MEASURING RESPONSES OF WILDLIFE TO OIL OPERATIONS IN MURCHISON FALLS NATIONAL PARK

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Executive Summary

This report summarises the impacts of oil exploration activities on large mammals and birds in the Murchison Falls National Park. It specifically assesses how animals respond to pad construction, pad maintenance between activities and the impacts of drilling at a pad up to 2 kilometres from the pad or drill site. The results come from a 16 month monitoring program around four drill pads between February 2010 and June 2011 that was undertaken by staff of the Uganda Wildlife Authority and the Wildlife Conservation Society with funding from the USAID WILD program.

Most large mammals were negatively affected by the activities at a drill pad site, even pad maintenance where there is not much activity but a presence of people and some vehicle traffic. Elephants, buffalos and giraffes were most negatively affected with avoidance up to 750-1000 metres being exhibited. Smaller mammals such as oribi, warthog and Uganda kobs showed some avoidance up to 250-500 metres away but in some cases the presence of the pad seemed to benefit these species and they could occur at relatively high densities near the pad. It is thought they may have learnt to avoid predation by staying around the pads at night where there are spotlights.

Total bird density was lower near the pads but stabilized between 200-400 metres from the pad/drill site. We could not calculate densities at different distances from the pads for all species because of the need for many sightings but for the more common species this was possible. During drilling operations the African palm swift, rattling cisticola, croaking cisticola, black-headed gonolek, black-crowned tchagra, yellow-billed oxpecker, helmeted guineafowl and grey-backed fiscal all showed lower densities near the pad up to 300-700 metres away (8 out of 13 species that could be estimated). Two species, piapiac and zitting cisticola, occurred at higher densities near the pad during drilling operations. The other three species showed no clear change with distance. When pad construction was taking place five of the 13 species showed lower densities near the pad and none showed increased densities. Most species showed no change under pad maintenance although a few occurred at lower densities near the pad site (0-500m)

We also assessed mammal densities at a time when seismic exploration was taking place but results are not so clear because the study was aimed at assessing the impacts of oil pad sites and not seismic activities which take place over a large area.

The results show that activities at the oil pads are leading to lower densities of the large mammals and birds in Murchison Falls National Park. Recommendations are given to help reduce these negative impacts on the wildlife of the park as well as ways to plan the exploration and production so that the impacts are minimized.

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Introduction

The ever-increasing worldwide demand for energy has resulted in unprecedented levels of oil and gas exploration, and one of the most recent finds has occurred in the Western arm of the East African Rift Valley, with some of the most intense activity occurring in Murchison Falls National Park (MFNP). This promises substantial economic development from oil and gas production for the country and the region.

MFNP is one of four savanna parks in Uganda which is recognized for its uniqueness and importance for biodiversity conservation (Lamprey, 2000), has the most spectacular falls along the Nile, is important for its wildlife concentrations, and is the main representation of the Sudanian vegetation form in East Africa. It is thus accorded a high level of conservation priority by IUCN (UWA 2001). It is also the only park in Uganda with a viable population of Rothschild's giraffe and crocodile, contains Uganda's largest population of Jackson's hartebeest, which has been nearly or completely eliminated from other protected areas in Uganda, and it is also one of the few places in Uganda with populations of soft-shelled turtle (Olupot *et al.* 2010).

Recognizing the high levels of biodiversity richness in MFNP, it is important to assess the potential impacts of oil exploration on the wildlife in the park and attempt to devise appropriate methods of minimizing any disturbance that is caused by these activities. Attention must be paid to the fact that behavior and response patterns can vary enormously between species, such that some mitigation measures may need to be site- or species-specific dependent on individual site circumstances. Impacts could include:

a. noise pollution causing animals to:
   - avoid areas where drilling is occurring,
   - change behaviour as noise interferes with vocalization as well as hearing (including for mating and alarm responses)
b. light pollution at the rig sites may:
   - interfere with visual stimuli and orientation leading to confusion
   - increase likelihood of mortality for some species which may be attracted to the lights on site,
c. increased traffic on roads may lead to road kills.

Noise can have significant impacts on animals because increased disturbance levels reduce the distance and area which might be perceived by animals as suitable for foraging, it can place them at greater risk of predation, can cause stress that affects reproduction and reproductive success and can lead to increased stress caused diseases (J.M. Kolowski, and A. Alonso 2009).

This report summarises the results of a 16 month monitoring study of the impacts of the establishment of drill pads, access roads and the resulting drilling operations on large mammals and birds in the MFNP. The study aimed to establish the responses of the different species to the noise and human activity at the pad sites and to assess the flight distances of each species in response to this disturbance.

Murchison Falls National Park History

The park (3,893 km^2) lies in the Albertine Rift and includes part of the valley floor and escarpment (UWA 2001). The Bugungu Wildlife Reserve (474 km^2) in the south and the Karuma Wildlife Reserve (678 km^2) in the south east are part of the Murchison Falls Conservation Area which includes Murchison Falls National Park (Ibid).

Murchison Falls National Park (MFNP) was gazetted in 1952, but had been inhabited in the past by humans since the Stone Age (Fagan and Lofgren 1966). The rinderpest and sleeping sickness outbreaks that occurred at the end of the 19^{th} century led to people moving out of this region which allowed animal populations to build up. The earliest written accounts of the park were recorded by the explorer Samuel Baker in 1866 (Laws et al. 1975), who named the falls "Murchison" in honor of Roderick Impey Murchison, then president of the Royal Geographic Society. When the National Parks Act was passed in 1952, it led to the formation of Queen Elizabeth National Park and Murchison Falls National Park that year. At the same time, the system of Game Reserves was expanded to protect wildlife and their habitats.

Study Objectives

Several objectives were planned at the beginning of the study which included:

- Monitoring animal densities around oil exploration sites to assess changes as oil exploration takes place.
- To determine species responses to the various activities involved in exploration operations.
- To identify flight distances from drill sites for each species so that planning of any network of drill sites can incorporate this information and minimize impacts on the species
- To identify which mammal and bird species are most susceptible to the disturbance and impacts of the oil industry
- To partner with Uganda Wildlife Authority to provide training necessary for a long-term oil impact monitoring program
- To help inform and guide oil companies, PEPD and UWA in managing the drilling operations in MFNP and the surrounding region in a way that minimizes their disturbance to wildlife.

Study Location

The study location is on the northern bank of MFNP in the main tourism circuit area. The study area habitat consists mainly of a mosaic of grassland, dense borassus woodland, open borassus woodland; open woodland, wooded grassland and bush/shrub.

The park's topography is rolling, reaching a maximum elevation of 1,291 m at Rabongo Hill in the south east of the park, and a low elevation of 619 m at Lake Albert on the rift valley floor in the west. The park is hot with mean minima and maxima around 22^0C and 29^0C respectively in all months. The eastern part of the park is wetter than the western part; Chobe to the East receives around 1,500 mm whilst Paraa receives about 1,100 mm. Murchison Falls National Park has two rainy seasons, from mid-March to mid-June, and from August to November (UWA 2001).

Figure 1 provides a map of the study area and its location in the western sector of the park near the Buligi Circuit. It shows the locations of the transects used to monitor the animal and bird populations (purple) and also the proximity of the four well sites which were planned to be drilled. Some transects were also placed perpendicular to access roads that were either existing park roads (shown on map) or were new roads, established for access to the oil pads (not shown on map). The survey effort was focused around 4 active Oil sites i.e. Buffalo East-1(BE-1), Buffalo East-3 (BE-3) and Buffalo East-5 (BE-5) and Buffalo East (BE-4). A total of 24 transects were established.

