Passive acoustic monitoring reveals seasonal patterns in European green toad calling activity but fails to accurately reflect population abundance (2025)

Introduction

- Over 40% of amphibian species are declining or threatened
- Amphibians make a variety of calls, including courtship, distress, aggressive, and advertisement calls
- Traditionally, human observers approximate presence and abundance at breeding sites based on visual observation and vocalization intensity - however, time-consuming and difficult to do simultaneously
- PAM suggested as alternative
    - Calling intensity (# calls produced in unit time) corresponds to population size?
    - Only males vocalize in many species, and findings have been inconclusive
- Amphibian call index method ranks call density from 0 (no frogs) to 3 (full chorus)
    - Relationship between call index, # calls, and population size has been observed
- Determine whether PAM recordings of European green toads can estimate # of calling males
    - Adaptations allow them to survive in increasingly urban areas
    - High ecological plasticity and tolerance to different environments
    - 5 month reproductive period in which males vocalize to attract females
- Recorded soundscapes in 3 locs, observed # of individuals in 2 of the locs, used automatic signal detection and classification to count males, calculated acoustic indices for calling intensity

Methods

- Sites: Urban area of Poznań in western Poland
    - 2 locations in an urban park established on a former Prussian fortress
        - Shallow artificial ponds with concrete bottoms
    - 1 in a shallow artificial pond with a geomembrane bottom covered with gravel
    - Patchy frog distribution, some populations thriving in city parks and urban wastelands
- Field surveys carried out and sites 1 and 2, with soundscapes recorded using autonomous recorders covering the breeding season of european green toads
- Selected 1-min sound samples every 20 min and annotated vocalizations of European green toads within samples
- Remaining 1-min samples used to develop algorithm for automatic detection and classification, with frequency limits (1000-1700 Hz), additional parameters (duration between 1-4s, max cluster distance of 1, FFT window size of 128, etc.)
    - Pearson, recall/precision calculated for # calls detected manually and automatically
- Acoustic Complexity Index (ACI) and Bioacoustic Index (BI) calculated for 1-min samples and averaged for each full hour

- Evaluated relationship between human observer and outputs of automated acoustic approach using two sets of generalized linear mixed models (GLMMs), considering # calls, ACI and BI

Results

- Strong, significant Pearson correlation between # manually detected and automatically detected calls ($r=0.727$, $p<0.001$)
    - $r=0.36$, $p=0.96$
- ACI and BI showed moderate, statistically significant correlation with # manually detected calls

Discussion

- Passive acoustic monitoring is effective for monitoring occurrence and breeding phenology, but not necessarily population size, as the relationship between soundscape complexity and male abundance is often complex
    - # calls and values of acoustic indices are not correlated with # males present
    - Certain toads have non-calling strategies and remain silent

Estimating Owl Population Density Using Acoustic Spatial Capture-Recapture (2024)

Introduction

- Owls are key predators especially vulnerable to anthropogenic threats, often due to nonmigratory behavior, dependence on forests, and small distributions
    - Over half of all owl species are in decline, necessitating population monitoring
- Lack of information on population trends due to nocturnal behavior
- Autonomous recording units (ARUs) are particularly useful for studying cryptic species and has the potential to study population density through acoustic spatial capture-recapture (SCR)
    - “Captures” as detected calls, “recaptures” as identical call repeated across other ARUs
- Some methods capable of estimating call rate and population density from ARU alone

Methods

- Site: National parks in north-central Georgia, areas >30m from trails or roads containing suitable habitats for owls
- Arrays of four ARUs approximately 100m from each other
- Recordings taken of breeding season, when owls are most vocally active
    - Every other night for 9h
- Detections extracted based on parameters including typical frequency range and duration of owl calls, then manually checked to identify species of interest (Great Horned Owls, Barred Owls, Eastern Screech Owls, etc.)
- Developed capture histories for each detected call signal, indicating which ARUs detected it, and identified individuals using various techniques (classification by sex, # notes, spectrogram cross correlations, etc.)

- Fitted acoustic SCR models to estimate animal density, call rate and detection function parameters

Discussion
- Successfully detected presence and estimated population density for Great Horned Owls but had to estimate call density for Barred Owls due to poor results in clustering
	- Great Horned Owl density estimate similar to known density in other places in the U.S.
- Attempted to filter noise above and below frequency ranges, but impossible to filter out noise occurring at the same frequency, causing difficulty discerning individuals
	- However, SCR is generally effective in discerning individuals
- ARU data can effectively estimate density if ARUs are well distributed, though some species are difficult to estimate due to low call rate

Estimating colony sizes of emerging bats using acoustic recordings (2016)

Introduction
- Decline of bats due to white-nose syndrome, wind turbine collisions, and habitat loss
- Bat censusing needed to guide conservation efforts
- Traditional methods of bat censusing include visual estimation, photographic estimation, mark-recapture, and thermal imaging
	- First three methods are prone to bias, thermal imaging requires expensive materials
- PAM provides low-cost alternative, but still need to find a way to estimate population size

