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Low-Frequency Detection and Classification (LFDCS) 2.0 Reference Guide

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Low-Frequency Detection and Classification (LFDCS) 2.0 Reference Guide

Julianne Wilder[1], Genevieve Davis[1], Annamaria DeAngelis[1], Sofie Van Parijs[1], Mark Baumgartner[2]

[1]NOAA Northeast Fisheries Science Center, 166 Water St., Woods Hole, MA 02543 USA
[2]Woods Hole Oceanographic Institution, 266 Water St., Woods Hole, MA 02543 USA

US DEPARTMENT OF COMMERCE
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Northeast Fisheries Science Center
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EXECUTIVE SUMMARY

This document is a guide for how to use and apply the Low-Frequency Detection and Classification System (LFDCS) built by Dr. Mark Baumgartner at the Woods Hole Oceanographic Institution (WHOI). The LFDCS is a software system created for automated detection and classification of low-frequency baleen whale vocalizations in archival and real-time acoustic data (Baumgartner and Mussoline 2011).

Part 1: Introduction to LFDCS 2.0 Desktop of this reference guide includes instructions for installing the desktop version of the LFDCS 2.0 onto Mac, Linux, or Windows machines and the fundamentals of that program: the generation of pitch tracks (contour lines that trace tonal sounds), building and managing a call library, browsing/exporting autodetections and analysis results, and species-specific analysis protocols.

The LFDCS desktop program has been used to process decades of acoustic data collected from multiple regions and recording platforms. For specific studies, the LFDCS was used to detect multiple species' acoustic occurrence from recordings collected along the eastern seaboard by many collaborators (Davis et al. 2017, 2020). Those data were analyzed using the protocols described in Part 1 of this guide. These analyses have helped provide insight into the year-round distribution of fin (*Balaenoptera physalus*), sei (*Balaenoptera borealis*), humpback (*Megaptera novaeangliae*), blue (*Balaenoptera musculus*), and North Atlantic right (*Eubalaena glacialis*) whales along their migratory routes.

Part 2: Introduction to LFDCS Real-Time Analysis Protocol of this reference guide covers the use of the LFDCS to detect and classify vocalizations recorded and transmitted via satellite in near real time by autonomous buoys and ocean gliders equipped with the programmable digital acoustic monitoring (DMON) instrument. These detections are then uploaded to the publicly accessible website Robots4Whales: Autonomous Real-time Marine Mammal Detections created by Mark Baumgartner (Baumgartner, n.d.a). This reference guide includes an introduction to the main features of the website, as well as data evaluation protocols, which analysts can refer to in their reviews of pitch track data to confirm the presence of fin, sei, humpback, and North Atlantic right whales.

The LFDCS real-time analysis protocol is currently being used to analyze data from past and active deployments of autonomous platforms that are uploaded to Robots4Whales. With training, the real-time analysis protocol can help ensure inter-analyst and within-analyst consistency in confirming detections (Baumgartner et al. 2020). The uses of the near real-time system include monitoring shipping lanes, fishing grounds, wind energy construction areas (Van Parijs et al. 2021), migratory hotspots, and aiding visual surveys. The pitch tracking technology of the LFDCS provides accurate information about which species are present in a given area in near real time (Baumgartner et al. 2019).

Using the LFDCS 2.0 Desktop and Real-Time programs to process archival and real-time acoustic data has advantages, including the ability to: process large archival datasets quickly for all species of interest, process and transmit duty cycled up to 24-hour acoustic data from active platforms in near real time, customize the criteria used to process those datasets, and function on a variety of operating systems with only an IDL runtime license. The adaptability of the detector/classifier system allows new call types to be added and existing call types to be updated with new exemplars. Processing time for a full year of acoustic data is often completed within 24-48 hours, and reclassifying datasets with new call libraries takes a fraction of that time, allowing for a quick turnaround for other analyses steps. This versatility makes the LFDCS a useful tool for processing and analyzing data from different regions with different target species across multiple years (e.g., new humpback call types may be added as the song shifts from season to season). Having this historical and real-time perspective is critical in improving conservation efforts by providing scientists, industries, and the public with information on whale presence.

HOW TO USE THIS REFERENCE GUIDE

This document is the second version of the original LFDCS Reference Guide and contains installation and operating instructions for the LFDCS 2.0 version that can operate on Mac, Linux, and Windows computers with an IDL 9.0 runtime license. Similar to the first version, this reference guide is organized into 2 parts: Introduction to LFDCS 2.0 Desktop and Introduction to LFDCS Real-Time Analysis Protocol. The first part breaks down all of the different programs that are available for use with the LFDCS Desktop 2.0 version, using a Windows computer as an example. This includes detailed descriptions and instructions for creating/managing call libraries, processing archival acoustic data, reviewing/analyzing data, and exporting data.

The LFDSC Desktop 2.0 offers a user interface that is more user-friendly than the previous version's use of code in the terminal window. For users who are using the original version of the LFDCS with a command-line interface on a Mac computer, please refer to the original version of the reference guide (Wilder et al. 2023). If you are using the LFDCS Desktop 2.0 version on a Mac, Windows, or Linux computer, you do not need to reference the code and can proceed with the instructions for the new user interface in Part 1 of this reference guide.

CONTACT INFORMATION

If you have questions or require assistance with anything related to the LFDCS, please contact the appropriate person below:

Julianne Wilder - julianne.wilder@noaa.gov

- For help with navigating this and previous versions of the reference guide
- For questions about operating desktop/real-time versions of LFDCS
- For questions about archival/real-time analysis protocols

Genevieve Davis - genevieve.davis@noaa.gov

- For help with download/installation of LFDCS
- For questions about the desktop version of LFDCS
- For questions about archival analysis protocols

Mark Baumgartner - mbaumgartner@whoi.edu

- To be added to email/text alerts about detections from real-time platforms
- To be added to any of the listservs where questions can be asked and answered collectively:
    - lfdcs_users@whoi.edu listserv- for anyone using the original or LFDCS 2.0 versions of the desktop software
    - r4w_users@whoi.edu listserv- for any principal investigators, operators, or analysts of real-time platforms that utilize the Robots4Whales website
    - r4w_analysts@whoi.edu listserv- for anyone who analyzes data from the real-time platforms as they get uploaded to the Robots4Whales website
- For inquiries about setting up a real-time platform for your research

PART 1: INTRODUCTION TO LFDCS 2.0 DESKTOP

The Low-Frequency Detection and Classification System (LFDCS; Baumgartner and Mussoline 2011) is an acoustic detection software system that was written by Dr. Mark Baumgartner at the Woods Hole Oceanographic Institution (WHOI). It is used to scan sound files and identify marine mammal calls by analyzing frequency-modulated signals and producing pitch tracks, which trace changes in the frequency (pitch) of a call over time. Scientists typically examine spectrograms (frequency vs. time visual display of sound) to identify marine mammal calls, such as the one below, and pitch tracks are derived from these spectrograms. The LFDCS then compares attributes of these signals to a reference call library of species-specific call types (e.g., fin whale [*Balaenoptera physalus*], humpback whale [*Megaptera novaeangliae*], etc.) to classify the pitch track to the species' vocalization. The call library that each dataset is processed with may contain as many target species vocalizations (or call types) as desired, and pitch tracks are compared and classified for all call types for the specific call library processed with that dataset.

Pitch Tracks: What Are They?

Pitch tracks are the colored lines that the LFDCS will overlay onto sounds (typically the sounds detected at 10 dB above background noise) on a spectrogram to describe their amplitude and frequency. Exemplars of pitch tracks of known sounds (i.e., common notes from a humpback song theme) can be collected from archival sound files to create a call type that the detector can then use to detect those calls as it scans new sound files.

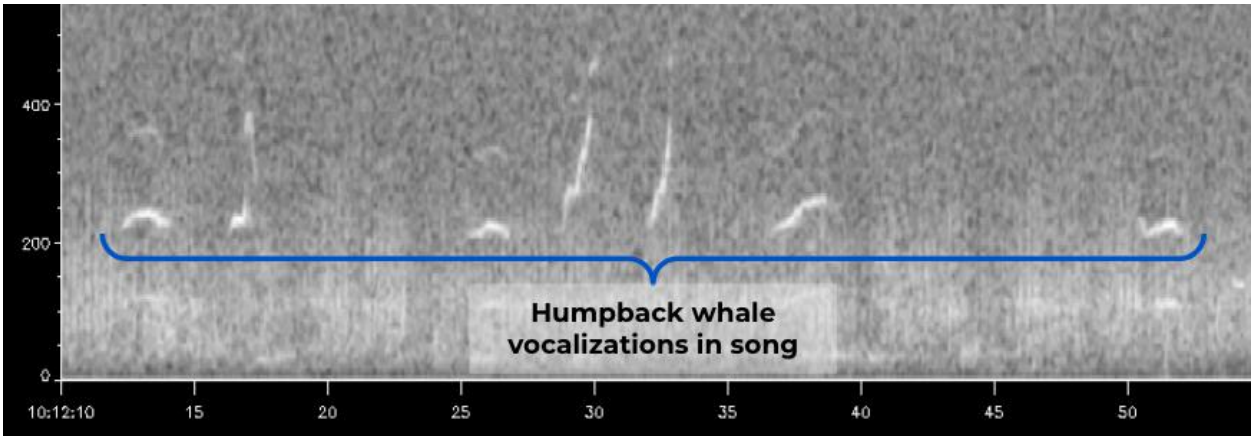


Figure 3. Spectrogram of humpback song with frequency in Hz on the y-axis and seconds on the x-axis.

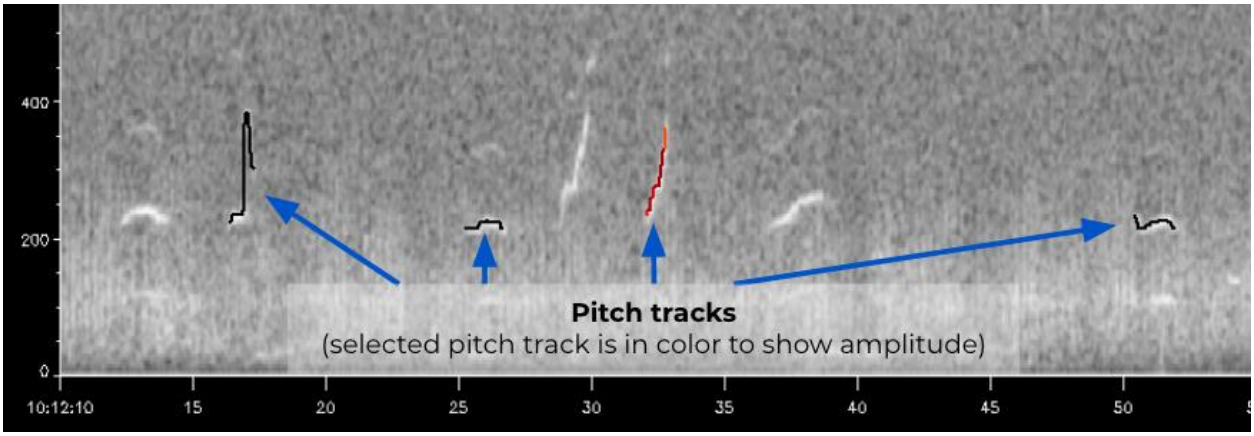


Figure 4. Spectrogram showing the pitch tracks (black and color lines) tracing the humpback whale vocalizations. The spectrogram axes are frequency (Hz) over time (hh:mm:ss). As the analyst clicks between pitch tracks, the Low-Frequency Detection and Classification System (LFDCS) will highlight the selected pitch track in color showing the amplitude of that sound (warmer colors are louder; cooler colors are quieter). Surrounding pitch tracks will appear black until the analyst clicks to the left or right to select a different pitch track. The LFDCS will automatically center the selected pitch track in the spectrogram window.

Installing LFDCS

This section describes the installation process for IDL and the LFDCS. The LFDCS Distribution File used to install the LFDCS contains two *.tar (or may be *.tar.gz) files: the main distribution file and a supplemental SoundTrap test dataset (kept as a separate file due to its size). The main distribution file contains the LFDCS program files and supplemental materials including example parameter files, call libraries, program preset files, resources, and test datasets. A second, smaller test dataset from a Marine Autonomous Recording Unit (MARU) is also included in the main distribution file. Both *.tar files must be downloaded and unzipped in the same directory on your computer. When unpacked in the same location, the SoundTrap test dataset will automatically unpack under the "supplemental\test_datasets" directory within the file structure of the main distribution file.

Installing IDL 9.0 with a Runtime License (required)

IDL is the programming language that the LFDCS is written in. To install and use the LFDCS, you'll need to first obtain an IDL 9.0 runtime license and install IDL following the instructions from NV5 Geospatial Software, the IDL software distribution company downloads center (if you don't already have it installed). Once you have purchased a license, then you will receive the download links and license information for IDL from NV5.

Installing LFDCS 2.0 on a Mac Computer

1. Download the LFDCS Distribution File from Google Drive.
2. Move the two *.tar (or may be *.tar.gz) distribution files to wherever you would like the program to be stored on your computer (e.g., \Users\julianne.wilder\Documents\LFDCS). Make sure both files are stored in the same directory before unzipping them.
3. Double click on the *.tar files and they will automatically unpack in the folder that they are stored in. Once the folders are unpacked, you should see 4 new folders under LFDCS: bin, dlm, process, and supplemental.
4. Go into the "process" folder and look for the "lfdcs_app_launcher" file. Create a shortcut to that, and save it to your desktop.
5. Double click on the launcher shortcut to open the LFDCS Graphical User Interface (GUI).

Installing LFDCS 2.0 on a Linux Computer

1. Download the LFDCS Distribution File from Google Drive.
2. Move the two *.tar (or may be *.tar.gz) distribution files to wherever you would like the program to be stored on your computer (e.g., \Users\julianne.wilder\Documents\LFDCS). Make sure both files are stored in the same directory before unzipping them.
3. Follow these steps to unzip each of the distribution files:

a. Open a terminal window.
b. Type “cd” into the terminal window.
c. Navigate to the current directory where you saved the distribution files and drag one of the folders where it is stored over to the terminal line, then hit “Enter”. Example: >cd \Users\julianne.wilder\Documents\LFDCS
d. Type “tar –xf [filename]” into the command window, then hit “Enter”. Example: >tar –xf lfdcs-distrib.tar.gz
e. Once the folder is unpacked, you should see 4 new folders under LFDCS: bin, dlm, process, and supplemental.

4. Go into the "process" folder and look for the "lfdcs_app_launcher" file. Create a shortcut to that and save it to your desktop.
5. Double click on the launcher shortcut to open the LFDCS GUI.

Installing LFDCS 2.0 on a Windows Computer

1. Download the LFDCS Distribution File from Google Drive.
2. Move the two *.tar (or may be *.tar.gz) distribution files to wherever you would like the program to be stored on your computer (e.g., \Users\julianne.wilder\Documents\LFDCS). Make sure both files are stored in the same directory before unzipping them.
3. Unzip the distribution files (if you do not see an option to unzip the file, skip to Step 6). Once the folders are unpacked, you should see 4 new folders under LFDCS: bin, dlm, process, and supplemental.
4. Go into the "process" folder and look for the "lfdcs_app_launcher" file. Create a shortcut to that and save it to your desktop.
5. Double click on the launcher shortcut to open the LFDCS GUI.
6. *Alternative method:* If your computer does not give you the option to unzip the distribution files, follow these alternative steps for each file:
    a. Open Command Prompt (can search for “Command Prompt” or “cmd” in your search bar).
    b. Type “cd” into the command window.
    c. Navigate to the current directory where you saved the distribution files and drag one of the folders where it is stored over to the terminal line, then hit “Enter”. Example: >cd C:\Users\julianne.wilder\Documents\LFDCS
    d. Type “tar –xf [filename]” into the command window, then hit “Enter”. Example: >tar –xf lfdcs-distrib.tar.gz
    e. Once the folders are unpacked, you should see 4 new folders under LFDCS: bin, dlm, process, and supplemental. Note: If the command window is in the wrong drive (e.g., H:), then type “cd /d C:\” into the command window to redirect it.

Required for Installing on a Windows Computer: Configuring the "dlm" Folder

Follow these steps after you have installed the LFDCS on a Windows computer for the first time. If these steps are not completed, you may have issues with processing or playing audio and will receive error messages. You should only have to do this once. However, if you have completed this step but still receive an error message when you try to process your data, try completing this step again (you may need to deselect the directory and select it again).

1. Open the "configure_dlm_folder" file from the process folder.

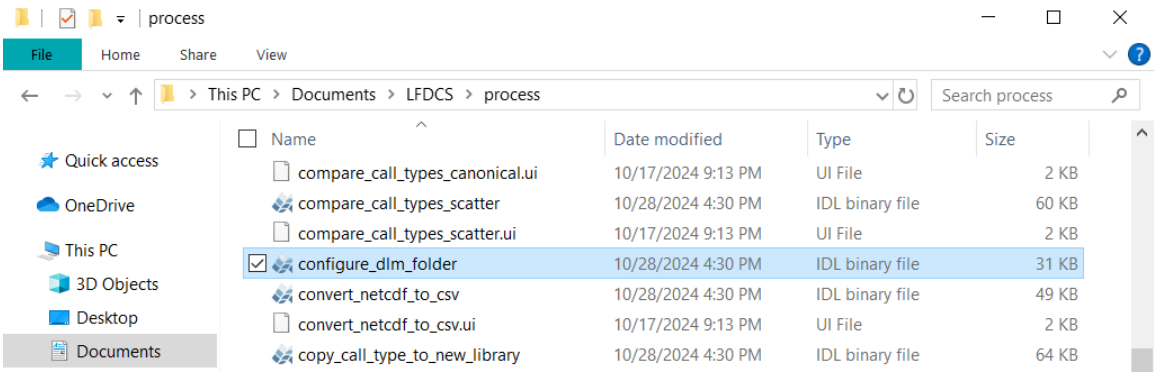


Figure 3. The file location of the "configure_dlm_folder".

2. Click "Yes" when this popup window appears. If the files are already recognized it will not prompt you for a directory, it will just show the path location.

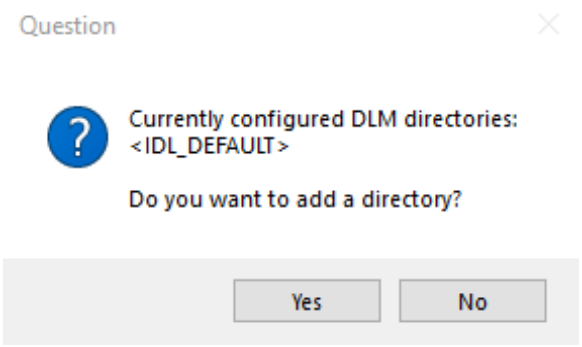


Figure 4. Popup window asking if you want to add a DLM directory.

3. In the folder selection window that appears, select the folder that contains the "PlayAudioWrapper.dll", "PlayAudioWrapper.dlm", "call_tracking_lfdcs_dlm.dll", and "call_tracking_lfdcs_dlm.dlm" files. This will allow you to set the IDL preference for where to find the DLL/DLM files. Click into the "dlm" folder where the LFDCS distribution files are stored (e.g., \Users\julianne.wilder\Documents\LFDCS\dlm) and then click "Select Folder".

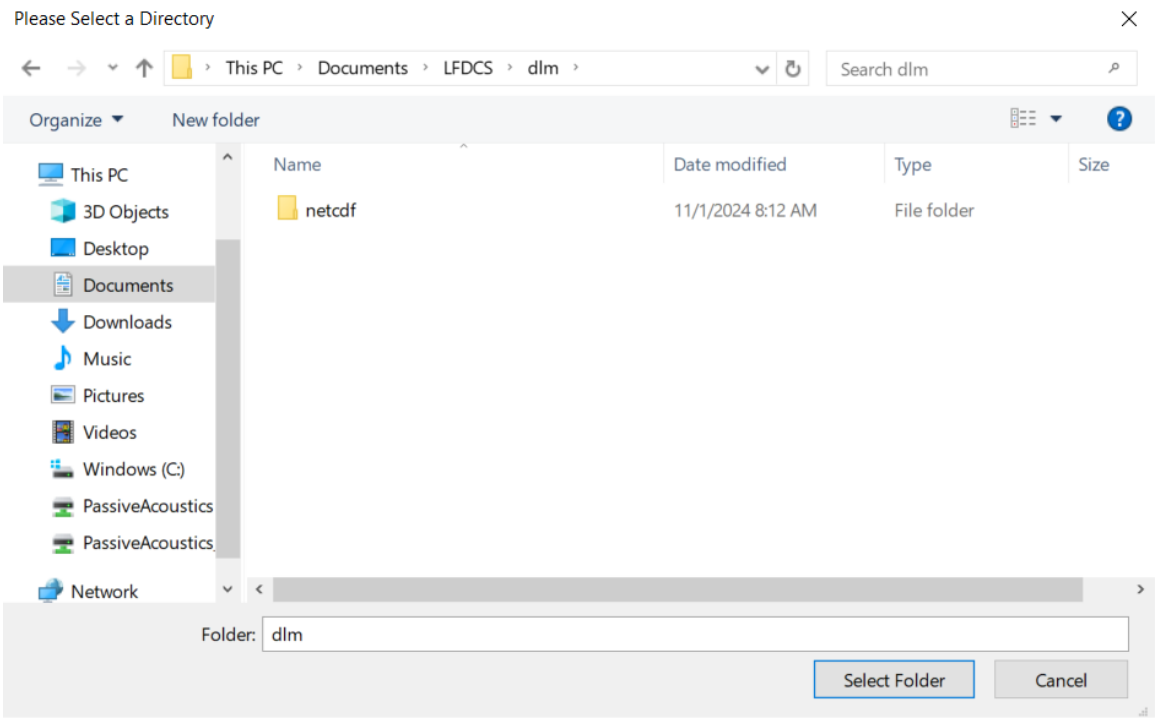


Figure 5. Folder selection window.

4. *Important:* If the folder selection from Step 3 does not work, then look for the *.dll and *.dlm files in your folder directly before going through the selection window because you will not see them in the selection window.

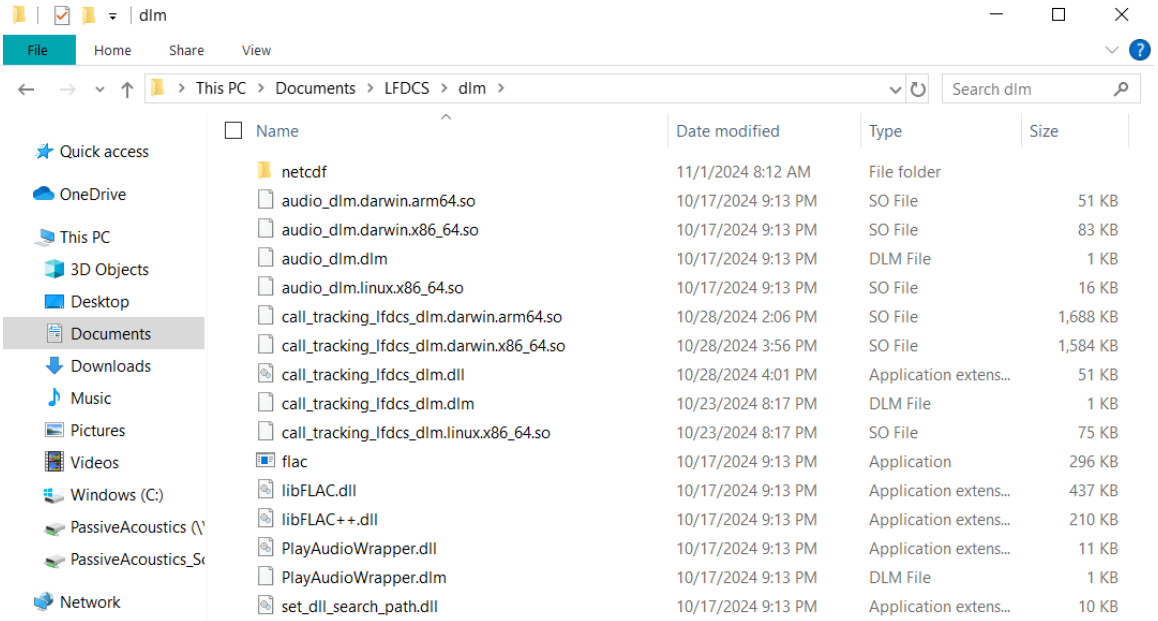


Figure 6. Example of what the directory looks like when you are looking at the folder directory outside of the selection window.

Opening the LFDCS 2.0 on All Operating Systems

This section describes how to open the LFDCS App Launcher once you have installed IDL and LFDCS.

1. Navigate to the folder where you stored and unpacked the LFDCS Distribution File (e.g., \Users\julianne.wilder\Documents\LFDCS).
2. Open the "process" folder and double click on the lfdcs_app_launcher.
   Note: You can right click on the lfdcs_app_launcher file and select "Create shortcut", then drag that to another location such as your desktop to create a shortcut.
3. From the LFDCS App Launcher window, you can then select the LFDCS program you would like to use.

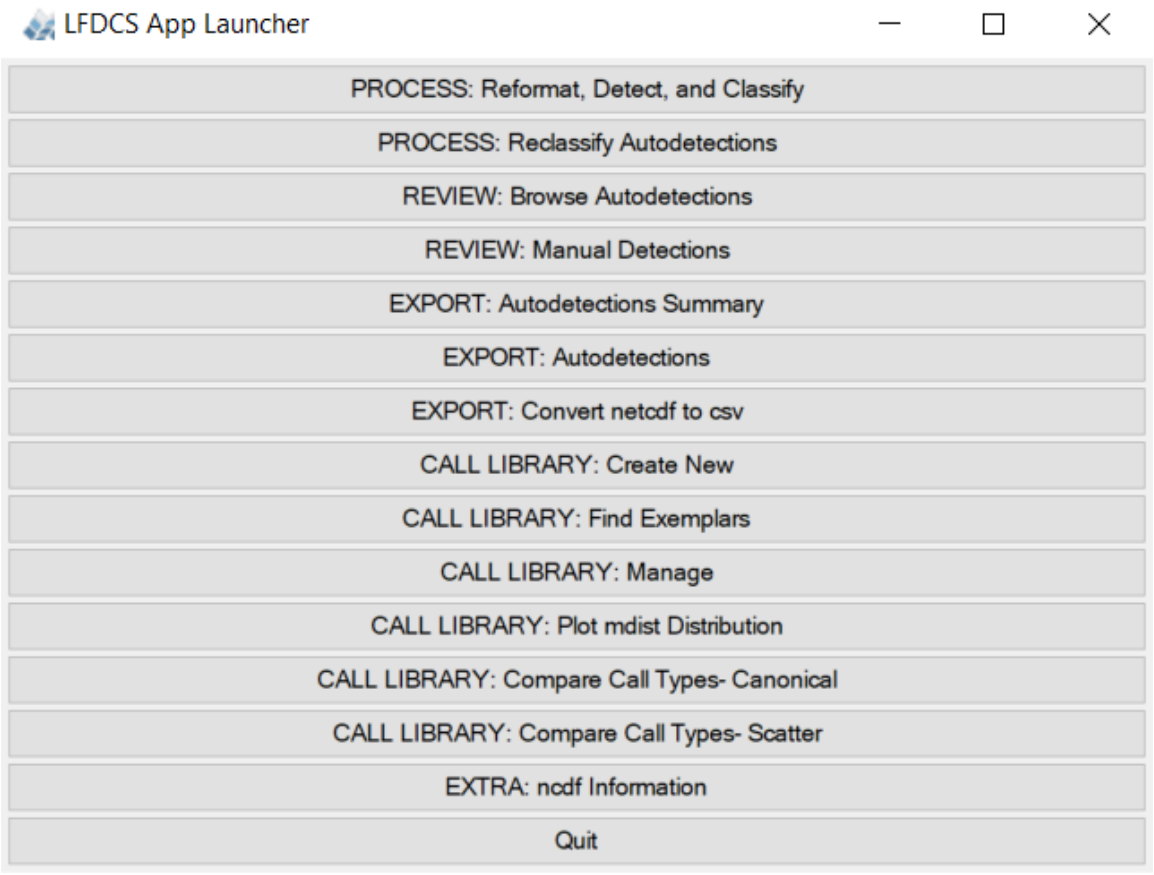


Figure 7. The LFDCS App Launcher window with buttons for the various LFDCS programs.

Common Program Features

This section includes descriptions of common features between all of the LFDCS programs.

Optional and Required Fields

When you click on a program from the LFDCS App Launcher, a pop-up window will appear with settings fields that you can edit to direct how you want the program to run. Any fields marked with an asterisk (*) are required to run the program. Fields without an asterisk are optional and provide additional settings you can specify depending on how you would like the program to run.

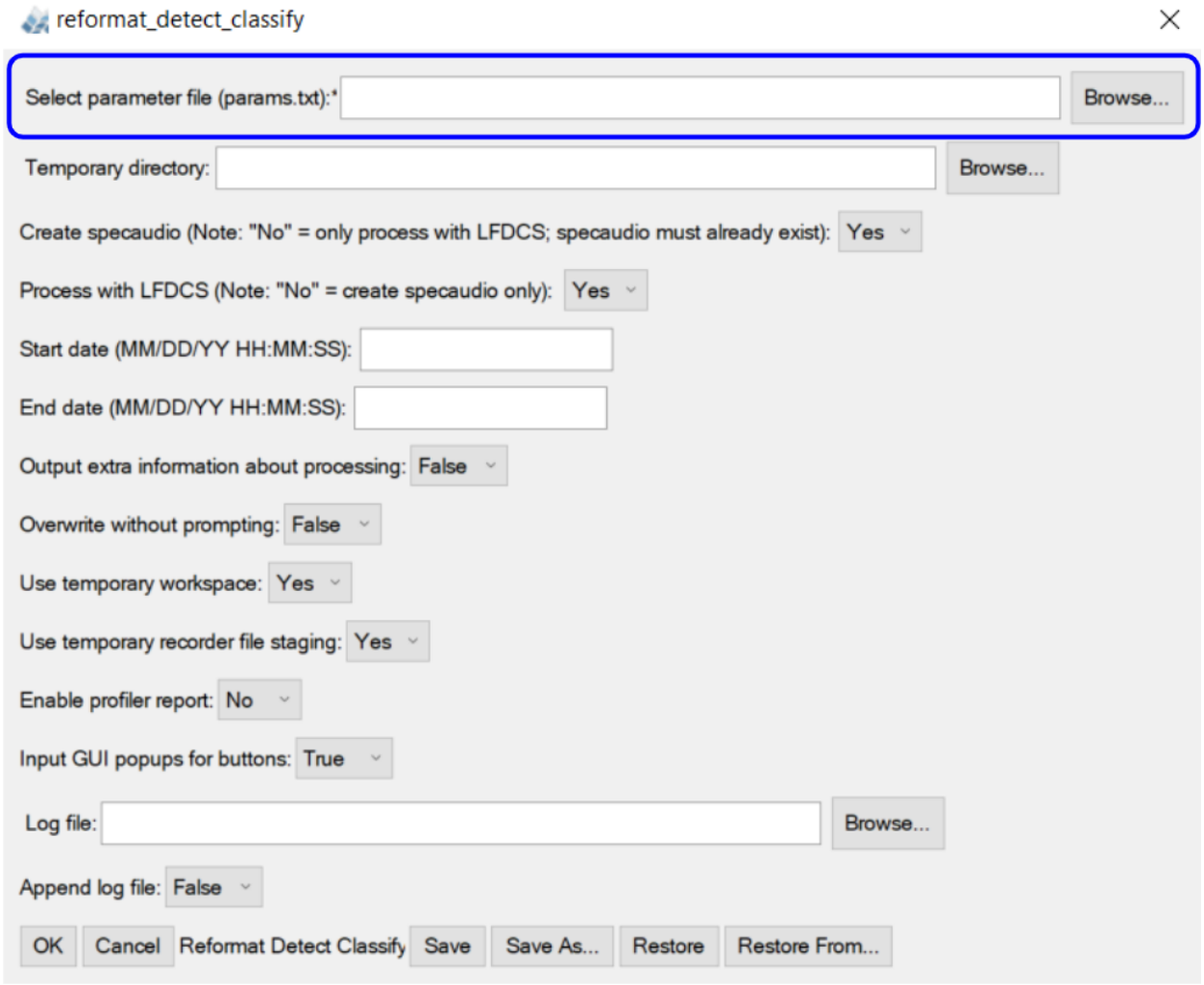


Figure 8. The reformat_detect_classify program window with an example of a required field marked with an asterisk in the blue box.

Log File Fields

For every program, there are a few optional fields near the bottom of the program window. The “Log file” field allows you to select a pathway where a log file will be exported each time you run a program. This log file functions similarly to a terminal window in that it will show you a record of the program’s operations. You will need to either use the “Browse…” button, or copy and paste a file pathway into the textbox to direct it where to store your log file.

The “Append log file” field provides a True/False dropdown menu. Select “True” to append or add to a previously saved log file when you run the program again (you can specify the name and file pathway of the existing log file in the “Log file” field or leave it blank). Select “False” to generate a new log file (you must enter a new log file name and pathway in the “Log file” field).

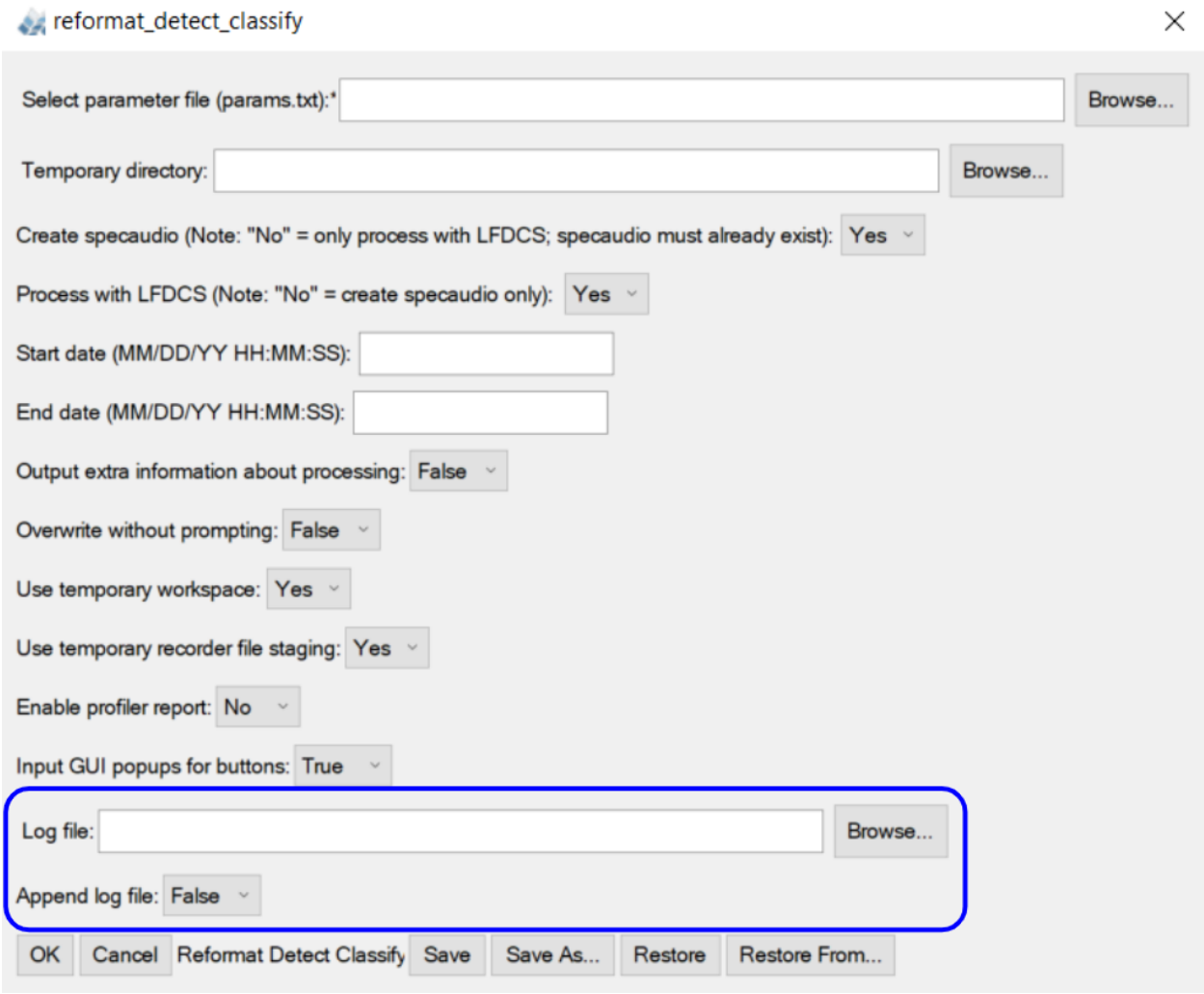


Figure 9. The reformat_detect_classify program window with an example of the “Log file” and “Append log file” fields in the blue box.