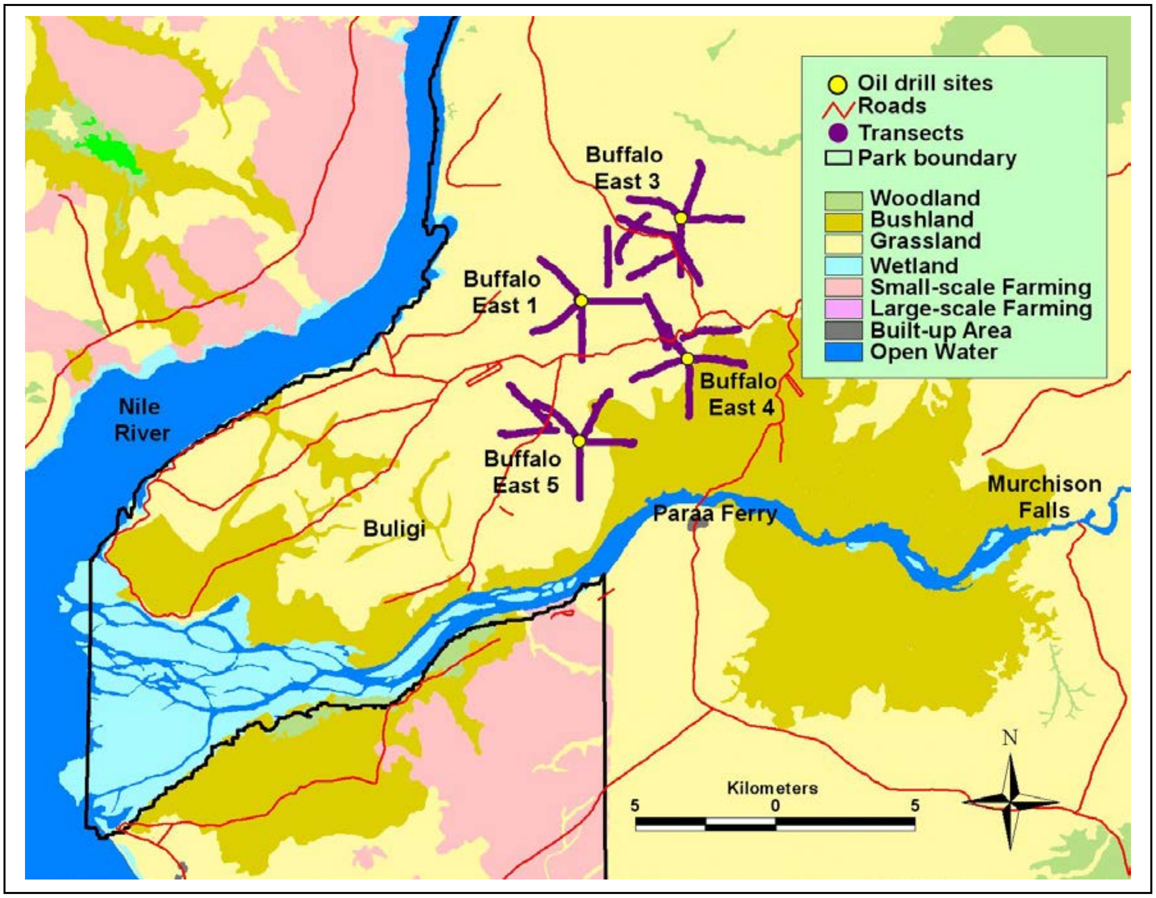


Figure 1. The location of the transects (purple lines) around the four drill pad sites (yellow dots) which were monitored together with transects from access roads to the drill pad sites.

Methods

Overview

The study commenced in February 2010 involving six survey rounds. The aim of the monitoring was to monitor before activities started, during the drilling operation and after the drilling to assess changes over time. However, a conflict between Tullow Oil and the Uganda Government over their contract affected the planned timing and meant that we were not able to monitor after a drilling event. We established six-2km transects at each of the four selected oil sites. Four transects radiated from the drill pad sites and two were sited perpendicular to access roads to the pads. During their establishment compass directions were followed but in the case of some lines the person reading the compass was not very proficient and as a result lines were not straight. However, we don't believe the lines were biased because of habitat or topography and so have continued to use the results from these lines.

The monitoring periods are given in Table 1 together with the main activities at the Pads. Two teams of large mammal observers walked two transects each morning and two transects each evening, rotating times of day for each transect and site. Two ornithological teams walked two of the transects every day at each pad but only walked the same transect each time (ie two transects were surveyed at each pad only for birds).

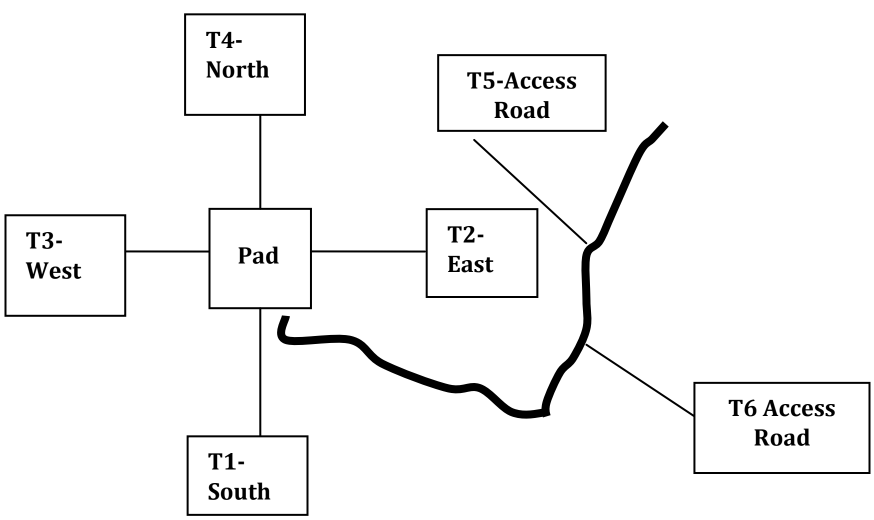


Figure 1. The basic monitoring design for each pad.

A four day rotation was observed. Transects were visited twice every four days for the pads and access route transects were surveyed on a fifth day. Visits were made in the early morning on first day and from 4:00pm in the evening on the next day. This enabled the team to monitor four sites at any one time to allow for enough sightings for the density analysis (see below) and to account for varying detectability of animals and differences in animal activity/behavior at the different times of the day (figure 3).

Table 1. The dates of monitoring at the four pads and the activities happening at each pad at the time of survey.

Monitoring time	Dates	Activity at Pad site			
		BE-1	BE-3	BE-4	BE-5
Round 1	22 Feb-31Mar 2010	Pad completed – under maintenance	Pad under construction	Pad construction started	Pad completed – under maintenance
Round 2	1 Apr – 4 May 2010	Pad maintenance	Pad Maintenance	Completion of construction	Pad maintenance
Round 3	3 Jun - 10 Jun 2010	Seismic survey activity	Seismic survey activity	Seismic survey activity	Seismic survey activity
Round 4	22 Jul – 29 Jul 2010	Maintenance only	Maintenance only	Maintenance only	Maintenance only
Round 5	31st Aug - 25 Sep 2010	Maintenance only	Maintenance only	Maintenance only	Maintenance only
Round 6	22 Mar – 20 Jun 2011	Rig used to drill site	Storage of drilling eqpt	Maintenance only	Maintenance only

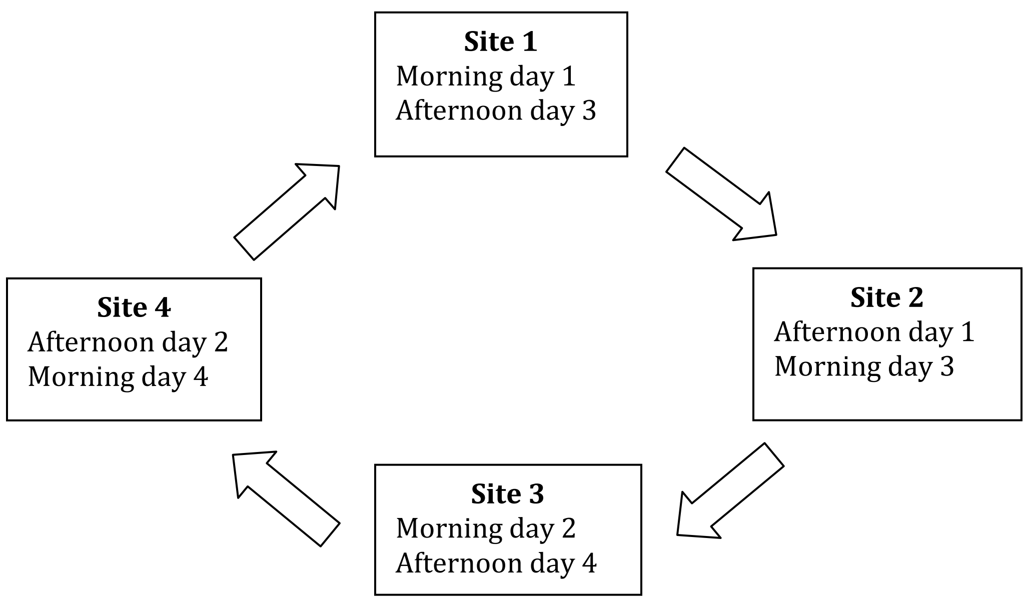


Figure 3. The four day rotation period used to survey each of the transects at each of the pads. Access routes were surveyed on separate days after each round.

Data collection was carried out during different types of oil exploration activities, including site clearance for pad establishment, new access road construction, seismic activities and drilling of a test well (Table 1).

Site Selection

The four pad sites were chosen for the following reasons:

- Buffalo East-1(BE-1) was chosen because it was likely to be drilled first out of the various sites.
- Buffalo East-3(BE-3) was chosen because construction was then ongoing at the site. This was thought appropriate for comparison between BE-1and BE-5 whose construction had already been completed by commencement of monitoring.
- Buffalo East-4 (BE-4) was selected at the start of monitoring as the only site where no construction work had been made. This pad was prepared during the first round of the survey.
- Buffalo East-5 (BE-5) was favored by its location in the Buligi circuit area rich in animal populations, and more distant from the earlier selected sites

Initially the four sites were supposed to have been drilled over the period of the monitoring program with the opportunity to monitor recovery of the site after drilling had taken place. However, delays in Tullow Oil's ability to work in the park meant that we were only able to monitor at the time of the drilling of one of the pads (BE-1 – Table 1).