Methods
- Site: Lava tube cave structure on private land in Sierra County, New Mexico
	- 2 caves, each with 700,000-900,000 Mexican free-tailed bats
		- Estimate obtained by extrapolating exact counts using thermal imagery
- Synchronized audio and video recorded for each cave each night
- Every 10 seconds, a video frame and corresponding 1 second audio file were extracted
- 3 acoustic parameters calculated for each clip (root mean square (RMS) pressure, peak-to-peak pressure, total energy) and bat counts extracted from video frames
- Fit linear regression models with bat counts as response variable and each of the 3 acoustic parameters as predictor variables
	- Bat counts log transformed for RMS pressure and peak-to-peak pressure

Results
- Linear regression models predicted bat counts well
- Multiple regression not used as each pair of acoustic parameters were highly correlated
- Analysis of covariance (ANCOVA) revealed non-significant relationship between cave and RMS pressure
	- Relationship between RMS pressure and bat counts likely did not differ by cave

- Video counts and acoustic models agreed when averaged across recording days

Discussion
- First successful usage of PAM data to estimate bat counts
- Significant relationship determined between acoustic pressure and individual count at one cave location
    - Model trained could successfully predict bat count at another cave location
- Data gathered with low-cost equipment and open-source software
- Limitations
    - Method can only be applied to emergence rates of >=10 bats/s
        - Low correlation between acoustic pressure and counts of <10 bats due to circular flight patterns
    - Study was conducted in a cave located in an area, more vegetation in an area may affect stream intensity
    - Method was used on a cave with a single species of bat
    - Method was limited to the period of visible emergence (although the relationship is expected to hold for the entire period and the results can be extrapolated)
    - Further studies need to account for differing heights of emerging bats, species compositions, bat densities and topographies to determine additional factors

[Estimating population size for California spotted owls and barred owls across the Sierra Nevada ecosystem with bioacoustics]() (2023)

Introduction
- Passive acoustic monitoring (PAM) involves using autonomous recording units (ARU) to record, extract detection data, and use for occupancy modeling
    - Potential to support population trend modeling
- Not all individuals recorded by PAM are necessarily residents —> ecological false positives
    - Reduced by greater distances between sites and filtering based on count, timing, etc.
- Combine ecosystem-scale PAM data with local monitoring data to monitor population and estimate abundance
    - Useful strategy for species with both PAM and monitoring data available

Methods
- Species: California spotted owl
    - Associated with forests threatened by large fires and deforestation in Sierra Nevadas
    - Also affected by barred owls, a dominant invasive species
    - Also threatened by rodenticides and rising temperatures causing thermal stress
- Sites: PAM program spanned western slope mixed-conifer forests (as the eastern slope had very few owls)

    - Covered 7/7 national forests, 3/4 national parks, and some private lands
    - Divided into 6236 cells, each 4 km^2
    - Cells were excluded if they crossed highways, were >50% water, or lacked road access
- Deployed 1-3 SwiftOne recorders in each grid
- Trained custom version of BirdNET to identify vocalizations, then manually reviewed
- Used single-season occupancy models applied to generated detections
- Estimated abundance based on converting occupancy estimations to density estimations across ecosystems

Results
- Occupancy was much more widespread and predictable for spotted owls due to barred owl detections being more rare
- Based on occupancy and density estimates, about 2000 spotted owls were found - barred owl density could not be estimated

Discussion
- PAM data can expand the range and precision of occupancy and abundance estimates
- Low detection of barred owls seems in line with extensive removal efforts
- Detections of spotted owls indicate that they are still distributed throughout the Sierra Nevada
- Bioacoustics approach for monitoring population size instead of occupancy should improve understanding of how spotted owls respond to climate change

Acoustic monitoring yields informative bat population density estimates (2024)

Introduction
- Bat population has historically been estimated during the winter, since bats are relatively stationary, but this doesn't necessarily capture migrating bats of that population
    - New methods needed to measure bat populations during non-hibernating periods
- Established methods (capture surveys, counting at roosts) of estimating summer populations are costly and difficult due to bat behavior
- Acoustic monitoring may be a cheaper and more effective alternative
- Density estimation using acoustic data is a new and promising method, for example by using acoustic amplitude correlated with # of bats coming out of a cave
- Generalized random encounter model (gREM) to estimate density and see how density is affected by factors like time and space

Methods
- Sites: 6 state-owned conservation areas in Missouri, 10 sites per area with controls for distance to water bodies to avoid inflated populations
- Species: Indiana bat
- Calls recorded with Anabat Swift detectors along with directional microphones

