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Centre for Marine Science and Technology

A Matlab toolbox for Characterisation Of Recorded Underwater Sound (**CHORUS**)

USER'S GUIDE

Version 5**.0b**

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Contents

1. Introduction

A Matlab toolbox for the Characterisation Of Recorded Underwater Sound (CHORUS) is an updated version of the Sea Noise Processing Toolbox V.4 (CMST Report 2012-23: Sea noise Matlab toolbox manual). Additional information about CHORUS and its applications can be found in Gavrilov & Parsons, 2014.

Sea noise data processing and analysis with CHORUS consist of two parts:

1. Data pre-processing. This involves: (1) extraction of necessary timing data from the recording files; (2) calculation of Power Spectrum Density (PSD) using a time window of chosen length in each recording; and (3) correction of PSD for recorder's sensitivity, gain and, when possible, frequency response to get the output data in sound pressure units (µPa). The resulting data are saved in MAT-files in a format suitable for further data analysis in CHORUS Graphic User's Interface (GUI). Data pre-processing of a single set of recordings is done in a batch mode, so no operator attendance is required.

2. Data analysis in CHORUS GUI. CHORUS GUI can be run either in the Matlab environment or as a stand-alone executable program, CHORUS_GUI.exe. See Sections 3 and 4 for details of data analysis.

The current version of CHORUS works with sound recordings made only in two formats: (1) Waveform Audio File Format (.WAV) and (2) binary .DAT with ASCII headers and footers supported in the CMST-DSTO sea noise loggers.

The current version of the pre-processing routines works with sound data files recorded by four models of sea noise recorders: (1) CMST-DSTO low-frequency noise logger, (2) CMST high-frequency noise loggers with SM2+ digital recorder boards, (3) SM2 noise recorders from Wildlife Acoustics, and (4) Sound Trap recorders from Ocean Instruments. These routines can be more or less straightforwardly modified to pre-process data from other sea noise recorder models in a way suitable for CHORUS GUI.

2. Short instructions for data pre-processing

Before starting data pre-processing, make sure that all raw data files with sea noise recordings from a single dataset are stored in or copied into one folder. Also make sure that this folder does not contain other files with the same extension as the raw data files (.WAV or .DAT).

Add the folder with CHORUS routines in Matlab path (Set Path – Add Folder – Save).

2.1 Data from CMST-DSTO low-frequency noise loggers (including all IMOS datasets)

Run CMST_LF_data_preprocessing.m then follow instructions in the Matlab Command Window:

1. Input a dataset ID, a digital ID of arbitrary length (use four digit IDs for CMST datasets);
2. Find and open the calibration file (with the white noise calibration signal) in a dialog box (Windows Explorer window). The calibration file MUST be stored in a different folder than the raw data folder;
3. Input the level of the calibration white noise signal in dB re 1 V^2/Hz.
4. A figure with the recorder frequency response (system through gain vs frequency) will be displayed. Make sure that the curve is acceptable. If it is not acceptable (e.g. with spikes), stop the routine and rerun it with a different calibration file (if such exists);
5. Input the hydrophone sensitivity in dB re 1 V/µPa;

6. Specify length of the time window in seconds to calculate PSD of sea noise. The default length is the length of each recording. If a shorter window (e.g. 10s, 20s or 50s) is specified, PSD for each time window in each recording will be calculated and saved. This will not affect analysis in CHORUS GUI in any way. This option is added only for an additional spectrum analysis in Matlab outside CHORUS GUI.
7. Input the time period in the number of days for which the calculated PSDs will be saved in a single file. Five days is a default option, which is acceptable for a recording frequency bandwidth of 24 kHz to 48 kHz, depending on computer's RAM. Use shorter time periods (1 to 3 days) for broader frequency bands of recording (higher sampling rates).

2.2 Data from CMST high-frequency noise loggers with SM2+ digital recorder boards

Run CMST_HF_data_preprocessing.m, then follow the same instructions in the Matlab Command Window, as those for CMST-DSTO noise logger data.

