Determinants of elephant distribution at Nazinga Game Ranch, Burkina Faso

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Abstract

We used seasonal ground total counts and remote sensing and GIS technology to relate elephant (*Loxodonta africana africana*) distribution at Nazinga Game Ranch to environmental and anthropogenic factors. Variables used in analyses were normalized difference vegetation index, elevation, stream density, density of poaching and human illegal activities, distance to dams, distance to rivers, distance to roads, and distance to poaching risk. Contrary to our expectation, road traffic did not disturb elephants. Strong negative relationships were documented between elephant abundance and stream density, distance to dams, and poaching density. Density of poaching and other human illegal activities explained 81%, vegetation greenness 6%, and stream density 3% of the variation in elephant density. Elephant distribution represented a survival strategy affected by poaching, food quality and abundance, and water availability.

Additional key words: environmental and anthropogenic factors

Résumé

Nous avons utilisé des données d'inventaires totaux terrestres, de télédétection et de Système d'Information Géographique pour étudier les facteurs environnementaux et anthropogéniques qui déterminent la distribution des éléphants au Ranch de Gibier de Nazinga. Les variables étudiées comprenaient l'indice de végétation par différence normalisée, l'élévation, la densité des ruisseaux, la densité des activités illégales et de braconnage, la situation des éléphants par rapport aux barrages, rivières, routes, et activités illégales et de braconnage. Nos résultats ont indiqué que contrairement a notre hypothèse de base, la principale route avec son trafic ne semble pas perturber la quiétude des éléphants. Aussi, de fortes corrélations négatives ont été observées entre les éléphants et la densité des ruisseaux, la situation par rapport au barrage, la densité des activités illégales et de braconnage. L'analyse des variables les plus importantes à l'aide de régression multiple a montré que la densité des activités illégales et de braconnage, l'indice de végétation ainsi que la densité des ruisseaux expliquent respectivement 81 %, 6 %, et 3 % de variation de la densité des éléphants. La distribution des éléphants au Ranch de Gibier de Nazinga semble représenter une stratégie de survie déterminée par les activités illégales et de braconnage, l'abondance et la qualité du fourrage et enfin le disponibilité de l'eau.

Mots clés supplémentaires: facteurs environnementaux et anthropogéniques

Introduction

Understanding ecological parameters that influence animal distribution can provide insight into which areas are important for that animal population (Foley 2002). Fryxell and Sinclair (1988) stated a characteristic of the African savanna ecosystem was the spatial and temporal variation in resource availability that forces savanna wildlife to move to where food and water can be obtained. Viljoen and Bothma (1990) showed that seasonal variation in food availability and quality affect ranging patterns and migration of elephants, modified by water availability, which is dictated by rainfall. Poole (1996) pointed out that in dry and open savanna, elephants tend to aggregate and reduce their home range in response to poaching or the threat of human hostility. Our objectives in this investigation were to determine elephant seasonal distribution at Nazinga Game Ranch and relate it to environmental factors and human illegal activities.

We hypothesized that because vegetation greenness is an index of food availability, elephants would be in the greenest areas. Secondly, we hypothesized that elephants observed would be close to dams, rivers, and areas of high stream density because elephants need water daily. Lastly, we thought elephants would be far from human illegal activities, to avoid poachers and disturbed areas. Integrating global positioning data from elephant counts and poaching records with digital maps and environmental data from satellite images can help test these hypotheses and provide insight into variables that affect elephant distribution at Nazinga.

Material and methods

Study area

Nazinga Game Ranch lies in the south of Burkina Faso, on the border with Ghana (fig. 1). It covers 970 km^2 and is separated into a preservation and game viewing zone (9%), a hunting zone (86%) and a buffer zone (5%) separating the viewing and the hunting zones. The landscape is mostly flat, with elevation ranging from 270 m to 325 m above sea level for an average of 280 m. Soils are developed on a granite substrate and are the tropical ferruginous type. Climate is sub-Sudanian (Guinko 1984); rainfall averages 800 mm to 1100 mm annually and falls in a unimodal pattern from April to October. Average monthly temperature ranges between 18.1 °C and 38.4 °C.

The ranch is drained by the Sissili River and its two seasonal tributaries, the Dawevele and Nazinga Rivers. Eleven dams were built to supply wildlife with permanent water in the dry season. Vegetation that characterizes the ranch is a woody savanna dominated by *Combretum* spp., *Terminalia* spp., *Vitellaria paradoxa* and *Isoberlinia doka*. Common grasses are 1 m to 3 m high and include *Andropogon* spp. and *Schizachyrium* spp.