    - Paper describes exact configurations and settings of microphones
- Decision tree with filter used to identify files with Indiana bat echolocation
    - Accuracy of filter was tested on manually reviewed calls from a known roost
- # of detections may be biased by a single bat triggering the microphone multiple times, so used # of 1-min intervals containing a call instead
- Estimated density based on gREM equations and tested for best fitting distributions
- Compared to counts found from capture and exit counts strategies

Results
- 312,059 total calls recorded, 45,512 of which passed the filter
- 0-806 bats found per km^2, with a mean of 46 pre-volancy and 74 post-volancy
- Acoustic density estimates didn't consistently correlate with exit counts, but were comparable to known colony sizes and capture estimates
- Increased density post-volancy likely caused by increase in pups
- Density estimates varied based on conservation area (clutter in environment, area size, % forest)
- Density estimates could be biased by misidentification of other sounds, bats passing by multiple times, proximity of detectors to roosts and foraging areas
- Overall, PAM data has potential and requires much less labor and time than mist-netting
    - Future work could incorporate covariates, like flight and echolocation behaviors, to improve on using raw acoustic data
    - Could also compare acoustic data and exit counts on known roosts

Assessment of cue counting for estimating bird density using passive acoustic monitoring: recommendations for estimating a reliable cue rate (2021)

Introduction
- Dividing detections by ACR (average cue rate) to estimate bird abundance
- Cue counting assumed to be density dependent, originally developed for whales
    - Found to be effective when used with covariates, such as environmental conditions
    - Can be used without collection of complementary data
    - Requires minimal effort and expertise regarding interpreting recordings
- Obtaining reliable ACRs is a challenge
    - Requires monitoring cue rate over long periods
    - # of individuals and minimum time required to reliably estimate ACR is still unknown
- Study evaluated whether cue counting could infer abundance

Methods
- Species: Dupont's Lark, as vocal behavior already thoroughly studied in previous studies
    - Focused on vocalizing males

- Different cues were clearly defined
- Sites: Guadalajara, Soria, and Lleida provinces in Spain
- Recordings taken at dawn during peak vocal activity, with only vocalizations above a certain amplitude considered
- ACR estimation
    - 1. Calculated ACR of each lark monitored in a previously published study
    - 2. Took directional recordings in study area
    - 3. Download calls from Xeno-Canto database
- Transect surveys conducted near each ARU to count # of individuals
- Cue counts divided by ACR and compared to transect survey results using CIs and regression analysis

Results
- Methods 1&2 of ACR estimation produced similar results, but Xeno-Canto produced much higher ACRs, leading to overestimation of # individuals
- Directional recordings estimated # individuals within 10% of actual counts at 74% of sites
- Longer recordings produced more accurate results when less individuals are counted, and vice versa
- Higher # individuals produced more accurate results

Discussion
- If the ACR is accurate, cue counting can reliably estimate bird density
- Directional recordings are the best method of obtaining accurate ACRs, while Xeno-Canto data is not reliable
- Record >= 10 individuals over several days, under different conditions, and include silent individuals

Estimation of population density of stored grain pests via bioacoustic detection (2016)

Introduction
- >100 species of beetles associated with various grain products like cereals may cause significant damage in storage
- Different methods of detecting stored grain pests
    - Visual inspection, trapping, heat-extraction, acoustic sensors, etc.
    - However, these methods tend to be high cost and limited capacity
- Apart from detection, acoustic monitoring and signal processing techniques may be useful for estimating density of the pest inside the grain mass

(Unfinished because article could not be accessed)

Counting the chorus: A bioacoustic indicator of population density (2024)

Introduction

- Different methods of measuring animal density
    - Distance sampling along point/line transects
    - PAM data methods
        - Triangulation using time of detection, direction of arrival
        - Distance estimation based on sound pressure
        - Vocal activity rates, detection rates
- Call density - alternative method based on proportion of audio windows containing target sound, independent of classifier performance

Methods

- Sites: 4 sites in Hawai'i with varying levels of historical damage from cattle grazing or logging, and restoration
- Species: 8 native forest bird species
    - Previously suffered from diseases like malaria, so less sensitive sites were picked
- Bird density estimates
    - Pop surveys conducted using point-transect distance sampling
    - Densities, variances and 95 CIs estimated using R package "distance"
- Call density estimates
    - Recordings analyzed and custom classifiers trained in perch
    - Took samples of clips and sorted into bins based on confidence scores
    - In each bin, manually checked clips to see how many actually had the call
    - Shows likelihood of an actual call in each range of confidence scores
    - Compared to DCAT (detection counts above a threshold) and DR (detection rate)

Results

- Moderate to strong correlations between bird densities and DCAT, but poor predictive power
- Strong correlations between bird densities and call density, with strong predictive power

Discussion

- Call density can be an effective indicator for bird density
    - Dense, highly vocal animal populations in PAMs can be challenging
- Call density is more robust to variation in density and classifier performance
- DR might be more useful for smaller group sizes