Ecological Modelling 350 (2017) 79–86

Contents lists available at ScienceDirect

Ecological Modelling

journal homepage: www.elsevier.com/locate/ecolmodel

Quantifying the bias in density estimated from distance sampling and camera trapping of unmarked individuals

Alienor L.M. Chauvenet[a,b,*], Robin M.A. Gill[c], Graham C. Smith[a], Alastair I. Ward[a], Giovanna Massei[a]

[a] National Wildlife Management Centre, Animal and Plant Health Agency, Sand Hutton, York YO41 1LZ, UK
[b] Centre for Biodiversity and Conservation Science & ARC Centre of Excellence for Environmental Decisions, The University of Queensland, Goddard 8, Level 5, St Lucia, QLD 4072, Australia
[c] Centre for Human and Ecological Sciences, Forest Research, Surrey, GU10 4LH, UK

ARTICLE INFO

Article history:
Received 16 May 2016
Received in revised form 10 February 2017
Accepted 11 February 2017
Available online 23 February 2017

Keywords:
Individual based model
Sus scrofa
Transects
Population monitoring
Population size
Random encounter model

ABSTRACT

Population size estimates are an integral part of any species conservation or management project. They are often used to evaluate the impact of management intervention and can be critical for making decisions for future management. Distance sampling and camera trapping of unmarked populations are commonly used for such a task as they can yield rapid and relatively inexpensive estimates of density. Yet, while accuracy is key for decision-making, the potential bias associated with densities estimated with each method have seldom been investigated and compared. We built a spatially-explicit individual based model to investigate the accuracy and precision of both monitoring techniques in estimating known densities. We used the wild boar population of the Forest of Dean, UK, as a case study because both methods have been employed in situ and offer the chance of using real life parameters in the model. Moreover, this is an introduced species in the UK that has the potential to impact natural and agricultural ecosystems. Therefore, improving the accuracy of density estimates is a priority for the species' management. We found that both distance sampling and camera trapping produce biased density estimates for unmarked populations. Despite large uncertainties, distance sampling estimates were on average closer to known densities than those from camera trapping, and robust to group size. Camera trapping estimates were highly sensitive to group size but could be improved with better survey design. This is the first time that the amount of bias associated with each method is quantified. Our model could be used to correct estimated field-based densities from distance sampling and camera trapping of wild boar and other species with similar life-history traits. Our work serves to increase confidence in the results produced by these two commonly-used methods, ensuring they can in turn be relied upon by wildlife managers and conservationists.

1. Introduction

Monitoring population size fluctuations is a key aspect of any species conservation and/or management project (Nichols and Williams, 2006; Yoccoz et al., 2001). The aim is to monitor population trends over time in order to detect changes in abundance associated with management actions or potential threats (Li et al., 2010; Pollock et al., 2002; Smart et al., 2004). This may involve any number of different monitoring techniques, including spot count surveys, distance sampling, camera traps (both of unmarked and marked individuals), and capture-mark-recapture. Among these methods, those that account for the variability in detectability of individuals are known to produce more robust estimates (Focardi et al., 2001; Pollock et al., 2002; Rosenstock et al., 2002). Capture-mark-recapture studies are generally considered state-of-the-art due to a large body of theoretical and empirical literature (Buckland et al., 2000; Karanth and Nichols, 1998; Lindberg, 2012). However, while capture-mark-recapture offers reliable estimates of population density, it is applicable only when animals can be marked or have distinctive natural markings, it is not appropriate for all species.

As a result, monitoring methods that require less time and investment are often favoured by managers. Distance sampling and camera trapping of individuals that cannot be uniquely identified, for example, can be used to estimate population density (Parrott

* Corresponding author at: Centre for Biodiversity and Conservation Science, The University of Queensland, St Lucia, QLD 4072, Australia.
E-mail address: a.chauvenet@uq.edu.au (A.L.M. Chauvenet).

http://dx.doi.org/10.1016/j.ecolmodel.2017.02.007

et al., 2012; Roberts, 2011; Rovero and Marshall, 2009). Moreover, data collected with both techniques can be analysed with methods that account for the fact that the probability of detecting individuals present in the study site is almost always below one (Bartolommei et al., 2013). Distance sampling is usually implemented through point or transects surveys: one or several observers either staying in one spot (point survey) or moving along a pre-defined line in the study habitat (transect survey) record all individuals or groups of the target species they can spot, alongside the estimated distance between the transect and each animal detected. The detectability function associated with the study site, is then defined in terms of the detection probability as a function of distance of the animal to the transect (e.g. Thomas et al., 2010) and the density is calculated taking into account this detectability function (see Thomas et al., 2010). Camera trapping consists of placing cameras throughout the study site. Cameras take a picture each time their sensors are activated, i.e. when an individual pass through their detection field, whether it is from the species of interest or not. As a result, while the surveying is automated, data need to be processed to record instances of the target species. Then, by knowing the camera's specifications (angle and radius of detection) and details of the species' behaviour (group size and movement speed, estimated independently), density can be estimated for the study area (Rowcliffe et al., 2008). Both distance sampling and camera trapping have advantages and disadvantages. For example, the initial cost for camera trap equipment can be quite high, and replacing damaged or stolen cameras to complete a project, costly. However, this is a relatively inexpensive method in terms of staff time as it requires leaving the camera in situ and only returning to the site at the end of the monitoring period, usually lasting a few weeks. Conversely, distance sampling can be fairly inexpensive to set up with initial equipment costs being relatively low. However, the amount of effort required to carry out the survey can be quite high, as it requires returning to the same area multiple times and actively monitoring for hours on end.

