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Using local ecological knowledge to improve large terrestrial mammal surveys, build local capacity and increase conservation opportunities

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A B S T R A C T

Field information is essential for developing conservation actions, but standard methods for surveying wildlife are often inefficient in large, remote areas. Without efficient methods, surveying is difficult or even impossible. Consequently, some of the most threatened species and regions remain un- or under-surveyed, e.g. South American Chaco. Survey methods based on local ecological knowledge (LEK-methods) could be useful for surveying these areas and species. However, LEK-methods may be inaccurate and are rarely evaluated or compared to standard-methods. This is the first large-scale study evaluating the performance of two LEK-methods, and comparing it with the performance of standard-methods, for detecting three species of large terrestrial mammals. We used a locally-based survey (LBS) and interviews as LEK-methods, and transect and camera trapping as standard survey methods. We estimated the probability of detecting each species with each method, of having false-presences and their cost. We also quantitatively analysed the ability of LBS to build local capacity, focusing on conservation, research and working skills. We found that compared to standard-methods, LEK-methods increase detection probabilities of three species while providing accurate information. LBSs are more expensive than interviews but improve local capacities, raising the chances of successful implementation of community-based conservation programmes. Interviews are optimal for rapid assessments and can be useful for wildlife monitoring. Before using LEK-methods, we recommend pilot studies to determine estimators´ variability. Overall, this study shows that LEK-based methods can be efficient and accurate for detecting large mammals in remote areas. Furthermore, LEK-methods can help develop legitimate conservation initiatives.

1. Introduction

To develop successful actions for conserving wildlife, we need information on species´ distribution, habitat requirements and population parameters (Clare et al., 2017; MacKenzie et al., 2006; Sutherland et al., 2004). This information can only be accurately estimated using reliable field-data, which are often unavailable (Clare et al., 2017; MacKenzie et al., 2006). In these cases, we must survey and gather information in the field (Clare et al., 2017; Fragoso et al., 2016; MacKenzie et al., 2006). Yet, surveying wildlife can be challenging as funds are limited, and the probabilities of detecting certain species can be extremely low (MacKenzie et al., 2006; Nichols and Williams 2006). Accordingly, it is important to use conservation and research resources efficiently by using field-methods that maximize the probabilities of detecting our target species (Fragoso et al., 2016; MacKenzie et al., 2006).

The methods we use in the field largely define the success or failure

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of our surveys (Fragoso et al., 2016). Methods that maximize detection probabilities improve survey efficiency and reduce the probability of obtaining false-absences, i.e. considering that a species is absent when it is present (MacKenzie et al., 2006; Fragoso et al., 2016; Guillera-Arroita, 2016). Also, it is important to survey with accurate methods to avoid species misidentifications and false-presences, i.e. registering the presence of a species that is absent (Clare et al., 2017; Miller et al., 2015; Munari et al., 2011). Thus, when developing a survey, it is essential to know which methods will provide high detection probabilities while being cost-effective and accurate (Fragoso et al., 2016; Guillera-Arroita, 2016).

Transect sampling and camera trapping are common methods for surveying large terrestrial mammals (Sutherland, 2006; Tobler et al., 2008; Espartosa et al., 2011; Lyra-Jorge et al., 2008; Munari et al., 2011). These standard survey methods (standard-methods) require large investment in time, equipment and/or human resources. Consequently, these methods can be expensive and inadequate for large areas (Brook and McLachlan, 2008; Espartosa et al., 2011; Lyra-Jorge et al., 2008; Munari et al., 2011; Zeller et al., 2011). Also, despite their popularity, standard-methods can provide low detection probabilities for rare, quiet and nocturnal species, and in areas of low visibility (Carvalho et al., 2016; Espartosa et al., 2011; MacKenzie et al., 2006). Moreover, transect sampling can lead to species misidentification and false-presences (Munari et al., 2011; Clare et al., 2017). Without efficient and accurate survey methods, gathering field information is difficult and even impossible. Thus, many species in large remote areas remain under- or un-surveyed, e.g. ungulates of the Dry Chaco (Periago et al., 2015).

Local ecological knowledge (LEK) is the environmental knowledge held by people that live in close contact with nature (Brook and McLachlan, 2008). Due to the limitations of standard-methods, some researchers are using methods based on LEK (LEK-methods) to detect and monitor mammals (e.g. Parry and Peres, 2015) and to estimate their distribution (e.g. Zeller et al., 2011), threats, conservation status (e.g. Parry and Peres, 2015), abundance, abundance trends, demographics, trophic interactions and spatial ecology (e.g. Dolrenry et al., 2016). LEK-methods have also been used to study other taxa, including invertebrate and vertebrate marine species (e.g. Beaudreau and Levin, 2014; Peñaherrera-Palma et al., 2018), birds (e.g. Gilchrist et al., 2005) and reptiles (e.g. Anadón et al., 2009). LEK-methods were useful for covering large, populated and remote areas (e.g. Zeller et al., 2011) and provided information on both cryptic (e.g. Nash et al., 2016) and conspicuous species (e.g. Dolrenry et al., 2016).

