

BATscreen PRO

for Windows XP / Vista / 7 / 8 / 8.1 / 10 / 11

USER MANUAL

bat bio acoustic technology

Version: 3.2.2

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1. Introduction

BATscreen PRO is a powerful and easy to use tool for the analysis and classification of bat call files.

Files recorded with BATmode-Systems or other systems utilizing ultrasonic recording hardware of Avisoft Bioacoustics as well as files produced by the batcorder of ecoobs are displayed as spectrograms in the main window of the application. An automized bat call detector based on neural networks, multiple markers, zooming tools, power density spectra as well as adjustable audio playback enable the user to identify bat calls and assign them to different bat species.

Since long-term acoustic monitoring of bat activity on wind turbines produces a lot of data, the application focuses on a fast and intuitive visualization and classification of the recorded files. Evaluated bat data can be exported in Probat compatible files, to allow a fast and easy calculation of shutdown times and cut-off wind speeds.

2. Hard- and Software Requirements

To run the software a Windows™ XP/Vista/7/8/8.1/10 PC with at least 8 GB RAM and about 50 MB free hard-disk space is required.

3. Supported Files

BATscreen PRO supports ".wav" and ".raw" files, which are recorded ,e.g., with the BATmode-System or other recordings hardware of Avisoft Bioacoustics, the AudioMoth from OpenAcousticDevices as well as with the batcorder of ecoobs. Since spectrogram calculation is memory extensive, file length is limited to 120s. For longer files, only the first 120s can be analysed.

4. Installation

To install the software, run the installation program either from the supplied USB flash drive (Setup_BATscreenPRO_X.X.X.exe) or the website of bat bioacoustictechnology (www.bioacoustictechnology.de).

Free software updates that provide bug fixes and improved functionality are available from www.bioacoustictechnology.de.

5. License

BATscreen PRO includes a free trial license with limited functionality. To use all features please purchase a BATscreen PRO license. Several licenses are available:

- Single License for a single PC that is identified by its Signature ID
- Enterprise License for all PCs of a company

You can check the current license status and retrieve the Signature ID of your PC in the LICENSE INFORMATION DIALOG that you find in the menu option ? -> LICENSE (see Figure 1).

To purchase a license please send us an email (info@bioacoustictechnology.de), which includes the Signature ID of your PC.

Licenses are sold as individual license files. To activate a purchased license please copy the retrieved license file to a freely selectable location on the hard disc of your PC. Subsequently, set the path to the License File in the LICENSE INFORMATION DIALOG.

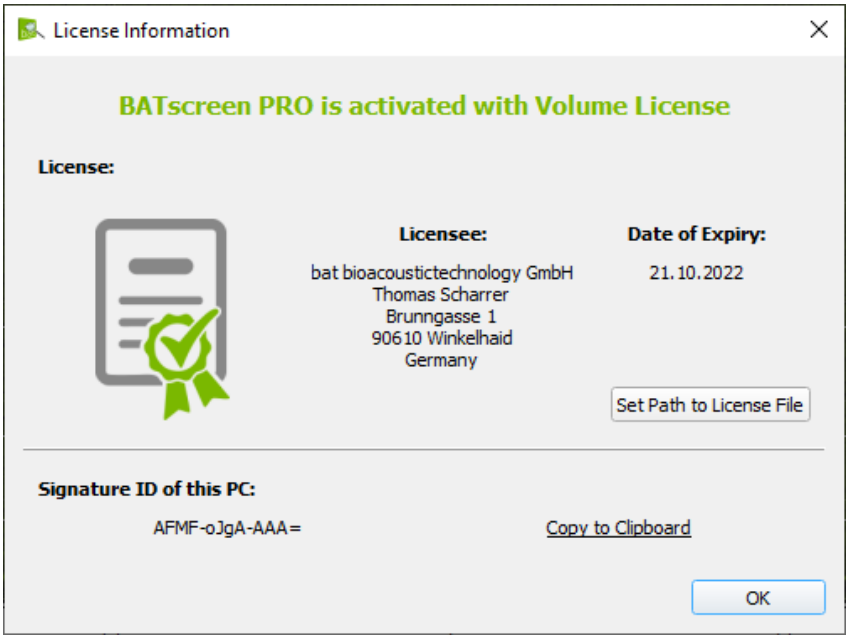

Figure 1: License Information Dialog

6. Getting Started

The following procedure describes the basic visualization of recorded bat call files:

- Start BATscreen PRO
- Select the file/folder that you want to visualize either by menu option FILE -> OPEN FILE or FILE -> OPEN FOLDER (see Figure 2).

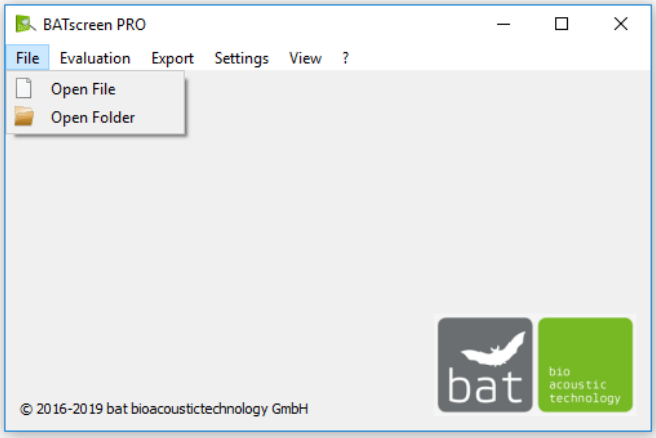

Figure 2: Start Window

Optionally, you can also use “drag & drop” to visualize a file/folder you choose in the explorer.

- After spectrogram calculation, the file or first file in a folder is visualized in the Main Window Area (see Figure 3). In default mode, the Time-Axis Plot shows the normalized transient amplitude envelope of the time signal in dark green and the respective moving RMS values of the time signal in light green. The Frequency-Axis Plot depicts the power density spectrum and the Spectrogram Plot shows the corresponding spectrogram.
- Right next to the plots the automatically detected calls of the AI Call Detector are shown in the AI Call list and manually labeled calls loaded from the WAV-file header are shown in the Manual Labels list.
- If a folder with multiple bat call files was selected, a list of all files is shown below the Main Window Area.
- You can open a file by double clicking on the desired list entry, using the arrow keys of the keyboard or the two arrow buttons right next to the file list.
- To zoom in, select the Zoom Cursor Selection in the tool bar and span a rectangular around the area you want to enlarge in the spectrogram by using the left mouse button. The depicted time and frequency period is marked in the upper x-axis and lower left y-axis plot, respectively.
- To zoom out, click on the right mouse button.
- To start the audio playback of the opened file, please use the audio control buttons in the upper left corner or the respective keyboard short cuts (<F1> - <F3>).

7. Main Window Area

The Main Window Area shows in the tool bar AUDIO CONTROLS, CURSOR SELECTION buttons, a SPECTROGRAM ADJUSTMENT section, the LOAD COMPLETE FILE BUTTON and a FILE INFORMATION section (see Figure 3). Below, you find the plot area. It consists of the main SPECTROGRAM PLOT as well as a corresponding TIME-AXIS PLOT above the spectrogram and a FREQUENCY-AXIS PLOT on the left of the spectrogram. While the AI CALLS list at the right side lists all bat calls detected by the AI Call Detector and respective species suggestions, the MANUAL LABELS list lists all manually labeled calls within the file.

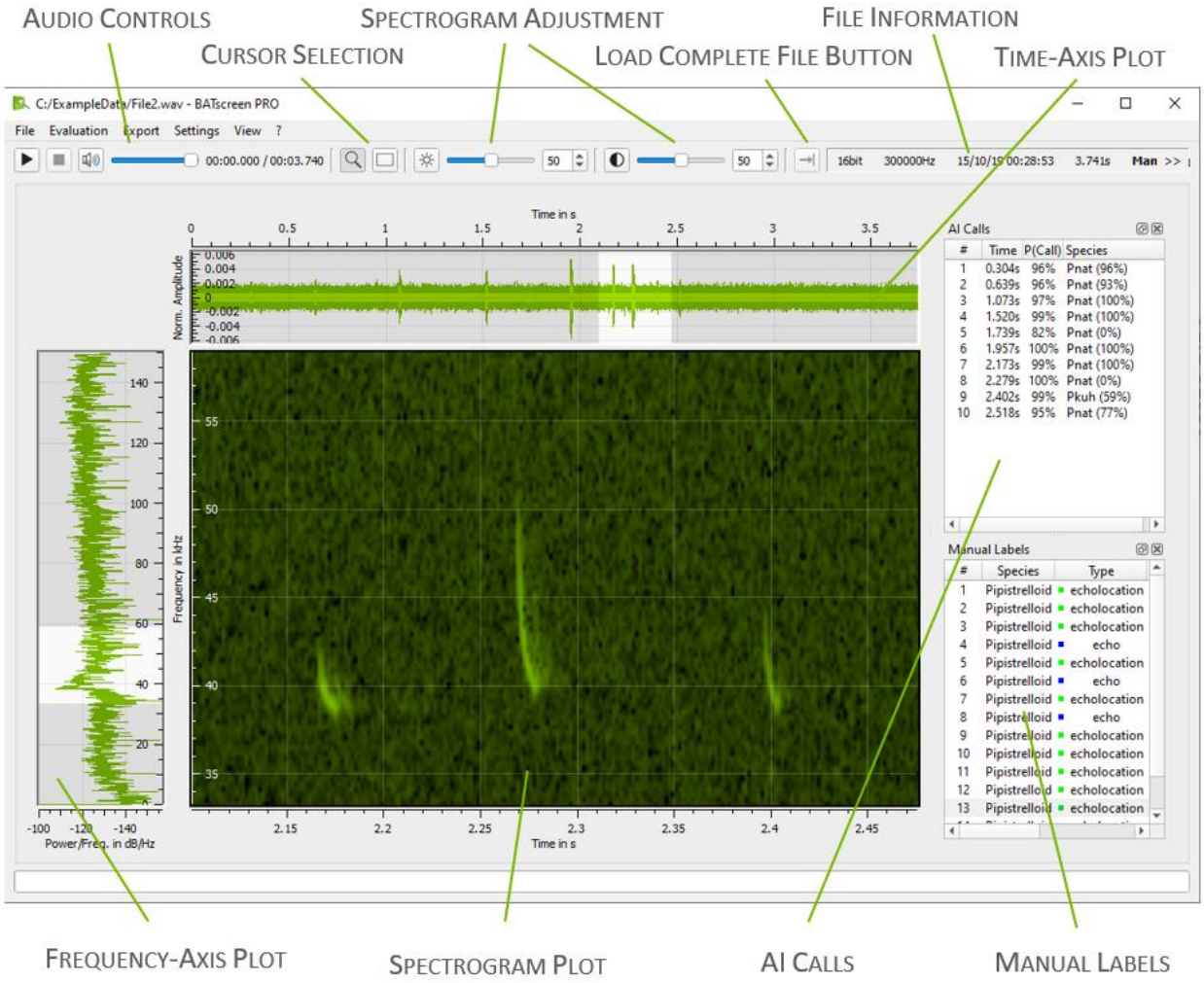

Figure 3: Main Window Area

Audio Controls

Press the ▶ button or <F1> to play the current loaded file. Use ⏸ or <F1>to pause and ■ or <F2> to stop playback. The volume can be adjusted or muted by the slider, the 🔊 button or <F3>, respectively.

To change the playback rate, set undersampling or configure a frequency mixer please use the menu SETTINGS -> AUDIO SETTINGS.

Cursor Selection

For a detailed inspection of the spectrogram, you can either use zooming or marking of interesting areas.

If the 🔍 button is selected, span a rectangular around the area you want to enlarge by using the left mouse button. To zoom out, click on the right mouse button.

If the ⬚ button is selected, span a rectangular around the area you want to mark by using the left mouse button. The time and frequency range as well as the start and stop point of the marked area are depicted next to the rectangular (see Figure 3). Use the mouse to adjust the rectangular by “drag & drop” mechanism. To delete the rectangular, press the right mouse button.

To use the marking option, when the zooming cursor is enabled, you can also span a rectangular by using the left mouse button and simultaneously pressing the <Shift>-key instead of selecting the marking cursor. To delete the rectangular, press the <Esc>-key.

To use the zooming option, when the marking cursor is enabled, you can also span a zooming rectangular by using the left mouse button and simultaneously pressing the <Shift>-key instead of selecting the zooming cursor. To zoom out, press the <Esc>-key.

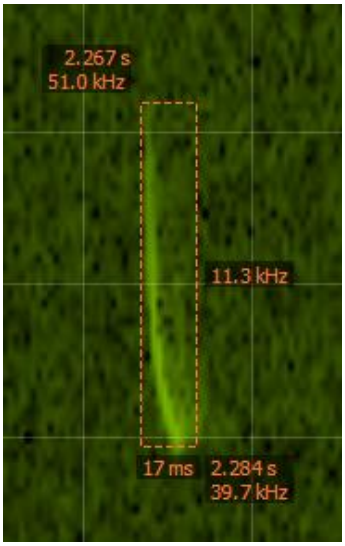

Figure 4: Marked rectangular in spectrogram

Spectrogram Adjustment

Use the SPECTROGRAM ADJUSTMENT section to adjust the contrast and the brightness of the SPECTROGRAM PLOT. By clicking the  or  button the brightness or the contrast are reset to 50, respectively.

Load Complete File Button

For a time-efficient evaluation of audio files, BATscreen PRO allows to initially load only a certain time period from the beginning of the file (see section 11). By clicking the LOAD COMPLETE FILE BUTTON or pressing <F5> the remaining data in the file is loaded.

File Information

In the FILE INFORMATION section, you find the Bits/Sample, the Samplerate, the recording Timestamp and Length of the currently loaded file. Furthermore, the in the WAV-file header saved species assignments of the different evaluation methods as well as user notes are shown. By using the right-click menu, you can decide which information is shown in the FILE INFORMATION section. For further information saved in the WAV-file header press the Button. BATscreen PRO can read BEXT (from Avisoft Bioacoustics), WAMD (from Wildlife Acoustic), ID3 (from AudioMoth of OpenAcousticDevices) and GUANO headers. For a convenient processing BATscreen PRO converts the relevant header information from all the named header types to a GUANO header.

Time-Axis-Plot

The TIME-AXIS PLOT depicts various file information, which are plotted vs. the time axis.

To change the plot type, use the menu SETTINGS -> AXIS PLOTS SETTINGS.

Frequency-Axis-Plot

The FREQUENCY-AXIS PLOT depicts various file information, which are plotted vs. the frequency axis.

To change the plot type, use the menu SETTINGS -> AXIS PLOTS SETTINGS.

Spectrogram Plot

The SPECTROGRAM PLOT displays multiple short time signal spectra. Each spectrum is placed as vertical single line next to the previous one. By this, the vertical axis becomes the frequency scale and the amplitude information of the spectrum is converted to color or intensity for the single line. By placing multiple short time spectra next to each other, the display horizontal axis becomes the “time axis”, and the three dimensions of the signal are all visible (Frequency, Amplitude, Time).

AI Calls

The AI CALLS list shows the result of the AI Call Detector (see chapter 20). While the first two columns list the number and time-in-file of the detected calls, the third column P(Call) depicts the probability of a bat call at the specified time-in-file. The 4th column shows the species suggestion with the highest probability. The respective probability is depicted in parentheses. If a probability of – is given, this species suggestion was determined by the Maximum Likelihood Ratio Test. By hovering over the items, the detected call positions are shown as vertical magenta lines with species label at the respective temporal position in the spectrogram.

Manual Labels

The MANUAL LABELS list lists all manually labeled calls saved in the WAV header. Each labeled call is assigned to a species (2nd column) and a type (3rd column) and is defined by its start time (4th column), end time (5th column), minimal frequency (6th column) and maximal frequency (7th column). By hovering over the items, the labeled calls are shown as colored bounding boxes at the respective position in the spectrogram. To add new calls or change existing ones use the MANUAL CALL LABELING evaluation mode (see section 16).

8. File Menu

To open a new file, select OPEN FILE in the FILE menu. To open a new folder, select OPEN FOLDER.

Optionally, you can also use “drag & drop” mechanism to visualize a file/folder you choose in the explorer.

If a folder was selected, a list of all supported files in the folder is shown below the Main Window Area (see Figure 5). Subsequently, the header information of all files is loaded in the list. The progress bar right next to the list gives you feedback of how many files the header is already loaded.

Use the or button to select the view of the files list. In the list view detailed, information of the file including all species assignments saved in the WAV file header are shown (see Figure 5). In the thumbnail view (see Figure 6), a small spectrogram thumbnail is shown. The temporal length of the thumbnail is 0.2s. The temporal position of the thumbnail with respect to the file can be adjusted in the SPECTROGRAM SETTINGS.

You can open a file by double-clicking on the desired list entry, using the <Left> and <Right> arrow keys of the keyboard or the two arrow buttons and on the right of the file list (supported files see section 3).

The right-click menu of the files list header allows to select which header information is shown in the files list.

Use the right-click menu of the files list to export the visible header information of selected files as CSV-file. Furthermore, it is also possible to copy selected files to the Clipboard or delete them permanently.

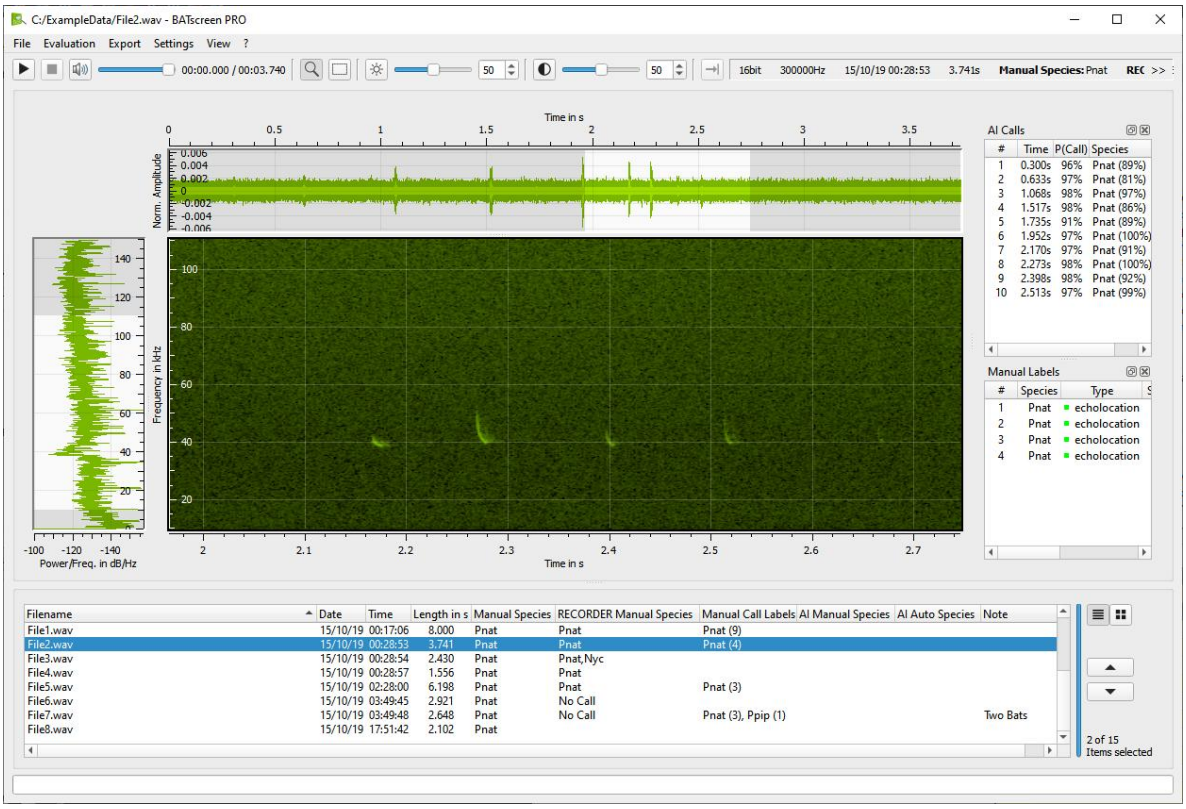

Figure 5: Open Folder Window – List View

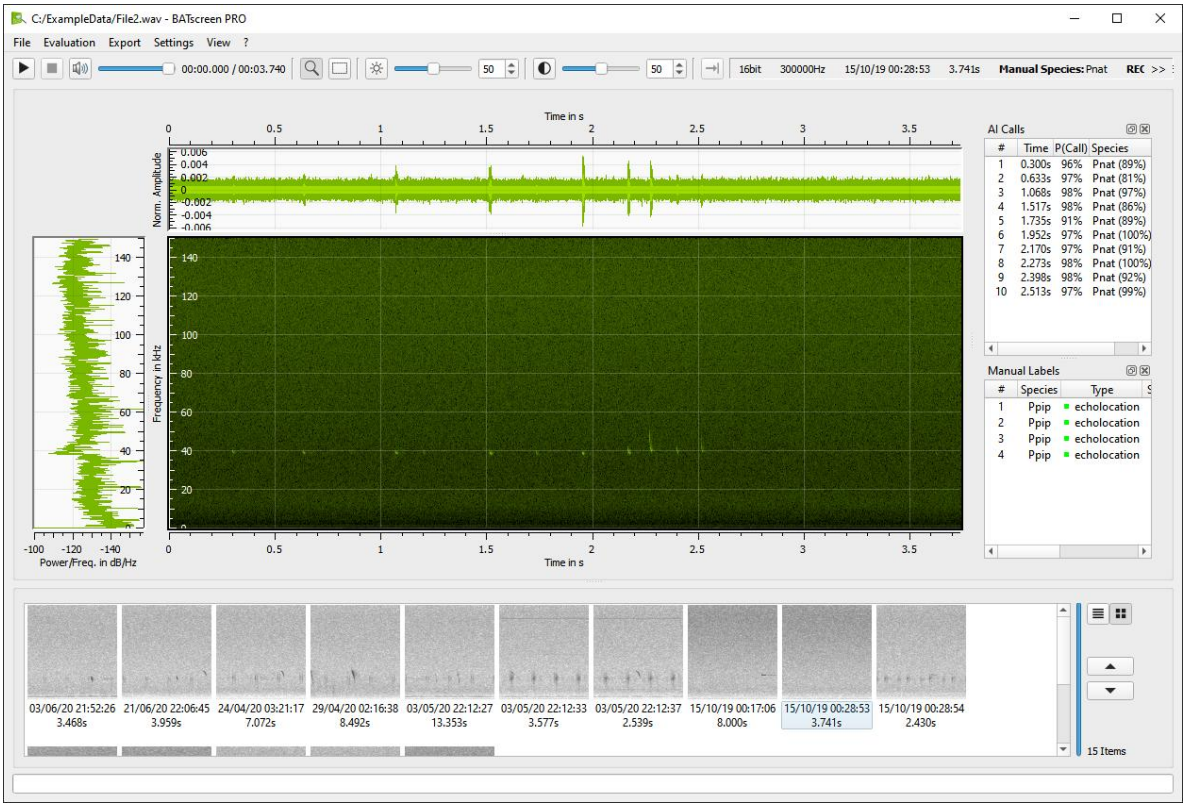

Figure 6: Open Folder Window – Thumbnail View

9. Evaluation Menu

Manual Evaluation

To start the manual evaluation and classification of bat call files with your own classification model, select MANUAL EVALUATION and in the sub menu FILES IN FOLDER or FILES DEFINED IN CSV FILE respectively. Read Chapter 13 for further information about the manual evaluation and classification procedure.

