bisonpicsuite: A set of R packages to estimate wood bison population parameters from remote camera data.

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Statement of Need

Knowledge of population status and trends is integral to the effective conservation and management of wildlife populations. To this end, demographic ratios (e.g., Calf:Cow ratios, Fig. 1) are routinely used in wildlife management as a readily observable measure of productivity and for forecasting population trajectories (Bender, 2006; Fuller et al., 2007; Wittmer et al., 2005). More complex population modeling approaches (Buckland et al., 2004; Mizuki et al., 2020; Newman et al., 2023; Paterson et al., 2019) can also be used to estimate survival and fecundity. To understand the age composition of a population, both approaches require classified (by age and sex) counts of individuals.

The use of remote cameras to monitor wildlife species for conservation and management has become widespread and R packages have been developed to manage camera data and estimate species occupancy, density and abundance (Doser et al., 2022, 2024; Moeller & Lukacs, 2022; Naimi & Araújo, 2016; Niedballa et al., 2016). In animals without individual markings, other population parameters are seldom estimated, although exceptions exist (Chitwood et al., 2017; Horne & Thompson, 2021; Ikeda et al., 2013). We are unaware of any other R packages that use classified counts from camera data to generate estimates of survival and recruitment, even though different age and sex classes can be readily distinguished in remote camera photos for many species (Laskin et al., 2020). We demonstrate an R package using a Bayesian integrated population model to generate estimates for these vital rates, combined with a Gaussian process regression to account for spatial and temporal correlations.
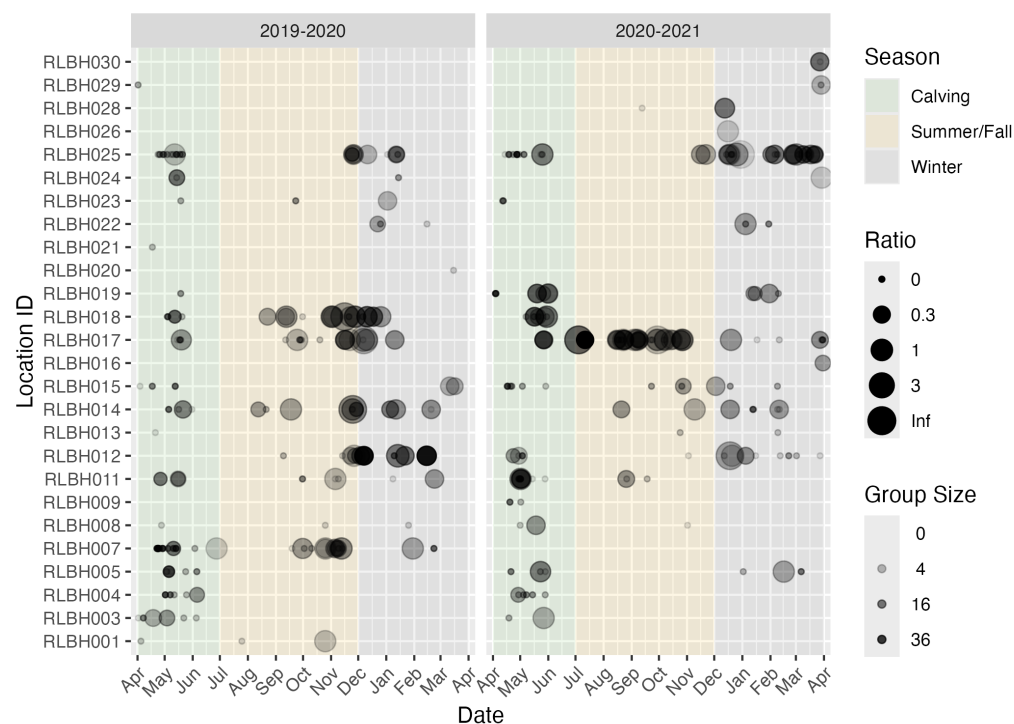
Figure 1: *Shinybisonpic app data exploration plot showing calf:cow ratios over time from individual remote cameras in the Ronald Lake Wood Bison range in northeast Alberta. Ratios are shown with camera trap ID, observation date, study year, season, and group size. A ratio of 0 represents a group of entirely cows, while an infinite ratio (Inf) represents a group of entirely calves.*

Summary

We present a method utilizing classified counts from remote cameras to evaluate wood bison (*Bison bison athabascae*) herd demographics. We modeled demographic ratios, survival, and productivity using a Bayesian integrated population model (IPM) to combine stage-structured information from multiple data sources and estimate demographic states and transitions (Schaub & Kéry, 2022). The data included classified counts from camera traps and calf proportion and census estimates from aerial surveys.