LEK-methods include interviews and locally-based surveys. Interviews are widely used in social sciences; they are a process of direct communication where the researcher obtains information from interviewees (Briggs, 1986; Rubin and Rubin, 2005). The researcher pre-defines questions and uses questionnaires or informal conversations to find the answers (Rubin and Rubin, 2005). In contrast, in a locally-based survey (LBS), LEK-holders are active participants (Danielsen et al., 2009). Depending on the format of the LBS, participants may define objectives, gather field-data and/or analyse information (Benchimol et al., 2017; Danielsen et al., 2009; Dolrenry et al., 2016). LBSs may increase local capacity and empower local communities, raising legitimacy of conservation actions, and their chances of success (Danielsen et al., 2009; Davis and Wagner, 2003; Dolrenry et al., 2016).

LBSs´ ability to build local capacity, empower communities and develop legitimate and successful conservation initiatives is very important. Particularly when surveying areas that are inhabited by local communities and where conservation actions are urgent. Local communities are often excluded from conservation, management and economic initiatives (Bennett, 2016; Mistry and Berardi, 2016). Involving locals in research, increasing their capacities and empowering their communities may contribute to reduce poverty and increase the chances of success of conservation initiatives (Bennett, 2016; Danielsen et al., 2009). Yet, LBSs´ impact on local capacities remains poorly understood and quantitative studies on this are necessary (Davis and Wagner, 2003; Gilchrist et al., 2005; Joa et al., 2018, but see Benchimol et al., 2017; Dolrenry et al., 2016).

LEK-methods can be powerful instruments for surveying endangered species and areas where there is an urgent need for information and conservation. Yet, many scientists criticise LEK-methods because they are often used without evaluation or standardisation, knowingly that peoples´ perceptions, subjectivities and experiences may bias results (Beaudreau and Levin, 2014; Davis and Wagner, 2003; Daw et al., 2011; Gilchrist et al., 2005; Howard and Widdowson, 1996; Joa et al., 2018). Studies evaluating LEK-methods´ performance have been increasing in the last two decades, and constitute a great advance in conservation science and practice (see references at Supplementary material, S1). Research showed that Amazonian large vertebrates (Benchimol et al., 2017) and Kenyan lions (Dolrenry et al., 2016) can be detected accurately using LBSs. Also, that interviews provide reliable detections and estimates of distribution, habitat preferences, abundance and abundance trends for several species of different taxa (e.g. Gilchrist et al., 2005; Peñaherrera-Palma et al., 2018; more references at Supplementary material, S1). However, research also found that interviews can provide inaccurate, wrong or incomplete information for some migratory birds or marine species (Gilchrist et al., 2005; Daw et al., 2011). Research on LEK-methods has focused mainly on interviews, with LBSs receiving less attention. No study has evaluated both methods simultaneously.

The dry portion of the South American Chaco (Dry Chaco) has one of the highest deforestation rates in the world (Kuemmerle et al., 2017). The region may be undergoing a process of defaunation but information on most species is insufficient for developing conservation plans (Periago et al., 2015). Scarce information on the wildlife of the Dry Chaco is due to the difficulties of surveying this region. Survey constraints include harsh environmental conditions, e.g. >50 °C summer-temperatures, low visibility and lack of roads to access most of the region (Camino et al., 2017). It is urgent to find suitable methods for surveying wildlife in this large, remote, region. This is particularly true for large mammals, that have large spatial requirements, high hunting pressure and thus, are more susceptible to habitat loss and fragmentation (Cardillo et al., 2005; Periago et al., 2015).

We worked in the Dry Chaco and focused our study on the white-lipped (*Tayassu pecari*), the collared (*Pecari tajacu*) and the chacoan peccary (*Parachoerus wagneri*). These species are thought to be rapidly disappearing from this region and have important ecological roles (Beck et al., 2010; Periago et al., 2015). The three species have differing body-traits, ecologies, behaviours and conservation status (Supplementary material, S2). The white-lipped peccary may be extinct in some portions of the study area, the collared peccary seems more abundant, and the chacoan peccary is endemic and endangered (Supplementary material, S2). The three species are difficult to detect with standard-methods, particularly the cryptic chacoan peccary (e.g. Ayala and Noss, 2000; Altrichter and Boaglio, 2004; Núñez-Regueiro et al., 2015). Most information about peccaries of the Dry Chaco comes from untested LEK-methods (e.g. Altrichter and Boaglio, 2004; Camino et al., 2016, 2018; Periago et al., 2017).

This is the first study in the world to evaluate two different LEK-methods for surveying three different species of large terrestrial mammals. We evaluated the performance of LBS and of interviews for detecting target species and providing accurate information on their presence. We then compared the performance of LEK-methods with the performance of two standard-methods, transect sampling and camera-trapping. We also estimated and compared the cost of each method in terms of time and money. Additionally, we quantitatively analysed the ability of LBSs to increase local participants´ conservation, research and working capacities. We end this article discussing the contribution of LEK-methods for developing legitimate conservation initiatives.

