Quantifying wildlife-livestock interactions and their spatio-temporal patterns: is regular grid camera trapping a suitable approach?

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ABSTRACT

Camera trapping use has increased significantly in ecological studies in recent decades due to its ability to register information about cryptic and/or elusive species and, more recently, due to its ability to derive population parameters, such as population abundance or density. For these latter applications, camera traps set in a regular grid pattern (CT-RG) are required to obtain representative information of the study area. The present work aims to assess the usefulness of the information collected through CT-RG to study interspecific interactions between animals, in terms of frequency of interaction and their spatiotemporal pattern. The results from CT-RG were compared with those obtained from GPS collars. For this latter methodology, 31 individuals were monitored with GPS-GSM collars (9 red deer [*Cervus elaphus*], 7 fallow deer [*Dama dama*], 6 wild boar [*Sus scrofa*] and 9 cows). The results showed that all the types of interactions recorded by GPS devices were also recorded by CT-RG. However, the relative frequency of each type of interspecific interaction was not precisely estimated using CT-RG. Nor did we observe an overlap between methodologies in the temporality of the interactions. These results are possibly due to most of the interactions tending to occur at aggregation points, which cannot be sufficiently represented by a regular grid. Finally, the spatial pattern obtained from CT-RG correlated with those obtained with GPS collars. Nowadays, camera trapping is being established as an affordable and effective tool to study different population parameters and, therefore, a huge amount of area is monitored with these devices using regular grids. Our results suggest that the information obtained through CT-RG can also be used to study the patterns of interaction between species.

KEYWORDS

Camera traps; regular grids; GPS; telemetry

INTRODUCTION

The spatial interactions between wildlife species have long been studied to understand different ecological processes, such as animal behaviour, predation and reproduction (Ji et al. 2005). Furthermore, direct and indirect interactions at the wildlife-livestock interface cause conflicts from a socio-economic, ecological and epidemiological point of view (Gortázar et al. 2010). The studies of such interactions in given contexts are useful to understand the actors involved and the potential risk factors explaining the interaction pattern (Perrotton et al. 2017). However, they cannot be generalized to all the interfaces nor to scenarios of the same interface, since spatial heterogeneity drives local differences in community and population processes, which could have consequences in the transmission of pathogens (Real and Biek 2007; Keeling and Rohani 2011). Thus, studies at local scale are necessary to accurately characterize the interaction pattern between species and their spatio-temporal variation.

Multiple methodologies have been used to study intra and interspecific interactions between wildlife and domestic animals (reviewed in Triguero-Ocaña et al. in press). Among the most used methods, direct observation, epidemiological questionnaires and individual tracking devices (global positioning system [GPS] and proximity loggers) are the most employed to quantify interactions. Despite their usefulness, these methodologies have some practical limitations, since they are normally expensive, time-consuming, invasive, or limited to large or easily detectable species (Ji et al. 2005; Kukielka et al. 2016; Triguero-Ocaña et al. 2019). Therefore, it becomes necessary to test new practical methods and sources of data to characterize the interaction patterns.

The use of camera trapping has increased in recent years to monitor wildlife due to its ability to detect elusive species in a non-invasive way (Rovero and Zimmermann 2016). The applications of camera trapping in ecology include, among others, the study of wildlife communities, their activity rhythms and behaviour, population monitoring, occupancy, habitat use and habitat selection (Rovero et al. 2013). This methodology has also been extensively used to determine the abundance and density of species over recent years (Burton et al. 2015). Besides, the recent initiatives of citizen science (i.e. volunteers who participate in the collection of field information for scientific purposes; Cohn 2008) allow an expanding of the spatial coverage of the information collected (Caravaggi et al. 2017). Nowadays lots of data are becoming available from camera trapping for large-scale population monitoring, and initiatives at a global scale are emerging to compile the information under quality standards (www.mammalnet.com).

Previous studies have already used camera traps (CT hereafter) to record interactions among species (Kukielka et al. 2013; Sparkes et al. 2016). However, these studies focused on the study of interactions at aggregation points or known animal paths in order to maximize the probability of registering contacts. Random sampling design based on the placement of camera traps in regular grids (CT-RG) is often required in many ecological studies (Rowcliffe et al. 2008). This provides the opportunity to explore the potential use of this information (increasingly available and following a grid design) to characterize interactions, particularly at the wildlife-livestock interface, a priority for wildlife and shared disease management (Vicente et al. 2019). In this context, the aim of this work is to assess the potential use of camera traps located in regular grids to study the interspecies interaction pattern.