2.3 Data from SM2 noise recorders from Wildlife Acoustics (no calibration circuit)

Run SM2plus_data_preprocessing.m then follow instructions in the Matlab Command Window:

1. Input a dataset ID, a digital ID of arbitrary length (use four digit IDs for CMST datasets);
2. Input the channel number, 1 or 2, used for recording (SM2 recorders have 2 channels);
3. Input SM2 board gain (governed by DIL switches on board) set for the recording channel;
4. Input the hydrophone sensitivity in dB re 1 V/µPa;
5. Point 6 in Section 2.1;
6. Point 7 in Section 2.1.

2.4 Data from Sound Trap recorders from Ocean Instruments

If noise recordings were made by a Sound Trap recorder in a continuous recording mode, split large (GBs) recording files into sections of chosen length using ST_split_long_files_into_sections.m

Run ST_data_preprocessing.m then follow instructions in the Matlab Command Window:

1. Input a dataset ID, a digital ID of arbitrary length (use four digit IDs for CMST datasets);
2. Input sensor's sensitivity in dB re 1 µPa (according to either low or high gain setting of the recorder and the sensitivity values given in specs for each unit;
3. Point 6 in Section 2.1;
4. Point 7 in Section 2.1.

3 Data review and analysis in CHORUS GUI

Start CHORUS GUI either in the Matlab environment (CHORUS_GUI.m) or as a stand-alone program (CHORUS_GUI.exe).

Select the folder with data (recording files and pre-processed MAT-files. The window shown in Figure 1 will be displayed.

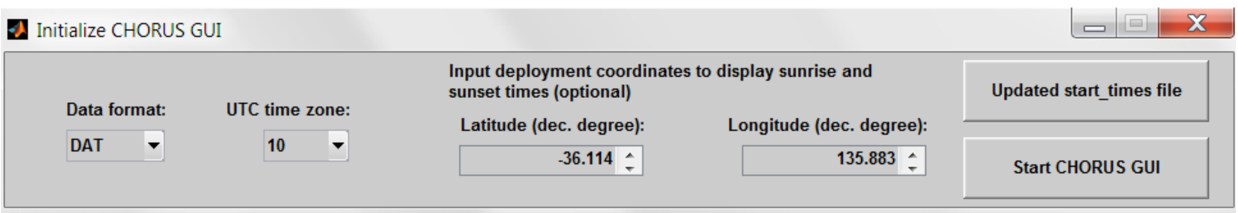

Figure 1: Initial menu of CHORUS GUI.

- A proper data format will automatically appear, if the analysed set was pre-processed with the current CHORUS version. For datasets pre-processed in the older versions, select the proper data format from the pop-up menu.
- Select the time zone from the pop-up menu, if needed.
- Input coordinates of the deployment. The coordinates are needed only to display the sunrise and sunset times in CHORUS GUI, otherwise these fields can be left empty.
- Press “Update start_times file” to save new data in the Data format, UTC time zone and Coordinates fields in the *start_time.mat file in the data folder. The updated values will be automatically displayed in the next sessions of CHORUS with the analysed dataset, so the user will not need to input them again. If the data folder is write protected, then an error message will be displayed, but the values shown/inputted in all fields will be used by CHORUS nevertheless.
- Press “Start CHORUS GUI” to open the main CHORUS menu.

The Main GUI menu is shown in the top menu panel in Figure 2. In this menu you can specify the time period (first and last days) for which a long-time average spectrogram of sea noise, compiled from the pre-calculated PSDs, will be displayed after pressing “Spectrogram” button. The minimum averaging time is the duration of individual recording. At the minimum averaging time, the maximum number of days that can be displayed in the spectrogram is 15 to 30 depending on computer’s capacity. The averaging time can be increased by a factor of 2, 3 or 4, if the user wishes to display a longer time period. In this case, the corresponding number of pre-calculated PSDs will be averaged. If the deployment coordinates were specified, press the “Sunrise/set” button after displaying the spectrogram to add the sunrise and sunset times indicated by red triangles pointed up and down respectively. The dynamic range of PSD levels displayed by different colours can be changed using the minimum and maximum level pop-up menus.