Manual Review of RECORDER WEA Offline Analysis

Since version 4.2.28, which was released on the 10th December 2018, the Avisoft-RECORDER USGH software of Avisoft Bioacoustics includes the so-called *WEA Offline Analysis* configuration preset. This offline analysis preset was developed and defined in the research project RENEBAT III and enables a standardized automated post-recording step for the evaluation of bat call files recorded with the BATmode or any other hardware based on the UltraSoundGate of Avisoft Bioacoustics. It detects noise-triggered files and if possible, assign bat calls to specific bat species. By this, the manual evaluation in BATscreen PRO before importing the dataset into the Probat software can be shortened significantly.

For more information on the automated WEA Offline Analysis with the software Avisoft-RECORDER USGH, please read the manual of the Avisoft-RECORDER USGH software.

To start the manual review of data, which was already analysed with the automated RECORDER WEA Offline Analysis, please press EVALUATION -> MANUAL REVIEW OF RECORDER WEA OFFLINE ANALYSIS.

Read Chapter 14 for further information about the WEA Offline Analysis with Avisoft-RECORDER USGH and the manual review with BATscreen PRO.

Manual Review of AI Call Detector Analysis

As of version 3.0.0 an automated AI Call Detector is integrated in BATscreen PRO. This AI Call Detector is based on convolutional neural networks and a Maximum-Likelihood-Ratio-Test. It detects bat calls and identifies the corresponding bat species. The MANUAL REVIEW OF AI CALL DETECTOR ANALYSIS allows to analyse all WAV-files in a folder with the AI Call Detector automatically. Subsequently, the user can review the suggestions of the AI Call Detector and identify wrong call and species identifications time-efficiently.

To start the MANUAL REVIEW OF AI CALL DETECTOR ANALYSIS, please press EVALUATION -> MANUAL REVIEW OF AI CALL DETECTOR ANALYSIS.

Read Chapter 20 for further information on the AI Call Detector and section 15 for the manual review with BATscreen PRO.

Manual Call Labeling

While all other evaluation methods of BATscreen PRO, namely the MANUAL FOLDER EVALUATION, the MANUAL REVIEW OF RECORDER WEA OFFLINE ANALYSIS and the MANUAL REVIEW OF AI CALL DETECTOR ANALYSIS aim to assign complete files to one or more bat species, the MANUAL CALL LABELING method is a tool to manually mark calls with rectangular bounding boxes. Each bounding box can be assigned to a species as well as a call type.

To start the MANUAL CALL LABELING method, please press EVALUATION -> MANUAL CALL LABELING.

Read Chapter 16 for further information on the MANUAL CALL LABELING method.

AI Call Detector Performance Evaluation

The AI Call Detector detects bat calls in audio files and make respective species suggestions. As background noises in audio files can have many different causes, it is impossible to cover the whole variety of potential noises in the detector training process. Consequently, it is important to assess the performance and accuracy of the bat call detection process for a specific dataset of audio files prior to evaluate the dataset with the AI Call Detector.

For more information on the AI Call Detector and the AI CALL DETECTOR PERFORMANCE EVALUATION, please read Chapter 17.

To start the AI Call Detector Evaluation, please press EVALUATION -> AI CALL DETECTOR PERFORMANCE EVALUATION.

Activity Plots

In many cases, plots can help to detect correlations in large datasets. The ACTIVITY PLOTS feature of BATscreen PRO allows correlating a dataset of bat call files to different parameters, like night-time, month, temperature, wind speed or precipitation. Please read Chapter 18 for further information about the ACTIVITY PLOTS feature.

To start the ACTIVITY PLOTS feature, the headers of all files in the respective evaluation folder has to be loaded to the list view. Please wait until the blue progress bar right next to the list completes.

Microphone Sensitivity / Recording Periods Validity

The BATmode bat detector logs daily measured microphone sensitivity as well as system calibration and recording periods. Select EVALUATION -> MICROPHONE SENSITIVITY / RECORDING PERIODS VALIDITY to evaluate these data and get an evaluation of valid recording periods. Please read Chapter 19 for further information about the MICROPHONE SENSITIVITY / RECORDING PERIODS VALIDITY feature.

10. Export Menu

Export Time Axis Plot

To export the current time-axis plot, select EXPORT -> EXPORT TIME AXIS PLOT.

Supported export formats are:

- Vector graphics: pdf, svg and ps.
- Images: bmp, jpg, jpeg, pbm, pgm, png, ppm, xbm and xpm.

Export Frequency Axis Plot

To export the current frequency-axis plot, select EXPORT -> EXPORT FREQUENCY AXIS PLOT.

Supported export formats are:

- Vector graphics: pdf, svg and ps.
- Images: bmp, jpg, jpeg, pbm, pgm, png, ppm, xbm and xpm.

Export Spectrogram Plot

To export the current spectrogram, select EXPORT -> EXPORT SPECTROGRAM PLOT.

Supported export formats are:

- Vector graphics: pdf, svg and ps.
- Images: bmp, jpg, jpeg, pbm, pgm, png, ppm, xbm and xpm.

Export CSV-File

To export your current loaded files and examination as CSV (comma-separated values) file, click EXPORT -> EXPORT CSV FILE.

In the EXPORT CSV FILE dialog check all classes, which should be included in the exported CSV-file. All files, which are assigned to at least one checked class, are included in the export file.

Set the TIME SETTINGS since this information is needed to calculate the OUTPUT OF CLASS EVENTS.

OUTPUT OF CLASS EVENTS

A class event is triggered when the recording start time of at least on recorded file is within a specific time interval (1min/5min/10min). No other files with recording start times within this time interval will trigger an additional class event. The time intervals can be either static or dynamic. Static time intervals are fixed intervals in relation to the time of day, e.g. from 12:05:00 – 12:09:59 (5min interval) or from 17:30:00 – 17:30:59 (1min interval). Dynamic time intervals start at the recording start time of the class event-triggering file. This means, if the recording start time of a class event-triggering file is at 20:22:45 the time interval for a 10 min dynamic interval is 20:22:45 – 20:32:44. To include an additional column, with for example the 1min class event, in the exported CSV-file, please enable the respective checkbox. Class events are calculated separately for each assigned class. If a file triggers a class event, the triggering class is included in the respective class event column. If several assigned classes of

a file trigger a class event, they are inserted in the column separated by commas. Table 1 depicts an example for an exported CSV-file with static and dynamic 5min class events.

Table 1: Sample of CSV Export with different class events

FileName	Date	Time	Class1	Class2	5min class event (static)	5min class event (dynamic)
File1.wav	23.11.2017	16:25:30	Nyc	Pip	Nyc, Pip	Nyc, Pip
File2.wav	23.11.2017	16:28:38	Nyc			
File3.wav	23.11.2017	16:30:25	Nyc		Nyc	
File4.wav	23.11.2017	16:32:07	Nyc	Pip	Pip	Nyc, Pip
File5.wav	23.11.2017	16:32:34	Nyc			
File6.wav	23.11.2017	16:35:03	Nyc	Pip	Nyc, Pip	

To start the EXPORT CSV FILE functionality the headers of all files in the evaluation folder files list has to be loaded to the list view. Please wait until the blue progress bar right next to the list completes.

A CSV-file can be opened and edited with Microsoft Excel or other spreadsheets.

Export Probat File

To export your current loaded files and examination as Probat compatible file click EXPORT -> EXPORT PROBAT FILE. In the EXPORT PROBAT FILE dialog (see Figure 7), check all classes, which should be included in the export file. Since Probat considers all included classes in the export file as bat calls, all noise and no call classes have to be unchecked. This is only necessary for the export of a Probat file when you are using MANUAL FOLDER EVALUATION. When evaluating a folder with the MANUAL REVIEW OF RECORDER WEA OFFLINE ANALYSIS you do not have to check or uncheck the desired classes.

By selecting the appropriate time zone in which your data was recorded as well as if daylight saving was considered or not, all recording times of your files are adapted in the export file to UTC +02:00 (MESZ), the required time zone for Probat.

For further information about the required data format of Probat please read the documentation of Probat (http://windbat.techfak.fau.de/tools/).

To start the EXPORT PROBAT FILE functionality the headers of all files in the evaluation folder files list has to be loaded to the list view. Please wait until the blue progress bar right next to the list completes.

Since Probat accepts only files, in which all data is recorded within one year, BATscreen PRO will ask you to convert the timestamps of all data in the export file to one desired year, if multiple years are detected.

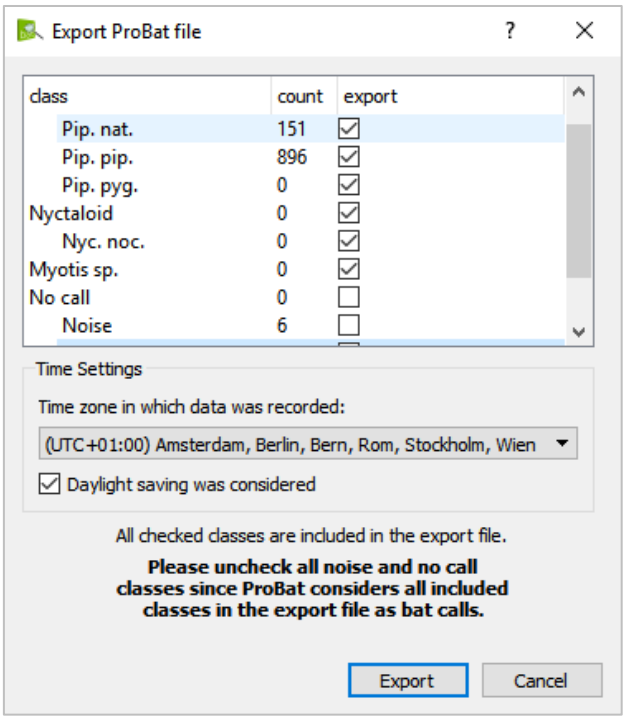

Figure 7: Export ProBat File Dialog

Copy Audio Files

To separate audio files assigned to different classes, it may be necessary to copy all files assigned to a specific class to another folder.

Click EXPORT -> COPY AUDIO FILES to select the new folder and open the COPY AUDIO FILES dialog. Files, which are assigned to at least one checked class, are copied to the selected new folder.

To start the COPY AUDIO FILES functionality the headers of all files in the evaluation folder files list has to be loaded to the list view. Please wait until the blue progress bar right next to the list completes.

If you use the Copy Audio Files feature in the AI CALL DETECTOR PERFORMANCE EVALUATION mode, it is possible to copy a proportion of the shuffled WAV files to another folder. The selected number of files from the beginning of the shuffled files list is copied to the specified folder (further information read section AI Call Detector Performance Evaluation).

11. Settings Menu

Spectrogram Settings

The spectrogram settings allow adjusting the displayed spectrogram to get the most possible information about the sound signal.

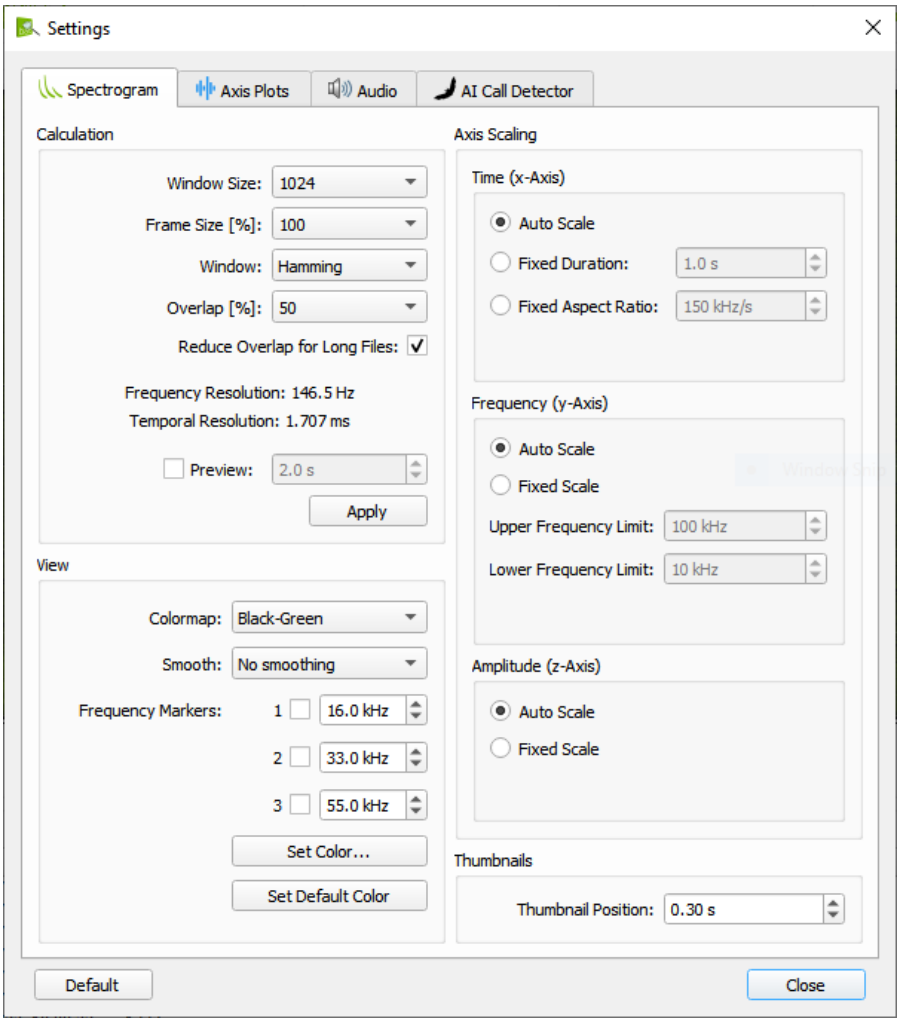

Figure 8: Spectrogram Settings

CALCULATION

The WINDOW SIZE determines the number of sample points used to calculate the short time spectra. Larger Window Sizes increase the frequency resolution of the spectrogram. However, temporal resolution is reduced, simultaneously.

The FRAME SIZE determines the percentage of the FFT length that is actually used for the spectrum computation (zero-padding). Low values will result in a higher time resolution. This is accompanied by lower frequency resolution. A frame size of 100% is recommended for normal applications.

The evaluation WINDOW determines the suppression of the unwanted spectrum distortion (so called “side lobes” that are associated with the analysis of stationary signals) and the analysis

bandwidth. The available window types are RECTANGLE, HAMMING, HANN, BLACKMAN, BARTLETT (triangle), FLATTOP and BLACKMAN-HARRIS. The FLATTOP or HAMMING windows provide the best results in most cases. The FLATTOP window provides a “flat top” band-pass filter characteristic that is ideal for taking precise magnitude measurements.

OVERLAP increases the temporal resolution of the spectrogram by overlapping the windows used for spectrum calculation. If you select a WINDOW SIZE of 1024 for example and an OVERLAP of 87.5%, the windows for the spectra calculation will overlap 896 sampling points. Since a larger OVERLAP goes along with a larger number of spectra that have to be computed, calculation time increases significantly.

REDUCE OVERLAP FOR LONG FILES automatically reduce the overlap for large files. By this, system memory usage is limited and memory exceptions are prevented. Unchecking this feature can cause program crashes.

The resulting FREQUENCY RESOLUTION as well as the TEMPORAL RESOLUTION, which equals the dimensions of a single spectrogram pixel, are depicted below the Calculation Settings.

By activating the check box PREVIEW, only the selected period of time from the beginning of the file is loaded. Clicking the LOAD COMPLETE FILE button in the Main Window toolbar or pressing <F5> will load the remaining data of the file.

Click APPLY to recalculate the spectrogram with your selected settings.

VIEW

To change the color map for spectrogram displaying, select your preferred color map in the dropdown menu COLOR MAP.

By enabling SMOOTHING the spectrogram will be smoothed with a Bilinear Interpolation between data points (pixels).

Frequency Markers can be adjusted interactively using the mouse and “drag & drop” mechanism at the right-side triangle symbol of the frequency markers in the spectrogram plot or by setting the frequencies directly in the respective spin boxes. Use the check boxes to show or hide the respective frequency marker. The color of the frequency markers can be adjusted by SET COLOR. Use the ALPHA CHANNEL value to adjust the transparency of the frequency markers from 0% transparency (alpha=255) to 100% transparency (alpha=0). To return to default color scheme, click SET DEFAULT COLOR.

AXIS SCALING – TIME (X-AXIS)

Select AUTO SCALE to always show the complete length of the file in the spectrogram. If you prefer a fixed time scaling, choose FIXED DURATION and set the desired time duration the spectrogram should show. As bat calls are often classified by their shape or the steepness of the frequency sweep a fixed aspect ratio can be helpful to allow fast classifications. To use this feature, choose FIXED ASPECT RATIO and set your desired time-to-frequency ratio.

Axis Scaling – Frequency (Y-Axis)

The scaling of the frequency axis (y-axis) can be set to either Auto Scale or Fixed Scale. By enabling Auto Scale, the minimum frequency is set to zero and the maximum frequency to half the sample rate of the opened file. When Fixed Scale is enabled, you can define the minimum and maximum of the frequency axis with Upper Frequency Limit and Lower Frequency Limit, respectively.

Axis Scaling – Amplitude (Z-Axis)

The Amplitude Scaling allows adjusting the brightness and contrast of the Spectrogram. By enabling Auto Scale, brightness and contrast are automatically adapted to the current file. By choosing Fixed Scale the amplitude scaling remains fixed to the defined limits of brightness and contrast, when loading a new file.

Thumbnails

In the Open Folder mode files in the folder can be displayed as a list of small spectrogram thumbnails. The thumbnails have a duration of 0.2s. By changing the Thumbnail Position, it is possible to select the temporal mid of the thumbnail image with respect to the time axis of the whole file. To see the events that triggers the recordings, it is recommended to select the pretrigger of the recorded file as Thumbnail Position.

Default

The Default button sets all Spectrogram Settings to their defaults.

Axis Plots Settings

In the TIME AXIS PLOT and FREQUENCY AXIS PLOT some additional information about the signal visible in the spectrogram (see Figure 3) can be displayed. The AXIS PLOTS SETTINGS allows adjusting these plots.

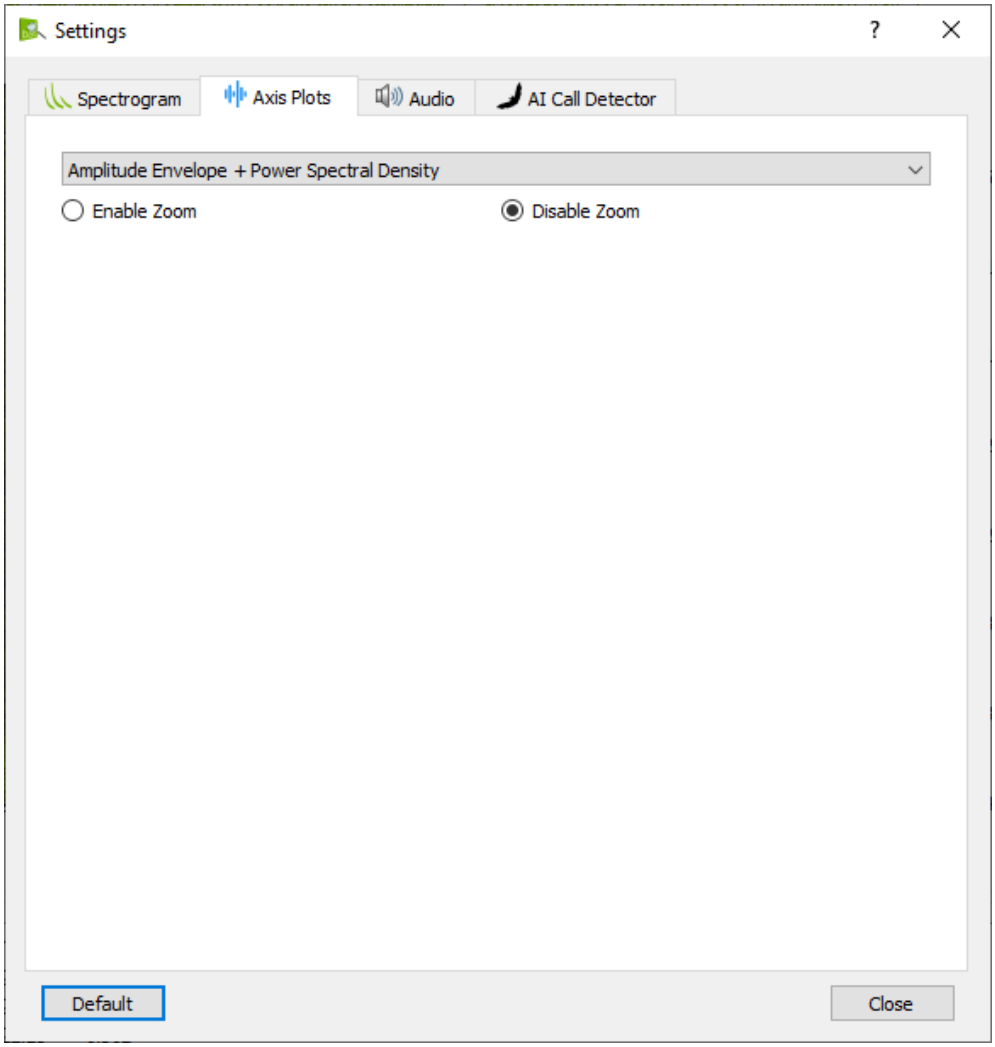

Figure 9: Axis Plots Settings

The drop-down menu allows choosing the information displayed in both plots.

