

# Is human disturbance causing differential preference of agricultural landscapes by taruka and feral donkeys in high Andean deserts during the dry season?



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## ABSTRACT

Areas with high shrub and grass cover are scarce and important for arid-land ungulates. Unfortunately, agricultural activities are often concentrated in such areas causing ungulates either to include croplands as foraging areas or being displaced to less desirable and more restrictive habitats. Considering this conflict, we assessed the spatial overlap of taruka (*Hippocamelus antisensis*) and feral donkeys (*Equus asinus*) at intermediate scales (0–2000 m) and compare their habitat preferences in the highland desert of northern Chile. We visited the area during the dry season; we estimated the vegetation cover and measured distance to croplands from animal sightings and control points. We found that there was an aggregated spatial pattern between donkey and taruka and both species used areas with shrub ( $p = 0.770$ ) and bare ground cover ( $p = 0.124$ ) as available. Nevertheless they differed on their location relative to crops (taruka used areas as available  $p = 0.964$ , feral donkeys avoided areas near crops  $p < 0.001$ ). Our results suggest that there is a low potential for competition between species considering their habitat preferences. In spite of human persecution, this pattern appears to be driven by the taruka's dependence upon humid habitats near water and thus crops while feral donkeys can avoid such areas because of their tolerance of more arid environments than the native deer.

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## 1. Introduction

In deserts, areas with high shrub and grass cover throughout the year are important and perceived as good habitats by wild ungulates, because they are a source of high quality food and shelter against natural predators (Pierce et al., 2004). Shrubs and grasses are scarce in deserts and form patchy patterns across the landscape, especially

in proximity to water sources. Unfortunately, in human-modified arid environments agricultural activities are usually concentrated near water sources, where local farmers produce subsistence crops and compete with native plants and wildlife for space, soil and water. This overlap between human activities and wild organisms affects the viability of local ungulate populations in the long-term, because it enables wild ungulates to include crops as a new source of forage, which in turn creates human-wildlife conflicts, or forces them to move to poorer habitats (Verlinden, 1997).

In this study we focused on the northern Andean deer or taruka (*Hippocamelus antisensis*) and feral donkeys (*Equus asinus*) that inhabit human-modified areas in the Andean highland desert of northern Chile. This zone is dominated by native vegetation interspersed with crops that are planted on terraced hillsides near water

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sources (Goykovic, 2012). This technique of agriculture was inherited from the Aymara indigenous people, who started shaping this landscape ca. 3000 years ago (Rundel and Palma, 2000). In this environment the taruka, a mid-sized native deer, has coexisted with native people for thousands years (Rundel and Palma, 2000) and feral donkeys have increased their presence since their introduction in the 18th Century. Both species are pursued and poached by local farmers because they feed on alfalfa (*Medicago sativa*) crops throughout the year (taruka Sielfeld and Guzmán, 2011; feral donkey AV, pers. obs.). It is expected that an interspecific competition is occurring between both species for fresh vegetation and/or crops in this area. Our objectives here were the following: i) assess the spatial overlap of taruka and feral donkeys at intermediate scales, ii) describe the habitat preferences of taruka and feral donkeys, and their proximity to croplands, and ii) explore the potential for competition between both ungulates as the first step to understand their interspecific interaction in the highland desert of the Andean mountains.

## 2. Methods

The study area was located between 2500 and 4200 m above sea level in the Andean foothills of Arica y Parinacota and Tarapaca districts (18°11'49"S, 69°33'35"W). The total study surface was 904 km<sup>2</sup> where 45.52 km<sup>2</sup> were covered by crops. This highland desert zone is dominated by canyons and gullies interspersed with agricultural areas. Vegetation is characterized by high elevation shrub chaparral with a mean height <0.5 m (Luebert and Pliscoff, 2006) dominated by shrubs from genus *Baccharis* and *Parastrephia* and grasses from genus *Festuca* and *Stipa* (Villagran et al., 1981). Water is limited to gullies with streams, where human settlements, crops, and shrub cover concentrate (Goykovic, 2012). The average monthly temperature varies from 0 °C to 18 °C with an annual precipitation between 50 and 200 mm, concentrated between December and March (Novoa and Villaseca, 1989). The estimated population of taruka and feral donkeys in the study area are approximately 800 (RCE, 2007) and 1700 individuals (BG, pers. obs.) respectively. Agricultural crops are planted on terraced hillsides with high slopes near streams. The primary crops are corn (*Zea mays*), oregano (*Origanum vulgare*), potatoes (*Solanum tuberosum*), and alfalfa as pasture for llamas (*Lama glama*), alpacas (*Vicugna pacos*), cattle and sheep (Pérez, 2008).