Once the long-time average spectrogram is displayed (Figure 2), the Recording menu will automatically appear below the spectrogram (bottom menu panel in Figure 2). The first action to be done in the Recording menu is to press the “Select time” button and then click the mouse (controlling a cursor) on the top panel spectrogram at the time you choose to analyse sea noise in detail, based on the spectral features in the long-time average spectrogram (e.g. intense noise at whale call frequencies). The corresponding raw data file will be found and loaded. Select settings in the Recording menu according to your preferences and press “Display” to display the waveform and spectrogram of sea noise recorded at the chosen time (bottom panels in Figure 3).

Using the zoom function of the standard Matlab figure menu, you can select a section of the waveform to zoom in. After zooming in or out, press “Display” to update the spectrogram in the right panel (Figure 4).

The settings available in the Recording menu are as follows:

<u>FFT length</u>: The length of FFT window can be chosen in the pop-up menu from 0.05s to 2s depending on the duration and frequency contents of signals to be properly displayed in the spectrogram;

<u>FFT overlap</u>: Overlap of FFT windows can be varied from 10% to 90% with a 10% increment;

<u>Frequency scale:</u> The frequency scale in the spectrogram can be either logarithmic (default) or linear;

<u>High-pass cut-off frequency:</u> High-pass filtering of noise signal. The cut-off frequency is specified as a fraction of Nyquist frequency (default 0 for no filtering);

Low-pass cut-off frequency: Low-pass filtering of noise signal. The cut-off frequency is specified as a fraction of Nyquist frequency (default 1 for no filtering);

Speed up: Factor 1, 2, 5 or 10 to speed up signal's playback (see Playback button description). Default is 1 to play back with normal speed.

The actions available from the Recording menu are as follows:

De-spiking: If it is selected "on" from the pop-up menu, an additional de-spiking menu will pop up with several settings. Use the default ones as optimum for depressing snapping shrimp noise. Once the settings are saved, press the "Display" button to see results of de-spiking in the waveform and spectrogram panels. The de-noised waveform is shown by the blue line in Figure 5 for illustration of the effect. An auto-regression (AR) method (Vaseghi and Rayner, 1990) is used to locate impulses of snapping shrimp noise, remove those and interpolate the signal waveform within the resulting gaps.

Signal stats (applicable primarily to transient signals): By pressing this button, some characteristics of the signal displayed in the waveform panel will be calculated. These characteristics are: maximum peak-to-peak pressure in Pa, maximum received level in dB re 1 μPa, sound exposure level in dB re 1 $\mu Pa^2 \times$ s, and signal duration in seconds containing 90% of its energy. After pressing "Signal stats" a modal dialog box will appear asking to select the option for correcting the calculated values for background noise (correction panel in Figure 6). If automatic correction is selected, the program finds a 5% section of the waveform with minimum RMS pressure, which is assumed to correspond to the intensity of background noise used for correction. If manual correction is chosen, the user will be asked to indicate the start and end times of the waveform fragment, containing only background noise, by clicking the mouse in the waveform panel. Once the correction option is chosen, the program calculates the required characteristics and the results are displayed in a separate window and at the bottom of the waveform panel (Figure 6).

Display: Press this button to update the waveform and spectrogram panels every time the settings are changed.

Play, pause and stop: Use this buttons to play back, pause or stop sound. The waveform shown in the waveform panel will be played back (rather than the whole recording). Playback is sped up according to the speed-up factor chosen. A sliding vertical bar in the waveform panel indicates playback progress.

