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How many are there? Multiple covariate distance sampling for monitoring pampas deer in Corrientes, Argentina

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Abstract

Context. Pampas deer (*Ozotoceros bezoarticus*) is an endangered species in Argentina. Scarce information existed about one of its four last populations that survives in Corrientes province, where direct counts estimated a population of <500 individuals.

Aims. To evaluate the status of Corrientes' pampas deer population applying a standardised methodology and to develop methodological recommendations for future deer monitoring.

Methods. We carried out six population censuses between 2007 and 2011 using line transects placed on roads throughout 1,200 km^2 of grasslands in the Aguapey region, Corrientes, Argentina. From a moving vehicle, we counted every pampas deer group observed along transects. We used Distance 6.0 and its Multiple Covariates Distance Sampling Engine to estimate deer density, while exploring the potential effect of roads, habitat type, hour, observer experience, and survey effort on deer occurrence and density estimation.

Key results. Pampas deer occurrence was irrespective of transects location (minor or major road) but a greater number of animals were detected over transects in minor roads and in areas covered by grasslands with young pine plantations. We estimated a density of 1.17 deer/km^2 (SE=0.52), being habitat type the most important covariate for density estimation.

We estimated a total population of 1495 deer (95% CI=951-2351, CV = 23.27%) for the Aguapey region in Argentina.
Conclusions. Corrientes hosts one of the largest population of pampas deer in Argentina with >1000 individuals. The fact that we estimated a larger population than previous studies could be explained both by an actual population growth during the last 10 years, and by the use of more exhaustive and sophisticated sampling design and data analysis.
Implications. Population surveys using covariate distance sampling on ground line transects can provide more realistic population estimates than other simpler methods. Our population estimates and methods can be used as a baseline for future monitoring of this population as long as factors as sampling effort, type of roads for locating transects and habitat type should be considered in future analysis.

Additional keywords: Argentina, distance sampling, habitat type, line transects, multiple covariate, *Ozotoceros bezoarticus*, roads, survey effort.

Introduction

Until livestock arrival, pampas deer (*Ozotoceros bezoarticus*) was the dominant ungulate over most of the vast plain areas of Brazil, Bolivia, Paraguay, Uruguay and Argentina (Jackson and Giulietti 1988; González *et al.* 2010). Originally distributed throughout the Argentinean grasslands, pampas deer population has suffered a dramatic decline within this country due to habitat loss and fragmentation, hunting, and probably the competition with livestock for forage (Jackson and Giulietti 1988; Demaría *et al.* 2004). Despite of being internationally considered a nearly threatened species (González and Merino 2008), pampas deer is considered endangered in Argentina and therefore, precise estimations about its population status are highly needed (Díaz and Ojeda 2000; Pastore 2012).

Of the four pampas deer populations remaining in this country, one of them is located on the Aguapey basin (Corrientes province, north-eastern Argentina) (**Error! Reference source not found.**), belonging to the *O. b. leucogaster* subspecies (Goldfüss 1817). As in other populations of the species in Argentina, the one in Corrientes is isolated and with scarce protection (Jiménez Pérez *et al*. 2009; Merino and Beccaceci 1999; Parera and Moreno 2000). Hunting pressure and competition with cattle were the activities that historically have threatened pampas deer in Corrientes (Merino and Beccaceci 1999; Parera and Moreno 2000). However, since the end of the last century, habitat loss through forest plantations, which had occupied 24% of deer's available habitat by 2008, has become a major threat to this population (Jiménez Pérez *et al.* 2009). These growing threats have lead to government and NGOs to seek for urgent actions in order to conserve this population, either by *in situ* protection actions or by the translocation of individuals to establish a new population within Iberá Nature Reserve, located adjacent to Aguapey's population (Fig. 1). This has accentuated the need of having precise estimates of population size and trends to support these management actions.

Aerial and terrestrial surveys combined with interviews were previously carried out to assess the number of pampas deer present within the Aguapey region (Jiménez Pérez et al. 2009; Merino and Beccaceci 1999; Parera and Moreno 2000). By the end of the last century, the total estimated population of pampas deer in Corrientes ranged from 130 to 500 individuals (Merino and Beccaceci 1999; Parera and Moreno 2000). These were isolated surveys that used different methodologies and survey designs, hindering the possibility of estimating population trends, but also reducing the opportunity of using this data in population monitoring.

Abundance estimation is essential to understand population dynamics, and to guide conservation management (Caughley and Sinclair 1994). However, biased results or high variation in population estimates prevents the detection of changes within populations over time and reduces the possibility of finding differences when comparing between populations (Conroy and Carroll 2009). Among survey techniques used for non-volant mammals, line transect distance sampling has been increasingly used due to its ability to estimate the detection probability of animals, which is essential for an accurate population estimation (Buckland *et al.* 1993; Rudran *et al.* 1996; White 2005). This survey technique it is one of the recommended methods for monitoring deer in open areas (Andriolo *et al.* 2010) and is already being used to estimate population size for different species of South American deer (Mourão *et al.* 2000; Tomás *et al.* 2001). Additionally, the analysis capabilities for distance sampling data are also advancing, making possible to deal with other factors besides distance, which could affect animal detection (Buckland *et al.* 2004).

Different factors as the transect location, the sighting time, or the environmental heterogeneity could all influence the number of animals detected on surveys (Buckland *et al.* 1993; Rudran *et al.* 1996). Many times, transects are located in existing roads and trails because it is the most efficient or the unique way to survey certain areas (Gill *et al.* 1997). Road-based sampling may bias population estimates due to their non random distribution (Buckland *et al.* 1993), or their influence on animal behaviour, as some animals may avoid roads due to its relation with humans or for other habitat factors (Rost and Bailey 1979a; Ward *et al.* 2004). Daily activity pattern of animals may also influence our capacity of detect animals during surveys (Gill *et al.* 1997). In heterogeneous areas, habitat preferences and different detectability conditions can also have a great impact in animal census (Putman *et al.* 2011). Additionally, observer expertise and survey effort should also be considered when analysing census data (Jachmann 2002). Pampas deer, for example, are rather cryptic, hindering their detection by unexperienced observers (González *et al.* 2010). In order to obtain more accurate results, we need to consider all or at least some of these factors when analysing data and estimating parameters, especially when dealing with heterogeneous data (Putman *et al.* 2011). Precise results are essential for guiding improved data collection and survey design for monitoring endangered populations or species (Thomas *et al.* 2010; Porteus *et al.* 2011; Oedekoven *et al.* 2013).

Our main objective was to assess the use of multiple covariate distance sampling to obtain precise abundance estimations for pampas deer in Corrientes, Argentina, while making recommendations for their long-term population monitoring.

Materials and methods

Study site

The Aguapey river basin is located in the northeast of Corrientes province, Argentina. Our study area comprises 2,000 km^2 of grasslands located between the Paraná River on the North, the Iberá Marshlands on the West and the Aguapey river on the East (central coordinates 28º 04'2.89"S 56º32'46.69"W) (Heinonen Fortabat *et al.* 1989) (**Error! Reference source not found.**). The landscape is a matrix of natural humid grasslands sited on flat lowlands, locally known as *'malezales'* (Carnevalli 1994; Di Giácomo *et al.* 2010). All the region is comprised of private properties, generally larger than 10,000 ha, which are dedicated to extensive cattle ranching on natural grasslands (Parera and Moreno 2000). Starting on the 1980s, timber plantations became established on the region and it is estimated that they have already substituted 24% of natural grasslands within the Aguapey basin, and their range is still increasing (Srur *et al.* 2009). The Aguapey basin is adjacent to the 1,3 million ha Iberá Provincial Reserve, and it presently lacks of any formal conservation status.