The fieldwork was conducted during the dry season (4–27 August 2014), when the strongest influence of water availability on ungulate habitat preferences is expected (Pierce et al., 2004). Data were collected between 9 a.m. and 7 p.m. by four independent teams, who looked for taruka and feral donkeys while driving roads and walking line transects away from roads. Each transect was monitored once. We covered 484.7 km on transects travelled by car using a pick-up truck that went over the majority of roads within taruka distribution in Chile (Sielfeld and Guzmán, 2011). Only closed roads were not considered for safety reasons. We covered 40.7 km on 158 walking line transects that were separated from each other by 2.5 km. They randomly varied in eight directions (north, south, east, west, north-west, north-east, south-west and south-east) and five Euclidean lengths (150–350 m increasing by 50 m). Control points were set at the beginning and the end of line transects (Iranzo et al., 2013). Control points were set for estimating habitat availability in the study area and comparing it with availability in sighting points (Marcum and Loftsgaarden, 1980). When direct (encounters with animals) or indirect (faeces, footprints and skulls) animal signs were found, an observer recorded the geographical position using a GPS (Garmin GPSMAP® 60CSx) and visually estimated the proportion of surface with shrub cover and bare ground within a surrounding radius of 50 m following

methodology in Iranzo et al. (2013). In order to describe 100% of the area other types of cover (e.g. water, natural grassland, wetland, buildings) were recorded, but those were not used in the analyses. Same vegetation estimation was performed in control points. Finally, the minimum distance from each sighting and control to crop fields was calculated using LANDSAT images and QGIS 2.4.0. Although livestock (llamas, alpacas, cattle and sheep) could compete with taruka and feral donkeys, they were not included in the analysis because their movement is limited to croplands and totally controlled by shepherds (Pérez, 2008).

We used taruka and feral donkey locations to perform a point pattern analysis in order to determine spatial overlap between species at intermediate scales (0–2000 m). We assessed spatial aggregation with the bivariate function  $L(r)$ , which is a mathematic transformation of K- Ripley analysis using Passage software version 2 (Rosenberg and Anderson, 2011). If aggregation is detected, we can infer potential interspecific competition.

Differences in shrub cover, bare ground, and distance to crops between controls and sightings were assessed using generalized linear models (GLM) with quasi-Poisson distribution (log link function). Where vegetation cover and distance to crops were the predictive variables and total number of controls and sightings with specific vegetation cover and distance to crops were the response variables. Data from shrub and bare ground cover were grouped every 5% units (e.g. 0, 1–5%, 6–10% etc.), and from distance to crops every 25 m (e.g. 0, 1–25 m, 26–50 m etc.). Data from distance to crops were log transformed to improve their fit. To assess preference we used the index proposed by Neu et al. (1974) and clarified by Byers and Steinhorst (1984). Expected and observed usages were estimated from controls and sighting points respectively (Marcum and Loftsgaarden, 1980) and compared with chi-square test of homogeneity. When there was no significant difference between expected and observed usage ( $p > 0.05$ ) we concluded the habitat usage was according to availability. When there was significant difference ( $p < 0.05$ ), we visually assessed from the plot if there was preference (the slope of the observed usage is bigger than the slope of the expected usage) or avoidance (the slope of the observed usage is smaller than the slope of the expected usage) to that type of habitat (Byers and Steinhorst, 1984). All statistical analyses were performed in R (R Development Core Team, 2008).