Save to WAV: Press this button to save the waveform shown in the waveform panel in a Windows wave sound (*.wav) file. The sampling frequency in the saved file is the original sampling frequency times the speed-up factor. The amplitude is normalized so that it does not exceed unity. An additional file with the same name but different extension, .clb, will also be saved. This is a text file containing just one number – a factor by which the signal amplitude must be multiplied to convert it into μPa.

4 Detection

Press this button in the Main menu to start detection of specific sounds. Only detection of calls from pygmy blue whales is implemented in the Toolbox so far. Other sounds of both biological and man-made origin will be added as detection algorithms for those sounds are developed and tested. Detection is carried out over the time period specified by the first and last days selected in the Main menu. It is NOT NECESSARY to display the spectrogram for the specified period, so the time period specified for detection can be as long as needed.

Pygmy blue whales

When pygmy blue whales are selected in the main Detection menu (left menu panel in Figure 7), Pygmy blue whale detection menu appears (middle menu panel in Figure 7). It contains several settings and options to be selected from:

Detect: Press this button to start detection. Progress in searching through the recordings during the selected time period is indicated by a sliding bar in the Detection progress panel (right panel in Figure 7). The detection process can be interrupted by pressing button “Stop” in the Detection progress panel.

Sensitivity (low, normal, high): Select “Low” to get less false detections at the cost of some increase in the missed detection rate. Select “High” to get less missed detections at the cost of some increase in the false detection rate. Use “Normal” as a trade-off.

Display detection progress: If this option is chosen, a spectrogram of every next recording containing detected whale calls will be displayed to review the correctness of detection (Figure 8). Press Enter to proceed to the next recording with detected calls.

Estimate number of animals: If this option is selected, the number of different whales vocalising in the same time interval (length of individual recording) will be estimated.

Save signals: When searching through the chosen time period is finished, the detection times and some signal parameters (such as RMS pressure or received level) will be saved in a MAT-file. If “Save signals” is selected, the waveform of all detected signals will also be saved in the output MAT-file. BE CAREFUL with this option, as the waveforms to be saved can require too much memory, when whale calls are frequent and the time period chosen for detection is long.

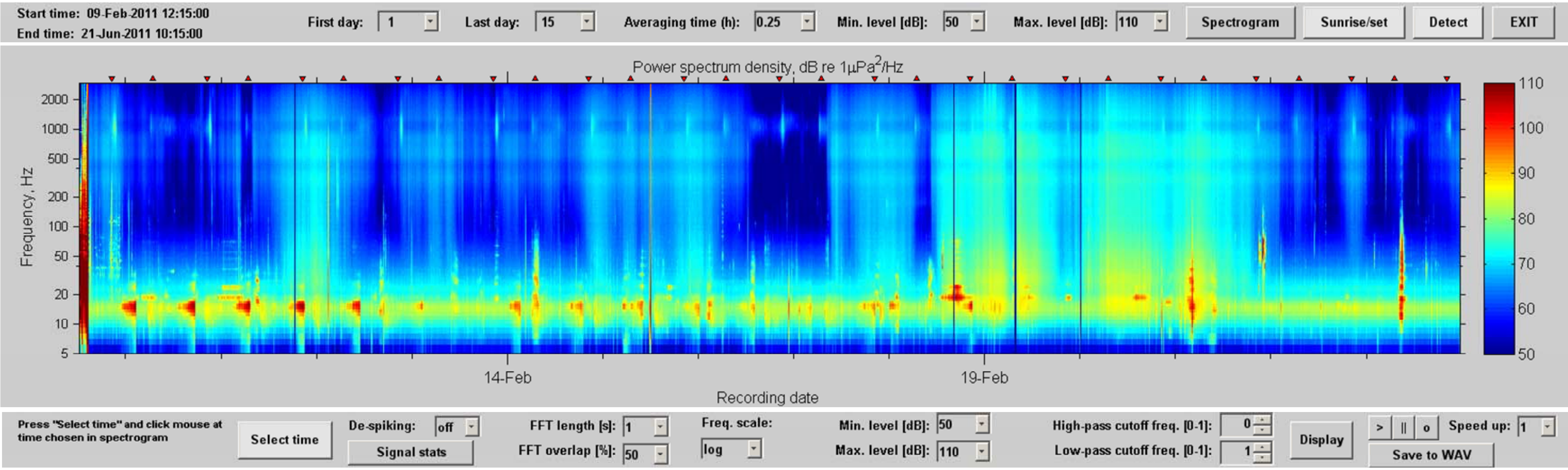

Figure 2: Main GUI menu (top panel), long-time average spectrogram panel (middle), and Recording menu (bottom).