Save and Restore Buttons

At the bottom of each program window, there are a series of buttons (definitions listed below). These allow you save your program presets so you do not have to reenter all of the fields every time you open a program.

Note: You can access some preset files examples in the "program_presets" folder that was unpacked from the distribution file when you installed LFDCS. Most of the preset files are for either the browse_autodetections or the export_summary_autodetections programs, with one for each of the large baleen whale species. You can access these presets by clicking "Restore From…" in your program window and then navigating to where you stored the LFDCS distribution file.

- OK

  Runs the program with the settings you entered into the fields above

- Cancel

  Cancels the program and closes out the program window

- Save

  Saves any settings you entered into the program fields above. The preset file will automatically save to your ".idl" folder under your computer user directory (e.g., \Users\julianne.wilder\.idl\noaa_nv5\lfdcs).

- Save As...

  Allows you to name the settings file and select a location where you would like to save any settings you entered into the program fields

- Restore

  Restores the settings you last entered into the program fields

- Restore From...

  Allows you to search for and select the desired settings to populate the program fields

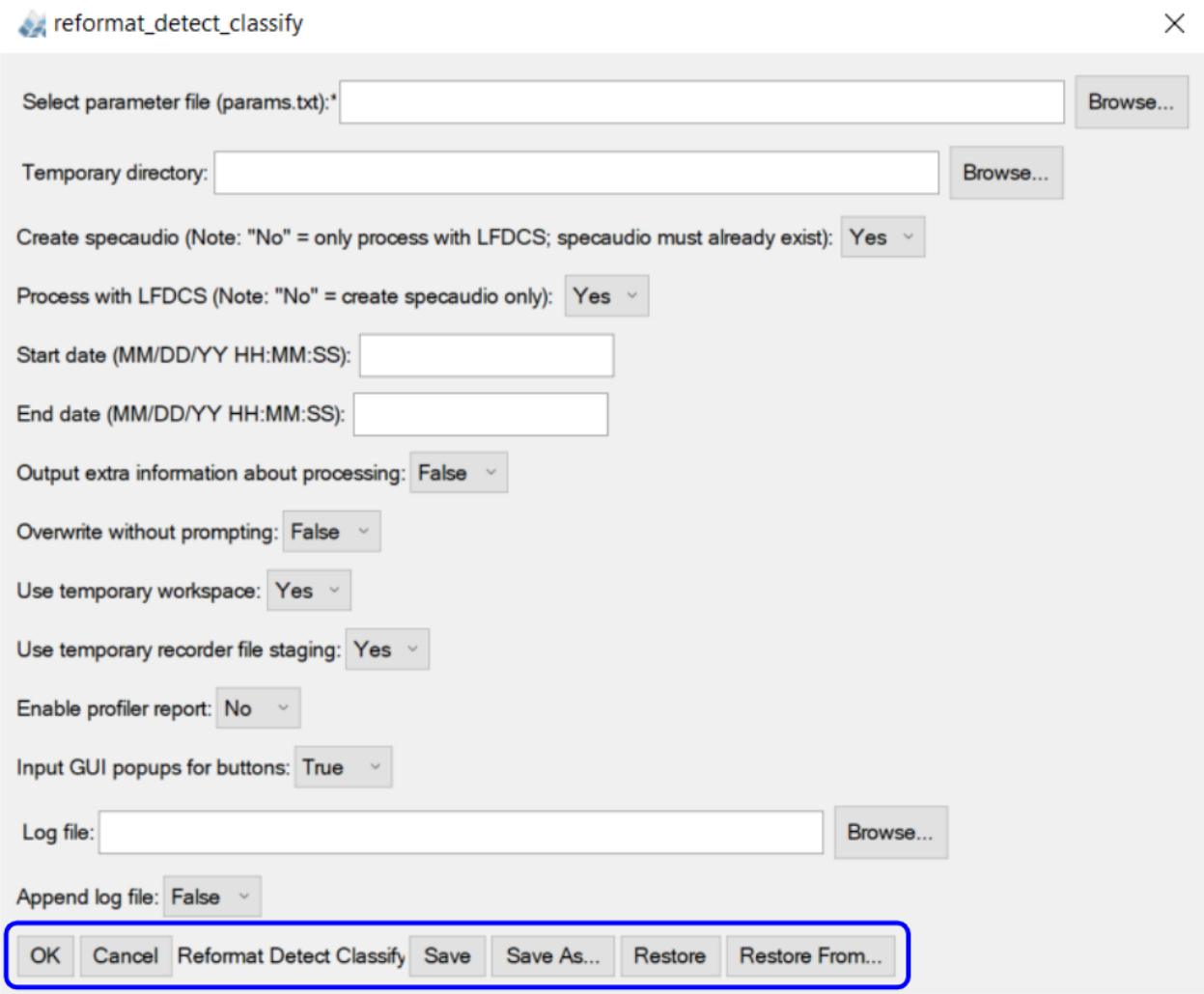


Figure 10. The reformat_detect_classify program window with an example of the save and restore fields in the blue box.

Call Libraries

This section includes instructions for how to create, build, manage, and evaluate a call library using the LFDCS. This section may be skipped if using an existing call library.

Creating a Call Library on a Windows Computer

CALL LIBRARY: Create New

The following directions explain how to create a new call library that can be built upon and used to process datasets.

1. From the LFDCS App Launcher, click on the "CALL LIBRARY: Create New" button. This popup window will appear:

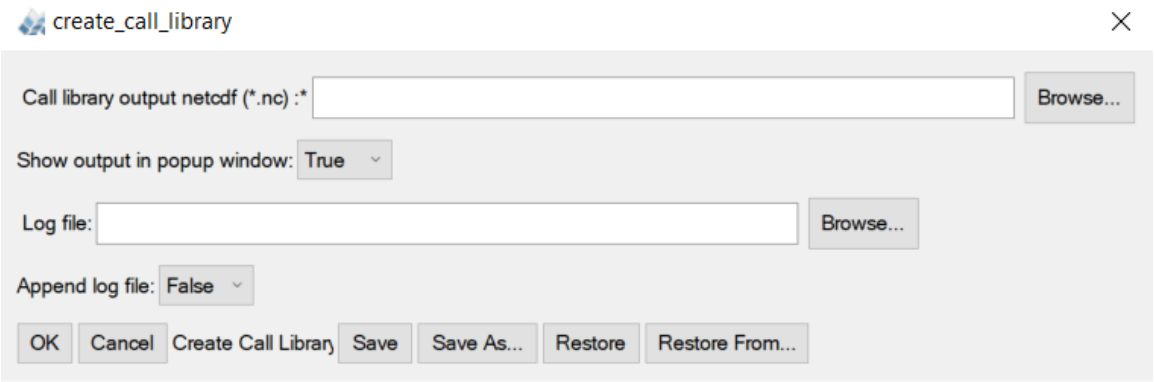


Figure 11. The create_call_library program window where you can select where the call library output files will be exported.

Note: Only fields with an asterisk (*) are required.

2. In your Windows File Explorer, create a new folder clXX_ZZZZ (e.g., clnb_test) where you would like your call library output files to export to (e.g., \Users\julianne.wilder\Documents\LFDCS\clnb_test).
Note: XX = nb for narrowband call library or *bb for broadband call library; ZZZZ = call library name (e.g., "gom" for Gulf of Maine)

*The LFDCS has the capacity to process broadband data, but it is still under development and not yet functional with the software.

Example: "clnb_gom9", or in the following case, "clnb_test".

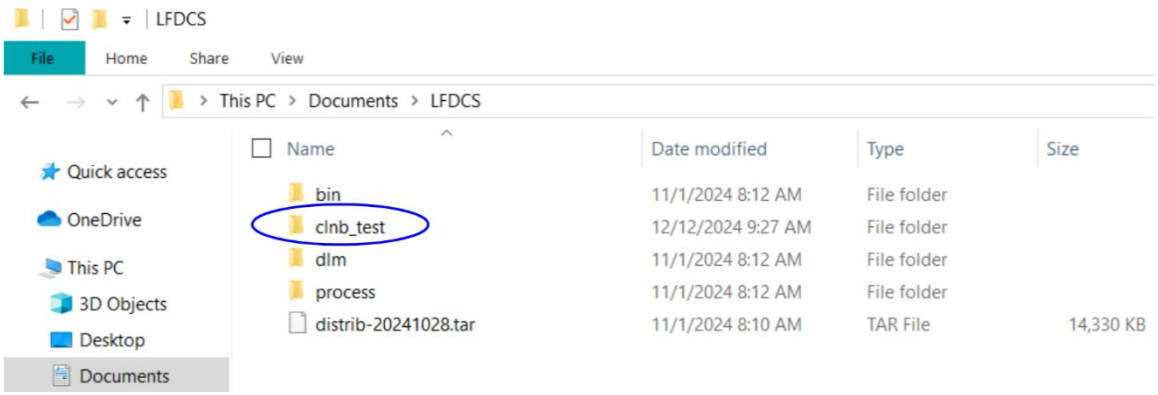


Figure 12. Call library file setup.

3. In the "Call library output netcdf (*.nc)" field of the create_call_library window, use the "Browse…" button to navigate to, or copy and paste your file pathway to your new call library folder.

   At the end of the file pathway, type in the desired name of your new call library and add the ".nc" extension to the end of the name.

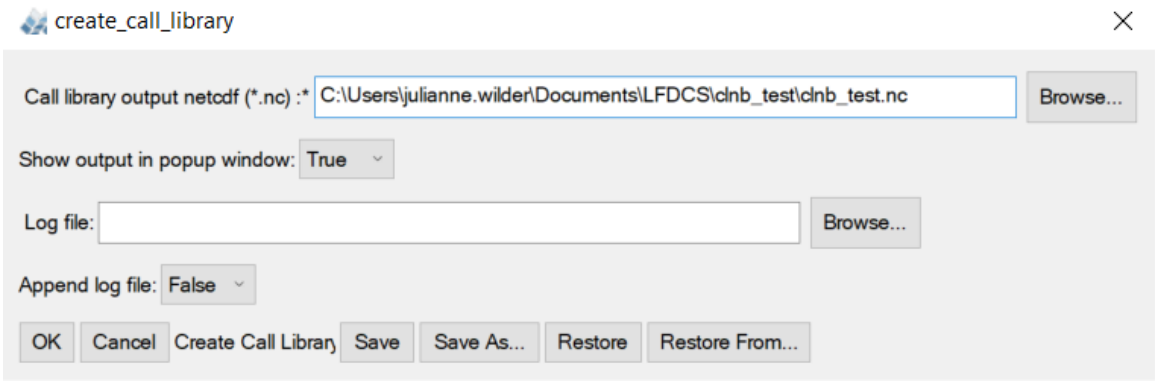


Figure 13. The create_call_library program window with the file pathway and new call library file name ending in ".nc".

4. Click "OK" and a new window will appear where you can enter a unique description of your new call library (e.g., "Baleen whale call library for the Gulf of Maine").

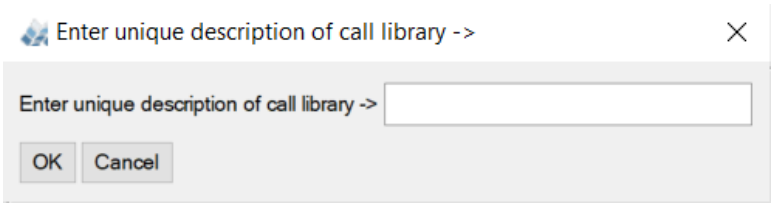


Figure 14. The window where you can enter a unique description for your call library.

5. Click "OK" and another window will appear where you can specify whether your call library will be narrowband or *broadband. Click "Yes".

   *The LFDCS has the capacity to process broadband data, but it is still under development

and not yet functional with the software.

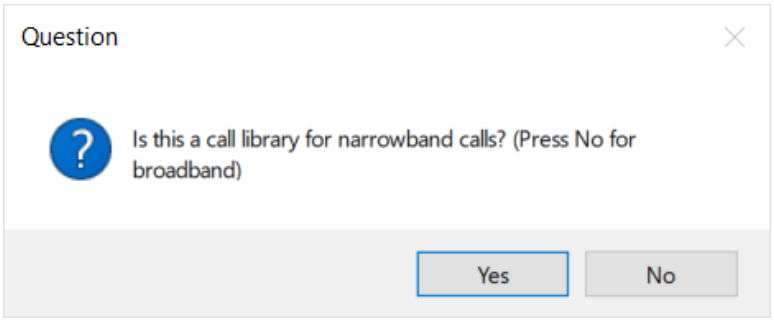


Figure 15. The window asking whether your new call library is for narrowband or broadband calls.

Once these steps are complete, you will see four new call library files in the folder you created (e.g., \Users\julianne.wilder\Documents\LFDCS\clnb_test).

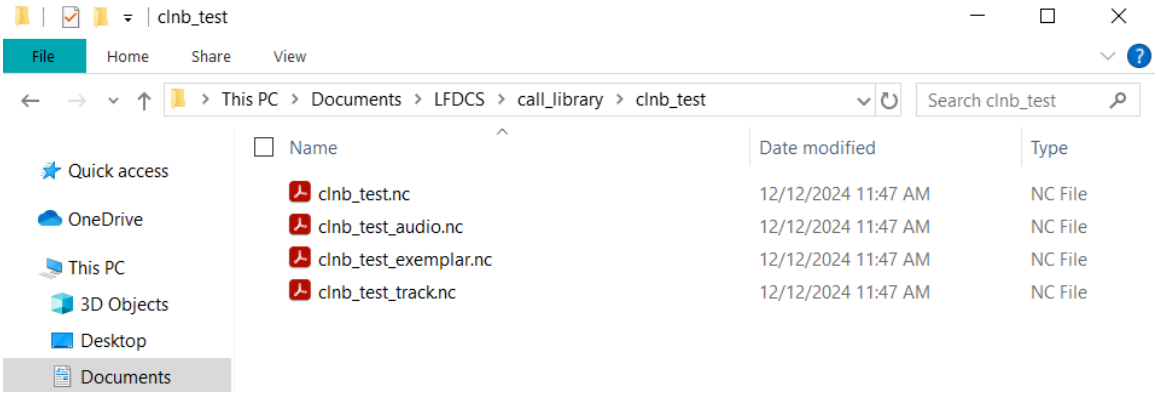


Figure 16. The four new call library files generated by the create_call_library program.

Finding Exemplars to Build a Call Library on a Windows Computer

CALL LIBRARY: Find Exemplars

The following directions explain how to build a new call library by adding exemplars of calls to create distinct call types within the library. This can be used after creating a new call library or to add new call types or exemplars to a pre-existing call library. This step requires you to have processed the deployment you want to obtain exemplars from with the LFDCS, as you will select pitch tracks from the data and assign them to a designated call type.

You can specify parameters for the pitch tracks to narrow down what you have to browse. This is helpful if you do not know if or where target calls are in your dataset, and to scroll more quickly to possible exemplars by filtering out pitch tracks that are not suitable for the target call types.

For adding exemplars to a new call library that does not have any existing call types, you can fill in the top two fields: "Select index" (select the lfdcs_file_index.nc file from the lfdcs folder

of your processed data) and "Select call library" (select the file in your new call library folder that just has the name of your call library, i.e., not the ones that end in _audio, _exemplar, or _track). Click “OK” and it might give you an alert that there are no call types in your call library and you need to add one. Click “OK” again and the browsing window should pop up. On the left side there is an "Add call type" button that you can click and follow the prompts to add your first call type. You can also add new call types using the CALL LIBRARY: Manage program once you have done the first one.

1. From the LFDCS App Launcher, click on the “CALL LIBRARY: Find Exemplars” button. This popup window will appear:

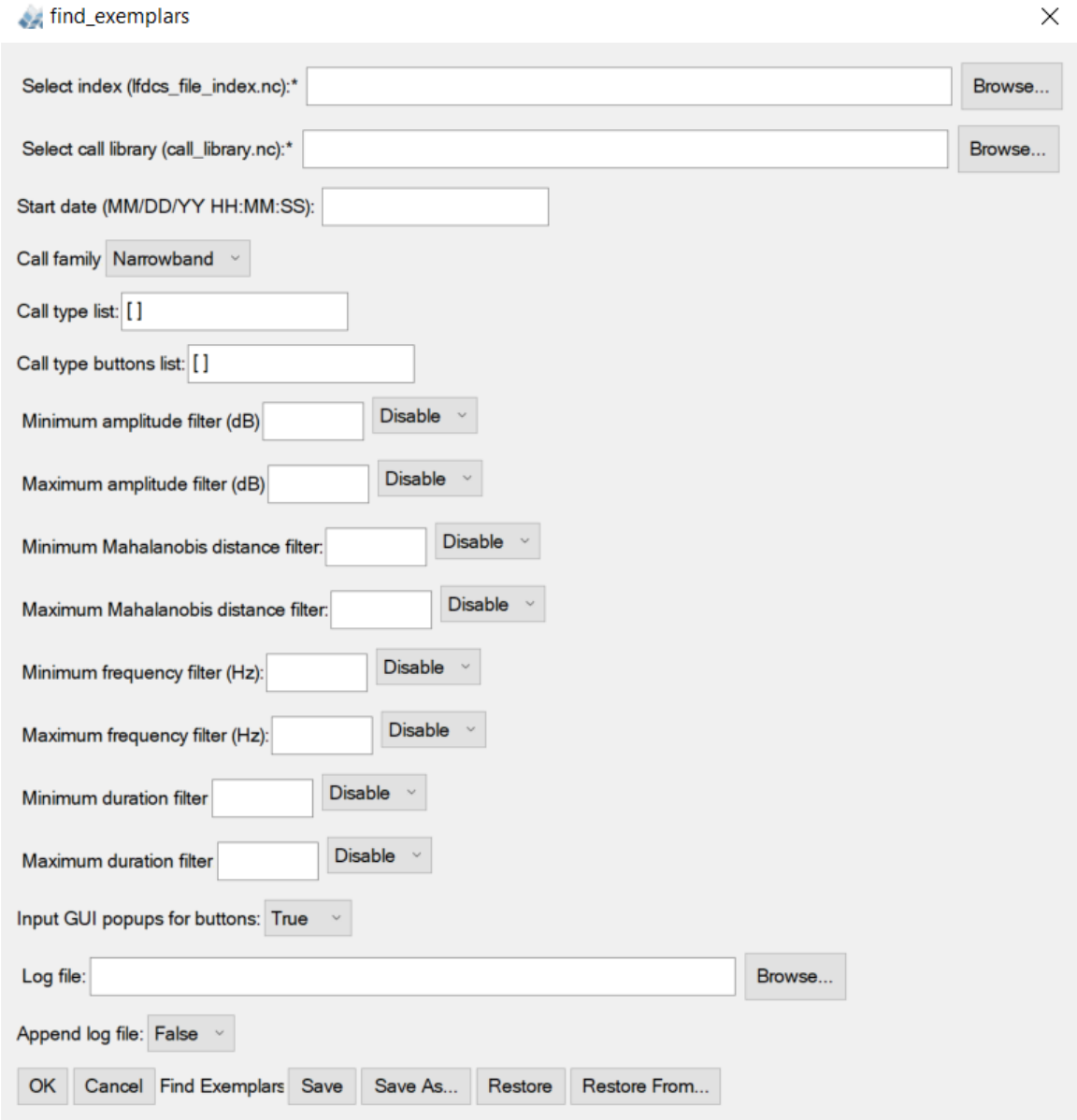


Figure 17. The find_exemplars program window where you can select which call library to add exemplars to and set filters for which pitch tracks you would like to view from your data.

2. Use the definitions below to help you fill in the fields of the find_exemplars window (fields with an asterisk are required). Once you have filled out the fields, click "OK" and a new window will appear where you can start selecting exemplars to add to your call library.

    - Select index (lfdcs_file_index.nc)*

        Use the "Browse…" button to select the "lfdcs_file_index.nc" file from the processed\lfdcs folder of your previously processed dataset. You will select the exemplar calls that you will add to your call library from this dataset.

    - Select call library (call_library.nc)*

        Use the "Browse…" button to select the *.nc file with just the call library name (e.g., clnb_test.nc) from its call library folder. You will be adding the exemplar calls you find to this call library.

    - Start date (MM/DD/YY HH:MM:SS)

        Enter the date/time in your dataset where you want to start browsing for exemplars (e.g., 01/20/23 19:30:00).

    - Call family

        Select "Narrowband" from the dropdown menu to view all autodetections in the *narrowband call family.

        *The LFDCS has the capacity to process broadband data, but it is still under development and not yet functional with the software.

    - Call type list

        Enter the call type number(s) you want to browse for and use in your call library (e.g., [1,2,3]).

    - Call type buttons list

        Enter the call types you would like to appear as buttons in the viewing window (e.g., [1,2,3,4,6,7,8,10]).

        Note: If there are more than 8 call types in a call library, only 8 of them will display as buttons along the right side of the viewing window. Use the "Call type buttons list" field to specify which call types you would like to display as buttons.

    - Minimum amplitude filter (dB)

Enter a minimum amplitude threshold to view all autodetections with amplitudes greater than or equal to that value (in dB above background noise; e.g., 12).

- Maximum amplitude filter (dB)

  Enter a maximum amplitude threshold to view all autodetections with amplitudes less than or equal to that value (in dB above background noise; e.g., 20).

- Minimum Mahalanobis distance filter

  Enter a minimum Mahalanobis distance threshold to view all autodetections with a Mahalanobis distance greater than or equal to that value (e.g., 1.0).

- Maximum Mahalanobis distance filter

  Enter a maximum Mahalanobis distance threshold to view all autodetections with a Mahalanobis distance less than or equal to that value (e.g., 3.0).

- Minimum frequency filter (Hz)

  Enter a minimum frequency threshold to view all autodetections with frequencies greater than or equal to that value (e.g., 200).

- Maximum frequency filter (Hz)

  Enter a maximum frequency threshold to view all autodetections with frequencies less than or equal to that value (e.g., 800).

- Minimum duration filter

  Enter a minimum duration threshold to view all autodetections with durations greater than or equal to that value (in seconds; e.g., 1.0).

- Maximum duration filter

  Enter a maximum duration threshold to view all autodetections with durations less than or equal to that value (in seconds; e.g., 4.0).

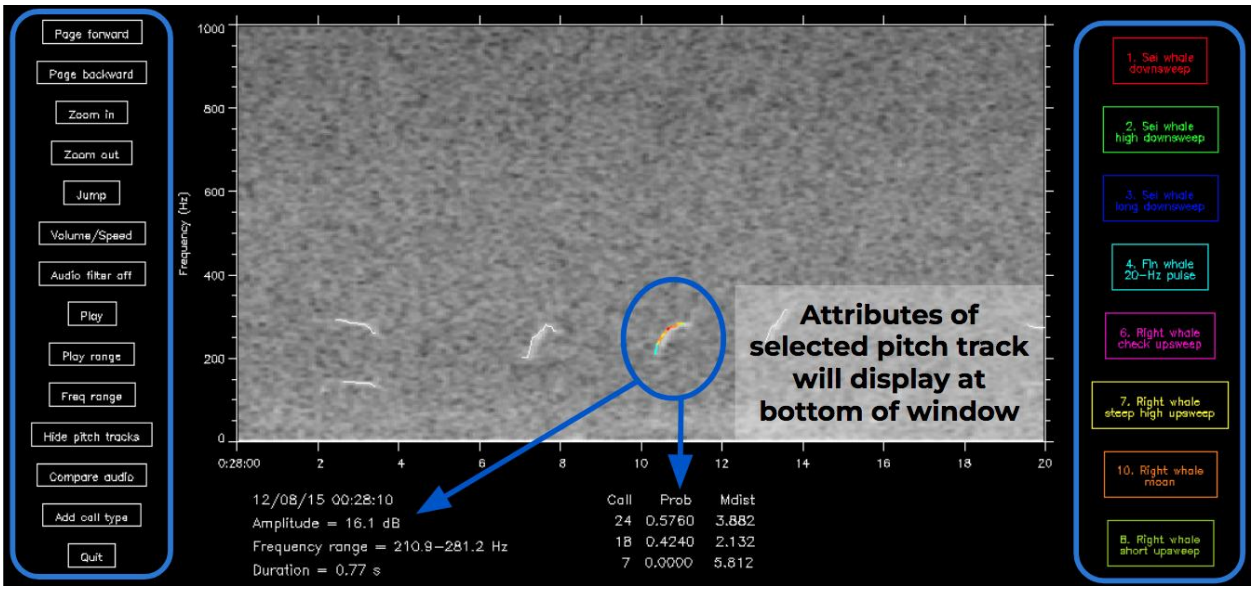


Figure 18. The find_exemplars browsing window showing a pitch tracked humpback call in color (color is indicative of amplitude; the surrounding white lines also pitch tracks but only the currently selected pitch track will show in color). The spectrogram axes are frequency (Hz) over time (hh:mm:ss). This image and the following descriptions explain the basic functions available when browsing the processed autodetections/pitch tracks. The buttons along the left side of the window are standard in most LFDCS programs; the buttons along the right side of the window are specific to the find_exemplars program.

- Scroll forward (not a visible button in Fig. 18):

  Click on the black background (or hover cursor over the spectrogram window and scroll to) anywhere on the right side of the window to scroll forward in the data.

- Scroll backward (not a visible button in Fig. 18):

  Click on the black background (or hover cursor over the spectrogram window and scroll to) anywhere on the left side of the window to scroll backward in the data.

- Page forward

  Click on (or hover cursor over button and scroll to) the “Page forward” button to move forward to the next section (new window) of the spectrogram.

- Page backward

  Moves back to the previous section of the spectrogram.

- Zoom in

Zooms in on the time (x) axis.

- Zoom out

  Zooms out on the time (x) axis.

- Jump

  Jumps to the specified section of the spectrogram/audio file. After clicking, a small popup window will appear (Fig. 19) and you can enter the desired date and time in the MM/DD/YY HH:MM:SS format (e.g., 01/29/16 04:13:58).

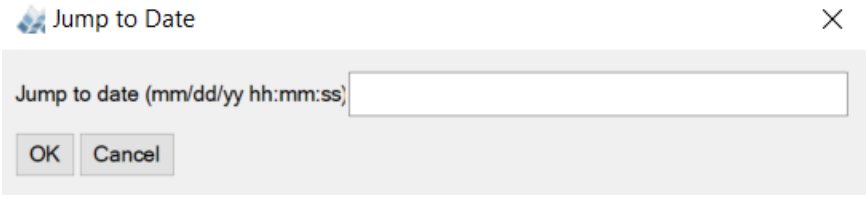


Figure 19. The Jump to Date popup window where you can enter a date and time to jump to in your dataset.

- Volume/Speed

  Adjusts volume and playback speed of audio file. After clicking, a small popup window will appear (Fig. 20) and you can enter the desired volume and speed. Default values are both 1 whenever a processed deployment is opened from the terminal.

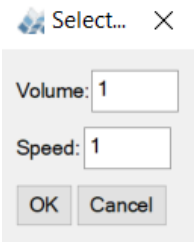


Figure 20. The Select Volume and Speed popup window where you can adjust your amplitude and audio speed settings.

- Audio filter off

  Applies a band pass filter to filter out background noise above and below the selected pitch track. If this is toggled on, you will only hear the frequency range in which the pitch tracked call occurs.

- Play

Plays the selected pitch track with a 1-second buffer on either side (at selected volume and speed).

- Play range

  Plays a clip selected by the analyst. After clicking, click a point on the spectrogram where range should start, then click a point on the spectrogram where listening range should end. The selected audio range will start playing automatically.

  Note: If a click is made anywhere on the black background before or after the spectrogram, it will be included in the playback.

- Freq range

  Adjusts the maximum frequency range (y-axis) of the viewing window. After clicking, a small popup window will appear (Fig. 21) and you can enter the desired maximum frequency in Hz. The minimum frequency will remain 0 Hz.

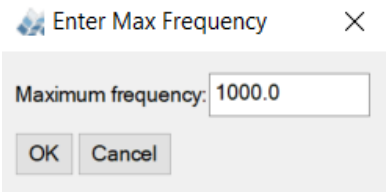


Figure 21. The Enter Max Frequency popup window where you can adjust the maximum frequency of your spectrogram.

- Hide pitch tracks

  Hides the pitch tracks to reveal the raw spectrogram image. Click the button again to show pitch tracks.

- Compare audio

  Plays the selected pitch track audio and the audio of the exemplars of the call type to which you are comparing it. After clicking, a small popup window will appear (Fig. 22) and you can select the call type to which you would like to compare your currently selected pitch track. Once the call type is selected, you will hear the audio for your selected pitch track, followed by the audio of the first exemplar of the selected call type, followed by your selected pitch track, followed by the second exemplar of the selected call type, and so on through all the exemplars of that call type.

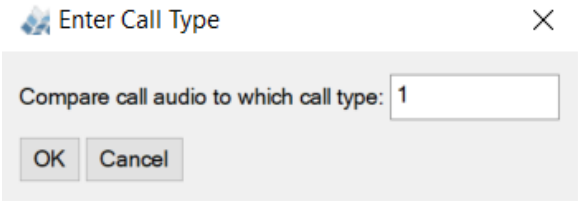


Figure 22. The Enter Call Type popup window where you can select a call type for comparison.

To stop the audio, click "Stop audio playback" in the small popup window that will appear once the sounds start playing, and it will quit the function.

- Add call type

  After clicking, follow the prompts in the popup windows to add a new call type and its description to the call library.

- Quit

  Quits the LFDCS program, allowing the analyst to close out of the browsing window. Use this button to properly exit the program.

- Call type buttons along the right side of the desktop window:

  Each call type button will appear with a different color and call type number that was specified when the call type was first created.

  Once the pitch track of interest is selected (in color) in the browsing window, click on the target call type button along the right side of the window to add the pitch track as an exemplar for that call type.

  Click on the black background (or hover cursor over and scroll to) anywhere on the left or right side of the window (not on a button) to navigate between the automated detections (pitch tracks) without selecting them as exemplars for a call type.

Managing a Call Library on a Windows Computer

CALL LIBRARY: Manage

The following directions explain how to manage a call library and assess the attributes of the different call types and their respective exemplars that have been added to the library. All 7 call type attributes are amplitude-weighted (AW) statistics.

The program will list call types within the call library and prompt you to select which call type for which you want to view the attributes. Once a call type is entered, a series of three windows (Fig. 27-29) will pop up. A fourth window (Fig. 30) will appear with buttons list for the various

actions you can take relating to the call type (e.g., play case, spectrogram view of case, delete exemplar, move case to a different call type). You can use the different command buttons to view and manage exemplars and distribution of attributes for that call type.

1. From the LFDCS App Launcher, click on the "CALL LIBRARY: Manage" button. This popup window will appear:

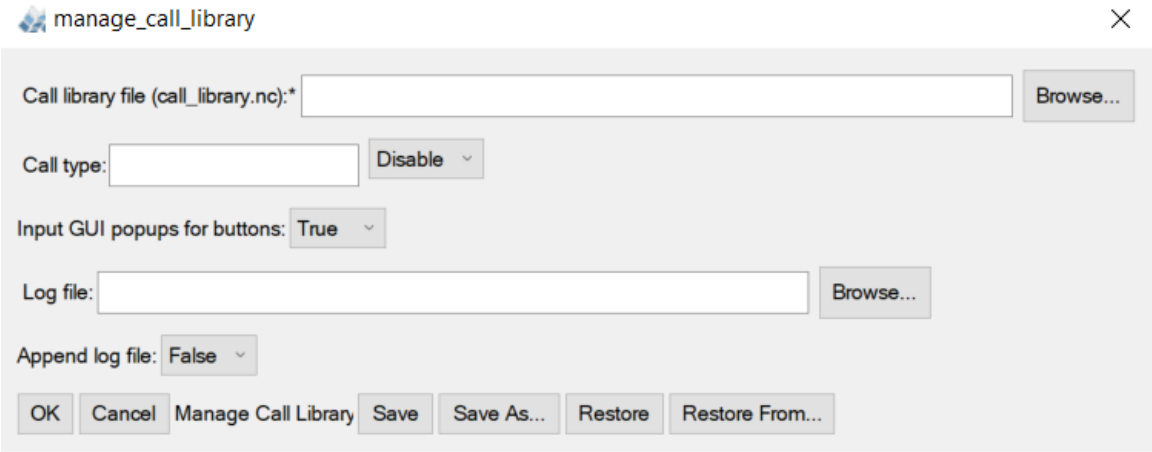


Figure 23. The manage_call_library program window where you can select which call library you want to manage.

2. In the "Call library file (call_library.nc)" field of the manage_call_library window, use the "Browse…" button to select your call library file (e.g., call_library_gom9.nc).

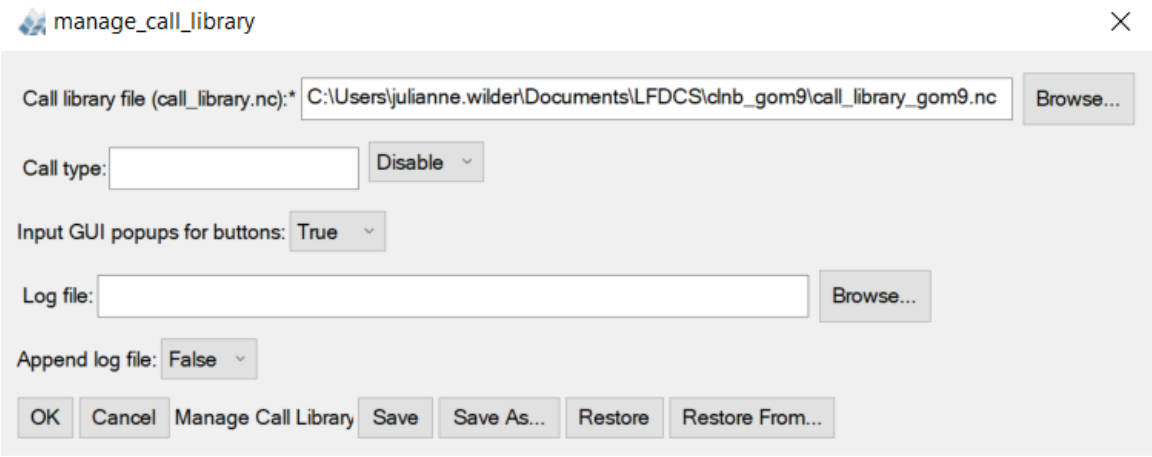


Figure 24. The manage_call_library program window with the file pathway to your call library.

   a. In the "Call type" field, you can select "Disable" from the dropdown menu and, once you click "OK", the program will display a full list of the call types with their respective information and provide a "Call type ->" window where you can select a particular call type to view its attributes.

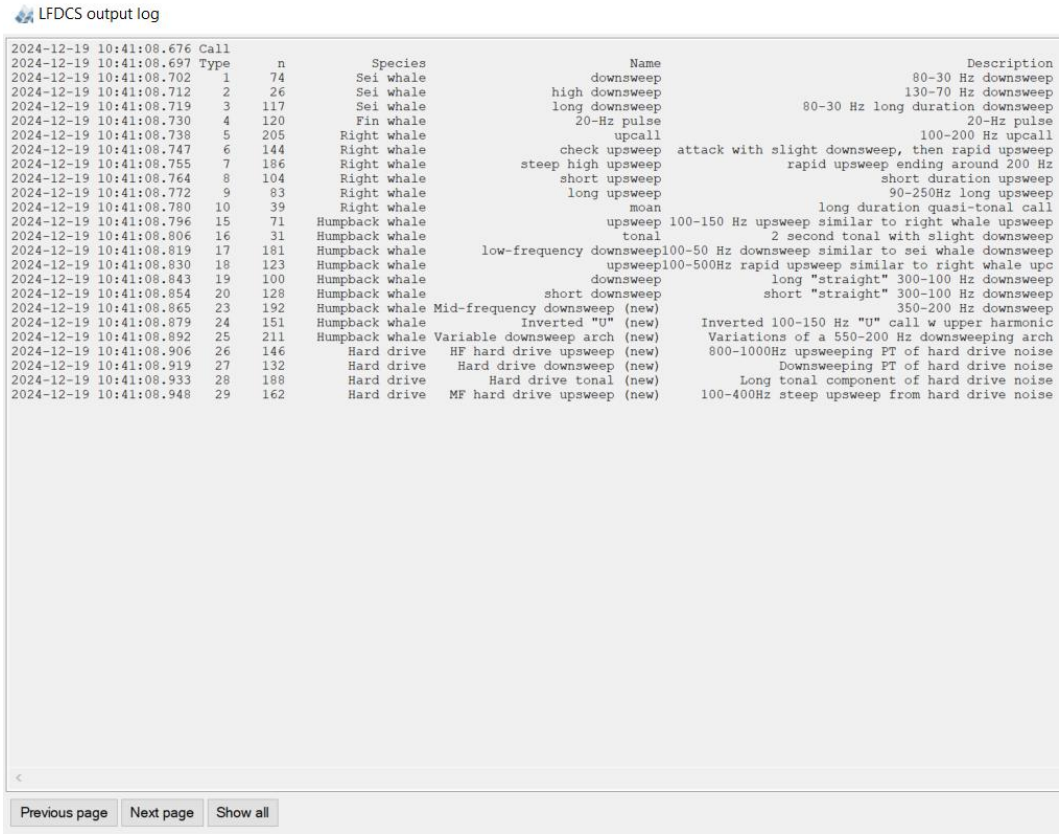


Figure 25. The list of call types within your selected call library that will be displayed when you run the manage_call_library program with the “Call type” field disabled.