MATERIALS AND METHODS

The information relating to camera trapping used in the present work proceeds from two studies carried out in Doñana National Park (hereafter, DNP; 37°0’ N, 6°30’ W; Spain) for the estimation of wild ungulate densities through the utilization of CT-RG. The surveys were conducted in two periods: October – December 2015, and March – April 2016. During the 2015, 38 motion infra-triggered camera traps (LTL Acorn, LTL-5310 series IR LED Invisible) were deployed (1548 days-camera), and 27 during 2016 (728 days-camera). The cameras were set on wooden stakes between 30-50 cm above the ground, without bait, with a separation of 500 m (2015) and 1000 m (2016) and were programmed to record 3 consecutive pictures once the motion sensor was activated.

Regarding the reference methodology, during July 2015, 31 ungulates were captured and equipped with GPS-GSM collars in DNP, including 9 adult red deer (*Cervus elaphus*), 7 adult fallow deer (*Dama dama*), 6 adult wild boar (*Sus scrofa*) and 9 cows. The captures were performed following the protocol approved by the Animal Experiment Committee of Castilla-La Mancha University and by the Spanish Ethics Committee (PR-2015-03-08). All the collared individuals belonged to different social groups and their home ranges (kernel 95% utilization distribution [UD]) include the area covered by CT-RG surveys, in both periods (see Figure 1). GPS collars were programmed to acquire one geographical location every two hours. The mean positioning error was estimated to be 26 m following the protocol presented by Barasona et al. (2014a).

To characterize interactions using camera trapping information, the temporal window between consecutive pictures to be considered as an interaction was defined (Kukielka et al. 2013). It was 2 h, according to the frequency of location fixation of the GPS devices. Using R software 3.5.3 (R Core Team, 2018), for each picture in a specific sampling point, a picture of other species inside the temporal window previously defined was searched and when it appeared, the information of date, time, and the species involved in the interaction were saved. The characterization of interactions through GPS technology was conducted following the methodology presented by Triguero-Ocaña et al. (2019). First, the spatio-temporal window between locations to be considered as an interaction was defined. The spatial window was established as 52 m due to the positioning error of the GPS devices. The temporal window was 2 h according to the frequency of location fixation. Subsequently, using R software, for each relocation the relocation of other individuals inside the spatio-temporal window previously defined was identified and the information of the Euclidean distance between both locations, date and time, plus the coordinates of the interaction were saved.

Interactions recorded by both methodologies were compared to assess the capacity of camera trapping to register the interaction pattern, namely the frequency of interactions between pair of species and the spatio-temporal pattern of them in both years. For each pair of species, the frequency recorded by CT-RG was obtained by dividing the number of interactions by the total number of days that all cameras were working. In the case of GPS, the frequency was obtained by dividing the number of interactions by the number of individuals available to interact (i.e. number of collared individuals which had an overlapping home range with the reference individual; see Triguero-Ocaña et al. 2019). Frequencies obtained from GPS refer to available individuals, whereas that obtained from CT-RG refer to the overall population. Therefore, for direct comparisons, frequencies from GPS were corrected for the density of animals in DNP, in that, for each pair of species the frequency was divided by the density of the less abundant species. Densities were 6.3 ind 100 ha^{-1}, 3.9 ind 100 ha^{-1}, 5.7 ind 100 ha^{-1} and 2.26 ind 100 ha^{-1}, for red deer, fallow deer, wild boar and cattle, respectively (Vicente et al. 2014).

In addition, CT-RG has the potential to identify the temporal and spatial interaction patterns. We first calculated the activity pattern of each species with both CT-RG and GPS, then we calculated for each methodology the overlap coefficient between the activity patterns of pairs of species using the R package “overlap” version 0.2.3. (Meredith and Ridout 2014) (see methodological approach in Figure 2a). This overlap in activity patterns can be interpreted as a potential for interaction appearance. To calculate the overlap coefficient between the activity patterns of different species using GPS technology, we followed the protocol presented by Lashley et al. (2018). In a second step we studied the daily variation in the frequency of interactions, and its consistence between methodologies, also using the R package “overlap”. For each year and pair of species, we calculated the coefficient of overlap between the daily patterns in the interaction frequencies described by both methodologies (Figure 2b). Finally, for the spatial pattern we assessed the consistency between methodologies in identifying the most relevant predictors (risk factors) explaining the spatial variation in the interaction frequency. For this purpose, we used the distance to water and the distance to vera ecotone, the most relevant risk factors explaining aggregation of wildlife and livestock in the study area (Barasona et al. 2014b). For each methodology, the frequency of interactions obtained was modelled against the above-mentioned factors using a general lineal model with a binomial distribution and a logit link function ("lme4" R package, Bates et al. 2014). In the case of camera trapping, the response variable was the frequency of interaction (see above) of each camera, and the information of the two environmental variables was calculated, using QGIS 3.4 (QGIS Development Team, 2018), as the average value of each variable contained in a buffer of 1000 m around each camera trap. In the model parameterized with the GPS information we used, as response variable, the number of contacts regarding the number of locations contained in a 100 x 100 m grid covering all the study area and containing the environmental predictors.