Data Collection - Large Mammals

Two mammal teams, comprising two data collectors accompanied by a UWA ranger, were formed and trained in the methods to be used. The team walked the transect at a speed of about 1 km per hour recording all large mammals sighted and measuring the perpendicular distance from the transect to the mammals. Group size was counted and recorded. GPS coordinates were taken for every sighting using a Garmin C60Sx GPS unit, which has a more sensitive computer chip and can find a GPS location under dense canopy. These points were used to assess the distance of the sighting from each of the four pads (see analysis section). Mammal data were collected in six periods: February-April 2010, April-May 2010, July 2010, August-September 2010, October-November 2010 and March-Jun 2011. Pad construction was taking place at pad BE-4 during February-May 2010 and Drilling took place at Pad Be-1 between March-June 2011.

Data Collection - Birds

Every 100 metres along two of the pad transects at each pad, a team of two ornithologists made 5 minute point counts from 0 metres (at the pad boundary) up to 2 kilometres (for a total of 21 points per transect). The team would arrive at a point, rest for two minutes and then record all birds seen or heard during the five minute point count period. The distance from the point centre to the bird was estimated in the following distance categories: 0-10m; 10-20m; 20-50m; 50-100m; 100-200m; and 200-500m. Bird data were collected in five periods: February-April 2010, April-May 2010, August-September 2010, October-November 2010 and March-Jun 2011.

Data Analysis

All GPS points for the sightings of large mammals were entered into ArcGIS 9.1 and the distance to each pad calculated for every point (direct line of sight distance). The same analysis was made for each point used for the bird point counts. These distance measurements were then grouped in distance intervals of 0-250m; 250-500m; 500-750m; 750-1000m; 1000-1250m; 1250-1500m; 1500-1750m; and 1750-2000m.

The data for the large mammals and birds were analysed as follows:

- Densities of large mammals were calculated within 2 km of the pads under different management activities taking place on the pad.
- Densities of all bird species were calculated for each point at 100m intervals from the pad.
- For each 250m section of the transect densities were calculated using DISTANCE (Thomas *et al.* 2010) for each pad separately for large mammals using the repeated surveys for each census period (1-6).
- Densities were calculated using DISTANCE on the radial distances from the point counts for the more abundant bird species in 300m intervals from the pad (Buckland *et al* 2001).

The densities were then compared between survey periods to assess how they had changed between surveys and whether any differences observed were correlated with activity at the pad site. No allowance has been made here for seasonal variations during the survey rounds, although this could be the subject of further analysis in the future.

Results

Large mammal density

Large mammal densities were calculated for the four transects radiating from each pad up to 2km. This effectively calculates the density of each species within a radius of 2km of each pad. Densities were compared for those pads that had been established but had no activity happening apart from routine maintenance and those pads that had activities taking place (Construction of a pad, Drilling on the pad, storage of equipment at a pad for drilling). In addition in the third round of the surveys seismic detonations were taking place across the region of all the well pads. Some species such as the bushbuck and bush duiker showed much lower densities where activities were taking pace around a pad (figure 4) but most exhibited little pattern.

Charts should be read bearing in mind that the baseline animal distribution is affected by varying habitat and terrain around the sites, with many mammals showing distinct preferences for certain habitats.

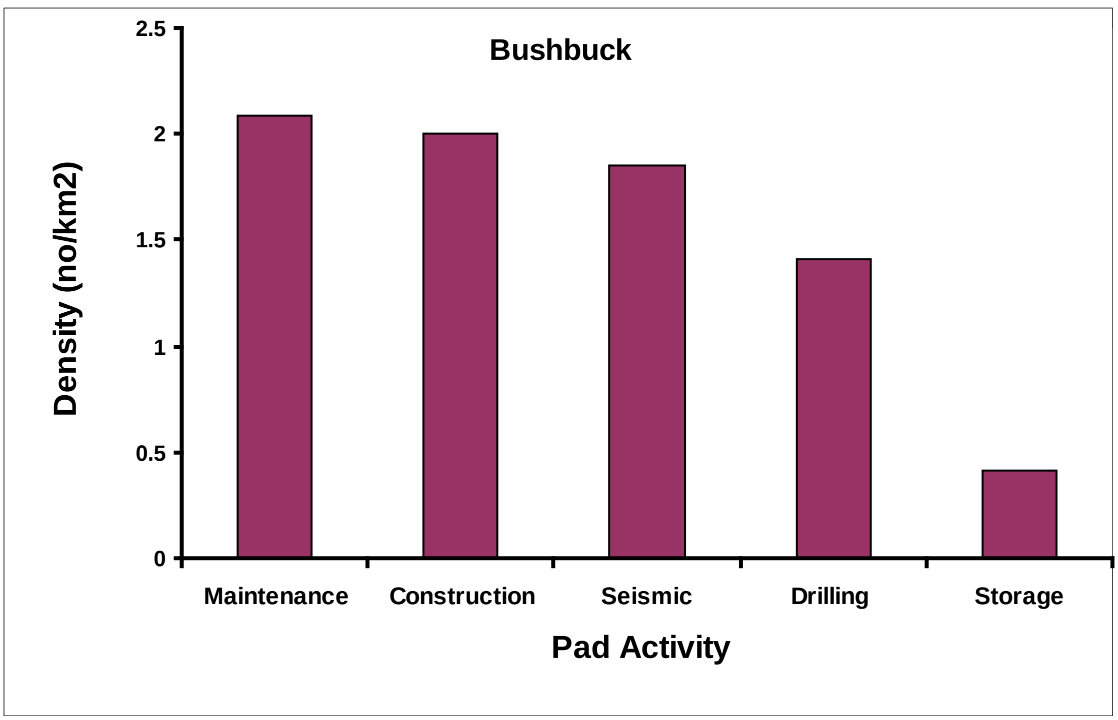
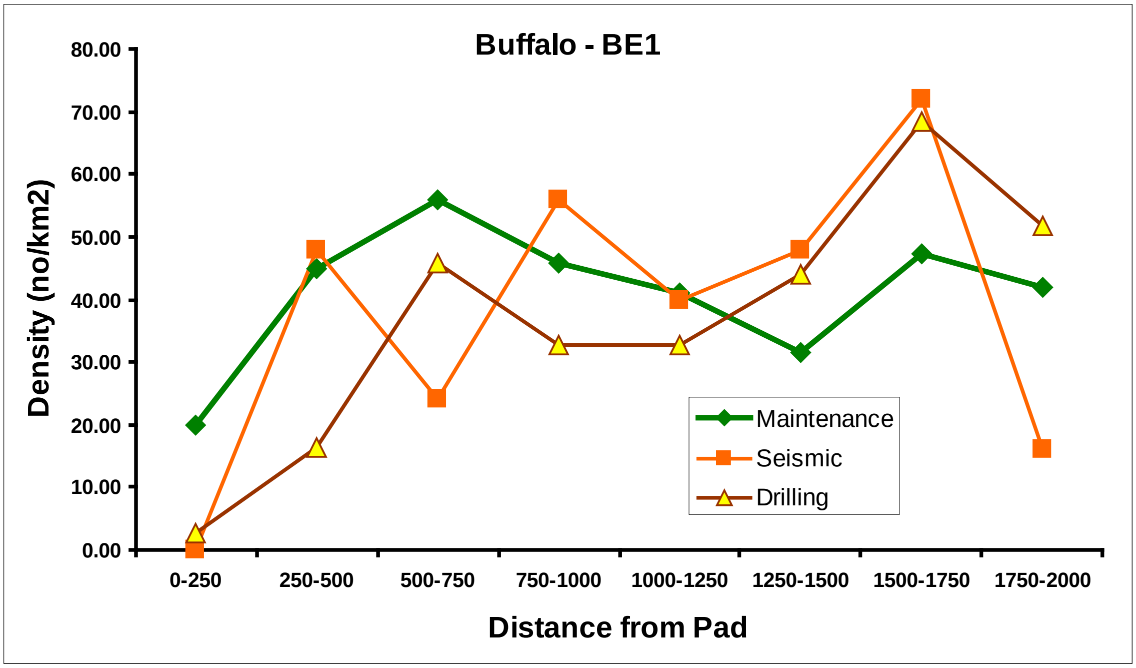


Figure 4. Average density of bushbuck within 2 km of the pads where different activities were taking place. Densities are averaged across the four pads for each activity.

This result is likely because the response of the animals 2km away from the pad is likely to be very different to that near the pad. We therefore analysed how the more common species reacted with distance from the various pads under different activities. Pad BE-1 which was drilled in the 6th round and BE-4 where pad preparation took place in the first two rounds were analysed because this was where the more intense activities were taking place. The results show that many species avoid the pads when activities are happening and this avoidance effect occurs within the nearest 500-750 metres of the pad (figure 5).