Fauna of the game ranch are diverse: 290 species of birds (Portier 2000), 26 species of fish (Ouedraogo 1987), and 10 genera and 11 species of ungulates, which include African buffalo (*Syncerus caffer brachyceros*), roan antelope (*Hippotragus equinus koba*), hartebeest (*Alcelaphus buselaphus major*), waterbuck (*Kobus ellipsiprymnus defassa*), western kob (*Kobus kob kob*), Nagor reedbuck (*Redunca redunca redunca*), oribi (*Ourebia ourebi quadriscopa*), bush duiker (*Sylvicapra grimmia coronata*), bushbuck (*Tragelaphus scriptus scriptus*), red-flanked duiker (*Cephalophus rufilatus rufilatus*), and warthog (*Phacochoerus africanus africanus*). The elephant is the only species of the order Proboscidae and the aardvark (*Orycteropus afer*) of the Tubilidentata. Primates are represented by the baboon (*Papio anubis*), the vervet (*Cercopithecus aethiops sabaeus*), and the patas monkey (*Erythrocebus patas*).

Elephant data—poaching and other illegal activities

Two total ground surveys were undertaken, in the second 10-day period of September 2002 for the wet season and in January 2003 for the dry season. An initial time series analysis of vegetation greenness from 2000 to 2005 indicated these dates were representative of both seasons. The survey modified the buffalo survey design of Ouedraogo (2001) and separated the ranch into 11 zones (fig. 2). Elephants were tracked three days, from 0600 to 1800 by 11 teams of three rangers each, equipped with GPS 12 XL, binoculars, pedometers, tents, rifles, detailed maps of habitat blocks, data sheets and food provisions. When an elephant group was sighted, teams collected data on the habitat, elephant social structure, and geographic coordinates in UTM (universal transverse mercator). Care was taken to minimize double counting groups. During the patrol, poaching and any human activity, such as encounters with poachers and shepherds, cattle presence, trees cut, thatch collected, poacher's camps, shepherd's camps, or gunshots, were recorded and their location in UTM coordinates indicated.

We displayed elephant locations in ArcMap display of ArcGIS 9 (ESRI Inc., Redlands, California), and then created a polygon around distribution points, to determine the seasonal distribution and the year-round area elephants used. Elephant density and poaching density were calculated in each zone by dividing the number of events by the zone area in square kilometres.