## 3. Results

We identified 65 sites with taruka signs (12 groups, 42 faeces, 10 footprints, and 1 skull), 108 sites with feral donkey signs (7 groups, 82 faeces, 18 footprints, and 1 skull) and 310 controls points. Taruka

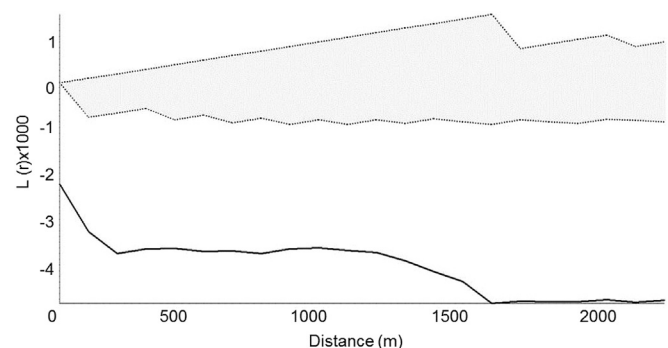


Fig. 1. Pattern of spatial aggregation between taruka and feral donkey. Grey area indicates random pattern with 95% confidence interval. Area above envelope indicates segregation and below indicates aggregation between species. Solid black line indicates the observed pattern.

groups varied between one and seven individuals ( $3.08 \pm 1.85$  individuals), and feral donkey between one and three ( $2.1 \pm 0.94$  individuals). Data that we used for performing habitat preference analyses are showed in Tables S1–S4. In relation to spatial overlap at intermediate scales, point pattern analyses showed an aggregated pattern between donkey and taruka at all spatial scales (0–2000 m; Fig. 1).

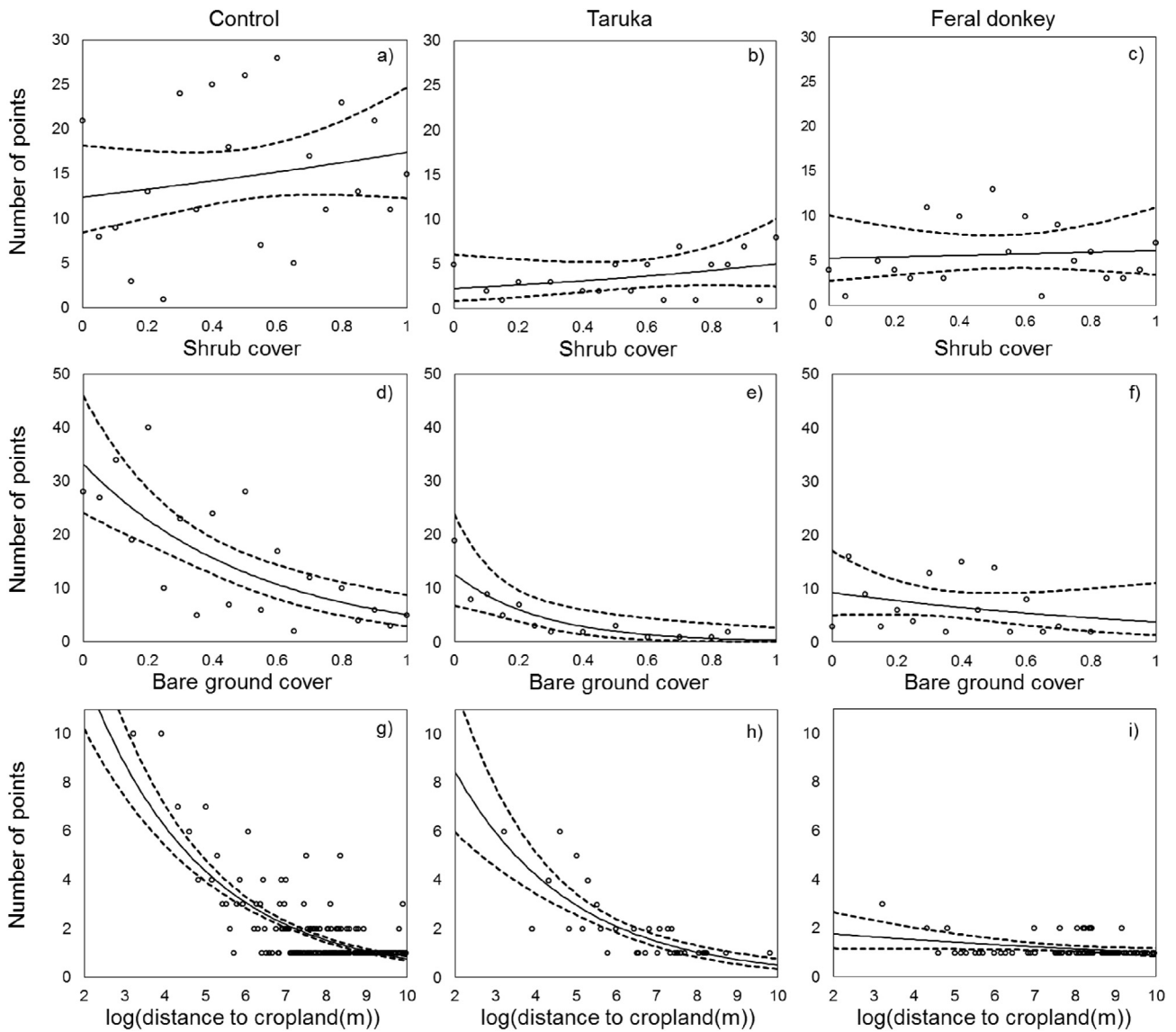
When we compared expected usage of habitat (controls) with the observed usage of each species (sightings), we found that both species used areas with shrub ( $\chi^2 = 1.438$ ,  $df = 2$ ,  $p = 0.770$ ; 53% of deviance explained) and bare ground cover ( $\chi^2 = 13.570$ ,  $df = 2$ ,  $p = 0.124$ ; 64% of deviance explained) as available (Table S5 sections “a” and “b”), but they differed on their location regarding to crops ( $\chi^2 = 16.602$ ,  $df = 2$ ,  $p < 0.001$ ; 62% of deviance explained). Feral donkeys avoided areas near crops ( $p < 0.001$ ; Fig. 2 graph “i”), but taruka were distributed according to availability ( $p = 0.964$ ; Fig. 1 graph “h”) (Table S5 section “c”). Although not significant, feral donkeys appeared to be less affected by bare ground cover than