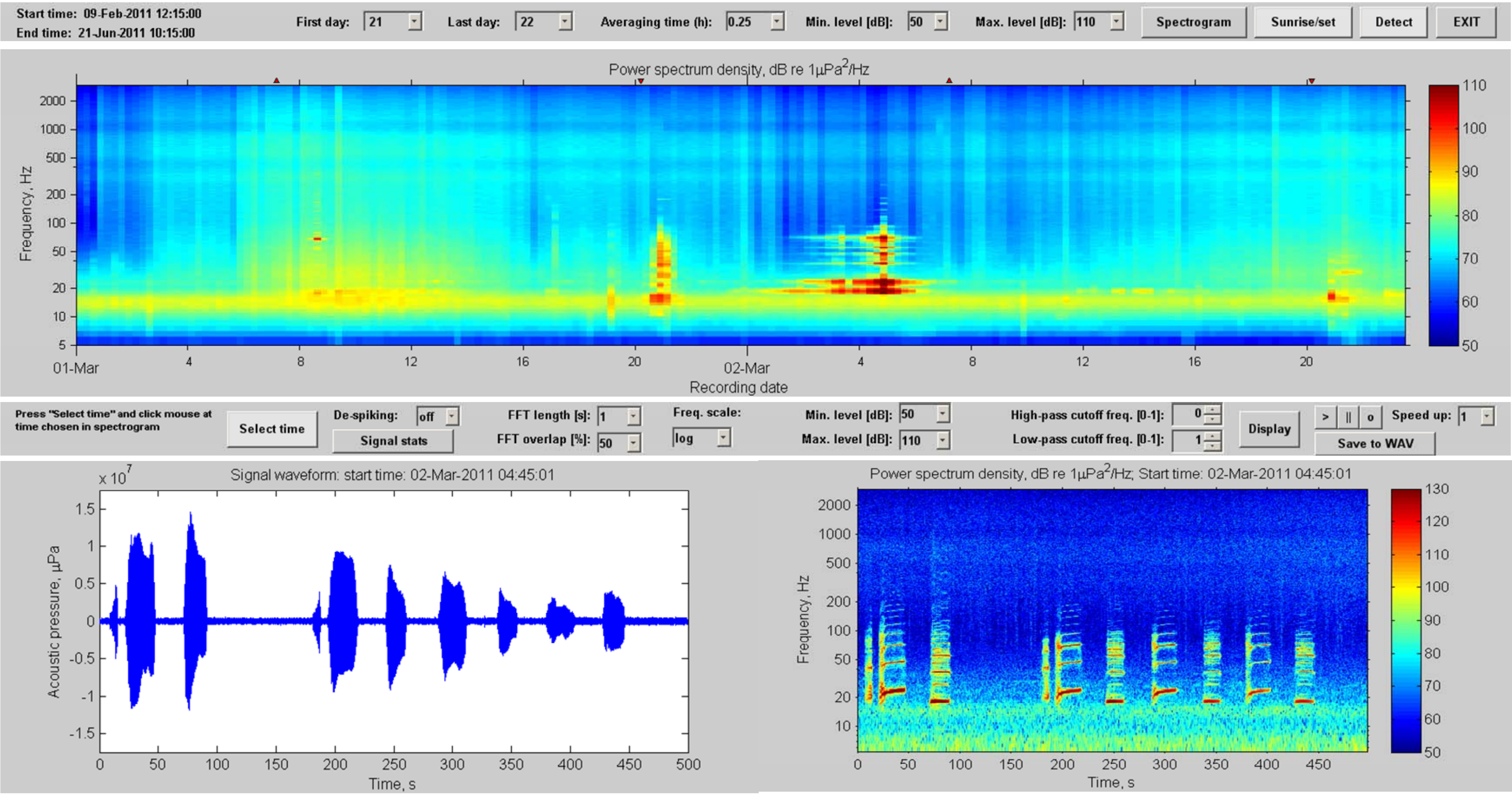

Figure 3: Waveform (bottom left) and spectrogram (bottom right) panels of an individual recording which corresponds to the time selected in the top panel spectrogram.