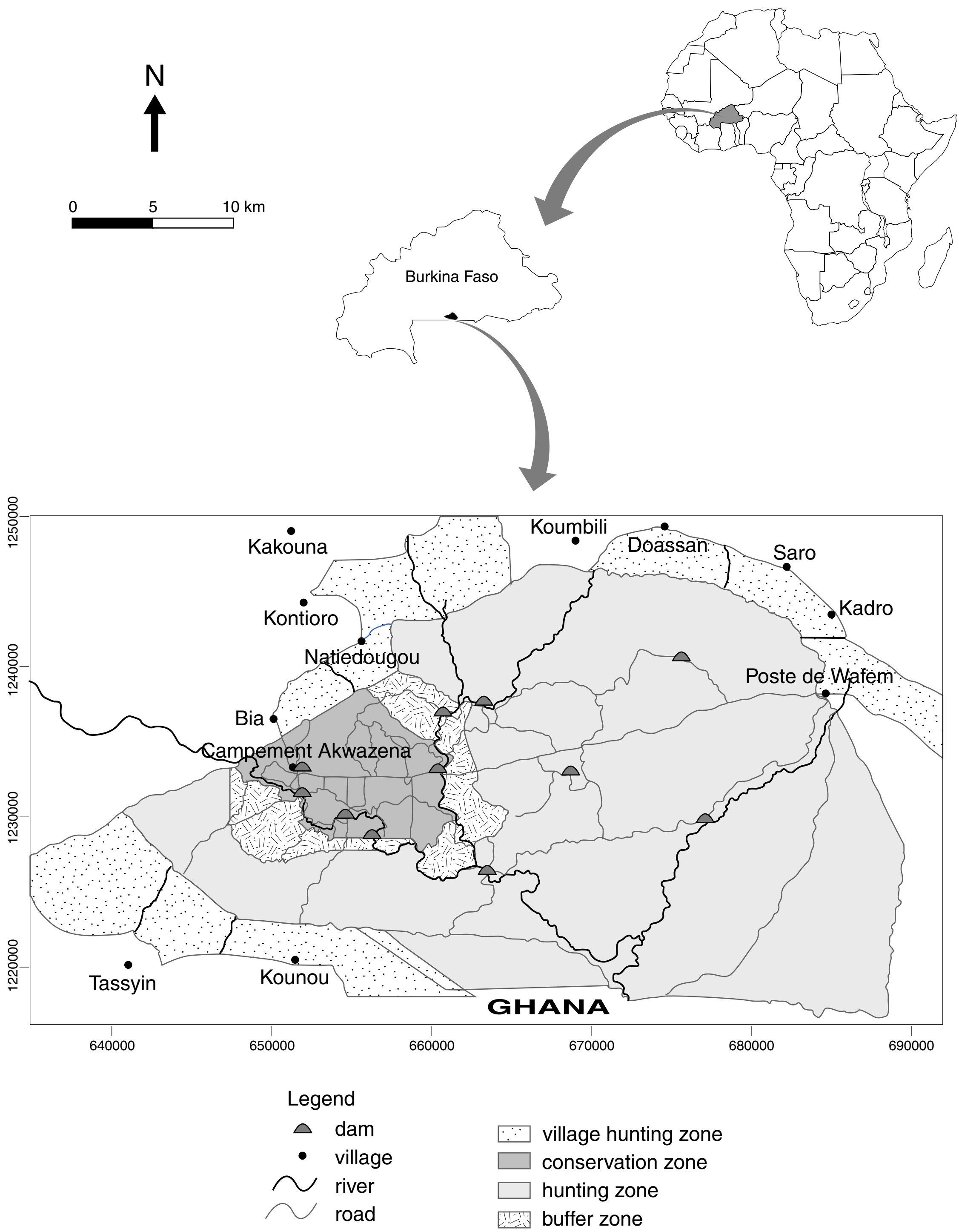

Figure 1. Location of Nazinga Game Ranch in southern Burkina Faso.

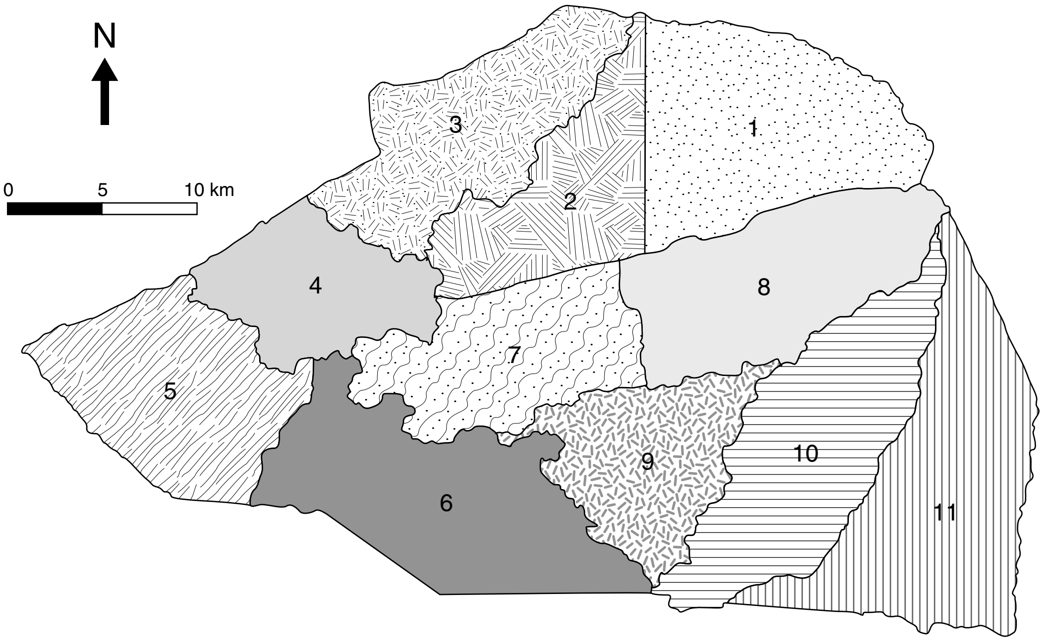

Figure 2. Zones delineated for counting elephants at Nazinga Game Ranch, Burkina Faso.

Normalized difference vegetation index data

If elephants migrate in response to seasonal rainfall and food, then a vegetation greenness or a normalized difference vegetation index (NDVI) should be useful for movement (Western and Lindsay 1984; Foley 2002) and seasonal distribution. NDVI is a remotely sensed measure of vegetation quality based on the spectral properties of green vegetation contrasting with its soil background (Tucker 1979; ADDS 2001; Oindo and Skidmore 2002). It is derived by dividing the difference between near infrared and red reflectance measurements by their sum (Sellers 1989). The formula for NDVI is *(NIR – R) / (NIR + R)*. NIR is the near infrared measurement and *R* the visible red measurement. High positive values correspond to greater vegetation vigour (actively growing dense vegetation cover), whereas negative values are usually associated with bare soil, snow, clouds, or non-vegetated surfaces (Oindo and Skidmore 2002).