While distance sampling (Karanth et al., 2004; Ruette et al., 2003) and camera trapping (e.g. Ahumada et al., 2011; Kelly et al., 2008; Silver et al., 2004) are commonly used in the field, there is no empirical evidence as to which one yields the most accurate estimate of density. Moreover, the bias associated with each method has been rarely quantified (Roberts, 2011). Comparisons of relative accuracy have been produced under experimental settings; e.g. only relative validity of camera trapping has been studied in situ in a multi-site studies (De Bondi et al., 2010; Rovero and Marshall, 2009). Yet, biases in density estimates from distance sampling and camera trapping studies could have severe consequences on the management or conservation of species; for example, an underestimate of the true species density could lead to further unwarranted investment into their management, or to a failure to recognise management actions as successful; an overestimation of the density could see vital intervention being discontinued. In case of overabundant wildlife populations, over- or underestimation of densities could also lead to making the wrong decisions when planning the removal of animals from an area or when measuring the impact of actions aimed at population control.

One way to estimate the potential bias in density associated with camera trapping and distance sampling is simulation modelling. While, in theory, a large scale field experiment could be created to test the accuracy and precision of both methods (i.e. by releasing a known number of individuals into an enclosed study site), it would be both costly and difficult. On the other hand, simulation modelling, offers the opportunity to create a virtual experiment, which can be repeated many times at negligible costs. Here, we created a spatially-explicit individual based model (IBM) that simulated a closed wildlife population and its monitoring using both camera trapping and transect-based distance sampling. We used the population of wild boar *Sus scrofa* in the Forest of Dean, UK, as a case study. This is because both camera trapping and distance sampling through thermal imaging (Gill and Brandt, 2010) have been used to monitor this population in the wild and the ecology of the population has been extensively studied, allowing us to parameterise our model with data collected in the field. Moreover, the species has been recently expanding in the UK, due to escapes from farms and illegal releases after a *c.*300 years absence (Baker, 2010) and is known to be increasing in size in European countries (Massei et al., 2015). In comparison with other ungulates, wild boar have the highest reproductive rate and expanding populations have the potential to affect both natural and agricultural ecosystems through predation and competition, habitat modification and degradation, and disease transmission such as classical swine fever or foot and mouth disease (Engeman et al., 2013; Focardi et al., 2000; Massei and Genov, 2004; Rossi et al., 2005; Ruiz-Fons et al., 2008; Wilson, 2004). Wild boar are thus of management concern and require accurate monitoring of population trends.

The aim of this paper was to quantify the potential bias in density estimated from distance sampling and camera trapping in the field, using simulations. We hypothesized that (H1) both methods would be sensitive to the size of the population (i.e. number of wild boar groups here) as it likely to be easier to accurately estimate density of large populations rather than small ones; (H2) both methods would be sensitive to the survey efforts (i.e. number of transects conducted for distance sampling and number of camera days for camera trapping); (H3) camera trapping estimates would be sensitive to group size as each individual has a chance to trigger the camera. Our results were used to make recommendations for the monitoring of unmarked wildlife populations.

2. Methodology

2.1. Model description

We built an individual-based spatially explicit model using R (v3.2.3; see Appendix A in online supplementary material; R Core Development Team, 2013). The model process is illustrated in Fig. 1. Briefly, a known number of wild boar groups (50, 100 and 200) were randomly assigned inside a single cell representing the habitat being monitored (*c.*56 km^2 study site). The time step was 1 min and the model was that of a closed population, i.e. birth, death, emigration or immigration were assumed not to occur during the study period; this was a realistic assumption due to the small timeframe of 15 days. At each time-step, wild boar groups were allowed to move in any direction, which was chosen randomly. The size of the step was determined by the average observed speed for wild boar (Gill and Brandt, 2010), and set to 1 m per minute during the day, and 4 m per minute during the night. Initially, wild boar groups were allowed to move freely in the habitat; after 5 days, monitoring began.

Camera traps were placed randomly inside the study site based on the survey design (Table 1) and were allowed to continuously record sightings during the whole survey period. We tried three common survey design: placing cameras throughout the whole site once at the beginning of the survey (i.e. 100% area covered), placing cameras in only part of the site (< 100% covered) once at the beginning of the survey, and placing cameras in only part of the site (< 100% covered) and rotating their locations every 2 days. Because of the social nature of wild boar, when camera trapping, pictures within 10 min of each other are considered of the same family group (Ferretti et al., 2014). To reproduce this in the model, we allowed a maximum of one picture per camera being taken within 10 min of monitoring. Moreover, the chance of triggering a camera will be dependent on the number of individuals within a group. Each group