RESULTS AND DISCUSSION

Both by CT-RG and GPS technology we were able to record all types of interspecific interactions taking place in our study area. However, we observed significant differences, for both study periods, in the frequency of interactions recorded by CT-RG as regards GPS technology (see Supplementary Material: Figure S1). The differences between methodologies in the frequency of interaction may be due to the lack of representativeness of aggregation points by the CT-RG. The relevance of aggregation points in explaining wildlife abundance and frequency of interactions was previously described in DNP (Barasona et al. 2014b; Triguero-Ocaña et al. 2019). On the contrary, the use of CT-RG would not allow recording of the interactions produced in these areas, but only to record those indirect interactions that occurred due to the movement of different animals on the landscape. In this respect, by reducing the distance between consecutive cameras we could have more opportunities to account for the activity close to aggregation points even when working with a regular grid. Future studies should, therefore, use CT-RG with a shorter distance between devices, or include the simultaneous monitoring of aggregation and random points by means of camera trapping, to test if the discrepancies between rates estimated with CT-CR and those obtained from the reference method (GPS in this case) can be explained by those interactions at the aggregation points. In the absence of this complementary information, the results presented here show the potential of CT-RG to identify the species involved in the interactions process within a multi-host community.

Both methodologies registered a high overlap in the activity patterns of all the pairs of species but the obtained overlap indices from CT-RG were not correlated with those from GPS (rho = -0.29, p = 0.58). Firstly, this overlap can be interpreted as a measure of the potential that two species have to interact, and therefore, results suggest a high potential for interactions even when CT-RG once more were not able to properly quantify the expected frequency. Surprisingly, these activity patterns were different when comparing methodologies and, in some occasions, the characteristic crepuscular activity peak of wild ungulates was not detected with CT-RG (see Supplementary Material: Figure S2). Similar results were described by Lashley et al. (2018), which observed differences in the activity peaks recorded by camera traps regarding radio-tags. As a step forward, we explored the overlap in the daily variation of the interaction frequency obtained with each methodology and we did not observe a clear overlap. Secondly, the higher frequency of interactions did not correspond to the moments of greatest overlap. These results suggest that the interactions did not occur randomly during the day in response to species activity and probably their frequency is related to the use of key resources where most interactions occur. We also realize that possibly an insufficient sampling effort, mainly in 2016, could have driven the weak relationships detected and therefore we suggest that more studies are needed to disentangle the capability of CT-RG to register the temporal pattern of interactions.

Regarding the spatial pattern of interactions, the general linear models showed that there was a greater frequency of interactions around water points and near to vera ecotone (see Supplementary Material: Figure S3 and Table S1). This pattern was not observed for CT-RG in 2016, probably due to the low number of interactions recorded with CT-RG in this period. In fact, by randomly reducing the number of interactions recorded with GPS for this period, we observed that the expected association between the frequency of interaction and the predictors did not always occur (data not included), so we can assume that a greater number of interactions recorded by CT-RG would describe the same spatial pattern and identify the same risk factors, and therefore spatial pattern, as GPS. More studies are needed to verify this claim.

CONCLUSIONS

Camera trapping is currently an affordable and efficient methodology to carry out different studies about population parameters, so it is expected that the information collected through this tool will continue growing over time. The present study aims to assess the potential of CT-RG for studying the pattern of interaction between species. This information can be highly relevant for epidemiological studies carried out in multi-host communities to develop efficient measures for the control of shared diseases. Our first results show that CT-RG can be used to detect the species involved in the interaction process and the spatial pattern of such interactions; however, CT-RG fail in quantifying precise frequencies and describing the temporal pattern. We realize that neither our dataset nor the experimental design was the best to assess the performance of this approach. However, we believe that this note can be a timely first evidence of the potential that this kind of data can have in the future for studying interactions. Further studies in this area are needed to accurately describe the ability of this tool to record intra and interspecific interactions.

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FIGURES

Figure 1. Study area, grid of camera traps for the two time periods and home range (kernel 95%) of targeted individuals collared with GPS technology.

Figure 2. Methodological approach to study the agreement between methodologies recording the temporal pattern of interactions. A) Overlap between the activity pattern of different species and the expected number of interactions (boxplot) grouped in four time periods (Hour1: 0:00 – 5:59, Hour2: 6:00 – 11:59, Hour3: 12:00 – 17:59, Hour4: 18:00 –

23:59); this approach has to be calculated for both methodologies. B) Overlap plot of the daily interaction frequency recorded by methodology.