AMPLITUDE AND RMS + POWER SPECTRAL DENSITY

By selecting AMPLITUDE AND RMS + POWER SPECTRAL DENSITY the time axis plot above the spectrogram displays the amplitude of the loaded audio file in dark green. Furthermore, in bright green a moving Root Mean Square (RMS) of the audio signal is superimposed to the amplitude plot (see Figure 10). The frequency plot left to the spectrogram shows a power spectral density estimate of the signal. Hereby, the power spectral density is calculated with

the evaluation WINDOW selected in the SPECTROGRAM SETTINGS and a fixed window length of 4.096 samples.

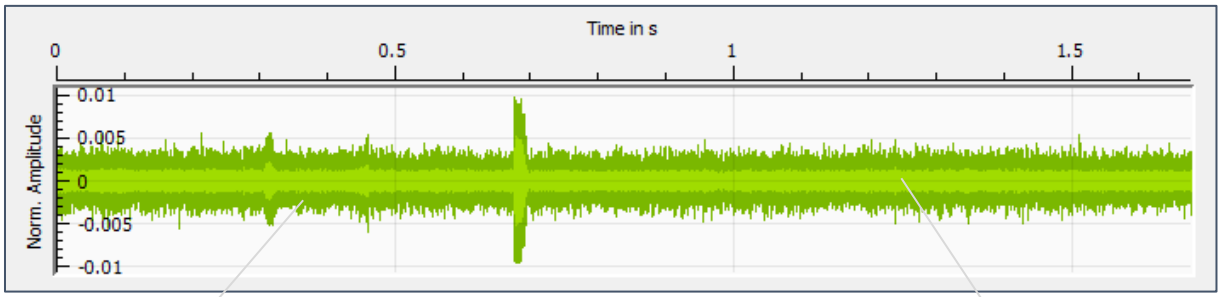

Figure 10: Amplitude and RMS Plot

AMPLITUDE

MOVING RMS

SPECTRAL AMPLITUDES OF CURRENT CURSOR POSITION

The time axis plot above the spectrogram displays the intensity of a single frequency along the time axis defined by the cursor position in the spectrogram. The frequency axis plot left to the spectrogram shows the intensity of a single short time spectrum defined by the position of the cursor in the spectrogram.

MAXIMUM SPECTRAL AMPLITUDES

The time axis and frequency axis plots show the maximum amplitudes in the spectrogram along the time or frequency axis, respectively.

ENABLE / DISABLE ZOOM

If ENABLE ZOOM is selected, both axis plots will follow the zooming in the spectrogram. If DISABLE ZOOM is selected, both axis plot will not zoom when the spectrogram is zoomed. However, on zooming in the spectrogram the zoomed area is marked in both axis plots.

DEFAULT

The DEFAULT button sets all AXIS PLOT SETTINGS to their defaults.

Audio Settings

The AUDIO SETTINGS provide a few options to playback audio signals and make also high ultrasonic frequency components audible. To start, stop and pause audio playback use the audio controls in the upper left corner of the Main Window (see Figure 3).

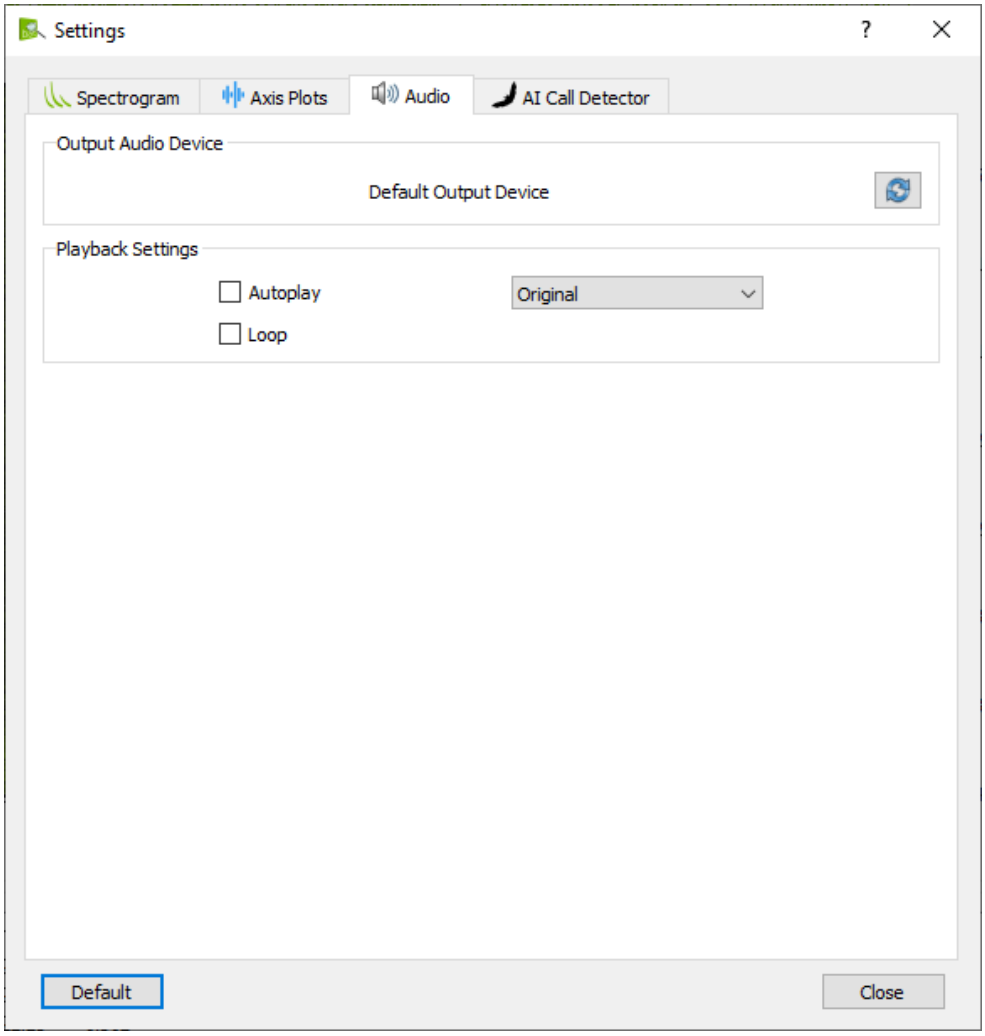

Figure 11: Audio Settings

OUTPUT AUDIO DEVICE

Depicts the detected default audio device on the system. Please, change the device in your operating system if the output device is not the desired on. To refresh the default audio device, press the button.

AUTOPLAY

AUTOPLAY will automatically start audio playback after a new file is loaded or the spectrogram is zoomed.

LOOP

LOOP will loop audio playback.

PLAYBACK MODE

The playback mode drop-down menu provides several options for processing audio data to make also high frequency components audible.

ORIGINAL: The audio signal is played with its original sample and playback rate. High frequency components above the frequency threshold of the human ear will be inaudible.

UNDERSAMPLED: The audio signal will be undersampled for playback. Undersampling an audio signal results in a frequency shift to lower frequencies. By this, high frequency components become audible, while playback time stays constant.

PITCHED: The audio signal will be played with a slower playback rate. This will slow-down the audio playback and high frequency components become audible.

MIXED: The audio signal is mixed with a reference signal of a specific frequency (mixer frequency) before it is played. This frequency mixing allows a so-called heterodyne detection of high frequency components as it results in a frequency shift of +/- the mixer Frequency. Playback time will stay constant.

DEFAULT

The DEFAULT button sets all AUDIO SETTINGS to their defaults.

AI Call Detector Settings

The AI CALL DETECTOR (see chapter 20) allows to detect bat calls in audio files and suggests bat species for each call. Detected calls and species suggestions are listed in the AI CALLS list (see Figure 3).

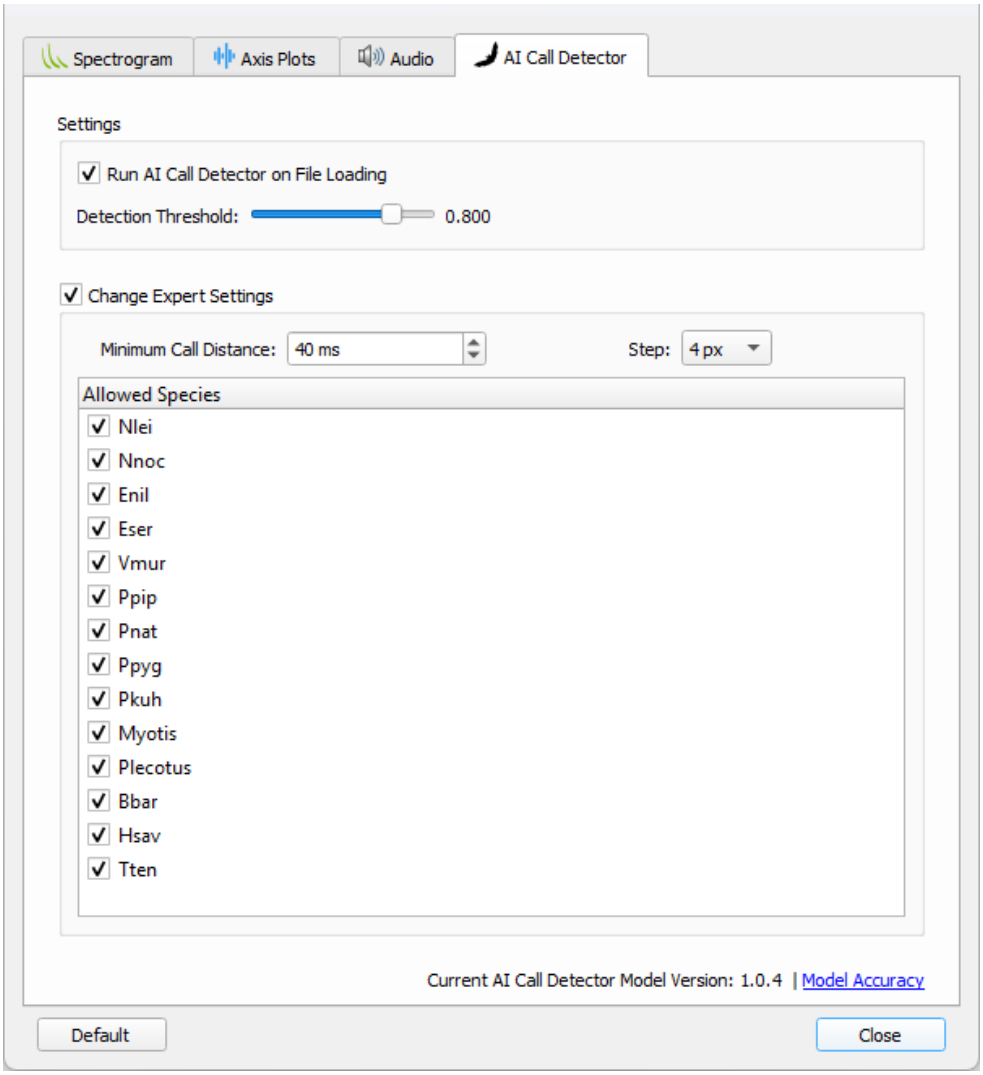

Figure 12: AI Call Detector Settings

RUN AI CALL DETECTOR ON FILE LOADING

Activate this check box to run the AI Call Detector automatically when a new file is loaded to be shown in the plots. Results will be listed in the AI CALLS list.

DETECTION THRESHOLD

The probability of a bat call at a specific time-in-file P(Call) have to be above the DETECTION THRESHOLD to include the bat call in the AI CALLS list and to mark it as a bat call in the MANUAL REVIEW OF AI CALL DETECTOR ANALYSIS.

Change Expert Settings

Activate Change Expert Settings to change the Minimum Call Distance and Step. Furthermore, you can exclude species from the AI Call Detector output. Manipulating these settings may result in different bat call detection probabilities of the AI Call Detector. This may affect the combability of the results with Probat, for instance.

Minimum Call Distance

Represents the minimum time between two detected bat calls. Default setting is 40ms.

Step

To detect bat calls in an audio file, a sliding window is moved in time over the calculated spectrogram. For each position in time, the probability of an included bat call is calculated by the AI Call Detector. The Step setting gives the number of pixels-in-time the sliding window is moved in the spectrogram between each calculation. Larger step widths will speed up the AI Call Detector calculation but on the other side may also reduce the accuracy of the detector. Default setting is 4px.

Allowed Species

By deactivating species in the species list, the probability for those species is always set to 0%. This allows you to exclude species from the AI Call Detector species identification results if for example these species are typically not present at the recording location.

Current AI Call Detector Model Version

The AI Call Detector of BATscreen PRO is based on convolutional neuronal networks and a Maximum-Likelihood-Ratio-Test. The accuracy of the automated call detector highly depends on the training data used to generate these network models as well as the input confusion data for the Maximum-Likelihood-Ratio-Test. As we will further work to make the models better and increase accuracy, we will release new model versions frequently. These models will be available for download as Installer on our website. However, as new models will of course also change the results of the AI Call Detector, it is important to log the model version used to analyse the data. Here you find the currently installed model version. While file evaluation with the AI Call Detector, the used model version as well as the used detector settings are saved to the WAV-file header.

Default

The Default button sets all AI Call Detector Settings to their defaults.

12. View Menu

Time Axis Plot

Show or collapse Time Axis Plot above the Spectrogram Plot.

Frequency Axis Plot

Show or collapse Frequency Axis Plot left to the Spectrogram Plot.

Frequency Marker 1

Show or hide the Frequency Marker 1 in the Spectrogram Plot.

Frequency Marker 2

Show or hide the Frequency Marker 2 in the Spectrogram Plot.

Frequency Marker 3

Show or hide the Frequency Marker 3 in the Spectrogram Plot.

Grid

Show or hide the Grid in the Spectrogram Plot, the Time-Axis Plot and the Frequency-Axis Plot.

AI Calls

Show or collapse the AI Calls list right to the Spectrogram Plot.

Manual Labels

Show or collapse the Manual Labels list right to the Spectrogram Plot.

Theme

Change the color theme to dark or light. “Windows Theme” adopts the color theme from Windows.

13. Manual Evaluation

BATscreen PRO provides a fast and intuitive procedure to effectively and fast manually examine large numbers of recorded bat call files. After file classification is completed, data can be exported either in a CSV-file format or in a Probat compatible file to calculate shutdown times and cut-off wind speeds.

Select Evaluation Folder

To start the manual examination, select MANUAL EVALUATION in the EVALUATION menu and then either FILES IN FOLDER or FILES DEFINED IN CSV FILE from the sub menu.

If you select FILES IN FOLDER, all bat call files must be stored in a folder that have to be selected in the following dialog box.

Choosing FILES DEFINED IN CSV FILE the paths of the bat call files are defined in a CSV file. Each line of the CSV file contains the path to a bat call file.

Define Species Tree

Subsequently, a SET SPECIES TREE dialog opens (see Figure 13). Here, you have to define the species/subspecies in which you want to group your recorded files. The simplest case is one class “Bat” and one “No call”.

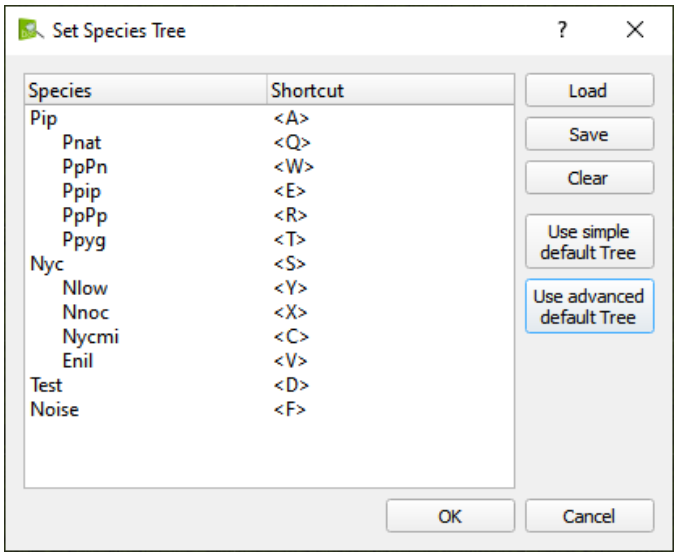

Figure 13: Set Species Tree Dialog

By clicking USE SIMPLE DEFAULT TREE or USE ADVANCED DEFAULT TREE predefined species trees are loaded. While the classes for the simple default tree are the already mentioned “Bat” and “No call”, the advanced default tree consist of numerous species and subspecies as depicted in Figure 13.

To allow for a fast classification of files, one shortcut per species/subspecies has to be defined. Later in the examination process, you can easily assign a file to a species by pressing the respective shortcut on the keyboard.

If you want to define your own species tree or adapt an existing one, use the right click menu to add, rename and delete species/subspecies as well as change a dedicated shortcut.

To save your species tree or to load an already saved tree click SAVE or LOAD, respectively.

Assign files to your species

After determining the species tree model, you can start to assign bat call files from the specified folder to your species tree model. Each file can be assigned to up to four species ("Manual Species #1", "Manual Species #2", "Manual Species #3" and "Manual Species #4").

Therefore, the first file in the specified folder is visualized in the Main Window Area. Below on the left, you can find your defined species tree model and on the right side a list of all sound files in the specified folder (see Figure 14).

The species tree model view lists all defined species/subspecies, their corresponding shortcuts and the number of currently assigned files ("Count") in the specified folder. In red, you can find the number of unassigned files at the end of the list. Species, which was not defined in the DEFINE SPECIES TREE step, but were already assigned to at least one file, when the MANUAL FOLDER EVALUATION is started, are depicted in blue. For editing the specified species tree model, utilize the right click menu. To save your current species tree model use the SAVE SPECIES MODEL button right to the file list.

The file list shows all WAV- or RAW-files in the selected folder and gives information about filename, recording time, file length, species assignment and note. To open an item double click it, use the <Left> and <Right > arrow keys of the keyboard or the buttons  and . Use the right click menu to delete files. **Warning: By deleting files in the right click menu, they are deleted permanently from your hard disc drive!**

To assign the current opened file to one or more species/subspecies click on the  buttons right next to the desired species /subspecies entries in the species tree model. Alternatively, you can also press the associated shortcuts on the keyboard or use the right click menu in the file list. By selecting multiple files in the file list, it is also possible to assign multiple files, simultaneously. To allow a fast reassigning (changing) to another species/subspecies, press <Alt> while assigning a file. This will overwrite the last species assignment. If you want to delete an assignment or reassign (change) a specific species, use the right-click menu in the file list.

To edit the note column of a file, double click in the note column.

The AI Calls list in the right part of the Main Window Area shows you species suggestions produced by the AI Call Detector. By hovering over the list entries, the respective call position and the suggested species are depicted as a vertical magenta line with text label in the spectrogram plot.

If you work with WAV-files, for example, recorded by BATmode-Systems or hardware of Avisoft Bioacoustics, assignment and note information are stored in the file headers. Consequently, assignment and note information are preserved if you close the application or interrupt the classification process. In contrast, if RAW-files are used, assignment and comment information will be lost by closing the application or opening a new file or folder since the RAW-file format does not support header information.

Export only selected files to a CSV- or Probat-file

If you want to export only specific files in a folder, select them in the file list and use the right-click menu to export them. The exporting options are described in Chapter 10 (EXPORT CSV-FILE and EXPORT PROBAT FILE).

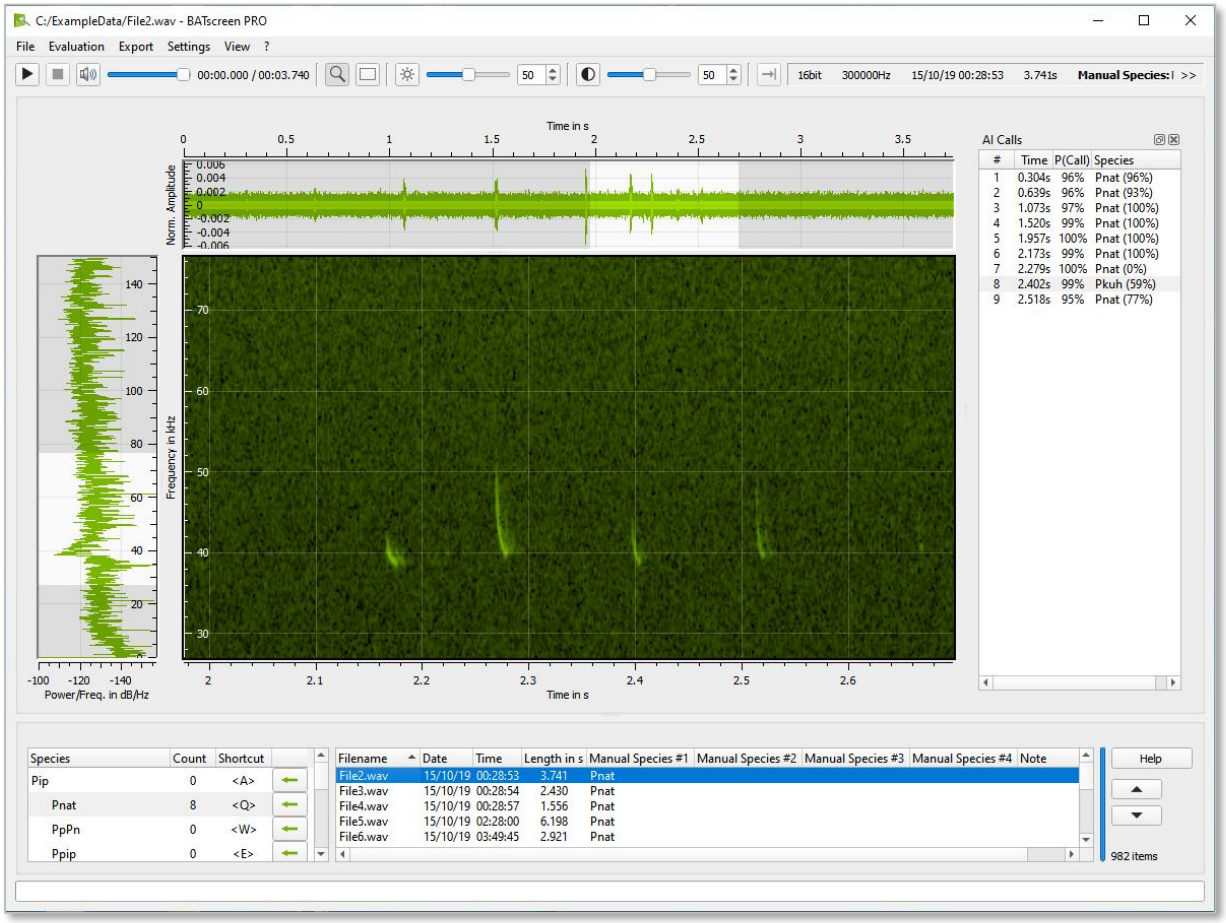

Figure 14: Manual Evaluation Window

14. Manual Review of RECORDER WEA Offline Analysis

In general, the Avisoft-RECORDER USGH software of Avisoft Bioacoustics allows an automated call classification and evaluation as a post-recording step. The calls are visualized and measured with a spectrogram. The most important values are call duration, call interval, start frequency, end frequency, bandwidth, amplitude and slope of the individual calls. However, to achieve good classification results it is indispensable to identify a classification parameter set that enables a reliable class assignment and defines appropriate parameter ranges for each class.