2. Methods

2.1. Study area

We conducted our study in a portion of the Dry Chaco. The Dry Chaco is the largest tropical dry forest in the world (Morello et al., 2012), dominated by forests of quebrachos (*Schinopsisi lorentzeii* and *Aspidosperma quebracho-blanco*), with patches of *Prosopis* spp., *Ziziphus mistol, Bulnesia sarmientoi*, among others. Forests alternate with grasslands, shrubland and other vegetation covers (Morello et al., 2012). Rainfall mainly occurs between October and April (550–800 mm/year; Morello et al., 2012).

We sampled ~54,000 km^2 of the Argentine Provinces of Salta, Formosa and Chaco using transects and interviews. The vertices of our study area were: −22.015, −63.406; −25.655, −63.304; −25.646, −61.708; −25.258, −60.978; −23.624, −61.172. The area of the locally-based and camera trapping surveys was smaller due to logistical constraints (circle centred at −25.128, −61.539, radius 58 km; detail also given in Camino, 2014). We assumed that the probability of detecting target species was similar between this smaller area and the whole study area (Supplementary material, S3). We chose this study area because it contains the largest patch of continuous forest of the Argentine Dry Chaco but there is little information available on the wildlife present.

The area is inhabited by indigenous *Wichí* and local mestizos, called *Criollos*, who are the mixture of the first Spanish settlers and different indigenous groups (Camino et al., 2016, 2017, 2018). *Wichís* live in communities of up to 30 houses and *Criollos* live in settlements that usually consist of one or two households though they may reach over 15 houses. Communities and settlements are spread throughout the forest (Camino et al., 2016, 2017, 2018). Both *Wichís* and *Criollos* have a close relationship with their natural environment and hold unique knowledge about wildlife (Camino et al., 2016, 2017, 2018). Peccaries are hunted for subsistence by *Criollos* and, to a lesser degree, by *Wichís* (Camino et al., 2018). Our surveys were conducted in indigenous' and mestizos' lands, and in public lands used by them.

2.2. Surveys to detect target species

Our objective was to evaluate the performance of LEK-methods for detecting large terrestrial mammals, and to compare it with the performance of standard-methods. We applied a LBS and interviews with local *Criollos* as LEK-methods, and transect and camera trapping sampling as standard-methods. For each method, we estimated the probability of detecting target species, of having false-presences, and their cost. We further evaluated if participants of the LBS increased their capacities, i.e. skills and knowledge in (i) conservation, (ii) research and work, and (iii) communication.

Before field-work, we designed a survey for each species separately, considering their spatial requirements and defining independent sample units (Supplementary material, S1 & S3). Then, for each species, we randomly selected the units we were going to sample and surveyed each unit three times ($N_{white\text{-}lipped\_peccary}$ = 118; $N_{collared\_peccary}$ = 183; $N_{chacoan\_peccary}$ = 127). In each survey, we used the method we wanted to evaluate and registered if we did or did not detect our target species (Supplementary material, S3). We chose the method based on the accessibility and time of arrival to the sample unit, the weather conditions and human habitation.

We carried out the LBS between March 2011 and December 2015. To reduce bias, we estimated detection probabilities using data gathered in a shorter period, and after data-gathering standardisation (September 2013–December 2015; Camino et al., 2017; MacKenzie et al., 2006; Supplementary material, S3). The LBS was framed in a monitoring programme of large terrestrial vertebrates and locals participated in delignating objectives and data gathering (Camino, 2014; Camino et al., 2017). Participants were *Wichí* hunters of the community *Nueva Población,* and *Criollos* (hunters and non-hunters) from different settlements. In their daily activities these people walk through natural environments (4 km/day avg.; Camino et al., 2016–2018). During these walks, participants registered the presence of peccaries and of other species detected by sighting or sign (e.g. tracks). They also registered the vegetation-cover and the location where the species was detected. The number of participants changed during the study period with an average of 20 people collecting data. Besides gathering data in the field, participants met monthly with the scientific team for follow ups and debriefings. Participants were also trained in the use of research and communication tools, e.g. GPS units and computers. Camino (2014) and Camino et al. (2017) describe the LBS in detail.

We conducted semi-structured interviews with *Criollo* inhabitants of the study area (*N* = 1248) between September 2011 and September 2013. Semi-structured interviews were informal conversations covering a list of topics (Supplementary material, S4). Interviews were always performed by two highly trained team members. Through the interview, we determined which peccary species were present in that sample unit and respondents´ capacity to differentiate peccary species (Supplementary material, S4). Interviews were undertaken in Spanish with family heads, lasting between 1 and 6 h. Before starting the interview, we introduced ourselves and explained our objectives. This introduction was useful to avoid bias due to mistrust (Danielsen et al., 2005), and we started the interviews after we had respondents´ verbal consent (detail in Supplementary material, S4). The economic/subsistence importance of a resource may affect the LEK held by an individual (Howard and Widdowson, 1996). Therefore, after performing the interviews we split the data into (a) hunters (*N* = 779) and (b) non-hunters (*N* = 469). We then analysed results of (a) and (b) separately.