West African NDVI images with a 500-m spatial resolution and an Albers equal area conic projection were acquired from the US Geological Survey (EROS—http://edcdaac.usgs.gov/modis/mod13a1v4.asp). Images were from the moderate resolution imaging spectroradiometer (MODIS). Projection of the study area digital map was converted to the image projection and then masked with second-decade images of September 2002 and January 2003. These decades corresponded to the wet and dry seasons by a five-year (2000–2005) time series analysis. Scaled NDVI values (range of 0 to 250) were derived for each season and transformed into actual NDVI values (range of 0 to +1) using the formula:

$$Actual\ NDVI = \frac{Scale\ NDVI - Offset}{Scale}$$

Actual NDVI was displayed in ArcMap and then separated into five classes, which allowed for the overlay of elephant data to determine NDVI values associated with each observation. Mean NDVI in each zone was computed using zonal statistics in the spatial analyst menu of ArcMap.

Elevation data

West African elevation data were acquired from USGS/EROS as well. Raster data were clipped by setting a mask and extent in the template of spatial analysis extension. The raster calculator was used to produce masked grids. Afterward, elevation data were reclassified into five elevation groupings using the quantile classification method. Zonal statistics were used to compute mean elevation per zone.

Stream density

We quantified stream density by zone to compare it with the elephant distribution. Using the identity tool, we overlaid the linear stream density network onto the study area map. We summed stream length (km) per zone. Stream density (km/km^2) was calculated by dividing the total stream length in the zone by area of the zone.

Distance to roads, rivers, dams, poaching events

About 5000 visitors each year enter Nazinga Game Ranch from the registration post on the eastern side of the ranch and drive 35 km on the main road to reach the camp, where accommodations are available. Such traffic on the main road may create disturbance that influences the elephant distribution. Rivers and dams also may influence elephant distribution. To derive the distance from elephant locations to roads, rivers, dams and poaching areas, we created straight-line distance raster models with an output cell size of 26.35 m.

Relationship between variables and elephant density

A 2-sample *t*-test with season as the grouping variable was used to test whether the average value for each factor (NDVI, elevation, stream density, poaching density, distance to dams, distance to rivers, distance to the main road and distance to poaching events) in the wet season differed from that of the dry season. Pearson correlation was used to measure the degree of linear association between elephant density and each factor. We log-transformed the variable poaching density to meet the assumption of normality and used a backward stepwise regression to determine variables that explained elephant density; significance level for variable entry into the model was 0.15.

Results

Variability in the distribution

Eleven sightings with 89 individuals were made in the wet season and 37 sightings with 230 individuals in the dry season. Elephants occupied 161.29 km^2 or 16.8% of the ranch area during the wet season (fig. 3). The distribution was central and west to east, with a southern shift. In the dry season, the distribution,

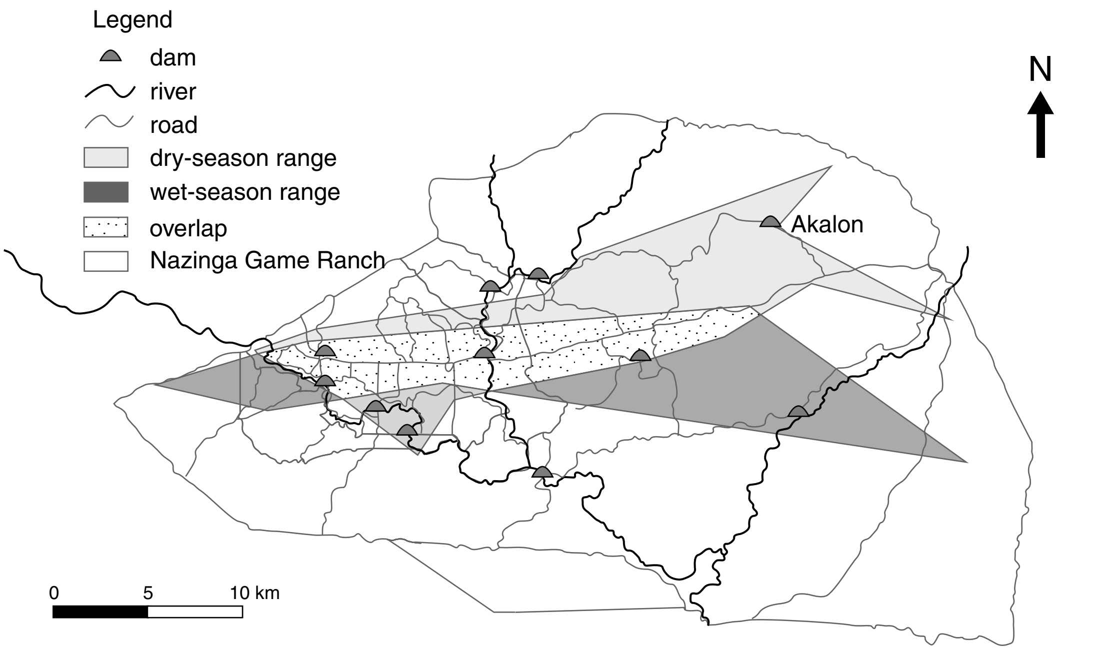

Figure 3. Elephant seasonal dispersal at Nazinga Game Ranch, Burkina Faso, 2002–2003.

which remained west to east, enlarged south-west and then shifted north toward the Akalon permanent water point, which increased the occupied area to 173.3 km^2 or 18% of the ranch. Overlap between wet- and dry-season distribution indicated year-round use. Year-round use occurred along the main road and around four permanent water points with an area of 68.9 km^2, which represented 7.2% of the ranch. The south and the north of the ranch were avoided.