In the research project RENEBAT III such a parameter set was developed and published in the resulting report[1]. To allow an easy use of this parameter set, it is included as configuration preset in the Avisoft-RECORDER USGH software from version 4.2.28 on, which was released on the 10th December 2018.

The results of the automated call classification are saved in text files. The MANUAL REVIEW OF RECORDER WEA OFFLINE ANALYSIS of BATscreen PRO allows to import these results, make a fast manual check of the automated classification results and export the data as CSV or Probat compatible file.

Classification Parameter Set developed in RENEBAT III

The class model tree as well as the parameter boundaries for each class, which both were defined in RENEBAT III and published in the resulting report[1] (chapter 4.2, page 42 and following) are depicted in Table 2. The model uses only the two parameters “end frequency” and call “duration” to distinguish detected calls. Following the research report, the logic for file assignment is shown in Figure 15.

[1] Behr, O., Brinkmann, R., Hochradel, K., Mages, J., Korner-Nievergelt, F., Reinhard, H., Simon, R., Stiller, F., Weber, N., Nagy, M., (2018). „Bestimmung des Kollisionsrisikos von Fledermäusen an Onshore-Windenergieanlagen in der Planungspraxis“ - Endbericht des Forschungsvorhabens gefördert durch das Bundesministerium für Wirtschaft und Energie (Förderkennzeichen 0327638E). O. Behr et al. Erlangen / Freiburg / Ettiswil.

Table 2: Calls model tree and boundaries for the call parameters, end frequency and duration, defined in the resulting report[2] of RENEBAT III. min: minimum value, max: maximum value. End frequency is depicted in kHz and duration in ms.

Class	End Frequency min	End Frequency max	Duration min	Duration max	Possible Species
Nyc	8.0	< 33.0	2.9	36.0	*Tadarida teniotis, Nyctalus lasiopterus, Nyctalus noctula, Nyctalus leisleri, Eptesicus serotinus, Vespertilio murinus, Eptesicus nilsonii*
Nlow	8.0	< 15.0	5.9	28.0	*T. teniotis, N. lasiopterus*
Nnoc	15.0	< 21.0	5.9	32.0	*N. noctula*
Nycmi	21.0	<26.5	5.0	30.0	*N. leisleri, E. serotinus, V. murinus (sometimes also high N. noctula or low E. nilsonii calls)*
Enil	26.5	<26.5	5.0	25.0	*E. nilssonii (sometimes also E. serotinus and N. leisleri) Pip*
Pip	33.0	65.0	1.4	20.0	*Pipistrellus nathusii, Pipistrellus pipistrellus, Pipistrellus pygmaeus (Pipistrellus kuhlii)*
Pnat	35.0	< 41.2	2.9	18.0	*P. nathusii (P. kuhlii)*
PpPn	41.2	< 42.5	2.9	18.0	*P. nathusii, P. pipistrellus*
Ppip	42.5	< 49.5	2.0	18.0	*P. pipistrellus*
PpPp	49.5	< 51.0	2.0	15.0	*P. pipistrellus, P. pygmaeus*
Ppyg	51.0	64.0	2.0	15.0	*P. pygmaeus*
Testsignal	-	-	36.0	3000.0	

[2] Behr, O., Brinkmann, R., Hochradel, K., Mages, J., Korner-Nievergelt, F., Reinhard, H., Simon, R., Stiller, F., Weber, N., Nagy, M., (2018). „Bestimmung des Kollisionsrisikos von Fledermäusen an Onshore-Windenergieanlagen in der Planungspraxis“ - Endbericht des Forschungsvorhabens gefördert durch das Bundesministerium für Wirtschaft und Energie (Förderkennzeichen 0327638E). O. Behr et al. Erlangen / Freiburg / Ettiswil.

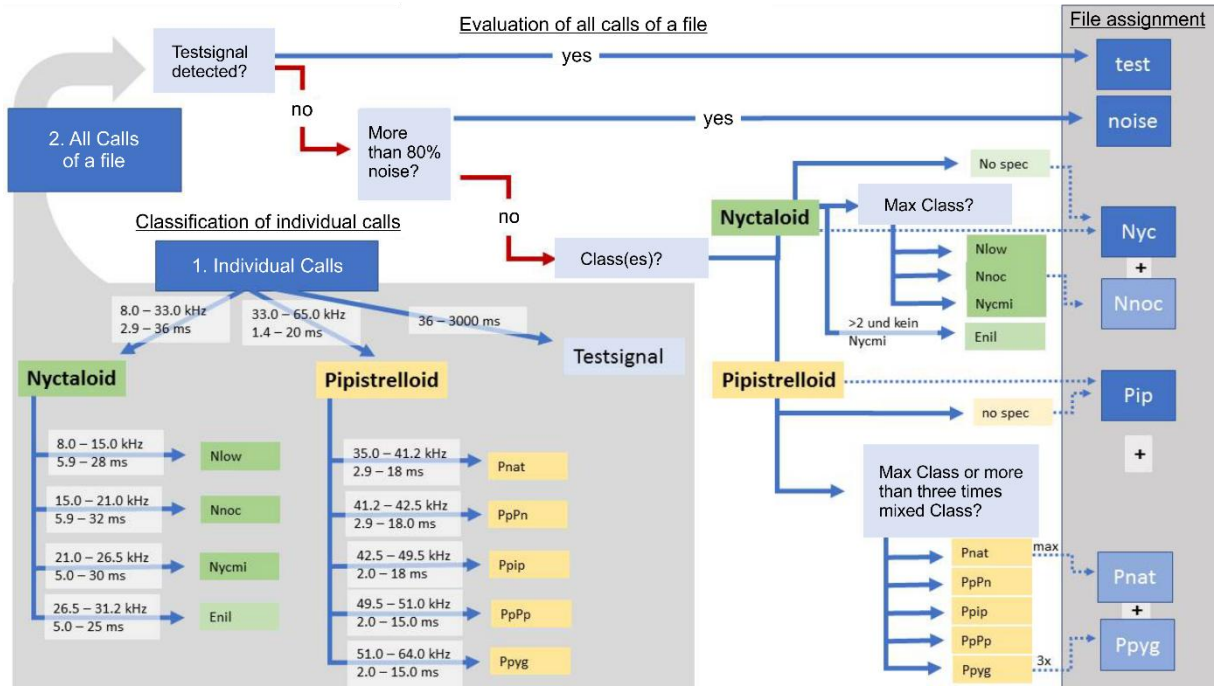

Figure 15: Logic of the automated evaluation of the recorded files following the resulting report[3] of RENEBAT III. The first step classifies all the individual calls of a file into species groups and types. The classification is based on the "end frequency" and "duration" of each call. If no call class can be determined, the recorded noise is assigned as noise. In the second step of the evaluation, the totality of all individual calls of a file are considered and a defined logic is used to decide which species groups and/or species are contained in the file, or whether the file contains noise or a test signal. With dashed lines, the procedure for the case is shown that individual calls of the call classes Nnoc, Pnat and Ppyg are present. In this case, both species groups Nyctaloid and Pipistrelloid and additionally Nnoc, Pnat and Ppyg are assigned in the output file according to their number. If no species are detected, only the recognized species group and no spec are entered in the output file. "Max Class" refers to the most frequent call class within the respective species group.

[3] Behr, O., Brinkmann, R., Hochradel, K., Mages, J., Korner-Nievergelt, F., Reinhard, H., Simon, R., Stiller, F., Weber, N., Nagy, M., (2018). „Bestimmung des Kollisionsrisikos von Fledermäusen an Onshore-Windenergieanlagen in der Planungspraxis" - Endbericht des Forschungsvorhabens gefördert durch das Bundesministerium für Wirtschaft und Energie (Förderkennzeichen 0327638E). O. Behr et al. Erlangen / Freiburg / Ettiswil.

Automated WEA Offline Analysis in the Avisoft RECORDER USGH software

To evaluate a data set of WAV-files recorded by a BATmode system with the automated WEA Offline Analysis install the latest Avisoft-RECORDER USGH software on your evaluation PC. The software can be downloaded from www.avisoft.com for free.

Please note that in Avisoft-RECORDER USGH software versions 4.3.02 (16.06.2021) to 4.4.1-20 (20.06.2023) the loading of the "WEA Offline Analysis (BMU-Projekt)" presets sets a too high magnitude threshold of -60dB. This may result in the detection of only bat call of higher call amplitude and the missing of low amplitude calls. To avoid this issue, install the latest Avisoft-RECORDER USGH software or set the magnitude threshold to -80dB manually.

To start the software, connect your Avisoft UltraSoundGate USB dongle to your evaluation PC. The UltraSoundGate is included in the delivery scope of your BATmode system and contains the required software license for the Avisoft-RECORDER USGH software.

Subsequently, load the WEA OFFLINE ANALYSIS configuration presets by clicking OPTIONS -> CONFIGURATION MANAGEMENT -> PRESETS -> BAT CALLS -> WEA OFFLINE ANALYSIS (BMU PROJEKT) (see Figure 16). Confirm all opening configuration windows with OK.

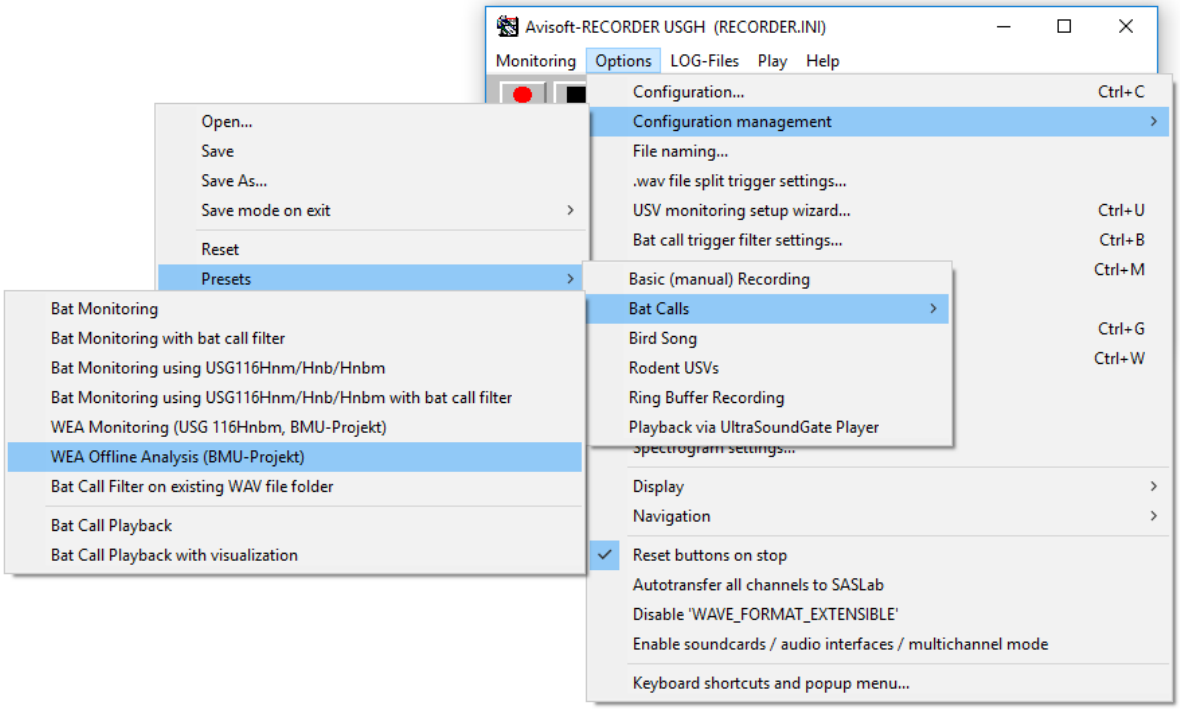

Figure 16: Load configuration presets for WEA Offline Analysis

To start the WEA Offline Analysis, select the folder, which contains the recorded data set, in the Windows Explorer and "drag & drop" it on the start window of the Avisoft-RECORDER USG

software. We recommend making a copy of your original data set first and removing all testsignal recordings from the copied data before starting the WEA Offline Analysis. As data sets with large numbers of files are often impractical to handle, it is possible to split a data set in numerous parts by placing them in different folders and run the WEA Offline Analysis on each folder subsequently.

The results of the WEA Offline Analysis are stored in three text files “calls_ch1.txt”, “calls_ch1_files.txt” and “calls_ch1_stat.txt” in the selected folder. Hereby, the file “calls_ch1_files.txt” contains the results for each file line by line. The most important columns of the result file are described in Table 3.

Table 3: Most important columns of the result file "calls_ch1_files.txt"

Column	Name	Description
0	**timestamp**	*Recording time of the file*
1	**filename**	*Filename of the file*
2	**duration**	*Duration of the file in s*
3	**bat activity**	*Can contain “bat”, “noise” or “test” and is a summary of the following results.*
4	**Probat1**	*The first Probat class[4] the file is assigned to.*
5	**#Probat1**	*Number of detected calls, which are assigned to the first Probat class[4].*
6	**Probat2**	*The second Probat class[4] the file is assigned to.*
7	**#Probat2**	*Number of detected calls, which are assigned to the second Probat class[4].*
8	**species1**	*The first class the file is assigned to following the logic depicted in Figure 15.*
9	**#species1**	*The number of detected calls, which are assigned to species 1.*
10	**species2**	*The second class the file is assigned to following the logic depicted in Figure 15.*
11	**#species2**	*The number of detected calls, which are assigned to species 2.*
12	**species3**	*The third class the file is assigned to following the logic depicted in Figure 15.*
13	**#species3**	*The number of detected calls, which are assigned to species 3.*

Manual Review of the RECORDER WEA Offline Analysis with BATscreen PRO

After the automated WEA Offline Analysis is performed with the Avisoft-RECORDER USGH software, the results have to be manually reviewed to delete remaining noise recordings and erroneous assigned bat calls in the resulting data set. This can be done with BATscreen PRO.

To start the MANUAL REVIEW OF RECORDER WEA OFFLINE ANALYSIS, click EVALUATION -> MANUAL REVIEW OF RECORDER WEA OFFLINE ANALYSIS.

[4] Probat classes are a simple representation of the depicted class model tree in Table 2. Probat classes can be “Nyctaloid”, “Pipistrelloid” or “Pnat”. An empty field represents a test or noise signal. However, for the calculation of shutdown times Probat interprets both “Nyctaloid” and “Pipistrelloid” as equal bat call files. Consequently, it is irrelevant for Probat calculation, which one is assigned. In contrast, it is important to assign “Pnat” just to files, which really contains “Pnat” calls, since Probat uses different weighting factors for “Pnat” assigned files.

Select the folder, which has to be evaluated and contains the recorded WAV-files as well as the resulting file “calls_ch1_files.txt” of the automated WEA Offline Analysis. If the data set was split and analyzed in several subfolders, select the folder which contains all these folders as first-level subfolders. Please make sure that each subfolder contains its own “calls_ch1_files.txt” file as well as the corresponding WAV-files.

In the subsequent WEA OFFLINE ANALYSIS REVIEW SETTINGS Dialog, check the box INCLUDE FIRST-LEVEL SUBFOLDERS if you want to include the named first-level subfolders in your evaluation. Furthermore, you have to choose the species model tree you want to use for the review of your WEA Offline Analysis (see Figure 17). The default SIMPLE SPECIES TREE for Probat Export contains only “Pip”, “Pnat”, “Nyc” and “No Call” and refers to the Probat species in the resulting “calls_ch1_files.txt” file (“Pipistrelloid” is replaced by “Pip” and “Nyctaloid” by “Nyc”). Probat species are a simple representation of the depicted species model tree in Table 2 since Probat does not pay attention to a more detailed species tree. Furthermore, for the calculation of shutdown times Probat interprets both “Nyctaloid” and “Pipistrelloid” as equal bat call files. Consequently, it is irrelevant for Probat calculation, which one is assigned. In contrast, it is important to assign “Pnat” just to files, which really contains “Pnat” calls, since Probat uses different weighting factors for “Pnat” assigned files. If you want to have an ADVANCED SPECIES TREE with all classes defined in Table 2, select ADVANCED SPECIES TREE. This species model tree can also be used for a Probat evaluation since Probat interprets “Pnat” as bat call with different weighting factor and all other species just as equal bat call. It is possible to add further species to the default trees by clicking with the right mouse button in the species tree. The same way you can also change the shortcuts of the species. Use the SAVE and LOAD buttons to save or load a saved model tree, respectively.

Please pay attention that all species assignments, which are already saved in the files headers, but not included in the current species tree, will be discarded permanently, when opening the folder for the Manual Review of RECORDER WEA Offline Analysis.

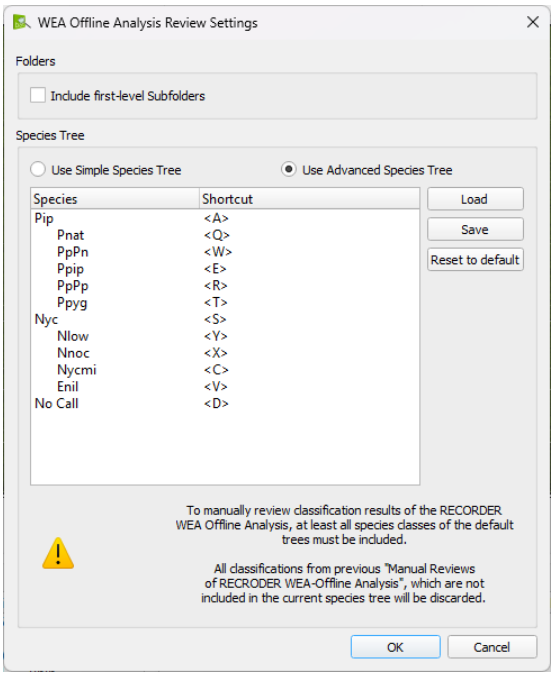

Figure 17: Select and edit Species Tree for the Review of a WEA Offline Analysis

After selecting the species tree, BATscreen PRO opens the selected folder and visualizes the first file in the Main Window. Below on the left, you can find your selected species tree model and on the right side a list of all bat call files in the specified folder (see Figure 18).

The species tree model view lists all species/subspecies of the selected species tree, their corresponding shortcuts and the number of currently assigned files (“count”) in the specified folder. In red, you can find the number of unassigned files at the end of the list. The species “Detected No Call” that is depicted in blue represents all files, which were assigned as either “test” or “noise” by the WEA Offline Analysis.

The file list shows all WAV- and RAW-files in the selected folder/subfolders and gives information about filename, recording time, file length, assignment proposal of the WEA Offline Analysis, class assignment and note. Files that were detected as “test” or “noise” by the WEA Offline Analysis are disabled and marked in grey. To open an item double click it, use the <Left> and <Right > arrow keys of the keyboard or the buttons ▲ and ▼.