taruka when this coverage was low ( $p = 0.062$ ; Fig. 2, graphs “e” and “f”).

**4. Discussion**

This study focused on understanding local distributions of feral and native mid-sized ungulates within an agricultural landscape in the Andean highland desert. Malo et al. (2016) found differences in habitat preferences of feral donkeys and native camelids (guanaco *Lama guanicoe* and vicuña *Vicugna vicugna*) in northern Chile. Understanding these patterns will help improve ungulate management in this area, especially since the Andean foothills have been the historical scenario of a long story of coexistence and recently of unsolved conflict between the Aymara people and native ungulates in this region (Rundel and Palma, 2000).

Our results showed that both species were spatially aggregated at intermediate scales (0–2000 m) and used shrub and bare ground areas as available. This could suggest that feral donkeys and taruka



**Fig. 2.** Predicted distributions for shrub cover, bare ground cover, and distance to crops. Graphs a), b) and c) show predicted distribution for cover of shrubs in control points, and taruka and feral donkey sightings, respectively. Graphs d), e) and f) show predicted distribution for the cover of bare ground in control points, and taruka and feral donkey sightings, respectively. Graphs g), h) and i) show predicted distribution for log distance to cropland in control points, and taruka and feral donkey sightings, respectively. Black and dashed lines represent predicted values and confidence intervals, respectively.

could be using similar habitats as observed for donkeys and other native species in the Sonoran desert of North America (mule deer *Odocoileus hemionus* Marshal et al., 2012; bighorn sheep *Ovis canadensis* Marshal et al., 2008) and the Andean semi-desert in Argentina (Borgnia et al., 2008).

Nevertheless, in spite of the spatial aggregation at intermediate scales, there was no spatial overlapping at local scale, because feral donkeys avoided zones near crops and taruka used them as available. Considering current differences in the spatial distribution in relation to croplands, our analysis suggests that there is a low potential for competition between taruka and donkeys close to agricultural landscapes.

The low potential for competition between both species could be caused by a trade-off between adaptation to arid conditions and human harassment near crops. Although both species use shrub and bare ground as available, feral donkeys would be able to forage on lower quality vegetation present in drier areas (Grinder et al., 2006), whereas taruka might not avoid areas that are found near crops (Siefeld and Guzmán, 2011). These responses may be driven by differences on forage digestion. Mid-sized deer have a small rumen, allocating only small amounts of food in the digestive tract, which forces them to feed mainly on high quality vegetation, keeping them near to humid ravines to fulfill their nutritional requirements (Müller et al., 2013). On the other hand, equids, like donkeys, are opportunistic species that have a cecal digestion with shorter retention times, but with larger volume intake, allowing them to feed on lower quality senescent and dry plants, enabling them to inhabit areas with low moisture (Müller et al., 2013).

