**Course overview:**

The study of animal acoustic signals is a central tool for many fields in behavior, ecology, evolution and biodiversity monitoring. The accessibility of recording equipment and growing availability of open-access acoustic libraries provide an unprecedented opportunity to study animal acoustic signals at large temporal, geographic and taxonomic scales. However, the diversity of analytical methods and the multidimensionality of these signals posts significant challenges to conduct analyses that can quantify biologically meaningful variation. The recent development of acoustic analysis tools in the R programming environment provides a powerful means for overcoming these challenges, facilitating the gathering and organization of large acoustic data sets and the use of more elaborated analyses that better fit the studied acoustic signals and associated biological questions. The course will introduce students on the basic concepts in animal acoustic signal research as well as hands-on experience on analytical tools in R.

By the end of the course, participants should:

* Understand the basic concepts of bioacoustics and how animal acoustic signals are analyzed
* Gain proficiency in handling and manipulating acoustic data in R, including working with 'wave' objects and other audio formats
* Develop skills in building and interpreting spectrograms using Fourier transform techniques and the seewave package in R
* Import Raven Pro annotations into R and refine these annotations with warbleR functions
* Understand how to quantify the structure of acoustic signals through various approaches
* Gain experience in quality control of recordings and annotations, ensuring data integrity and accuracy
* Compare different methods for quantifying acoustic signal structure and understand the implications of each approach

Intended Audience

* Academics and post-graduate students conducting research in bioacoustics, animal behavior, ecology, or related fields
* Applied researchers and analysts in public, private, or non-profit organizations who require robust, reproducible, and flexible tools for analyzing acoustic data
* Current R users seeking to expand their knowledge into the field of bioacoustics and learn how to utilize specialized packages for acoustic analysis
* Wildlife biologists, and conservationists interested in leveraging bioacoustic methods for species monitoring and behavioral studies
* Data scientists and programmers interested in applying their coding skills to the analysis of animal acoustic signals

Venue – Delivered remotely

Time zone – UK (GMT)

Availability – TBC

Duration – 4 days / 4 hours a day

Contact hours – Approx. 20 hours

ECT’s – Equal to 3 ECT’s

Language – English

PLEASE READ – CANCELLATION POLICY: Cancellations are accepted up to 28 days before the course start date subject to a 25% cancellation fee. Cancellations later than this may be considered, contact oliverhooker@prstatistics.com. Failure to attend will result in the full cost of the course being charged. In the unfortunate event that a course is cancelled due to unforeseen circumstances a full refund of the course fees will be credited.

Teaching Format

Introductory lectures on the concepts and refreshers on R usage. Intermediate-level lectures interspersed with hands-on mini practicals and longer projects. Data sets for computer practicals will be provided by the instructors, but participants are welcome to bring their own data.

Assumed knowledge

A basic understanding of statistical, biological research and bioacoustics concepts.

Assumed computer background

Good familiarity with R. Ability to import/export data, manipulate data frames and generate simple exploratory plots.

Sure! Here is an expanded description of each topic within the bioacoustics course program:

**Day 1**

**Introduction**

- **How animal acoustic signals look like?**

An overview of the variety of acoustic signals produced by animals, with examples from different species. This includes visualizing sound waves and spectrograms to understand their structure and complexity.

- **Analytical workflow in bioacoustics research**

Introduction to the step-by-step process involved in bioacoustic research, from recording and data collection to analysis and interpretation. This session will outline the typical workflow, emphasizing the importance of each step.

- **Advantages of programming**

Discussion on the benefits of using programming languages like R for bioacoustic analysis, including reproducibility, efficiency, and the ability to handle large datasets. This will highlight how programming can enhance research capabilities.

**What is sound?**

- **Sound as a time series**

Explanation of how sound can be represented as a time series, with each point in the series representing the sound pressure level at a given moment in time. This forms the basis for further analysis and manipulation.

- **Sound as a digital object**

Discussion on the digitization of sound, including sampling rates, bit depth, and the conversion of analog sound waves into digital formats that can be analyzed using software.

- **Acoustic data in R**

Introduction to handling and analyzing acoustic data in R. This includes importing sound files, basic data exploration, and visualization techniques.

- **‘wave’ object structure**

Explanation of the ‘wave’ object in R, its structure, and the information it contains. This is essential for understanding how to manipulate and analyze sound data in R.

**- ‘wave’ object manipulations**

Techniques for manipulating ‘wave’ objects, including trimming, concatenating, and modifying sound files. Practical exercises will be provided to reinforce these concepts.

**- Additional formats**

Overview of other audio file formats (e.g., MP3, FLAC) and how they can be converted and used in R for bioacoustic analysis.

**Day 2**

***Building spectrograms***

**- Fourier transform**

Explanation of the Fourier transform and its application in converting time-domain signals into frequency-domain representations. This is the foundation for creating spectrograms.

**- Building a spectrogram**

Step-by-step guide on how to construct spectrograms, including parameter selection (e.g., window size, overlap) and interpretation of the resulting visual representations.

**- Characteristics and limitations**

Discussion on the strengths and limitations of spectrograms, including resolution trade-offs and potential artifacts. Participants will learn to critically evaluate spectrograms.

**- Spectrograms in R**

Practical session on generating and customizing spectrograms in R using the seewave package. Participants will create spectrograms from their own data.