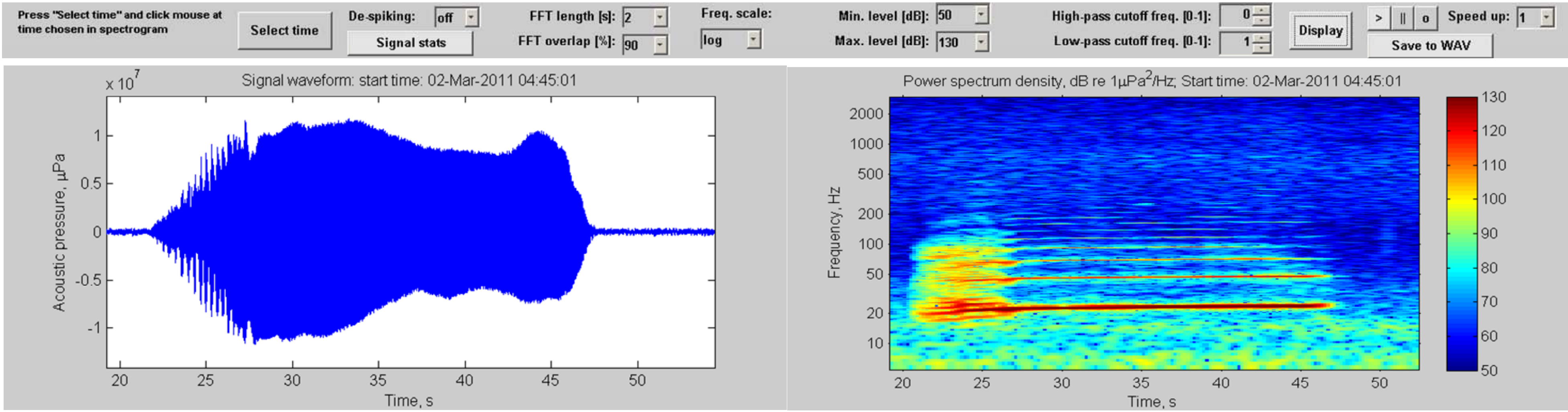

Figure 4: Waveform (bottom left) and spectrogram (bottom right) panels of the individual recording in Figure 3 after zooming in.

