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Density and activity patterns of ocelots (*Leopardus pardalis*) in northern Peru and the impact of oil exploration activities

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ABSTRACT

The western Amazon is experiencing unprecedented levels of oil and gas exploration, a trend of particular concern given the high levels of biodiversity found in this relatively pristine and unstudied region. Despite the widespread use of seismic reflection technology for exploration, no studies have investigated the response of wildlife populations to this disturbance in the tropics. We conducted a trail camera survey inside a large oil concession (Block 39) in the Peruvian Amazon near the Ecuador border with ongoing 2D seismic explorations to investigate its effects on ocelot (*Leopardus pardalis*) activity and abundance. The estimated size of the ocelot population within our 22 km^2 study area was the same before (control period: 34 ± 6.9 ocelots) and during exploration operations (disturbance period; 34 ± 4.6 ocelots) and we detected no change in activity patterns between the two periods. Ocelot capture rate was unaffected by the presence of seismic crews, and distance to the nearest seismic line was not correlated with capture rate at individual stations. Our density estimates (ocelots/100 km^2) from the control (75.2) and disturbance period (94.7) include the highest reported for the species, and represent the first ocelot density estimates from the northwest Amazon forest. These high values conform to recent research showing a positive association between ocelot density, annual rainfall, and proximity to the equator (this study: >2500 mm annual rainfall; <200 km from equator). We discuss the potential short- and long-term environmental impacts of seismic operations, particularly as they relate to large mammal populations.

1. Introduction

The ever-increasing worldwide demand for energy has resulted in unprecedented levels of oil and gas exploration in the western Amazon, with some of the most intense activity occurring in Peru. As of 2008, 72% of the Peruvian Amazon was zoned by the government for oil and gas activities into 64 separate concessions or "blocks", 48 of which are currently active (Finer et al., 2008). Many of Peru's concessions are already, or will soon be subjected to active exploration, which includes the use of seismic reflection technology along a grid of "seismic lines". Along these straight-line transects, underground explosives are detonated to register reflected sound waves, which provide information about the presence and depth of potential oil and gas reserves. The frequency of use of seismic exploration in tropical rainforest ecosystems, combined with the fact that much of the western Amazon is relatively pristine and harbors some of the highest levels of biodiversity in the world (Ceballos and Ehrlich, 2006; Orme et al., 2005; Ter Steege et al., 2003), highlights the need to understand the impacts of these activities on the ecosystem, and exposes a remarkable gap in our understanding of the environmental impact of oil and gas industry presence in the Amazon.

Few studies have investigated the impact of terrestrial seismic exploration activities on mammal populations or any aspect of ecosystem function. The majority of the existing research has been conducted in Canada and the northern United States and has resulted in mixed conclusions regarding the extent to which these activities influence mammal populations. Based on radio-telemetry data, grizzly bears (*Ursus arctos*) in British Columbia showed no significant habitat displacement in response to seismic exploration activities (McLellan and Shackleton, 1989), whereas larger-scale landscape use modeling indicated that secondary effects of seismic lines on landscape structure influenced grizzly bear movements in Alberta, Canada (Linke et al., 2005). In the same region, GPS-monitored woodland caribou (*Rangifer tarandus caribou*) avoided areas within 250 m of seismic lines (Dyer et al., 2001), yet seismic lines, unlike roads, did not act as barriers to caribou movement (Dyer et al., 2002). Finally, although behavioral changes occurred in woodland caribou in response to noises simulating seismic exploration, no significant displacement occurred (Bradshaw et al., 1997). To our knowledge, no formal studies have investigated responses of wildlife to disturbances associated with seismic oil exploration in tropical systems.

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The ocelot (*Leopardus pardalis*) is the largest of the world's small spotted cats, exhibits an extensive range stretching from southern Texas to northern Argentina, and occurs in a wide variety of ecosystems, from thornscrub to tropical rainforest (Murray and Gardner, 1997). Due to the key role that large carnivores play in regulation of ecosystem function (Crooks and Soule, 1999; Ray et al., 2005; Ripple and Beschta, 2006; Terborgh et al., 1999), knowledge of how their populations respond to human disturbances is crucial to ecosystem conservation efforts. Unlike puma (*Puma concolor*) or jaguar (*Panthera onca*), ocelots do not exhibit the extensive home ranges that make population surveys problematic, and a relatively focal disturbance such as seismic exploration can influence numerous ocelot territories within a short time period, making ocelots a potentially more responsive indicator of disturbance impacts. Although their geographic range suggests a behaviorally flexible species, ocelots can be sensitive to habitat loss and fragmentation resulting from human development and habitat conversion (Haines et al., 2005; Tewes and Everett, 1986), and recent research also indicates that more subtle forms of anthropogenic disturbances (e.g. poaching and logging) in otherwise suitable habitat can significantly reduce local ocelot abundance (Di Bitetti et al., 2008).

