Biological Conservation 143 (2010) 1017–1024

Contents lists available at ScienceDirect

Biological Conservation

journal homepage: www.elsevier.com/locate/biocon

Oil prospecting and its impact on large rainforest mammals in Loango National Park, Gabon

Luisa I. Rabanal, Hjalmar S. Kuehl, Roger Mundry, Martha M. Robbins *, Christophe Boesch

Max-Planck-Institute for Evolutionary Anthropology, Department of Primatology, Deutscher Platz 6, 04103 Leipzig, Germany

ARTICLE INFO

Article history:
Received 26 July 2009
Received in revised form 8 December 2009
Accepted 18 January 2010
Available online 18 February 2010

Keywords:
Apes
Elephants
Noise disturbance
Oil exploration
Seismic activities
Spatial distribution

ABSTRACT

Resource extraction is increasingly affecting protected areas worldwide. However, aside from studies on logging, limited information is available about the effect this has on wildlife, which may be of great consequence, especially when endangered species could be affected. Specifically, the effect of intense human-induced noise during oil exploration on wildlife is poorly understood. We explore the effect of seismic oil exploration on large mammal distribution in an 80 km^2 area of Loango National Park, Gabon. Following the ecological theory of habitat disturbance, we predicted that changes in habitat use in response to noise disturbance would scale with the body/home range size of each species examined. Our study was conducted over six months before, during and after low-impact seismic operations. We recorded counts along transects of indirect signs of elephants (*Loxondota africana cyclotis*), chimpanzees (*Pan troglodytes troglodytes*), gorillas (*Gorilla gorilla gorilla*), duikers (*Cephalophus* spp.), and the vocalizations of five monkey species (*Cercocebus torquatus, Cercopithecus cephus, C. nictitans, C. pogonias* and *Lophocebus albigena*) and modeled seismic impact over different spatial scales (small, intermediate and large). We found that elephants avoided seismic activity on all three spatial scales, apes avoided on the intermediate and small scales, and there was no effect for duikers and monkeys. We conclude that low-impact seismic operations can cause considerable temporary habitat loss for species with large ranges and suggest that the impact on those endangered species can be minimized by adequately spacing seismic lines and activity in space and time to enable species to move away from the progressive noise disruption.

1. Introduction

Global economic development has led to an increase in the extraction of natural resources such as wood, oil and minerals in developing countries. As a consequence the pressure on protected areas has intensified worldwide. Many of these projects involve high noise production, such as chain saw noise for logging and dynamite explosions during seismic activities for oil prospection and the extraction of certain minerals. The impact of intense human-produced noise has been the subject of several studies on a variety of marine and terrestrial dwelling species, but in general the effects are poorly understood (Larkin et al., 1996; Brown, 2001). First, activities that create loud noise and the studies that concern their impact are generally not conducted simultaneously. Second, not all species respond to noise disturbance in the same manner.

The most common behavioral change exhibited by wildlife to intense human-produced noise is active avoidance. Examples of this phenomenon in response to seismic sound are reported for several whale species, e.g. blue whales (*Balaenoptera musculus*; McDonald et al., 1995) and humpback whales (*Megaptera novaeanglia;* McCauley et al., 2000). For some terrestrial large mammals, such as grizzly bears (*Ursus arctos*; McLellan and Shackleton, 1988) and caribou (*Rangifer tarandus*; Dyer et al., 2002), between 8.7% and 48% of their available habitat may be lost through active avoidance.

Seismic activities can also produce physiological responses in large mammals, for example a significant increase in heart rate in grizzly bears (Reynolds et al., 1986). More extreme cases reveal that weddell seals (*Leptonychotes weddellii*; Bohne et al., 1985) and humpback whales (Ketten et al., 1993) can suffer temporary or persistent damage to their auditory systems. In the long term, species may even be adversely affected by a decrease in survival probability (caribou; Harrington and Veitch, 1992).

In contrast, studies deemphasizing the impact of noise on wildlife include reports on moose (*Alces alces*) which seem to be less sensitive than other wildlife, and do not show intense reactions to aircraft flying overhead (Klein, 1973). Consequently, generalizations across species are of limited use (Larkin et al., 1996), and currently no coherent framework exists that would help to understand differences in species' responses to noise disturbance.

Evidently wildlife responses to noise disturbance depend on a variety of factors pertaining to the species such as the auditory

* Corresponding author. Tel.: +49 341 3550 210; fax: +49 341 3550 399.
E-mail address: robbins@eva.mpg.de (M.M. Robbins).

0006-3207/$ - see front matter © 2010 Elsevier Ltd. All rights reserved.
doi:10.1016/j.biocon.2010.01.017

system, inherent physiological responses, ranging patterns and many other factors related to species ecology. Yet species' reactions will also vary with sound properties such as noise level, frequency distribution, duration, number of events, and level of ambient noise (Brown, 2001). In contrast to the multifaceted analysis that such a complex issue would require, many of the existing noise disturbance studies have been rather anecdotal and do not quantitatively measure the behavioral response related to the noise impact. Very often noise disturbance is evaluated as a case study with a single species only, and predictive models relating quantifiable behavioral or physiological responses to disturbance dosage are only rarely applied. A potential solution to this problem would be to study a specific type of response on a number of species simultaneously, and make predictions of the response following the ecological theory of habitat disturbance and the species' biological characteristics. Studies of the effect of habitat disturbance, in particular habitat fragmentation, have revealed that species' body size is a key factor in understanding species' responses (Johns and Skorupa, 1987).