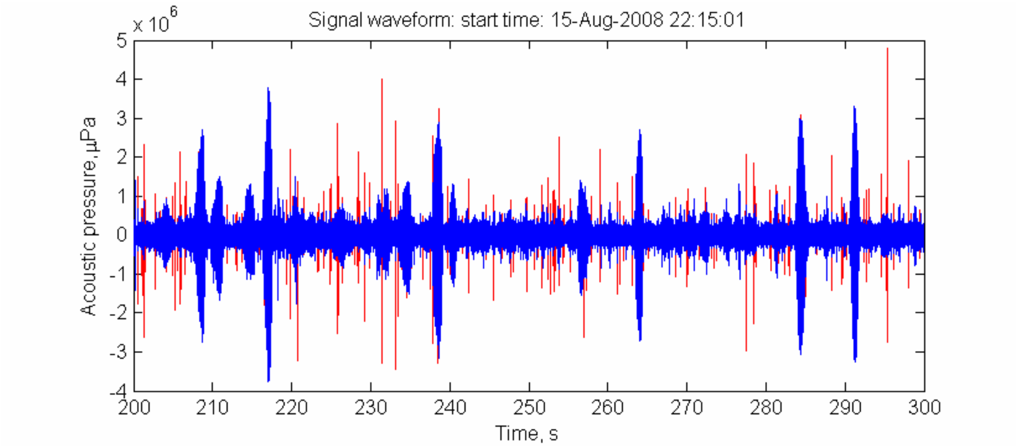

Figure 5: Waveform of a series of humpback calls after signal de-noising using an AR-algorithm for detection and interpolation of spiky noise from snapping shrimp (blue) and spikes of snapping shrimp noise removed (red).

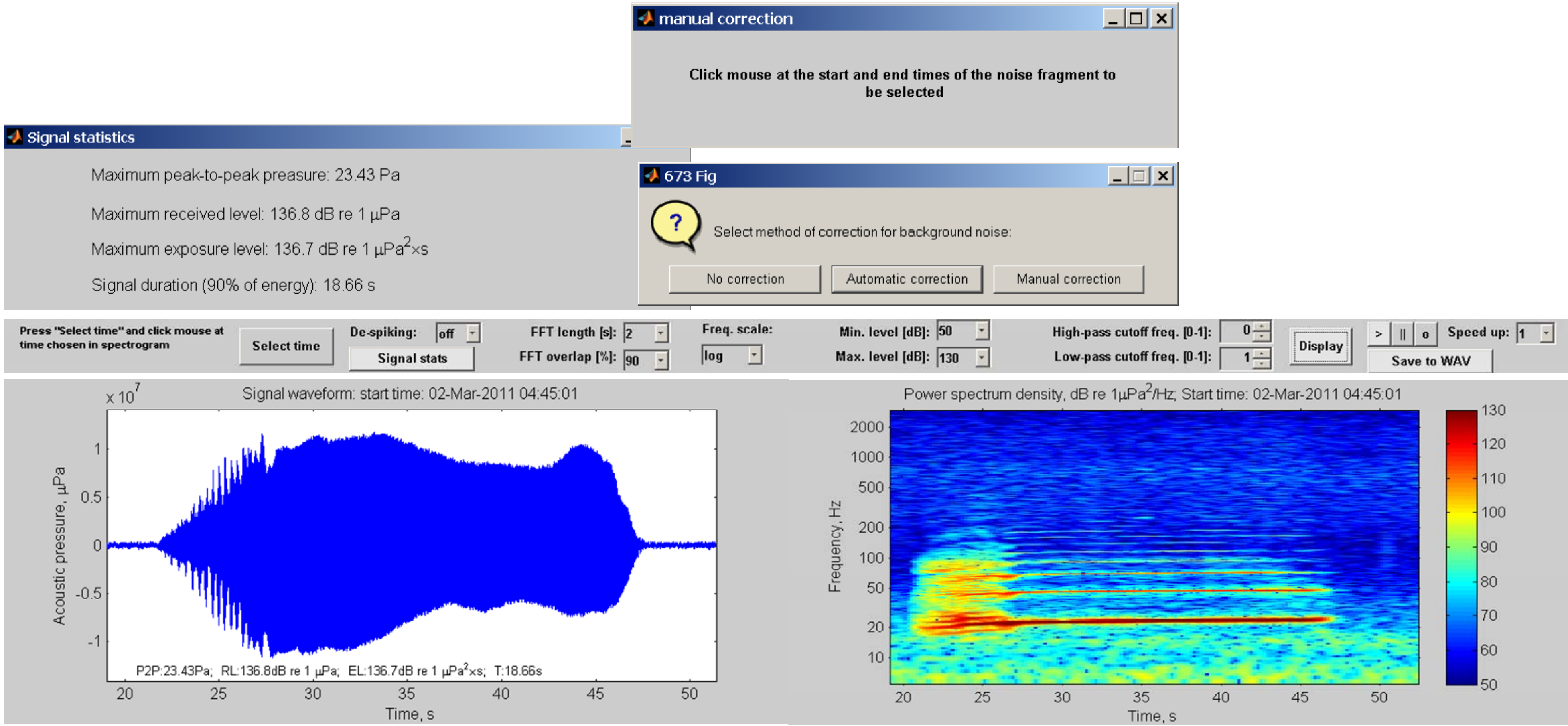

Figure 6: Menu (top right panels) and results (top left) of measuring signal characteristics.