Use the right click menu to delete selected files or copy them to the clipboard. **Warning: By deleting files in the right click menu, they are deleted permanently from your hard disc drive!**

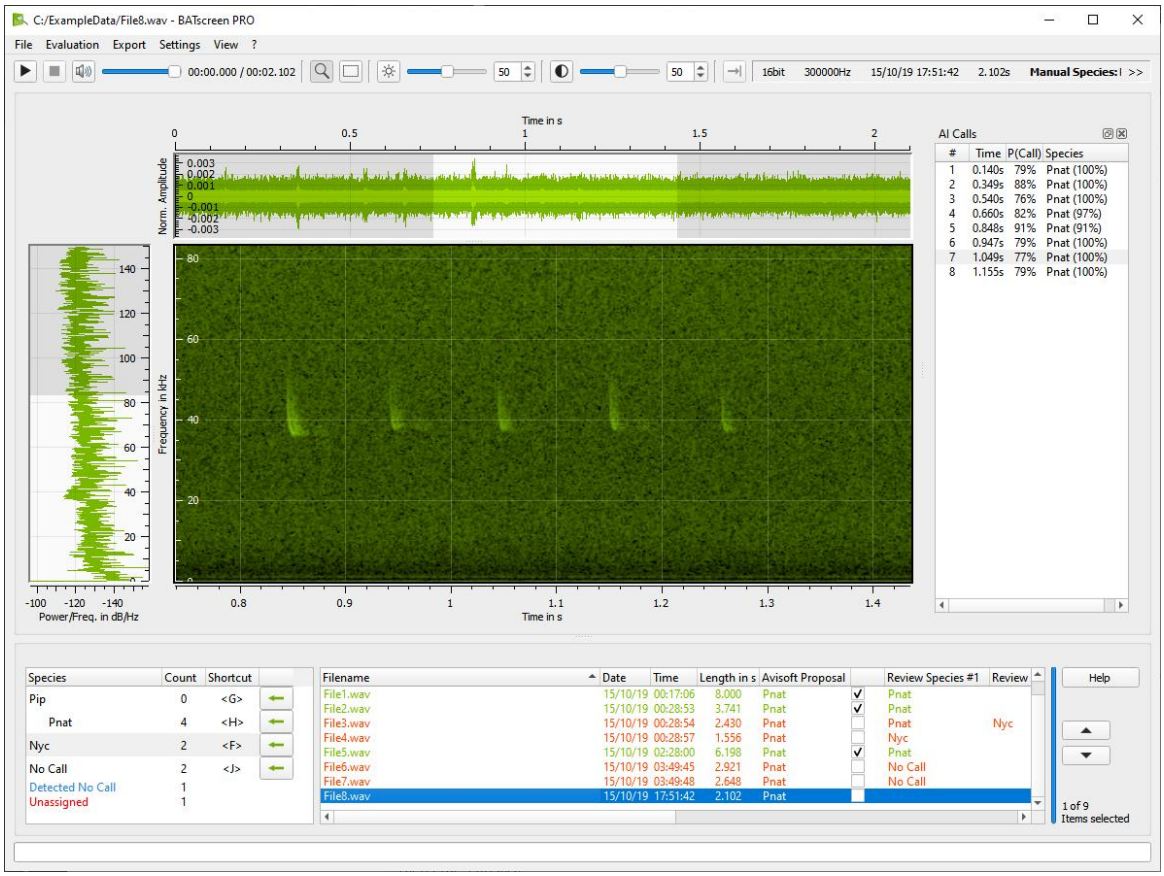

Figure 18: Window of Manual Review of WEA Offline Analysis

While reviewing a current opened file you can accept the proposal of the WEA Offline Analysis by checking the respective box right to the Avisoft Proposal in the file view list. Alternatively, you can also accept the proposal by using the <Space> key of your keyboard or use the right click menu in the files list. By selecting multiple files in the file list, it is also possible to accept the Avisoft Proposal for multiple files, simultaneously. An accepted file will be marked in green and the proposed species are written to the file header of the file. If you want to decline a proposal, just assign the file to (a) different species by clicking on the green arrow buttons right next to the desired species/subspecies entries in the species tree model. Alternatively, you can also press the associated shortcut on the keyboard or use the right click menu in the file list. The file with the declined proposal will be marked orange. By selecting multiple files in the file list, it is also possible to assign multiple files, simultaneously. To allow a fast reassigning (changing) to another species/subspecies, press <Alt> while assigning a file. This will overwrite the last species assignment. If you want to delete an assignment or reassign (change) a specific species, use the right-click menu in the file list. By choosing RESET ALL FILES in the right click menu of the file list, you can delete the species assignments of all files and discard all accepted proposals.

The AI Calls list in the right part of the Main Window Area shows you species suggestions produced by the AI Call Detector. By hovering over the list entries, the respective call position and the suggested species are depicted as a vertical magenta line with text label in the spectrogram plot.

To edit the note column of a file, double click in the note column of the files list.

Export the review result to a CSV- or Probat-file

After finishing the review, you can export your result as CSV or Probat compatible file by using the menu EXPORT. If you want to export only specific files in a folder, select them in the file list and use the right-click menu to export them. The exporting options are described in Chapter 10 (Export CSV-File and Export Probat File).

15. Manual Review of AI Call Detector Analysis

Since version 3.0.0, BATscreen PRO includes an automated AI Call Detector. It is based on convolutional neural networks and a Maximum-Likelihood-Ratio-Test (see section 20). Consequently, it allows to detect the temporal position of bat calls with high reliability and make accurate species suggestions. For a detailed evaluation of the AI Call Detector on your individual data set please execute the AI Call Detector Performance Evaluation (see section 17).

The MANUAL REVIEW OF AI CALL DETECTOR ANALYSIS allows to run the AI Call Detector successively on all sound files within a folder. Subsequently, the user can manually review the call and species suggestions and correct false call detections or wrong species suggestions time-efficiently.

To start the MANUAL REVIEW OF AI CALL DETECTOR, click EVALUATION -> MANUAL REVIEW OF AI CALL DETECTOR.

Select the folder, which has to be evaluated and contains the recorded WAV-files. BATscreen PRO will visualize the first file in the folder and list all files in the folder in the files list. Successively, BATscreen PRO will run the AI Call Detector on all files in the files list and present the species suggestions in the AI Proposal column of the list. The blue progress bar on the right side depicts the progress with respect to the number of files in the folder. Please be aware that the AI Call Detector will be executed on all files with the same AI Call Detector settings that were selected when the MANUAL REVIEW OF AI CALL DETECTOR was started.

A species tree model placed in the lower left corner will show all species covered by the AI Call Detector. The species tree model view lists their corresponding shortcuts and the number of currently assigned files (“Count”) in the specified folder. In red, you can find the number of unassigned files at the end of the list. The species “Detected No Call” that is depicted in blue represents all files, in which no bat call was detected.

The file list shows all WAV- and RAW-files in the selected folder and gives information about filename, recording time, file length, assignment proposal of the AI Call Detector, species assignments (Review Species #1 - #4) and notes. To open an item double click on it, use the <Left> and <Right > arrow keys of the keyboard or the buttons  and  .

Use the right click menu to delete selected files or copy them to the clipboard. **Warning: By deleting files in the right click menu, they are deleted permanently from your hard disc drive!**

While reviewing a current opened file you can accept the proposal of the AI Call Detector by checking the respective box right to the AI Proposal in the file view list. Alternatively, you can also accept the AI Proposal by using the <Space> key of your keyboard or use the right click menu in the files list. By selecting multiple files in the file list, it is also possible to accept the AI Proposal for multiple files, simultaneously. An accepted file will be marked in green and the proposed species are written to the file header of the file. If you want to decline an AI Proposal assign the file to (a) different species by clicking on the green arrow buttons  right next to the desired species/subspecies entries in the species tree model. Alternatively, you can also press the associated shortcut on the keyboard or use the right click menu in the file list. The

file with the declined proposal will be marked orange. By selecting multiple files in the file list, it is also possible to assign multiple files, simultaneously. To allow a fast reassigning (changing) to another species/subspecies, press <Alt> while assigning a file. This will overwrite the last species assignment. If you want to delete an assignment or reassign (change) a specific species, use the right-click menu in the file list. By choosing RESET ALL FILES in the right click menu of the file list, you can delete the species assignments of all files and discard all accepted proposals. Furthermore, all AI proposals will be deleted in the files list as well as in the WAV-files header. This allows you for example to restart a MANUAL REVIEW OF AI CALL DETECTOR with different AI Call Detector settings or a different AI model version.

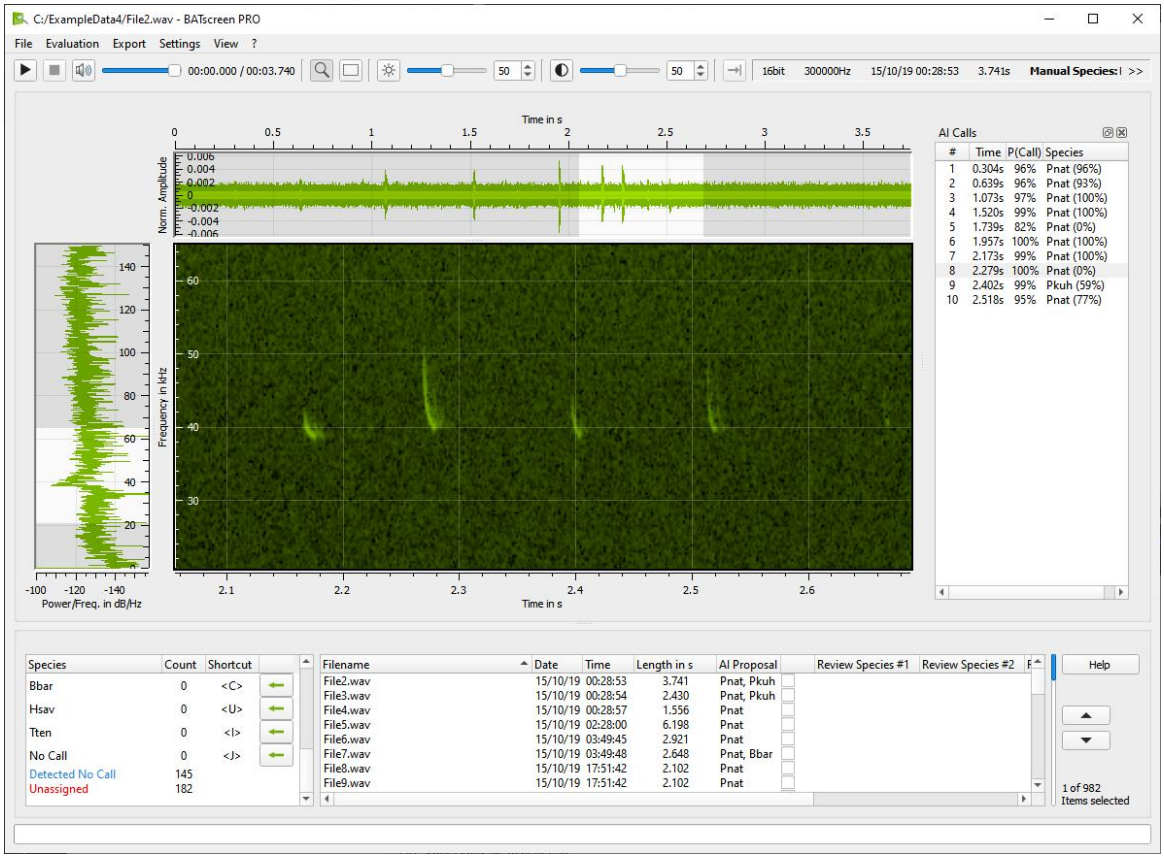

Figure 19: Window of Manual Review of AI Call Detector Analysis

The AI Calls list in the right part of the Main Window Area shows you species suggestions produced by the AI Call Detector for the current loaded file. By hovering over the list entries, the respective call position and the suggested species are depicted as a vertical magenta line with text label in the spectrogram plot. Please be aware, that the live calculated species proposals for AI Calls list are calculated with the current AI Call Detector settings that do not necessarily have to match the AI Call Detector settings used to calculate the AI Proposals in the files list.

To edit the note column of a file, double click in the note column of the files list.

Export the review result to a CSV- or Probat-file

After finishing the review, you can export your result as CSV or Probat compatible file by using the menu EXPORT. If you want to export only specific files in a folder, select them in the file list and use the right-click menu to export them. The exporting options are described in Chapter 10 (Export CSV-File and Export Probat File).

16. Manual Call Labeling

Sometimes bat call file analysis requires not only to assign complete files to one or more bat species. For a more detailed evaluation it furthermore may be required to mark the temporal position as well as the respective frequency range of calls within the file. For this, BATscreen PRO uses so called bounding boxes which are labeled with species name and call type. Use the MANUAL CALL LABELING method to define and change those bounding boxes as well as export the respective data for further use.

To start the MANUAL CALL LABELING, click EVALUATION -> MANUAL CALL LABELING.

Select and Open Evaluation Folder

Select the folder that includes the WAV-files you want to analyse. BATscreen PRO will list all files in the folder in the files list and visualize the first of them. Already saved bounding boxes will be shown at the respective position in the spectrogram plot. Each bounding box is titled with its species label and the respective call type is depicted by the box's color. Additionally, all bounding boxes with the respective information are listed in the MANUAL LABELS list right next to the spectrogram plot (see Figure 20).

While the first file of the folder is visualized, the file header information of all other files is loaded and appended to the respective files in the files list. This information includes the timestamp, the length, the note and the saved bounding boxes (Labels). The Labels are depicted as species and the number of occurrences in parentheses. The blue progress bar on the right side of the files list depicts the progress of the file header loading.

To open an item double click on it, use the <Left> and <Right > arrow keys of the keyboard or the buttons ▲ and ▼ .

Use the right click menu to delete selected files or copy them to the clipboard. **Warning: By deleting files in the right click menu, they are deleted permanently from your hard disc drive!**

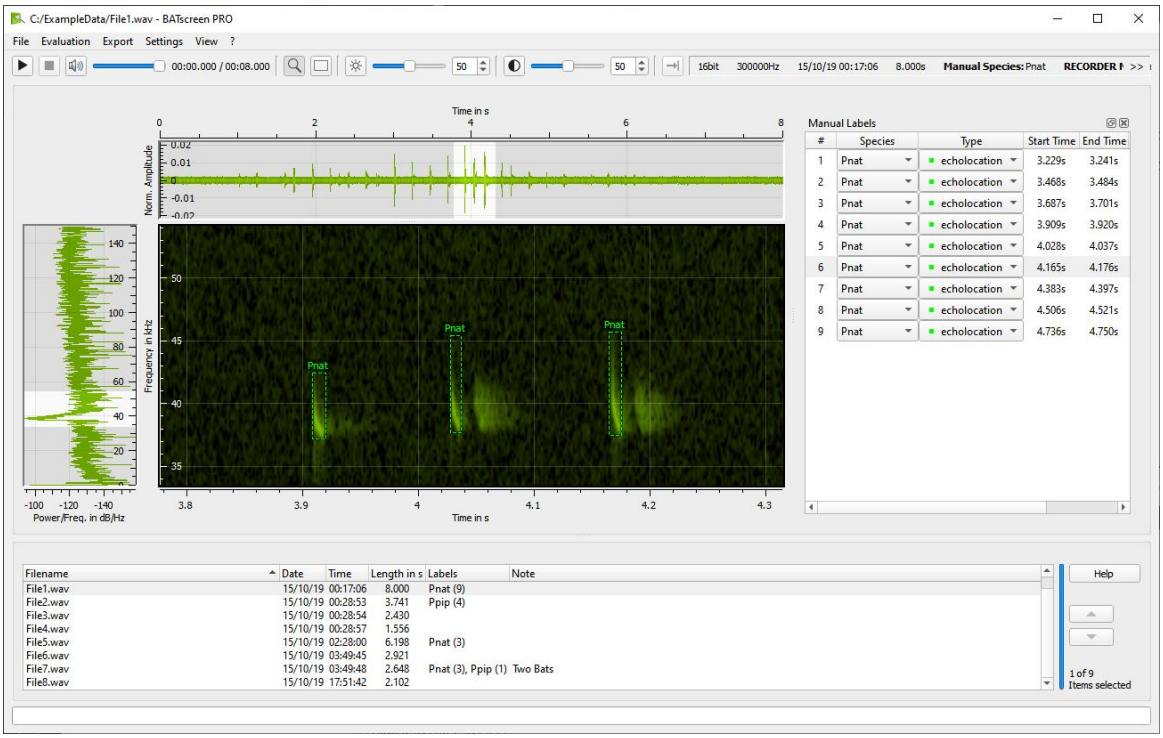

Figure 20: Window of Manual Call Labeling

Edit Bounding Boxes

Bounding boxes can be added by selecting the area of the call as rectangular in the spectrogram plot. To do so, select marking cursor by pressing the button in the CURSOR SELECTION and span a rectangular around the call area by using the left mouse button. The time and frequency range as well as the start and stop point of the marked area are depicted next to the rectangular. Use the mouse to adjust the rectangular by “drag & drop” mechanism. To add the selection to your manual labels, click on the + - button left below the selected rectangular (see Figure 21). To discard the rectangular, press the right mouse button.

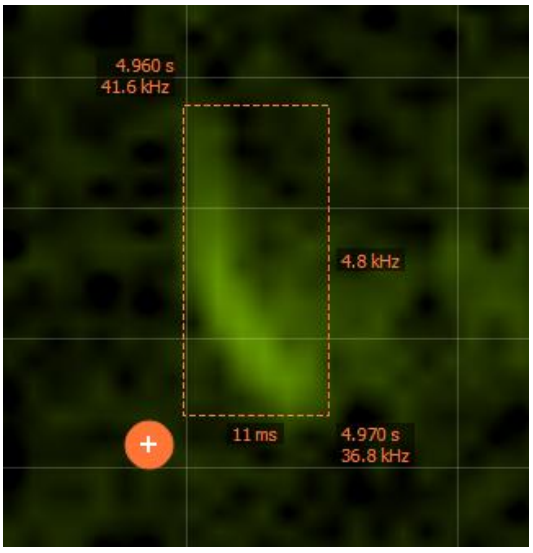

Figure 21: Add Bounding Box (Label)

To use the marking option, when the zooming cursor is enabled, you can also span a rectangular by using the left mouse button and simultaneously pressing the <Shift>-key instead of selecting the marking cursor. To delete the rectangular, press the <Esc>-key. Instead of using the + - Button to add the bounding box to your manual labels, it is also possible to press <Space> on the keyboard.

The species and call type labels of a bounding box can be edited in the MANUAL LABELS list, by using the dropdown buttons of the respective list entry. Use the right-click menu to delete one/all bounding boxes or change species and call type of all bounding boxes in a file (see Figure 22).

All information regarding labels and bounding boxes are saved in the header of the respective WAV-file.

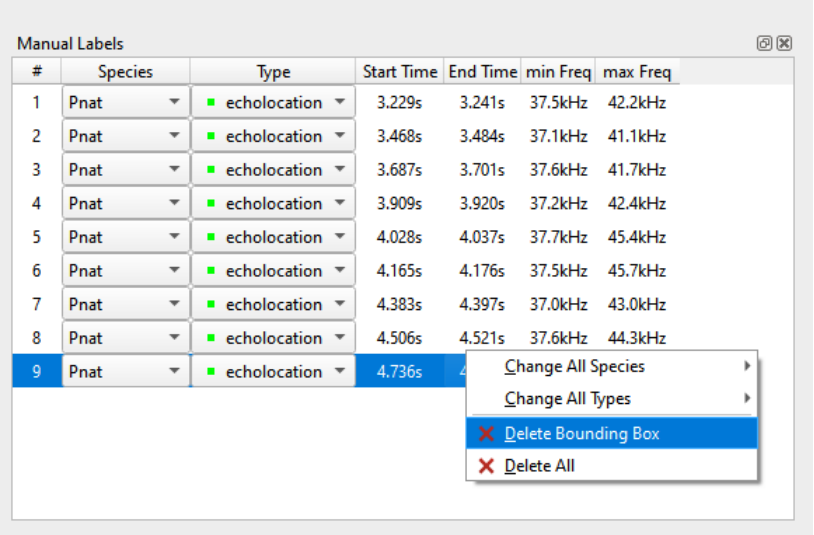

Figure 22: Edit Bounding Box (Label)

Export Bounding Boxes and Labels as CSV- or JSON-file

After finishing the labeling process, you can export the information in the files list as CSV compatible file by using the menu EXPORT. If you want to export only specific files in a folder, select them in the file list and use the right-click menu to export them.

In the right-click menu it is also possible to export the Labels and Bounding Boxes of selected files as JSON compatible files. In this export method, one JSON-file is created for each selected WAV-file. The JSON-file, will have the same filename as the respective WAV-file.

17. AI Call Detector Performance Evaluation

The AI Call Detector is based on Convolutional Neural Networks (CNN) and a Maximum Likelihood-Ratio-Test (MLRT). It is designed as a three-stage process:

- First Stage: Detect bat calls in sound files (CNN)
- Second Stage: Assign the calls to bat species (CNN)
- Third Stage: Statistically review species assignments (MLRT)

In the first stage, a bat call is classified as bat call if the predicted call probability exceeds an adjustable Detection Threshold.

The AI Call Detector's first stage was trained with a huge amount of bat call and noise recordings. However, since background noise can have many different causes, it is impossible to cover the whole variety of potential noises in the network training process. Consequently, it is important to assess the performance and accuracy of the AI Call Detector's first stage for a specific set of recordings prior to run the automated file discrimination.

To evaluate the performance and accuracy of the AI Call Detector's first stage and find the optimal Detection Threshold the so-called Ground Truth, the truth if a file really includes a bat call or not, must be known for a certain proportion of recorded files. Subsequently, the Probability of correct Discrimination depending on the Detection Threshold and Level of Significance α as well as the F_2-Score can be calculated by comparing the Ground Truth with the results of the AI Call Detector's first stage. BATscreen PRO offers an AI CALL DETECTOR PERFORMANCE EVALUATION method.

To start the AI CALL DETECTOR PERFORMANCE EVALUATION, click EVALUATION -> AI CALL DETECTOR PERFORMANCE EVALUATION.

Select Evaluation Folder and set Source of Ground Truth

Select the folder, that includes the WAV-files on which you want to evaluate the AI Call Detector Performance.

Subsequently, the SET SOURCE OF GROUND TRUTH Dialog allows to determine if the Ground Truth is obtained by either loading the results of a previous EVALUATION or performing a LIVE LABELING (see Figure 23).

If you want to use the results of a previous EVALUATION as source of Ground Truth select the Evaluation method to determine which file header information is loaded and wait until the header data of all files is loaded to the list. The progress of the header loading process is depicted by the blue progress bar right next to the list. When the process finishes, please check all Classes that are related to a bat call in the IS BAT column.

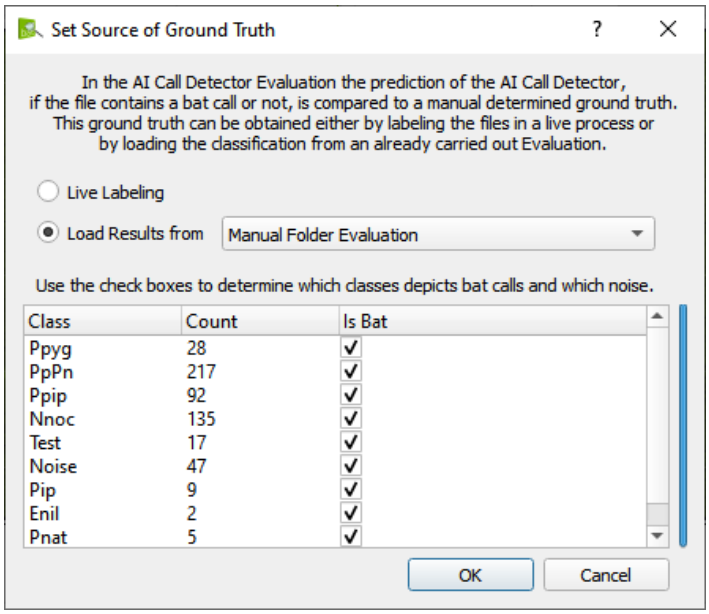

Figure 23: Set Source of Ground Truth Dialog

Run AI Call Detector Performance Evaluation Process

As soon as the SET SOURCE OF GROUND TRUTH Dialog is accepted, BATscreen PRO starts to run the AI Call Detector subsequently on all files in the selected folder.