Surveys

We conducted six successive surveys between 2007 and 2009 (Table 1). Surveys consisted on lineal transects placed across the Aguapey basin, where two people looked for deer from the back of a pick-up truck moving at around 20 km/hour. Due to the difficult terrain conditions, transects were randomly placed over the whole study area on existing main dirt roads and minor roads placed inside private lands (**Error! Reference source not found.**). Main dirt roads were approximately 10 m wide and showed low traffic by vehicles and some people riding horses, while minor roads were around five meters wide and showed minimum traffic of vehicles and horses.

When possible, all selected transects were travelled for each survey, with a minimum of 10 and a maximum of 26 transects surveyed each time, totalising an average survey effort of 129.3 km. To achieve independence between transects each one was placed at least five km from the other.

For each deer observation we registered the perpendicular distance from the animal or cluster of animals to the transect, type of habitat and time of sighting. Habitat was categorised in grasslands, grasslands with cattle presence, grasslands with pine plantations younger than four years old, and pine plantations older than four years old. In order to avoid double counts, we never surveyed the same area twice within the same survey and all neighbouring transects where surveyed during the same day.

Considering that animals may tend to avoid roads and their surroundings (Forman and Alexander 1998), we evaluated differences in deer detection and encounter rate on transects located over main vs. internal roads. We also evaluated the difference on the number of deer observed in different habitat types. For both analyses we carried out a Chi-square test using R ver. 2.15.0 (R Development Core Team 2012) following procedures recommended by Logan (2010). The same software was used to develop an Odds ratio test, in order to explore differences in the number of observed deer among the categories of habitat.

To estimate deer density we analysed the data using Distance 6.0 software (Thomas *et al.* 2009), where 5% of the data was right truncated, as recommended by Buckland *et al.* (1993). Data was grouped in distance intervals, selecting the number and width of each interval by Chi square (χ^2) goodness of fit values, selecting the model with the lowest χ^2 value (Buckland *et al.* 2004).

We considered the six surveys as strata and we used the Multiple Covariate Distance Sampling (MCDS) engine of Distance in order to estimate the detection function separately for each covariate value. The two analysed covariates were habitat type and sighting time. The most influential covariate or combination of them was selected by AIC values comparisons. For habitat type, we grouped the different types into two categories of habitat according to their potential effect on deer detectability: open (including grassland, grassland with cattle and grasslands with pine plantations younger than four years old) and closed (pine plantations older than four years old). For sighting time we differentiated sightings occurred during the morning (AM) and in the afternoon (PM). The detection functions obtained with the chosen covariates was used for the estimation of the final density of deer in the study area. For mean cluster size and detection function estimation, data from all strata were used together due to the low number of data for each survey, assuming that those parameters did not vary between surveys.

The overall encounter rate was the average of encounter rates for each survey, weighting each of them by survey effort. We calculated the density for each stratum, which were averaged as well as the encounter rate for obtaining the mean density. We used linear regression to analyse the potential effect of survey effort and the previous experience of the observers in relation to the density estimation error.

Overall population size was obtained by extrapolating overall density over two possible ranges. The first range (1278 km^2) included the region that included all deer sightings excluding areas covered by pine plantations older than four years. The second area (945 km^2) excluded all pine plantations irrespective of their age in order to obtain a more conservative estimation of population size that did not include plantations as deer habitat, following Parera and Moreno (2000).

Results

An overall of 123 transects were travelled, totalising 777.5 km of surveying effort (mean = 129.2 km/survey, SE = 15.9). We obtained a total of 209 deer detected with an average of 34.8 deer/survey (SE = 7.8) (Table 1).

The detection of deer (presence/absence) was independent of transects location over main or secondary roads (χ^2 = 0.02, p = 0.886). However, deer encounter rate in transects located over main roads was lower than expected by survey effort (χ^2 = 8.95, p = 0.003) (Fig. 2).

Deer tended to be observed at larger distances on transects located over main roads, compared to those located on secondary roads (Fig. 3). Pampas deer were observed more frequently than expected in grasslands with young pine plantations (χ^2 = 9.76, p = 0.021), and the probability of observing deer was higher in these areas than in other habitat types (Table 2).

Estimates of population density and abundance

The best grouping option for our data was seven unequal intervals. Hazard Rate key function and Cosine adjustment term were selected for our analysis following the Akaike´s Information Criterion (AIC) (lowest AIC value) (Buckland *et al.* 2004).

The selected model for estimating the detection function was the one containing habitat type as covariate (Table 3). As it was expected, a higher detection probability was observed at long distances in open habitats, whereas in closed habitats the detection probability fell abruptly after 25 m (Fig. 4).

The mean density estimation for each survey varied between 0.74 and 1.84 ind/km^2 (Fig. 5). Data from spring of 2009 (survey E) was discarded due to its high SE (1.28 %). This value could be explained by the scarce number of transects performed during that survey (10 vs. 14 to 25 from other surveys) due to adverse climatic conditions, joined to the fact that out of the 15 overall sightings in survey E, 13 were achieved over the same transect. With and without considering survey E, a reduction of the estimation variability was observed when increasing the survey effort, but we did not find effect of the observers' previous experience (Fig. 6).

Extrapolating final average density of 1.17 ind/km^2 (SE = 0.52 ind/km^2) (Table 4) over the surface criterion that includes young pine plantations (1278 km^2), pampas deer abundance for the Aguapey region resulted in 1495 individuals (95% CI of 951-2351, CV = 23.27%). If we consider only grasslands without plantations as deer habitat, estimated deer population size decreased to 1105 individuals (95% CI of 703-1739 CV 23.27%).

Discussion

Population status of the pampas deer in Corrientes

Our six-year survey using distance sampling showed that pampas deer population in Aguapey, Corrientes, currently holds more than 1,000 individuals. Our results differ from previous estimates of the same population. Merino and Beccaceci (1999) performed two aerial surveys by airplane, which consisted of 300 m fix-width double sided line transects, covering an area of 108.2 km^2. They assumed total detectability of animals within each transect and used the Jolly method (Jolly 1969) to estimate a population of 127 pampas deer for the complete Aguapey region. Parera and Moreno (2000) performed aerial counts by helicopter, travelling 13 E-W transects with a fix width of 200 m on each side, which covered an area of 108.6 km^2. They estimated a population of 200 to 500 individuals in this population, though they did not show the calculations behind these numbers. More recently, some of the authors (Jiménez Pérez *et al.* 2007) performed terrestrial surveys in 2006 covering a larger area than the previous authors, though they did not use any formal sampling design or method of analysis. They observed a total of 106 individuals and they agreed with previous authors in their estimations of population size.

Differences in population estimates could be explained by differences in sampling design and analysis, and/or by an actual increase on abundance during the past years. Even though the total number of deer observed in each of our surveys was lower (34.8 ± 7.8 deer/survey) than the number seen by Jiménez Pérez *et al.*(2007), the ability to estimate a detection function, and therefore, to correct for unseen animals, allowed us to reach more reliable and higher abundance estimates than any of the other previous authors. This would be enough to explain for differences in density estimates. These same differences in methodology hinder any reliable comparison between studies to ascertain an actual increase in population abundance through the last 10 years and the application of other census methods (e.g. aerial surveys) would be valuable to corroborate our population numbers. However, qualitative data from researchers with years of experience in the area (i.e. Alejandro Giraudo and Marcelo Beccaceci) and local ranchers support the idea that there has been a significant increase of the pampas deer population in Corrientes.