We conducted transect sampling between November 2011 and November 2013. Before applying this method, Camino and Cortez went to the field with local hunters (3 *Criollos* and 5 *Wichís*) and trained themselves in detecting and differentiating species´ signs. Then, one of these researchers was always present when sampling a transect. Sampling consisted of two people walking through natural environments and looking for peccaries or their signs (Supplementary material, S2). We preselected the route by randomly selecting a start and end point inside the sample units. We intended to traverse 4 km during each walk but this was usually impossible due to high bush and ground-bromeliad density. Therefore, our walking surveys were of different lengths according to logistical restrictions. The length of a transect may affect the probability of detecting wildlife species (Sutherland, 2006; Carvalho et al., 2016). As we could not incorporate the length of transects in detection probability models (Supplementary material, S3), we differentiated long transects (>1.5 km, *N* = 88) and short transects (0.7–1.5 km, *N* = 93), and analysed them separately. We walked a total of 285.62 km at an average speed of 0.5 km/h. We avoided sampling on trails as the probability of peccaries using trails is low (Di Bitetti et al., 2014).

We conducted the camera-trapping survey from March 2016 to April 2017. It consisted of 30 camera-trap stations with one camera (Bushnell Strike Force HD®) working 24 h/day for 95 days on average. We located sampling stations randomly in forests and shrublands, off of trails and at an average height of 25 cm from the ground. We placed 15 cameras for 25–48 consecutive days and then moved them to sample other stations (Di Bitetti et al., 2006).

2.3. Data analysis

2.3.1. Estimation of detection probabilities

By estimating detection probability, we accounted for the probability of each survey-method of generating false-absences (MacKenzie et al., 2006; Guillera-Arroita, 2016). In our surveys, for each species, we sampled each unit three times and hence, we obtained a history of detections/non-detections for each species in each site (Supplementary material, S3). Using this history, we estimated the detection probability of each unit. Then we used maximum likelihood and logistic regression models (logit-link) to model the probability of detecting each peccary species (Supplementary material, S3; MacKenzie et al., 2006). In the models, we treated survey-methods as binary variables, e.g. logit-link $_{\text{(detection probability)}} = \beta_0 + \beta_1$* (method 1), where betas are coefficients and "method 1" has the value of 1 when that was the method used in the survey and 0 when another method was applied (complete list of models in Supplementary material, S3).

We selected the model that best explained each species´ detection probability using Akaike Information Criterion corrected by sample size and model weights (AICc, QAIC; Burnham and Anderson, 2002). For each species, its detection probability is explained by the model with the lowest AIC or the group of models that had a difference ≤ 2 with the lowest AIC (Burnham and Anderson, 2002; Supplementary material, S3). A survey method was positively or negatively related to the detection probability when the confidence interval for its coefficient in the logistic regression model was positive or negative, respectively (Burnham and Anderson, 2002; MacKenzie et al., 2006). To estimate the detection probability obtained with each method, we back-transformed the logit-link equation (Supplementary material, S3).

We accounted for over-dispersion in the modelling by estimating c-hat for each species´ global model, i.e. model that includes all covariates (MacKenzie et al., 2006). To decrease potential bias, we eliminated ambiguous or uncertain data and also, included other variables in the models that could also affect peccaries´ detection probabilities (MacKenzie et al., 2006; Miller et al., 2015). These variables were: forest cover, density of roads and trails, distance to nearest road and to nearest city. For white-lipped peccaries we also considered the effect of the season (dry/wet) given the species´ seasonal behavioural changes (Supplementary material, S3). To create, test and select our models, we used the R-freeware with the packages unmarked, AICcmodavg and MuMIn of (Fiske and Chandler, 2011; Mazerolle, 2015; Barton, 2015).

2.4. False-presences

For each method, we evaluated the probability of obtaining false-presences. For LEK-methods, the sources of false-presences are species´ misidentification or deliberate data falsification (Luzar et al., 2011). For standard-methods, we considered that false-presences could only result from species´ misidentification. For camera-traps, we assumed there were no false-presences after eliminating ambiguous data, i.e. unidentifiable detections ($N = 2$).

To estimate the probability of obtaining false-presences with the LBS, we assessed the probability of data falsification and the probability of species misidentification. To determine the probability of data falsification we did 29 visits to check information provided by local participants. We only went to the field to check information when all the following conditions occurred: (i) the local participant registered the presence of a species through footprints or tracks, (ii) there was no wind or rain that could erase the species´ signs and (iii) the species was recorded by the local participant the same day. We estimated the probability of data falsification as the number of times we went to check species-presence and its signs were not there, divided by 29.