***Package seewave***

**- Explore, modify and measure ‘wave’ objects**

Hands-on exploration of the seewave package, focusing on functions for modifying and measuring 'wave' objects. This includes exercises on filtering, re-sampling, and extracting acoustic features.

**- Spectrograms and oscillograms**

Creating and interpreting both spectrograms and oscillograms in R. Participants will learn to visualize sound data in different ways to highlight various aspects of the signal.

**- Filtering and re-sampling**

Techniques for filtering (e.g., band-pass, high-pass) and re-sampling sound files to focus on specific frequency ranges or standardize sampling rates.

**- Acoustic measurements**

Using the seewave package to perform detailed acoustic measurements, such as peak frequency, dominant frequency, and frequency range. Practical examples will be provided.

**Day 3**

***Annotations***

**- Introduction to the Raven Pro Interface**

A guided tour of the Raven Pro software, its main features, and interface elements. Participants will learn how to navigate the software efficiently.

**- Introduction to selections and measurements**

Instruction on how to make selections within sound files and take basic measurements such as duration and frequency using Raven Pro.

**- Saving, retrieving, and exporting selection tables**

How to save, retrieve, and export selection tables in Raven Pro for further analysis. This session will cover best practices for data management and organization.

**- Using annotations**

Techniques for annotating sound files in Raven Pro, including the use of labels and notes to mark significant events or features within the recordings.

***Quantifying acoustic signal structure***

**- Spectro-temporal measurements (spectro\_analysis())**

Introduction to the spectro\_analysis() function in R for extracting spectro-temporal measurements from audio recordings. Participants will learn to describe acoustic signals in terms of their temporal and spectral characteristics.

**- Parameter description**

Detailed explanation of key acoustic parameters, such as duration, frequency range, and amplitude, and how they are used to describe sound signals.

**- Harmonic content**

Techniques for analyzing the harmonic content of signals, including identifying harmonic series and measuring harmonic-to-noise ratios.

**- Cepstral coefficients (mfcc\_stats())**

Introduction to Mel-frequency cepstral coefficients (MFCCs) and their use in characterizing the timbral properties of sound signals. Participants will use the mfcc\_stats() function to extract MFCCs.

**- Cross-correlation (cross\_correlation())**

Explanation of cross-correlation techniques for comparing sound signals. Participants will use cross\_correlation() to measure the similarity between different recordings.

**- Dynamic time warping (freq\_DTW())**

Introduction to dynamic time warping (DTW) and its application in aligning and comparing time-series data. The freq\_DTW() function will be used to compare sound signals.

**- Signal-to-noise ratio (sig2noise())**

Techniques for calculating the signal-to-noise ratio (SNR) of recordings, which is crucial for assessing the quality of sound data.

**- Inflections (inflections())**

Identifying and measuring inflections in sound signals, which can indicate changes in pitch or other dynamic features.

**- Parameters at other levels (song\_analysis())**

Exploring acoustic parameters at higher hierarchical levels, such as entire songs or sequences of vocalizations, using the song\_analysis() function.

**Day 4**

***Quality control in recordings and annotations***

**- Create catalogs**

Compiling catalogs of annotated sound files, which can be used for further analysis or as reference materials.

**- Check and modify sound file format (check\_wavs(), info\_wavs(), duration\_wavs(), mp32wav() y fix\_wavs())**

Techniques for checking and modifying sound file formats using various functions in R. This includes converting files, checking file integrity, and fixing common issues.

**- Tuning spectrogram parameters (tweak\_spectro())**

Adjusting spectrogram parameters to optimize the visualization and analysis of sound signals. Participants will use tweak\_spectro() to fine-tune their spectrograms.

**- Double-checking selection tables (check\_sels(), spectrograms(), full\_spectrograms() & catalog())**

Methods for verifying and refining selection tables, ensuring that all annotations are accurate and comprehensive.

**- Re-adjusting selections (tailor\_sels())**

Techniques for re-adjusting selections in response to quality control checks, ensuring that all annotations are precise and correctly positioned.

***Characterizing hierarchical levels in acoustic signals***

**- Creating ‘song’ spectrograms (full\_spectrograms(), spectrograms())**

Building spectrograms that represent entire songs or sequences of vocalizations, providing a higher-level view of acoustic patterns.

**- ‘Song’ parameters (song\_analysis())**

Measuring and analyzing parameters at the song level, such as song duration, number of elements and element rate, using the song\_analysis() function.

**Day 5**

***Choosing the right method for quantifying structure***

**- Compare different methods for quantifying structure (compare\_methods())**

Comparing various methods for quantifying acoustic signal structure. Participants will use compare\_methods() to evaluate different approaches.

***Quantifying acoustic spaces***

**- Intro to PhenotypeSpace**

Introduction to the concept of acoustic spaces and the PhenotypeSpace framework, which allows for the visualization and comparison of acoustic diversity.

**- Quantifying space size**

Techniques for measuring the size of acoustic spaces, which can provide insights into the variability and complexity of vocalizations.

**- Comparing sub-spaces**

Methods for comparing different sub-spaces within the overall acoustic space, allowing for the analysis of variations between species, populations, or other groups.

*Each of these topics will be covered with detailed explanations, practical examples, and hands-on exercises to ensure that participants gain a comprehensive understanding of bioacoustics research using the R platform.*