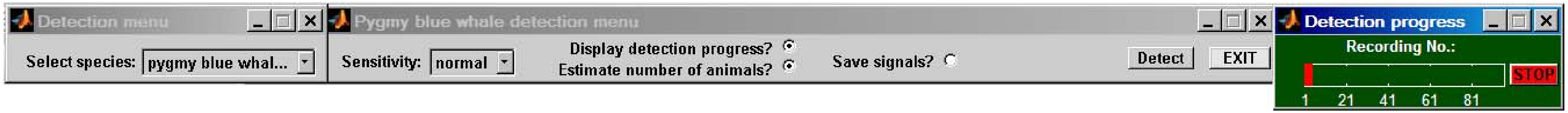

Figure 7: Main detection menu (left panel), Pygmy blue whale detection menu (middle panel) and Detection progress panel (right).

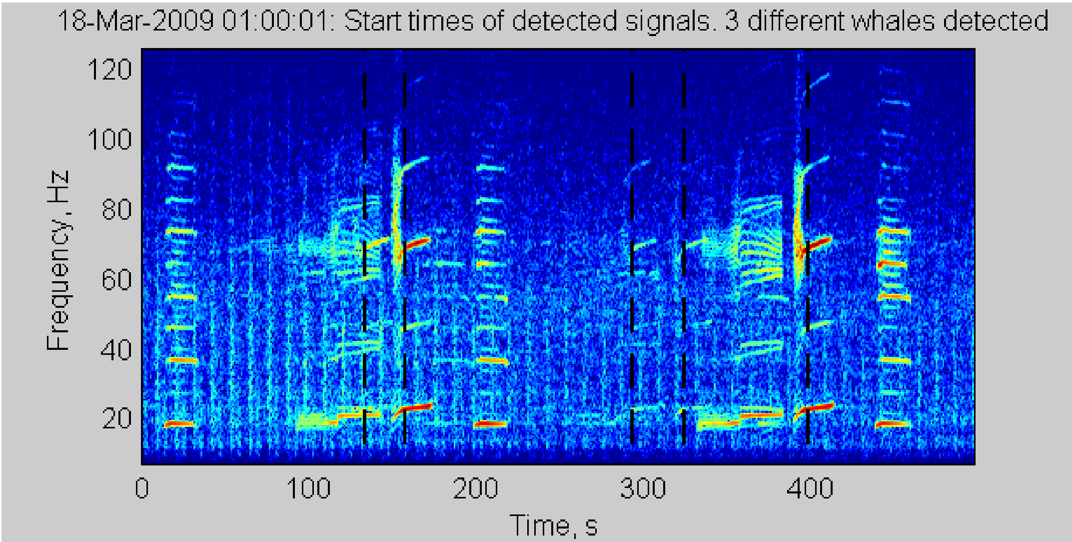

Figure 8: Spectrogram of an individual recording with the detection times of pygmy blue whale calls indicated by vertical dashed lines.

References

Gavrilov A.N. and Parsons M.J.G. (2014), “A Matlab tool for the Characterisation Of Recorded Underwater Sound (CHORUS)”, *Acoustics Australia* v.42, No.3, pp. 190-196.

Vaseghi S.V. and Rayner P.J.W. (1990), “Detection and suppression of impulsive noise in speech communication systems”, *IEE Proceedings*, v.137, Pt.1, No.1, pp. 38-46.