Distribution relative to environmental and illegal activities variables

Wet-season NDVI was significantly higher (P = 0.0005) than in the dry season. Elephant association to NDVI was calculated for each season. Despite fairly high probability values because of the low number of observations, there was a positive relationship for elephant density (r = 0.82, P = 0.08) and a negative relationship for vegetation greenness (r = –0.51, P = 0.19) during wet and dry seasons (figs. 4a, 5a). Elevation, stream density, poaching density, distance to dams, distance to rivers, distance to the main road, and distance to poaching and other illegal events caused no difference ($P > 0.05$) in seasonal mean values.

Topography at Nazinga is relatively flat with a difference of 68 m between lowest and highest elevations. During both seasons, elephants primarily used the 301–312 m elevation (fig. 5b). Density was not related linearly to elevation (r = –0.19, P = 0.51). As for water, strong negative relationships were found between elephant density and stream density (r = –0.69, P = 0.009) (figs. 4c, 5c) and between elephant density and distance to dams (r = –0.71, P = 0.006) (figs. 4d, 5d). However, elephants were not associated (P = 0.47) with rivers, presumably because of the presence of fishermen (figs. 4e, 5e). Poaching and other human illegal events recorded encompassed traps, encounters with poachers, gunshots, elephant carcasses, carcasses of other species, poachers' camps, bushmeat-smoking sites, poachers' trails, poachers' bikes, encounters with shepherds, encounters with herds of domestic animals, shepherds' camps, cut trees, thatch collection sites, charcoal production sites, honey extraction sites, huts, farms, and market gardens. Overall density of poaching and other illegal activities was 0.065 events/km^2 during the wet season and 0.09 events/km^2 during the dry season. No seasonal difference (t = 0.017; df = 10.8, P = 0.98) was found. Elephants were mostly located 2–3 km from poaching and other illegal events (fig. 5f) in areas of low poaching density (fig. 5g). Elephant density was correlated inversely with density of poaching and other illegal activities (r = –0.66, P = 0.01) but was not correlated with distance to poaching and other illegal activities (P = 0.35). Similar to stream density, the linear relationship between elephant density and distance to the main road was negative (r = –0.57, P = 0.03), indicating that traffic on the road did not disturb elephants. More than 63% of sightings in wet seasons and 64% of sightings in dry seasons were within1.6 km of the main road (fig. 5h).

Multiple regression analysis confirmed the hypothesis that at least one variable was related to elephant density (F = 31.21, $P < 0.0001$). Three variables (NDVI, stream density, poaching density) met 0.15 significance for entry into the model. These variables explained 90% of the variation in elephant density (r^2 = 0.90, C(p) = –0.208) (table 1). Density of poaching and other human illegal activities explained 81%, vegetation greenness 6% and stream density 3%.

Discussion

Seasonal variation in food availability and quality affects elephant ranging patterns and migration, modified by water availability, which is dictated by rainfall (Western 1975; Viljoen and Bothma 1990). The elephant distribution at Nazinga Game Ranch did not encompass the entire ranch. Elephants did not use about half of the area south and one-third of the area north. Elephant abundance was determined by poaching and human illegal activities, vegetation greenness and stream density. Elephant distribution was likely a survival strategy affected by disturbance, food quality and water availability.

Fires are set annually in Nazinga between November and December, which may contribute to lower vegetation greenness in the dry season. Elephants were associated with low vegetation quality in the dry season and high vegetation quality in the wet season. Elephant dispersal to areas with lower NDVI was documented by Foley (2002). In Nazinga, the elephant association with low NDVI in the dry season, rather than being a preference, could be explained by dams in these areas. In the wet season, species select forage with the highest energy levels whenever possible (Western and Lindsay 1984). The wet-season elephant distribution areas have higher-quality forage, which has higher concentrations of nitrogen and calcium

