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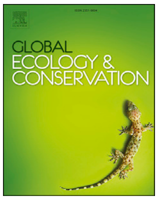

Original Research Article

Estimating density for species conservation: Comparing camera trap spatial count models to genetic spatial capture-recapture models

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ABSTRACT

Density estimation is integral to the effective conservation and management of wildlife. Camera traps in conjunction with spatial capture-recapture (SCR) models have been used to accurately and precisely estimate densities of “marked” wildlife populations comprising identifiable individuals. The emergence of spatial count (SC) models holds promise for cost-effective density estimation of “unmarked” wildlife populations when individuals are not identifiable. We evaluated model agreement, precision, and survey costs, between i) a fully marked approach using SCR models fit using non-invasive genetic data, and ii) an unmarked approach using SC models fit using camera trap data, for a recovering population of the mesocarnivore fisher (*Pekania pennanti*). The SCR density estimates ranged from 2.95 to 3.42 (2.18–5.19 95% BCI) fishers 100 km^{-2}. The SC density estimates were influenced by their priors, ranging from 0.95 (0.65–2.95 95% BCI) fishers 100 km^{-2} for the uninformative model to 3.60 (2.01–7.55 95% BCI) fishers 100 km^{-2} for the model informed by prior knowledge of a 16 km^2 fisher home range. We caution against using strongly informative priors but instead recommend using a range of unweighted prior knowledge. Thin detection data was problematic for both SCR and SC models, potentially producing biased low estimates. The total cost of the genetic survey ($47 610) was two-thirds of the camera trap survey ($77 080), or comparable ($75 746) if genetic sampling effort was increased to include sex and trap-behaviour covariates in SCR models. Density estimation of unmarked populations continues to be a series of trade-offs but as methods improve and integrate, so will our estimates.

1. Introduction

Estimating the density of animals is integral to researching, conserving, and managing wildlife populations (Williams et al., 2002). Population data are imperative for applying appropriate and effective conservation interventions, such as deciding when and where to focus protection efforts for threatened species (Bradley et al., 2017), delineating sustainable

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harvest levels (Kachel et al., 2016), or mitigating human-wildlife conflict (Mcgregor et al., 2015). Effective conservation management requires that density estimates are both accurate and precise, and produced with sufficient frequency to ensure informed decision-making (Jiménez et al., 2017). This is especially true for species of conservation concern where inaccurate and imprecise estimates can provide a false signal of stability (Tobler and Powell, 2013) and result in a lack of needed conservation effort (Bauer et al., 2015).

The past decade has seen parallel and complementary developments in field and statistical density estimation methods. There has been a move away from labour-intensive and invasive field surveys to the use of non-invasive remote sensing devices, such as camera traps (e.g., Burton et al., 2015). At the same time, analyses are shifting from traditional (e.g., capture-recapture models) to more complex statistical techniques, such as spatial capture-recapture (SCR) models (Borchers and Efford, 2008; Efford, 2004; Royle and Young, 2008). SCR models are an extension of traditional capture-recapture models that explicitly account for trap location and animal movement. They have been widely applied to field data, predominantly to estimate mammalian (carnivore) density (e.g., Royle et al., 2011) but also for birds (Mollet et al., 2015), sharks (Bradley et al., 2017), amphibians (Muñoz et al., 2016), and insects (Torres-Vila et al., 2012). The majority of SCR models are applied to camera trap survey data of naturally marked individuals (e.g., Avgan et al., 2014), secondly to data generated from genetic sampling methods (e.g., Gardner et al., 2010), and less frequently to other data types, such as acoustic recordings (Dawson and Efford, 2009). With the advancement of both field and analytical methods, density estimates are now being produced for previously unstudied populations (e.g., Sollmann et al., 2014). While SCR models are proving extremely useful for estimating the density of uniquely identifiable individuals — e.g., unique pelage markings or genetic analysis of hair and scat samples — many species are not uniquely identifiable from camera trap images, and other means of individual identification may be prohibitively costly or invasive.

The global increase in camera trap surveys has generated large volumes of data on a broad range of species (Steenweg et al., 2017), raising the possibility of simultaneously monitoring multiple species, including those that were not the original focus of the study (Rayan et al., 2012; Scotson et al., 2017). Indeed, 60% of camera trap studies comprise multiple species surveys (Burton et al., 2015), potentially representing a wealth of data available for species density estimation if models could reliably estimate densities of unmarked populations. Based on the results of previous simulation studies, spatial mark-resight (SMR) and spatial count (SC) models show great promise for estimating densities of populations where some or all individuals within the population are unmarked (Chandler and Royle, 2013). However, few published papers apply these models to field data (Evans et al., 2017; Jiménez et al., 2017; Kane et al., 2015; Rich et al., 2014; Sollmann et al., 2013), and when applied, SMR and SC models do not always converge (e.g., Sollmann et al., 2013). As conservation scientists and practitioners begin to use these more advanced models, there is a need to further assess their potential for producing reliable estimates from empirical datasets.

In this study, we capitalized on data collected as part of a study on the genetics and landscape connectivity of a recovering population of the mesocarnivore fisher (*Pekania pennanti*) (Stewart et al., 2017). Previous research on fishers in other regions includes estimates of density and home range size (e.g., Fuller et al., 2001; Koen et al., 2007; Linden et al., 2017), making it a useful species with which to compare SCR and SC models for conservation objectives. Our study goals were threefold: 1) estimate fisher density from an SCR model using non-invasive genetic survey data; 2) evaluate the ability of an SC model using concurrent camera trap survey data to produce comparable estimates; and 3) compare the costs and benefits associated with both sampling methods.

Our study builds on a recent fisher population study that compared density estimates using individual genetic data in a SCR model to camera detection data in a Royle-Nichols model (Linden et al., 2017). The unmarked modelling approach that we evaluate (SC) explicitly uses the spatial correlation of count data to estimate density (Chandler and Royle, 2013), in contrast to the Royle-Nichols model, which assumes that individuals are counted only once per sampling occasion (Royle, 2004), a condition violated in our survey. We include a cost comparison of methods as managers and conservationists must routinely weigh the benefits of a sampling approach against the feasibility, including costs, of implementation. Thus, our goal was to evaluate the analytical component while considering field costs, as conservation practitioners rarely consider one without the other when designing a monitoring program. We recognize that the type of survey is dictated by the research question; it is not our intention to discourage the use of either genetic or camera trap surveys. Rather, our analyses provide guidance on the advantages and limitations of using these field and statistical methods for estimating population density and informing conservation decisions.

2. Materials and methods

2.1. Study area and sampling design

Our study took place on the Cooking Lake Moraine (53.381 °N, 113.063 °W), a multi-use landscape of exurban development, protected areas, and agriculture covering 1596 km^2 in central Alberta, Canada (Fig. 1). The forested sections of this landscape were dominated by trembling aspen (*Populus tremuloides*) and balsam poplar (*P. balsamifera*), with clusters of white and black spruce (*Picea glauca* and *P. mariana*) interspersed with small water bodies characteristic of a glacial moraine. A diverse mammal community occupied this heterogeneous landscape, including fisher, a medium sized mustelid (2.2–7.0 kg) native to North American forests (Powell, 1982; Stewart et al., 2018).