A series of binomial distributions were used to inform both the counts of classified individuals each age class (calf, yearling, adult) and corresponding sex ratios from each camera trap observation. Using binomial distributions, as opposed to a multinomial distribution, allowed us to account for individuals that were classified by age, but not by sex. The probabilities for each of the binomial draws were informed by the estimated proportions of individuals in each age and sex class in the population on a given date, which was modeled using a Birth-Age-Survival (BAS) subprocess formulation of a population projection model (Newman et al., 2014).

For example, the count of calves at the ith camera trap observation was modeled as follows:

$$C_i \sim \text{Binomial}(N_i, p_{C_i})$$

where C_i is the number of calves, N_i is the total group size, and p_{C_i} is the sum of the expected proportions of male and female calves on the date of the ith observation.

The sex ratio of calves was modeled as follows:

$$F0_i \sim \text{Binomial}\left(F0_i + M0_i, \frac{p_{F0_i}}{p_{F0_i} + p_{M0_i}}\right)$$

where $F0_i$ is the number of female calves, $M0_i$ is the number of male calves, and p_{F0_i} and p_{M0_i} are the expected proportion of female and male calves on the date of the ith observation, respectively.

The model also estimated the fecundity rate, the proportion of fecund cows aged two and older, the annually-varying survival rates for each class, and produced derived estimates of several key population ratios (Fig. 2). The information from the aerial surveys was integrated into the model, helping inform the total number of individuals (i.e., the sum of the class-wise abundances) and the proportion of calves (i.e., $p_{F0_i} + p_{M0_i}$) on the dates of the aerial surveys. A Gaussian process regression (McElreath, 2016) accounted for the spatial and temporal correlation of the camera trap observations. Collectively, these methods could be applied non-invasively to a wide array of hard-to-survey species to estimate key parameters driving population dynamics.
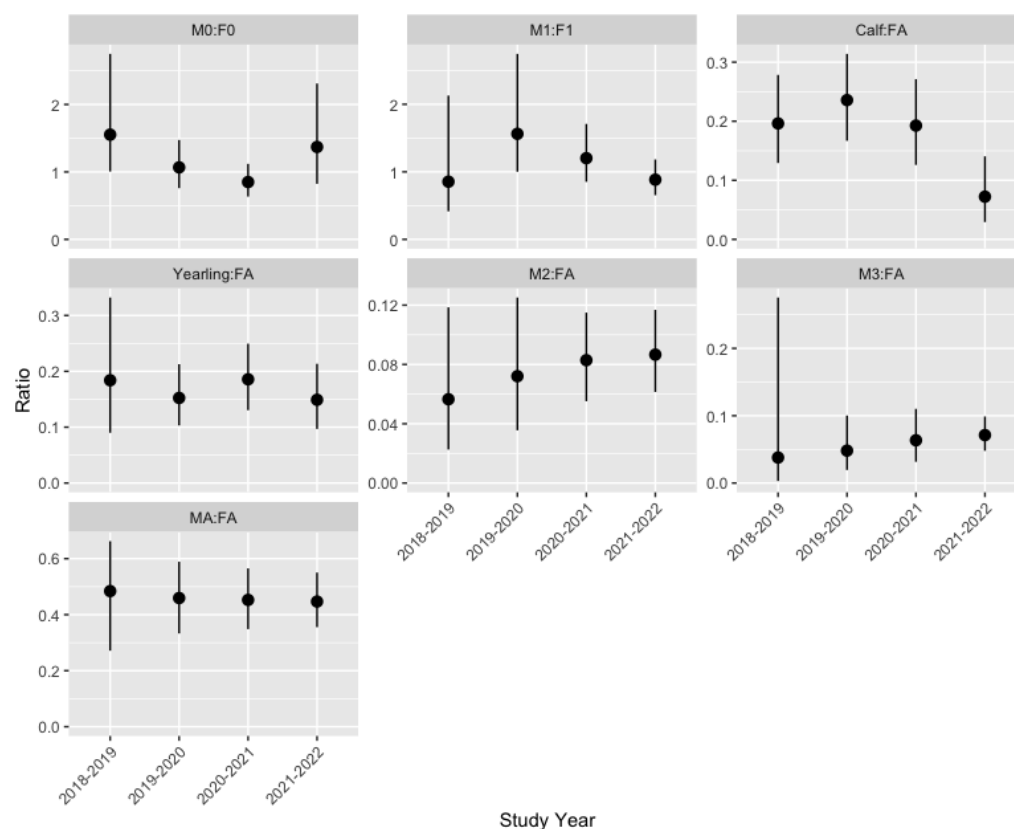