Figure 26. The window that will be displayed where you can select a call type from your call library.

b. In the “Call type” field, you can also specify the call type number in the text box that you would like to manage (i.e., view the attributes and edit existing exemplars). When you type in a number, the dropdown menu will automatically change to “Enable”. That will prompt the program to open the plots for that particular call type.

3. Once you have selected your call type to view (either by selecting it from the list as specified in step 2a, or typing the call type number directly into the manage_call_library window as specified in step 2b), then you will see 3 new windows open and a “Manage Call Library” Graphical User Interface (GUI) with command buttons.

   You can then browse through exemplars using the command buttons in the Manage Call Library GUI (Fig. 30) to see where they fall on the distribution plots and can further

delete an exemplar or move it to a new call type. The current pitch track selected will be highlighted in yellow in windows IDL 2 and 3 (Figs. 28 and 29), and there will be a vertical line on the bar plots in window IDL 0 (Fig. 27) indicating where that exemplar lies in the distribution. If there are any exemplars that are outliers, they will be highlighted in red.

Caution: Highlighted outliers will change drastically as you add/adapt your call library, and as you delete one outlier, it will likely create another. Use caution when removing outliers until you have sufficiently built your call library to have enough exemplars that deleting an outlier will only improve your call library.

Key for Seven Call Type Attributes

- awfreq = Average frequency of the exemplar call pitch tracks
- awfreq_stdev = Frequency variation of the pitch tracks
- awtime_stdev = Duration of the pitch tracks
- awslope = Average time-frequency slope of the pitch tracks
- aws1 = Average slope of the beginning (first third) of the pitch tracks
- aws2 = Average slope of the middle (second third) of the pitch tracks
- aws3 = Average slope of the end (last third) of the pitch tracks

- mdist = Mahalanobis distance (the Mahalanobis distance is a multivariate measurement of each pitch track that is calculated by combining all seven call type attributes; see explanation in the Plot mdist Distribution section)

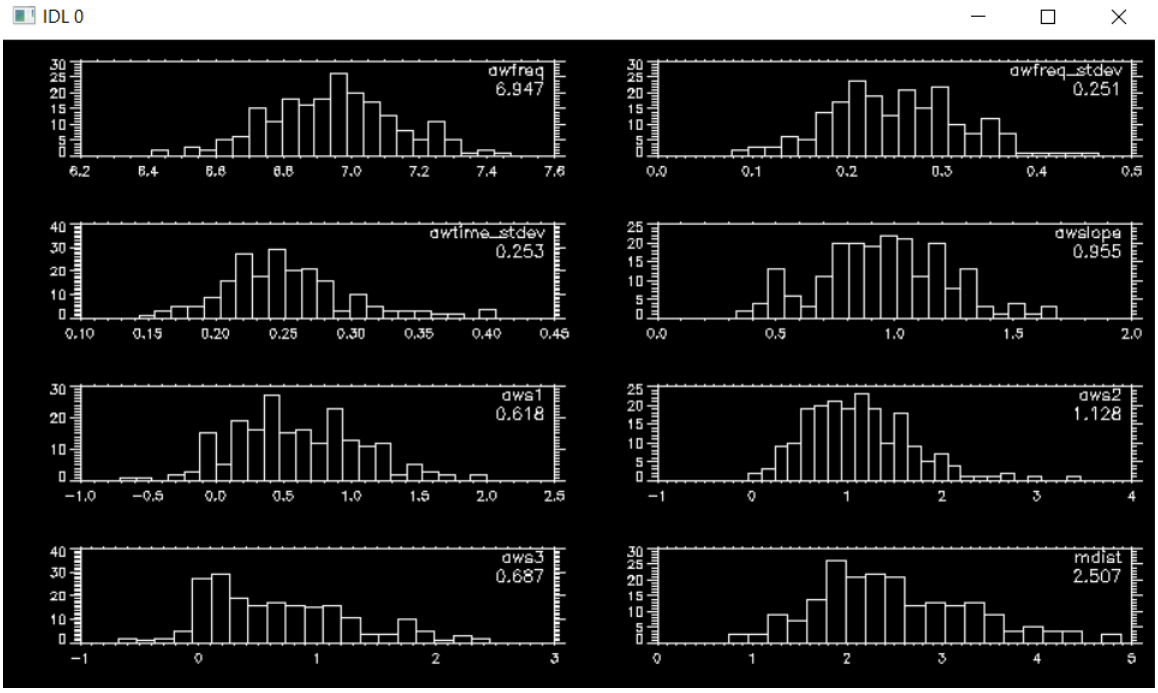


Figure 27. The IDL 0 window shows the histogram distribution of each attribute for all of the exemplars for the call type specified.

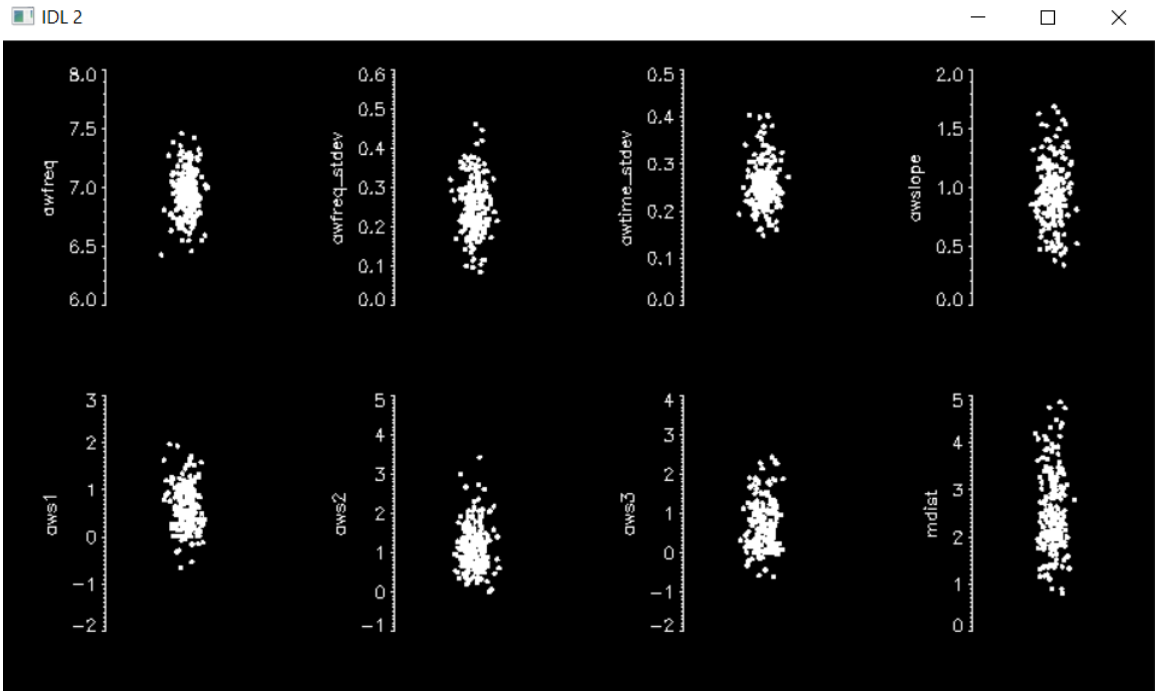


Figure 28. The IDL 2 window shows the dot plot distribution of each attribute for all of the exemplars for the call type specified.

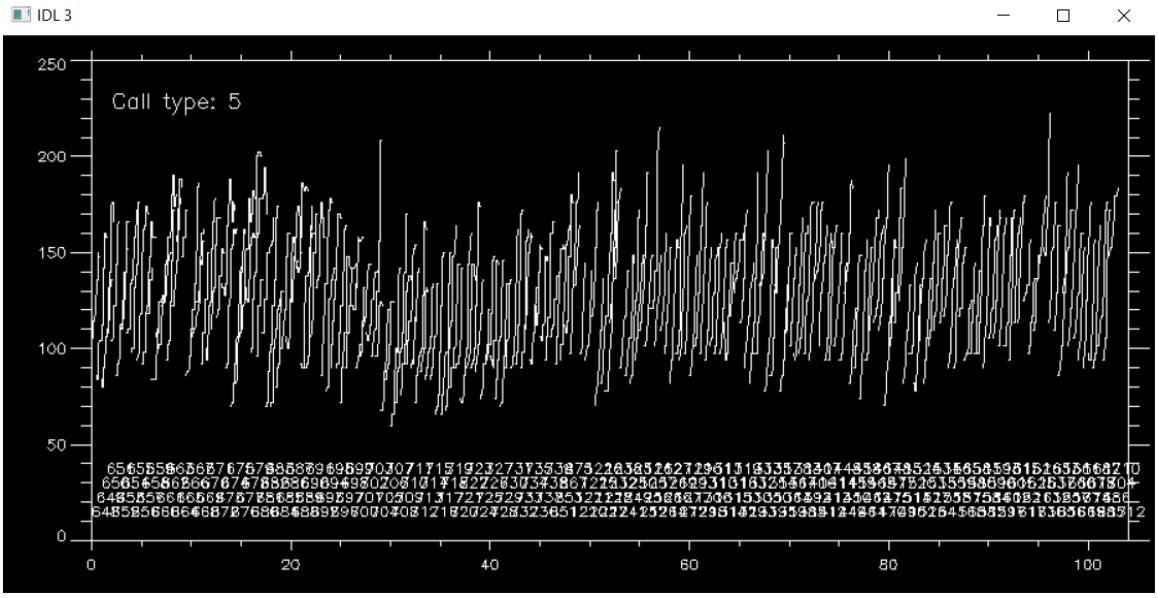


Figure 29. The IDL 3 window shows all of the exemplar pitch tracks for the call type selected, with the exemplar's identification number below.

Note: The exemplar numbers at the bottom of the IDL 3 window can sometimes show up as condensed or overlapping with each other. To make them more visible, you can click and drag the bottom right corner of the IDL 3 window to a desired size, then click "Change call type" in the Manage Call Library window (Fig. 30) and select your call type again from the drop down menu that pops up. The window should reopen to the adjusted size and the exemplar numbers will appear more spread out.

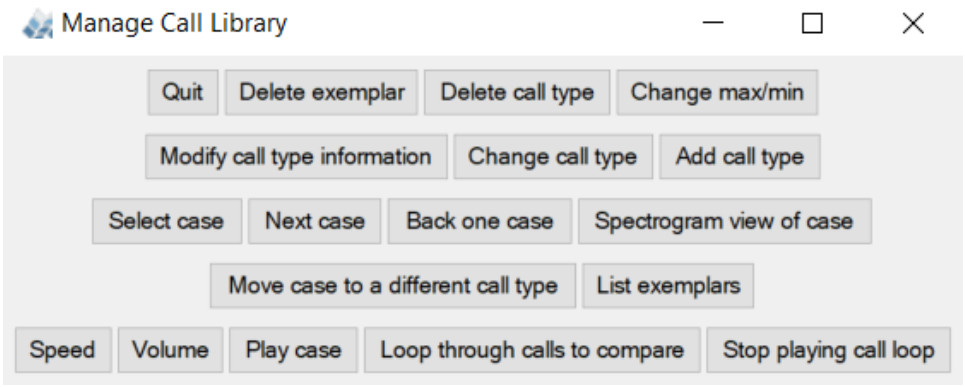


Figure 30. The GUI with the buttons used for listening to and editing exemplars in a call library.

4. Use the definitions below to help you navigate the command buttons in the Manage Call Library window.

    - Quit

        Quits the manage_call_library program and closes out of all windows.

    - Delete exemplar

        Deletes the selected exemplar. Note: This action is irreversible within the manage_call_library program. To add that exemplar back into the call type, you will need to quit the manage_call_library program and open your original dataset from which you retrieved the exemplar using the find_exemplars program. Then select your original exemplar from the pitch tracks and add it back to the call type.

    - Delete call type

        Deletes the selected call type. Note: This action is also irreversible, but you will be prompted to confirm your decision to delete the call type before the action is completed.

    - Change max/min

        Allows you to select one of the 8 exemplar variables (e.g., awfreq, mdist) and set a maximum and minimum values for that variable (Fig. 31). Once you have set the values (Fig. 32), you will see all of the exemplar calls that fall within that range highlighted in white in the IDL 2 and 3 scatter plot and pitch track windows. Exemplars that fall outside of the set max/min values will appear in red (Fig. 33).



Figure 31. The Select variable popup window where you can select an exemplar variable and max/min values to filter your view.

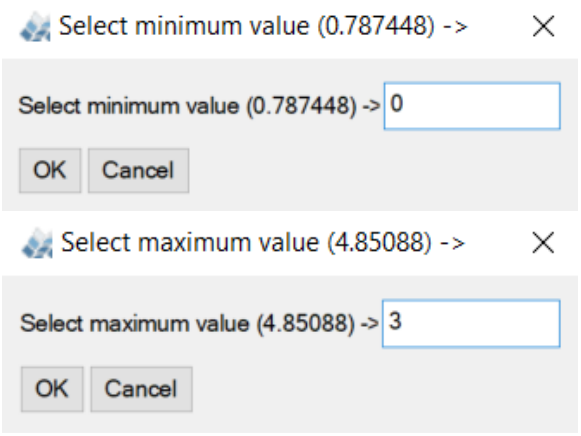


Figure 32. The Select minimum and maximum popup windows that will appear sequentially where you can select the max/min values to filter your view.

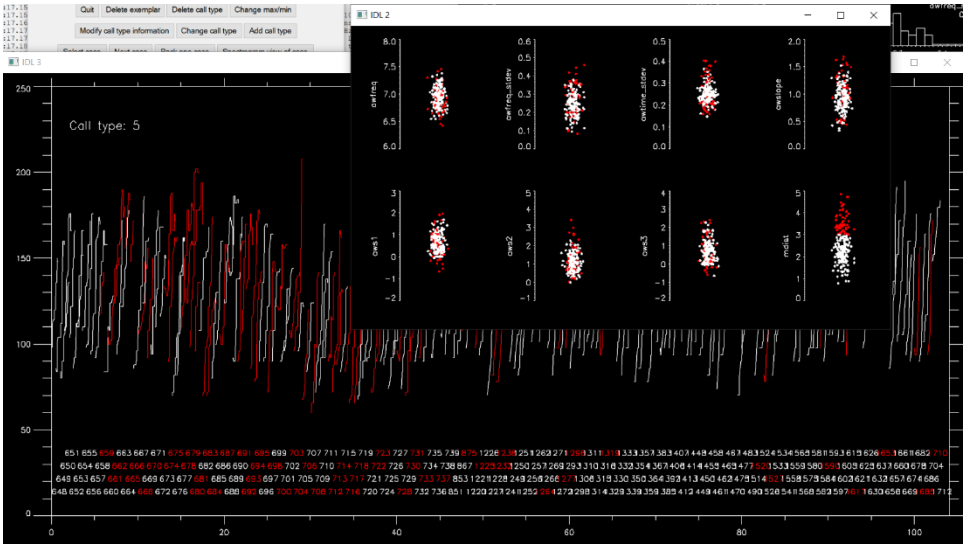


Figure 33. The IDL 2 and 3 windows where any exemplar pitch tracks that do not fall within the set max/min values (e.g., have a Mahalanobis distance between 0 and 3) will appear in red in the scatter plot and pitch track views.

Key for Seven Call Type Attributes

- awfreq = Average frequency of the exemplar call pitch tracks

- awfreq_stdev = Frequency variation of the pitch tracks
- awtime_stdev = Duration of the pitch tracks
- awslope = Average time-frequency slope of the pitch tracks
- aws1 = Average slope of the beginning (first third) of the pitch tracks
- aws2 = Average slope of the middle (second third) of the pitch tracks
- aws3 = Average slope of the end (last third) of the pitch tracks

- mdist = Mahalanobis distance (the Mahalanobis distance is a multivariate measurement of each pitch track that is calculated by combining all seven call type attributes; see explanation in the Plot mdist Distribution section)

- Modify call type information

  Allows you to modify the call type name or description that was originally given to that call type when it was created.

- Change call type

  Allows you to select a different call type to view.

- Add call type

  Allows you to add a new call type to the call library.

- Select case

  Allow you to select a specific case or exemplar within a call type, to view its characteristics in relation to the other exemplars within that call type.

- Next case

  Moves the selection to the next case or exemplar in the call type.

- Back on case

  Moves the selection to the previous case or exemplar in the call type.

- Spectrogram view of case

  Opens a zoomed in spectrogram image of that particular case or exemplar.

- Move case to a different call type

Allows you to move a case or exemplar to another call type (e.g., useful if you accidentally added an exemplar to the wrong call type when you were using the find_exemplars program).

- List exemplars

  Lists all of the exemplars in that call type along with their characteristics.

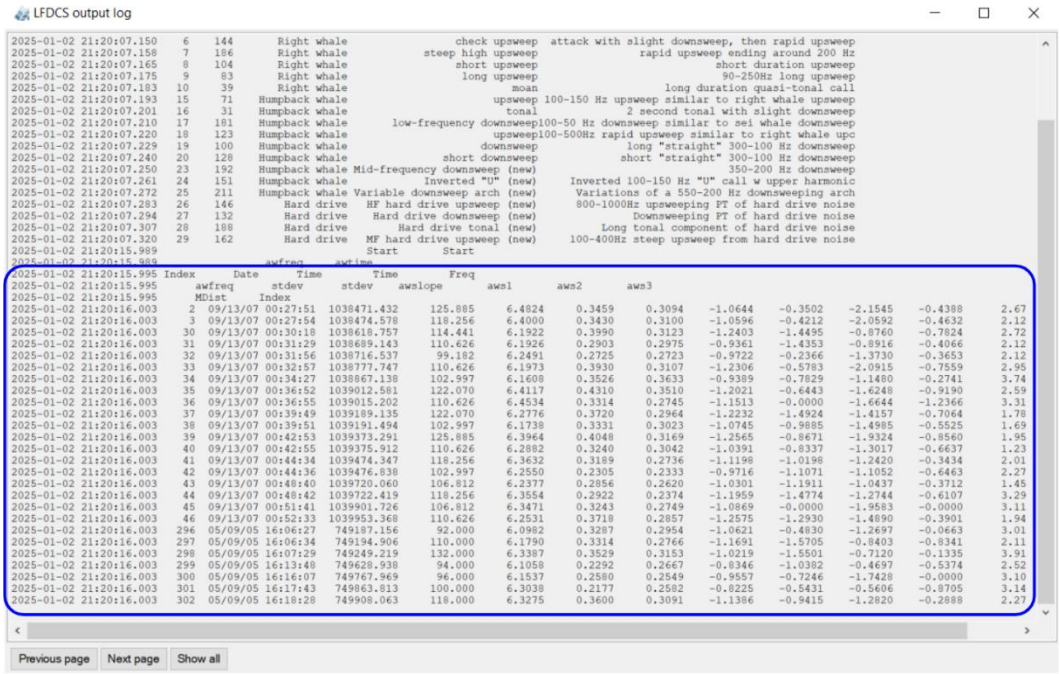


Figure 34. The list of exemplars for a selected call type in the blue box (a list of all the call types in the call library precedes the exemplar list), including a list of the column headers (e.g., exemplar index number, start date and time, frequency, average frequency).

- Speed

  Allows you to adjust the audio speed when you play the selected exemplar.

- Volume

  Allows you to adjust the volume of the selected exemplar.

- Play case

  Plays the selected case or exemplar.

- Loop through calls to compare

Plays the exemplar clips on loop, alternating between replaying the selected exemplar and playing each of the other exemplars in the call type.

- Stop playing call loop

  Stops the playing of the calls in comparison to the selected exemplar.

Evaluating a Call Library on a Windows Computer

The following directions explain how to evaluate a call library. Quadratic discriminant function analysis relies on the assumption that the distribution of the 7 attributes for a particular call type are multivariate normal (or nearly so). Visualizing data from tens to hundreds of exemplars in 7 dimensions is impossible; the following tools can be used to aid in evaluating the exemplar data. It is also important to ensure that call types do not overlap in multivariate space too much, as the discriminant function analysis will confuse such overlapping call types. When these overlapping call types are produced by different species, the chance of misclassifying species increases.

Comparing Actual vs. Expected Mahalanobis Distance

CALL LIBRARY: Plot mdist Distribution

Samples drawn from a multivariate normal population have a known distribution of univariate Mahalanobis distances (the distance from the sample to the mean vector that accounts for the shape of the multivariate normal distribution as described by the variance-covariance matrix). The square of the Mahalanobis distance should have a chi-squared distribution with p degrees of freedom where p is the number of attributes in the call library ($p = 7$ in this case).

If the distribution of Mahalanobis distances for a call type does not conform to the expected distribution (the chi-squared distribution), then it is likely that the underlying distribution of attributes for the call type in question is not multivariate normal. When a call type is not multivariate normal, the discriminant function analysis may not always classify calls as expected (since it is violating one of the underlying assumptions of discriminant function analysis). The following directions allow you to check the Mahalanobis distribution of each call type in a call library.

1. From the LFDCS App Launcher, click on the "CALL LIBRARY: Plot mdist Distribution" button. This popup window will appear:

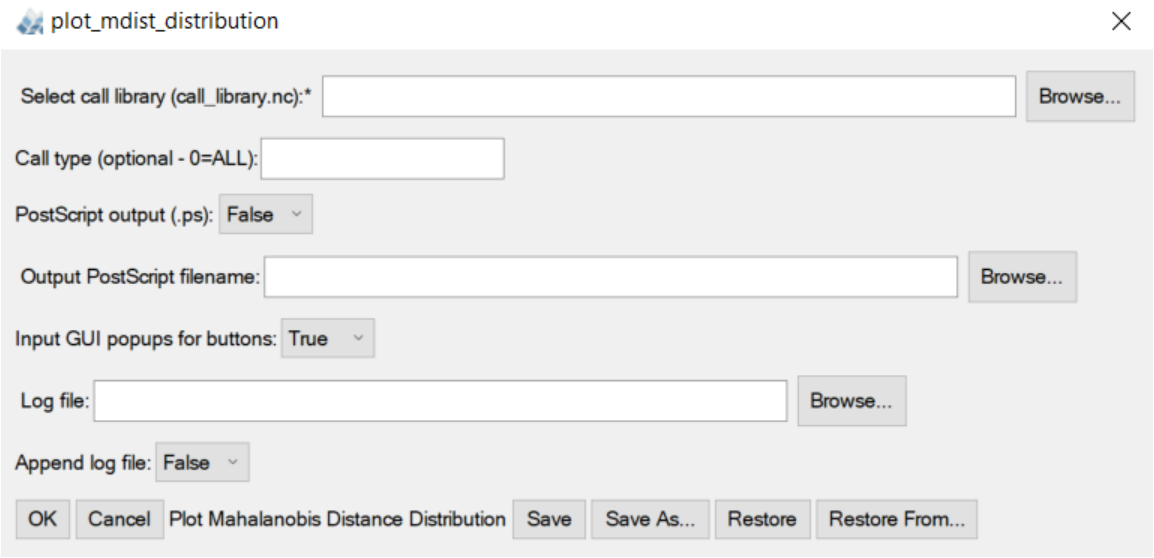


Figure 35. The plot_mdist_distribution program window where you can select which call library and call type Mahalanobis distances you want to plot.

2. In the "Select call library (call_library.nc)" field of the plot_mdist_distribution window, use the "Browse…" button to select your call library file (e.g., call_library_gom9.nc).

   You can either leave the "Call type (optional – 0=ALL)" field blank or type in a call type number (e.g., 2). If the field is left blank, when you click "OK" it will automatically display the Mahalanobis distance distribution plots for the first two call types in the call library. A small popup window will ask if you want to "Continue?". Each time you click "Yes" in the popup window it will switch the display to the next two call types in the call library.

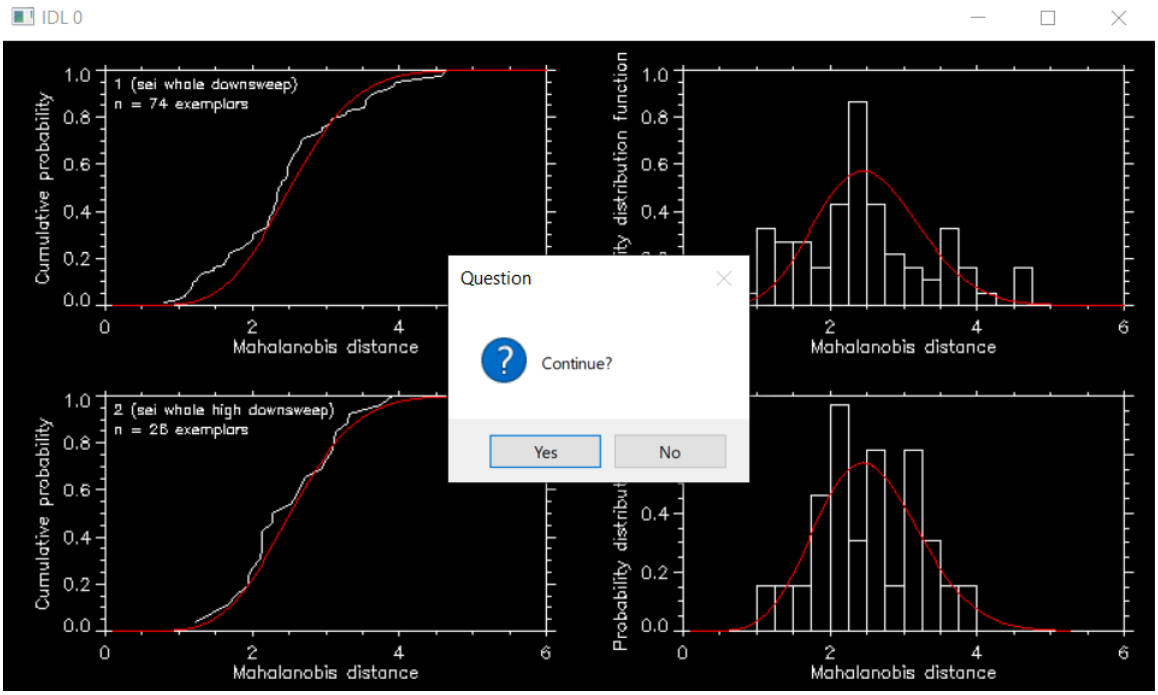


Figure 36. The IDL 0 window of the plot_mdist_distribution program, showing the Mahalanobis distance distribution plots for the first two call types in the call library with a popup window that allows you to navigate to the next two call types. Each plot shows the Mahalanobis distances for a call type compared to the ideal distribution for a multivariate normal distribution (in red).

If you enter a specific call type number (e.g., 5) in the "Call type (optional – 0=ALL)" field, when you click "OK" it will display the Mahalanobis distance distribution plots for only that call type. Only one call type can be selected at a time. A small popup window will appear saying "The end". If you click "OK" in that window, the program will close.

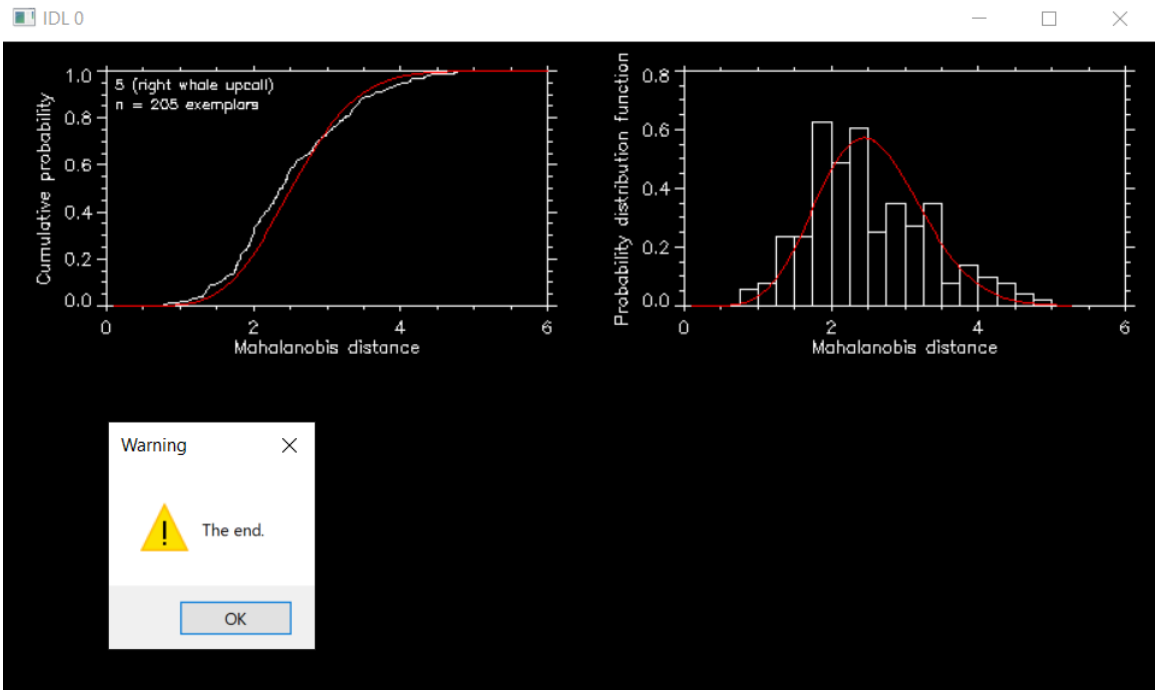


Figure 37. The IDL 0 window of the plot_mdist_distribution program, showing the Mahalanobis distance distribution plots for call type 5 of the selected call library. Each plot shows the Mahalanobis distances for a call type compared to the ideal distribution for a multivariate normal distribution (in red).

3. To export the distributions as a PostScript file that can be opened with a PDF reader, select "True" from the dropdown menu in the "PostScript output (.ps)" field and type a file name and select a file pathway where you would like the *.ps file to export to in the "Output PostScript filename" field.

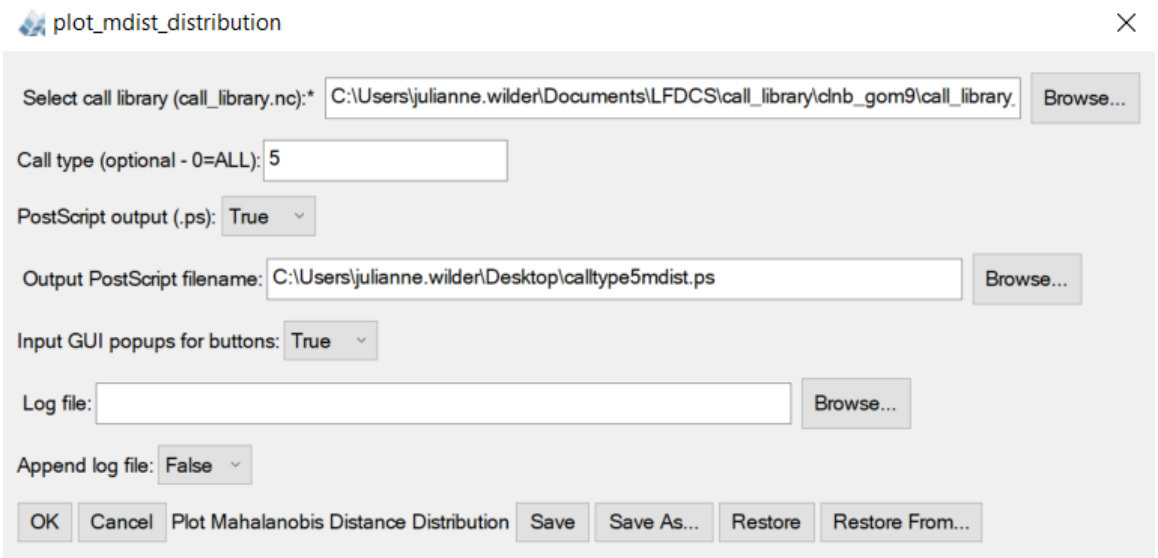


Figure 38. The plot_mdist_distribution program window where you can select which call library and call type Mahalanobis distances you want to plot, with settings entered to export a PostScript file with plots upon running the program.

Multivariate Distributions with Canonical Discriminant Function Analysis

CALL LIBRARY: Compare Call Types- Canonical

To assess overlap in multivariate distributions, canonical discriminant function analysis (CDFA) can be used to reduce the 7 attribute dimensions down to 2 so the distributions can be directly visualized using scatterplots. CDFA seeks to find linear combinations of the 7 variables that best discriminates between the call types. By plotting the first 2 linear combinations (canonical variables), it is possible to visualize which call types are well separated and which overlap. It is important to recognize that the CDFA plots are a representation of the 7-dimensional distribution of the attributes for each call type; they are not the actual multivariate distributions. Caution is warranted when interpreting these plots, but they can give helpful clues about which call types may interfere with one another. Follow the directions below to generate the CDFA plots.

1. From the LFDCS App Launcher, click on the "CALL LIBRARY: Compare Call Types- Canonical" button. This popup window will appear:

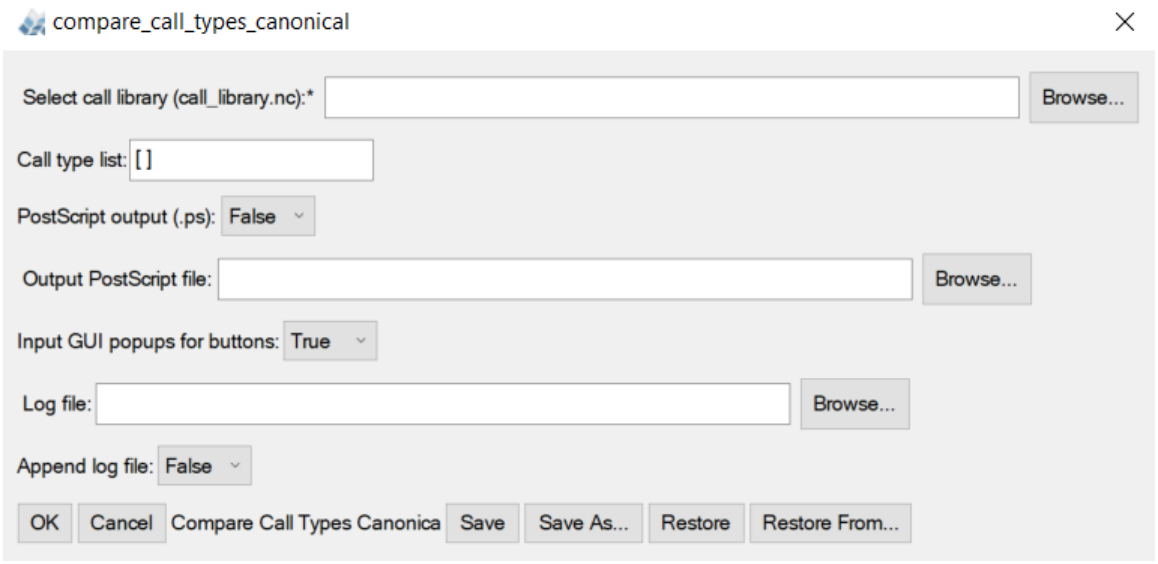


Figure 39. The compare_call_types_canonical program window where you can select which call library and call type(s) you want to plot.

2. In the "Select call library (call_library.nc)" field of the compare_call_types_canonical window, use the "Browse…" button to select your call library file (e.g., call_library_gom9.nc). If you do not specify your call type number(s) in the "Call type list" field, when you click "OK" the program will automatically display CDFA plots comparing all of the call types in the call library.

