-Haas, 2006).

2.2. Faunal occupancy and structure of forest patches

Sampling took place within 136 communal tenure landholding units [hereafter, *ejidos*] and 11 private properties within each of which we identified at least one key informant per sampled forest patch. As a prerequisite, key informants were defined as a long-term resident or landowner familiar with the large-bodied vertebrate fauna, who was knowledgeable about the disturbance history of the forest patch in question, which they had visited regularly for at least the last five years. Key informants were mainly hunters that spent much of their time in the forest. Informants were interviewed *in situ* in the forest patch, defined as an even-aged stand with a relatively homogeneous degree of disturbance, assessed visually and by information provided by the interviewee. Patches were either distinct forest fragments surrounded by pastures or croplands, or even-aged stands within a forested landscape with other adjacent patches varying in their degree of disturbance. Key informants rather than forest patches were selected beforehand. However, we initially selected large study areas based on landscape characteristics using three georeferenced Landsat ETM images, to sample evenly across the gradient of forest extent within the state of Quintana Roo and eastern Yucatán.

Obtaining vertebrate species occupancy data from local interviews is a cost-effective approach successfully tested in several landscape-wide studies of large carnivores (Gros, 1998; Ortega-Huerta and Medley, 1999) and other vertebrates (Lawes et al., 2000; Michalski and Peres, 2005). Occupancy records were defined as occurrences within forest patches visited, when interviewees were certain that the species was present at the time of interviews or in the recent past ($\leqslant$5 yr). Absences were defined as species that had not been sighted, heard or detected by tracks or scats within the 5 yr prior to the study.

The species considered (Table 1) were restricted to mid-sized and large-bodied mammals (>600 g) and birds (>200 g) readily recognised by long-term residents with the aid of field guide colour plates (Reid, 1997; Howell and Webb, 1995) and photographs. Sympatric species of brocket deer (*Mazama americana*/*M. pandora*) and tinamous (*Crypturellus cinnamomeus*/*C. boucardi*/*C. soui*) were pooled as informants could not reliably differentiate these congeners in the field. To verify the incidence of Type II errors, 12 species known not to occur within the Yucatán Peninsula were included in the pictorial