Taruka cope with human persecution near croplands by hiding during daylight and feeding at night (A. Muñoz, pers. obs.). Nevertheless, inhabiting near crops puts taruka under high conservation risk because Aymara people poach them to prevent crop damage (NFA, pers. obs.). As a result, human harassment and poaching are important causes of local extirpation of taruka, which has also been reported in Bolivia (Rechberger et al., 2014). There, a 30-year extinct population near La Paz reappeared when people left the area.

In order to reduce the human-deer conflict, during 2005–2008 Chilean authorities built fences to enclose villages, crops and their proximities, keeping deer away from rural areas and protecting them from poaching (Pérez, 2008). Unfortunately, they misunderstood that taruka proximity to croplands was motivated by crop presence, instead of considering that crops were located within their former optimal habitats (shrubs nearby water sources, Barrio, 2013). These actions were also contrary to the fencing policies for dryland ecosystems proposed by Durant et al. (2015), who recommend not to fence large extensions of land to allow animal migrations and movements among their feeding sites. Today the Chilean fencing program has stopped due to lack of funding and most of their fences have been cut by farmers and shepherds (NFA personal observation), which has allowed taruka to continue using areas nearby crops. Actions to measure and monitor the damage (Haney and Conover, 2013), and give value to this native water-dependent deer (Rechberger et al., 2014) are urgently needed to reduce the conflict between native herbivore and Aymara people in the highland desert of northern Chile.

Our results highlight the impact that human activities have on modifying the habitat use of mid-sized ungulates in northern Chile, at least based on the variables we measured, where feral donkeys seem to be more flexible than taruka.

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## Appendix A. Supplementary data

Supplementary data related to this article can be found at <http://dx.doi.org/10.1016/j.jaridenv.2016.08.018>.