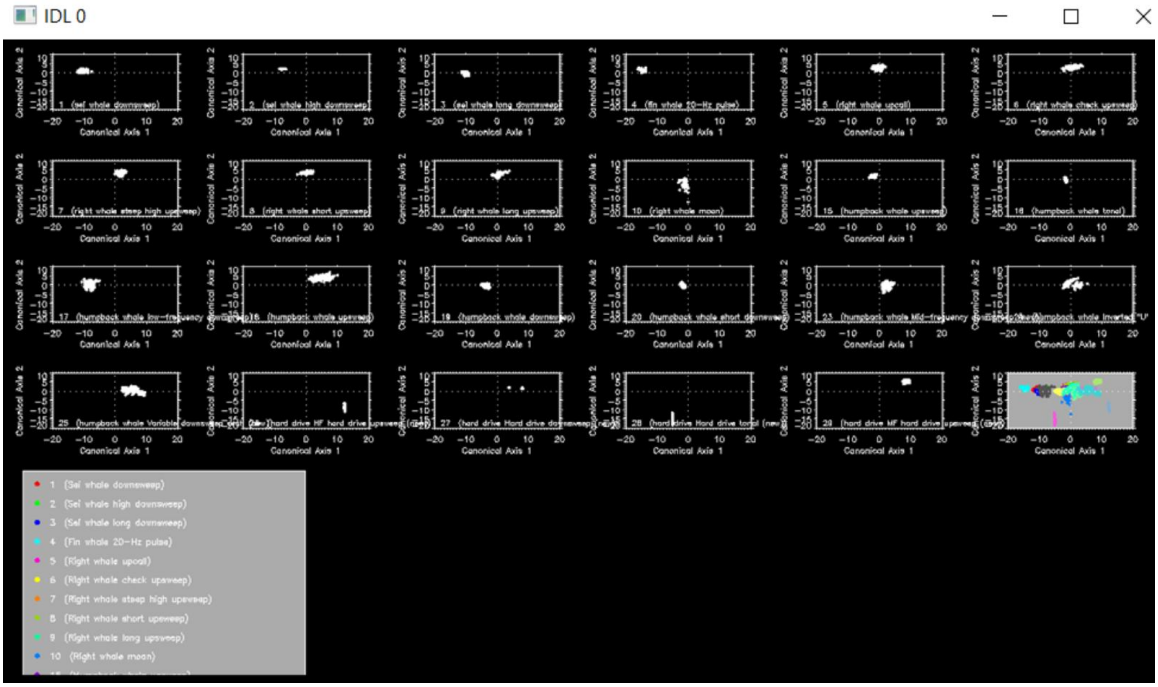


Figure 40. The IDL 0 window of the compare_call_types_canonical program showing the **canonical discriminant function analysis** (CDFA) scatterplots to assess overlap in multivariate distributions between call types.

Note: The plots in the IDL 0 window can sometimes show up as condensed or overlapping with each other. To make them more visible, skip to Step 3 to export them as a PostScript file that can be opened with a PDF reader.

If you enter specific call type numbers (e.g., 5, 6, 7 in the "Call type list" field, when you click "OK" it will display the CDFA plots comparing only those call types. Note: You must list 3 or more call types in the "Call type list" field for the program to work.

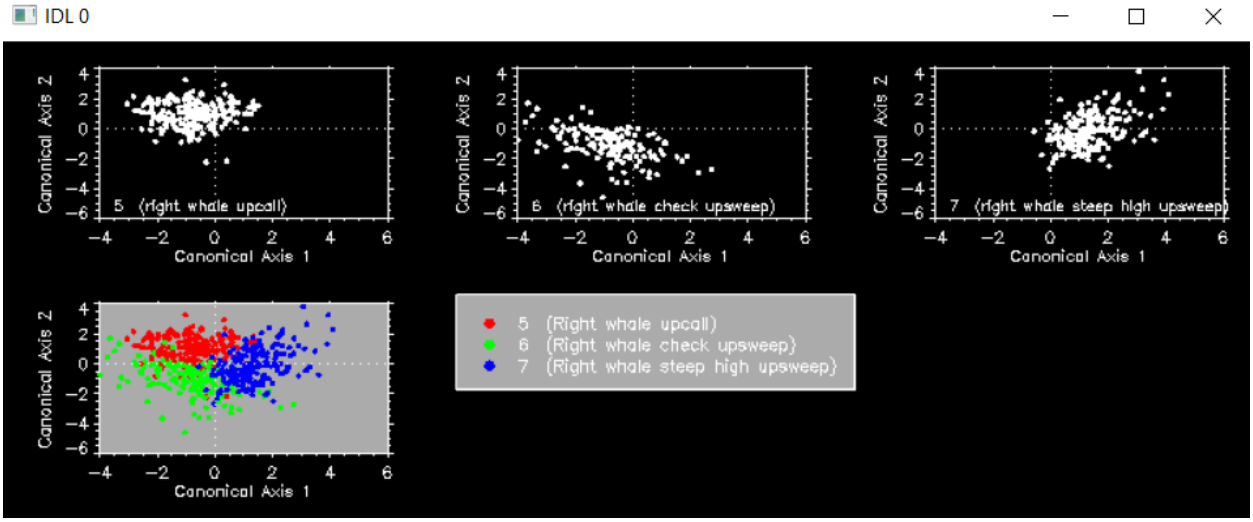


Figure 41. The IDL 0 window of the compare_call_types_canonical output showing the CDFA plots for the selected call types (5, 6, and 7).

3. To export the CDFA plots as a PostScript file that can be opened with a PDF reader, select "True" from the dropdown menu in the "PostScript output (.ps)" field and type a file name and select a file pathway where you would like the *.ps file to export to in the "Output PostScript filename" field.

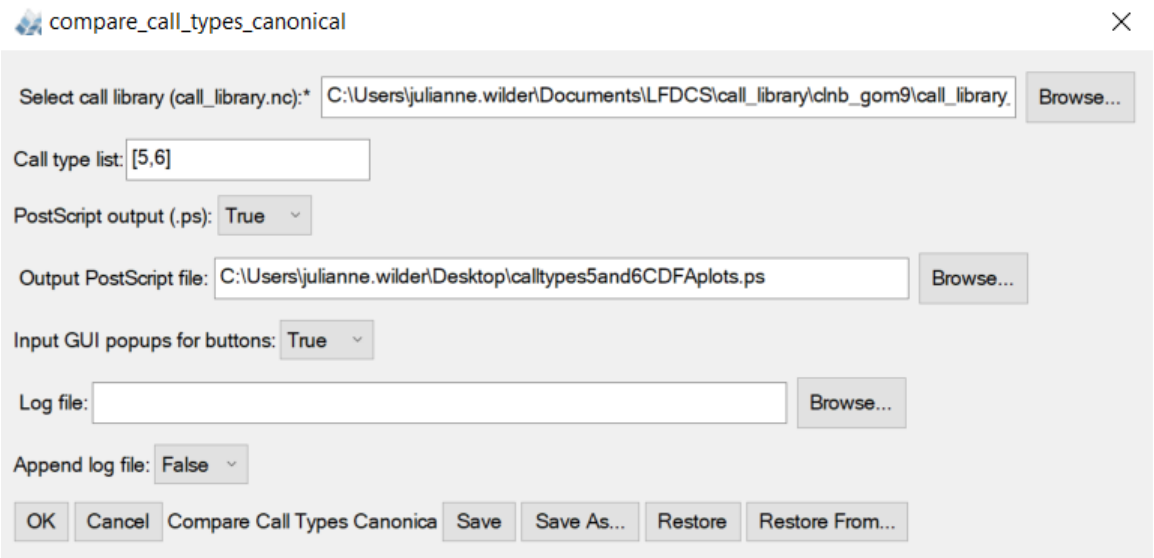


Figure 42. The compare_call_types_canonical program window where you can select which call library and call types you want to plot, with settings entered to export a PostScript file with plots upon running the program.

Multivariate Distributions with Scatterplots

CALL LIBRARY: Compare Call Types- Scatter

To assess overlap in multivariate distributions, you can export a set of scatterplots showing each call type's attributes plotted against one another. Separation between call types in one or more of these plots suggests that the call types can be discriminated.

1. From the LFDCS App Launcher, click on the "CALL LIBRARY: Compare Call Types- Scatter" button. This popup window will appear:

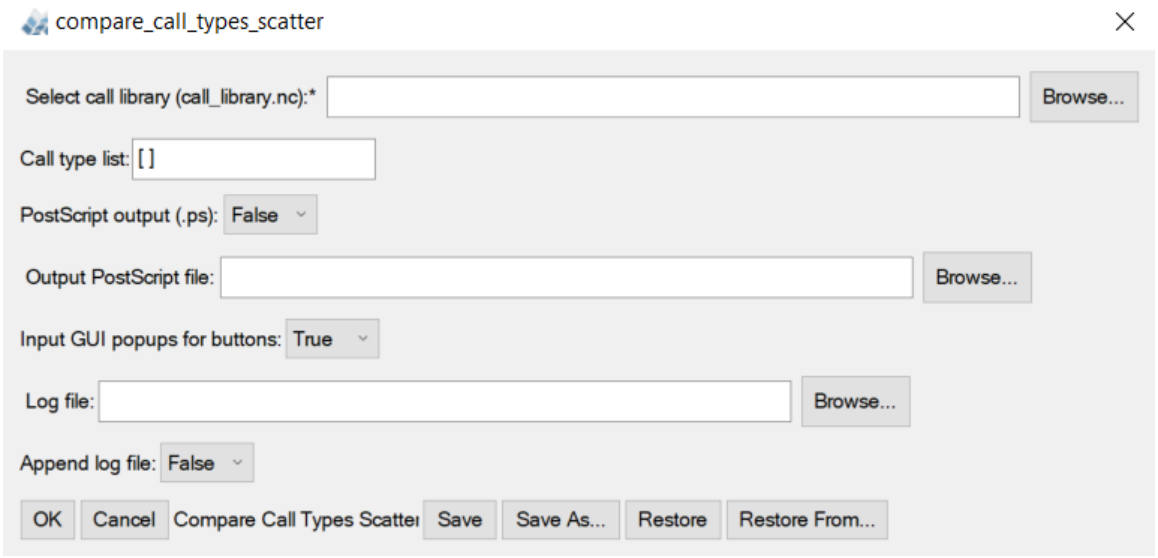


Figure 43. The compare_call_types_scatter program window where you can select which call library and call type(s) you want to plot.

2. In the "Select call library (call_library.nc)" field of the compare_call_types_scatter window, use the "Browse…" button to select your call library file (e.g., call_library_gom9.nc). If you do not specify your call type number(s) in the "Call type list" field, when you click "OK" the program will automatically display multivariate scatter plots comparing all of the call types in the call library.

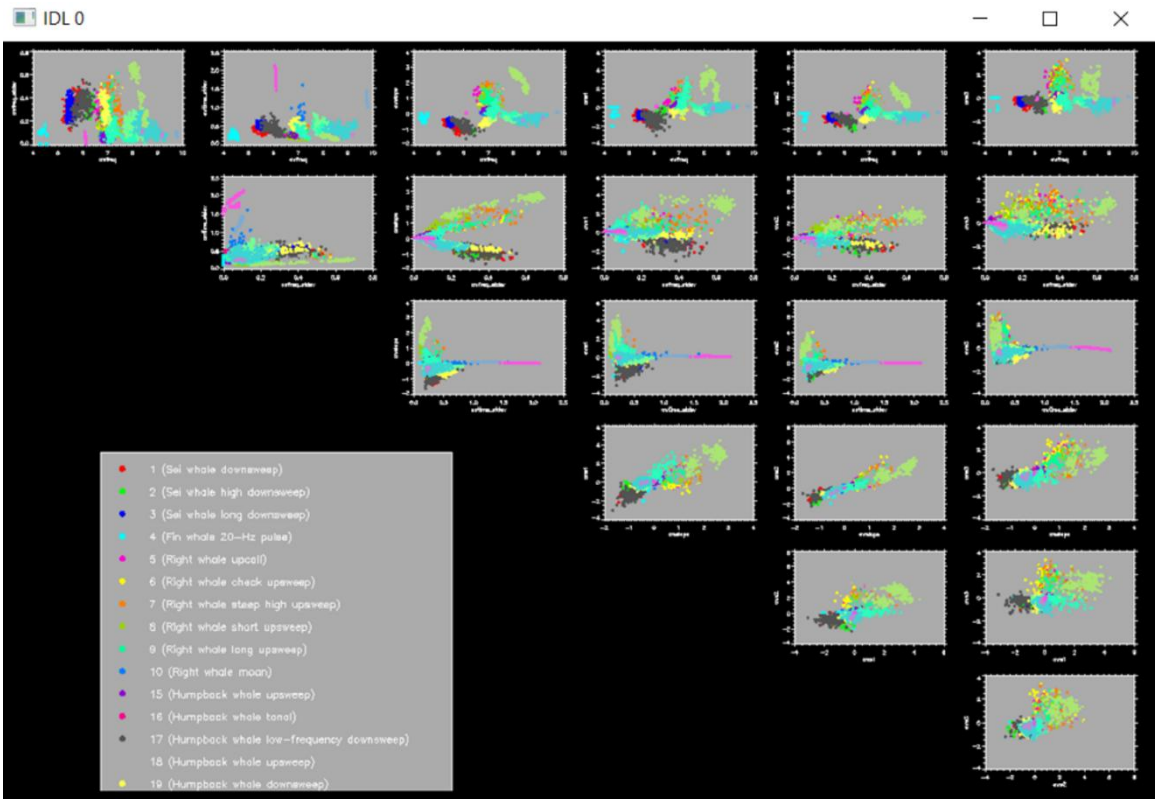


Figure 44. The IDL 0 window of the compare_call_types_scatter output showing the scatter plots of the multivariate distributions for each call type.

Note: The plots in the IDL 0 window can sometimes show up as condensed or overlapping with each other. To make them more visible, skip to Step 3 to export them as a PostScript file that can be opened with a PDF reader.

If you enter specific call type numbers (e.g., 5, 6) in the "Call type list" field, when you click "OK" it will display the scatter plots comparing only those call types.

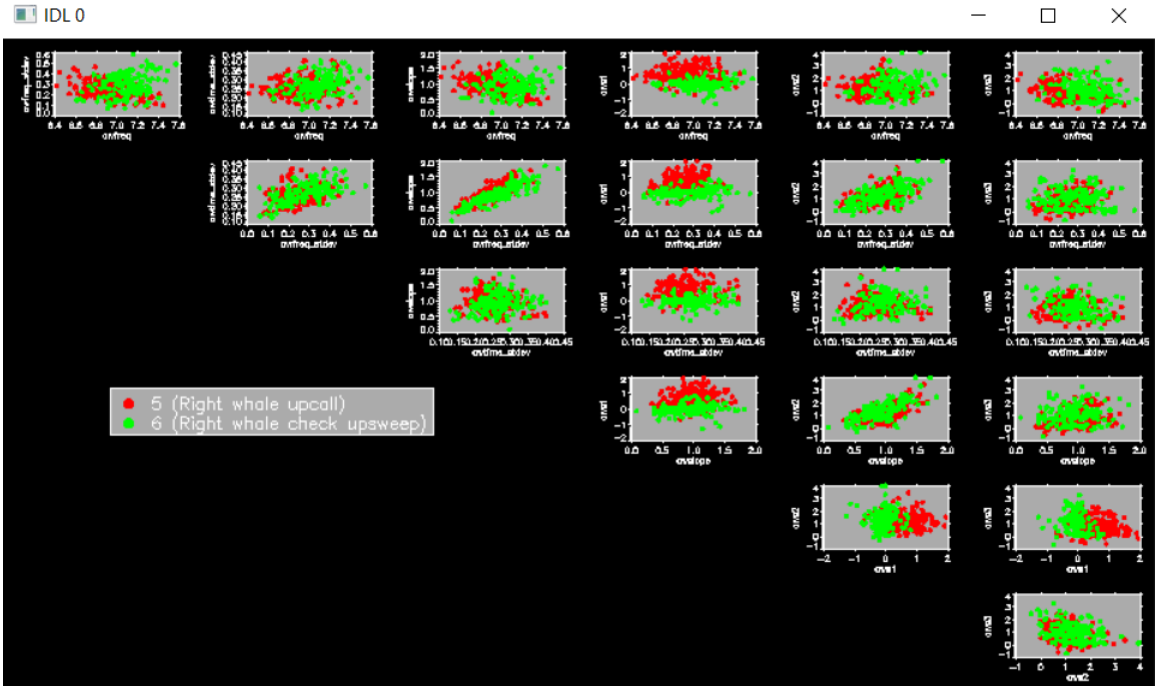


Figure 45. The IDL 0 window of the compare_call_types_scatter output showing the scatterplots of the multivariate distributions for the selected call types (5 and 6).

Key for Seven Call Type Attributes

- awfreq = Average frequency of the exemplar call pitch tracks
- awfreq_stdev = Frequency variation of the pitch tracks
- awtime_stdev = Duration of the pitch tracks
- awslope = Average time-frequency slope of the pitch tracks
- aws1 = Average slope of the beginning (first third) of the pitch tracks
- aws2 = Average slope of the middle (second third) of the pitch tracks
- aws3 = Average slope of the end (last third) of the pitch tracks

- mdist = Mahalanobis distance (the Mahalanobis distance is a multivariate measurement of each pitch track that is calculated by combining all seven call type attributes; see explanation in the Plot mdist Distribution section)

3. To export the scatter plots as a PostScript file that can be opened with a PDF reader, select "True" from the dropdown menu in the "PostScript output (.ps)" field and type a file name

and select a file pathway where you would like the *.ps file to export to in the “Output PostScript filename” field.

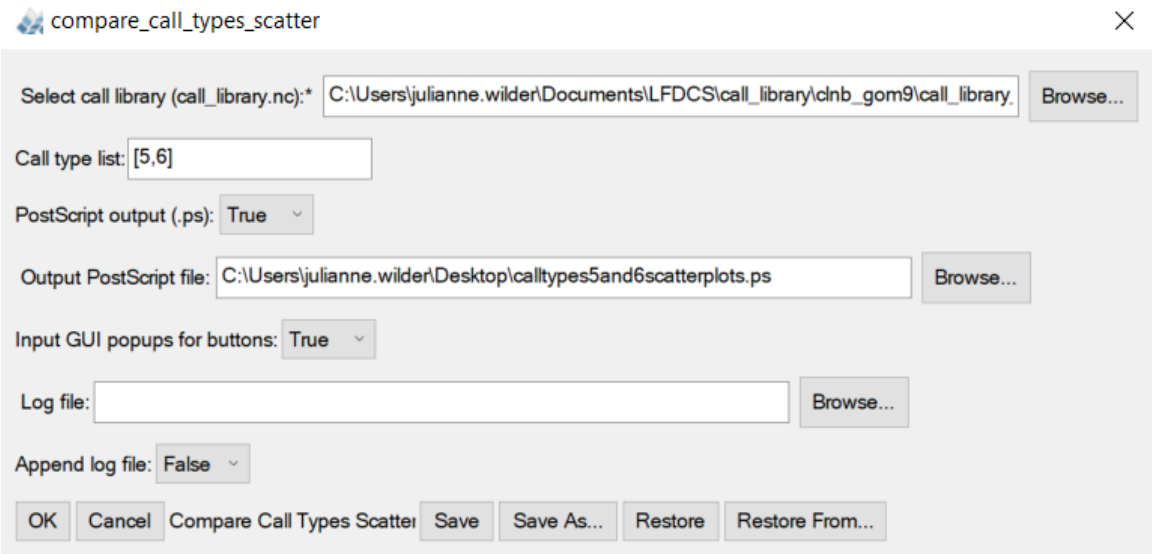


Figure 46. The compare_call_types_scatter program window where you can select which call library and call types you want to plot, with settings entered to export a PostScript file with plots upon running the program.

Data Processing

This section includes instructions for how to process new datasets and reclassify automated detections (i.e., autodetections) from previously processed data using the LFDCS.

Processing Datasets

PROCESS: Reformat, Detect, Classify

This section explains how to run audio files through the LFDCS to prepare for analysis. You must create a parameter file for each dataset (unique recorder) you want to process. See the "testparam.txt" file in the parameter_files folder included in your LFDCS Distribution File and Appendix A for an example and explanation of the parameters.

There are 2 steps that occur in this process; the first is creating a standalone version of the audio data—this reformats the recordings and spectrograms as netcdf files (.nc). This process does not affect your original audio and allows you to have a separate copy of the acoustic data that is compatible with all LFDCS programs and associated analysis. Once you process your acoustic files with LFDCS, you do not have to access the original audio again; the LFDCS will use the netcdf files created. These reformatted netcdf versions of the acoustic data are kept in the specaudio folder in the created output folder.

The second step of the processing is the LFDCS portion, where the specaudio files are screened and pitch tracks are generated. As the pitch tracks are generated, they are classified based on the call library you direct the program to in the parameter file. Pitch track information, including their classifications, are stored in the lfdcs folder of the output folder. Included in this folder is an archive of the call libraries that were run on the data (in the call_library_nb and call_library_bb folders). After a full, successful processing of a dataset, your output folder will have a specaudio and an lfdcs folder.

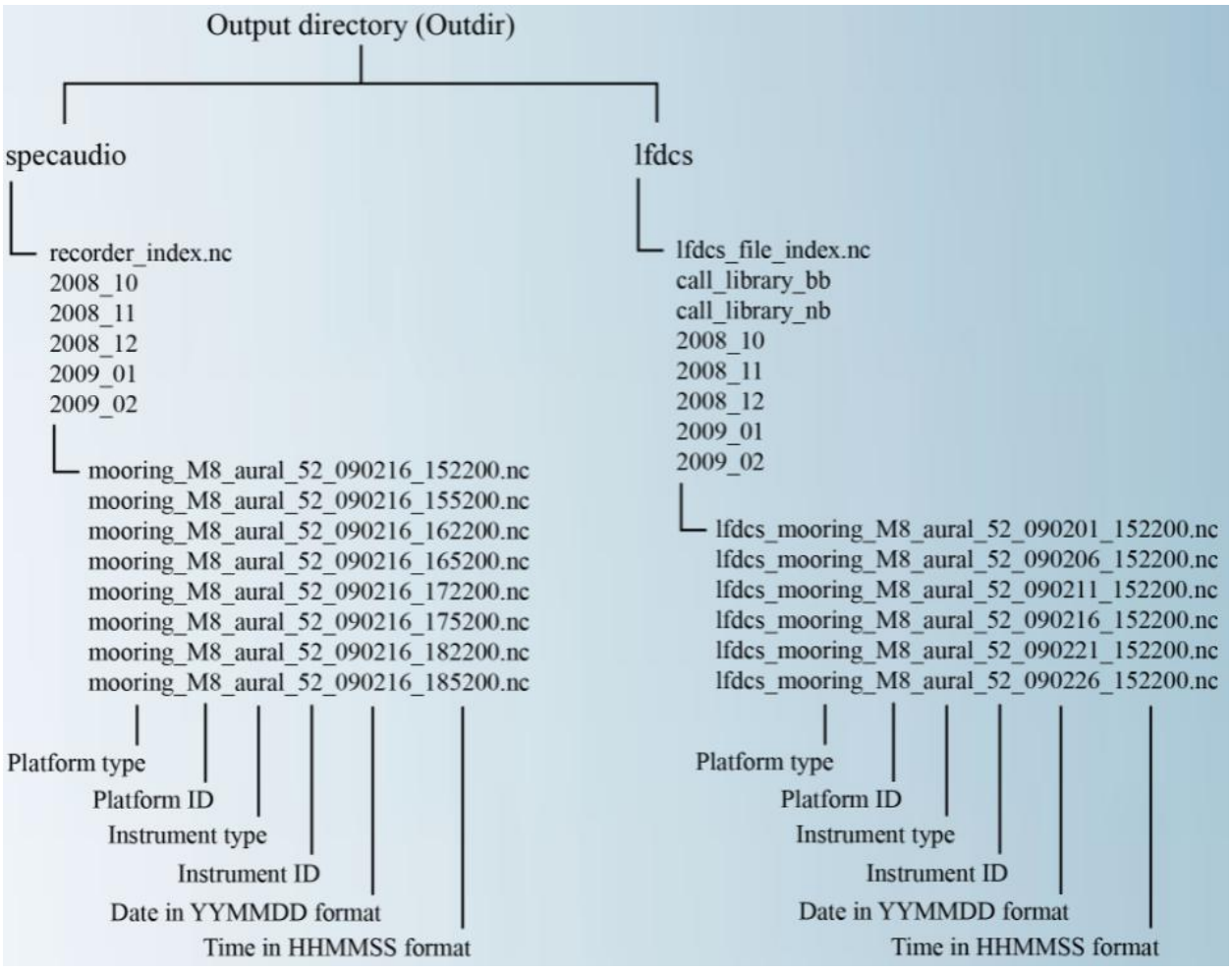


Figure 47. Example of the output directory of a successfully processed dataset.

Note: NEFSC processes and resamples datasets with 2 different sample rates and call libraries (for humpback, sei, and North Atlantic right whales, acoustic data is resampled in the processing stage to 2000 Hz; for fin and blue whales, datasets are resampled to 128 Hz). Once specaudio is created for the 2 kHz sample rate, you can use that specaudio to resample for lower frequencies rather than having to re-process the original audio. See example in parameter_files/davis_et_al_examples ending in "_LF_specaudio" for specification on how to do this. You can set the resample rate in the parameter file using "ResampleRate: X", where X is the sample rate in Hz to resample your raw data at; for any data that has a sample rate higher than 2kHz, you'll have to set this parameter for any processing.

Tip: If you have multiple projects/datasets, you may want to create folders for each, with 1 parameter per recorder/processing round. If, for example, you have data from multiple recorders from the Gulf of Maine and the Gulf of Mexico, it is good practice to have separate folders for these projects (e.g., "GOMaine", "GOMexico"), with specific names for each parameter file corresponding to the deployment/recorder being processed. If you are processing the same recorder with multiple sampling rates, it is good practice to add a specification in the parameter name (e.g., "_2kHz", "_LF"). See the Appendix A: Parameter File Processing Settings for 2 kHz and Low-

Frequency Datasets section for important information about how to set up your parameter file depending on the sampling rate of your data.

The following directions explain how to process your dataset with the LFDCS to produce the specaudio and lfdcs pitch track output.

1. From the LFDCS App Launcher, click on the "PROCESS: Reformat, Detect, and Classify" button. This popup window will appear:

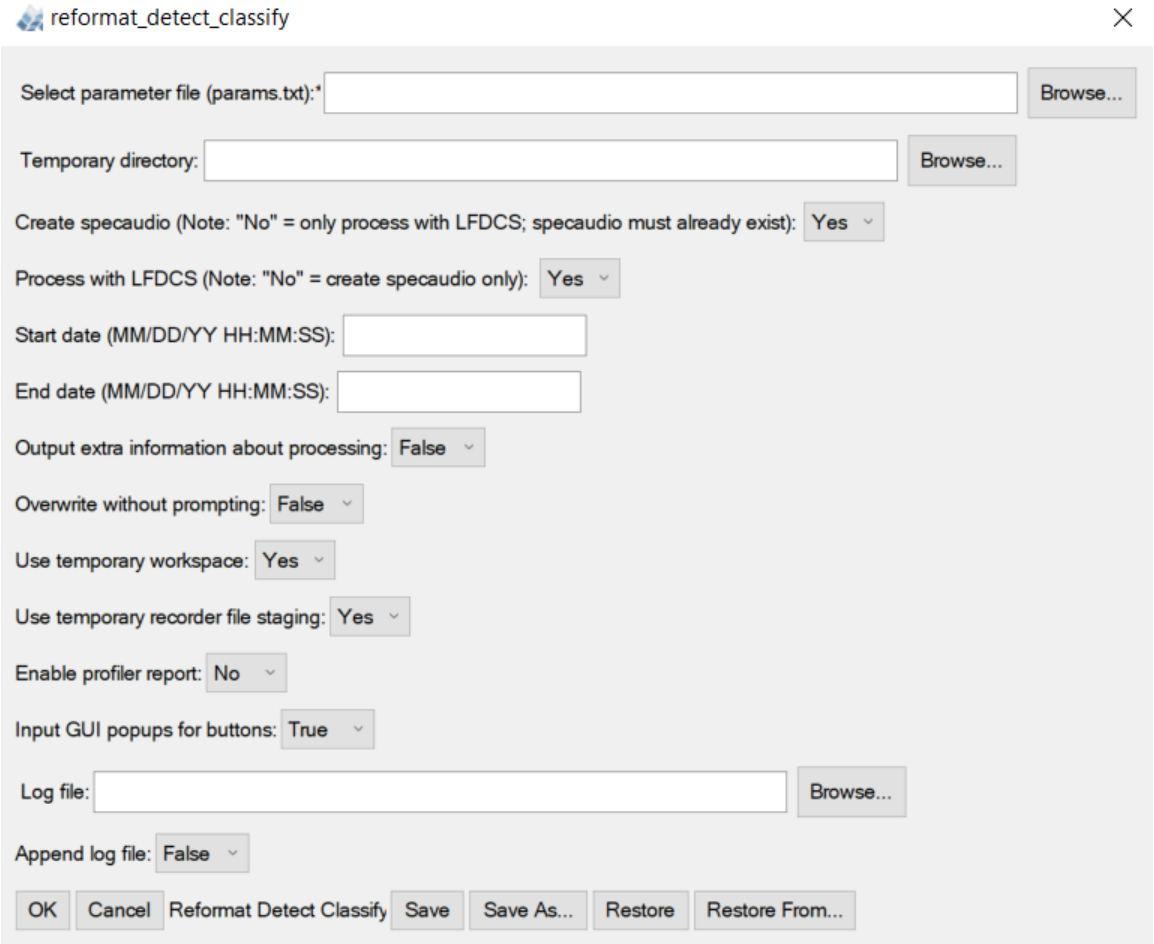


Figure 48. The reformat_detect_classify program window where you can select the parameter file you want to use to process your data.

2. Use the definitions below to help you fill in the fields of the reformat_detect_classify window (fields with an asterisk are required). When you are done filling out the fields, click "OK".

    - Select parameter file (params.txt)*

        Use the "Browse…" button to select the parameter file that you have already edited with the desired settings for processing your dataset.

    - Temporary directory

If you are processing multiple deployments at once, selected unique directories in this field each time you start your processing (this is to prevent the processing from writing to the same set of files for multiple deployments).

- Create specaudio (Note: "No" = only process with LFDCS; specaudio must already exist)

  Select "Yes" if you want to process your dataset so that both the lfdcs and specaudio files are created (e.g., if you are processing a new dataset). Select "No" if you only want to reproduce the lfdcs files with the pitch track data and not reproduce the specaudio files (this option only works if you have previously processed the specaudio).

- Process with LFDCS (Note: "No" = create specaudio only)

  Select "Yes" if you want to process your dataset so that both the lfdcs and specaudio files are created. Select "No" if you only want to reproduce the specaudio spectrogram images and not reproduce the lfdcs files with the pitch track data.

- Start date (MM/DD/YY HH:MM:SS)

  Enter the date/time in your dataset where you want to start processing the data (e.g., 02/01/10 00:00:00; can leave this blank if you want to process the whole dataset starting at the date/time specified in your parameter file).

- End date (MM/DD/YY HH:MM:SS)

  Enter the date/time in your dataset where you want to stop processing the data (e.g., 02/15/10 00:00:00; can leave this blank if you want to process the whole dataset starting at the date/time specified in your parameter file).

- Output extra information about processing

  Select "True" to output additional information in the log window as your data is processing (not essential and may slow down your processing slightly, it is recommended to leave this set as "False").

- Overwrite without prompting

  Select "True" if you want to process your data and overwrite an existing lfdcs folder in the same directory. If "False" is selected and an lfdcs folder already exists in your selected directory for the new processing job, you will be warned that it is there and the program will ask you if you would like to proceed. If there is a specaudio folder in the same directory it will

not warn you about overwriting, it will just automatically overwrite it.

- Use temporary workspace

  Select “Yes” to increase the processing speed, but you need to have enough storage space available in your temporary workspace. If you receive an error then switch back to “No”.

- Use temporary recorder file staging

  Select “Yes” to increase the processing speed depending on where your files are stored (i.e., on a server). This also requires enough disk space where the processing is taking place. If you receive an error then switch back to “No”. Depending on your setup, selecting “Yes” may actually slow down your processing.

- Enable profiler report

  Select “Yes” if you would like to output information about how fast different parts of the code ran during your processing (may slow down processing slightly).

- Input GUI popups for buttons

  Select “True” to have any prompts or questions appear as separate popup windows. If “False” is selected, then you may need to navigate back to your terminal window to answer any program prompts.

3. A new window will appear where you can confirm that you want to convert your files to NetCDF files (your original audio files will not be impacted). Click “Yes” and the LFDCS will start processing your data. You can use the “Previous page”, “Next page”, or “Show all” buttons at the bottom of the LFDCS output log window to view the processed files.

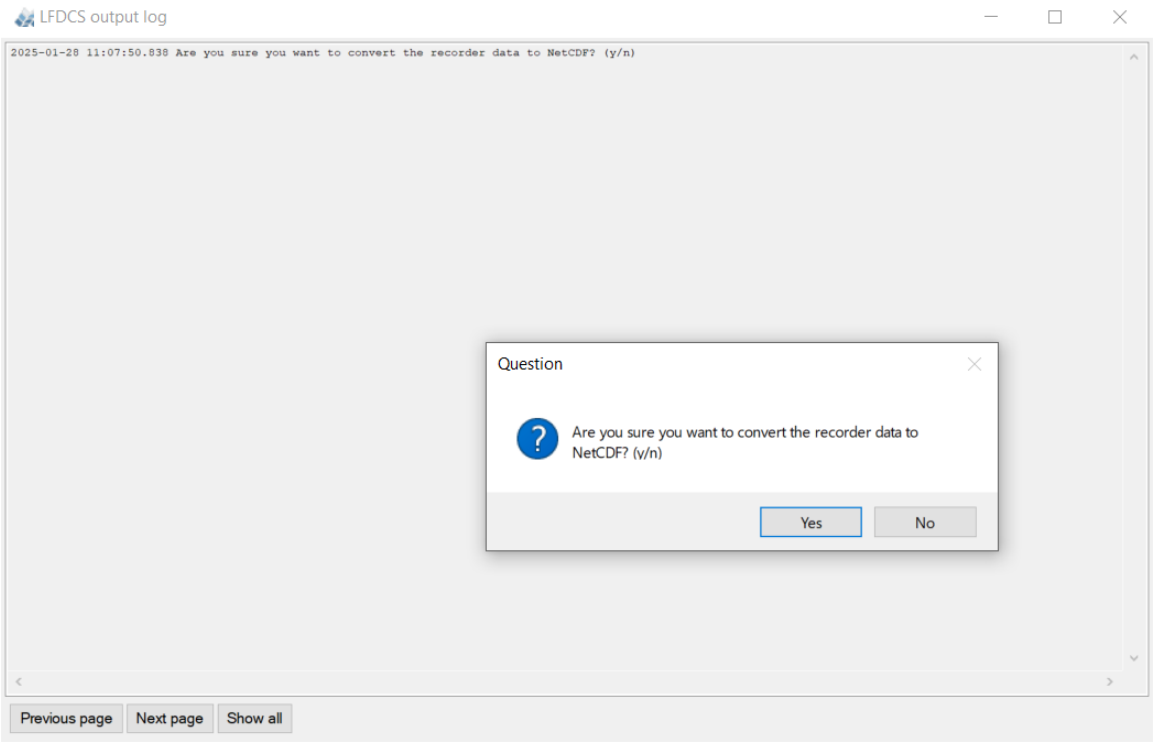


Figure 49. The window asking if you are sure you want to convert your recorder data to NetCDF files.

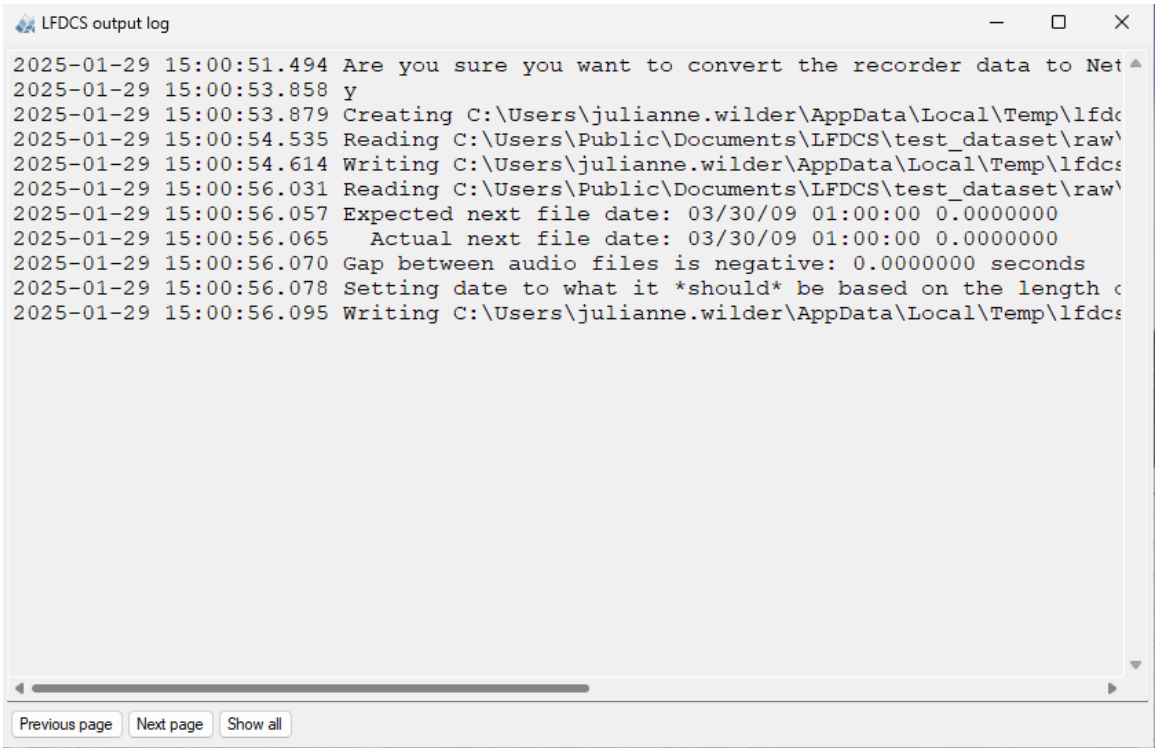


Figure 50. The LFDCS output log window showing the progress of the files as they are being processed.