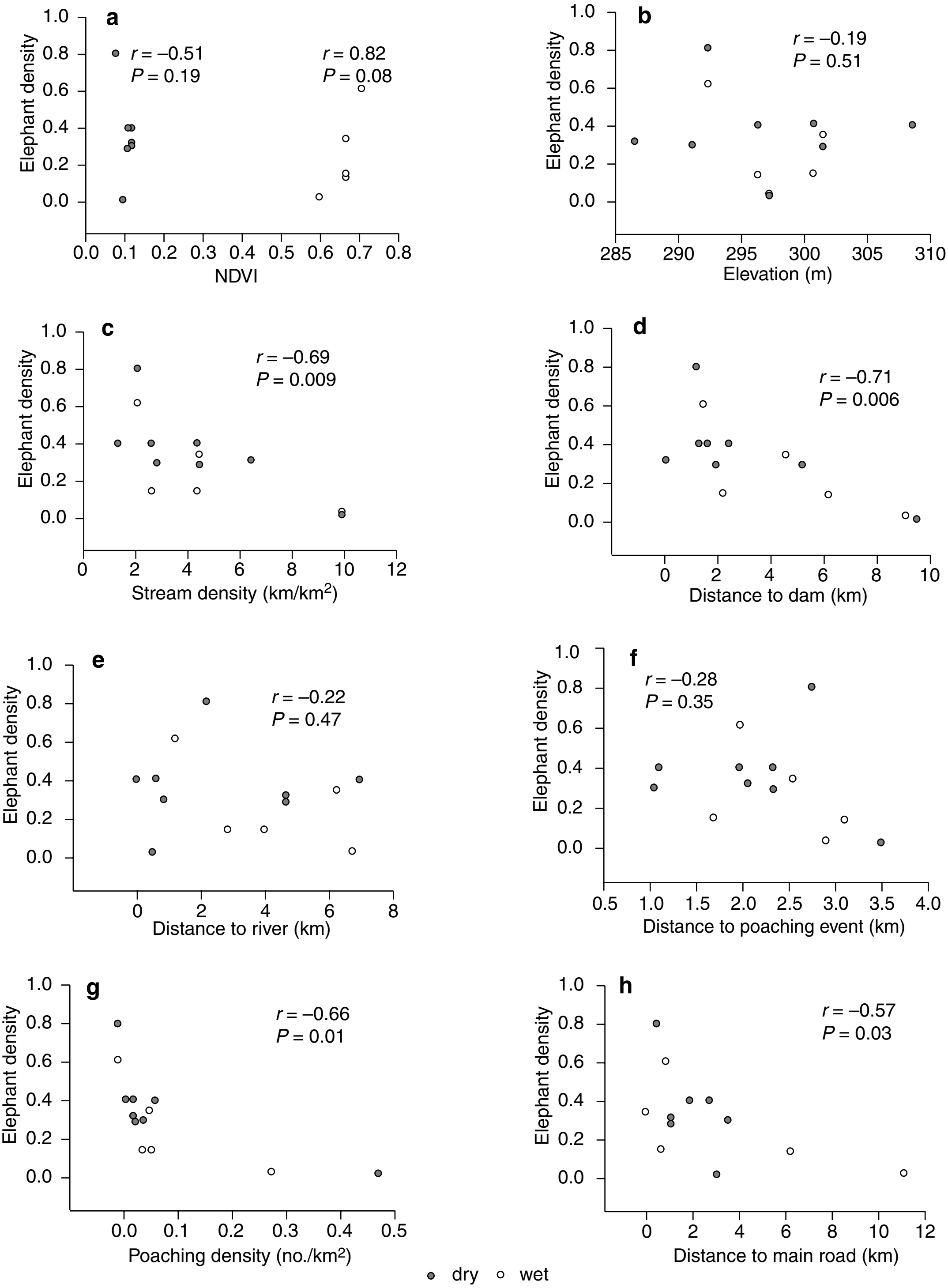

Figure 4. Elephant density (no./km^2) in Nazinga Game Ranch, Burkina Faso, 2002–2003, relative to a) NDVI, b) elevation, c) stream density, d) distance to river, e) distance to dam, f) distance to poaching event, g) poaching density, and h) distance to main road.