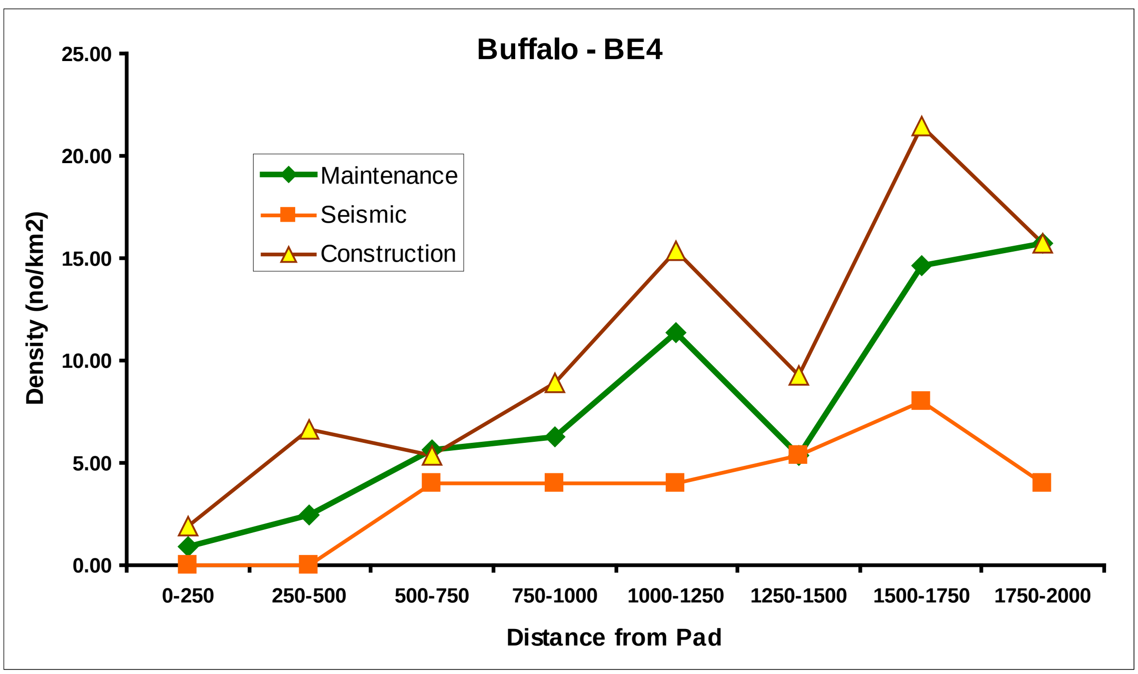
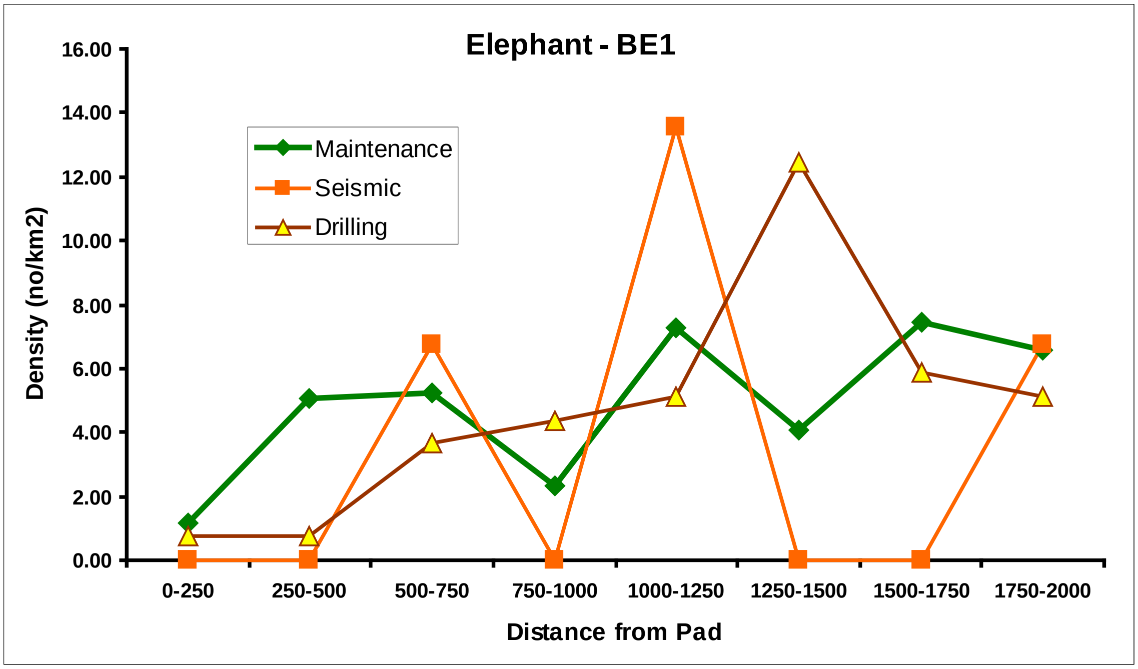


Figure 5a. Response of buffalo to pad construction (BE4), pad maintenance (both pads), drilling a well (pad BE1) and seismic exploration in the region. There is a clear avoidance of the pad up to 500-1000m from the pad under all operations (even when maintenance is only taking place) and that this is exacerbated when drilling or seismic operations are happening.



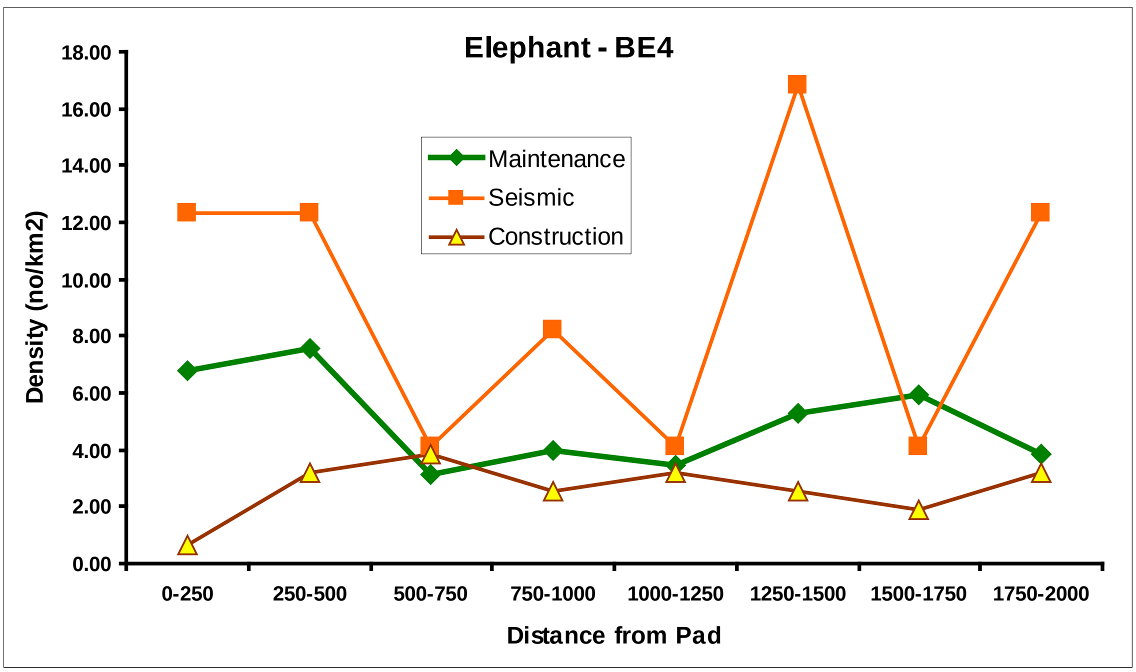
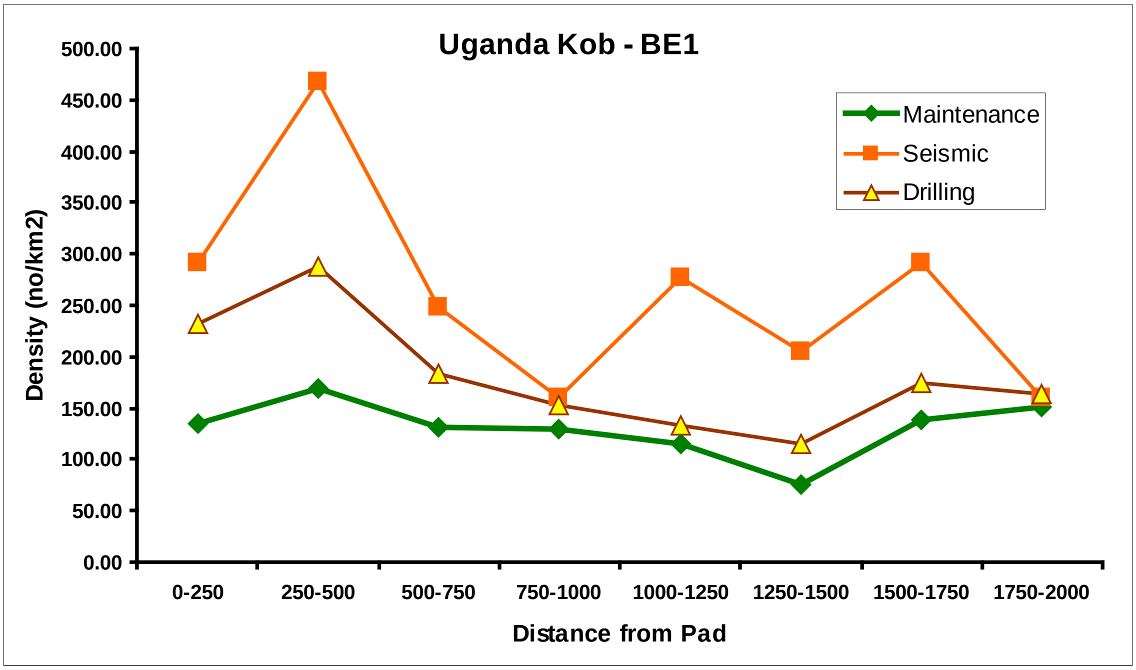


Figure 5b. Response of elephant to pad construction (BE4), pad maintenance (both pads), drilling a well (pad BE1) and seismic exploration in the region. They appear to avoid drilling up to 1-1.25 km away while construction took place, as densities were generally lower than at maintenance.