To determine the probability of species misidentification by participants of the LBS we did an independent survey between March 2016 and April 2017: We interviewed participants of the locally-based survey ($N = 30$) to determine their capability in distinguishing the three species in the field. We showed the interviewees pictures of target species and of their tracks using images of our own and of Canevari and Vaccaro (2007). We also included pictures of tracks of brocket deer *Mazama gouazoubira* and cow calf because we considered these may be confused with peccary tracks. Then, we estimated the probability of misidentifying peccaries as the total number of answers with at least one misidentification divided by the total number of interviews.

For the interviews, we considered that the probability of having false-presences was greater than zero when respondents: did not know or confused the species´ (i) appearances or (ii) behaviours or (iii) indicated the existence of >3 peccary species in the area. To assess i-iii we went through these topics during our semi-structured interviews (Supplementary material, S4). We considered that data-falsification was probable when the respondent (iv) gave an exaggerated answer regarding this or another topic. We defined exaggerated answers as those that were unique in comparison to the answers of other respondents and that described extraordinary events, e.g. a respondent fought a jaguar (*Panthera onca*) with his hands. Although these unique answers could be real, we preferred a conservative approach and considered them prone to falsification. We estimated the probability of having false-presences with interviews as the total number of interviews where i–iv occurred, divided by the total number of interviews.

For transects, after finding and identifying the sign of a species, we followed the track for one kilometre. We followed 18 tracks of white-lipped peccary, 39 of collared peccary and 22 of chacoan peccary ($N = 79$). We counted the number of occasions in which we identified a sign as belonging to a species and, after following the track, we found a clear sign that it belonged to a different species. We then estimated the probability of having false-presences as the number of wrong detections divided by 79.

2.5. Cost-analysis

We estimated the time invested in (i) setting each method up; (ii) training and meetings with local people per month once the method was functioning; (iii) sampling a unit. We also registered (iv) the number of technical team members, (v) the indispensable materials and (vi) their cost for surveying a unit. Further to this we looked at the total spending in a (vii) 30-day and (viii) 2-year survey.

2.6. Quantitative analysis of changes in local-capacities after the locally-based survey

To determine if LBSs increase the conservation, research/working and communication capacities of local participants, we assessed and compared local peoples´ capacities before and after participating of the LBS. We analysed the answers of *Wichís* and *Criollos* separately because cultural differences could affect results (Camino et al., 2018). Between 2010 and 2011 we performed semi-structured interviews with heads of families of rural communities and settlements. We only interviewed local people after gaining their verbal consent (Supplementary material, S4). We interviewed 41 *Wichís* and 64 *Criollos* but respondents did not answer all our questions and thus, our average N of respondents per question was 27 for *Wichís* and 53 for *Criollos*. During the interviews, we followed a checklist of topics while having informal conversations in Spanish, that lasted between 1 and 3 h. The checklist of topics included 4 questions to determine respondents´ conservation capacities and 6 questions associated to their research, general work and communication skills (Supplementary material, S4). We could not separate certain research and work skills (e.g. use of a computer) as when associated with both categories.

In 2016 we performed semi-structured interviews with participants of the LBS. Respondents had not been interviewed in the 2010–2011 survey in order to avoid bias generated by the first survey. We interviewed 31 *Wichís* and 52 *Criollos* and our average N for *Wichís* was 26 and for *Criollos* 44. To determine if local people's capacities changed after participating in the LBS we used Generalized Linear Models (GLM). We tested each question separately, adjusting the proportion of affirmative responses to a binomial distribution using the glm() function from the R software. We compared nested models using the AIC (Zuur et al., 2009, Supplementary material, S3). We used LBS as treatment factor and assumed its effect was significant when the difference between the AIC from the treatment-model and the simplified-model was <-2 (Logan, 2010).