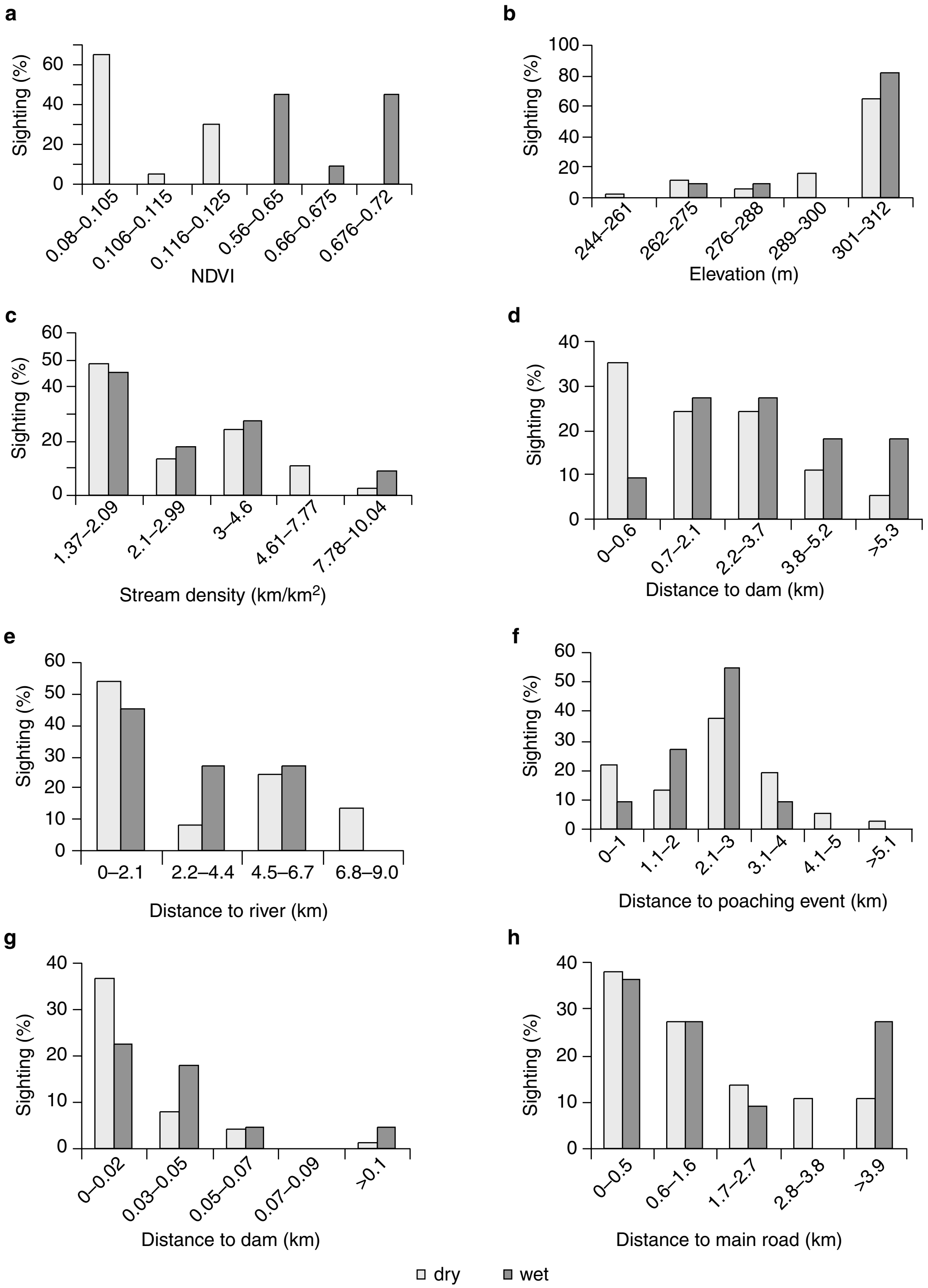

Figure 5. Seasonal sightings of elephants at Nazinga Game Ranch, Burkina Faso, in relation to a) NDVI, b) elevation, c) stream density, d) distance to river, e) distance to dam, f) distance to poaching event, g) poaching density, and h) distance to main road.

Table 1. Stepwise regression parameters to determine factors affecting elephant distribution in Nazinga, Burkina Faso, 2002–2003

Variable	Parameter	SE	F value	Pr > F
Intercept	0.213	0.08	6.27	0.033
NDVI	–0.195	0.08	5.36	0.045
Stream density	–0.016	0.01	2.57	0.143
Poaching density	–0.067	0.01	37.75	0.0002

(Fryxell and Sinclair 1988). High elephant densities in Kenya were explained as a result of dense grass cover and green grass (Leuthold 1977). Elephant association with higher NDVI in Nazinga during the wet season might be linked not only to forage quality, but also to its abundance.

Similar to Leuthold (1977), distance to dams was strongly associated with elephant density, confirming the hypothesis that elephants will be close to water because of daily requirements. A positive correlation with stream density was expected. This might not have occurred because of poaching in areas of high stream density (r = 0.83) and because of a higher number of dams in areas of low stream density. In the final model, distance to dams was eliminated because of the colinearity with stream density ($r = 0.69$, $P = 0.008$). Nevertheless, the model did show that water had an effect on elephant distribution.

In contrast to Jachmann's findings (1988), elephants at Nazinga Game Ranch were distributed widely in the dry season, but not in the wet season. Jachmann (1988) used transect dropping counts to estimate seasonal distribution. He did not calculate use area but concluded that Nazinga elephants had a restricted distribution in the dry season because of water availability and poaching. Poole (1996) also mentioned that elephants tended to aggregate in response to poaching or to threats of human hostility, particularly in dry open savanna, which reduced their home range. An aggregation of elephants in the wet season in response to the flush of annual grasses followed by a dry-season dispersion that provided a more even distribution was documented by Caughley and Goddard (1975) in Zambia.