Several factors could explain this increase in pampas deer population during the last years. First, the species was declared Natural Monument in Corrientes province in 1992 (Law No. 22.351), which prohibited and fined its hunting. Also, cattle ranchers have ended traditional open-access policies to their properties, thus limiting entrance by hunters. On top of this, during the last two decades the government of Argentina has implemented much more strict controls on cattle management and vaccination campaigns in order to prevent outbreaks of diseases like foot-and-mouth (Saraiva 2004). These preventive measures probably had a positive effect on pampas deer, as it seems to have been the case with its relative, the marsh deer (*Blostocerus dichotomus*), whose populations have experienced a sharp increase in Corrientes during the last two decades (De Angelo *et al.* 2011). Finally, several years of educational campaigns directed to increase awareness on pampas deer conservation may have had a positive change on the way landowners and their employees see and care about this species.

Within Argentina, density estimated for the Corrientes deer population in the present study (1.17 ind/km^2) does not differ greatly from the other two other main populations of pampas deer of the country, although estimation methods differ for each population, and animal distribution is not homogeneous. The population of *O. bezoarticus celer* from Bahía Samborombón, Buenos Aires (Fig. 1), has densities that range from 0.51 to 1.56 deer/km^2 for coastal and inner strata respectively (Vila 2006). Meanwhile, Dellafiore *et al.* (2003) estimated a density between 0.43 and 0.83 deer/km^2 for a population of the same subspecies located in San Luis province (Fig. 1). Merino *et. al.* (2011) estimated a density of 1.95

ind/km^2 for the largest pampas deer nucleus in the same population of San Luis province. Deer density of the *O. b. leucogaster* subspecies population located in Santa Fe province is uncertain (Fig. 1), but only scarce sightings were recorded (Pautasso *et al.* 2002) and population size would not be greater than 50 individuals (González *et al.* 2010). From all the mentioned studies, the only one that applied the distance sampling method was Merino *et. al*. (2011), though they used Conventional Distance Sampling without the inclusion of covariates.

Considering other pampas deer population densities estimated by distance sampling, we can observe that the population of Corrientes presents a relatively low density. Rodrigues (1996), estimated for the Brazilian Emas National Park population, a density of 1 deer/km^2, but for populations located in the Brazilian Pantanal, Tomás *et al.* (2001) estimated a density of 9.8 ± 3.8 deer/km^2, implementing the same methodology used in our study, and a density of 5.5 ± 0.7 ind/km^2 for transects surveyed on foot. The survey method of transects travelled by foot was also applied by Moraes Tomas *et al.* (2004) for another area in the Pantanal, estimating a density of 2.5 ± 0.6 deer/km^2 and by Desbiez *et al.* (2010) who estimated densities from 0.2 to 6 deer/km^2 for different habitats in Pantanal. These last three studies were done over *O. b. leucogaster* populations, the same subspecies inhabiting in Corrientes, and they show similar or higher densities than this population. Finally, Cosse and González (2013) estimated a density of 11 deer/km^2 for a population of *O. b. uruguayensis* in Bañados del Este, Uruguay.

Surveying and monitoring the pampas deer

The present study constitutes one of the first population size estimation for pampas deer implementing distance sampling within Argentina. This method is widely recommended because of its capability to determine estimates precision and for allowing data stratification and the addition of variables that improve that precision (Buckland *et al.* 1993). The technique also takes into account the two major sources of variation for obtaining unbiased estimations: spatial variation and detectability (Yoccoz *et al.* 2001). Another important issue for population monitoring is to standardise the sampling over time, which allows the detection of population variation over several years. Karanth and Nichols (2002) suggest that for monitoring large herbivores, estimates might have about 15% of variation in order to detect significant population changes over time. Even if our study represents six years of population survey, final abundance estimation possess a coefficient of variation of 23%, indicating that greater efforts are needed to reduce the factors that affect data variability in order to have a more sensitive monitoring. In this sense, the main factors that we recognise that are influencing the variability in density estimation of pampas deer are the location of transects (minor vs. main roads, Fig. 2), the habitat type (Tables 2 and 3) and the survey effort (Fig. 6).

A higher encounter rate over transects located in minor roads compared to transects placed in main roads, along with a possible trend of animals to avoid routes, could indicate a higher efficiency of surveys conducted over minor roads. Within cervids, a tendency to avoid more transited roads than those with less traffic has been found for example in mule deer (*Odoicoileus hemionus*) and elk (*Cervus canadensis* (Rost and Bailey 1979b). Secondary roads imply a lower traffic and width, which could explain why we saw a higher number of deer from these roads (Fig. 2).

Regarding habitat type, we found a higher number of deer than expected on grasslands with young pine plantation, which may imply that this environment could be positively selected by deer. Parera and Moreno (2000) have mentioned this pattern for the same pampas deer population in 1998. Contrarily, in adult pine forest we observed animals mostly over the internal roads or only in grassland areas surrounding plantations, suggesting that even if animals tend to avoid being inside the forest, they use part of this habitat in a certain level. This should be taken into account, mainly by land owners and forest companies in order to perform a sustainable management of their plantations with deer presence. These results are important not only for understanding the species habitat use, but also to obtain a proper estimation of the available habitat for estimating the total population size. Our final density estimation of deer was obtained in the basis of encounter rate and detection probability values that included sighting data from these areas with pine plantations. Considering this, the more confident population size estimation would be the one including young pine plantations as suitable habitat (~1495 pampas deer in Corrientes).

Finally, our results showed a clear relation between survey effort and the coefficient of variation (Fig. 6), a relationship that is expected in this kind of field surveys (Plumptre 2000; Buckland *et al.* 2004). However, the higher importance of survey effort in relation to other factors (e.g. the previous experience of observers) allows making important decisions for future monitoring. For example, to create a new survey team including new observers for increasing the survey effort would be preferably than surveying with only one group of experienced observers.

Conclusions

Our results bring new light to the conservation significance of the pampas deer population in Corrientes compared to the other three remnant populations in Argentina. Santa Fe harbours a population not greater than 50 individuals (Pautasso *et al.* 2002; González *et al.* 2010). Population estimates for Buenos Aires province refer to 247 ± 61 individuals (Vila 2006), and conversations with local experts talk of a decrease in numbers during the last years (Mario Beade, pers. Comm..) Finally, Merino, et. al. (2011) estimated 731± 121 individuals for the main population nucleus in San Luis province, and Merino (com. pers.) gives an approximate estimate of 1000 pampas deer in the whole population. With this new data, Corrientes would be hosting the largest or second largest population of pampas deer in Argentina, with an estimated number of 950 to 2350 individuals. Although these results should be corroborated with other census methods and further repetitions of the same transects, our findings concur with recent genetic analysis that identify the Corrientes population of pampas deer as the one maintaining the highest genetic diversity in Argentina (Raimondi 2013).

During the last 20 years, habitat loss through pine plantations have become the main threat for the species conservation within the region (Parera and Moreno 2000; Jiménez Pérez 2006; Jiménez Pérez *et al.* 2007; Srur *et al.* 2009). However, this has not hampered what it looks like a significant recovery in population numbers, most likely because of major improvements in law enforcement, private control of poachers, and human disease prevention campaigns. Other *in situ* conservation measures are currently being taken, such as the creation of a private reserve (Guazutí-Ñú) of 535 ha (Fig. 1), acquired for pampas deer conservation by a conservation NGO (Fundación Flora y Fauna Argentina) in 2008. Along with this, conservation NGOs and the government are promoting the awareness of land-owners and workers within the region, as well as producing a public awareness campaign about the species status and conservation (Jiménez Pérez *et al.* 2009; Dirección de Parques y Reservas 2011).