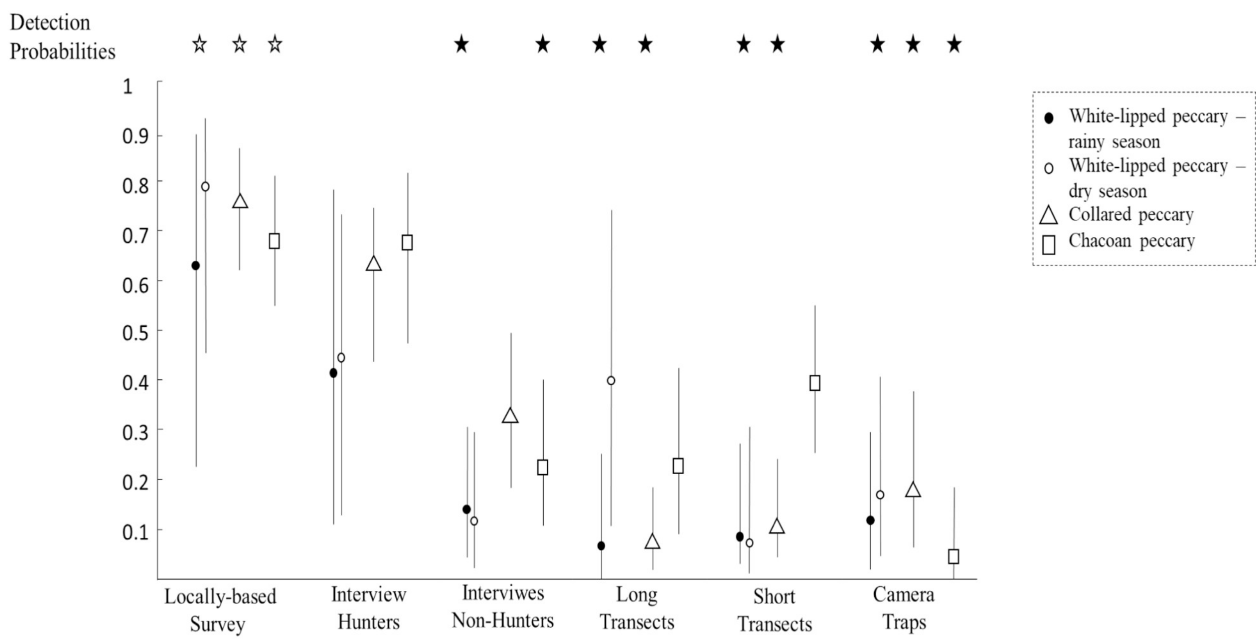

Fig. 1. Probability of detecting white-lipped, collared or chacoan peccaries (*Tayassu pecari*, *Pecari tajacu* and *Parachoerus wagneri*) using different survey methods. Bars represent the 95% confidence intervals of the estimations. The season (rainy/dry) was differentiated when estimating white-lipped peccary's detection probabilities because this factor had a significant effect on estimations. White stars represent a positive association between this method and the detection probability. Black stars represent a negative association between the survey method and the detection probability.

3. Results

3.1. Detection probabilities

The probability of detecting each species depends on the method used in the field (Fig. 1, Supplementary material, S5). The probability of detecting the three species is higher with the LBS than with the other methods (Fig. 1). After the LBS, interviews provided the highest detection probabilities (Fig. 1). All three target species had low detection probabilities when using camera-traps (Fig. 1).

There were other variables, besides the survey method, affecting peccaries´ detection probabilities (Supplementary material, S5). The probability of detecting white-lipped peccaries in the dry season was higher than in the rainy season (Fig. 1). Higher forest cover in a unit decreased the chances of detecting white-lipped peccaries. Distance to nearest city increased the chances of detecting this species but was inversely related to the probability of detecting chacoan peccaries (Supplementary material, S5).

3.2. False-presences

The probability of having deliberate data falsification with the LBS was equal to the probability of species' misidentification (p = .03). No participant confused peccary tracks with brocket deer's or cow calf's tracks, but one person confused footprints of white-lipped peccary with chacoan peccary's. With interviews, the probability of having false-presences was 0.23. But this probability was much lower when interviewing hunters (p = .01) in comparison to non-hunters (p = .51). With transects, of the 79 tracks that we followed to check if our detection was correct, we only reached conclusive signs in 67 cases. We correctly identified 16 out of 17 signs of white-lipped peccary tracks, 32 out of 34 collared peccary signs and 14 out of 16 chacoan peccary signs. Thus, the probabilities of having false detections with transects were 0.06 for white-lipped and collared peccaries, and 0.12 for the chacoan peccary.

3.3. Cost analysis

The time dedicated to setting-up the survey method and to train surveyors was higher for the LBS than for other methods (Table 1). However, the number of technical team members, the distances travelled, and the time invested per sample a unit, were lower than for the other methodologies (Table 1). The initial monetary cost of camera trapping survey was higher because of the equipment (Table 1). In 30-day surveys, camera trapping is the most expensive method but in 2-year surveys, LBSs are more expensive (Table 1).

3.4. Locally based survey, capacity building

Both *Wichís* and *Criollos* who participated of the LBS increased their conservation and research/working capacities (Table 2). Communication capacities of participants of the LBS did not change (Table 2).

4. Discussion

4.1. LEK-methods for surveying large terrestrial mammals

This is the first large-scale study evaluating two different LEK-methods for surveying large terrestrial mammals, and comparing their performance with the performance of standard-methods. We found that in large, remote areas where information and conservation actions are urgent, LEK-methods can be efficient, accurate tools for detecting the presence of large terrestrial mammals. For three species with differing ecologies and behaviours, well applied LEK-methods outperformed standard-methods. The LBS and interviews with local hunters provided the highest probabilities of detecting peccaries in the Dry Chaco. And the probability of misidentifying species and recording false-presences with these methods was low. Avoiding species misidentification and false-presences is important as these can cause large biases (Miller et al., 2015). Our results suggest that some of the main concerns among scientists about LEK-methods (e.g. Daw et al., 2011; Gilchrist et al., 2005; Howard and Widdowson, 1996; Joa et al., 2018) are not always valid, as LEK-methods can provide accurate information when correctly

Table 1
Cost analysis of four field methods applied to detect peccaries (*Tayassu peccary, Pecari tajacu, Parachoerus wagneri*).