## References

- Barrio, J., 2013. *Hippocamelus antisensis* (Artiodactyla: Cervidae). *Mamm. Species* 45 (901), 49–59.
- Borgnia, M., Vilá, B.L., Cassini, M.H., 2008. Interaction between wild camelids and livestock in an Andean semi-desert. *J. Arid Environ.* 72, 2150–2158.
- Byers, C.R., Steinhorst, R.K., 1984. Clarification of a technique for analysis of utilization-availability data. *J. Wildl. Manag.* 48 (3), 1050–1053.
- Durant, S.M., Becker, M.S., Creel, S., Bashir, S., Dickman, A.J., Beudels-Jamar, R.C., Lichtenfeld, L., Hilborn, R., Wall, J., Wittemyer, G., Badamjav, L., Blake, S., Boitani, L., Breitenmoser, C., Broekhuis, F., Christianson, D., Cozzi, G., Davenport, T.R.B., Deutsch, J., Devillers, P., Dollar, L., Dolrenny, S., Douglas-Hamilton, I., Dröge, E., FitzHerbert, E., Foley, C., Hazzah, L., Hopcraft, J.G.C., Ikanda, D., Jacobson, A., Joubert, D., Kelly, M.J., Milanzi, J., Mitchell, N., M’Soka, J., Msuha, M., Mweetwa, T., Nyahongo, J., Rosenblatt, E., Schuette, P., Sillero-Zubiri, C., Sinclair, A.R.E., Price, M.R.S., Zimmermann, A., Pettorelli, N., 2015. Developing fencing policies for dryland ecosystems. *J. Appl. Ecol.* <http://dx.doi.org/10.1111/1365-2664.12415>.
- Goykovic, V., 2012. Productive agricultural systems in the desert macro-region of Chile. *IDESIA* 30 (2), 3–10.
- Grinder, M.I., Krausman, P.R., Hoffmann, R.S., 2006. *Equus asinus*. *Mamm. Species* 794, 1–9.
- Haney, M.J., Conover, M.R., 2013. Ungulate damage to safflower in Utah. *J. Wildl. Manag.* 77 (2), 282–289.
- Iranzo, E.C., Traba, J., Acebes, P., González, B.A., Mata, C., Estades, C.F., Malo, J.E., 2013. Niche segregation between wild and Domestic herbivores in Chilean Patagonia. *PLoS One* 8 (3), e59326.
- Luebert, F., Plissock, P., 2006. Sinopsis Bioclimática y Vegetacional de Chile. Editorial Universitaria, Santiago.
- Malo, J.E., González, B.A., Mata, C., Vielma, A., Donoso, D.S., Fuentes, N., Estades, C.F., 2016. Low habitat overlap at landscape scale between wild camelids and feral donkeys in the Chilean desert. *Acta Oecol.* 70, 1–9.
- Marcum, C.L., Loftsgaarden, D.O., 1980. A nonmapping technique for studying habitat preferences. *J. Wildl. Manag.* 44 (4), 963–968.
- Marshal, J.P., Bleich, V.C., Andrew, N.G., 2008. Evidence for interspecific competition between feral ass *Equus asinus* and mountain sheep *Ovis canadensis* in a desert environment. *Wildl. Biol.* 14 (2), 228–236.
- Marshal, J.P., Bleich, V.C., Krausman, P.R., Reed, M.L., Neiberger, A., 2012. Overlap in diet and habitat between the mule deer (*Odocoileus hemionus*) and feral ass (*Equus asinus*) in the Sonoran Desert. *Southwest. Nat.* 57 (1), 16–25.
- Müller, D.W.H., Codron, D., Meloro, C., Munn, A., Schwarm, A., Hummel, J., Clauss, M., 2013. Assessing the Jarman/Bell Principle: scaling of intake, digestibility, retention time and gut fill with body mass in mammalian herbivores. *Comp. Biochem. Physiol., Part A* 164, 129–140.
- Neu, C.W., Byers, C.R., Peek, J.M., 1974. A technique for analysis of utilization-availability data. *J. Wildl. Manag.* 38 (3), 541–545.
- Novoa, R., Villaseca, S., 1989. Mapa agroclimático de Chile. Instituto de Investigaciones Agropecuarias, Santiago Chile.
- Pérez, J., 2008. Estudio Básico: Diagnóstico Poblacional Guanaco y Taruca, Provincia de Parinacota. INFORME FINAL. Corporación Nacional Forestal, Arica Chile.
- Pierce, B.M., Bowyer, R.T., Bleich, V.C., 2004. Habitat selection by mule deer: forage benefits or risk predation? *J. Wildl. Manag.* 68 (3), 533–541.
- RCE, 2007. DS 151 MINSEGPRES 2007 (1er Proceso RCE) (accessed 10.06.16.). [http://especies.mma.gob.cl/CNMWeb/Web/WebCiudadana/ficha\\_indepen.aspx?EspecieId=7&V/](http://especies.mma.gob.cl/CNMWeb/Web/WebCiudadana/ficha_indepen.aspx?EspecieId=7&V/).
- R Development Core Team, 2008. R: a Language and Environment for Statistical Computing. R Foundation for Statistical Computing, ISBN 3-900051-07-0. Vienna, Austria. <http://www.R-project.org>.

- Rechberger, J., Pacheco, L.F., Nuñez, A., Roldan, A.I., Martínez, O., Mendieta, G., 2014. The recovery of a population of the Vulnerable taruka *Hippocamelus antisensis* near La Paz, Bolivia: opportunities for conservation and education. *Oryx* 48 (3), 445–450.
- Rosenberg, M.S., Anderson, C.D., 2011. PASSaGE: pattern analysis, spatial statistics and geographic exegesis. version 2. *Methods Ecol. Evol.* 2, 229–232.
- Rundel, P.W., Palma, B., 2000. Preserving the unique puna ecosystems of the andean altiplano, a descriptive account of Lauca National Park, Chile. *Mt. Res. Dev.* 20 (3), 262–271.
- Siefeld, W., Guzmán, J.A., 2011. Distribution, reproduction and grouping patterns in the taruca deer (*Hippocamelus antisensis* D'Orbigny, 1834) in the extreme north of Chile. *Animal Prod. Sci.* 51 (clxxx–cxc).
- Verlinden, A., 1997. Human settlements and wildlife distribution in the Southern Kalahari of Botswana. *Biol. Conserv.* 82, 129–136.
- Villagran, C., Armesto, J.J., Kalin, M.T., 1981. Vegetation in a high andean transect between Turi and Cerro Leon in northern Chile. *Vegetatio* 48 (1), 3–16.