Besides this, since 2009 The Conservation Land Trust has been establishing a second population of pampas within Iberá Nature Reserve, some 90 km through the marshlands apart from the Aguapey region. This reintroduced population was made up of animals translocated from that area. By October 2013 it was composed of 34-37 animals and it was rapidly increasing (The Conservation Land Trust, unpublished data). Our results regarding to the Aguapey deer population status and the recommendations for its monitoring will help to evaluate *in situ* management actions and future decisions on the management and/or establishment of new pampas deer populations within other regions of Corrientes.

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Tables

Table 1. (line 191). Description of the six surveys performed for pampas deer monitoring in Corrientes, Argentina.

Table 2. (line 203) Differences in the number of deer observed among the habitat type categories surveyed in the Aguapey region.

Table 3. (line 208) Comparison among the different models evaluated for estimating the detection function for pampas deer in the Aguapey region.

Table 4. (line 226) Mean deer and group density, and cluster size estimated by Distance MCDS engine for the Aguapey region in Argentina.

Figures

Fig. 1. (line 133) Location of the pampas deer remaining populations in Argentina (left) and detailed map of the Aguapey region where the study was carried out (right). The later map shows the location of line transects used to estimate deer abundance between 2007 and 2010, and the distribution of pine plantations.

Fig. 2. (line 203) Relative proportion (represented by the square size) of deer groups observed over main and minor roads in comparison with the expected proportion according to the survey effort made in each type of road.

Fig. 3 (line 203) .Relative proportion (represented by the square area) of deer groups observed at different distances to the transect over main vs. minor roads. Distances were categorized as near (0-100m), middle (100-500m) and far (500-1000m).

Fig. 4. (line 212) Detection probability as a function of the distance for both habitat groups. a) Open habitats: grassland, grassland with cattle, and grassland with young pines. b) Close habitats; grassland with old pine plantations.

Fig. 5. (line 220) Densities estimates for pampas deer in the Aguapey region (black dots) and their confident intervals (grey lines) estimated for each survey. Survey E (spring 2009) was discarded because its high data variability. See Table 1 for details of each survey.

Fig. 6. (line 220) Regression analysis between Coefficient of Variation (CV expressed in percentage) for density estimation in each survey (circles) and the previous experience of

observers (a and b, expressed by the number of previous deer surveys) and the survey effort (c and d, expressed as overall km travelled within each survey). Both relations are shown including all surveys (a and c) and excluding survey E that presented an extreme CV (b and d), with their corresponding linear regression parameters (discontinuous line).

Tables

Table 1. (line 191). Description of the six surveys performed for pampas deer monitoring in Corrientes, Argentina.

Survey	Number of transects	Surveying effort (km)	Deer sightings
A (spring 2007)	17	123.24	22
B (autumn 2008)	26	170.74	73
C (spring 2008)	26	169.25	31
D (winter 2009)	22	142.75	23
E (spring 2009)	10	79.95	28
F (spring 2010)	20	89.45	32
Total	**123**	**775.48**	**209**
Mean	**20.5**	**129.24**	**34.8**
SE	**2.26**	**19.85**	**7.8**

Table 2. (line 203) Differences in the number of deer observed among the habitat type categories surveyed in the Aguapey region.

Odds ratio values lower than one indicate that the proportion within the first compared category is lower than the second one, and values greater than 1 indicate the opposite. The p value corresponds to a Chi-square test (Logan 2010). Significant comparisons ($p<0.05$) are shown in bold type. Habitat categories: Grasslands; G/pine<4: Grasslands with pine plantations with less than 4 years; G/pine>4: Grasslands behind which are located pine plantation older than 4 years; G/C: Grassland with cattle.

Comparison	Estimate	Confidence Interval	p
Grassland vs G/pine<4	**0.4**	**0.2-0.8**	**0.004**
Grassland vs G/pine>4	0.8	0.5-1.4	0.534
Grassland vs G/Cattle	1.1	0.7-2.0	0.654
G/pine<4 vs G/pine>4	**2.0**	**1.0-3.9**	**0.048**
G/pine<4 vs G/Cattle	**2.6**	**1.3-5.3**	**0.006**
G/pine>4 vs G/Cattle	1.3	0.7-2.6	0.379

Table 3. (line 208) Comparison among the different models evaluated for estimating the detection function for pampas deer in the Aguapey region.

Covariate	AIC	Delta AIC
Habitat	358.26	0
No covariate	364.50	6.24
Time	365.40	7.14
Habitat and time	365.98	7.72

Table 4. (line 226) Mean deer and group density, and cluster size estimated by Distance MCDS engine for the Aguapey region in Argentina.

The estimation considered habitat type covariate, discarding data from spring 2009 survey.

Estimated parameter	Value	CV	Confidence Interval (95%)	
			Lower	Upper
Mean cluster size	1.93	0.09	1.60	2.32
Cluster density (cluster /km^2)	0.71	0.22	0.46	1.09
Individuals density (deer/km^2)	**1.17**	0.23	0.74	1.84

