birdnetTools 2.0: Linking BirdNET outputs to occupancy modeling in R

Sunny Tseng Connor M. Wood

2025-09-23

Executive Summary

Signatories

Project team

Sunny (Yi-Chin) Tseng – PhD Candidate, University of Northern British Columbia, Canada

Sunny is an avian bioacoustic ecologist and the creator of `birdnetTools`, an R package for post-processing BirdNET output. Sunny's expertise combines bioacoustics and quantitative ecology to monitor bird communities at landscape scales. She has conducted bird acoustic research in Siberia, Taiwan, Canada, and Lithuania, collecting audio recordings from over 300 species. For this project, Sunny will lead package development, maintain the repository, and update functions and documentation based on user feedback.

Connor M. Wood – Research Faculty, Cornell Lab of Ornithology

Connor leads the BirdNET Ecology Team, focusing on the application of BirdNET algorithms for landscape-scale biodiversity monitoring and community ecology. He has extensive experience developing and implementing bioacoustic tools to inform conservation strategies, and regularly uses BirdNET outputs as occupancy model inputs. For this project, Connor will provide expertise on occupancy modeling and statistical methods, ensuring the package outputs are ecologically relevant and meet the needs of end users.

The Problem

BirdNET is the most widely used algorithm for automated bird species identification from audio recordings, which can identify more than 6,000 species, most of them birds, from audio data, making it a powerful tool for large-scale avian monitoring (Kahl et al. 2021). R packages such as `birdnetR` (to run BirdNET) (Günther and BirdNET Team 2025) and `birdnetTools` (for post-processing BirdNET outputs) (Tseng 2025) allow users to streamline acoustic data analysis. One of the most fundamental applications of BirdNET detections is generating species presence/absence data across sites and time periods for occupancy modeling, which provides essential information on species distribution, detectability, and probability of occurrence (e.g., Wood, Cruz, and Kahl (2023)). However, preparing BirdNET outputs to become occupancy model inputs is often challenging, particularly for ecologists without extensive programming experience. Existing R tools for occupancy modelling, like `unmarked`, `ubms`, and `spOccupancy` (Doser et al. 2022), require data in very specific formats and involve complex, multi-step workflows, creating barriers to efficient and reproducible analysis.

This project aims to reduce the current gap between the generation of animal encounter data by BirdNET and the use of that data in statistical models. Specifically, we will improve and expand the functionality of `birdnetTools` to facilitate the converstion of raw BirdNET outputs into usable population data. Because `birdnetTools` already offers generic tools for data wrangling, summarization, and validation, it is the natural point in the audio-to-inference pipeline for necessary improvements. We will expand the features to provide streamlined workflows specifically tailored for occupancy modeling. By designing functions that automate the transformation of BirdNET outputs into formats compatible with occupancy modeling packages, we enable ecologists and conservation practitioners to more easily leverage passive acoustic monitoring data for occupancy analyses and generate reproducible ecological insights.

The proposal

Overview

The proposed solution expands `birdnetTools` functions to transform species detections (output from `birdnetR`) into presence/absence detection matrix (input for `spOccupancy`). This adds a new data-wrangling path to the existing workflow, as illustrated in Figure 1 A. Occupancy modeling requires three key data components:

- **Detection matrix** (sites × surveys) indicating species presence (1) or absence (0).

- **Site covariates** (sites × covariates), such as habitat type, elevation, or other site-level descriptors.
- **Survey covariates** (sites × surveys × covariates), such as weather conditions, time of day.

New functions will streamline the creation of the **detection matrix** by building on existing `birdnetTools` capabilities (e.g., data import, cleaning, validation) and adding tools to extract site and survey information, aggregate detections, and reshape outputs into the formats required by `spOccupancy`. The proposed workflow is shown in Figure 1 B.

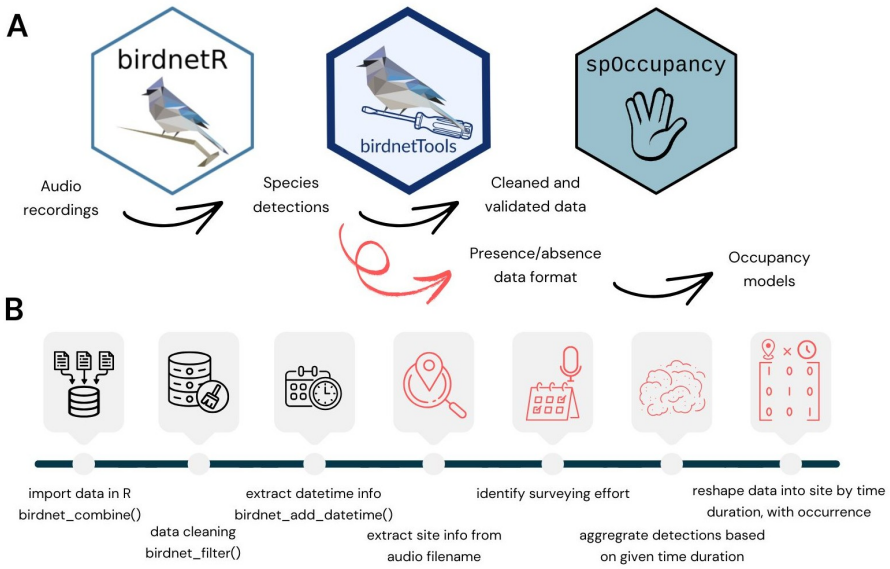

Figure 1: Workflow from raw audio files to occupancy models. Black arrows and graphics represent the current workflow, while red text and arrows indicate the proposed extensions for the package expansion.