If the LIVE LABELING process is chosen, simultaneously files in the selected folder are presented to the user as spectrograms in a random order. The user decides if the shown spectrograms contain a bat call or not by clicking the bat or no-bat button. Alternatively, the <X>- and <C>-keys on the keyboard can be used. To undo the LIVE LABELING decision for the last file, press the Undo Last button (see Figure 24)..

To discard all LIVE LABELING decisions and restart the LIVE LABELING process press the Undo button right next to the MANUAL EVALUATION progress bar.

The Undo button right next to the AI CALL DETECTOR progress bar discards all AI Call Detector results and restarts the process. This is necessary, when the model version of the AI Call Detector changed and data have to be analysed with the new models.

The progress of the AI Call Detector as well as the decisions of the Live Labeling process are saved in a new subfolder (“detectorEvaluationData”) in the current evaluation folder. This allows to continue an interrupted AI CALL DETECTOR PERFORMANCE EVALUATION process.

While the AI Call Detector and the Live Labeling process are running, the Confusion Matrix as well as the Probability of correct Discrimination vs. Detection Threshold Plot and the F_2-Score Plot are continuously updated.

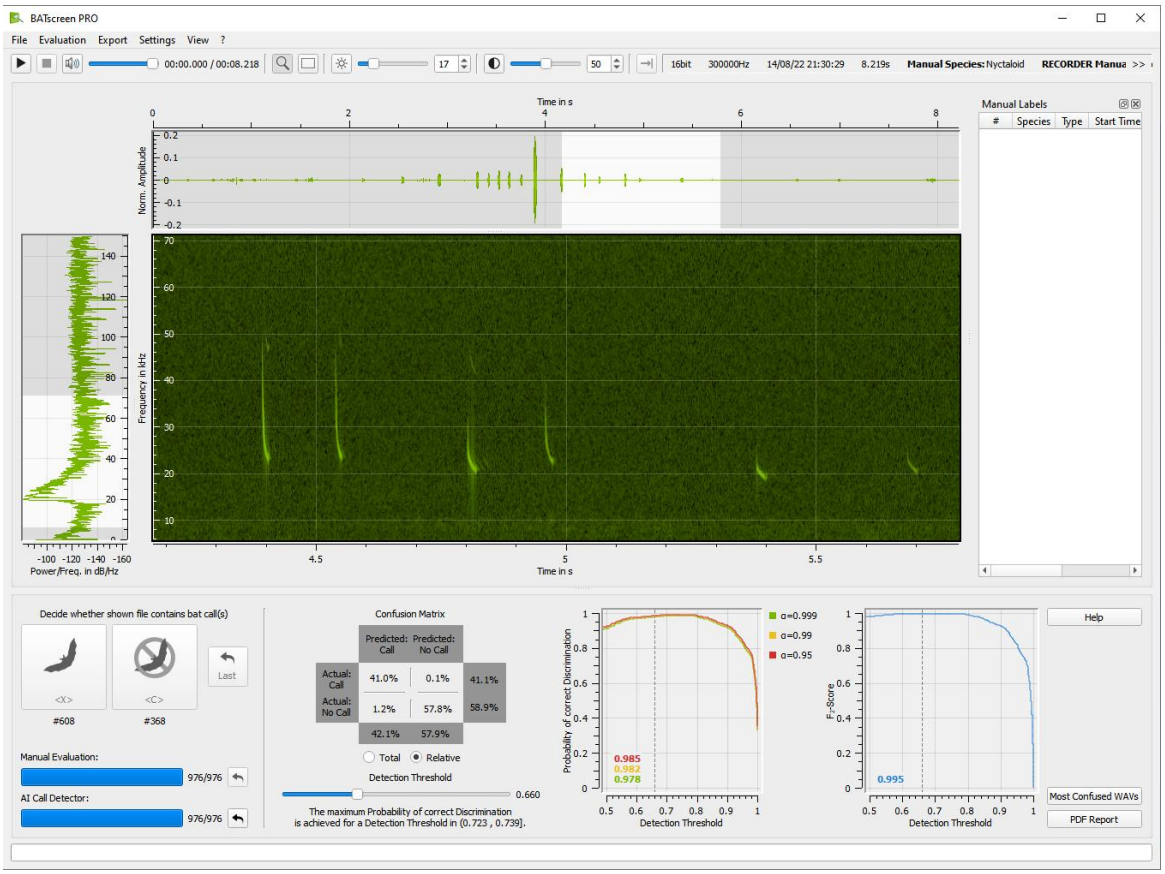

Figure 24: Window of AI Call Detector Performance Evaluation

Resulting Plots

The Confusion Matrix (see Figure 25) visualizes the performance of an AI Call Detector. Each row of the matrix represents the instances of the manual (actual) classification, while each column represents the instances of the AI Call Detector (predicted) classification. By moving the Detection-Threshold-Slider the Confusion Matrix is calculated for a specific Detection Threshold. Use the button ABSOLUTE and RELATIVE to switch between absolute and relative filenumbers. Relative file numbers are normalized based on the total file number that have been analysed in both, the MANUAL EVALUATION and the AI CALL DETECTOR EVALUATION process, so far.

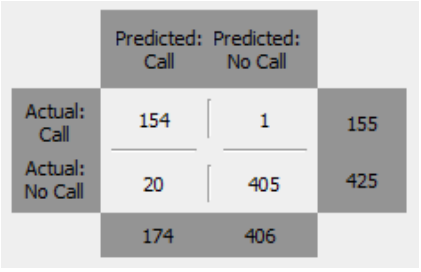

Figure 25: Confusion Matrix

The Probability-of-correct-Discrimination vs. Detection-Threshold Plot (see Figure 26) visualizes the result of a one-tailed hypothesis test in dependence of the Detection Threshold. The Probability of correct Discrimination depicts the probability that the AI Call Detectors distinguishes correctly between a call and a noise file for the respective Level of Significance α. The respective Probabilities of correct Discrimination at the selected Detection Threshold (marked with dashed line) are shown in the lower left corner of the plot.

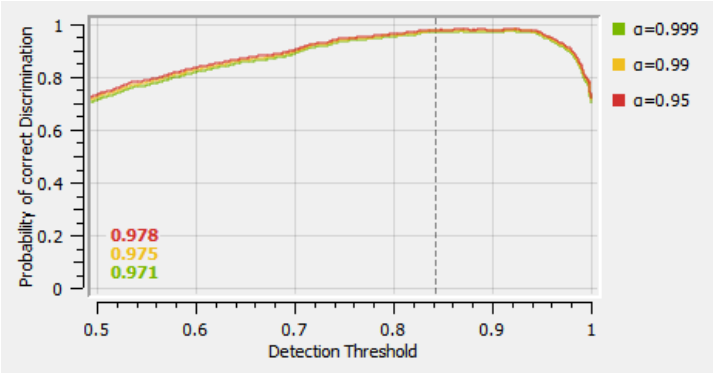

Figure 26: Probability of Correct Discrimination vs. Detection Threshold Plot

While in the Probability of Correct Discrimination False Positive and False Negatives are equally weighted, the F_2-Score allows to weight them differently. In case of F_2-Score the recall is consider twice as important as the precision of the test. That means that False-Negatives (an actual call file that is predicted as no call) are weighted twice as much as False-Positives (an actual no call file that is predicted as call). By this, the probability to miss a call file is minimized. The F_2-Score (see Figure 27) at the selected Detection Threshold (marked with dashed line) is shown in the lower left corner of the plot.

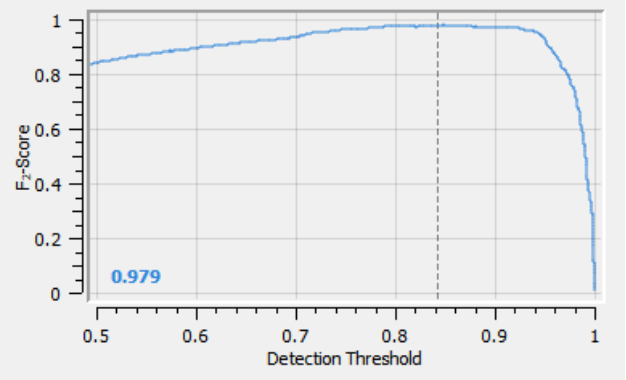

Figure 27: F_2-Score vs. Detection Threshold Plot

Naturally, the accuracy and the expressiveness of the plots increase with the number of evaluated files. This is determined by the user by classifying only a specific number of files manually or exporting data when the AI Call Detector is still running.

The evaluation plots are used to determine the “optimal” Detection Threshold for a specific set of recordings. The term “optimal” must be understood in relation to the requirements of the respective analysis. In some use cases it is of utmost importance to minimize the number of missed call recordings (False-Negatives), while accepting a higher number of False-Positives (an actual no call file that is predicted as call). In other cases, a more balanced ratio of False-Negatives to False-Positives is allowed.

Export

Use MOST CONFUSED WAVS to copy the WAV-files with the worst performance of the AI Call Detector to another folder. These files can be used to retrain the first stage model of the AI Call Detector. Contact bat bioacoustictechnology if you are interested in individual model retraining.

Click PDF REPORT to create a detailed evaluation report.

Export via Export Menu

It is possible to export the files along with the Ground Truth and the AI Call Detector result as CSV file by using the EXPORT -> EXPORT CSV FILE menu.

To access just a proportion of the shuffled files, a selectable number of files from the beginning of the shuffled files list can be copied to another folder by using the EXPORT -> COPY AUDIO FILES menu.

18. Activity Plots

In many cases, quality of recorded data can be easily estimated by plotting records over time, days, months or environmental parameters like temperature, wind speed or precipitation.

BATscreen PRO includes a fast and intuitive plotting tool to create a wide range of images for data evaluation and analysis. To start the plotting tool open a folder (see File Menu 8), run a manual folder evaluation (see Chapter 13) or review a RECORDER WEA Offline Analysis (see Chapter 14). Subsequently, when all headers in the file list are loaded (loading progress is depicted in the vertical progress bar right next to the file list), click EVALUATION -> ACTIVITY PLOTS to open the ACTIVITY PLOT window (see Figure 28).

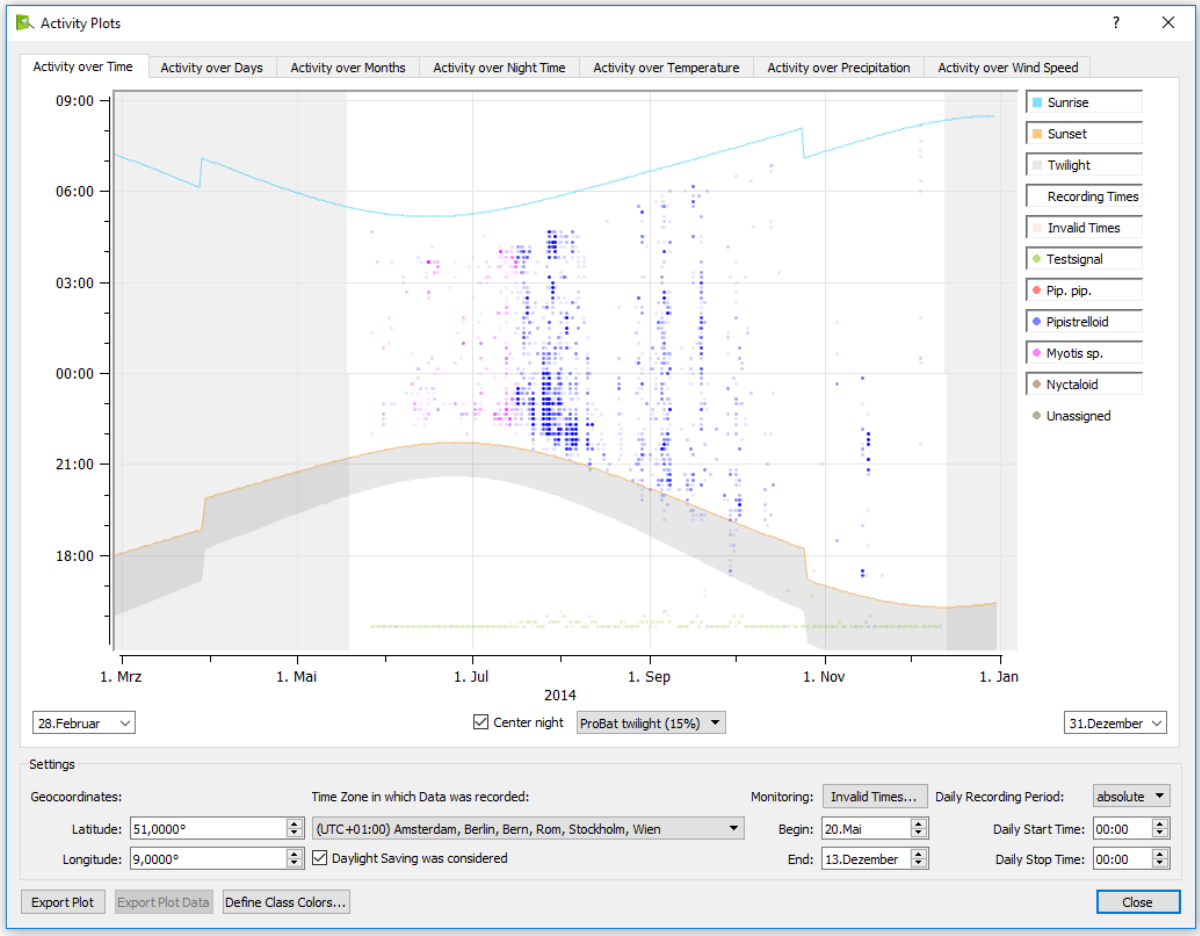

Figure 28: Activity over Time Plot

The ACTIVITY PLOT window shows in the upper part the plot selected in the Tab menu. Below you find the general SETTINGS box, which is applied for all plots.

To export created plots as pixel (*.bmp, *.jpg, *.jpeg, *.pbm, *.pgm, *.png, *.ppm, *xbm, *.xpm) or vector (*.pdf) graphic click EXPORT PLOT at the lower edge of the window.

With EXPORT PLOT DATA it is also possible to export the calculated plot data as CSV-file (not for ACTIVITY OVER TIME plot). These data can be imported in other plotting tools like Microsoft Excel to create your own styled plots.

To change the color representation within the plots, use the DEFINE CLASS COLORS... button. In the SET COLOR FOR CLASSES dialog (see Figure 29), the color representation of the assigned classes can be adapted by clicking on the respective SET COLOR... button. Click on DEFAULT to return to the default color scheme.

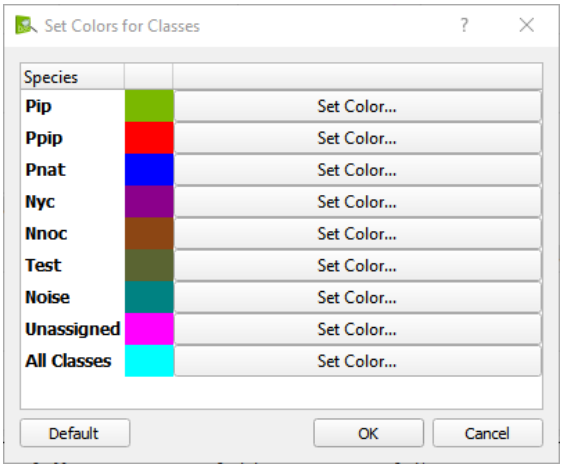

Figure 29: Set Colors for the class representation in the plots

Settings

The settings are necessary to calculate the plots.

Since in most cases settings are individual for each data evaluation, the settings are saved in the currently opened folder in the file "BATscreenSettings.ini". On opening the ACTIVITY PLOTS window, the respective settings will load automatically.

The both GEOCOORDINATES, LATITUDE and LONGITUDE, allows to calculate sunrise and sunrise times at the location of data recording. Please insert the GEOCOORDINATES as decimal values. You can use Google Maps for example to determine the GEOCOORDINATES of your data recording location.

To enable a correct time representation please select the TIME ZONE in which your data was recorded. Furthermore, if your recording device considers DAYLIGHT SAVING, please check the respective box. The BATmode systems always use the time zone settings of the Windows operating system. Consequently, in most cases DAYLIGHT SAVING has to be enabled, when analysing data recorded with a BATmode system.

In the MONITORING section the monitoring times of your data recording has to be specified. Insert the date you start and end the monitoring in the BEGIN and END field, respectively. If your monitoring data has several invalid periods, for example caused by downtimes of the

recording device or bad values of the microphone sensitivity, use the INVALID TIMES… button to specify those periods.

The DAILY RECORDING PERIOD settings represents the daily times the recording began and stopped. Absolute values depict fixed points of time for each day. If using relative values, the start and stop times are defined as delay relative to sunrise and sunset. A positive delay means a point of time after sunrise or sunset. Consequently, negative delays refer to point of times prior to daily sunset or sunrise. If a BATmode system was utilized for data acquisition, these values were specified in the BATcontrol software.

Activity over Time

The ACTIVITY OVER TIME is used to show the number of records within 10-minute intervals with respect to daytime and day of the year (see Figure 28). Hereby, y-axis represents daytime and x-axis days of a year. For each ten minute-interval dots of various opacity depicts the number of records within the respective 10 minutes interval. For each file opacity increases 10%. Consequently, the opacity is 100% for 10 or more files within the respective 10 minutes interval. Different colors allow distinguishing assigned classes of records.

INVALID TIMES specified in the SETTINGS are depicted in red. All times outside the DAILY RECORDING PERIODS and the START and END date of the monitoring are disabled and marked light grey.

By selecting a desired TWILIGHT option, shadowed twilight times are added to the plot. Here, civil, nautical and astronomical twilight, depict the time period from sunrise or sunset until the geometric center of the sun reaches 6°, 12° or 18° below the horizon, respectively. In contrast, PROBAT TWILIGHT (15%) determines 15% of the night`s duration before sunset.

Checking CENTER NIGHT allows focusing the plot on night times.

By checking legend items, respective elements within the plot become visible or invisible.

The date edit fields at the lower left and right edge of the plot allows zooming the plot to specific start and stop dates.

If the < > buttons are visible on the left and right edge of the plot, your data contains files of multiple years. Use these buttons to switch between the years.

Activity over Days

The ACTIVITY OVER DAYS Plot shows data activity (left y-axis) over day in year (x-axis) (see Figure 30). The right y-axis depicts the valid monitoring hours for each day.

For the left y-axis you can choose between:

- ACTIVITY IN RECORDINGS PER HOUR: Number of Files normalized to the valid monitoring hours on this day.
- NUMBER OF FILES PER DAY
- NUMBER OF EVENTS WITH DYNAMIC 1 MINUTE TIME INTERVAL
- NUMBER OF EVENTS WITH DYNAMIC 5 MINUTE TIME INTERVAL
- NUMBER OF EVENTS WITH DYNAMIC 10 MINUTE TIME INTERVAL

- NUMBER OF EVENTS WITH STATIC 1 MINUTE TIME INTERVAL
- NUMBER OF EVENTS WITH STATIC 5 MINUTE TIME INTERVAL
- NUMBER OF EVENTS WITH STATIC 10 MINUTE TIME INTERVAL

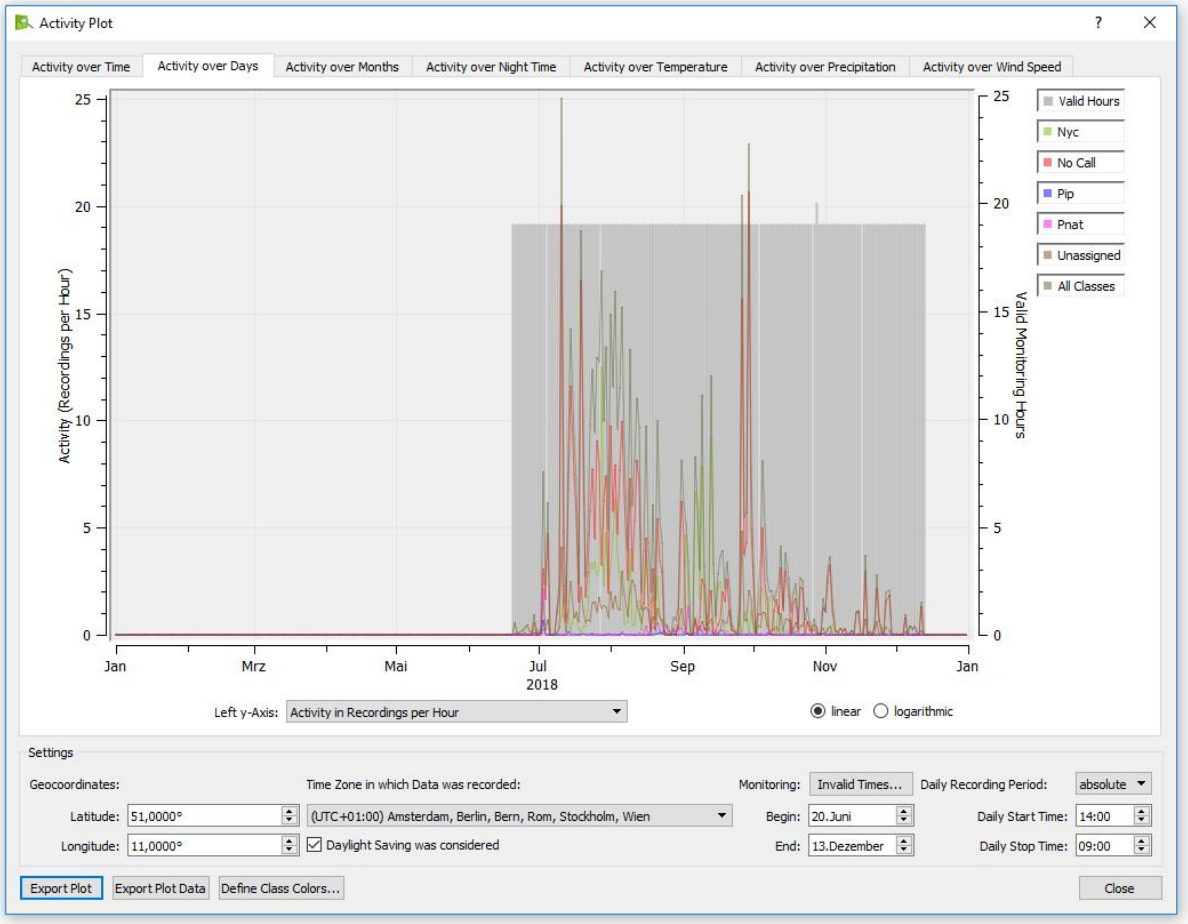

Figure 30: Activity over Days Plot

An event is triggered when the recording start time of at least one recorded file is within a specific time interval (1min/5min/10min). No other files with recording start times within this time interval will trigger an additional class event. The time intervals can be either static or dynamic. Static time intervals are fixed intervals in relation to the time of day, e.g. from 12:05:00 – 12:09:59 (5min interval) or from 17:30:00 – 17:30:59 (1min interval). Dynamic time intervals start at the recording start time of the class event-triggering file. This means, if the recording start time of a class event-triggering file is at 20:22:45 the time interval for a 10 min dynamic interval is 20:22:45 – 20:32:44. Events are calculated separately for each class.