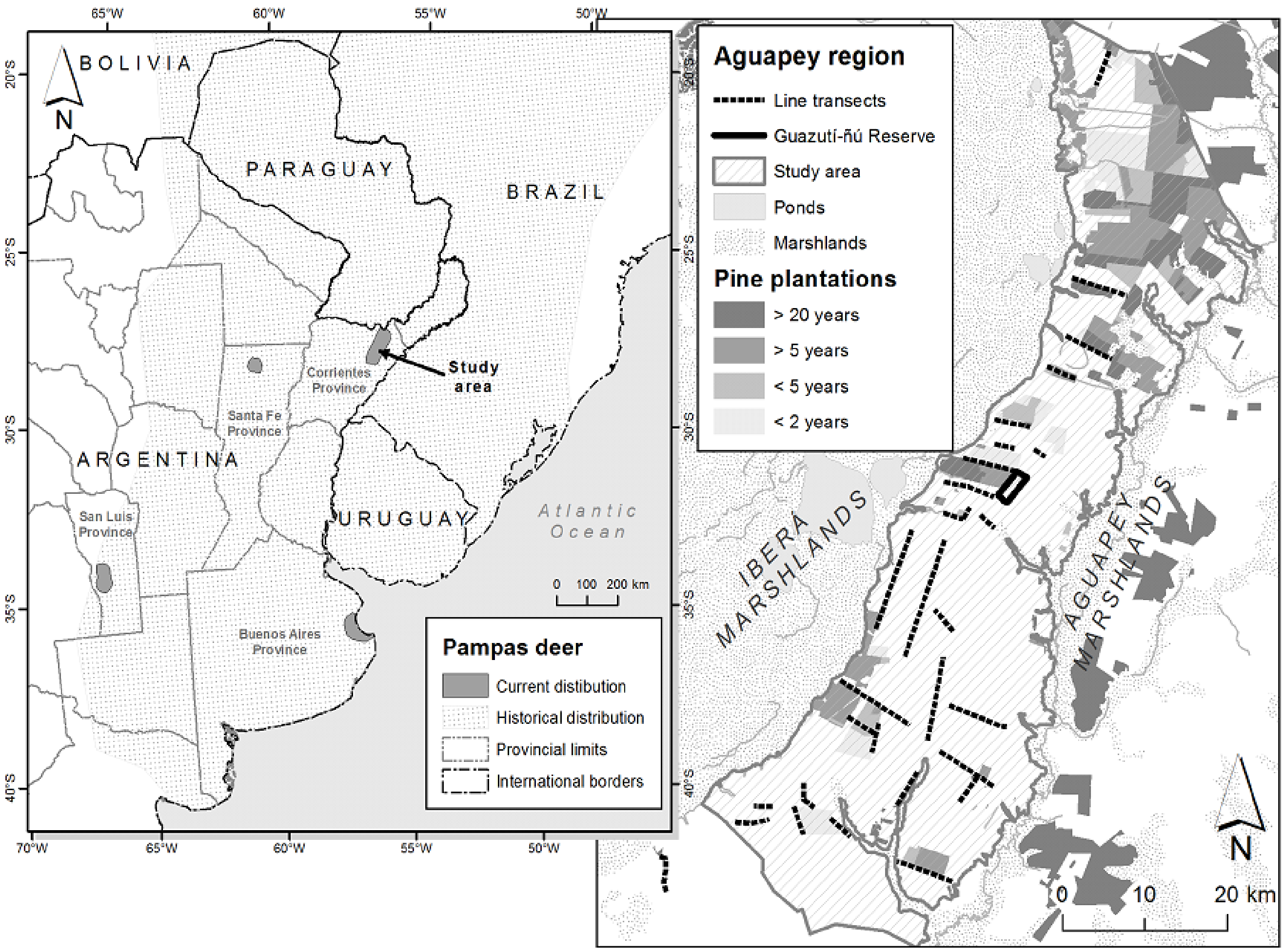

BOLIVIA
PARAGUAY
BRAZIL
ARGENTINA
URUGUAY
Corrientes Province
Santa Fe Province
San Luis Province
Buenos Aires Province
Study area
Atlantic Ocean
0 100 200 km
Pampas deer
Current distibution
Historical distribution
Provincial limits
International borders
Aguapey region
Line transects
Guazutí-ñú Reserve
Study area
Ponds
Marshlands
Pine plantations
> 20 years
> 5 years
< 5 years
< 2 years
IBERA MARSHLANDS
AGUAPEY MARSHLANDS
0 10 20 km

Figure 1

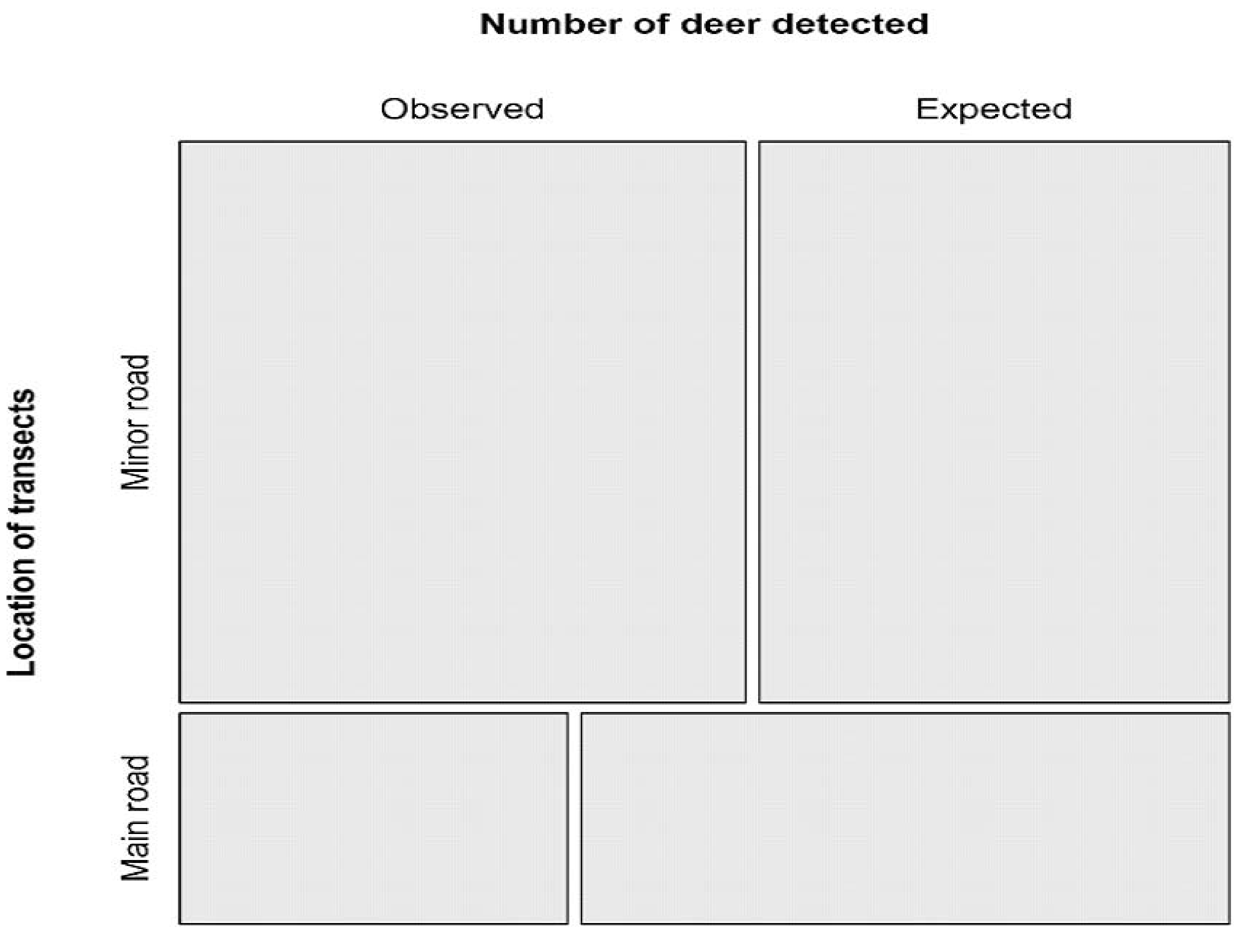

Number of deer detected
Observed
Expected
Location of transects
Minor road
Main road