Minimum viable product and external dependencies

The minimum viable product will be a single function, `birdnetTools::birdnet_det_mat()`, which converts BirdNET outputs into a **detection matrix** format - the critical missing piece in the existing software ecosystem. In short, BirdNET outputs are indefinitely long, with individual rows containing species predictions with associated metatdata. `birdnetTools` can already extract date and time information and compile species-by-species tables. Building on these capabilities, we will enable the streamlined conversion of the long-format output tables into the more consolidate site*day bins containing 1s (species observed above a specified score), 0s (audio recorded but no predictions above a specificed

score), and NAs (no audio recorded during that interval). That table, the **detection matrix**, can readily be ingested by `spOccupancy`(e.g., functions `PGOcc()` and `spPGOcc()`) and `unmarked` (e.g., function `occu()`; package `ubms` works direclty with `unmarked` input objects so no further adaptation would be required).

`birdnetTools` relies on several R packages to support its core functionality, including `av`, `tuneR`, and `seewave` for audio processing, and `dplyr` for data wrangling. A full list of dependencies is available in the `DESCRIPTION` file of the `birdnetTools` repository.

Project plan

Start-up phase

The planning phase will be completed within the first month of the project:

- ☐ Confirm and document open-source license (MIT).
- ☐ Set up GitHub repository with contribution guidelines, code of conduct, and issue templates.
- ☐ Establish reporting and feedback workflow via GitHub Issues/Discussions.
- ☐ Draft initial project roadmap and share with collaborators for feedback.
- ☐ Schedule bi-weekly check-ins between project contributors.

Technical delivery

The technical delivery phase will span months 2 to 5 of the project. Key milestones include:

- ☐ Month 2.: Finalize function specifications and data format requirements in collaboration with `spOccupancy` developers.
- ☐ Month 3: Develop and test initial versions of occupancy-specific functions in `birdnetTools` (i.e., the minimum viable product).
- ☐ Month 4: Create example workflows and vignettes demonstrating end-to-end analyses.
- ☐ Month 5: Conduct community testing, gather feedback, refine functions, and prepare for package release.
- ☐ Long term: The package will be distributed via CRAN and/or the rOpenSci R-universe to ensure broad accessibility for R users worldwide.

- ☐ Long term: Project updates and outcomes will be communicated through posts on the R Consortium blog, as well as via relevant R community events (e.g., useR! conference, ISC meetings).

Budget & funding plan

We request funding to support personnel time for developing, testing, and documenting the new 'birdnetTools functionality. Estimated costs are based on a five-month project divided into three deliverable-based milestones, calculated at an hourly rate of **USD 31/hour**.

Milestone	Deliverables	Hours (Sunny + Connor)	Estimated cost (USD)
Phase 1 Planning (2025 Dec.1 - 31)	Finalize data formats and function specs.	12 + 16	$868
Phase 2 Development (2026 Jan.1 - Mar.31)	Implement core functions, create example workflows.	80 + 16	$2,976
Phase 3 Testing & release (2026 Apr.1 - 30)	Conduct community testing, refine code and documentation	40 + 28	$2,108
Total		132 + 60 = 192	$5,952

Success

Definition of done

Measuring success

Future work

Doser, Jeffrey W., Andrew O. Finley, Marc Kéry, and Elise F. Zipkin. 2022. "spOccupancy: An r Package for Single-species, Multi-species, and Multi-season Occupancy Models." *Methods in Ecology and Evolution* 13 (8): 1670–78. https://doi.org/10.1111/2041-210X.13897.

Günther, Felix, and BirdNET Team. 2025. *birdnetR: Deep Learning for Automated (Bird) Sound Identification*. https://birdnet-team.github.io/birdnetR/.

Kahl, Stefan, Connor M. Wood, Maximilian Eibl, and Holger Klinck. 2021. "BirdNET: A Deep Learning Solution for Avian Diversity Monitoring." *Ecological Informatics* 61. https://doi.org/10.1016/j.ecoinf.2021.101236.

Tseng, Sunny. 2025. *birdnetTools: R Package for Working with BirdNET Output*. https://birdnet-team.github.io/birdnetTools/.

Wood, Connor M., Alicia Barceinas Cruz, and Stefan Kahl. 2023. "Pairing a User-Friendly Machine-Learning Animal Sound Detector with Passive Acoustic Surveys for Occupancy Modeling of an Endangered Primate." *American Journal of Primatology* 85 (8): e23507. https://doi.org/10.1002/ajp.23507.