4. After your data has finished processing, a message reading “LFDCS processing completed!” and a summary of the time elapsed during processing will appear in the LFDCS output log window. You can close out of the window and navigate to where you directed the processed data to output to in your parameter file to check that both the lfdcs and specaudio files were generated correctly.

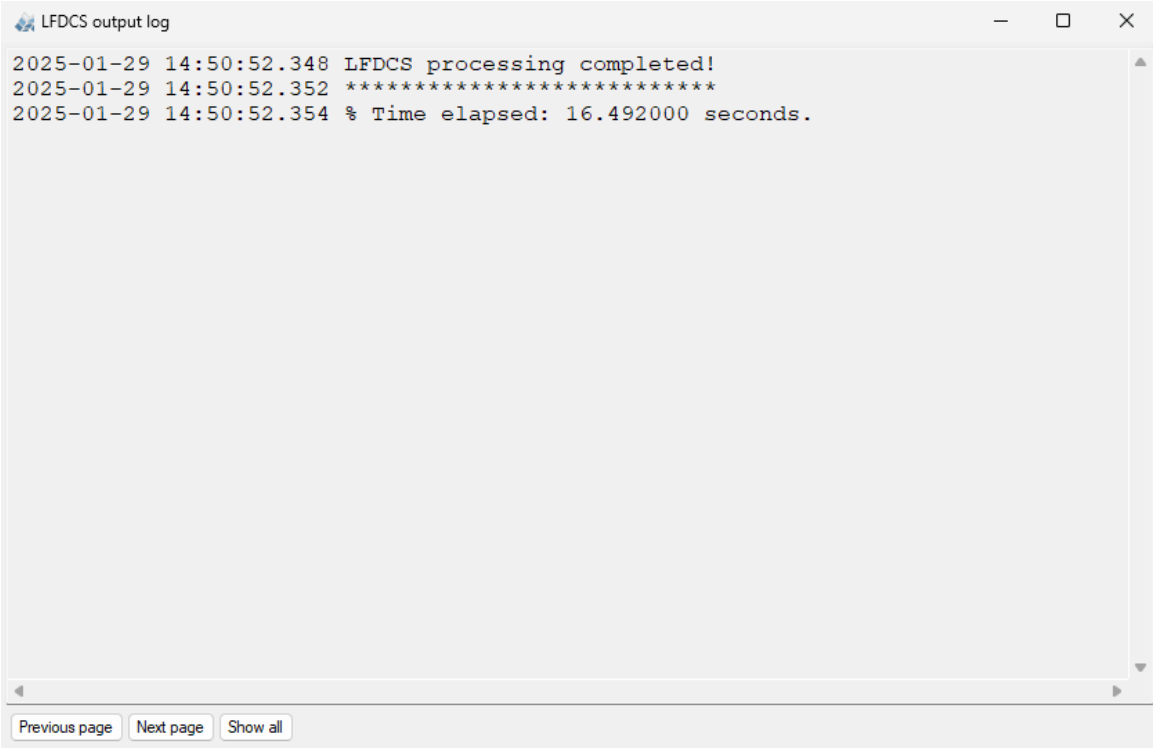


Figure 51. The LFDCS output log window showing the post-processing completion message.

Reclassifying Autodetections

PROCESS: Reclassify Autodetections

The following directions explain how to reclassify a processed dataset with a different call library. This may be needed if a new call library was created, or additional call types of a call library were created, and you wish to reclassify the pitch tracks to the new/different call library. This will overwrite your current lfdcs folder; however, please see the note below about classified pitch tracks. It is always a good idea to save a backup copy of your previous lfdcs folder in case you wish to compare or maintain previous analyses.

Note: If you already analyzed a dataset and marked detections as “correct,” “incorrect,” or “unknown,” the pitch tracks keep this marking even if their call type changes when reclassifying to a different call library. To erase and overwrite call classifications, you can reprocess the datasets using the reformat_detect_classify program (with the “Create specaudio” dropdown menu set to “No”) with a parameter file directing to the new call library and it will skip the process that writes the specaudio. In the parameter file, you will also want to change the parameters to direct to the specaudio to reflect the specaudio files, not the original audio files.

1. From the LFDCS App Launcher, click on the "PROCESS: Reclassify Autodetections" button. This popup window will appear:

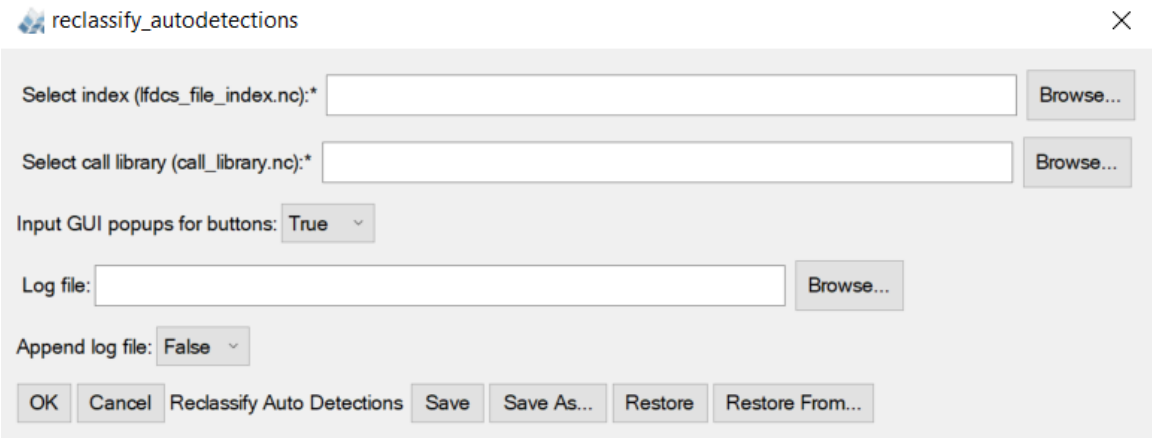


Figure 52. The reclassify_autodetections program window where you can select the LFDCS file index for the dataset you want to reprocess and a new call library file.

2. Use the definitions below to help you fill in the fields of the reclassify_autodetections window (fields with an asterisk are required). When you are done filling out the fields, click "OK".

    - Select index (lfdcs_file_index.nc)*

        Use the "Browse…" button to select the "lfdcs_file_index.nc" file from the processed\lfdcs folder of your previously processed dataset that you are reprocessing with a new call library.

    - Select call library (call_library.nc)*

        Use the "Browse…" button to select the "call_library.nc" file (e.g., "call_library_gom9.nc") from the call library folder (e.g, "clnb_gom9") for the new call library that you want to use to reprocess your data.

3. After your data has finished processing, a message reading "LFDCS reclassification completed!" will appear in the LFDCS output log window. You can close out of the window once it is complete.

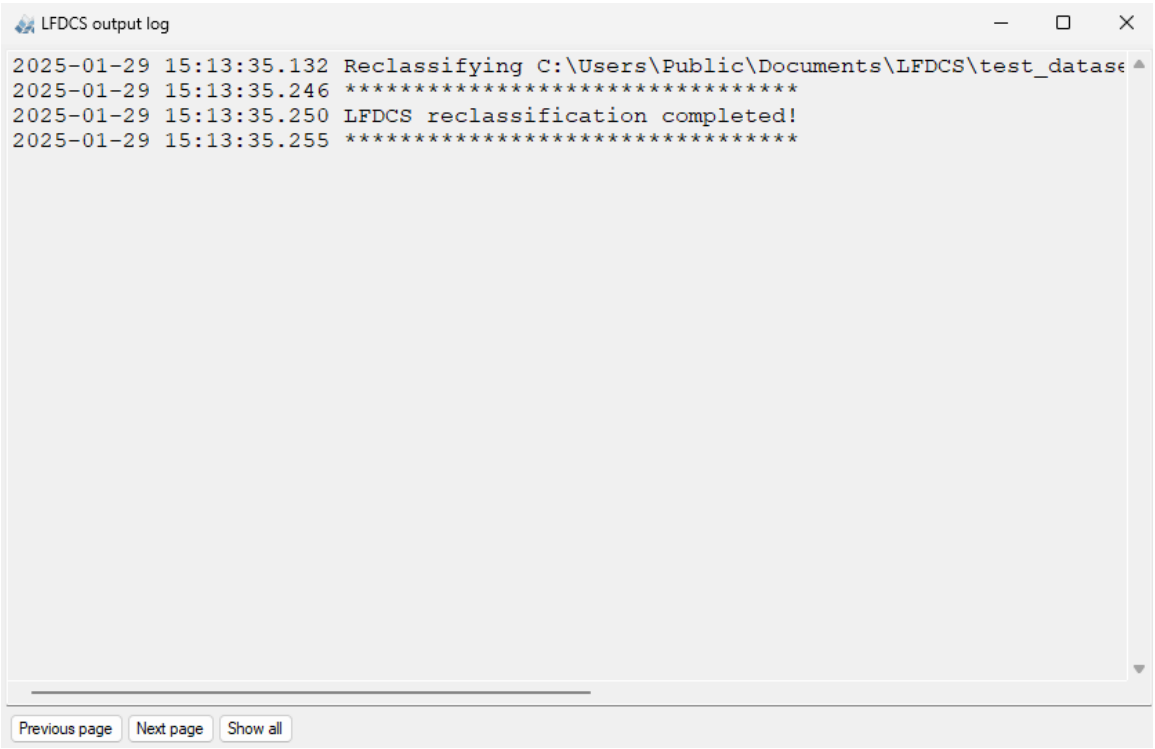


Figure 53. The LFDCS output log window showing the post-processing completion message.

Data Review

This section includes instructions for how to manually review raw data and browse the automated detections (i.e., autodetections) in data that have been processed using the LFDCS.

Manually Reviewing Data

REVIEW: Manual Detections

The following directions explain how to open LFDCS to view the spectrograms from the specaudio data without the processed autodetections/pitch tracks.

You can specify species buttons, so as you are viewing data, you can log calls by boxing them (by clicking on the spectrogram where you want the top left corner and bottom right corner of your box) and assign them to a species, which you can later export. The species and codes can be found in the Manual Species Codes table (Table 1). The Species Code value is what you can specify in the "Manual species list" field of the manual_detections program window. We have added Incorrect, Correct, Unknown, and Unclassified values in the Species Code column to allow for a Correct/Incorrect/Unknown manual analysis scoring (this is the method used in Northeast Fisheries Science Center daily presence analyses). Likewise, the Manual Species Codes table also has Call Type Code values that you can specify in the "Manual call types list" field of the manual_detections program window, which can provide further buttons based on species-specific call types if you are interested in that level of detail and scoring. For every call type specified, there should be the associated species code.

Table 1. Manual species codes.

Species	Species Code	Call Type	Call Type Code
Unknown	0		-32767
Blue whale	1		-32767
Fin whale	2		-32767
Fin whale	2	20-Hz pulse	1
Sei whale	3		-32767
Bryde's whale	4		-32767
Minke whale	5		-32767
Gray whale	6		-32767
NA right whale	7		-32767
NA right whale	7	up call	1

Species	Species Code	Call Type	Call Type Code
NA right whale	7	moan	2
NA right whale	7	gunshot	3
NP right whale	8		-32767
Southern right whale	9		-32767
Humpback whale	10		-32767
Bowhead whale	11		-32767
Beluga whale	12		-32767
Killer whale	13		-32767
Walrus	50		-32767
Bearded seal	51		-32767
Air gun	97		-32767
Unknown type B	98		-32767
Unknown type A	99		-32767
Correct	9999		-32767
Incorrect	-9999		-32767
Unclassified	-32767		-32767

1. From the LFDCS App Launcher, click on the “REVIEW: Manual Detections” button. This popup window will appear:

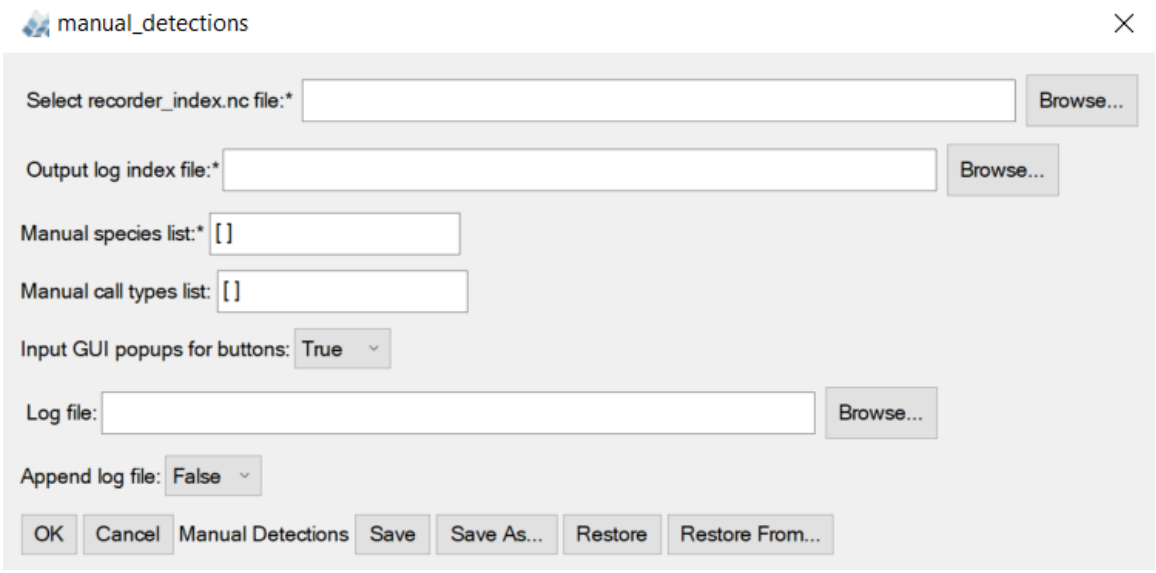


Figure 54. The manual_detections program window where you can select the LFDCS recorder and log indices for the dataset you want to manually browse.

2. Use the definitions below to help you fill in the fields of the manual_detections window (fields with an asterisk are required). When you are done filling out the fields, click "OK".

    - Select recorder_index.nc file*

        Use the "Browse…" button to select the "recorder_index.nc" file from the processed\specaudio folder of your previously processed dataset that you are wanting to manually browse.

    - Output log index file*

        Use the "Browse…" button to select where you would like your log index file with your manual selections data to be saved.

    - Manual species list*

        Enter the species code values (Table 1) that will appear as classification buttons to allow for manual classification of species (e.g., [7] as 7 is the code for North Atlantic right whale OR [9999,-9999,0,-32767] which are the 4 code values for the "Correct," "Incorrect," "Unknown," and "Unclassified" buttons, respectively, that you can use instead of species buttons).

    - Manual call types list

        To enter call type code values (Table 1) within a given species category that will appear as classification buttons (e.g., "Manual call types list: [1,2,3]"

if you want buttons for North Atlantic right whale upcalls [1], moans [2], and gunshots [3]). If no call type is needed (i.e., you are only identifying species or correct/incorrect), you can omit this command.

Note: If you do specify call types, you will need to list the species codes in the "Manual species list" field in the same order and as many times as their corresponding call types are listed in the "Manual call types list" field (e.g., "Manual species list: [7,7,7]" to be able to generate the classification buttons for North Atlantic right whale upcalls, moans, and gunshots (Fig. 55).

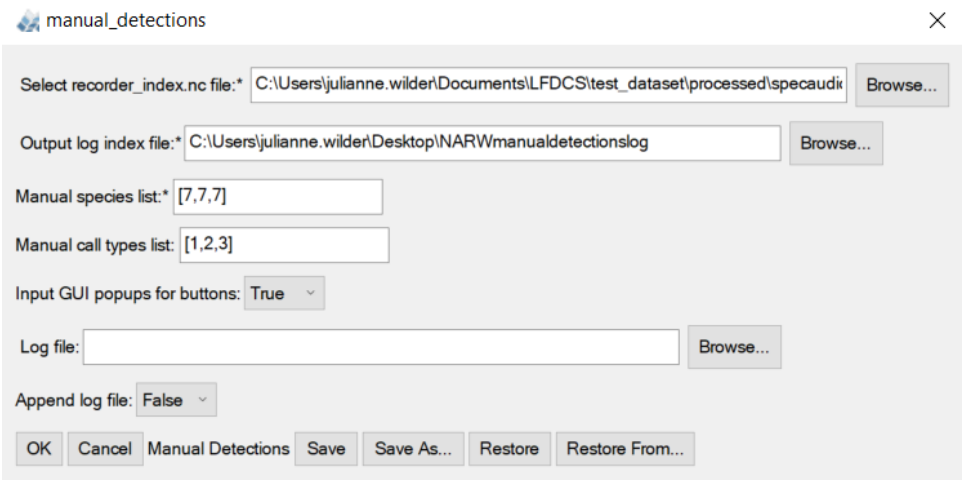


Figure 55. An example of the manual_detections program window with the "Manual species list" and "Manual call types list" fields populated to be able to generate classification buttons for North Atlantic right whale (species code=7) upcalls, moans, and gunshot call types (call type codes=1,2,3).

3. After you click "OK", a browsing window will appear showing a spectrogram with buttons on either side. Use the definitions below to navigate the buttons and features of the browsing window.

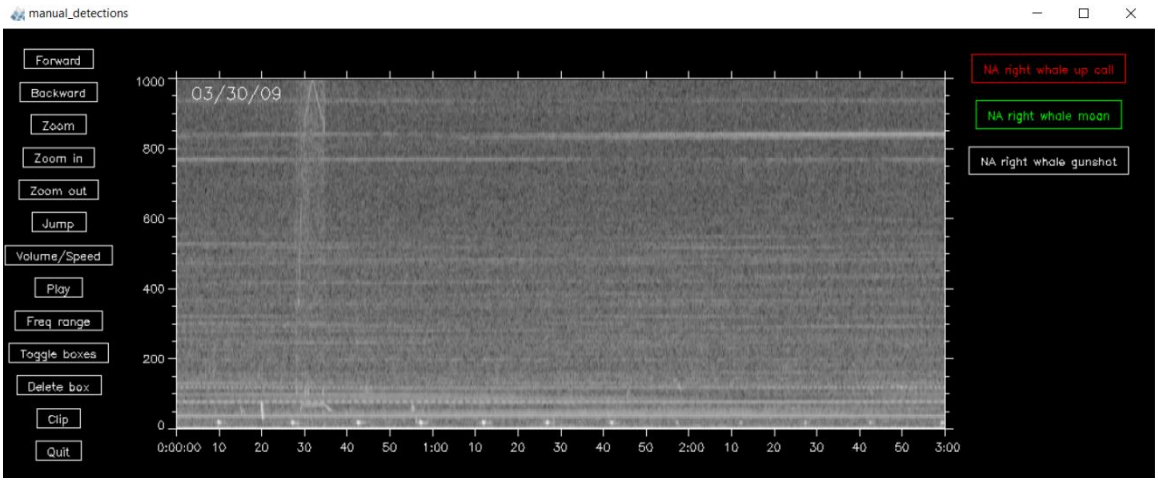


Figure 56. The manual_detections browsing window showing the full audio data without the autodetections/pitch tracks overlaid on the spectrogram. The spectrogram axes are frequency (Hz) over time (hh:mm:ss). The buttons on the right side of the window should correspond to the "Manual species list" and "Manual call types list" values you entered in the manual_detections program window prior to running the program (this window shows the output if you entered the same values as shown in Fig. 55).

- Scroll forward (not a visible button in Fig. 56):

  Click on the black background (or hover cursor over the spectrogram window and scroll to) anywhere on the right side of the window to scroll forward in the data.

- Scroll backward (not a visible button in Fig. 56):

  Click on the black background (or hover cursor over the spectrogram window and scroll to) anywhere on the left side of the window to scroll backward in the data.

- Page forward

  Click on (or hover cursor over button and scroll to) the "Page forward" button to move forward to the next section (new window) of the spectrogram.

- Page backward

  Moves back to the previous section of the spectrogram.

- Zoom in

  Zooms in on the time (x) axis.

- Zoom out

  Zooms out on the time (x) axis.

- Jump

  Jumps to the specified section of the spectrogram/audio file. After clicking, a small popup window will appear (Fig. 57) and you can enter the desired date and time in the MM/DD/YY HH:MM:SS format (e.g., 01/29/16 04:13:58).

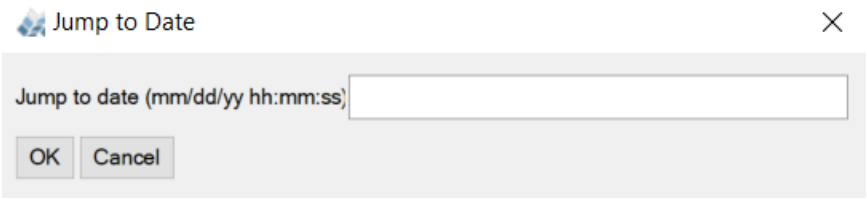


Figure 57. The Jump to Date popup window where you can enter a date and time to jump to in your dataset.

- Volume/Speed

  Adjusts volume and playback speed of audio file. After clicking, a small popup window will appear (Fig. 58) and you can enter the desired volume and speed. Default values are both 1 whenever a processed deployment is opened from the terminal.

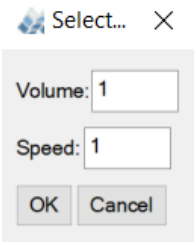


Figure 58. The Select Volume and Speed popup window where you can adjust your amplitude and audio speed settings.

- Play

  Plays a clip selected by the analyst. After clicking, click a point on the spectrogram where you want the playback to start, then click a point on the spectrogram where playback should end. The selected audio range will start playing automatically. If you have already created selection boxes around sounds, you can click “Play” then click inside a box and it will play only the sounds in the box.

  Note: If a click is made anywhere on the black background before or after the spectrogram, it will be included in the playback.

- Freq range

  Adjusts the maximum frequency range (y-axis) of the viewing window. After clicking, a small popup window will appear (Fig. 59) and you can enter the desired maximum frequency in Hz. The minimum frequency will remain 0 Hz.

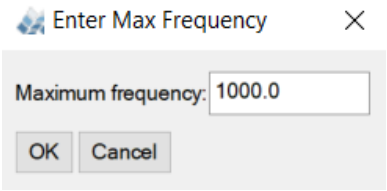


Figure 59. The Enter Max Frequency popup window where you can adjust the maximum frequency of your spectrogram.

- Toggle boxes

  Hides any boxes that you have created around sounds in the dataset to reveal the raw spectrogram image (this is convenient especially when you have already boxed a large number of calls and the boxes are obscuring the spectrogram). Click the button again to show the boxes.

  To create a box around a call or sound, click on the spectrogram where you want the top left corner and bottom right corner (or visa versa) of your box.

- Delete box

  Delete any box you have created by clicking on the spectrogram anywhere above and to the left of your box, and then below and to the right of your box (i.e., essentially clicking "around" the existing box to delete it).

- Clip

  Creates a clip selected by the analyst and saves it as a *.wav file to the computer. After clicking the button, click a point on the spectrogram where the sound clip should start, then click a point on the spectrogram where the sound clip should end. After selecting your clip, a small popup window will appear (Fig. 60) and you can select whether you want to save the clip with the normal (i.e., default of 1) or previously selected playback volume and speed. There is also a text field where you can enter the file name and you can click the "Browse…" button to select where you would like to save the file (if you don't select a location, the clip will automatically save to your process folder). Once the file name has been entered, click "OK" and navigate to where you saved your clip.



Figure 60. The Save WAV file popup window where you can select the audio volume/speed, name your clip, and save it to the desired location.

- Quit

  Quits the LFDCS program, allowing the analyst to close out of the browsing window. Use this button to properly exit the program.

Viewing/Browsing Automated Detections

REVIEW: Browse Autodetections

The following directions explain how to open a dataset in LFDCS that has already been processed through the detector with a specific call library. The browse_autodetections program can be used to view the spectrogram and pitch tracks of sounds that have been detected and classified by the LFDCS for specific call types (based on a specified call library) and score detections as "correct," "incorrect," and "unknown."

If you would like to manually classify autodetections, set the "Classify" field in the browse_autodetections program window to "True" and specify which species and call types you intend to classify using the "Manual species list" and "Manual call type list" fields of the window (e.g., Manual species list (buttons to display): [1,2,3], Manual call types list (buttons to display): [-32767,1,-32767]). This will provide a list of species on the right side of the display that an analyst can use to manually identify which species produced the call. This is used to evaluate the performance of the LFDCS or to manually reduce the false detection rate. See Table 1 in the previous section for default values. If no call type is needed (i.e., you are only identifying if the detection is correct, incorrect, or unknown), you can use "Manual species list (buttons to display): [9999,-9999,0,-32767]".

1. From the LFDCS App Launcher, click on the "REVIEW: Browse Autodetections" button. This popup window will appear:

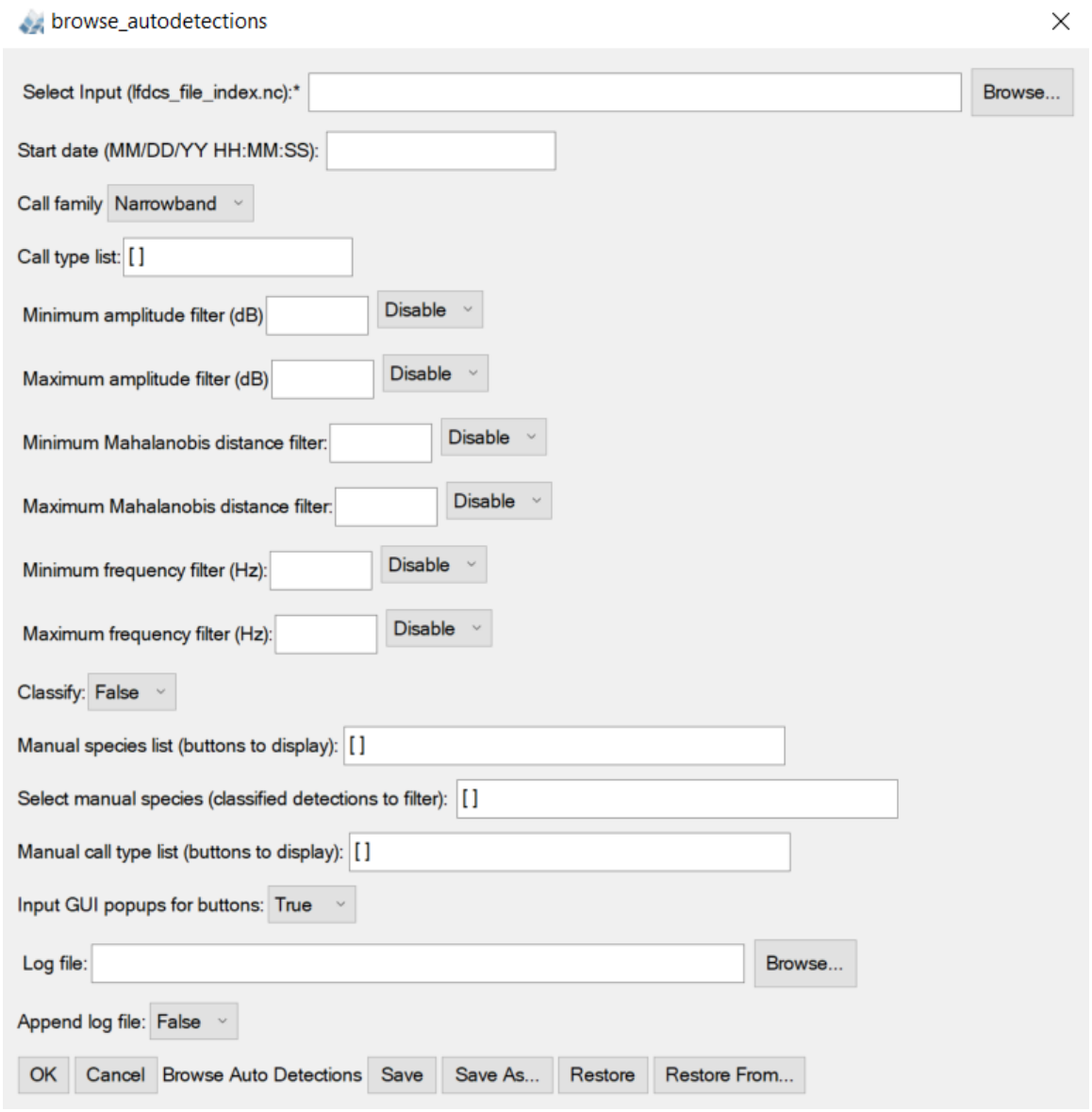


Figure 61. The browse_autodetections program window where you can select the LFDCS file index of the dataset you want to view.

2. Use the definitions below to help you fill in the fields of the browse_autodetections window (fields with an asterisk are required). When you are done filling out the fields, click "OK".

   Note: In the supplemental\program_presets folder that was unpacked from the distribution file when you originally installed the LFDCS, you will find preset files with the settings for browsing the autodetections for different baleen whale species (e.g., browse_autodetections_NARW). To use these, simply click the "Restore From…" button at the bottom of the program window and navigate to that folder to select the presets you want to use.

- Select Input (lfdcs_file_index.nc)*

  Use the "Browse…" button to select the "lfdcs_file_index.nc" file from the processed\lfdcs folder of your previously processed dataset that you want to open to view the autodetections.

- Start date (MM/DD/YY HH:MM:SS)

  Enter the date/time in your dataset where you want to start viewing the autodetections in the data (e.g., 02/01/10 00:00:00; can leave this blank if you want to view the whole dataset from the beginning).

- Call family

  Select "Narrowband" from the dropdown menu to view all autodetections in the *narrowband call family.

  *The LFDCS has the capacity to process broadband data, but it is still under development and not yet functional with the software.

- Call type list

  Enter the call type number(s) to view all autodetections of a particular call type (e.g., [1, 2, 3]).

- Minimum amplitude filter (dB)

  Enter a minimum amplitude threshold to view all autodetections with amplitudes greater than or equal to that value (in dB above background noise; e.g., 12).

- Maximum amplitude filter (dB)

  Enter a maximum amplitude threshold to view all autodetections with amplitudes less than or equal to that value (in dB above background noise; e.g., 20).

- Minimum Mahalanobis distance filter

  Enter a minimum Mahalanobis distance threshold to view all autodetections with a Mahalanobis distance greater than or equal to that value (e.g., 1.0).

- Maximum Mahalanobis distance filter

Enter a maximum Mahalanobis distance threshold to view all autodetections with a Mahalanobis distance less than or equal to that value (e.g., 3.0).

- Minimum frequency filter (Hz)

  Enter a minimum frequency threshold to view all autodetections with frequencies greater than or equal to that value (e.g., 200).

- Maximum frequency filter (Hz)

  Enter a maximum frequency threshold to view all autodetections with frequencies less than or equal to that value (e.g., 800).

- Classify

  Select "True" to enable the generation of the classification buttons to be able to manually classify each autodetection.

- Manual species list (buttons to display)

  Enter the species code values (Table 1) that will appear as classification buttons to allow for manual classification of species (e.g., [7] as 7 is the code for North Atlantic right whale OR [9999,-9999,0,-32767] which are the 4 code values for the "Correct," "Incorrect," "Unknown," and "Unclassified" buttons, respectively, that you can use instead of species buttons).

- Select manual species (classified detections to filter)

  Enter the species codes (Table 1) for the species that you want to filter previously analyzed manual detections for (e.g., [2,3] if you only want to view the detections that you classified as fin [2] or sei [3] whale).

  You can also use this field if you have already analyzed a dataset and want to browse through detections that you have only marked "Correct" or "Unknown" (e.g., [9999, 0]). Note: Entering only zero (e.g., [0]) may give you an error and you will need to list a second species code.

- Manual call type list (buttons to display)

  To enter call type code values (Table 1) within a given species category that will appear as classification buttons (e.g., "Manual call types list: [1,2,3]" if you want buttons for North Atlantic right whale upcalls [1], moans [2], and gunshots [3]). If no call type is needed (i.e., you are only identifying species or correct/incorrect), you can omit this command.

Note: If you do specify call types, you will need to list the species codes in the "Manual species list" field in the same order and as many times as their corresponding call types are listed in the "Manual call types list" field (e.g., "Manual species list: [7,7,7]" to be able to generate the classification buttons for North Atlantic right whale upcalls, moans, and gunshots (see Fig. 55 for an example of how to fill out these two fields).

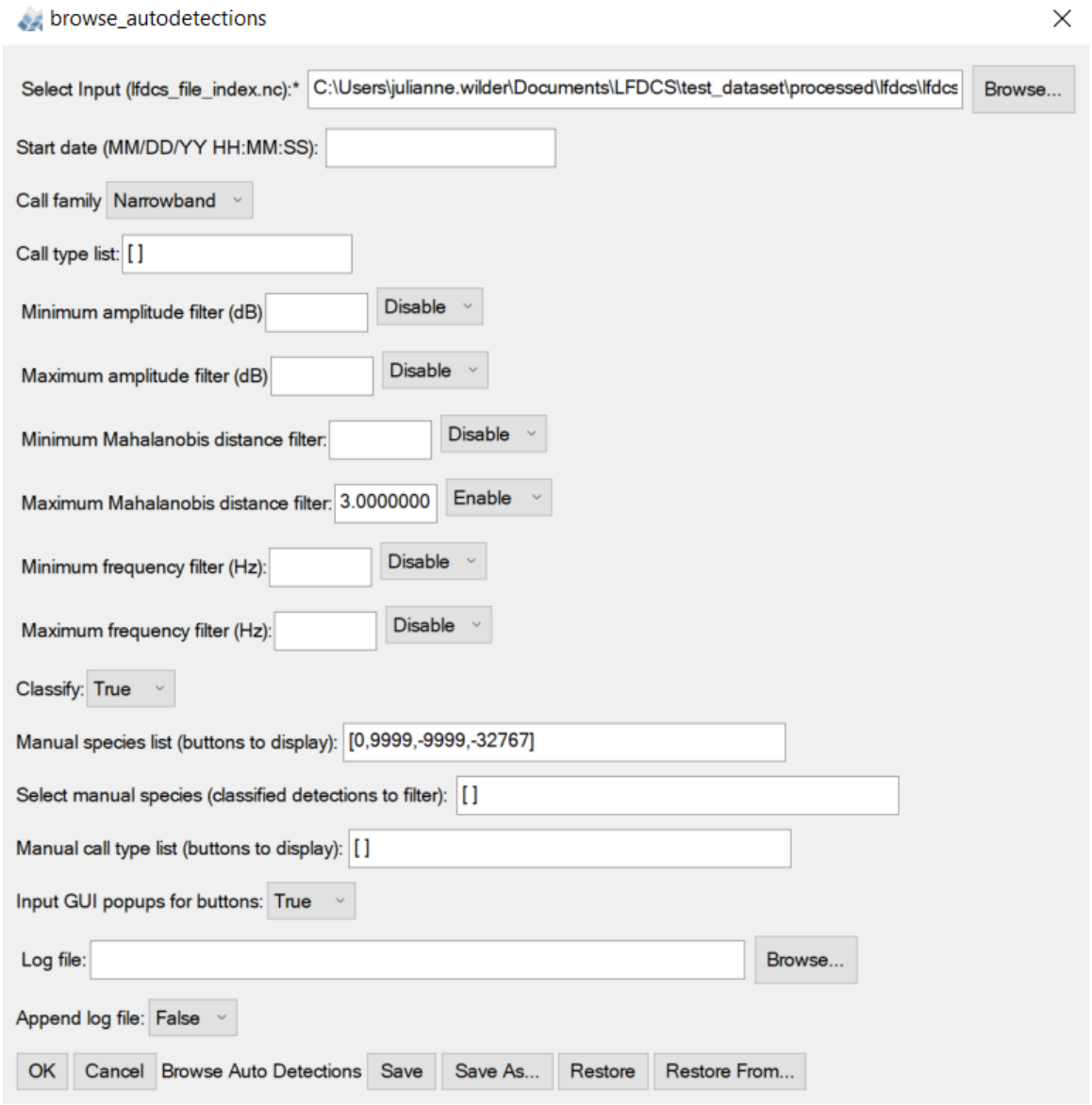


Figure 62. An example of when the browse_autodetections program window is filled out so that when the browsing window opens it will only show pitch tracks with a Mahalanobis distance of 3 or less and "Unknown", "Correct", "Incorrect", and "Unclassified" buttons (i.e., Manual species list (buttons to display): [0, 9999, -9999, -32767]) for classifying the pitch tracks during analysis.