Figure 2

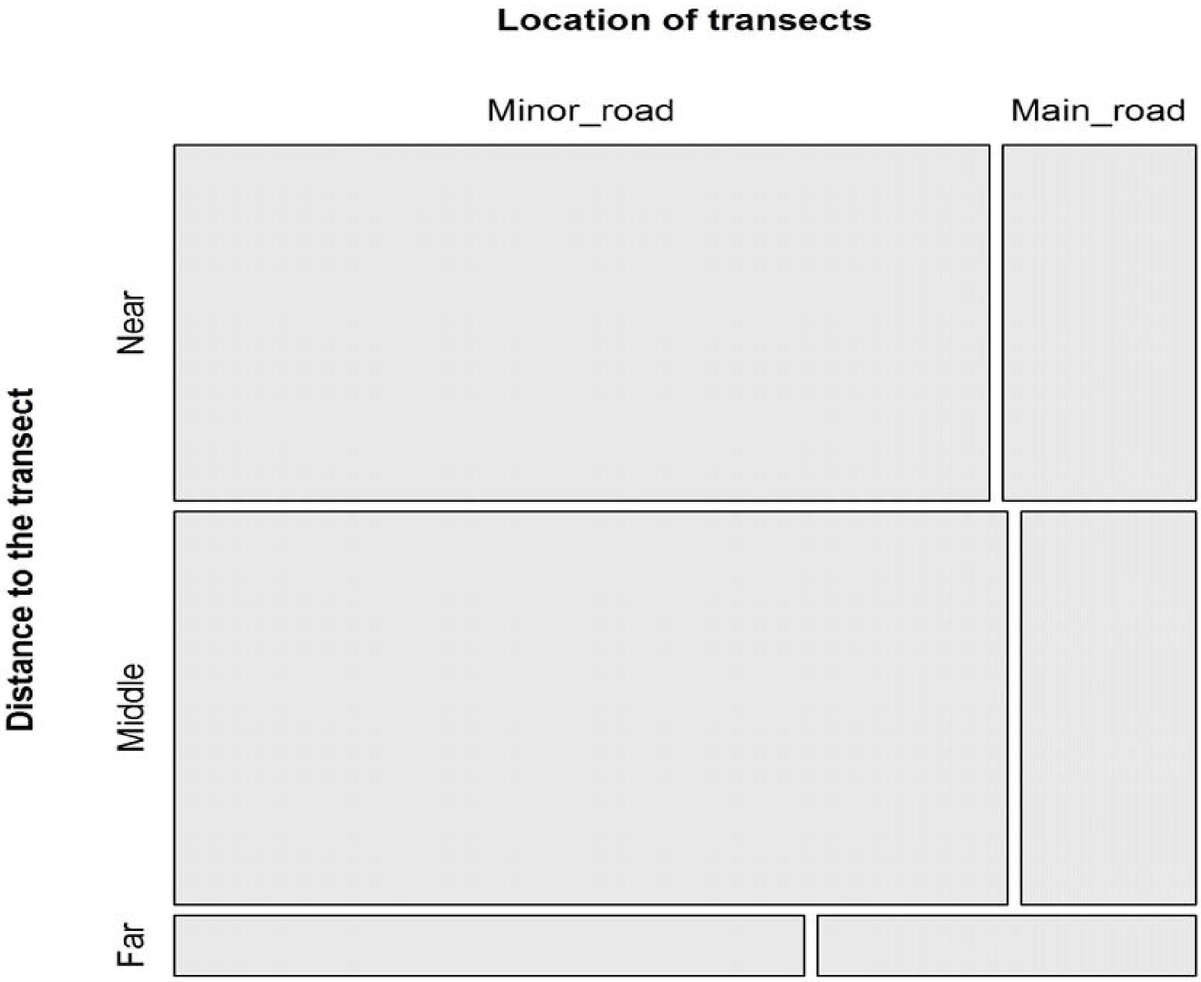
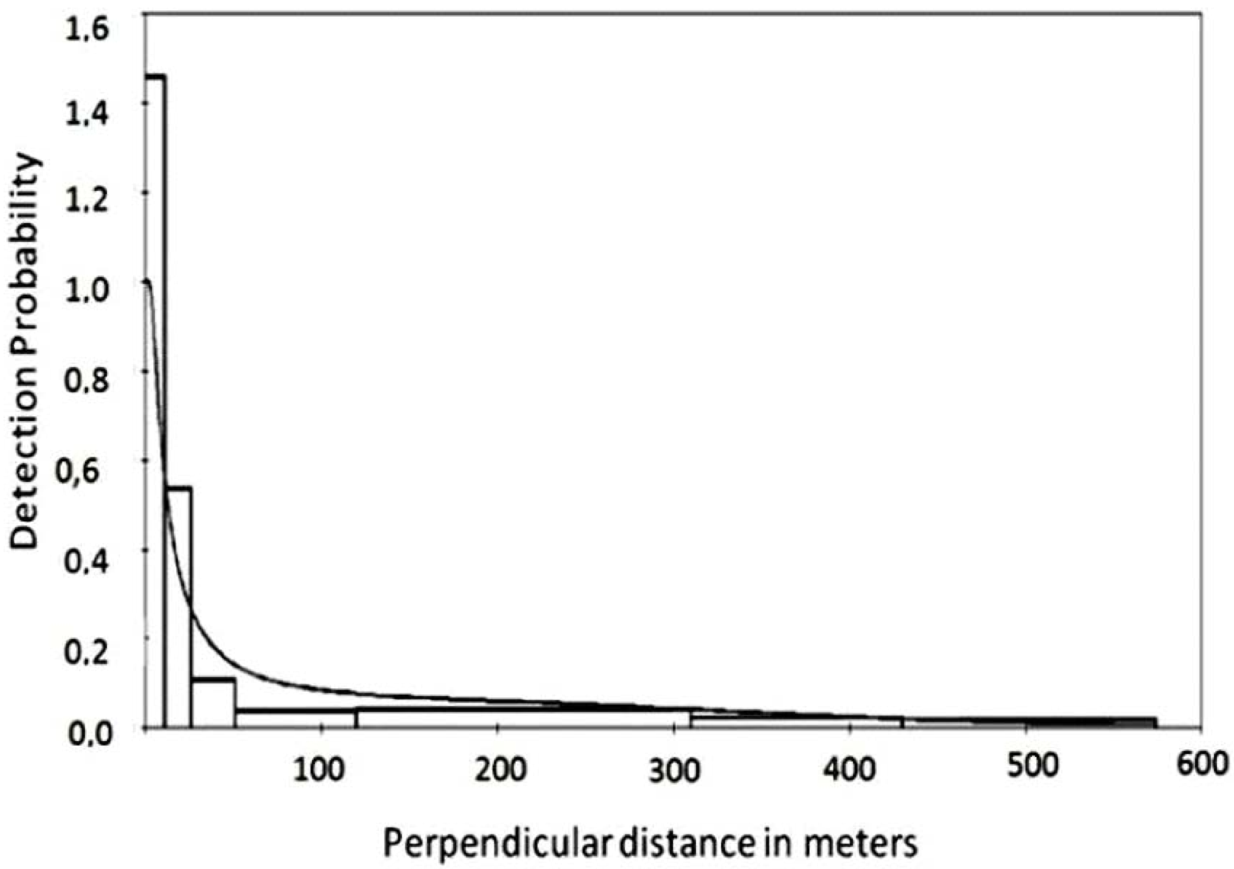

Location of transects
Minor_road
Main_road
Distance to the transect
Near
Middle
Far

Figure 3



Detection Probability
1,6
1,4
1,2
1,0
0,8
0,6
0,4
0,2
0,0
100
200
300
400
500
600
Perpendicular distance in meters