Poaching and other human illegal activities in the wet season could have explained the restricted use of Nazinga Game Ranch by elephants. However, there was limited evidence that density of poaching and other illegal events in the wet season was higher than in the dry season. Thus water, rather than inducing a restriction in distribution as found by Jachmann (1988), may explain the larger area used in the dry season. In the dry season, water was reduced considerably in dams, which could no longer support high concentrations of elephants. To face this scarcity, elephants might disperse strategically, to optimize dam use. In many African savanna regions, when water supplies become restricted during the dry season from the evaporation of water-filled depressions, grazing species unable to meet water requirements solely from forage concentrate around permanent water supplies (Western 1975). Optimal concentration around different water points can increase the size of the area used by elephants.

As expected, there was an inverse correlation between elephant concentration and poaching and other illegal events, confirming the hypothesis that elephants avoid areas of disturbance. Furthermore, among eight independent variables, our analysis indicated that poaching and other human illegal activities were the most important variable, explaining 81% of the variation in elephant abundance. Avoidance of the southern and northern areas could be attributed to disturbance of the habitat by poachers, farmers, shepherds and honey collectors. For many years, zone 11, which had the highest poaching density (0.472 events/km^2), had been the headquarters for human illegal activities. Though it was a part of the ranch, it was disregarded during annual wildlife surveys because managers believed that no fauna existed there. Seasonal elephant surveys not only led to quantifying the disturbance in the area but also indicated that some fauna that occasionally visited the area were deterred from staying because of human disturbance. Similar effects of poaching were mentioned by Barnes et al. (1991), who used dropping counts to study elephant distribution in a northern Gabon forest in relation to roads and villages. They found that elephants avoided zones within 7 km of roads because of human disturbance. In addition, there was a relationship between dropping density and distance to the nearest village, which led them to suggest that the most important factor determining elephant abundance was not vegetation but human activity. However, in the Bia Conservation Area in western Ghana, where the use of wire snares dominated signs of human illegal activities, Sam (2006) reported that water availability ($r^2 = 0.759$, $P < 0.05$) was more important than illegal activity in determining elephant distribution.

Contrary to expectations, traffic on the main road in Nazinga did not seem to disturb elephants because abundance decreased when distance to the road increased. This finding was likely due to the permanent traffic of tourists, which deterred poachers and provided a relatively secure environment for elephants within 1.6 km of the road. It is commonly believed that visitors in protected areas often disturb wildlife by displacing mammals and birds from preferred habitats. Though levels of disturbance might be considered, our results indicated that not all species, at least elephants, are likely to respond negatively to tours. Klein et al. (1995), studying the effect of ecotourism on the distribution of 38 species of waterbirds in Florida, found that resident species were less sensitive to disturbance than were migrants. As in our study, similar behaviour was reported by Bjornlie and Garrot (2001) and Hardy (2001). Bjornlie and Garrot (2001) noticed that grooming roads during winter in Yellowstone National Park did not affect bison (*Bison bison*) ecology whereas Hardy (2001) found that wintering bison and elk (*Cervus elaphus*) coexisted with winter recreation, their abundance remaining stable over 20 years, despite increasing visitation.

Conclusion

Use of counting blocks to relate elephant distribution to a variety of environmental and anthropogenic variables was found to be efficient. We would recommend increased monitoring activities for a better understanding of seasonal distribution and movement of elephants. Rather than considering two seasons, wet and dry, monitoring could be implemented four times a year, in the hot-dry, cold-dry, warm-wet and cold-wet seasons. Also, the study focused on Nazinga Game Ranch. Further research should consider the entire ecosystem: Nazinga Game Ranch, Safari Sissili and Kabore Tambi National Park.

Among immediate and continuous management actions that should be taken to secure wildlife, controlling poaching and other illegal activities should be of great concern for the administration of Nazinga. Yet law enforcement operations, such as anti-poaching, to be effective, require great investment in people, salaries and logistics, which Nazinga has fully acquired. Bike patrolling, in association with foot patrolling, has recently showed effectiveness in detecting and preventing illegal activities at Nazinga. However, the south-east area of the ranch is less likely to be frequented by rangers, which suggests a need to reorganize the patrolling system. As implemented in Pendjari National Park in Benin, a continuous presence in the field, 24 hours a day, seven days a week, could give effective results in deterring poaching and other human illegal activities. In addition, the construction of an additional checkpoint in the south of the ranch would help reduce pressure from Ghanaian shepherds, farmers and poachers. Finally, reconstructing the south-eastern dam to increase its capacity and period of retention would attract elephants to the south, increasing the area used by this pachyderm.

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