3. After you click “OK”, a browsing window will appear showing a spectrogram with buttons on either side. Use the definitions below to navigate the buttons and features of the browsing window.

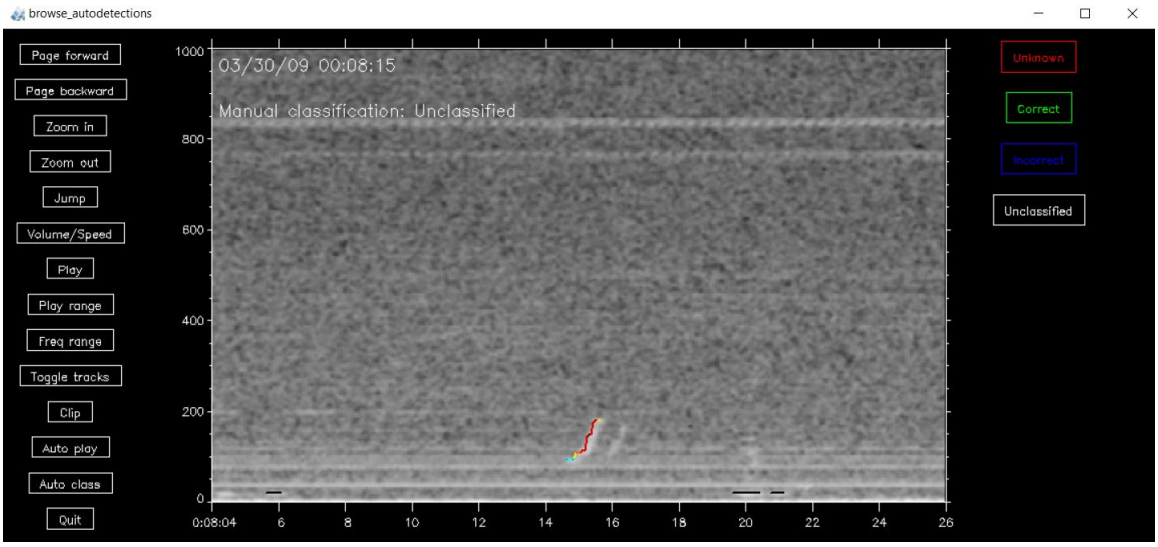


Figure 63. The browse_autodetections browsing window showing a pitch tracked North Atlantic right whale upcall in red (color is indicative of amplitude; the black horizontal lines near the bottom of the spectrogram are also pitch tracks but only the currently selected pitch track will show in color). The spectrogram axes are frequency (Hz) over time (hh:mm:ss). This image and the following descriptions explain the basic functions available when browsing the processed autodetections/pitch tracks. The buttons along the left side of the window are standard in most LFDCS programs; the buttons along the right side of the window are specific to the browse_autodetections program.

Tip: Hover cursor over any button in the LFDCS window and scroll forward or back to select that button. This function can be used (rather than repeatedly clicking the mouse or touchpad on the computer) to scroll or page through the detections more easily. Note: Hovering over a classification button (e.g., “Correct,” “Incorrect,” “Unknown,” or “Unclassified”) marks the detections based on the button you are hovering over (i.e., an easy way to scroll through a lot of false detections if you hover over the “Incorrect” button). However, it is easy for the cursor to fall slightly off the button when scrolling. It is good practice to go backwards and verify that detections are being marked, or not marked, how you intend them to be.

- Select next detection/pitch track (not a visible button in Fig. 63):

  Click on the black background (or hover cursor over the spectrogram window and scroll to) anywhere on the right side of the window to navigate to the next automated detection (pitch track).

- Select previous detection/pitch track (not a visible button in Fig. 63):

Click on the black background (or hover cursor over the spectrogram window and scroll to) anywhere on the left side of the window to navigate to the next automated detection (pitch track).

- Page forward

  Click on (or hover cursor over button and scroll to) the "Page forward" button to move forward to the next section (new window) of the spectrogram that has detections. This allows the analyst to scroll through detections more quickly on a viewing window basis rather than clicking through each individual pitch track.

- Page backward

  Moves back to the previous section of the spectrogram that has detections.

- Zoom in

  Zooms in on the selected pitch track on the time (x) axis.

- Zoom out

  Zooms out from the selected pitch track on the time (x) axis.

- Jump

  Jumps to the specified section of the spectrogram/audio file. After clicking, a small popup window will appear (Fig. 64) and you can enter the desired date and time in the MM/DD/YY HH:MM:SS format (e.g., 01/29/16 04:13:58).

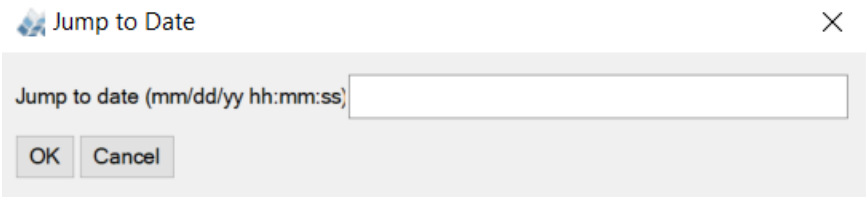


Figure 64. The Jump to Date popup window where you can enter a date and time to jump to in your dataset.

- Volume/Speed

  Adjusts volume and playback speed of audio file. After clicking, a small popup window will appear (Fig. 65) and you can enter the desired volume and speed. Default values are both 1 whenever a processed deployment is opened from the terminal.

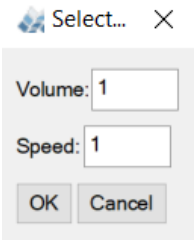


Figure 65. The Select Volume and Speed popup window where you can adjust your amplitude and audio speed settings.

- Play

  Plays a 5-second clip containing the selected detection (at selected volume and speed).

- Play range

  Plays a clip selected by the analyst. After clicking, click a point on the spectrogram where you want the playback to start, then click a point on the spectrogram where playback should end. The selected audio range will start playing automatically.

  Note: If a click is made anywhere on the black background before or after the spectrogram, it will be included in the playback.

- Freq range

  Adjusts the maximum frequency range (y-axis) of the viewing window. After clicking, a small popup window will appear (Fig. 66) and you can enter the desired maximum frequency in Hz. The minimum frequency will remain 0 Hz.

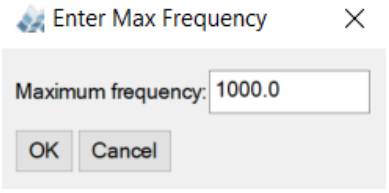


Figure 66. The Enter Max Frequency popup window where you can adjust the maximum frequency of your spectrogram.

- Toggle tracks

  Hides the pitch tracks to reveal the raw spectrogram image (this is convenient especially when determining that a certain pitch track is correctly classifying a sound and is not a false detection). Click the button again to show pitch tracks.

- Clip

  Creates a clip selected by the analyst and saves it as a *.wav file to the computer. After clicking the button, click a point on the spectrogram where the sound clip should start, then click a point on the spectrogram where the sound clip should end. After selecting your clip, a small popup window will appear (Fig. 67) and you can select whether you want to save the clip with the normal (i.e., default of 1) or previously selected playback volume and speed. There is also a text field where you can enter the file name and you can click the "Browse…" button to select where you would like to save the file (if you don't select a location, the clip will automatically save to your process folder). Once the file name has been entered, click "OK" and navigate to where you saved your clip.



Figure 67. The Save WAV file popup window where you can select the audio volume/speed, name your clip, and save it to the desired location.

- Auto play

  Automatically plays a 5-second clip containing each detection as the analyst scrolls through them. Click again to turn autoplay off.

- Auto class

  Displays the call type classification (name and call type number as specified in the call library), Mahalanobis distance, and probability of the detection match to the call type for the selected detection at the top of the spectrogram.

  Example:

  Auto class: Humpback whale downsweep (15), mdist = 2.1, prob = 0.9999

- Quit

  Quits the LFDCS program, allowing the analyst to close out of the browsing window. Use this button to properly exit the program.

- Unknown

  Click (or hover cursor over and scroll) the “Unknown” button on the right side of the browsing window to mark the currently selected pitch track (in color) as unknown for that species/sound source. The program will then automatically move forward to the next autodetection (pitch track).

  Hovering the cursor over the “Unknown” button and scrolling will continue to mark the following pitch tracks as unknown detections until the analyst stops scrolling.

  This button can be used to mark sounds that the analyst is unsure about. This allows the analyst to go back and review Unknown detections easily at a later point.

- Correct

  Click on (or hover cursor over and scroll to) the “Correct” button on the right side of the browsing window to mark the currently selected (in color) pitch track as correct for that species/sound source. The program will then automatically move forward to the next autodetection (pitch track).

  Hovering the cursor over the “Correct” button and scrolling will continue to mark the following pitch tracks as correct detections until the analyst stops scrolling.

- Incorrect

  Click on (or hover cursor over and scroll to) the “Incorrect” button on the right side of the browsing window to mark the currently selected (in color) pitch track as incorrect for that species/sound source. The program will then automatically move forward to the next autodetection (pitch track).

  Hovering the cursor over the “Incorrect” button and scrolling will continue to mark the following pitch tracks as incorrect detections until the analyst stops scrolling.

- Unclassified

  Click on (or hover cursor over and scroll to) the “Unclassified” button on the right side of the browsing window to mark the currently selected (in color) pitch track as unclassified. The program will then automatically move forward to the next autodetection (pitch track).

Hovering the cursor over the “Unclassified” button and scrolling will continue to mark the following pitch tracks as unclassified until the analyst stops scrolling.

This button can be used if the analyst mistakenly marks a pitch track as “Correct,” “Incorrect,” or “Unknown” and wants to go back and reset that pitch track as “Unclassified.” It is the default score that all pitch tracks have prior to being analyzed.

Data Export

This section includes instructions for how to export autodetections, summary sheets, and metadata using the LFDCS.

Exporting Automated Detections

EXPORT: Autodetections

The following directions explain how to export a *.csv file of autodetections and their associated attributes. The exported sheet contains header information for the metadata of the exported deployment and a description of each of the columns. Following the header, there is 1 row of data per detection that falls within the parameters specified (similar to the selection table logs in Raven). The default columns that are included in the exported sheet are: call type, detection start time (as seconds since the start date given in the original parameter file to process the data), detection end time (as seconds since the start date), times of the pitch track, duration (seconds), minimum frequency (in Hz), maximum frequency (in Hz), bandwidth (in Hz), amplitude (dB relative to background), and Mahalanobis distance.

You may use the fields in the export_autodetections program window to specify exactly the kind of calls you want to export (see below). For example, you can specify the call type numbers you want to export (e.g., Call type list: [1, 2, 3]) and any classification provided from the call library.

1. From the LFDCS App Launcher, click on the “EXPORT: Autodetections” button. This popup window will appear:

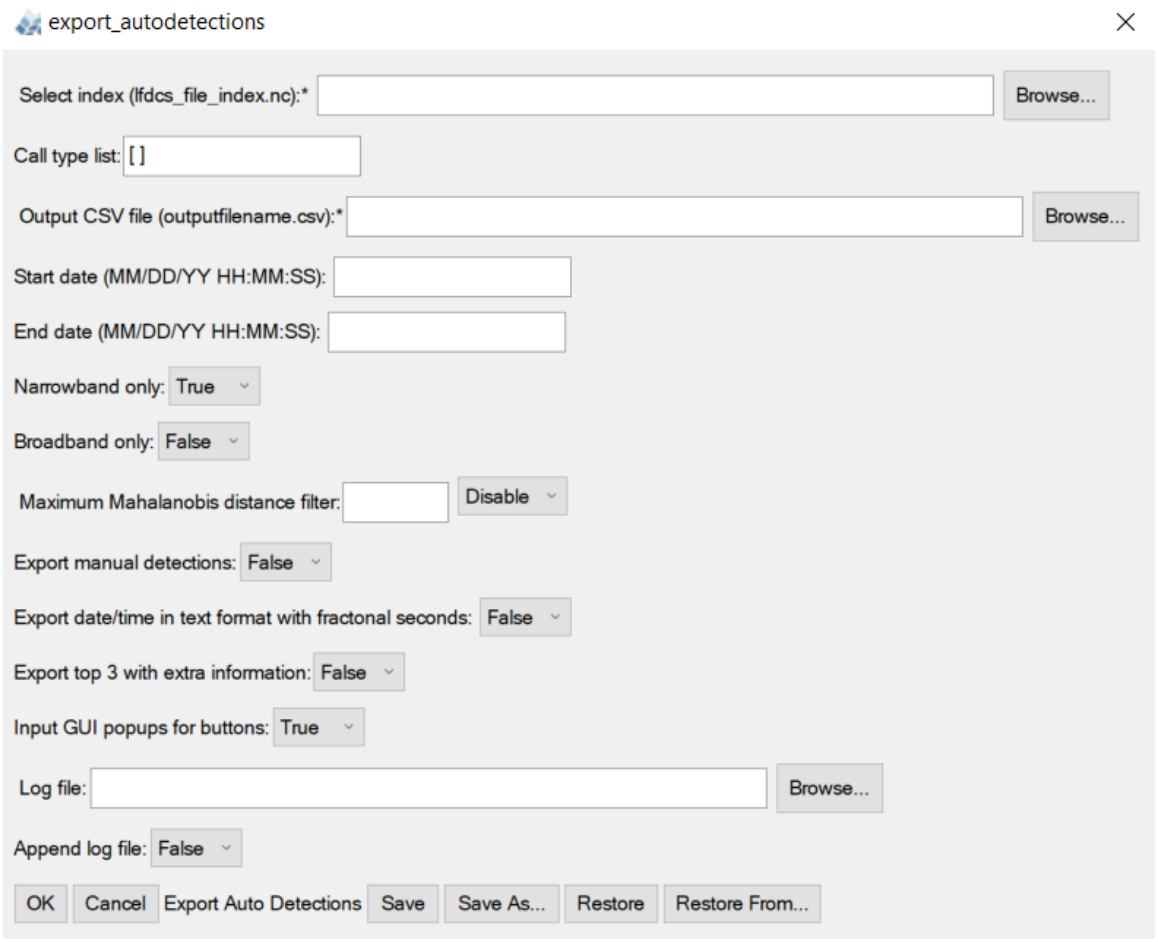


Figure 68. The export_autodetections program window where you can select the LFDCS file index of the dataset you want to export.

2. Use the definitions below to help you fill in the fields of the export_autodetections window (fields with an asterisk are required). When you are done filling out the fields, click "OK".

    - Select index (lfdcs_index_file.nc)*

        Use the "Browse…" button to select the "lfdcs_file_index.nc" file from the processed\lfdcs folder of your previously processed dataset for which you are exporting the autodetections.

    - Call type list

        Enter the call type number(s) to specify particular calls types you would like to export the autodetections for (e.g., [1, 2, 3]).

    - Output CSV file (outputfilename.csv)*

Enter the desired file name for your exported autodetections and click the "Browse…" button to select where you would like to save the file (if you don't select a location, the *.csv file will automatically save to your process folder).

- Start date (MM/DD/YY HH:MM:SS)

  Enter the date/time in your dataset where you want to start exporting the autodetections (e.g., 02/01/10 00:00:00).

- End date (MM/DD/YY HH:MM:SS)

  Enter the date/time in your dataset where you want to stop exporting the autodetections (e.g., 02/15/10 00:00:00).

- Narrowband only

  To export only narrowband autodetections ("True" is the default because the LFDCS has the capacity for, but is not currently developed for broadband detections).

- Broadband only

  To export only broadband autodetections ("False" is the default because the LFDCS has the capacity for, but is not currently developed for broadband detections).

- Maximum Mahalanobis distance filter

  To export all autodetections less than or equal to a specified maximum Mahalanobis distance (e.g., 3.0).

- Export manual detections

  Select "True" to also export associated manual classification information for all automated detections that are exported.

- Export date/time in text format with fractional seconds

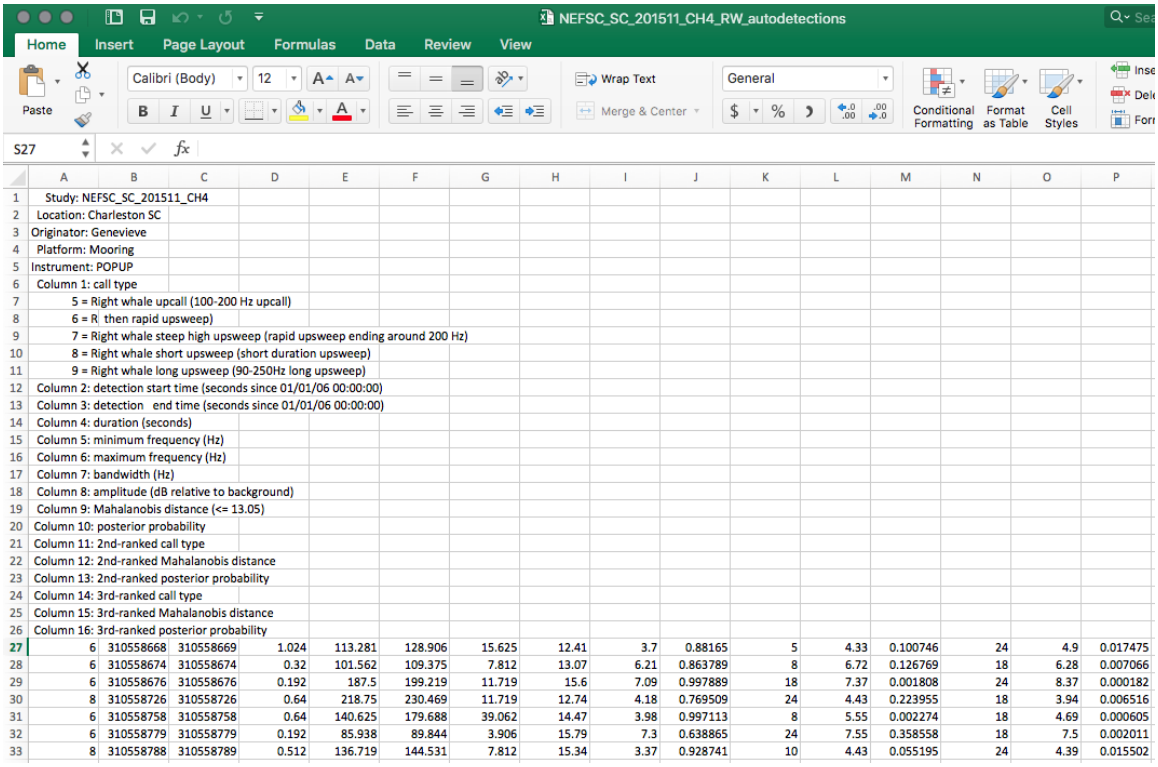
  Select "True" to export date/time in text format with fractional seconds.

- Export top 3 with extra information

  Select "True" to export the top 3 call types; this adds additional columns to the output which give the posterior probability and Mahalanobis distance

for the first 3 call types for that pitch track. If you select “False” you will get just the top (first) call type.

3. After you click “OK”, an LFDCS output log window will appear showing the program’s progress as percentages. When the line with “100%” appears, the export is complete. You can then navigate to the location where you exported your autodetections to find the *.csv file (if you didn’t select a location, the *.csv file will automatically save to your process folder).



	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
1	Study: NEFSC_SC_201511_CH4															
2	Location: Charleston SC															
3	Originator: Genevieve															
4	Platform: Mooring															
5	Instrument: POPUP															
6	Column 1: call type															
7	5 = Right whale upcall (100-200 Hz upcall)															
8	6 = R then rapid upsweep)															
9	7 = Right whale steep high upsweep (rapid upsweep ending around 200 Hz)															
10	8 = Right whale short upsweep (short duration upsweep)															
11	9 = Right whale long upsweep (90-250Hz long upsweep)															
12	Column 2: detection start time (seconds since 01/01/06 00:00:00)															
13	Column 3: detection end time (seconds since 01/01/06 00:00:00)															
14	Column 4: duration (seconds)															
15	Column 5: minimum frequency (Hz)															
16	Column 6: maximum frequency (Hz)															
17	Column 7: bandwidth (Hz)															
18	Column 8: amplitude (dB relative to background)															
19	Column 9: Mahalanobis distance (<= 13.05)															
20	Column 10: posterior probability															
21	Column 11: 2nd-ranked call type															
22	Column 12: 2nd-ranked Mahalanobis distance															
23	Column 13: 2nd-ranked posterior probability															
24	Column 14: 3rd-ranked call type															
25	Column 15: 3rd-ranked Mahalanobis distance															
26	Column 16: 3rd-ranked posterior probability															
27	6	310558668	310558669	1.024	113.281	128.906	15.625	12.41	3.7	0.88165	5	4.33	0.100746	24	4.9	0.017475
28	6	310558674	310558674	0.32	101.562	109.375	7.812	13.07	6.21	0.863789	8	6.72	0.126769	18	6.28	0.007066
29	6	310558676	310558676	0.192	187.5	199.219	11.719	15.6	7.09	0.997889	18	7.37	0.001808	24	8.37	0.000182
30	8	310558726	310558726	0.64	218.75	230.469	11.719	12.74	4.18	0.769509	24	4.43	0.223955	18	3.94	0.006516
31	6	310558758	310558758	0.64	140.625	179.688	39.062	14.47	3.98	0.997113	8	5.55	0.002274	18	4.69	0.000605
32	6	310558779	310558779	0.192	85.938	89.844	3.906	15.79	7.3	0.638865	24	7.55	0.358558	18	7.5	0.002011
33	8	310558788	310558789	0.512	136.719	144.531	7.812	15.34	3.37	0.928741	10	4.43	0.055195	24	4.39	0.015502

Figure 69. Example of resulting *.csv file containing autodetection metadata.

Exporting Summary Sheets of Autodetections

EXPORT: Autodetections Summary

The following directions explain how to export a *.csv file with a summary of the autodetections from a dataset that has been processed by the detector with a specific call library. The resulting *.csv file will include information for the number of each call type detected for each specified time bin and specified parameters of an acoustic deployment. Each exported *.csv file has header information with metadata about the deployment (stored from the original parameter file) and a list describing the column names and contents. The columns are as follows: start date, start time, end date, end time. There is then a column for each call type specified to be included (with the specified parameters, e.g., “Maximum Mahalanobis distance filter: 3”), with a tally for the number of detections in that time bin (between start and end date/times). The last column is a “sum” column, which gives the total number of detections for all of the call types called for.

The *.csv file can then be used as a daily/hourly/etc. “presence sheet” to provide a streamlined way of viewing basic detection summaries and recording analysis results including when species were found to be present, timestamps for positive or possible detections, and notes (see Examples of Daily Presence Sheets section).

1. From the LFDCS App Launcher, click on the “EXPORT: Autodetections Summary” button. This popup window will appear:

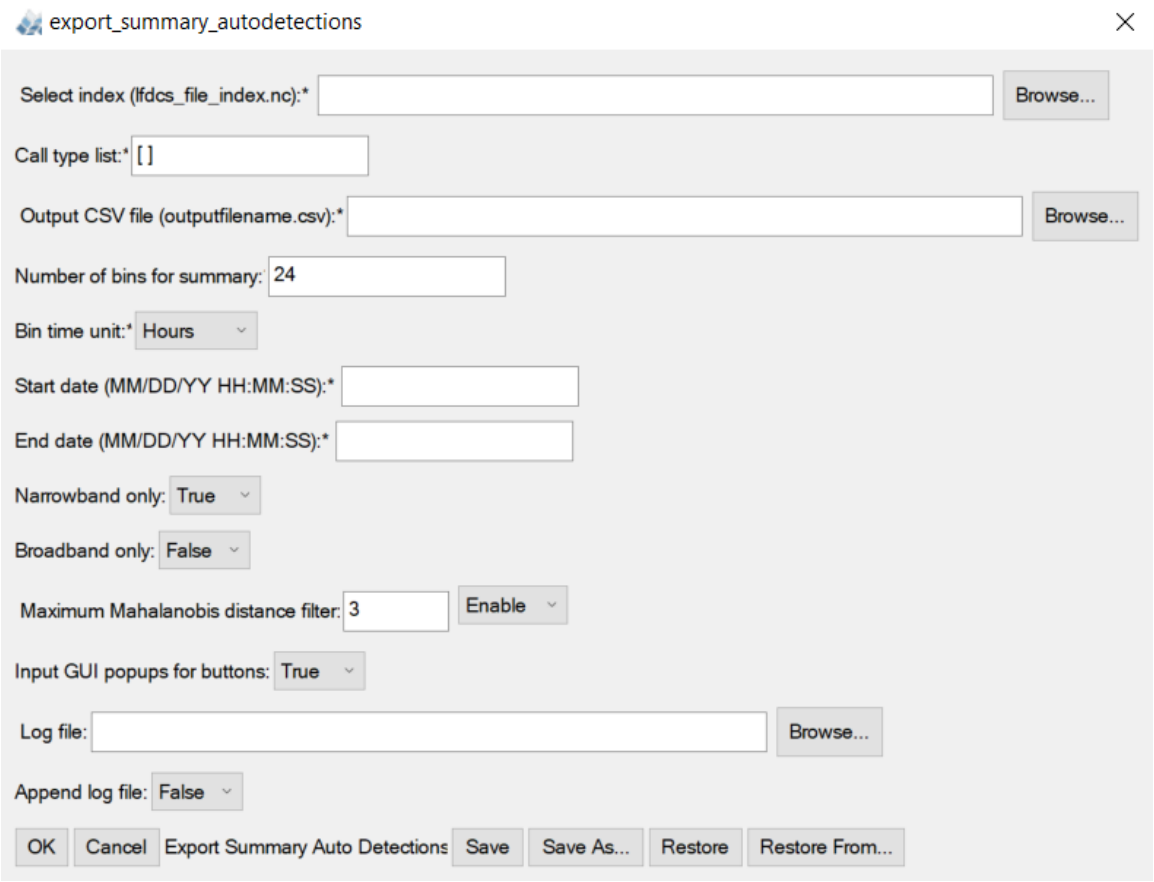


Figure 70. The export_summary_autodetections program window where you can select the LFDCS file index of the dataset you want to export.

2. Use the definitions below to help you fill in the fields of the export_summary_autodetections window (fields with an asterisk are required). When you are done filling out the fields, click “OK”.

   Note: In the supplemental\program_presets folder that was unpacked from the distribution file when you originally installed the LFDCS, you will find preset files with the settings for exporting a summary of the autodetections for different baleen whale species (e.g., export_summary_autodetections_NARW). To use these, simply click the “Restore From…” button at the bottom of the program window and navigate to that folder to select the presets you want to use.

- Select index (lfdcs_index_file.nc)*

  Use the "Browse…" button to select the "lfdcs_file_index.nc" file from the processed\lfdcs folder of your previously processed dataset for which you are exporting the summary of autodetections.

- Call type list*

  Enter the call type number(s) to specify the particular calls types you would like to export the summary of autodetections for (e.g., [1, 2, 3]).

- Output CSV file (outputfilename.csv)*

  Enter the desired file name for your exported summary of autodetections and click the "Browse…" button to select where you would like to save the file (if you don't select a location, the *.csv file will automatically save to your process folder).

- Number of bins for summary

  The amount of units to summarize the specified time bin, used in conjunction with the "Bin time unit" field (e.g., Number of bins for summer: "24" and Bin time unit: "Hours" means a 24-hour period, and Number of bins for summer: "30" and Bin time unit: "Minutes" means 30-minute bins).

- Bin time unit*

  The time period over which the data is summarized, used in conjunction with the "Number of bins for summary" field (e.g., Seconds, Minutes, Hours, Days).

- Start date (MM/DD/YY HH:MM:SS)*

  Enter the date/time in your dataset where you want to start summarizing the autodetections (e.g., 02/01/10 00:00:00).

- End date (MM/DD/YY HH:MM:SS)*

  Enter the date/time in your dataset where you want to stop summarizing the autodetections (e.g., 02/15/10 00:00:00). The end date must be included to avoid an endless exported sheet for dates over which there is no data (file will never finish writing).

- Narrowband only

To export the summary for only narrowband autodetections ("True" is the default because the LFDCS has the capacity for, but is not currently developed for broadband detections).

- Broadband only

  To export the summary for only broadband autodetections ("False" is the default because the LFDCS has the capacity for, but is not currently developed for broadband detections).

- Maximum Mahalanobis distance filter

  To export the summary of all autodetections less than or equal to a specified maximum Mahalanobis distance (e.g., 3.0).

Note: The following examples will export daily presence summary sheets, which were most commonly used for analyses conducted at the Northeast Fisheries Science Center and the Woods Hole Oceanographic Institution.

Examples of Daily Presence Sheets

Daily Presence Sheets will export as .csv files. Analysts can then manually enter additional columns for tracking detections and adding notes (outside of the lfdcs netcdf files). The examples below show the following added columns:

- Manual_Review

  The column for presence scores for each time bin based off of the manual review or analysis (e.g., 0=not present, 1=present, 2=possibly present)

- True_Tally

  The column for the number of positive detections determined for a given day.

- True_Tally_Timestamp

  The column for the exact timestamp(s) of the true detection(s).

- Unknown_Timestamp

  The column for the exact timestamp(s) of unknown detection(s).

- Suggested_Daily_Presence

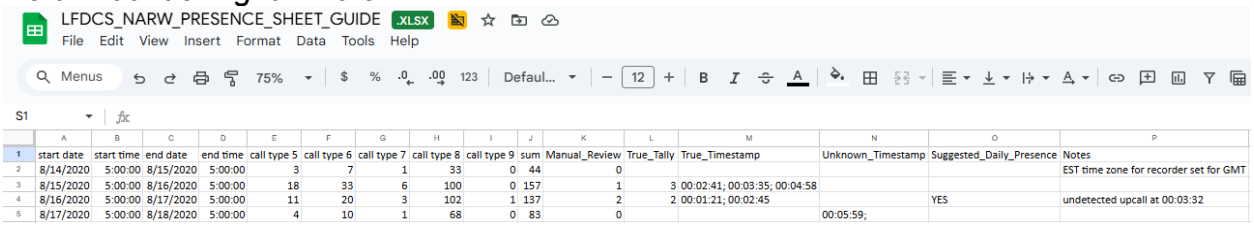
If you have a conservative protocol for daily presence that does not allow that day to be marked as "present," this column can aid for a final presence score for that day if following different criteria. I.e., if convincing evidence for presence is observed on a given day but it doesn't quite meet the criteria for scoring that day as "present" for a species, then this column could be used to flag days when presence is very likely but not able to be scored as "present" according to the current analysis protocol.

- Notes

  The column for analyst notes, e.g., the detection(s), day, noise conditions, additional species present.

See the following examples of Daily Presence Sheets for column headers that can be used for daily presence analysis of the 5 species. These are examples of columns manually entered next to the summary autodetection sheets that are exported by the LFDCS. Note: The following suggestions and examples correspond with daily presence summary sheets, which were most commonly used for analyses conducted at the Northeast Fisheries Science Center and the Woods Hole Oceanographic Institution.

North Atlantic Right Whale

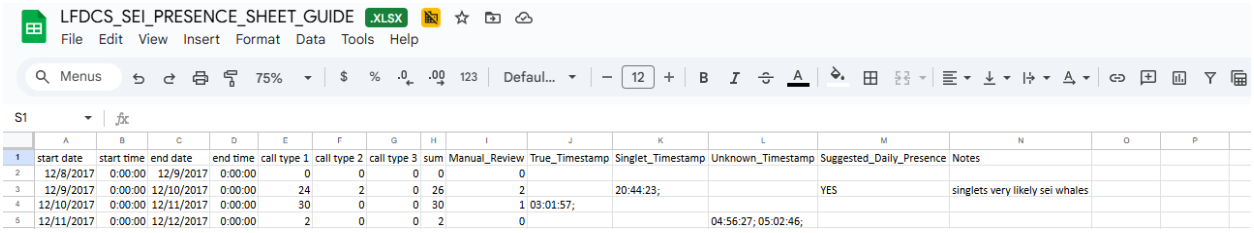

LFDCS_NARW_PRESENCE_SHEET_GUIDE .XLSX

File Edit View Insert Format Data Tools Help

start date	start time	end date	end time	call type 5	call type 6	call type 7	call type 8	call type 9	sum	Manual_Review	True_Tally	True_Timestamp	Unknown_Timestamp	Suggested_Daily_Presence	Notes
8/14/2020	5:00:00	8/15/2020	5:00:00	3	7	1	33	0	44	0					EST time zone for recorder set for GMT
8/15/2020	5:00:00	8/16/2020	5:00:00	18	33	6	100	0	157	1	3	00:02:41; 00:03:35; 00:04:58			
8/16/2020	5:00:00	8/17/2020	5:00:00	11	20	3	102	1	137	2	2	00:01:21; 00:02:45		YES	undetected upcall at 00:03:32
8/17/2020	5:00:00	8/18/2020	5:00:00	4	10	1	68	0	83	0			00:05:59;		

Figure 71. Example of summary sheet for confirmed North Atlantic right whale (*Eubalaena glacialis*) detections.

Sei Whale

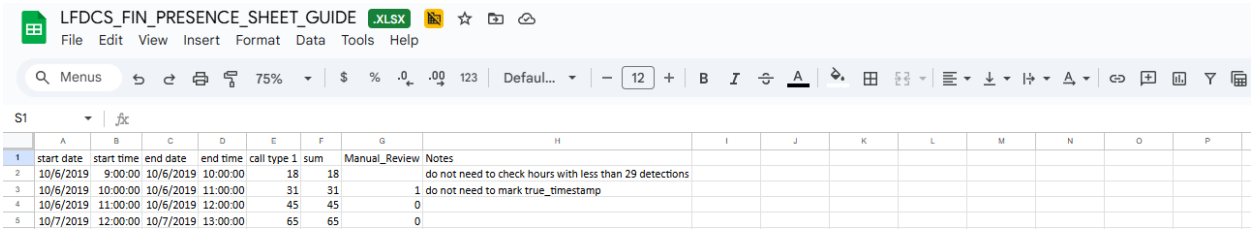

LFDCS_SEI_PRESENCE_SHEET_GUIDE .XLSX

File Edit View Insert Format Data Tools Help

start date	start time	end date	end time	call type 1	call type 2	call type 3	sum	Manual_Review	True_Timestamp	Singlet_Timestamp	Unknown_Timestamp	Suggested_Daily_Presence	Notes
12/8/2017	0:00:00	12/9/2017	0:00:00	0	0	0	0	0					
12/9/2017	0:00:00	12/10/2017	0:00:00	24	2	0	26	2		20:44:23;		YES	singlets very likely sei whales
12/10/2017	0:00:00	12/11/2017	0:00:00	30	0	0	30	1	03:01:57;				
12/11/2017	0:00:00	12/12/2017	0:00:00	2	0	0	2	0			04:56:27; 05:02:46;		

Figure 72. Example of summary sheet for confirmed sei whale (*Balaenoptera borealis*) detections.

Fin Whale

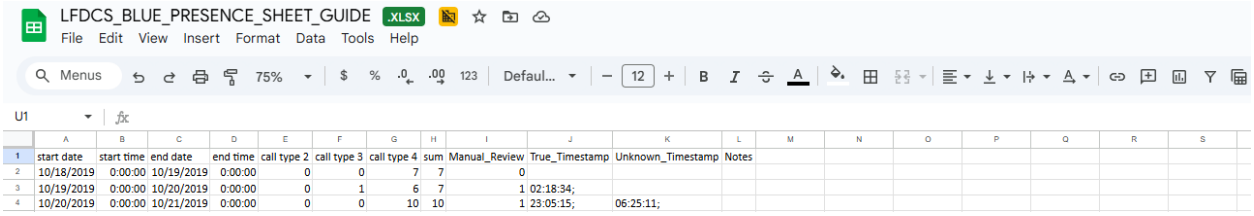

LFDCS_FIN_PRESENCE_SHEET_GUIDE .XLSX

File Edit View Insert Format Data Tools Help

start date	start time	end date	end time	call type 1	sum	Manual_Review	Notes
10/6/2019	9:00:00	10/6/2019	10:00:00	18	18		do not need to check hours with less than 29 detections
10/6/2019	10:00:00	10/6/2019	11:00:00	31	31	1	do not need to mark true_timestamp
10/6/2019	11:00:00	10/6/2019	12:00:00	45	45	0	
10/7/2019	12:00:00	10/7/2019	13:00:00	65	65	0	

Figure 73. Example of summary sheet for confirmed fin whale (*Balaenoptera physalus*) detections.