Figure 4a

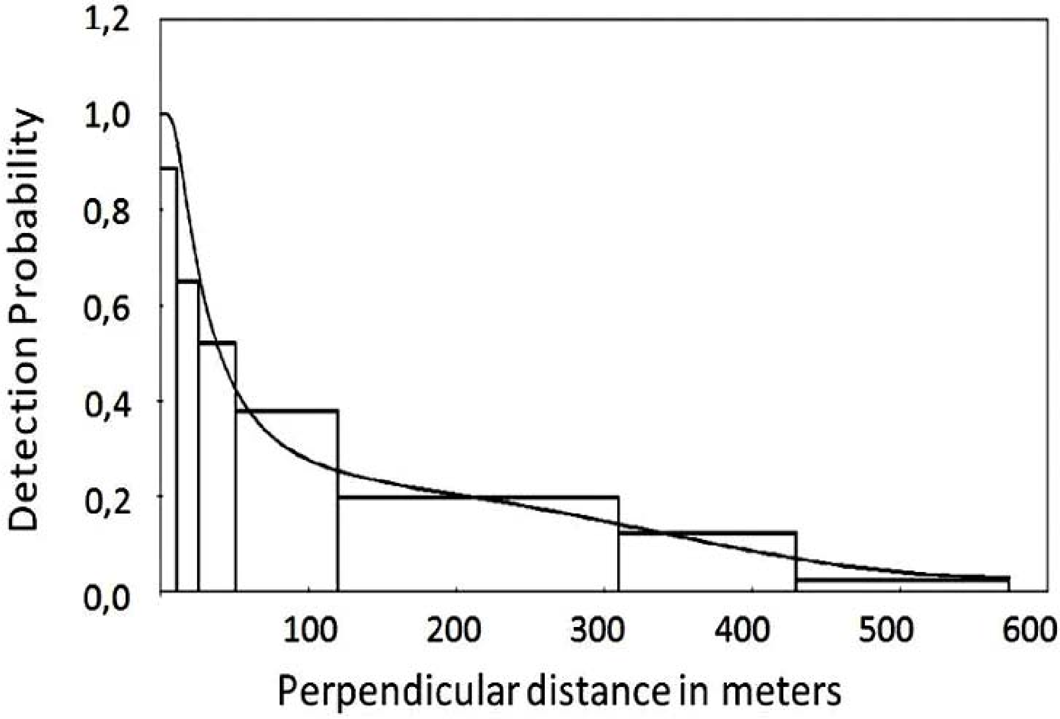

1,2
1,0
0,8
0,6
0,4
0,2
0,0
Detection Probability
100
200
300
400
500
600
Perpendicular distance in meters

Figure 4b

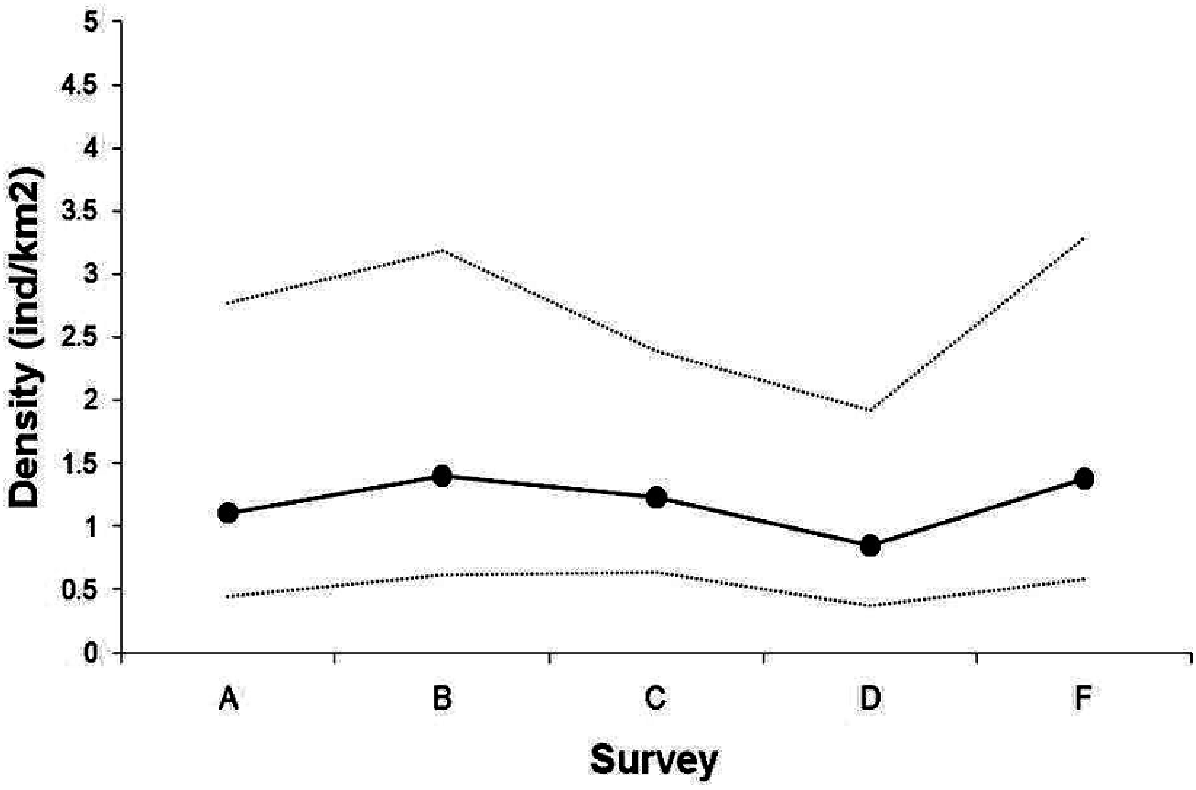


Figure 5

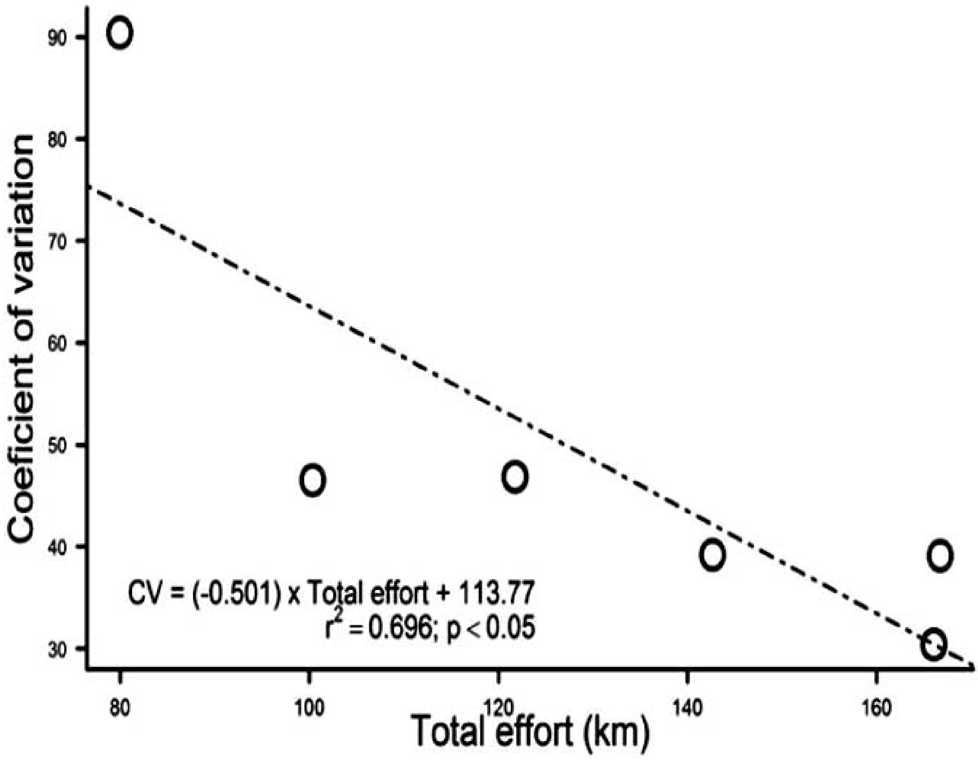

Coeficient of variation
90
80
70
60
50
40
30
CV = (-0.501) x Total effort + 113.77
r2 = 0.696; p < 0.05
80
100
120
140
160
Total effort (km)

