birdnetTools 2.0: Linking BirdNET outputs to occupancy modeling in R

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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. 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.

Consulted

The Problem

BirdNET is the most widely used algorithm for automated bird species identification from audio recordings, which can identify more than 6,000 bird species 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 output) (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 data for occupancy analyses is often challenging, particularly for ecologists without extensive programming experience. Existing R tools for occupancy modelling, like `unmarked` 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 bridge this gap by improving and expanding the functionality of `birdnetTools`. While `birdnetTools` already offers generic tools for data wrangling, summarization, and validation, it does not yet 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 can significantly reduce the technical burden on users, enabling 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.
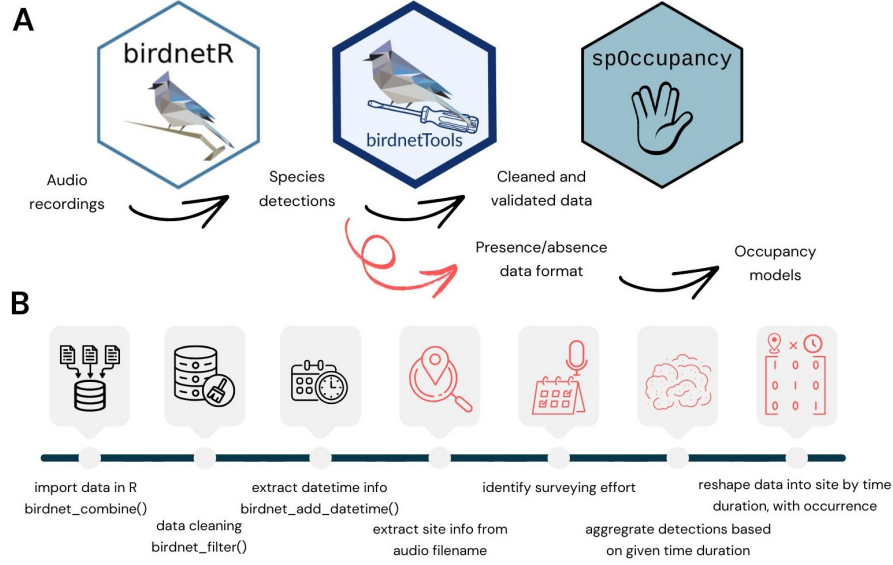

Figure 1: Workflow from raw audio files to occupancy models. Black arrows and graphics represent the current workflow, while red text and arrows indicate the proposed extensions for the package expansion.

Minimum viable product and external dependencies

The minimum viable product will be a single function, `birdnetTools::birdnet_add_site()`, which extracts and processes site-level information from BirdNET outputs. This function is essential for creating the detection matrix required for occupancy modeling. Over time, it will be integrated with additional tools and expanded to support the full suite of `spOccupancy` functions (`PGOcc()`, `spPGOcc()`, `spMsPGOcc()`, and `msPGOcc()`), enabling single- and multi-species spatial modeling.

`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.

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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

The requested funds will primarily support personnel time for development, testing, and documentation of the new `birdnetTools` functionality. Costs are estimated for a five-month project divided into three milestones tied to deliverables.

Milestone	Timeline	Deliverables	Estimated cost (USD)
Phase 1 - Consultation	2025 Dec.1 - 31	Meet with spOccupancy developers/users to finalize data formats and function specs.	$704
Phase 2 - Development	2026 Jan.1 - Mar.31	Implement core functions, create example workflows.	$3,488
Phase 3 - Testing & release	2026 Apr.1 - 30	Conduct community testing, refine code and documentation	$1,706
Total			$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.