By checking legend items, respective elements within the plot become visible or invisible.

By selecting linear or logarithmic, you can change between a linear or logarithmic scaling of the left and right y-axis.

If the < > buttons are visible on the left and right edge of the plot, your data contains files of multiple years. Use these buttons to switch between the years.

Activity over Months

The ACTIVITY OVER MONTHS Plot shows the activity in recordings per hour (y-axis) over month (y-axis) (see Figure 31). Hereby, activity is defined as the number of recorded files within a certain month, normalized to the valid monitoring hours in this month. The right y-axis depicts valid monitoring hours for each month.

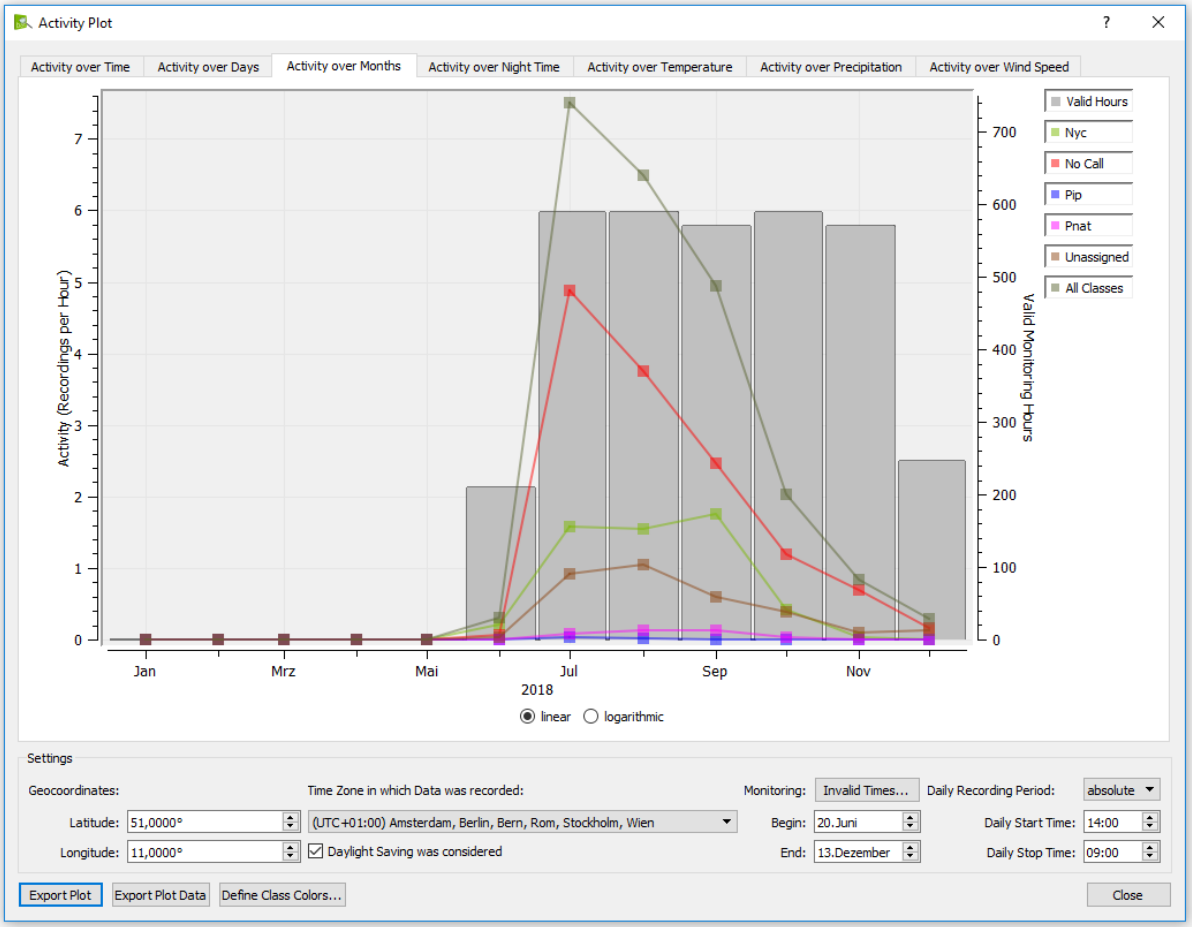

Figure 31: Activity over Months Plot

By checking legend items, respective elements within the plot become visible or invisible.

By selecting linear or logarithmic, you can change between a linear or logarithmic scaling of the left and right y-axis.

If the < > buttons are visible on the left and right edge of the plot, your data contains files of multiple years. Use these buttons to switch between the years.

Activity over Night Time

The ACTIVITY OVER NIGHT TIME Plot shows activity in recordings per hour (y-axis) over night-time (x-axis) (see Figure 32). Hereby, activity is defined as the number of recorded files within a certain period of night time, normalized to the valid monitoring hours in this night time period. The right y-axis depicts valid monitoring hours for each night time period.

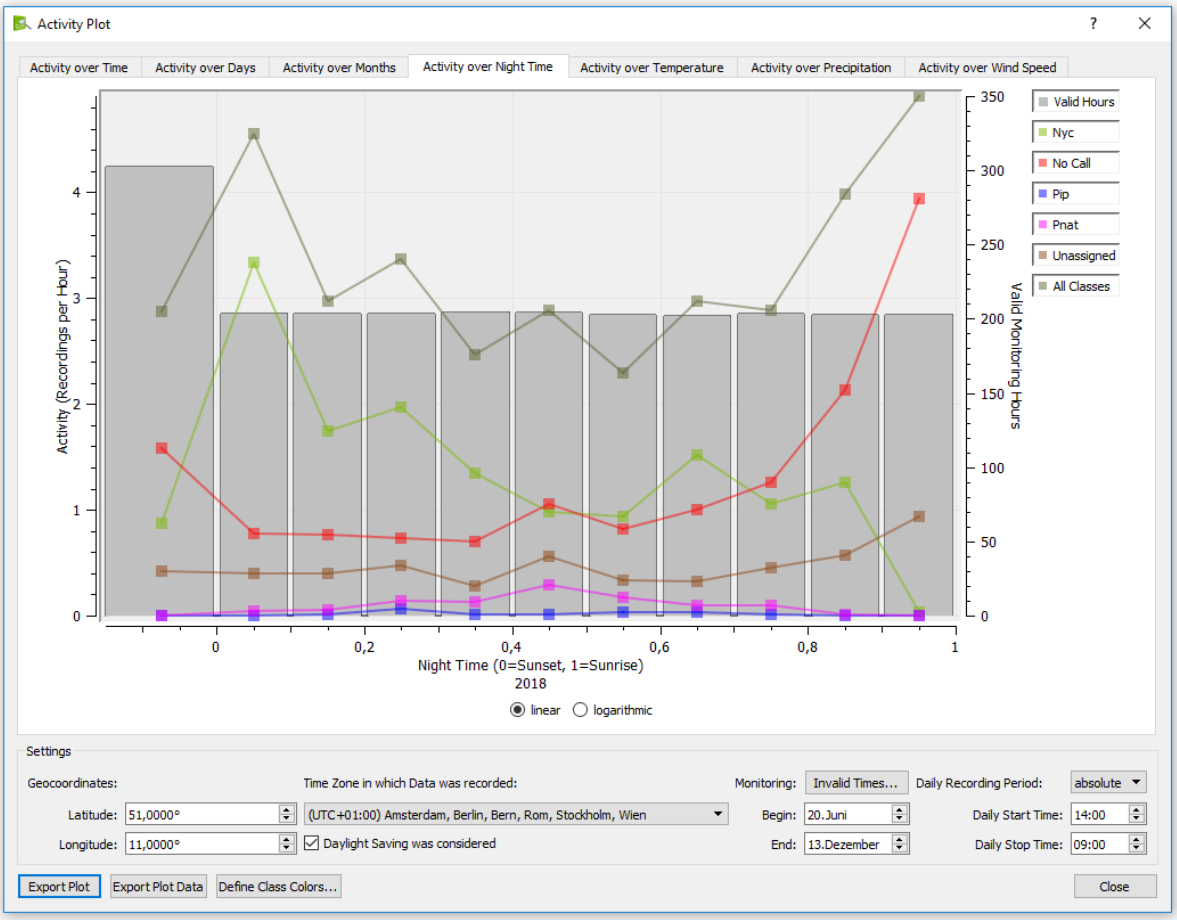

Figure 32: Activity over Night Time Plot

A night time is defined in percentage of night. Consequently, a night time of zero represents sunset and a night time of one represents sunrise. For plotting, the night is divided in 10 night time periods each including 10% of the night duration. Additionally, the so called Probat twilight night time interval is shown. This interval is defined as 15% of the night duration before sunset.

By checking legend items, respective elements within the plot become visible or invisible.

By selecting linear or logarithmic, you can change between a linear or logarithmic scaling of the left and right y-axis.

If the < > buttons are visible on the left and right edge of the plot, your data contains files of multiple years. Use these buttons to switch between the years.

Activity over Temperature

The ACTIVITY OVER TEMPERATURE Plot shows the activity in recordings per hour (y-axis) over temperature (y-axis) (see Figure 33). Hereby, activity is defined as the number of recorded

files within a certain temperature interval, normalized to the valid monitoring hours in this temperature interval. The right y-axis depicts valid monitoring hours for each temperature interval.

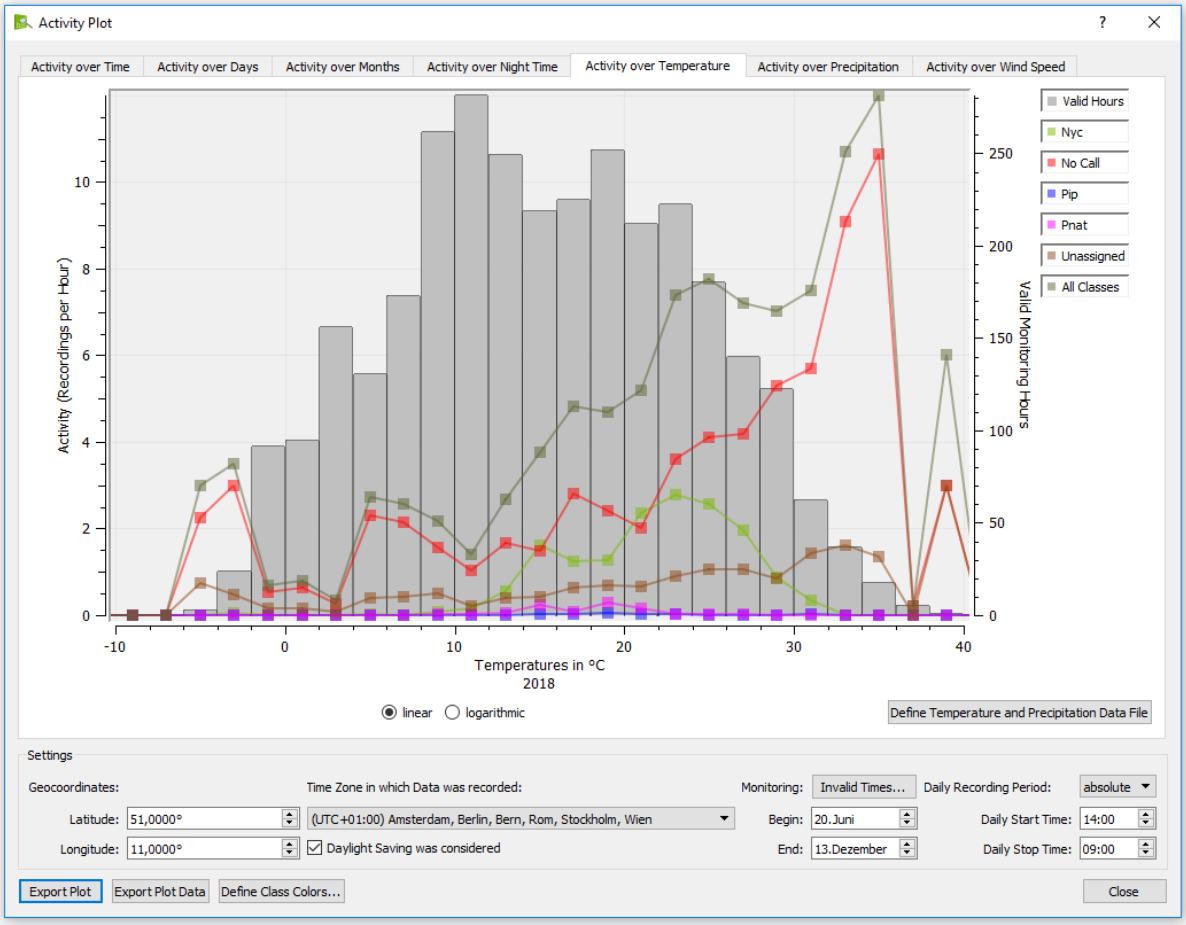

Figure 33: Activity over Temperature Plot

To create the ACTIVITY OVER TEMPERATURE plot, define the temperature data file by clicking DEFINE TEMPERATURE AND PRECIPITATION DATA FILE. The file has to contain temperature and precipitation data as mean values of 10 min intervals in three columns, separated by tabulators:

- **Datetime**: Represents the beginning of the 10 min interval in the format "yyyy-MM-dd hh:mm:ss".
- **Temperature** in °C
- **Precipitation** in mm/min

If a BATmode system was used for data acquisition, use the file "conditionlog.txt". This file stores all temperature and precipitation data acquired by the BATmode in the correct format.

By checking legend items, respective elements within the plot become visible or invisible.

By selecting linear or logarithmic you can change between a linear or logarithmic scaling of the left and right y-axis.

If the < > buttons are visible on the left and right edge of the plot, your date contains files of multiple years. Use these buttons to switch between the years.

Activity over Precipitation

The ACTIVITY OVER PRECIPITATION Plot shows the activity in recordings per hour (y-axis) over precipitation (y-axis) (see Figure 33). Hereby, activity is defined as the number of recorded files within a certain precipitation interval, normalized to the valid monitoring hours in this precipitation interval. The right y-axis depicts valid monitoring hours for each precipitation interval.

To create the ACTIVITY OVER PRECIPITATION plot, define the precipitation data file by clicking DEFINE TEMPERATURE AND PRECIPITATION DATA FILE. The file has to contain temperature and precipitation data as mean values of 10 min intervals in three columns, separated by tabulators:

- **Datetime**: Represents the beginning of the 10 min interval in the format “yyyy-MM-dd hh:mm:ss”.
- **Temperature** in °C
- **Precipitation** in mm/min

If a BATmode system was used for data acquisition use the file “conditionlog.txt”. This file stores all temperature and precipitation data acquired by the BATmode in the correct format.

By checking legend items, respective elements within the plot become visible or invisible.

By selecting linear or logarithmic you can change between a linear or logarithmic scaling of the left and right y-axis.

If the < > buttons are visible on the left and right edge of the plot, your date contains files of multiple years. Use these buttons to switch between the years.

Activity over Wind Speed

The ACTIVITY OVER WIND SPEED Plot shows the activity in recordings per hour (y-axis) over wind speed (y-axis) (see Figure 34). Hereby, activity is defined as the number of recorded files within a certain wind speed interval, normalized to the valid monitoring hours in this wind speed interval. The right y-axis depicts valid monitoring hours for each wind speed interval.

To create the ACTIVITY OVER WIND SPEED plot, define the wind speed data file by clicking DEFINE WIND SPEED DATA FILE. Since wind speed data is in most cases acquired by wind turbines, data format may vary from turbine manufacturer to turbine manufacturer. To allow a wide variety

of data formats you can specify the format in the SET FILE FORMAT dialog (see Figure 35), which opens when selecting a wind speed data file. In this dialog, the formats of the three columns **date**, **time** and **wind speed** have to be specified as well as the respective column separators. Furthermore, select the correct TIME/DATE DEFINITION and choose the time zone in which wind speed data was recorded as well as if daylight saving was considered or not. In the list view on the bottom edge of the dialog, a live preview of the first data values is shown. This helps to verify whether data format settings are correct.

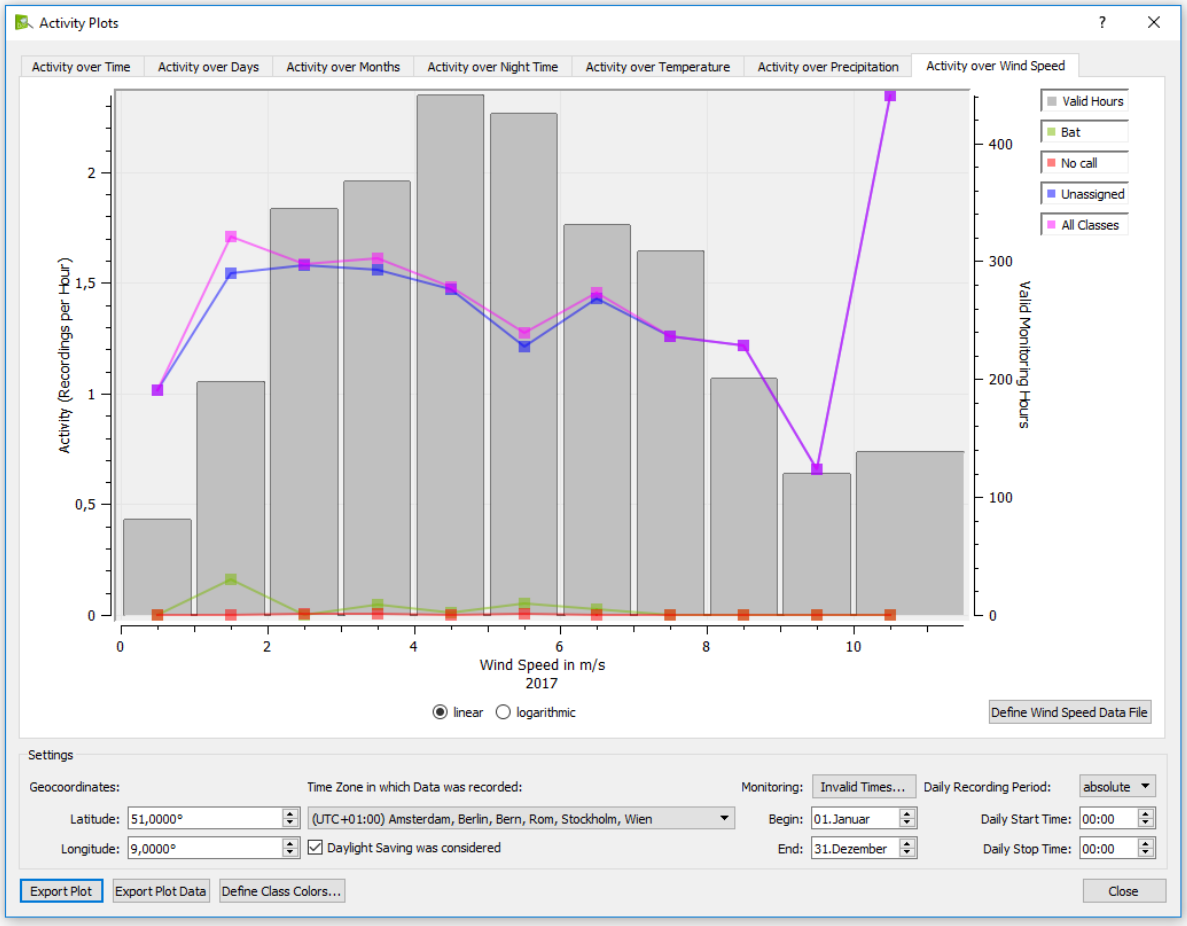

Figure 34: Activity over Wind Speed Plot

By checking legend items, respective elements within the plot become visible or invisible.

By selecting linear or logarithmic, you can change between a linear or logarithmic scaling of the left and right y-axis.

If the < > buttons are visible on the left and right edge of the plot, your data contains files of multiple years. Use these buttons to switch between the years.