A relatively new technique utilizing a combination of motion-triggered cameras and statistical methods associated with traditional mark-recapture techniques has allowed researchers to directly estimate the density and local abundance of spotted cat populations (Karanth, 1995; Karanth and Nichols, 1998) without the need for trapping and telemetry, or the problematic assumptions involved in track surveys (Karanth et al., 2003). Consequently, camera surveys have recently documented ocelot densities in various locations (e.g., Bolivia: Maffei et al., 2005, Argentina: Di Bitetti et al., 2006, Belize: Dillon and Kelly, 2007, Brazil: Trolle and Kery, 2003). However, densities have not been reported from a large portion of the western Amazon (Colombia, Ecuador and northern Peru). Ocelot densities are positively correlated to an area's rainfall, and negatively to its latitude (Di Bitetti et al., 2008); a suspected consequence of the connection between primary productivity and proximity to the equator. Due to its extremely high annual rainfall and proximity to the equator, this unstudied region of the western Amazon is therefore expected to support some of the highest ocelot densities throughout the species' range (Di Bitetti et al., 2008).

Our primary objective was to use a camera-trapping survey to assess the short-term impacts of seismic exploration on ocelot density, local abundance, and activity patterns by monitoring a single study area before and during the initiation and completion of a seismic exploration project. A secondary objective was to provide an important data point in the assessment of the continental correlates of ocelot abundance by estimating ocelot density at a location averaging more than 2500 mm of annual rainfall and located more than 700 km closer to the equator than any previous ocelot study site.

2. Methods

2.1. Study area

Our study was conducted within a large oil concession (Block 39; 1°35′12.3″S, 75°12′20″W) in the Peruvian Amazon in the department of Loreto near the Ecuador border. The concession covers approximately 8850 km^2 and is located 250 km NW of Iquitos (pop ~400,000), the closest center of commercial trading and residential development. The block includes the higher reaches of three notable rivers, the Curaray, which extends into Ecuador, the Arabela, and the Pucacuro. The watershed of the latter defines the Zona Reservada Pucacuro, an area set aside as protected by the government which is in the process of categorization. All rivers within the block drain into either the Tigre or Napo rivers which ultimately empty into the Amazon River near Iquitos. The block itself contains no roads and includes only a few small villages along its eastern edge. The largest of these, Buena Vista and Flor de Coco, are located along the Arabela River and each support less than 300 inhabitants (Vriesendorp et al., 2007).

Due to its remote location and the resulting relative isolation from development and exploitation, the vast majority of Block 39 is composed of pristine lowland tropical rainforest. The block is characterized by rolling topography and is included in the Napo Moist Forest ecoregion (Olson et al., 2001). There is no distinct dry season in this region and annual rainfall averages 2500–3000 mm. During our study period from April through August 2008 monthly rainfall in Block 39 averaged 256 mm (range: 119–465 mm), and monthly daytime minimum and maximum temperatures averaged 20° and 32 °C, respectively, with little variation among months.

Seismic oil exploration activities in Block 39 began in early 2008 with Repsol, the operating company, planning for seismic drilling along 590 km of straight-line transects (Fig. 1). We began our study before the arrival of seismic work crews to our study site, and thus the seismic lines shown in Fig. 1 were not yet cleared.

Using a combination of SRTM digital elevation models (van Zyl, 2001), LANDSAT ETM + imagery, and the planned seismic routes, we selected our study site based on two primary factors: (1) did not include any major rivers or areas likely to be seasonally or permanently inundated, and (2) contained a high density of proposed seismic lines. This latter factor was critical to ensure that our study area was subject to the highest levels of disturbance associated with this seismic operation. We identified an optimal study area (~22 km^2) in the west of Block 39 (Fig. 1) with an elevation range of 205–279 m, and which ultimately contained a seismic line density of 680 m/km^2. This is the most remote portion of the concession; it is completely inaccessible by river, and no signs of human presence or hunting were encountered. To ensure that disturbances associated with our research camp (e.g. helicopter supply flights, generator noise) did not influence ocelots in our study, we established our camp approximately 1 km outside of the study area.

2.2. Seismic operations

Technological advances and adoption of more strict environmental practices have allowed companies to reduce the environmental damage previously associated with seismic operations (Rosenfeld et al., 2001), and use of an "offshore model", (no road construction, access only by boat or helicopter) is now standard. However, seismic exploration activities continue to involve an extensive influx of personnel, equipment and potential disturbance to the ecosystem. Seismic exploration in Block 39, as carried out by Repsol and their subcontractors, followed the offshore model and included three waves of activity; topography, drilling and registration. During topography, a relatively narrow (~1.2 m) straight-line trail is cleared using chainsaws and machetes, leaving all trees >20 cm dbh. Along these transects, holes of 15 m depth are drilled every 50 m and an explosive charge is buried. The final wave of activity includes the largest number of field personnel and involves laying recording devices and cables along seismic lines, detonation of the charges, and registration of the resulting seismic reflection waves. Within our study area topography, drilling and registration team activity lasted 14, 28, and 23 days, respectively, and never occurred simultaneously. Throughout the topography phase, camps of approximately 10 × 20 m are cleared approximately every 4 km along each transect and are always associated