	Locally-based survey	Interviews	Transects	Camera traps
Time dedicated to the set-up stage (in months)	12	6	6	2
Hours per month dedicated to training and meeting with local people (once the method was functioning)	6	0	0	0
Number of technical team members to sample a unit once the method was functioning	0	2	2	2
Kilometres travelled to sample a unit from the camp (avg)	28	42	42	42
Time invested by the technical team to sample a unit once arrived (hrs, avg)	0	2,5	2.5	1.5
Essential resources to survey one sample unit	Salary for local participant, notebook, pen, gps with batteries, oil, water	Notebook, pen, gps with batteries, oil, water	Notebook, pen, gps with batteries, oil, water	Camera trap with memory card and batteries, notebook, pen, gps with batteries, oil, water
Total Spend (US$) in essential resources materials for surveying one unit	578	108	108	3308
Total spend (US$) in a 10-day survey once running the method	73.61	62.00	72.00	31.00
Total spend (US$) in a 30-day survey once running the method	194.03	166.00	166	51.5

applied.

LEK-methods are efficient and accurate for detecting wildlife species in the field, but only if correctly applied. In the case of LBSs, we consider that high initial time-investment is essential for the method's good performance. During this period, we standardised data-gathering, addressed participants´ doubts, worked on understanding their perceptions and needs, and on incorporating these into the project. We consider that this initial stage was important for local participants to take ownership of the project, commit with the survey and increase the accuracy of the method. Previous studies found that before standardisation and confidence-building, error rates and data falsification with LBS can be high (Luzar et al., 2011). Other experiences of LBSs have also found accurate results after investing time in data standardisation and local commitment (Benchimol et al., 2017; Davis and Wagner, 2003; Dolrenry et al., 2016; Luzar et al., 2011).

Regarding interviews, their correct application requires finding respondents with the relevant knowledge and expertise. In our study, qualified informants were local hunters. Detection probabilities and accuracy were low when interviewing non-hunters. Non-hunters may be less aware of wildlife presence because wildlife is not important in their livelihoods. Our results support the idea that LEK is affected by the economic importance of the species or resource being studied (Howard and Widdowson, 1996). This should not be a reason to reject LEK-methods for surveying wildlife but highlights the importance of working with qualified informants when recording LEK. Previous studies reached similar conclusions and found that, in some cases, local experts can provide higher quality data than professionals (Davis and Wagner, 2003, Parry and Peres, 2015; Supplementary material, S1). Finding qualified informants in the Dry Chaco should be easy as most *Criollos* are hunters (Camino et al., 2018). In other areas, differentiating interview respondents based on the importance of surveyed species in their livelihoods can improve results.

LBSs and interviews can be equally efficient and accurate for surveying peccaries but their characteristics and uses differ. The long preparation stage of LBSs hinders their use for rapid assessments. LBSs are more adequate for long-term wildlife monitoring, as they have been widely applied (e.g. Danielsen et al., 2009; Dolrenry et al., 2016; Luzar et al., 2011; Parry and Peres, 2015). Interviews are cheaper and faster than LBSs and hence, more appropriate for rapid assessments and for covering large areas. Our findings support previous research showing that interviews can be useful for surveying large populated areas (e.g. Zeller et al., 2011) and detecting rare species, as the chacoan peccary (e.g. Nash et al., 2016). In our study, white-lipped peccary detection probability estimates were imprecise. Variability may decrease by modelling the effect of other variables, e.g. soil hardness (MacKenzie et al., 2006), or abundance changes in space (Royle and Nichols 2003). But beyond this particular case, our results show that when using LEK-methods, we should ensure that variability in estimated parameters is low enough to reach our objectives.

The best field method depends on several factors, including the characteristics of our target species and our study area and the variables we measure, among others. Thus, LEK-methods´ high performance for detecting large mammals could change if focusing on other species, e.g. arboreal mammals, or measuring other variables, e.g. abundance. Yet, studies in other regions also found that LEK-methods are useful for studying other taxa and measuring other variables (Supplementary material, S1). It is important to acknowledge that certain studies may benefit from using camera traps despite their low capacity of detecting large terrestrial mammals and their inadequacy for covering large areas. Cameras provide accurate information and may be useful to meet particular objectives or to complement LEK-methods. E.g. cameras may add quantitative information to more comprehensive LEK on animal behaviour. In contrast, we discourage using transects in the Dry Chaco and similar ecosystems. This method demands large inputs of energy given this region's dense vegetation-covers and harsh environmental conditions.

Table 2
Number of people that had a perception, attitude or skill (1 – 10) before the locally based survey/after the locally based survey (LBS). Local capacity was significantly different between participants and non-participants of the LBS when $\Delta AIC < -2$. (*) Significant difference. (§) denotes occurrences where none of the respondent understood the question.