Blue Whale

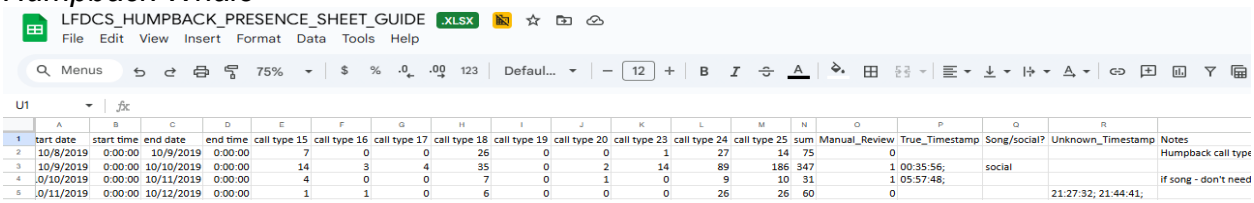

LFDCS_BLUE_PRESENCE_SHEET_GUIDE .XLSX

File Edit View Insert Format Data Tools Help

	A	B	C	D	E	F	G	H	I	J	K	L
1	start date	start time	end date	end time	call type 2	call type 3	call type 4	sum	Manual_Review	True_Timestamp	Unknown_Timestamp	Notes
2	10/18/2019	0:00:00	10/19/2019	0:00:00	0	0	7	7	0			
3	10/19/2019	0:00:00	10/20/2019	0:00:00	0	1	6	7	1	02:18:34;		
4	10/20/2019	0:00:00	10/21/2019	0:00:00	0	0	10	10	1	23:05:15;	06:25:11;	

Figure 74. Example of summary sheet for confirmed blue whale (*Balaenoptera musculus*) detections.

Humpback Whale


LFDCS_HUMPBACK_PRESENCE_SHEET_GUIDE .XLSX

File Edit View Insert Format Data Tools Help

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	
1	start date	start time	end date	end time	call type 15	call type 16	call type 17	call type 18	call type 19	call type 20	call type 23	call type 24	call type 25	sum	Manual_Review	True_Timestamp	Song/social?	Unknown_Timestamp	Notes
2	10/8/2019	0:00:00	10/9/2019	0:00:00	7	0	0	26	0	0	1	27	14	75	0				Humpback call type
3	10/9/2019	0:00:00	10/10/2019	0:00:00	14	3	4	35	0	2	14	89	186	347	1	00:35:56;	social		
4	10/10/2019	0:00:00	10/11/2019	0:00:00	4	0	0	7	0	1	0	9	10	31	1	05:57:48;			if song - don't need
5	10/11/2019	0:00:00	10/12/2019	0:00:00	1	1	0	6	0	0	0	26	26	60	0			21:27:32; 21:44:41;	

Figure 75. Example of summary sheet for confirmed humpback whale (*Megaptera novaeangliae*) detections.

How To Score Daily Presence for Different Species

These are the criteria that the Northeast Fisheries Science Center's Passive Acoustic Branch uses for analysis of daily presence of various baleen whale species. Terms such as "Manual_Review" and "True_Timestamp" correspond to the column titles within the exported Daily Presence Sheets where analysis results are recorded. These are the same protocols as those used in Davis et al. (2017) and (2020) with some minor updates and adaptations.

Right Whale

2 kHz sample rate, call types [5, 6, 7, 8, 9] from the clnb_gom9 call library, maximum Mahalanobis distance = 3

All detections browsed are marked as Correct, Incorrect, or Unknown in LFDCS (if the criteria for scoring a day as "1" for Manual_Review and Detected has been met, then you can jump to the next day and leave the remaining detections unscored). If true upcall detections are found, keep track of the number of true detections in the True_Tally column (up to 3 detections).

- Manual_Review = 1:

  3+ true ("Correct") upcalls in a day
  Once 3 true upcalls have been found in a given day, mark timestamps for those true detections as HH:MM:SS in the True_Timestamp column and jump to the next start date/time of the next row in your daily presence sheet.

- Manual_Review = 2:

1-2 true (“Correct”) upcalls in a day
If upcalls are convincingly right whale, i.e., loud and not associated with surrounding humpback song, then mark timestamps for true detections in the True_Timestamp column and add "YES" to the Suggested_Daily_Presence column for that day.

- Manual_Review = 0:

  No true (“Correct”) upcalls in a day
  Including days with only “Unknown” detections that are not confirmed as right whale. Mark times for at least the first few unknown detections as HH:MM:SS in the Unknown_Timestamp column.

Sei Whale

2 kHz sample rate, call types [1, 2, 3] from the clnb_gom9 call library, maximum Mahalanobis distance = 3

All detections browsed are marked as Correct, Incorrect, or Unknown in LFDCS (if the criteria for scoring a day as "1" for Manual_Review and Detected has been met, then you can jump to the next day and leave the remaining detections unscored).

Sei whale presence is manually verified, similarly to right whales. Likewise, blue whales produce a nearly identical downsweep (pers. communication with Julien Delarue), and using a single downsweep to determine sei whale presence is no longer reliable. Doublets and triplets (when 2-3 downsweeps appear in sequence separated by 2-4 seconds from the end of the first call to the start of the next call) seem to remain unique to sei whales and can be used for determining sei whale presence.

- Manual_Review = 1:

  1+ true (“Correct”) doublet or triplet with at least one downsweep pitch tracked within that doublet or triplet in a day
  Once 1 true doublet or triplet has been found in a given day, jump to the next start date/time of the next row in your daily presence sheet.

- Manual_Review = 2:

  1+ (“Correct”) singlets in a day
  If there are singlets and no true doublets or triplets, put the timestamp of the first singlet in the Singlet_Timestamp column as HH:MM:SS, then zoom out to a 5 minute period in LFDCS to see if there are any doublets or triplets that didn't get pitch tracked. If any convincing doublets or triplets are found that did not get pitch tracked then add "YES" to the Suggested_Daily_Presence column for that day and a note in the Notes column stating, e.g., "Undetected doublet at HH:MM:SS". If there are 3+ pitch tracked singlets that are very convincing as sei whale over the whole

day, then add "YES" to the Suggested_Daily_Presence column and a note in the Notes column stating, e.g., "Singlets likely sei whales".

- Manual_Review = 0:

  No true ("Correct") singlets, doublets, or triplets in a day
  Including days with only "Unknown" detections that are not confirmed as sei whale. Mark times for at least the first few unknown detections as HH:MM:SS in the Unknown_Timestamp column.

Fin Whale

Decimated data (resampled at 128 Hz), call type 1 from the clnb_gomlf_blue call library, maximum Mahalanobis distance = 3

A manual analysis was conducted with fin whales where subsampled hours of data were reviewed for whether or not there were true detections. A logistic regression curve was applied to the hours evaluated to determine the minimum number of detections per hour needed (for 90% confidence of fin whale presence). From a subsample of data from the Northeast U.S., the analysis found hours with 29 or more detections had a 90% chance that fin whales were truly detected. Manual verification of these true detection hours is still needed, however this greatly reduces the amount of manual analysis needed for daily presence review.

Presence sheets for fin whales are created with HOURLY bins. All hours with 29 or more detections are manually verified by an analyst (all other hours with fewer than 29 detections can be ignored and you do not need to include a "0" in the "Manual_Review" column for those hours). *Tip: You can select the "sum" column in the daily presence sheet and use the filter feature in Excel to only view rows with detection values greater than or equal to 29.* When one detection in a bout of 4 total calls (only one needs to be pitch tracked) is Correct, that hour will be given a "1" for "Detected" in the "Manual_Review" column, i.e., hours marked present are determined by having at least one true detection within a bout that had 4 or more pulses present (at least three other 20-Hz pulses including those not pitch tracked). Time does not have to be noted. Once an hour for a day is marked as "Detected", the analyst can then skip to the first hour with 29 or more detections on the next/new date.

- Manual_Review = 1:

  An hour with 29+ automated detections and 1+ true ("Correct") 20-Hz pulse pitch tracked within a sequence of 4+ 20-Hz pulses (you only have to score one true detection as "Correct" within the sequence, if there are more true, pitch tracked detections in the sequence they can be left as "Unclassified")
  Once a sequence of 4 pulses with at least 1 pitch tracked pulse is found in a given hour, jump to the start of the next day in your daily presence sheet that has an hour with 29+ automated detections.

- Manual_Review = 2:

An hour with 29+ detections and 1+ true (“Correct”) 20-Hz pulse pitch tracked within a sequence of 1-3 20-Hz pulses (you only have to score one true detection within the sequence, the rest can be left as "Unclassified")

- Manual_Review = 0:

  An hour with 29+ automated detections (according to the "sum" column of the daily presence sheet for that hour) that does not have any true (“Correct”) 20-Hz pulses within a sequence of 20-Hz pulses

Humpback Whale

2 kHz sample rate, call types [15, 16, 17, 18, 19, 20, 23, 24, 25] from the clnb_gom9 call library, maximum Mahalanobis distance = 3

All detections browsed are marked as Correct or Unknown in LFDCS (if the criteria for scoring a day as "1" for Manual_Review and Detected has been met, then you can jump to the next day and leave the remaining detections unscored).

- Manual_Review = 1:

  3+ true vocalizations in a 10-minute period (window zoom out max.) in a day with 1+ vocalizations pitch tracked and marked as “Correct”
  Incorrect detections can be left marked as "Unclassified" and do *not* need to be marked as “Incorrect” (due to the high number of false humpback detections). Only mark “Correct” and “Unknown” detections. If there are no “Correct” and “Unknown” detections but non-pitch tracked humpback vocalizations are observed, make note of this in the Notes column. If the vocalizations are social sounds, i.e., not part of an obvious song pattern, then add "SOCIAL" to the Song/social? column. If the sounds are difficult to distinguish between social and song, i.e., a short period of patterned calling or song fragment, then add "UNKNOWN" to the Song/social? column. Leave the column cell blank if it is song, since most of the detections will likely be from song units. If it is faint or hard to tell, err on the side of caution and add “UNKNOWN”.

- Manual_Review = 2:

  1-2 true vocalizations in a 10-minute period in a day with 1+ vocalizations pitch tracked and marked as “Correct”
  Mark any true, pitch tracked vocalizations as “Correct” with the timestamp in the True_Timestamp column and note in the Notes column that not enough vocalizations are present to score the day as "Detected".

- Manual_Review = 0:

No true vocalizations in a day
Including days with only “Unknown” detections that are not confirmed as humpback whale. Mark times for at least the first few unknown detections as HH:MM:SS in the Unknown_Timestamp column.

Blue Whale

Decimated data (resampled at 128 Hz), call types [2, 3, 4] from the clnb_gomlf_blue call library, maximum Mahalanobis distance = 6

All detections browsed are marked as Correct, Incorrect, or Unknown in LFDCS (if the criteria for scoring a day as "1" for Manual_Review and Detected has been met, then you can jump to the next day and leave the remaining detections unscored).

- Manual_Review = 1:

  3+ consecutive true song units in an ~11-minute period with 1+ song units pitch tracked and marked as “Correct” (you only have to score one true detection as "Correct" within the sequence, the rest can be left as "Unclassified")
  A unit can be an A, B, or AB call "packet". Blue whale detections will be viewed with a max_mdist = 6.0 to ensure blue whale presence is captured. Only clear calls will be marked; streams of noise that indicate either distant animals or are indistinguishable from noise will not be included as a true detection.

- Manual_Review = 2:

  1-2 true song units in a day with 1+ song units pitch tracked and marked as “Correct”
  If the true song units are pitch tracked, mark them as “Correct” with the time stamp in the True_Timestamp column and note in the Notes column that only 1-2 song units were present.

- Manual_Review = 0:

  No true (“Correct”) song units in a day
  Including days with only “Unknown” detections that are not confirmed as blue whale. Mark times for at least the first few unknown detections as HH:MM:SS in the Unknown_Timestamp column.

Exporting Metadata from Processed LFDCS Datasets

EXPORT: Convert netcdf to csv

It may be useful to pull out metadata from already processed LFDCS datasets to confirm the correct recorder/deployment was processed if any discrepancies are noticed or for general quality assurance/quality control (QA/QC). You can choose to pull metadata from the *.nc file from the specaudio folder or the lfdcs folder. The output from this will give all the parameters that were used to process the file, as well as the name of the call library and its last modification date.

1. From the LFDCS App Launcher, click on the "EXPORT: Convert netcdf to csv" button. This popup window will appear:

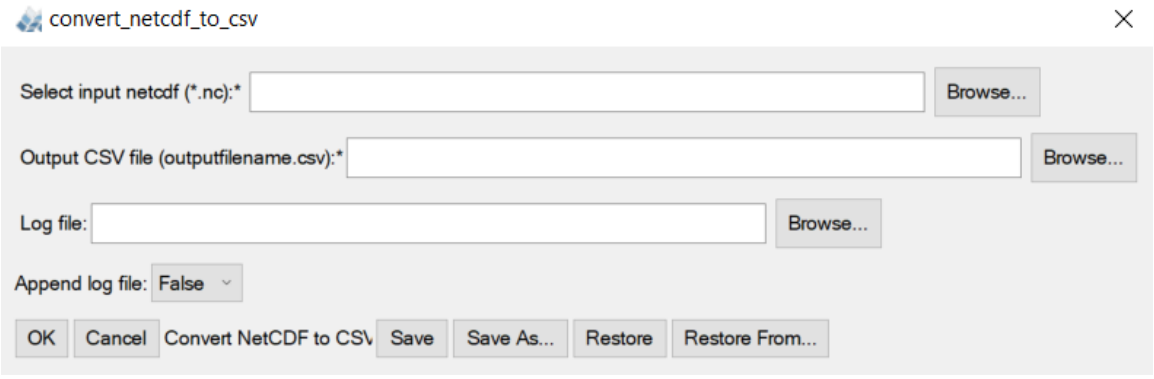


Figure 76. The convert_netcdf_to_csv program window where you can select the *.nc file that you want to export the metadata from for your processed dataset.

2. Use the definitions below to help you fill in the fields of the convert_netcdf_to_csv window (fields with an asterisk are required). When you are done filling out the fields, click "OK".

    - Select input netcdf (*.nc)*

        Use the "Browse…" button to select the *.nc file from the processed\lfdcs or processed\specaudio folders for which you want to view the metadata.

    - Output CSV file (outputfilename.csv)*

        Enter a name for your output file and use the "Browse…" button to select a pathway for where you want the *.csv file to be exported.

Exporting Metadata from Processed LFDCS Datasets

EXTRA: ncdf Information

The following directions explain how to output metadata related to your data processing. This program will output much of the same information that you used in your parameter file (e.g.,

whether the data was processed from raw audio or previously processed specaudio) to process your data originally, so it can be helpful if you have lost track of your parameter file.

1. From the LFDCS App Launcher, click on the “EXTRA: ncdf Information” button. This popup window will appear:

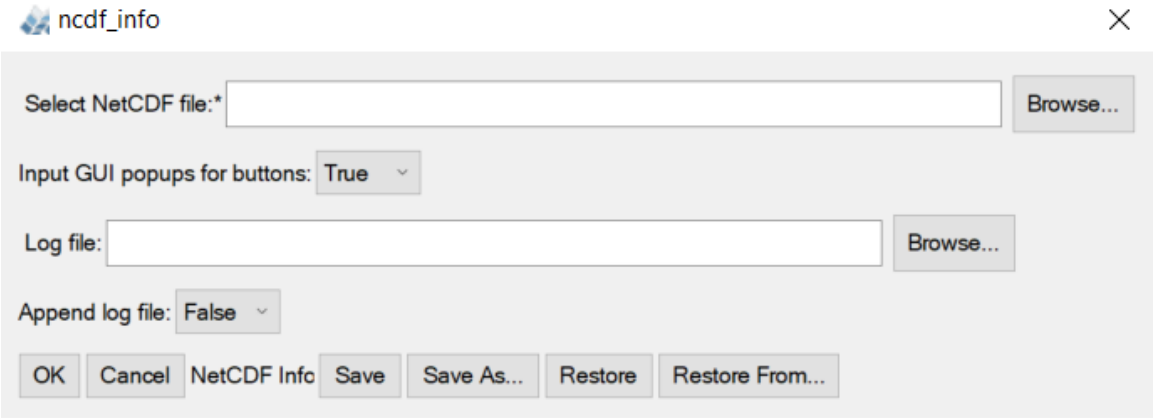


Figure 77. The ncdf program window where you can select the *.nc file that you want to export the metadata from for your processed dataset.

2. Use the definitions below to help you fill in the fields of the ncdf window (fields with an asterisk are required). When you are done filling out the fields, click “OK”.

    - Select NetCDF file*

USE THE “BROWSE…” BUTTON TO SELECT THE *.NC FILE FOR YOUR PROCESSED DATASET.

PART 2: INTRODUCTION TO LFDCS REAL-TIME ANALYSIS PROTOCOL

For near real-time applications, the LFDCS runs on the digital acoustic monitoring (DMON) instrument, which has integrated hydrophones for collecting, processing, and recording audio. When autonomous real-time detections are occurring from gliders, moorings, etc., the detections are uploaded onto the Robots4Whales: Autonomous Real-time Marine Mammal Detections web page under the Active Studies category, then the project's title (Baumgartner, n.d.a). Detections are reported in tables, figures, and pitch tracks, which can then be reviewed by an analyst. For more information, please refer to the main Robots4Whales website.

The purpose of Part 2 of this reference guide is to outline a procedure that scientists from the NEFSC, WHOI, and other organizations use when evaluating near real-time pitch tracks. Examples will be based on the Roseway Basin, Southwestern Scotian Shelf, Canada, Summer 2014 project (Baumgartner, n.d.b) The hope is that this guide will help to standardize and/or provide an example of the evaluation process between analysts for future real-time detection projects.

The Real-Time System: How Does It Work?

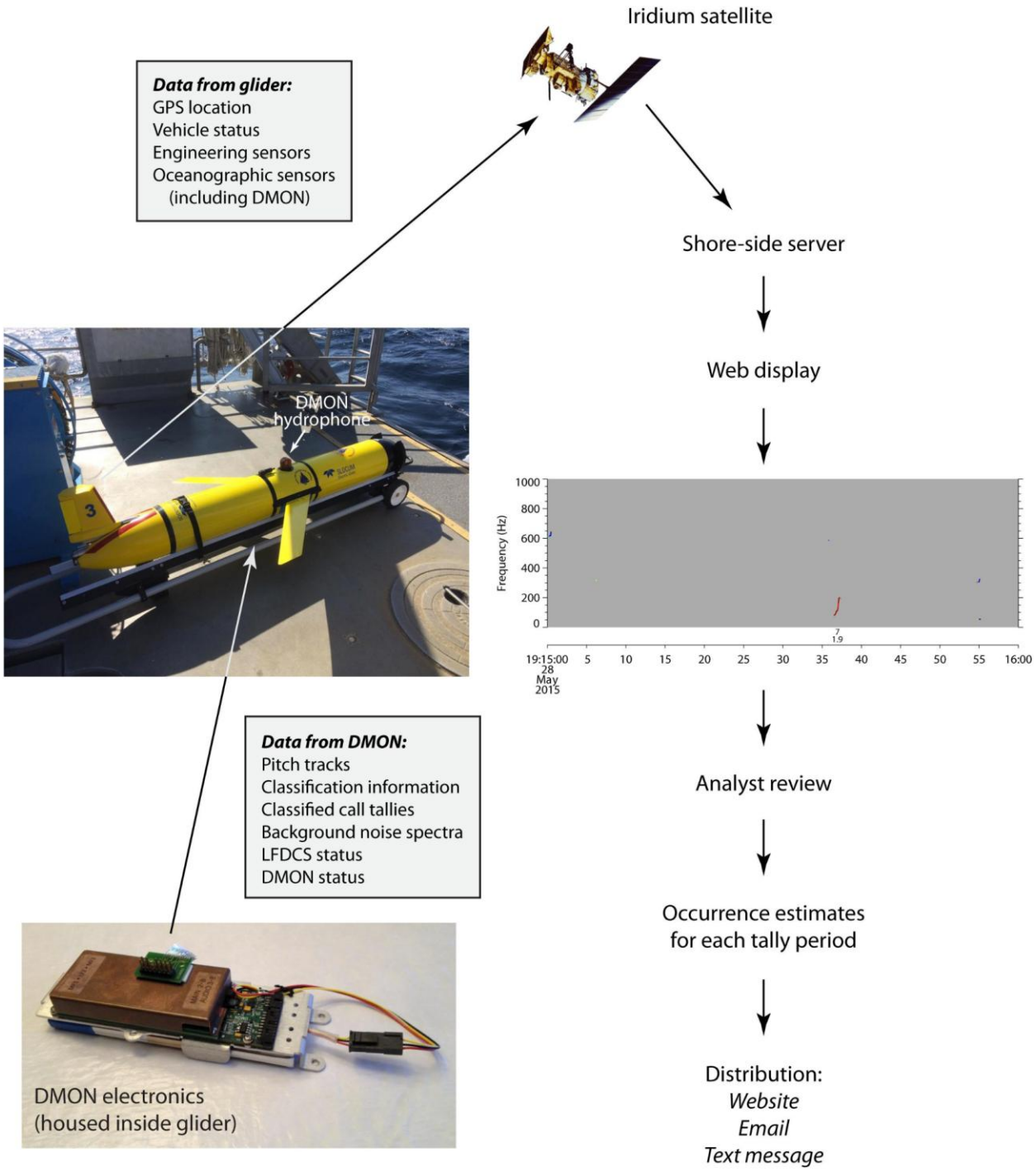


Figure 78. Diagram of data flow from the digital acoustic monitoring (DMON) integrated in a Slocum glider to a shore-side server via the Iridium satellite service. These data are displayed on the Robots4Whales website, and pitch tracks and classification information are reviewed by an analyst to produce species-specific occurrence estimates for each monitored tally period. Occurrence estimates are then distributed to users via the same publicly accessible website as well as email and text messages. Web display in the figure shows a pitch track of a single North Atlantic right whale (*Eubalaena glacialis*) upcall (Baumgartner et al. 2020).

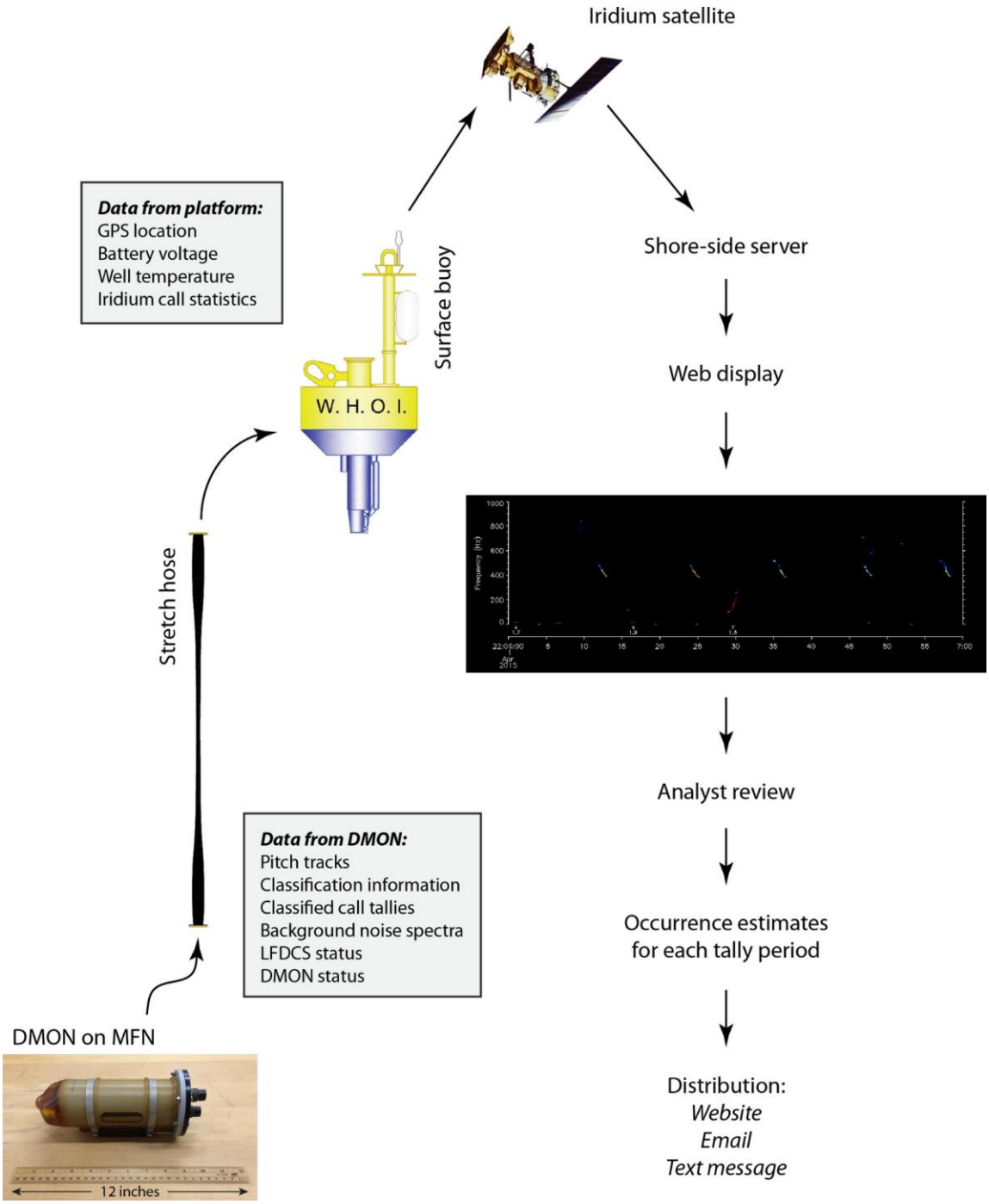


Figure 79. Diagram of data flow from the digital acoustic monitoring (DMON) mounted on the multi-function node (MFN) to a shore-side server via the stretch hoses, surface buoy and Iridium satellite service. These data are displayed on the Robots4Whales website, and pitch tracks and classification information are reviewed by an analyst to produce species-specific occurrence estimates for each monitored tally period. Occurrence estimates are then distributed to users via the same publicly accessible website as well as email and text messages. Web display in the figure shows a pitch track of a single North Atlantic right whale (*Eubalaena glacialis*) upcall, patterned downsweeps in a humpback (*Megaptera novaeangliae*) song, and 2 possible 20-Hz fin whale (*Balaenoptera physalus*) pulses (Baumgartner et al. 2019).

Reference Study

If at any point in time you have a question about a call type, or how to classify a detection, please refer to the Roseway Basin, Southwestern Scotian Shelf, Canada, Summer 2014 study, as that was fully annotated by Mark Baumgartner (Baumgartner, n.d.b).

Robots4Whales Website

This section includes information about the content on the Robots4Whales website (Baumgartner, n.d.a).

Main Page

The following sections describe the content that can be found on the main page of the website.

Latest Whale Detections Table

On the main page of the Robots4Whales website, the first section you will see is the Latest Whale Detections table, which contains links to all of the active deployments, a summary of species detected in the last 3 days, and the operators or collaborators involved with the mission.

Latest Whale Detections

Platform	Species detected in last 3 days	Operator(s)*
San Francisco buoy	Fin, Humpback whales	Woods Hole Oceanographic Institution
Santa Barbara Channel buoy	Fin, Humpback whales	Woods Hole Oceanographic Institution
Gulf of Maine Winter Slocum glider	Fin whales	Woods Hole Oceanographic Institution
Cape Ann buoy	Fin whales	Woods Hole Oceanographic Institution
Cape Cod Bay buoy	Right whales	Woods Hole Oceanographic Institution
Martha's Vineyard buoy	Fin whales	Woods Hole Oceanographic Institution
New York Bight SE buoy	Fin whales	Woods Hole Oceanographic Institution
Coastal New Jersey Slocum glider	Fin, Humpback, Right whales	Rutgers University and Woods Hole Oceanographic Institution
Atlantic City buoy	Fin, Humpback whales	Woods Hole Oceanographic Institution
Ocean City buoy	Fin, Humpback whales	Woods Hole Oceanographic Institution and University of Maryland Center for Environmental Science
Cape Charles buoy	Fin, Humpback whales	Woods Hole Oceanographic Institution and NAVFAC Atlantic
Norfolk buoy	Fin whales	Woods Hole Oceanographic Institution and University of South Carolina
Charleston buoy	No detections in the last 3 days	Woods Hole Oceanographic Institution and University of South Carolina
Savannah buoy	No detections in the last 3 days	Woods Hole Oceanographic Institution and University of South Carolina

Figure 80. Latest Whale Detections table on Robots4Whales website.

Platform Locations Map

Scroll down further, and you will find a map showing all of the current active deployments. You can hover your cursor over any of the buoy or glider locations on the map and it will display the platform name, type, operator, and latest species detections for that platform.

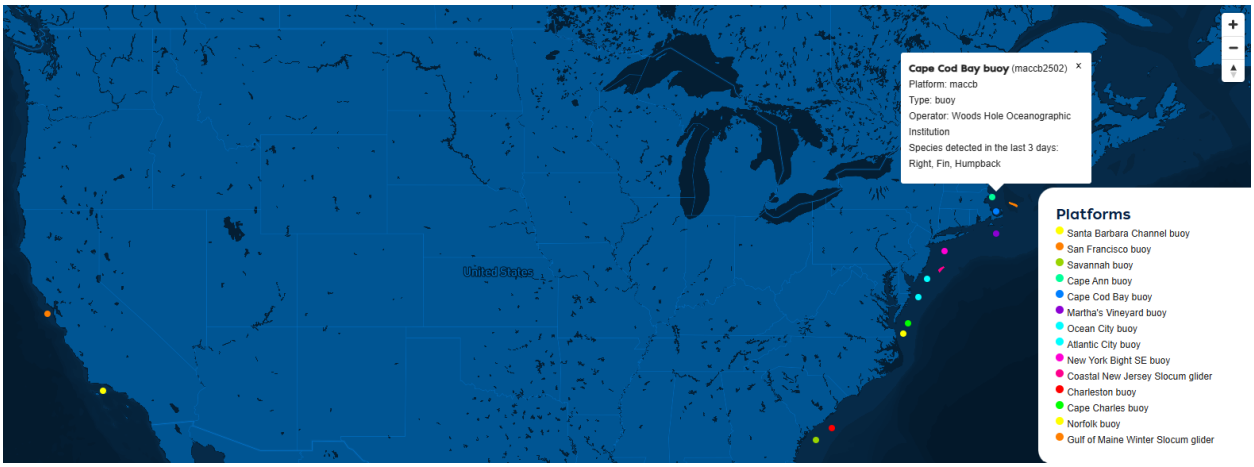


Figure 81. Platform Locations map on Robots4Whales website.

Missions Menu

Below the map under "Missions," you will find a scrollable menu starting with active missions and then archived missions with links to each project page. All raw pitch track data (and full spectrogram images for some deployments) from any Robots4Whales real-time deployment can be accessed here.

Active Missions

Slocum Glider G3, Coastal New Jersey (February 2024)
Moored Buoy, Cape Cod Bay, Massachusetts (February 2025)
Moored Buoy, Cape Ann, Massachusetts (February 2025)
Moored Buoy, San Francisco, California (January 2025)
Moored Buoy, Santa Barbara Channel (January 2025)
Moored Buoy, Martha's Vineyard, Massachusetts (January 2025)
Slocum Glider G3, Gulf of Maine Winter Survey (December 2024)
Moored Buoy, Charleston, South Carolina (December 2024)
Moored Buoy, Savannah, Georgia (December 2024)
Moored Buoy, Ocean City, Maryland (October 2024)
Moored Buoy, Atlantic City, New Jersey (August 2024)
Moored Buoy, New York Bight SE (August 2024)
Moored Buoy, Cape Charles, Virginia (July 2024)
Moored Buoy, Norfolk, Virginia (July 2024)

Archived Missions

Moored Buoy, New York Bight NW (August 2024)
Slocum Glider G2, New York Bight NE (February 2025)
Slocum Glider G2, New York Bight NW (January 2025)
Slocum Glider G2, Coastal Georgia (February 2025)
Slocum Glider G3, Gulf of Maine Fall Survey (October 2024)

Figure 82. Active and archived Projects menu on Robots4Whales website.

Vehicle Platforms

If you click on “Platforms” in the menu at the top of the main webpage, you will see photos and a brief description of each platform (most common being the Slocum glider and moored buoy).

Additional Resources

If you click on “About” in the menu at the top of the main webpage, you can select from options including: How it works, Sounds, Collaborators, Publications, and Resources. These sections provide a basic description of the pitch tracking algorithm, recordings of the species and their respective call types that we are listening for, collaborator and publications lists, acoustic diagnostics, updates about the latest calls to the Iridium server, the latest version of the LFDCS Reference Guide, and training videos.

Real-Time Acoustic Diagnostics

If you click on “Resources” from the “About” menu at the top of the webpage, you can select the “Acoustic Diagnostics” page, which contains a link to a page summarizing the platforms’ acoustic environments and real-time monitoring diagnostics. This diagnostic information can provide valuable insights into how much data are being transmitted by each platform, detections summaries, power spectra comparison, and background noise spectra for all active platforms. The following images are examples of some of the summary graphics you can find on the Acoustic Diagnostics page.

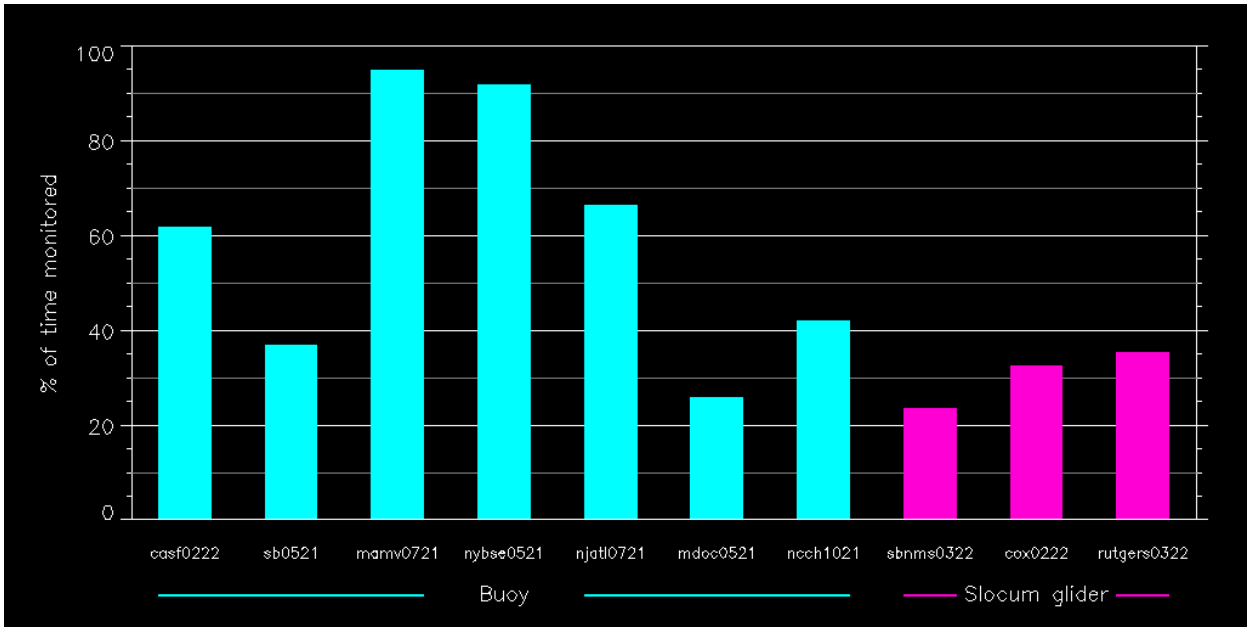


Figure 83. Graph showing the percentage of time that pitch track data is available for different platforms over the last 3 days of each deployment.