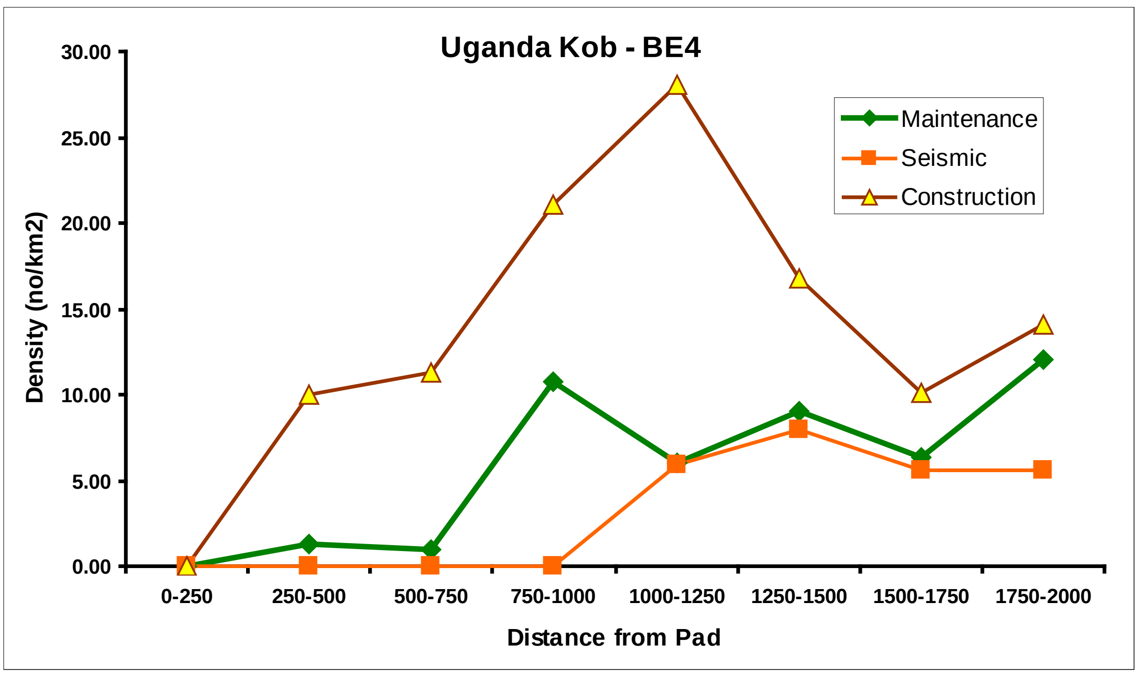
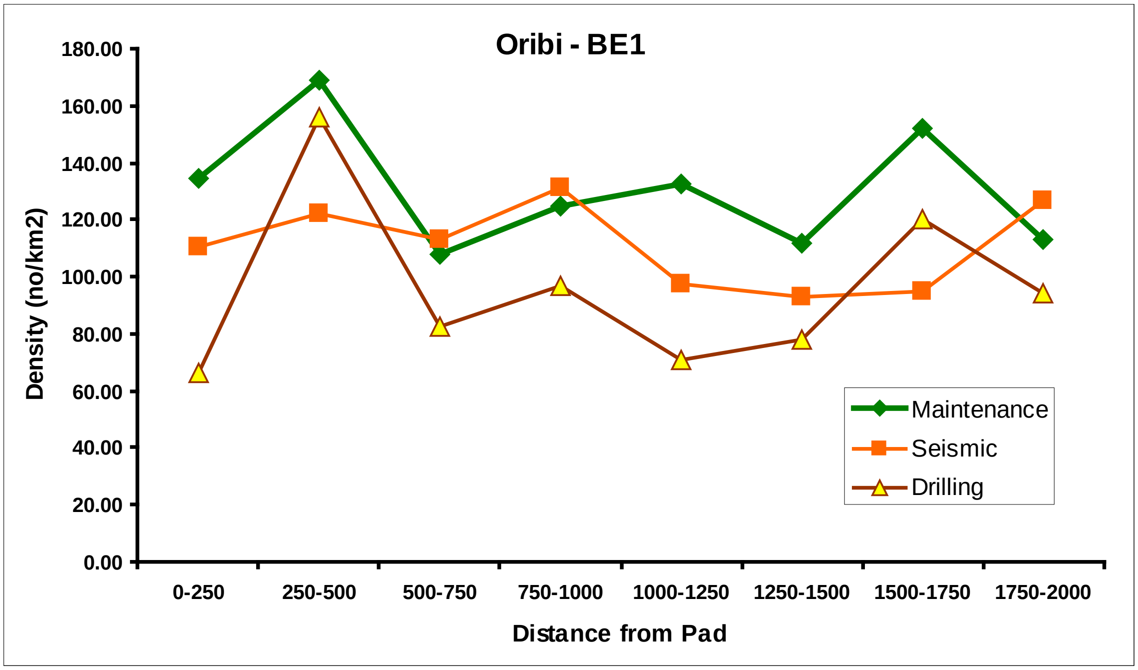


Figure 5c. Response of Uganda Kob to pad construction (BE4), pad maintenance (both pads), drilling a well (pad BE1) and seismic exploration in the region. At pad BE1 there was no obvious reaction to the activities with distance, with kob being more abundant in general within 2 km of the pad, while at pad BE4 there was a strong avoidance of the pad up to 750 metres under all operations. The differences may be due to several factors. Kob can be curious and want to see what is making any new noise. They may also hang around the pads when lights are on at night to help them detect predators so that they are numerous at certain times of day near the pad.