Figure 6a

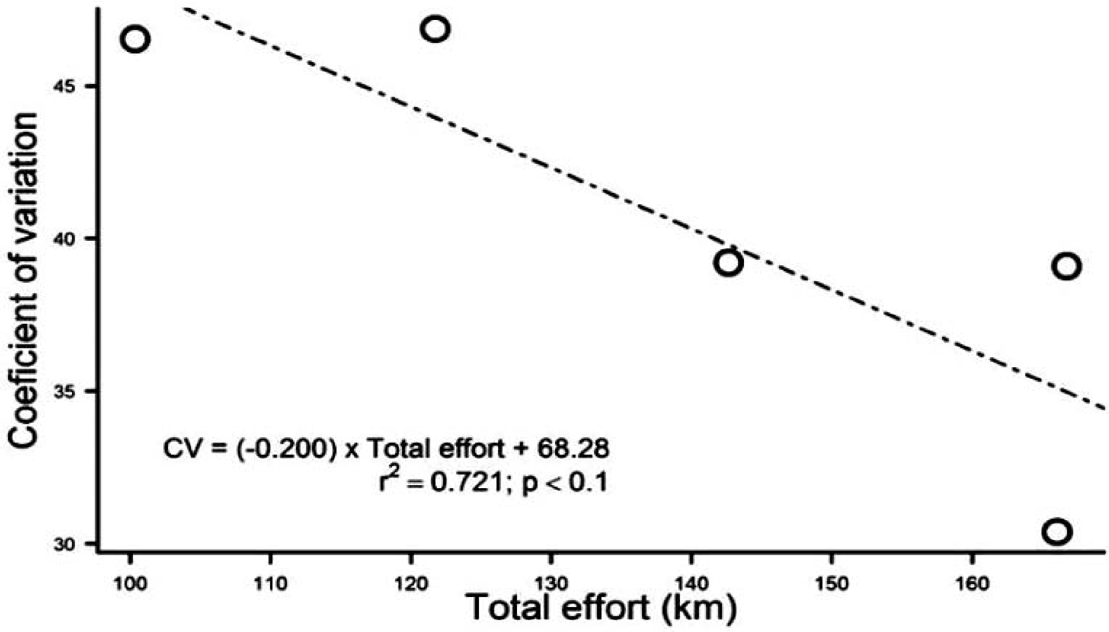

Coeficient of variation
45
40
35
30
CV = (-0.200) x Total effort + 68.28
r2 = 0.721; p < 0.1
100
110
120
130
140
150
160
Total effort (km)

Figure 6b

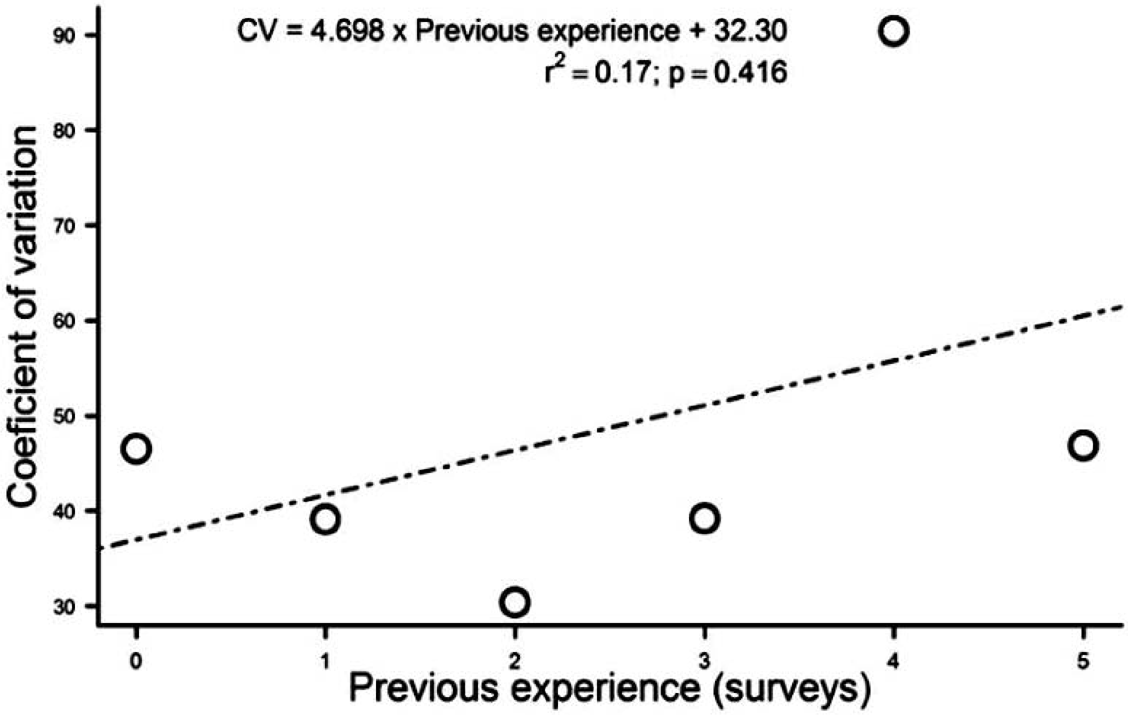

CV = 4.698 x Previous experience + 32.30
r2 = 0.17; p = 0.416
Coeficient of variation
90
80
70
60
50
40
30
0
1
2
3
4
5
Previous experience (surveys)

Figure 6c

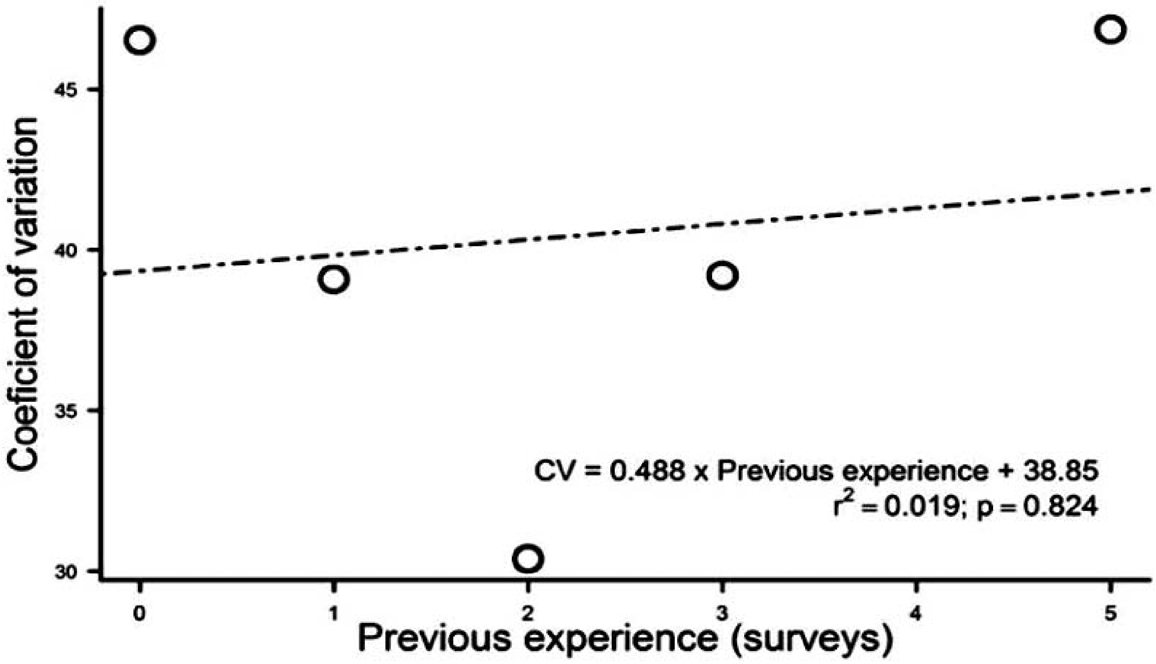

Coeficient of variation
45
40
35
30
0
1
2
3
4
5
Previous experience (surveys)
CV = 0.488 x Previous experience + 38.85
r2 = 0.019; p = 0.824

Figure 6d