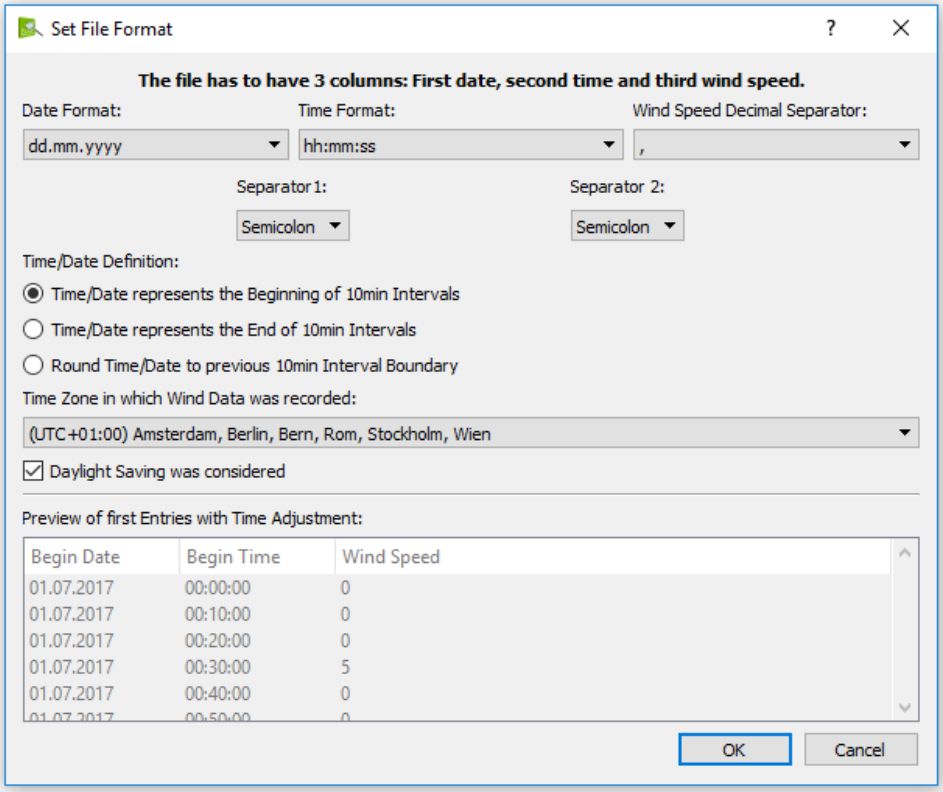

Figure 35: Set Wind Speed Data File Format

19. Microphone Sensitivity / Recording Period

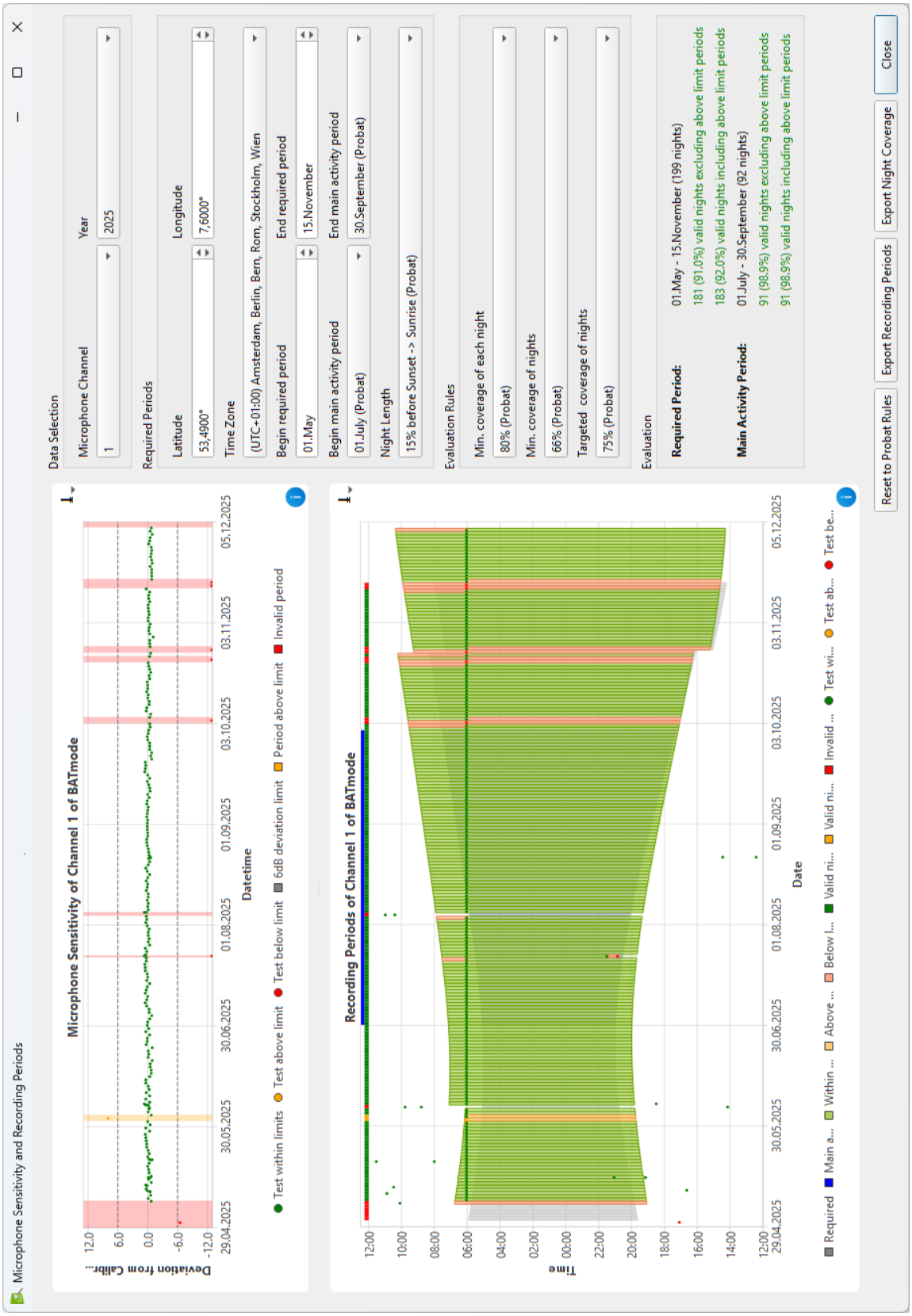

Figure 36: Microphone Sensitivity / Recording Periods Evaluation

The BATmode bat detector can test microphone sensitivity during an active monitoring to verify data validity. These tests are saved in the log file “reference.txt”. Furthermore, time stamps of recording periods as well as the set calibration of the BATmode system are stored in the “rectimelog.txt” file. Combined information of both files allows to determine valid recording periods as well as downtimes of the recorder.

To start the evaluation, select the folder containing the files “reference.txt” as well as “rectimelog.txt”. These files are stored by the BATmode in the folder named “Monitoring Directory”.

To update a Microphone Sensitivity and Recording Periods Evaluation with data from different log files, drag and drop the new “reference.txt” and “rectimelog.txt” file simultaneously on the evaluation window.

Microphone Sensitivity Plot

Microphone sensitivity over time is depicted in the plot “Microphone Sensitivity”. Limits of the valid range between +6dB and -6dB with respect to the calibration values are shown as dashed grey horizontal lines. Microphone sensitivity tests are plotted as red, orange or green dots, following their deviation from the calibration values. Green dots represent tests with a deviation within the limits of 6dB. The deviation of orange dots is above 6dB, while for red dots the deviation is below 6dB or cannot be determined at all.

Coloured background markings indicate invalid periods (red) or periods with a deviation exceeding the positive 6 dB threshold (orange). Following Probat 8 rules, only periods that are within the 6 dB deviation limits between two consecutive tests, and where the time interval between them does not exceed 26 hours, are considered valid recording periods.

Use mouse hover within the plot to get detailed information on the tests as tooltips.

To zoom in, you can use the mouse to select a rectangular area on the graph.

Click on the respective legend entry to hide or show the respective plot element.

To export the plots as PDF or PNG file, please use the export button in the upper right corner of the plot.

Click the info button in the lower right corner for an explanation of the plot.

Recording Periods Plot

Recording periods are drawn in the second plot with respect to daytime on the y-axis and day of the year on the x-axis. As the y-axis is centred to midnight, the daytime between 12:00 and 0:00 in the lower half of the plot corresponds to the actual date on the x-axis while the daytime in the upper part of the plot corresponds to the following day.

Tests of the microphone sensitivity are marked as coloured dots following the rules of the microphone sensitivity plot.

Recording periods during which the recorder was active and potential bat calls were recorded are shown as coloured rectangles also following the colour scheme of the microphone sensitivity plot.

While, grey rectangles in the background show the required recording periods, blue rectangles depict the proportion of these required periods that lies within the main activity period.

This main activity period is also shown as blue bar at the top edge of the plot.

Below the blue main activity bar, coloured rectangles depict for each night if it is valid or not. A night is valid (green) if the minimum coverage of the required recording period by valid (green) recording periods at this day is above the specified percentage. If only the coverage by valid plus recording periods above the 6dB limit are above the specified percentage, the day is depicted as orange. Days with a coverage by invalid recording periods of more than 100% minus the specified percentage are invalid and shown in red.

Use mouse hover within the plot to get detailed information on the tests as tooltips.

To zoom in, you can use the mouse to select a rectangular area on the graph.

Click on the respective legend entry to hide or show the respective plot element.

To export the plots as PDF or PNG file, please use the export button in the upper right corner of the plot.

Click the info button in the lower right corner for an explanation of the plot.

Data Selection

The BATmode can be equipped with up to four microphones. To plot the data for a different microphone channel, select the respective channel in the dropdown menu MICROPHONE CHANNEL.

If the log files include data of more than one year, use the YEAR dropbox to select the required year.

Required Periods

To calculate required periods set the geocoordinates (LATITUDE and LONGITUDE) that represent the location at which data was recorded. Furthermore, select used TIME ZONE as well as the annual beginning and end of required period.

The main activity period lying within the required period allows to ensure a proper coverage of an especially critical main bat activity period.

Use NIGHT LENGTH to define the time of the nights/days that should be covered by the required periods.

Evaluation Rules

To determine if the whole required period as well as the main activity period are adequately sampled evaluation rules can be defined.

The MIN. COVERAGE OF EACH NIGHT defines the percentage of the required period of a night that have to be at least covered by valid or valid + above limit recording periods.

MIN. COVERAGE OF NIGHTS represents the percentage of all nights that have to be valid or valid + above limit to meet the minimum criterion.

TARGETED COVERAGE OF NIGHTS represents the percentage of all nights that have to be valid or valid + above limit to meet the desired criterion.

Evaluation

Evaluation of the dataset for the whole required period as well as the main activity period following the specified rules. If shown in orange, the recording periods meet the minimum criterion. If show in green, the recording periods also meet the desired criterion.

Export and Settings Reset

Use the RESET TO PROBAT RULES button to reset all settings to the rules defined by Probat.

To export recording periods data as CSV file, click the button EXPORT RECORDING PERIODS. Each line of the resulting CSV file represents one recording period. Timestamps are given in ISO 8601 format with the UTC time offset appended. Values are separated by ";".

Use this option to export recording periods for Probat 8 and later.

Table 4: CSV Export Format of Recording Periods

start	End	testsignal_deviation_db
2025-03-21T15:59:59+01:00	2025-03-22T09:00:00+01:00	-2.9
2025-03-22T16:00:00+01:00	2025-03-23T09:00:00+01:00	-2.9
2025-03-23T15:59:58+01:00	2025-03-24T09:00:00+01:00	-3.3
2025-03-24T16:00:00+01:00	2025-03-25T09:00:00+01:00	-1.8

To export the coverage of each night of the required recording period as CSV file, click the button EXPORT NIGHT COVERAGE. Each line of the resulting CSV file represents one night of the required recording period in the format "yyyy-MM-dd". The coverage of the respective night by valid recording periods (column 2) or valid recording periods incl. periods above limit (column 3) are exported as value between 0 and 1. Values are separated by ";".

Table 5: CSV Export Format of Night Coverage

night	coverage_excl_above_limits	coverage_incl_above_limits
2025-03-21	0.00	0.00
2025-03-22	1.00	1.00
2025-03-23	0.50	0.74
2025-03-24	1.00	1.00

20. AI Call Detector

The AI Call Detector of BATscreen PRO is depicted in Figure 37. It is based on Convolutional Neuronal Networks (CNN) and a Maximum-Likelihood-Ratio-Test (MLRT). By this, it allows to detect the temporal position of bat calls within a sound signal and provides bat species suggestions for the detected calls. It is designed as a three-stage process:

- First Stage: Detect temporal position of bat calls in sound signal (CNN)
- Second Stage: Suggest a bat species for each detected call (CNN)
- Third Stage: Statistically review species suggestions (MLRT)

Stage 1: Detect Temporal Position of Bat Calls in Sound Signal

Stage 1 of the AI Call Detector was inspired by the paper "Bat detective—Deep learning tools for bat acoustic signal detection" from Oisin Mac Aodha et al.[5]. A five-step detection pipeline is used to determine temporal positions of bat calls within the audio signal:

1. *Resampling:* Audio signals of different sampling rates than 300kHz are resampled.

2. *Fast-Fourier-Transformation (FFT):* The audio signal is converted into a log magnitude spectrogram.

3. *Denoising and Preprocessing:* Background-Noise is reduced in the spectrogram data by removing the mean amplitude in each frequency band. Subsequently, the frequency range is trimmed to 10.3 – 86.4 kHz, the relevant frequency band for bat call detection.

4. *Convolutional Neuronal Network Inference:* A CNN that renders the detection of the bat calls as a multi-class classification problem is applied in a sliding-window fashion with a fixed length detection window size of 34ms on the preprocessed spectrogram data. The CNN was trained with many recordings of search-phase bat echolocation calls but also acoustical and electromagnetic noise from wind turbines and microphone testsignals. It returns probability values for three classes – Bat call, Noise and Testsignal. If the testsignal probability is above its threshold, the sliding-window inference process is aborted early to reduce calculation time. The AI Call Detector setting "Step" determines the increment with which the sliding window is moved along the temporal dimension of the spectrogram data. Consequently, larger values for "Step" will speed up the AI Call Detector calculation but may reduce the accuracy of the detector on the other side.

5. *Local Maxima Detection:* The probabilistic values for bat call classification are smoothed over time with a gaussian filter. Subsequently, a Non-Maxima Suppression

[5] Mac Aodha O, Gibb R, Barlow KE, Browning E, Firman M, Freeman R, et al. (2018) Bat detective—Deep learning tools for bat acoustic signal detection. PLoS Comput Biol 14(3): e1005995. https://doi.org/10.1371/journal.pcbi.1005995

allows to detect local maxima that corresponds to the predicted temporal positions of the search-phase bat calls. The minimum distance between two detected local maxima can be adopted by the AI Call Detector settings “Minimum Call Distance”. All local maxima with a probability value above the “Detection Threshold” will be considered as detected search-phase bat call.

The AI Calls List (see Figure 38) in BATscreen PRO right next to the Spectrogram Plot lists all detected search-phase bat calls. “Time” depicts the temporal position of a call and “P(Call)” the respective probability value.

Stage 2: Suggest a Bat Species for each Detected Call

In Stage 2, a CNN that poses the bat species suggestion as multi-label classification problem, is applied on the processed spectrogram data for each detected temporal position from Stage 1. The CNN distinguishes between 14 output classes, see Table 4. In “Species” the AI Calls list depicts the species with the highest probability. The respective probability is appended in parentheses. The propability of species deactivated in the AI Call Detector settings will be set to 0%.

Table 6: Stage 2 Species Tree of AI Call Detector

Class	Possible Species
Nlei	*Nyctalus leisleri*
Nnoc	*Nyctalus noctula*
Enil	*Eptesicus nilssonii*
Eser	*Eptesicus serotinus*
Vmur	*Vespertilio murinus*
Pnat	*Pipistrellus nathusii*
Ppip	*Pipistrellus pipistrellus*
Ppyg	*Pipistrellus pygmaeus*
Pkuh	*Pipistrellus kuhlii*
Myotis	*Myotis bechsteinii,*
	Myotis nattereri,
	Myotis daubentonii,
	Myotis mystacinus,
	Myotis myotis
Plecotus	*Plecotus auratus,*
	Plecotus austriacus
Bbar	*Barbastella barbastellus*
Hsav	*Hypsugo savii*
Tten	*Tadarida teniotis*

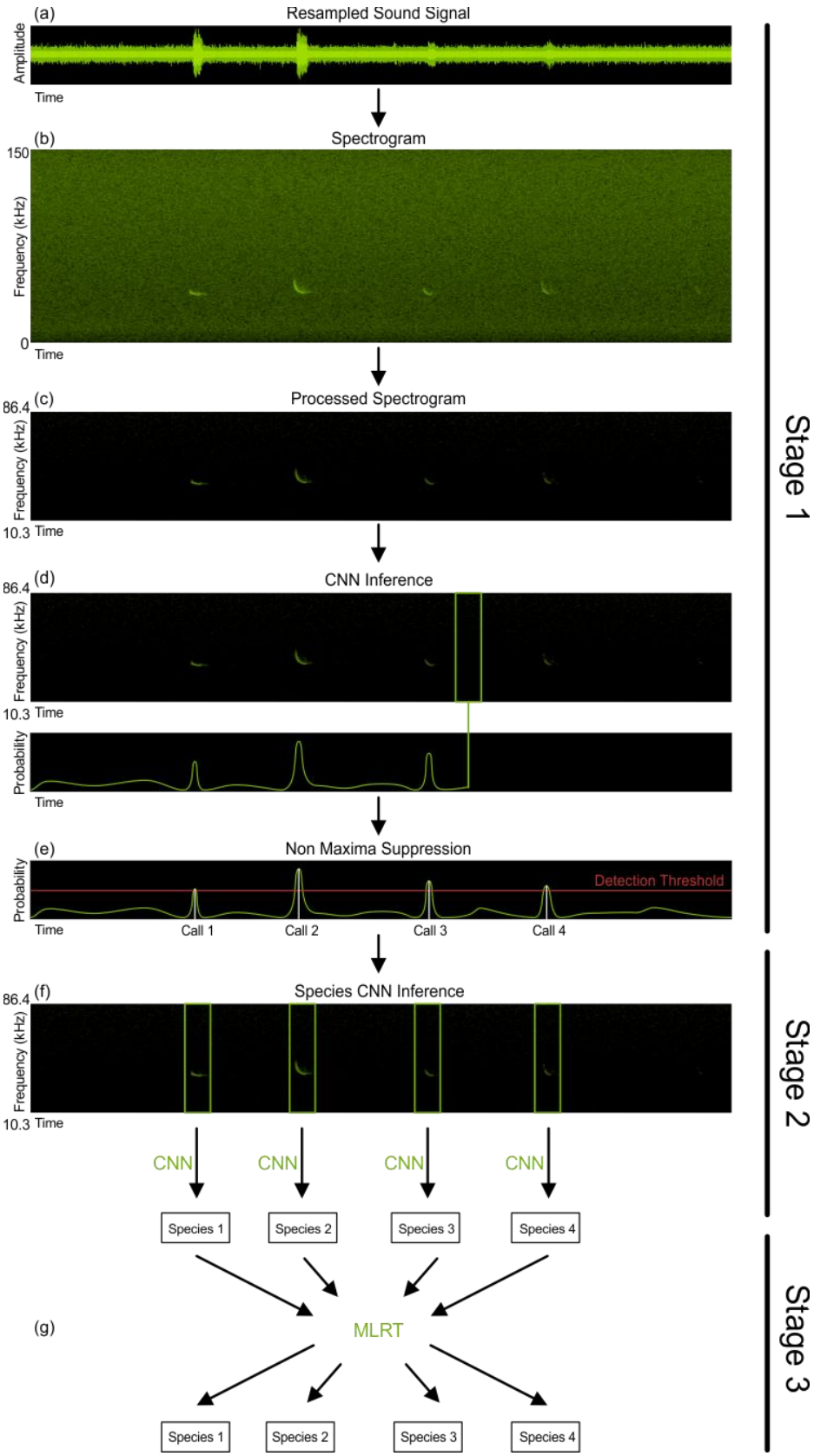

Figure 37: AI Call Detector pipeline. Stage 1: (a) Resampling of sound signal to 300kHz. (b) The sound signal is converted to a log magnitude spectrogram. (c) De-noising and pre-processing of spectrogram. (d) Run CNN call detection in a sliding-window fashion. (e) Smooth probability curve and execute Non-Maxima Suppression to determine calls. Stage 2: (f) Run CNN species identification on each detected call. Stage 3: (g) Execute Maximum-Likelihood-Ratio-Test for a final species identification determination in the analysed file.

Stage 3: Statistically Review Species Suggestions

In a last step, a Maximum-Likelihood-Ratio-Test (MLRT) is utilized for a final species identification determination in the analysed file. The MLRT is based on a 2002 paper by Eric Britzke et al.[6].

The method takes the species classification results from Stage 2 as well as a known inter-species confusion matrix, that means the error rates of the Stage 2 CNN across all the species listed in Table 4, as inputs.

In a first step, the Maximum-Likelihood-Estimator determines the most likely distribution of all different species for the given identifications and error rates. Subsequently, by clamping one species as absent and recalculating the Maximum-Likelihood-Estimator, it is possible to calculate the P-value as ratio between clamped and original likelihood. Like this, it is possible to perform a statistical test that accept the hypothesis that a species is absent or denies it.

If the suggested species for a call is determined as absent in the MLRT, the confusion matrix is used to determine the most likely alternative species. Species identifications that were changed due to the results of the MLRT are marked with a (-) as species probability in the AI Calls list (see blue selected call in Figure 38).

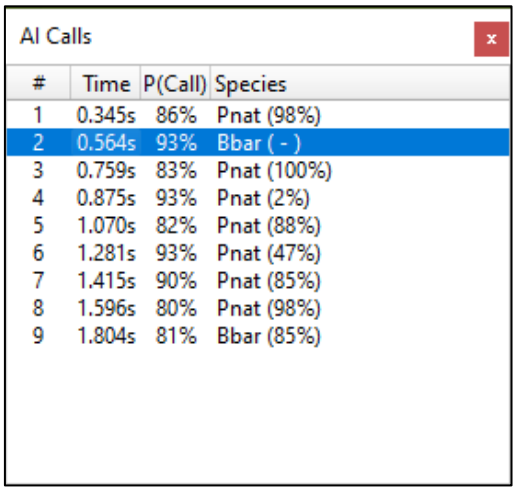

Figure 38: AI Calls List

AI Call Detector Models

The CNNs of AI Call Detector are based on a training process that included several ten-thousands of recordings and species identifications. While the challenge for Stage 1 is to include all types of potential noises in the training process, Stage 2 struggles with the limited availability of acoustic recordings of bats that were manually caught, identified, and released.

[6] Britzke E, Murray K, Heywood J, Robbins L (2002) Acoustic identification. The Indiana Bat: Biology and Management of an Endangered Species. 221–225.

Regrettably, even for known experts it is often very difficult to correctly distinguish between different bat species when only the acoustical fingerprint of a bat call is available. Consequently, especially species with a very similar call shapes and frequency ranges are often misidentified.

However, the accuracy of the AI Call Detector is subject of constant work and will increase with the included training data. As we will further work to make the models better and increase accuracy, we will release new model versions frequently. These models will be available for download as Installer on our website. However, as new models will of course also change the results of the AI Call Detector, it is important to log the model version used to analyse the data. The currently used Model version can be found in the AI Call Detector Settings (see section AI Call Detector Settings).

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BATscreen PRO is based in part on the work
of the Qwt project (http://qwt.sf.net)

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