Figure 2: *Runbisonpic app prediction plot showing estimated population ratios for the Ronald Lake Wood Bison herd, by study year. M0 and F0 are male and female calves, M1 and F1 are male and female yearlings, Calf and Yearling represent all individuals within those age classes including those with unknown sex, M2 and M3 represent male two- and three-year-olds, MA represents males aged four and older, and FA represents females aged two and older.*

This method is implemented using four related R packages, with `bisonpicsuite` loading the other three packages. Core functionality for checking, cleaning, processing, modeling, and visualizing data is provided by `bisonpictools`. The remaining two packages are R shiny apps that provide a user-friendly interface to `bisonpictools` (Fig. 3). Each app starts with an

upload data tab that allows users to upload their data and runs a series of checks to ensure the data follows the required format for the next steps. The first app, `shinybisonpic`, is a web-based app that allows users to explore data by viewing camera locations on a map in one tab and plots of ratios of selected sex-age groups by location and year (e.g., Fig. 1) in another tab. The second app, `runbisonpic`, is a locally-run app that enables users with limited R or Bayesian modeling experience to estimate class-specific and total abundance, survival and fecundity rates, and sex-age ratios (e.g., Fig. 2). Users select a thinning value in the run model tab, run the model, and view results as tables and plots in the results tab. Both apps have a help and about tab to provide instructions for users.
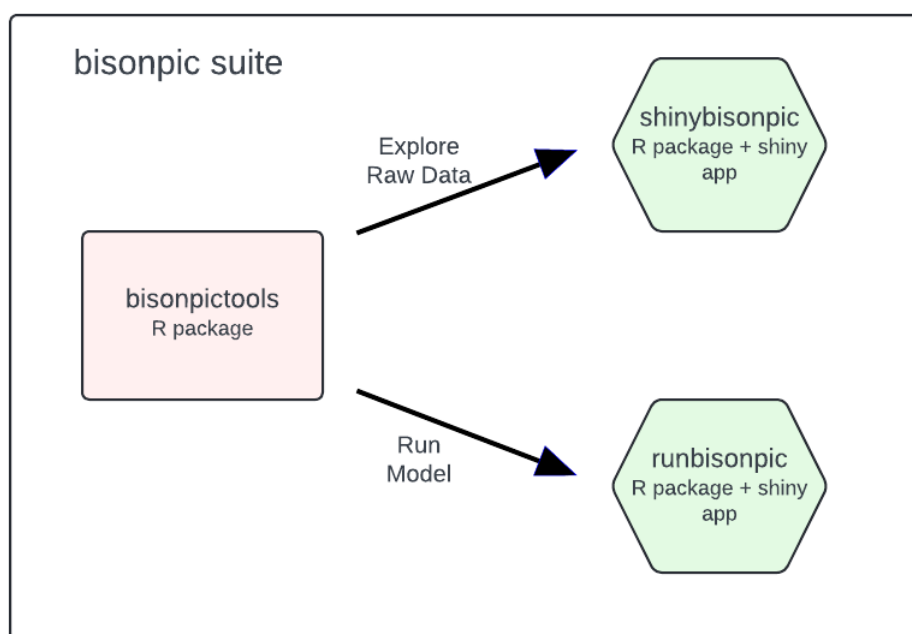

Figure 3: *Bisonpicsuite package structure*

Limitations

- The model can take over 5 hours to run.
- Key assumptions of the integrated population model include:
  - There is no grouping structure beyond what is accounted for by the covariance.
  - Every stage is equally detectable during a camera trap event.
  - Small and large groups are equally detectable.

Acknowledgements

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