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Effects of roads on the behaviour of the largest South American artiodactyl (*Lama guanicoe*) in an Argentine reserve

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Animals may divert time and energy in similar ways in the presence of predators, humans or landscape infrastructures. Roads have facilitated the economic and social development of human populations. Nevertheless their presence and human use cause environmental changes, such as clearing, which increase perception of predation risk. Among the responses to this are changes in animal behaviours. In the present study, we sought to assess whether roads in an Argentine reserve affect perception of predation risk by guanacos, *Lama guanicoe*, through behaviour changes. We analysed the effects of two types of roads (unpaved track and paved route) and their surrounding environment (e.g. vegetation structure) on group size variation and on three behaviours: vigilance, foraging and movement. We also used the group structure of guanacos, such as the number of calves, to explain these behaviours. Roads in the protected area had no impact on the size of guanaco groups. However, individuals in larger groups were less vigilant and foraged more closely to roads, indicating that closeness to roads is less risky for these animals. Although guanacos' time spent moving was not affected by roads, nearness to the unpaved track and high plant cover showed the highest proportions of animals moving in the area, and individuals moved more when in small groups and in areas with medium-height vegetation. The number of individuals displaying vigilance or foraging behaviours was not affected by any of the explanatory variables. Based on these findings, we conclude that guanacos perceive the roadside environment as safer, possibly because open areas adjacent to roads facilitate detection of predators. Knowing the effects of roads on wildlife in protected areas is necessary to find ways to reach a balance between the economic development of a region and conservation of its biodiversity.

Nonlethal human disturbances can be considered analogous to nonconsumptive effects of predation (Frid & Dill, 2002; Lykkja et al., 2009). Some studies suggest that animals invest time and energy similarly when in the presence of predators, humans or landscape infrastructures (Proffitt, Grigg, Hamlin, & Garrott, 2009; Walther, 1969). To remain in a place, animals must trade-off their energy needs so as to survive, taking into account the limitations imposed by the environment and predation (Searle, Stokes, & Gordon, 2008; Wolff & Van Horn, 2003). The human activities that condition these energy needs and produce behaviour changes have been defined as disturbance stimuli (Frid & Dill, 2002). When the energy cost involved in antipredator behaviour is high, individuals may move to other environments. When this is not possible, individuals may be compelled to stay in environments where the costs of antipredator behaviour are high (Gill, Norris, & Sutherland, 2001). Animal responses to humans would be the cause of the ancestral predator–prey relationship, and those elicited by human infrastructures would be the result of the environmental changes they bring about, all of which affect the animal's perception of predation risk (Beauchamp, 2010; Cappa et al., 2014; Taraborelli et al., 2014).

Among human infrastructures, roads (tracks and routes) facilitate the economic and social development of human populations. Nevertheless their presence and their human uses cause

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environmental changes (Forman et al., 2003). These changes, due to clearing, substrate compaction, introduction of materials foreign to the system and noise, among others (Casella & Paranhos Filho, 2013; Forman et al., 2003), along with human presence, may affect animals negatively or positively (Berger & Cunningham, 1988; Forman et al., 2003; Lacy & Martins, 2003). In species such as guanaco, *Lama guanicoe*, and other ungulates, in which sight is the most used sense for detecting predators, clearing could be beneficial because the cover and height of vegetation act as a visual barrier to early detection of predators (Mitchell & Skinner, 2003; Sarno, Grigione, & Arvidson, 2008).

Moreover, vegetation provides predators with hiding spots, increasing their likelihood of hunting success (Baldi, Campagna, & Saba, 1997; Frid & Dill, 2002; Périquet et al., 2010).

Nevertheless, a greater presence of humans is also associated with roads, and this may increase perception of predation risk by ungulates (Lykkja et al., 2009; Manor & Saltz, 2003). Avoidance of near-road areas has been reported for mule deer, *Odocoileus hemionus*, and wapitis, *Cervus canadensis*, in Roosevelt National Forest (Canada; Rost & Bailey, 1979). In guanacos, individuals occupying a protected area of Argentina's Patagonia were found to exhibit longer flight distances in areas with denser vehicle traffic and in areas used by poachers (Taraborelli et al., 2014). Conversely, pregnant moose, *Alces alces*, use areas near roads (Berger & Cunningham, 1988), and although wapitis avoid nearness to roads, they have been recorded more frequently using areas within 200–400 m of roads in Banff, Kookenay and Yoho National Parks (Canada), because these areas are avoided by predators (Rogala et al., 2011), which are very sensitive to human presence (Woodroffe & Ginsberg, 2000).

Variation in group size is another behavioural strategy related to perception of predation risk (Elgar, 1989; Mooring, Fitzpatrick, Nishihira, & Reisig, 2004; Taraborelli et al., 2014). For example, bison, *Bison bison*, and guanacos form larger groups in environments perceived as riskier (Cappa et al., 2014; Fortin, Boyce, Merrill, & Fryxell, 2004; Marino & Baldi, 2008), whereas red deer, *Cervus elaphus*, disaggregate themselves in areas with higher predation risk (Creel, Schuette, & Christianson, 2014). Group size variation is not species specific and may depend on the environment and predators (density and kind of hunting). Because of this, group size alone cannot be used to evaluate predation risk, raising the need to address complementary behavioural aspects such as time spent on different behaviours.