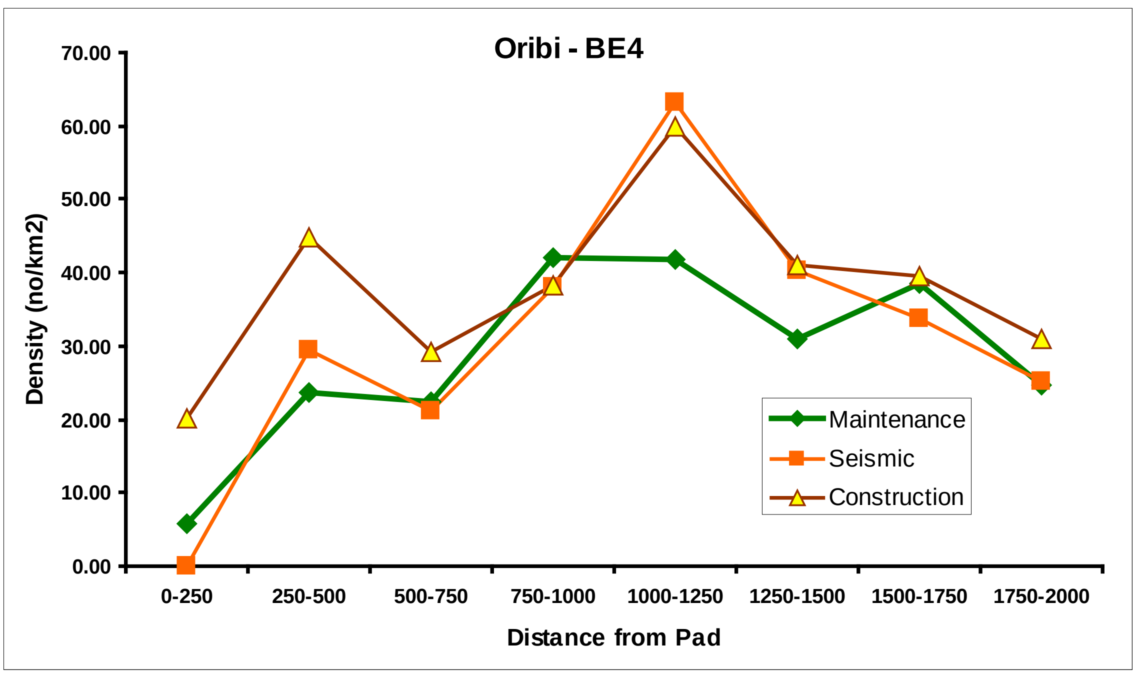
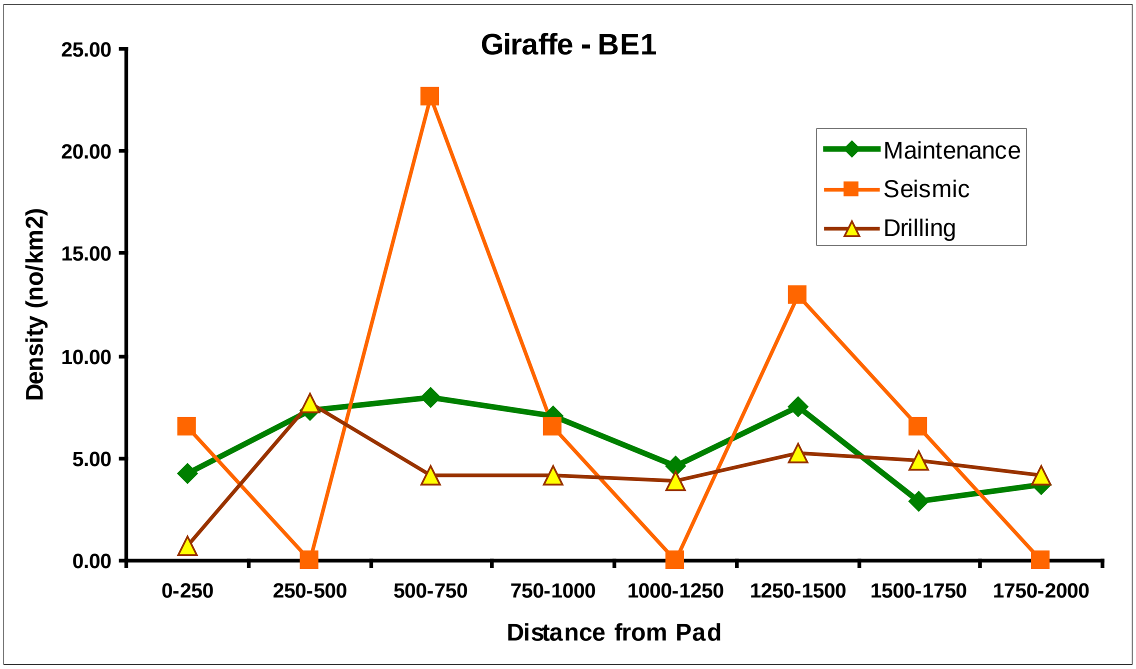


Figure 5d. Response of Oribi to pad construction (BE4), pad maintenance (both pads), drilling a well (pad BE1) and seismic exploration in the region. At pad BE1 there was no great reaction to the activities with distance although densities were lowest within 250m of the pad when drilling took place. At pad BE4 there was an avoidance of the pad up to 750 metres. The differences are similar to the Uganda Kob and may be a result of predator avoidance at night also.



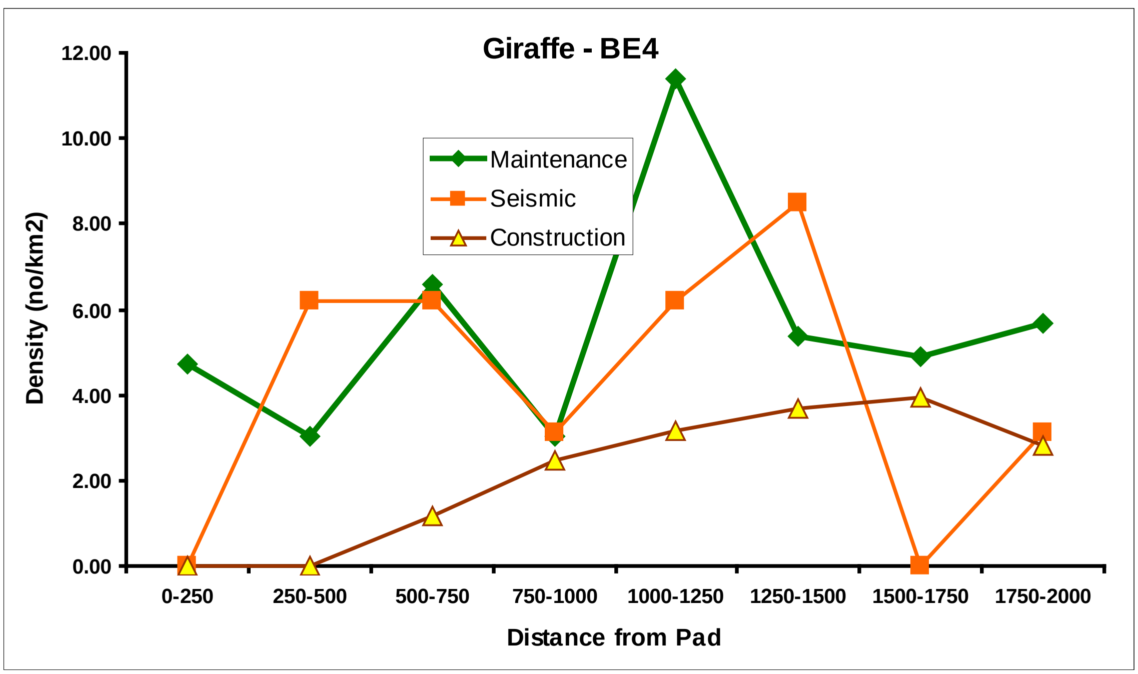


Figure 5e. Response of Giraffe to pad construction (BE4), pad maintenance (both pads), drilling a well (pad BE1) and seismic exploration in the region. At pad BE1 there was no great reaction to the activities with distance although densities were lowest within 250m of the pad when drilling took place. At pad BE4 there was a strong avoidance of the pad up to 750-1000 metres where construction was taking place.

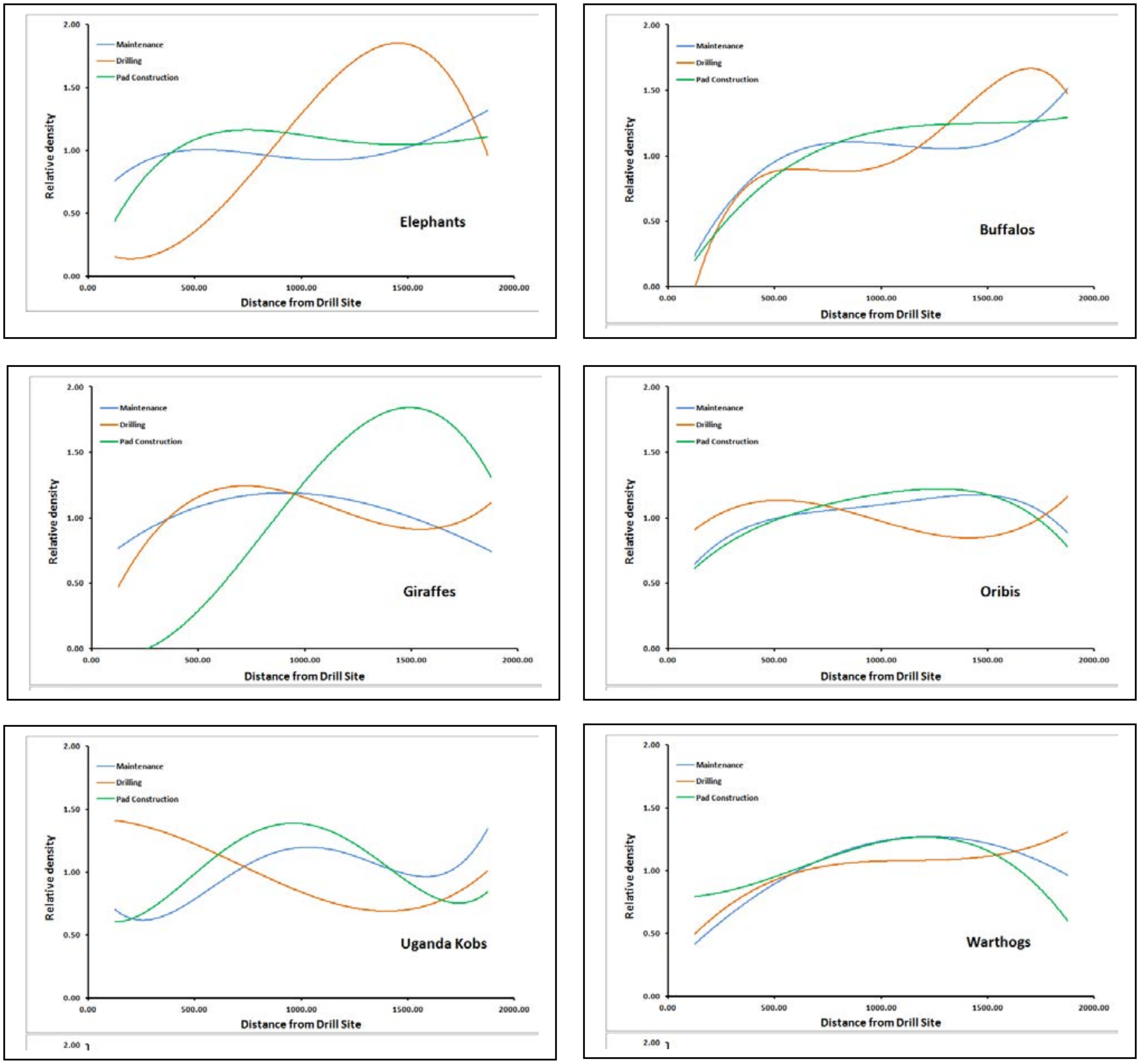


Figure 6. The relative densities of each large mammal between 0-2000 metres from the drill pad/site with curves fitted to data from pads BE1, BE3 and BE4. Where the curves are lower than one then the density of a species is less than the average and vice versa.