We therefore evaluated the impact of loud noise only, resulting from seismic exploration, on the spatial distribution of several large rainforest mammals. Although the effects of oil exploration include chemical pollution of water and soil that has the potential to impact on a broad range of species, we focused on large fauna, which are a main concern given their low survival ability as compared to smaller species following habitat disturbance (Johns and Skorupa, 1987). The longer maturation period and slow reproduction of large species render them particularly vulnerable and their population densities are also associated with hunting pressure (Peres and Palacios, 2007). Furthermore, our study examined the case of a petroleum company conducting seismic exploration inside Loango National Park, Gabon (Fig. 1a), an area which, like other protected areas in the Congo Basin, acts a stronghold for populations of endangered large mammals, such as elephants (*Loxondota africana*), chimpanzees (*Pan troglodytes*) and gorillas (*Gorilla gorilla*). To date, most of the available information regarding how these species are affected by such economic development projects comes from studies on the impacts of logging (Tutin and Fernandez, 1984; White and Tutin, 1996; Arnhem et al., 2008). Here we therefore expand on this knowledge by presenting the first results on the impact of oil exploration.

In 2006 seismic operations were undertaken in Loango National Park in the absence of clear environmental regulations. We were unable to conduct any research during this time due to the speed at which the seismic operations were initiated. Following this first period of oil exploration, an ecological and sociological impact assessment study was instigated by the Gabonese Ministry of the Environment. As a result, prior to the second phase of exploration which began in June 2007, several requirements were established to limit the impact of the seismic operation on the flora and fauna of the park. An auditing team headed by the Wildlife Conservation Society (WCS) and the World Wide Fund for Nature (WWF) was commissioned by the Gabonese Ministry of Environment to monitor the implementation of the following guidelines: (1) no chainsaws were to be used; (2) trees larger than 10 cm diameter could not be cut; (3) transects could be no wider than 120 cm; (4) all transects had to be walked by foot and not by using mechanized vehicles; (5) all rubbish and materials (e.g. cables) had to be removed from the forest; (6) dynamite explosives had to be placed at least 6 m deep; (7) no poaching was permitted; (8) only one access road for vehicles was made; (9) the bridge that gave access to the park would be destroyed after the end of the operations. In summary, these guidelines and the monitoring program lead to this being considered a relatively low-impact seismic operation.

For a period of six months before, during and after the 2007 seismic survey we monitored the spatial distribution of elephants, chimpanzees, gorillas, duikers (*Cephalophus* spp.) and monkeys (*Cercocebus torquatus, C.cephus, C.nictitans, C.pogonias, Lophocebus albigena*) using counts of signs along transects to obtain encounter rates. Specifically, we investigated if: (i) species would respond to the loud noise produced by the dynamite explosions from these seismic activities by avoiding areas of high-impact and (ii) a discernible pattern of inter-species differences existed in these responses. Due to the variation in home range size of the above species, we predicted a spatial response on a larger scale in the following large-bodied species using larger ranges: elephants, chimpanzees and gorillas. On the contrary, given the smaller home range sizes for monkeys we predicted that they would be less impacted by the exploration activities than the large-bodied mammals. In summary, we expected that the seismic impact on a species' spatial distribution would scale with home range/body size.

2. Methods

2.1. Study site and seismic exploration

The oil exploration site was located in the northeastern part of the 1550 km^2 Loango National Park, Gabon. The park contains a

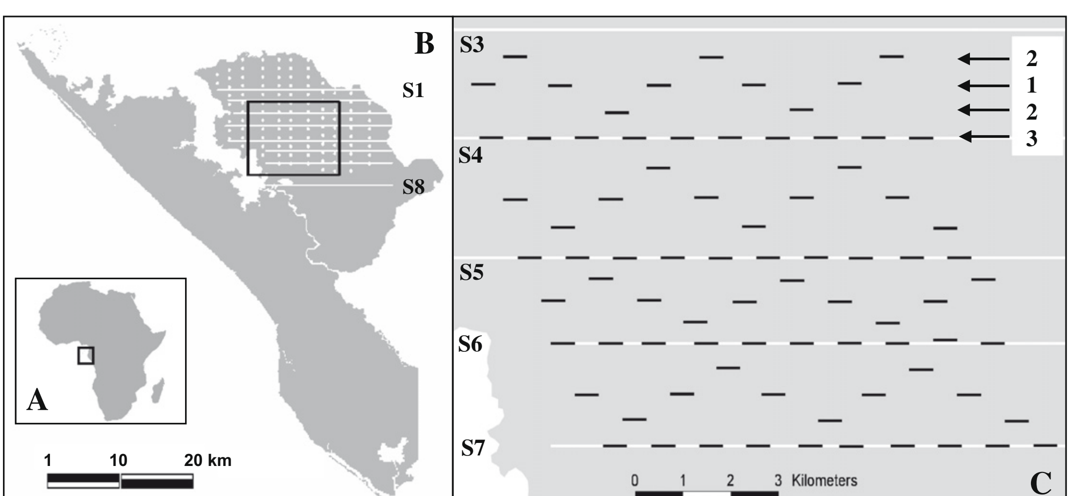

Fig. 1. Location of Loango National Park, Gabon (A), seismic transects exploded in 2006 (broken lines) and seismic lines exploded in 2007 (solid lines) in the northeast sector of Loango National Park (B), and study area (black square). The seismic impact monitoring design is shown in (C), transect length was 0.5 km. The impact of the dynamite explosions for each line of transects is indicated from 1 to 3 (3 being the highest), with the highest impact directly on seismic lines decreasing with increasing distance from the line.