Variation in vigilance can also be used as a measure of perceived predation risk (Ciuti et al., 2012; Marino & Baldi, 2008; Robinson & Merrill, 2013). Kudus, *Tragelaphus strepsiceros*, and giraffes, *Giraffa camelopardalis*, increase their vigilance time in the presence of lions, *Panthera leo* (Périquet et al., 2010). Guanacos also show variation in vigilance time in risky habitats, regardless of whether there are predators present (Cappa et al., 2014; Marino & Baldi, 2008). In deer, Proffitt et al. (2009) observed a decline in movement rate in places with low risk of predation from wolves or humans. An increase in time invested in vigilance and movement may compromise energy acquisition due to reduced time invested in foraging and other behaviours (Berger & Cunningham, 1998; Fortin et al., 2004; Frid & Dill, 2002).

In the present study, we hypothesized that the presence of roads and their use by humans cause environmental changes that increase guanacos' perception of predation risk. It is for this reason that we aim to assess whether roads in a protected area (Ischigualasto Provincial Park) affect perception of predation risk by guanacos. To achieve this, we studied the effects of the distance to two types of roads (unpaved track and paved route) on (1) group size and (2) time spent on different behaviours (vigilance, movement and foraging).

METHODS

Study Area

Ischigualasto Provincial Park (29°55′S, 68°05′W), declared a World Heritage Site by UNESCO (United Nations Educational, Scientific and Cultural Organisation) in 2000, together with Talampaya National Park, is located in the northeast section of San Juan province, Argentina. It stretches over 62 369 ha, with an average elevation of 1300 m above sea level.

The park includes the northern Monte, which is dominated by mountains and closed basins (Monte de Sierras y Bolsones; Pol, Camín, & Astié, 2005) and a small portion of Chaco Serrano (Burkart, Bárbaro, Sánchez, & Gómez, 1999; Torrella & Adámoli, 2005). It has a desert climate, with mean annual temperature below 18 °C and a mean annual rainfall of 100 mm, mainly concentrated in the summer season (Cortéz, Borghi, & Giannoni, 2005).

Vegetation cover is, overall, lower than 50%, and the dominant physiognomy is shrubland (Márquez, 1999). The wildlife occurring in the area is typical of the Monte ecoregion, with the puma, *Puma concolor* (Cortéz et al., 2005; Márquez, 1999) as apex predator.

We carried out work in two areas, each of which contained a different type of road: an unpaved track and a paved route. The unpaved track (a tourist circuit) was 40 km long and 5–7 m wide, with adjacent areas not cleared of vegetation. The paved route included a section of National Route No. 150, ~7 km long and ~80 m wide (10 m paved, with 5 m of roadside berm and 30 m of cleared area on each side), that leads to the park entrance. This route is part of the Central Bi-Ocean Corridor, aimed to link Porto Alegre (Brazil) with Coquimbo (Chile; Borghi et al., 2012). Traffic on the track is controlled, since vehicles are only driven in caravans guided by park rangers at agreed times (between 0900 and 1700 hours) and at controlled speeds (<40 km/h). On the route, all types of vehicles can be driven with no strict speed limit enforced, reaching speeds of up to 80–120 km/h (F. M. Cappa, personal observation).

Study Species

The guanaco is the largest-bodied wild camelid in America. It reaches 1.8 m in total height (1.2 m at wither) and weighs between 100 and 120 kg (Campos, 1996). It is a species with resource defence polygamy. Family groups constitute harems, formed by females and offspring, controlled by an adult territorial male (Franklin, 1982). Although the species is considered of minor concern by the IUCN (International Union for Conservation of Nature, http://www.iucnredlist.org/details/11186/0), the population inhabiting Ischigualasto Provincial Park is of particular importance because of its low density (<0.4 individuals/km^2; Acebes, Ovejero, Traba, Malo, & Borghi, 2010; Baigún, Bolkovic, Aved, Li Puma, & Scandalo, 2008), as well as for being one of the few populations under protection in the hyper-arid zone.

Roads have a greater effect on large animals and on those with greater mobility (greater likelihood of crossing roads; Carr & Fahrig, 2001), low reproduction rates and density, as well as those who are less able to rebound from low numbers and/or to persist with few individuals (Fahrig & Rytwinski, 2009; Gibbs & Shriver, 2002; Rytwinski & Fahrig, 2011). The guanaco meets all these features, which makes it an ideal model to answer our questions.

Ethical Note

This work was approved by the Bioethics Commission, Biology Department, Facultad de Ciencias Exactas, Físicas y Naturales, Universidad Nacional de San Juan, Argentina (FCEFyN-UNSJ, File No. 02-2962-C-14).