We can summarise the results of the surveys of mammal density around Pads BE1, BE3 and BE4 by standardizing the density away from the drill site by dividing the density estimate by the mean density obtained of all distances from the pad to estimate a *relative density*. This effectively shows where the density is equivalent to the average density (when the relative density =1) and where it is lower (relative density <1) or higher (relative density >1). This also allows us to compare results across Pads because densities may differ between sites because of habitat differences or differences in predator densities. We fitted curves to these relative densities for three pad activities: maintenance of the pad, construction of the pad and drilling taking place at the pad for all of the large mammals (figure 6).

We also looked at the effect of the different activities on average group sizes of the different species that form groups to assess if these differ. In general group sizes of large mammals within 2 km of pads were 23% smaller during drilling compared with during pad maintenance (apart from Uganda Kob and Oribi which were 40% larger). Under pad construction groups size was not different than during maintenance . During seismic operations groups were slightly larger (10%) at BE-1 but 10% smaller at BE-4 during . Elephant group sizes were only 15% of the sizes seen under pad maintenance during pad drilling around BE-1 (table 2).

It is clear therefore that large mammals are being affected by the construction, maintenance and drilling operations on oil pads in Murchison Falls National Park and that it not only affects their distribution around the pads but can also affect their social structure and tendency to form groups. In some species such as the small antelopes it appears they may form larger groups possibly as a defensive response while most of the larger mammals form smaller groups under the noisier operations such as drilling, and seismic activity, but not when pad construction is taking place.

Table 2. Average group sizes of mammal species around Pads BE-1 and BE-4 during the various oil company operations.

	BE-1			BE-4		
Species	**Drilling**	**Maintenance**	**Seismic**	**Construction**	**Maintenance**	**Seismic**
Buffalo	19.7	22	26.9	10.9	8.6	6.4
Elephant	4.5	29	5.5	6.9	7.2	3.6
Giraffe	5.8	6.2	3.9	5.7	5.8	2.2
Hartebeest	5.4	5.8	5.4	4.9	4.9	4
Oribi	7.7	5.3	5.5	3.2	3.2	2.5
Uganda Kob	21.2	14.2	18.8	13.6	5.3	7
Waterbuck	1.7	1.8	4.5	4.9	5.2	6.4

Bird densities

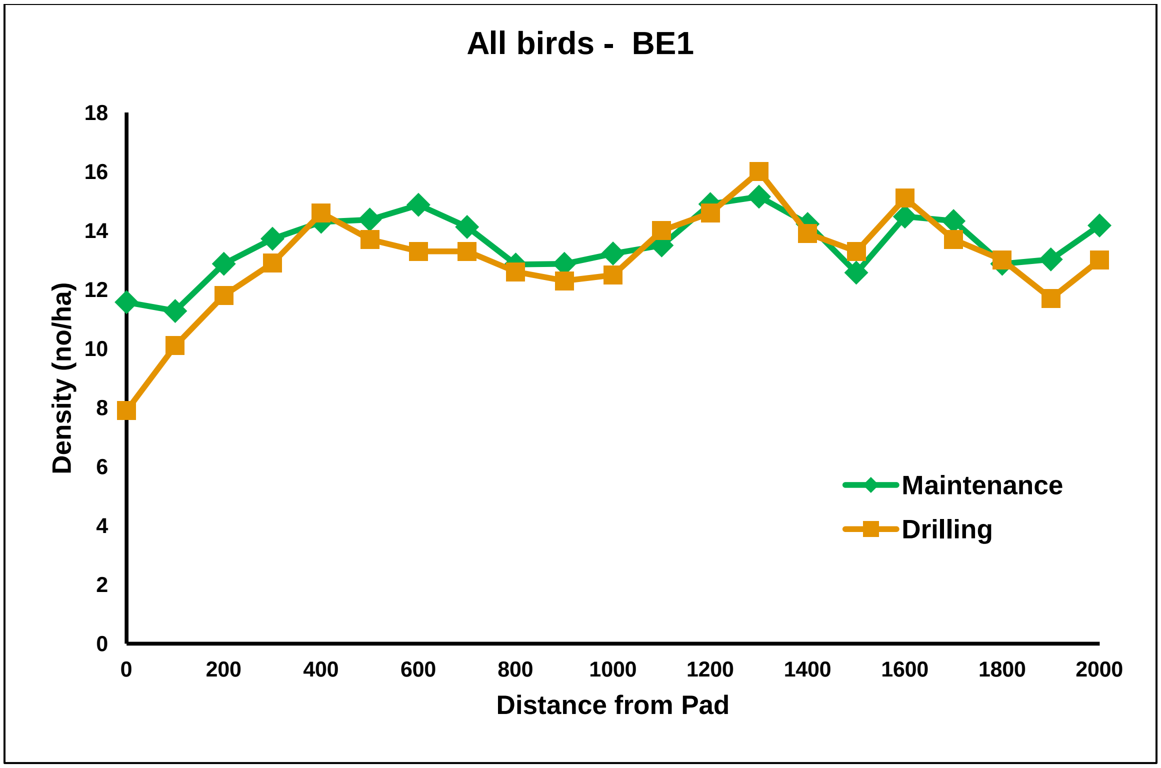
A total of 337 bird species were recorded from 11,147 point counts along transects from all four pads. Despite the very large number of point counts and sightings (over 68,000 bird records), many of the bird species were too infrequently seen to calculate densities at different distances from the pads. Some species such as Abdim's stork are also migrants and can be very abundant at some times of the year but absent at others. We therefore created a short list of species which were considered residents in Murchison Falls National Park and which had sufficient sighting records to calculate densities.

Initially we calculated densities of all bird species combined (not just the shortlist) at 100 metre intervals from the pads to assess is there was a response from the bird community as a whole. These results will be dominated by the more common species but do show that there is a clear decrease in density nearer the pads (figure 7) and that densities under drilling and pad preparation were in general lower than under pad maintenance.

The impacts on particular species (in the short list of species with sufficient data) were analysed by combining results for groups of 3 points adjacent to each other –effectively in 300 metre intervals) and are summarized in table 4. Only pads BE-4 and BE-1 are considered because only pad maintenance took place at the other two pads. No bird surveys were made during the seismic exploration so comparisons are only made with drilling, pad construction and pad maintenance.

Table 4. Responses of the more common bird species to oil company activities. Distances given are where there is a clear drop in density near the well pad. If no clear difference exists it is classified as 'None' and if there is great fluctuations in density 'Not clear' is stated. Lower density or higher desnity is given where the density of the species throughout the transect is lower/higher than density estimates for pad maintenance.

	BE-1		**BE-4**	
Species	**Maintenance**	**Drilling**	**Maintenance**	**Construction**
African Palm Swift	None	0-750m	None	None
Piapiac	None	Higher density	None	None
Zitting Cisticola	None	Higher density	None	Lower density
Rattling Cisticola	0-300m	0-300m	None	None
Tawny-flanked Prinia	None	None	None	None
Croaking Cisticola	None	0-700m	0-300m	Lower density
Red-cheeked Cordon-bleu	0-700m	None	None	0-700m
Grey-backed Camaroptera	0-300m	None	None	0-300m
Black-headed Gonolek	0-700m	0-700m	None	None
Black-crowned Tchagra	0-500m	0-700m	None	None
Yellow-billed Oxpecker	None	0-400m	None	0-1000m
Helmeted Guineafowl	None	0-300m	0-300m	0-300m
Grey-backed Fiscal	None	0-300m	0-500m	0-500m