	Wichis			*Criollos*		
	Non-participants	Participants	ΔAIC	Non-participants	Participants	ΔAIC
Conservation capacities						
(1) Consider that they can do something for conserving wildlife	14/21	27/29	−3.9*	23/38	34/43	−2.3*
(2) Would like to participate in initiatives for conserving wildlife (i.e. working for wildlife to last in time)	21/40	31/31	−25.1*	22/49	38/52	−6.4*
(3) Ideas for wildlife conservation	14/21	27/29	−3.9*	23/38	34/43	−2.3*
(4) Allow outsiders to hunt in their territories	§	0/29	–	14/29	3/38	−12.7*
Working, research and communication capacities						
(5) Use GPS	0/28	4/29	−3.7*	4/61	11/41	−6.0*
(6) Use satellite images?	0/28	15/29	−23.5*	0/61	15/39	−30.6*
(7) Use digital camera?	0/28	15/29	−3.7*	0/61	17/39	−35.8*
(8) Received basic training on the use of computer	0/28	26/29	−25.8*	0/61	7/39	−12.0*
(9) Know how to register information from the field (e.g. fill in a form)?	0/28	19/29	−33.2*	1/61	31/39	−73.6*
(10) Capable of developing a public presentation	0/28	0/29	2	0/61	1/39	0.1

4.2. *LEK-methods for building capacity and legitimate conservation initiatives*

Our study shows that LBSs can increase local skills. Compared to people who did not participate in the LBS, local participants had greater conservation, research and work capacities. Participants learnt how to gather scientific information in the field and how to use tools such as a computer or GPS. It is usually stated that LBSs increase local capacities but this is rarely quantitatively evaluated (but see Danielsen et al., 2009; Dolrenry et al., 2016). Building local capacity empowers communities, raises the likelihood of participants´ autonomy in resource management and of successfully applying legitimate conservation measures (Danielsen et al., 2009; Dolrenry et al., 2016). This is very important when working in ecosystems that are endangered and where local people depend on natural resources.

Thus, although LBSs can be costly, they are reliable survey methods and are useful tools in larger conservation processes. LBSs increase local capacity and increase the likelihood of converting survey results into legitimate conservation actions. Furthermore, LBSs – and interviews to a lesser degree – constitute platforms of interaction between scientists and local communities. Using these platforms, scientists and locals can co-produce knowledge as well as management and conservation alternatives. These co-productions are urgently needed for achieving locally legitimate solutions to the global environmental crisis, as these have higher chances of success than top-down alternatives (Bennett, 2016; Mistry and Berardi, 2016). However, LEK-methods can only contribute to these co-productions if we meet certain requirements while applying them. First, we must remember at all stages of our work that LEK is more than a tool for collecting field information. LEK is an epistemological construction, as valuable as scientific knowledge (Bennett, 2016; Mistry and Berardi, 2016). Second, before using LEK-methods we should prepare ourselves to work with non-dominant cultures. Horizontal work demands that we do not impose locals our politically dominant, market-based, Western views and agendas (Bennett, 2016; Mistry and Berardi, 2016). Finally, we recommend complementing LEK-methods with studies on local perceptions and needs (e.g. Camino et al., 2016, 2018; Bennett, 2016).

5. Conclusion (140/200)

Field information is essential for developing conservation actions but when standard methods are inefficient, surveying is difficult or even impossible. Consequently, some of the most threatened species and regions remain un- or under-surveyed, as in the South American Chaco. Our study shows that LEK-methods can be efficient and accurate for detecting large terrestrial mammals in large, remote areas. Compared to standard-methods, refined LEK-methods increase detection probabilities and reduce probabilities of false-presences. Our findings add to the growing body of literature studying the relevance of LEK-methods in wildlife research, focusing on their validation and evaluation (references in Supplementary material, S1). Our results provide a valuable framework for how these methods can be properly evaluated and support the use of LEK-methods to gather conservation relevant information worldwide.

Our research also highlights that the benefits of using LEK-methods go beyond the gathering of information. First, LBSs increase local capacity and raise the chances of success of further conservation actions. Second, LEK-methods are adequate platforms for working horizontally with local communities, co-producing knowledge and conservation initiatives. LEK is proving to play a fundamental role in conserving and sustainably managing ecosystems, their services and biodiversity (Bennett, 2016; Mistry and Berardi, 2016). Thus, by providing these urgently needed spaces of interaction, LEK-methods can be central to successful conservation actions.

Supplementary data to this article can be found online at https://doi.org/10.1016/j.biocon.2020.108450.

Declaration pf competing interest

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CRediT authorship contribution statement

Micaela Camino: Conceptualization, Methodology, Data curation, Formal analysis, Writing - original draft. **Jeffrey Thompson:** Formal analysis. **Laura Andrade:** Formal analysis. **Sara Cortez:** Data curation. **D. Matteucci Silvia:** Methodology, Formal analysis. **Mariana Altrichter:** Methodology, Formal analysis.

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