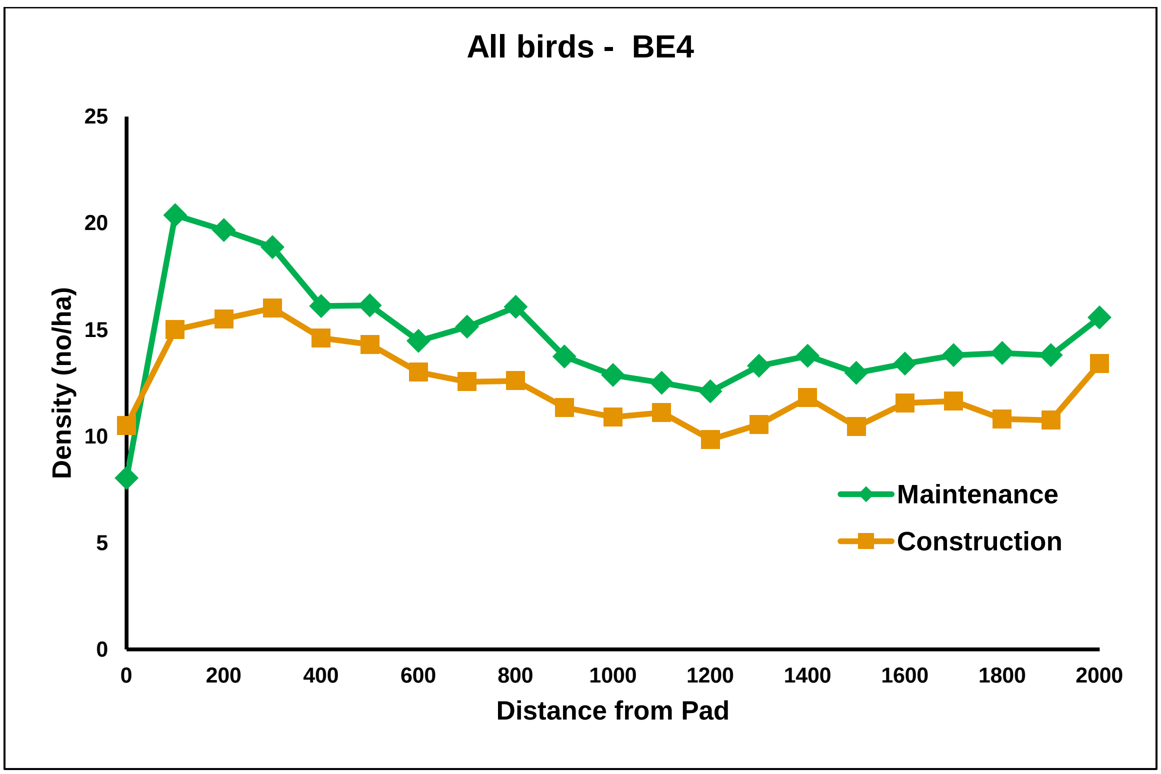


Figure 7. Densities of all birds at 100m intervals from Pads BE-1 and BE-4 under pad maintenance, pad construction and drilling operations.

Many of the more common species do not show any response to the presence of the pad when under maintenance but when drilling or pad construction were taking place there was some avoidance within zero to 300 - 700 metres of the pad (table 4).

Discussion

The results will continue to be analysed in detail but these results show that there does seem to be a response of the more common species to pad construction and drilling activities at the pads for both large mammal and bird species. The responses under seismic exploration were more difficult to interpret because the seismic explosions were taking place over the whole area so that they would not have led to a response in relation to the pad location. It appears though that activities at the pad (even simple pad maintenance where little activity occurred) could lead to an avoidance reaction by the animals. Where pad maintenance was taking place this was generally within 250-500 metres of the pad but where significant activities were happening such as pad construction and drilling on the pad where large machinery is being used and the noise is considerably greater, many of the animals avoided the nearest 500-1000m of the pad. Several of the wells in the park are 2-3 km apart at the moment and there is a good likelihood that many more wells will be drilled here in future. If this is to take place we would suggest that pads be placed at least 5km apart from each other, and that a process of rotation of activities takes place to ensure that a minimum of a 5km buffer is maintained to allow mammals to move between active pads while drilling or pad construction are taking place.

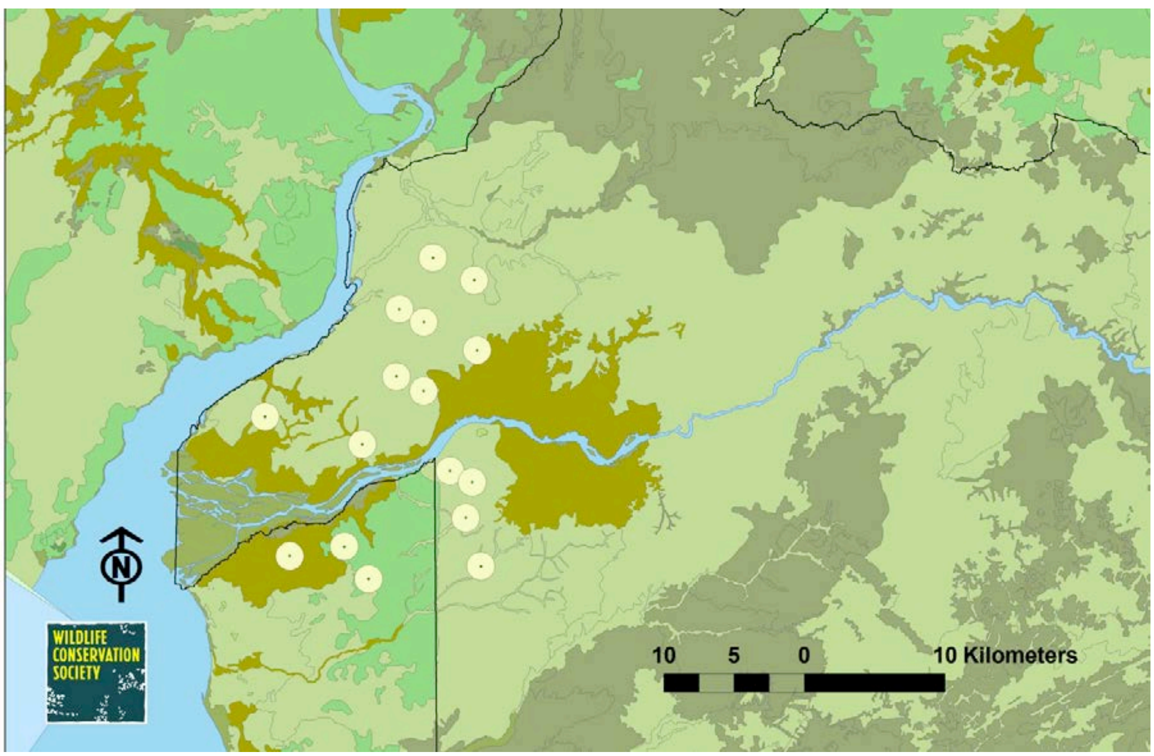


Figure 8. Map of the western half of Murchison Falls National park showing the location of each well site with a 1 km buffer around it. This is effectively the amount of habitat that was lost to elephants during the time of pad preparation and drilling.

The current distribution of the 13 well pads in Murchison Falls Park already impact a significant proportion of prime wildlife habitat within the park (figure 8) where wildlife is most abundant (Rwetsiba and Wanyama, 2010). If these had all been drilled simultaneously then a 1 km buffer (measuring where large mammals would avoid) around them would have removed about 40 km^2 of habitat for large mammals. Pad maintenance has less of an impact on wildlife but still has some impact and so while these 'halo's' of impact would be smaller they do still exist. The impact of increased road construction and traffic, including large trucks and buses, further adds to the proportion of affected environment.

Recommendations

Given the findings of this report it is clear that oil operations are having a significant impact on the behavior of large mammals and a less severe, but still measurable, impact on bird distributions. Given that this is happening we would make the following recommendations for the management of oil drilling operations within savanna protected areas in Uganda:

1. Minimize movements of vehicles and personnel to well pads when they are being maintained while waiting for drilling equipment so as to minimize disturbance at these sites.

2. Avoid drilling or constructing pads at the same time within 5 km of each other. Where this needs to be carried out then stagger the pad construction and drilling so as to avoid simultaneous activities at both sites.

3. Avoid placing well pads in relatively rarer habitat types where species have fewer options where they can disperse to in order to avoid the disturbance.

4. Avoid establishing well pads on ridge tops where noise disturbance will carry much further afield and likely have a larger radius of impact on wildlife.

5. Care should be taken in siting the access roads to the sites. These should not be created on an ad-hoc basis, rather the whole network of roads required should be contained within a single EIA report to allow judgement of their contribution to animal disturbance and to ensure the least impact.

6. Make efforts to minimize noise pollution from a site. Only switch on machinery when using it and avoid car horns and other loud noises.

7. Aim to bring traffic to and from a site in a convoy, or between closely defined periods so that it is not continuous during the day and only causes disturbance for a minimum period.

8. Once a site has been drilled it should be vacated and restored as quickly as possible to minimize the time that well pads are being maintained and disturbance occurs.

9. Minimize pad construction time and also drilling time to minimize the periods of greatest disturbance.

10. This research did not assess how predators are responding to the oil operations because sightings were too few from transects. We recommend a specific study of lions, leopards and hyaenas to assess how they are reacting to the disturbance.

11. Continue to monitor the movements of the large mammals within the drilling region and across the whole park to assess longer term impacts on their populations.

12. The impacts of seismic surveys were less clear in this study because the study was designed to assess the impacts on animal behavior with distance from the well pads and the seismic activity occurs across a much larger area. As a result we believe that a specific study is needed to assess what happens to animal movements when seismic operations are taking place.

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