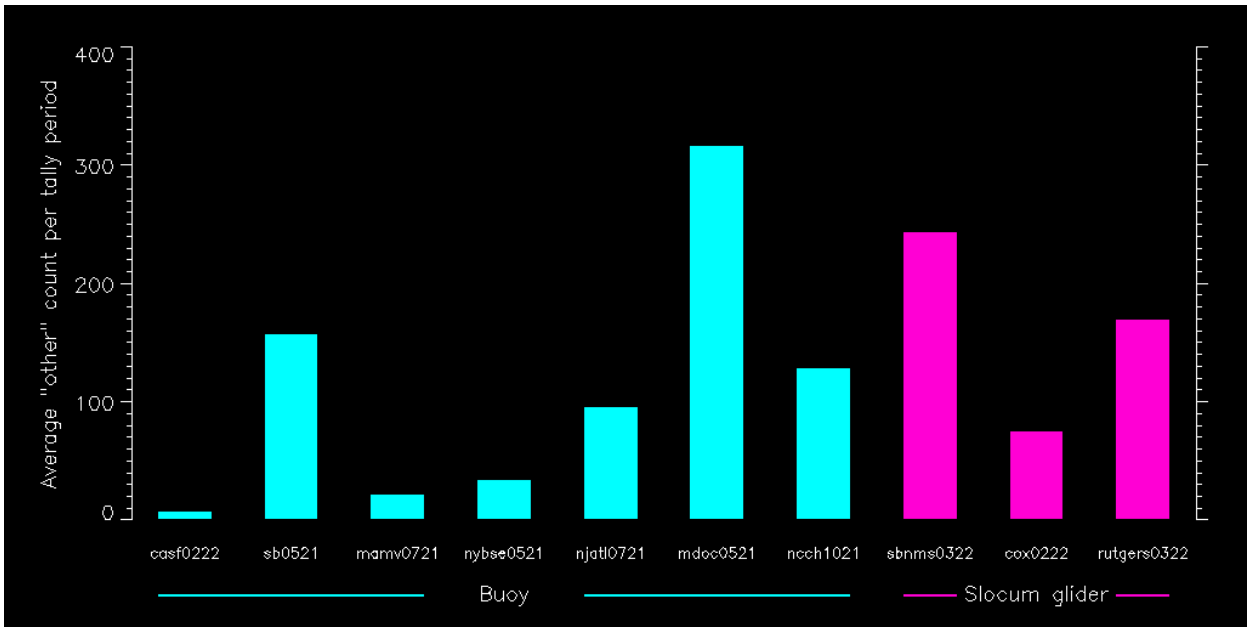


Figure 84. Graph showing the average count of "Other" detections per nominal 15-minute tally period over the last 3 days of each deployment.

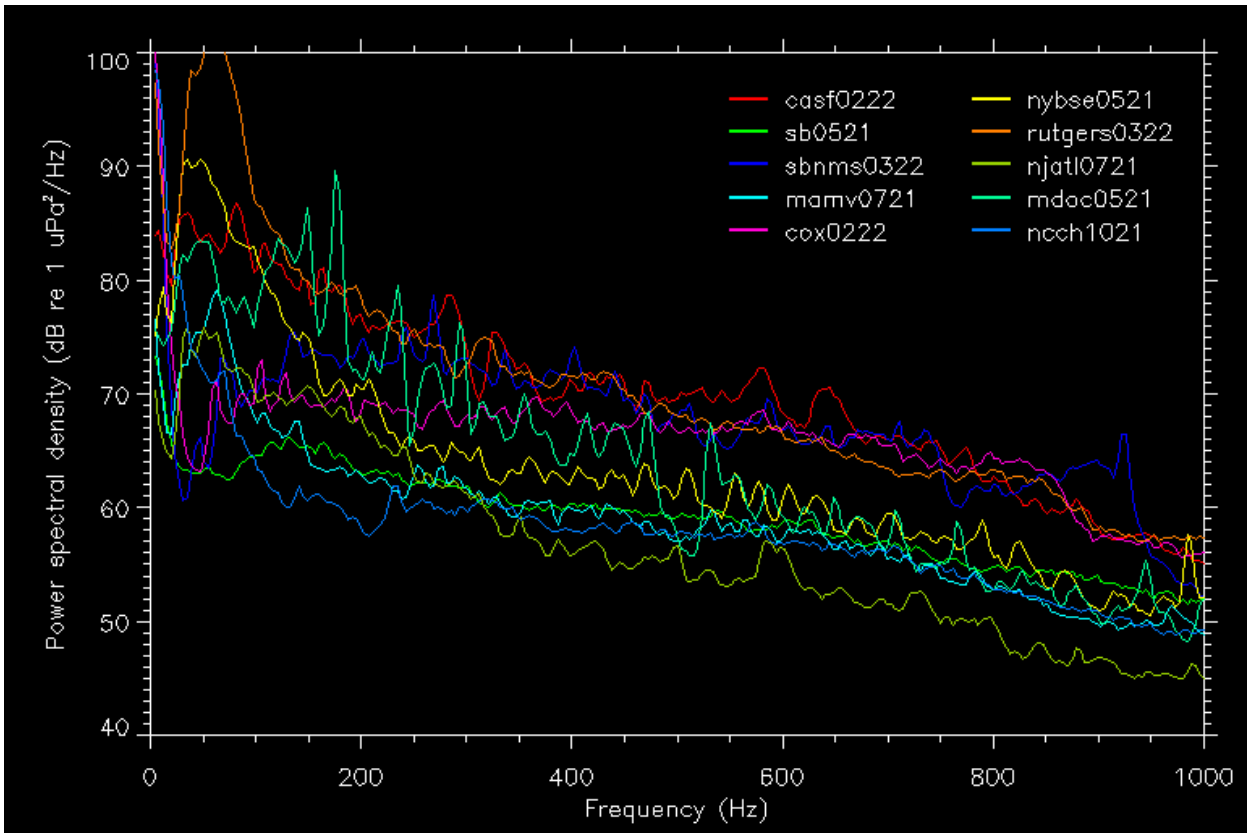


Figure 85. Graph showing the latest power spectra from all active platforms. This is also shown on the Diagnostics web page in separate graphics that isolate the power spectra from the moored buoys and the gliders.

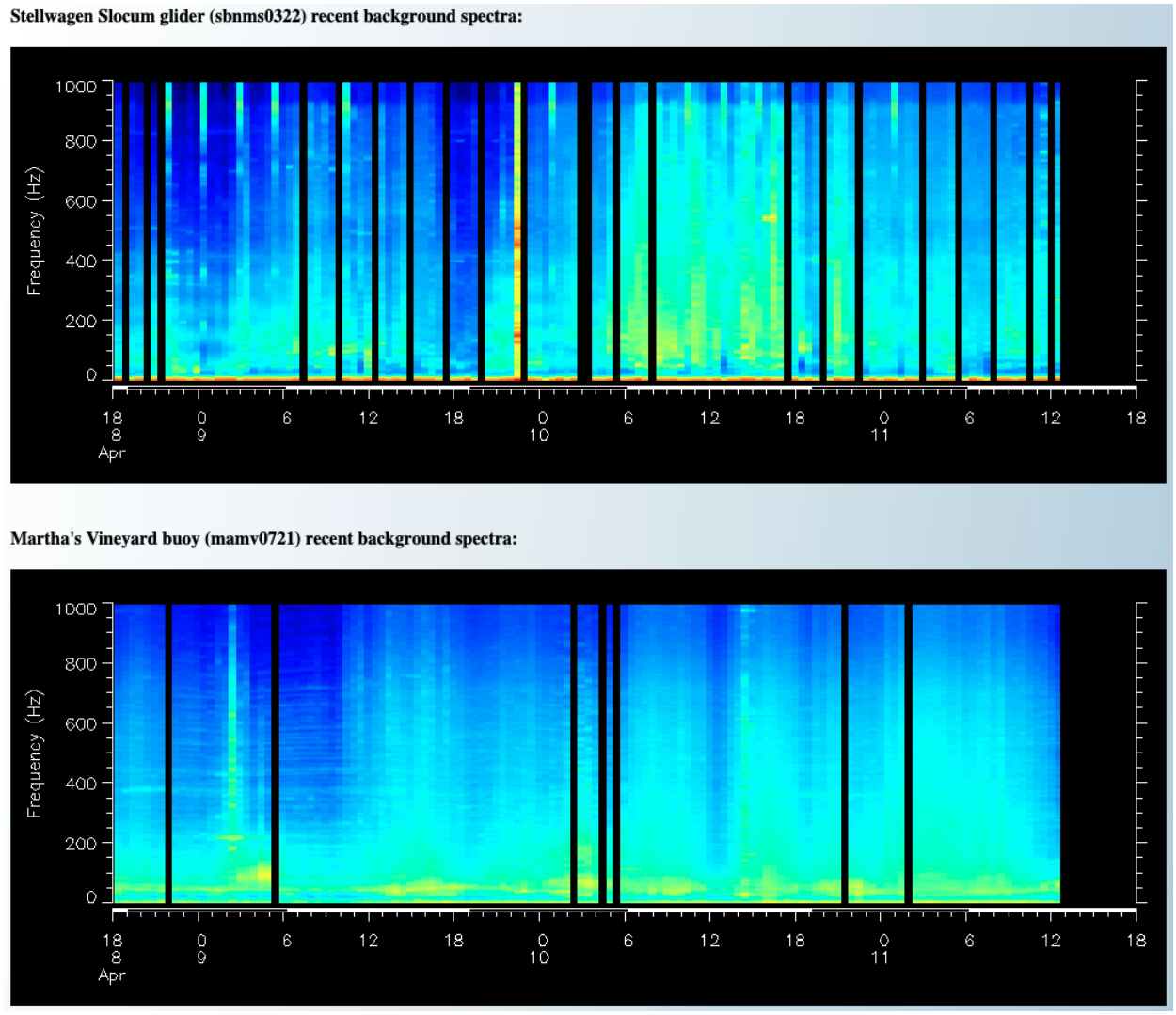


Figure 86. Examples of the recent background spectra from glider and moored buoy deployments. The Diagnostics web page includes recent background spectra for all platforms, which allows for convenient comparison of acoustic environments and data transmission between platforms.

Project Pages

You can access the individual project web pages via the links in the Latest Whale Detections table or the Missions menu on the main page of the website. Each project page may look a little different depending on the purpose of the project. The following sections describe most of the general information you can find on the individual project pages.

Note: The example of the spring 2022 Stellwagen Bank National Marine Sanctuary Slocum glider deployment is used in the following sections (Baumgartner, n.d.c). Project pages for glider deployments contain slightly different information than moored buoy project pages as there is additional information pertaining to detections along the glider tracks.

Study Objectives

The Study Objectives section of each project page describes the monitoring and, if applicable, the mitigation goals of that project. Principal investigators, collaborators, and analysts are also listed in this section with a picture of the platform.

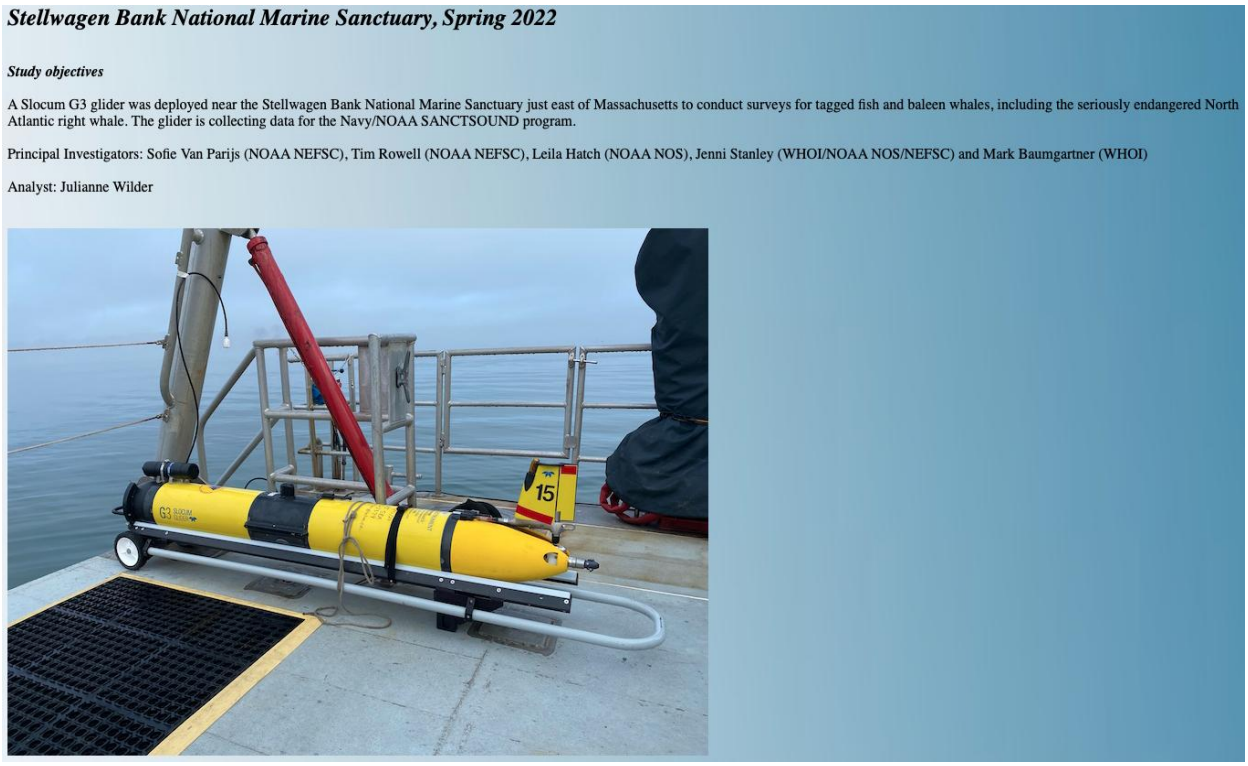


Figure 87. Study Objectives section on a sample project page on Robots4Whales website.

Platform Location

If you scroll down below the Study Objectives section, you will find a map showing the platform's current location. If the platform is a moored buoy, its location will be shown simply as a yellow star. If the platform is a glider, the full glider track will be shown in gray with the start location and the location of the last transmission.

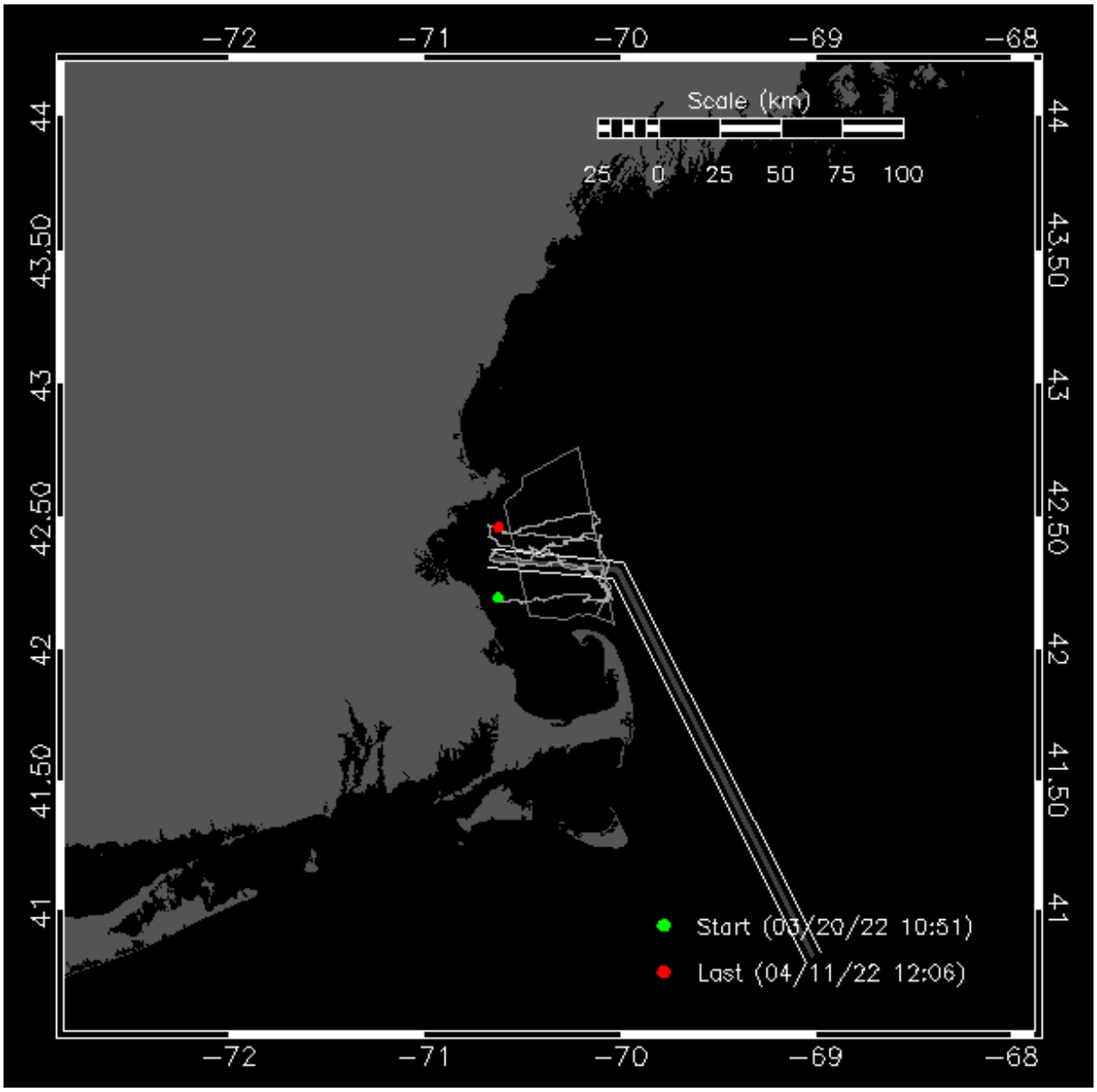


Figure 88. Platform Location map on a sample project page on Robots4Whales website.

Analyst-Reviewed Species Occurrence Maps

On any project pages for glider deployments, you will find maps of occurrence by species below the Platform Location map. These are based on the analyst's scoring of species presence from the pitch track data. The small gray dots indicate where there are pitch track data collected by the glider when it was at that location, but the species was scored as Not Detected by the analyst for that pitch track period. The yellow dots represent pitch track periods that the analyst scored as Possibly detected for that species when the glider was at that location. The red dots represent pitch track periods that the analyst scored as Detected for that species. These species presence scores are determined by the analyst for each pitch track tally period using the Real-Time Analysis Protocol.

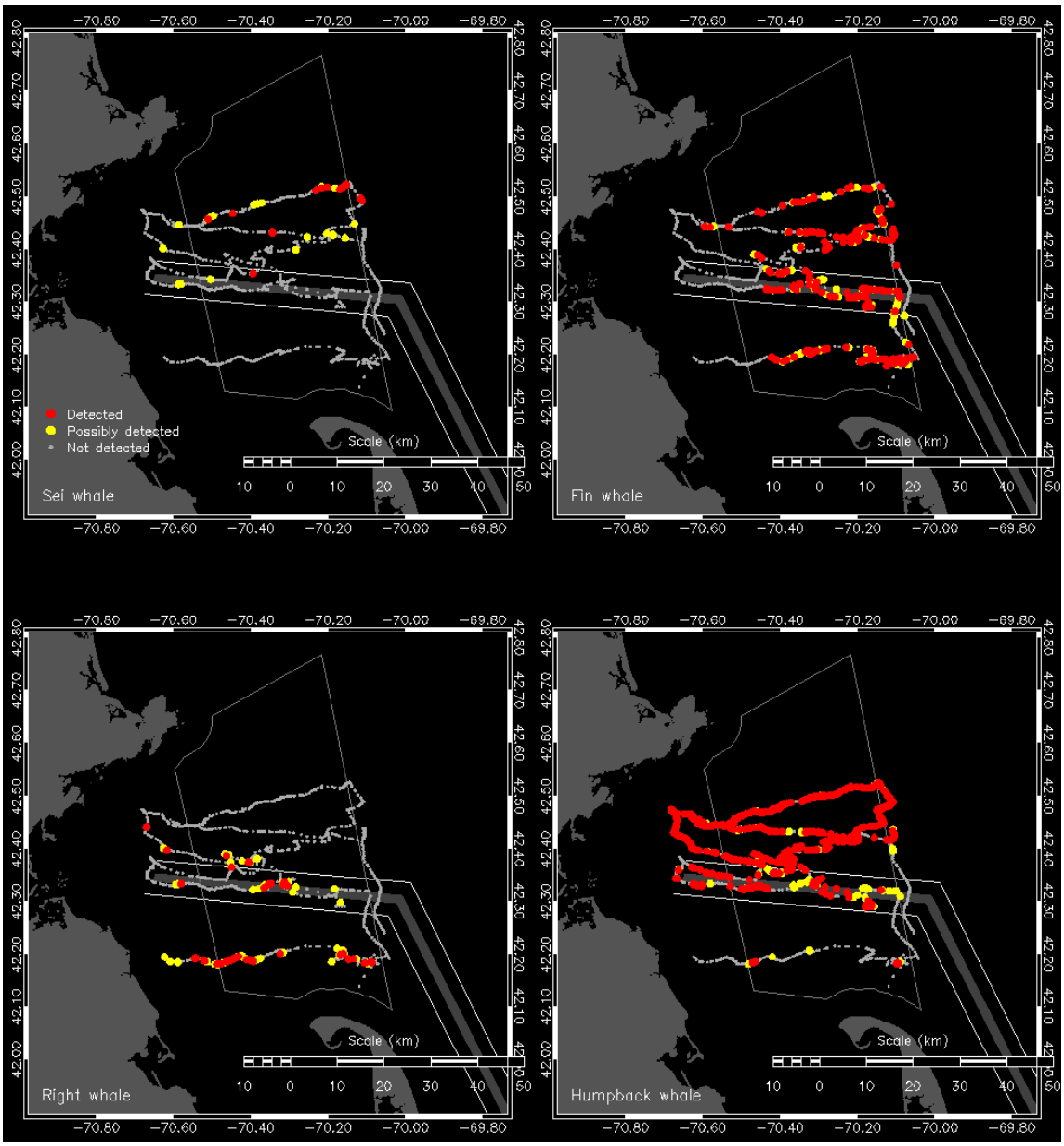
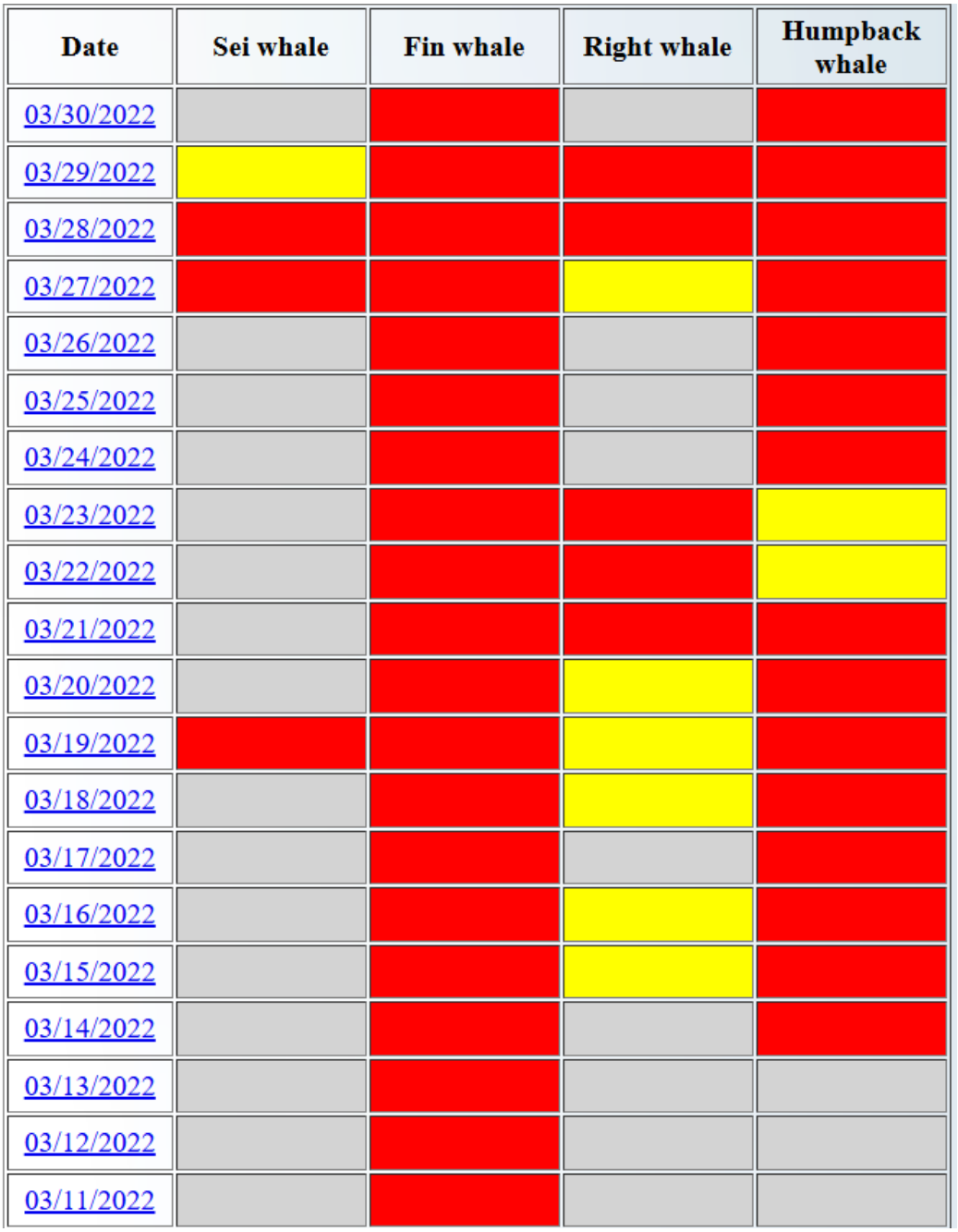


Figure 89. Analyst-Reviewed Species Occurrence maps on a sample project page on Robots4Whales website.

Daily Analyst Review Table

Scroll down further, and you will find the Daily Analyst Review table for that deployment. This shows a summary of which species have been scored as Detected (red), Possibly Detected (yellow), or Not Detected (gray) by the analyst for each day of the deployment. If just 1 pitch track tally period has been scored as Detected or Possibly Detected within a given day, that tally period will determine daily presence, and the box for that species on that day will turn red or yellow, respectively. These species presence scores are determined by the analyst for each pitch track tally period using the Real-Time Analysis Protocol.



Date	Sei whale	Fin whale	Right whale	Humpback whale
03/30/2022				
03/29/2022				
03/28/2022				
03/27/2022				
03/26/2022				
03/25/2022				
03/24/2022				
03/23/2022				
03/22/2022				
03/21/2022				
03/20/2022				
03/19/2022				
03/18/2022				
03/17/2022				
03/16/2022				
03/15/2022				
03/14/2022				
03/13/2022				
03/12/2022				
03/11/2022				

Figure 90. Daily Analyst Review table on a sample project page on Robots4Whales website.

Daily Analyst Notes

The dates in the left-hand column of the Daily Analyst Review table link to any notes that the analyst took for certain pitch track periods on a given day, organized by species. The date and timestamps in the left-hand column of the Notes tables link to the specific pitch track tally period for which notes were taken.

Right whale:

Date/time (local)	Occurrence	Latitude	Longitude	Notes
04/03/22 13:07:44	Detected	42.3970	-70.6169	Faint classified and unclassified upcalls throughout the period. All upcalls are isolated from any of the HW song in the period.
04/03/22 15:07:44	Possibly detected	42.4004	-70.6248	Two possible faint upcalls with one classification in P16 but they could also be HW.
04/03/22 15:22:44	Possibly detected	42.4011	-70.6259	Two possible unclassified upcalls in P2 and 3 but the first is extremely faint and the second is short and looks like it could be part of some faint HW song.

Humpback whale:

Date/time (local)	Occurrence	Latitude	Longitude	Notes
04/03/22 00:07:44	Detected	42.3776	-70.5023	
04/03/22 01:07:44	Detected	42.3788	-70.5150	
04/03/22 02:07:44	Detected	42.3791	-70.5219	
04/03/22 03:07:44	Detected	42.3814	-70.5296	
04/03/22 04:07:44	Detected	42.3832	-70.5351	
04/03/22 05:07:44	Detected	42.3858	-70.5414	
04/03/22 08:07:44	Detected	42.3916	-70.5658	One possible faint unclassified upcall in P5 but it could be HW, RW, or faint noise.

Figure 91. Daily Analyst Notes section on a sample project page on Robots4Whales website.

Time Series of Analyst-Reviewed Species Occurrence

Following the Daily Analyst Review table, there is a time series that shows the percentage of pitch track tally periods (i.e., summary periods) for which each species was scored as Detected (red) or Possibly Detected (yellow) for each day of the deployment.

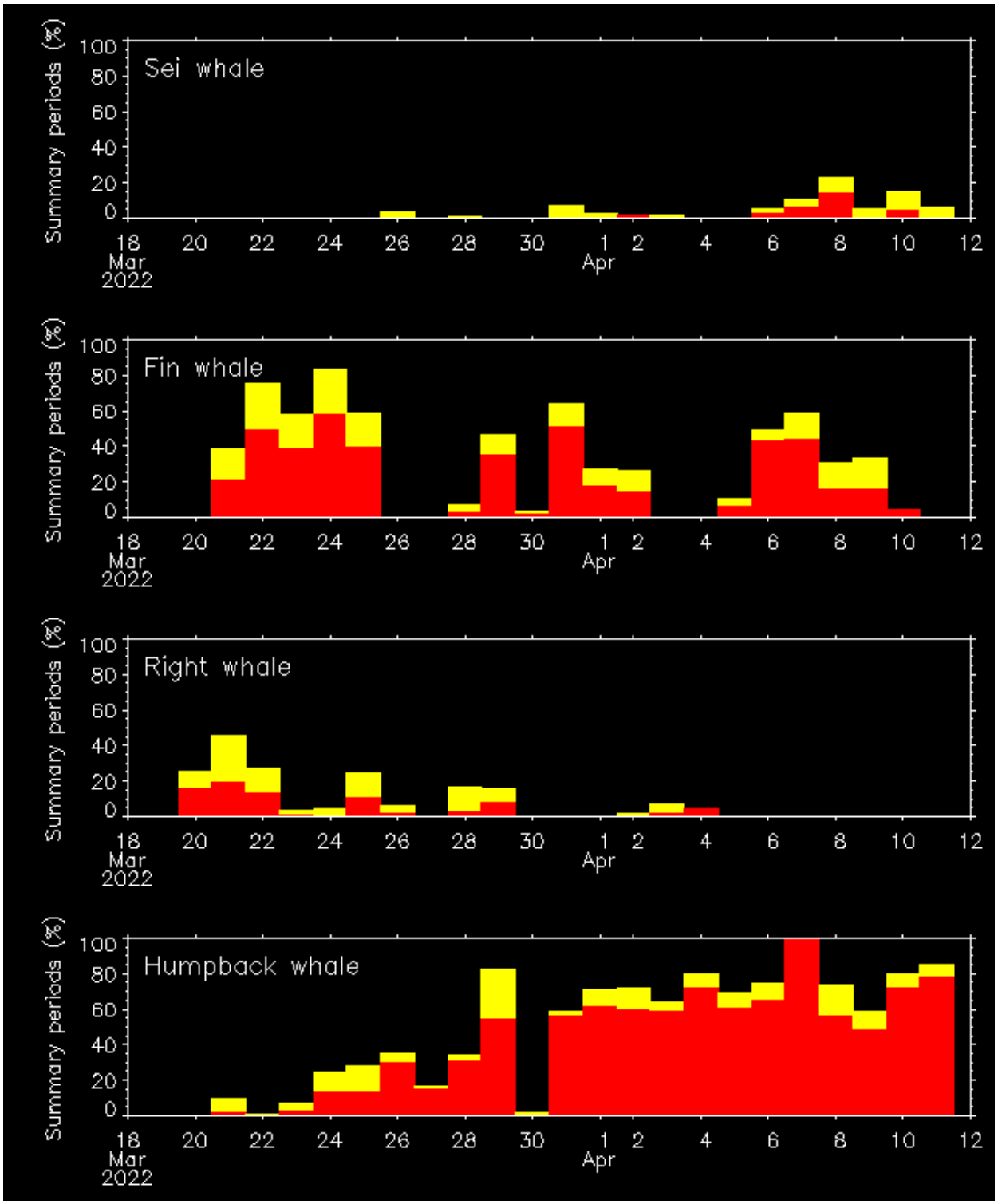


Figure 92. Time Series of Analyst-Reviewed Species Occurrence on a sample project page on Robots4Whales website.

Diel Plots of Analyst-Reviewed Species Occurrence

Following the Time Series table, there is an array of diel plots showing the analyst-reviewed species presence score for each pitch track tally period transmitted throughout each day of the deployment. Each dot in the diel plot represents 1 pitch track tally period, and the dot color represents the analyst's presence score of Detected (red), Possibly Detected (yellow), or Not Detected (gray) for that species over that period.

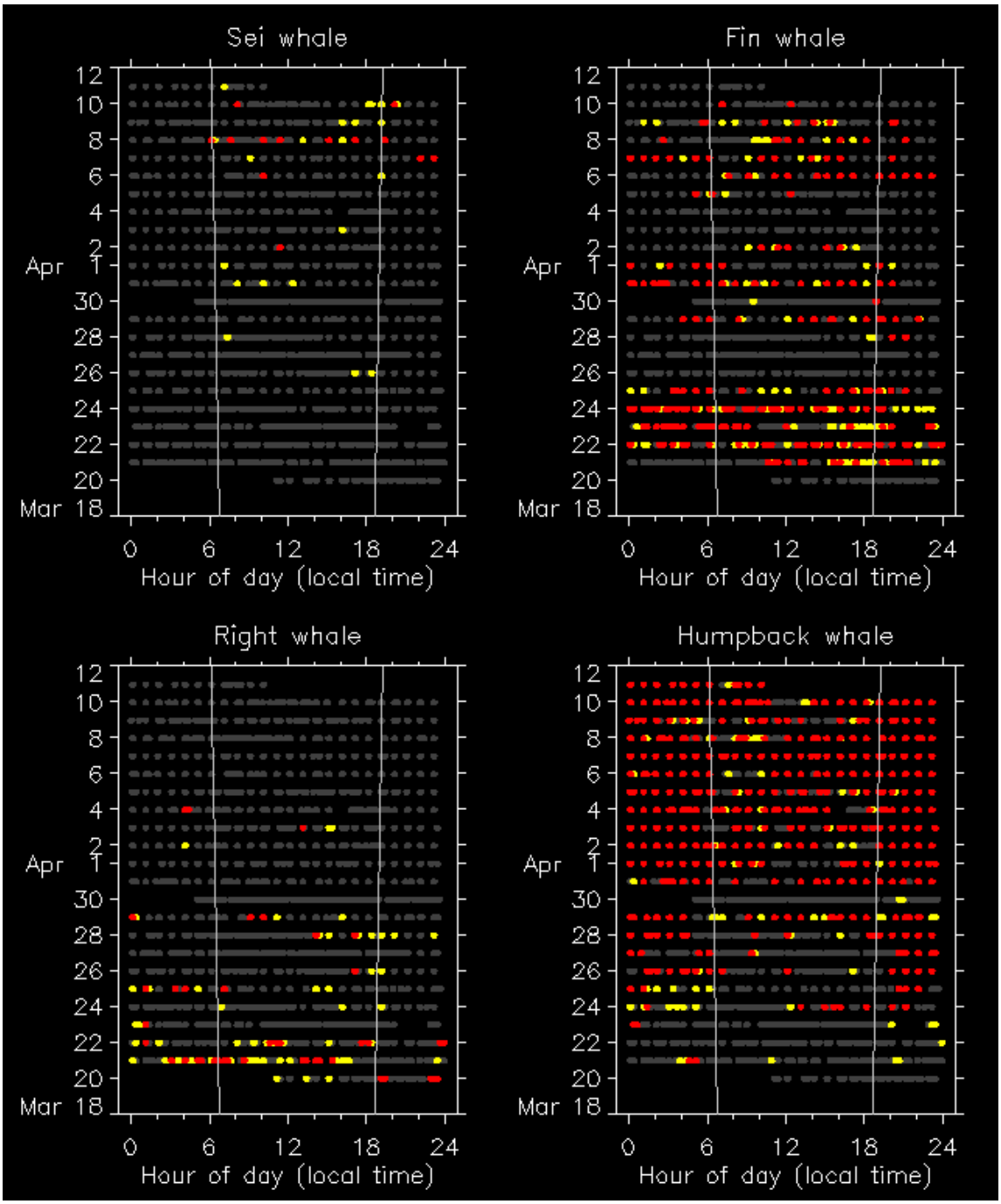


Figure 93. Diel Plots of Analyst-Reviewed Species Occurrence on a sample project page on Robots4Whales website.

Recent Background Noise Spectra

Below the diel plots, you will find spectra for Recent Background Noise. This shows the background noise spectra for the last 3 days of the deployment. These spectra can be viewed on the individual pitch track pages, as well.

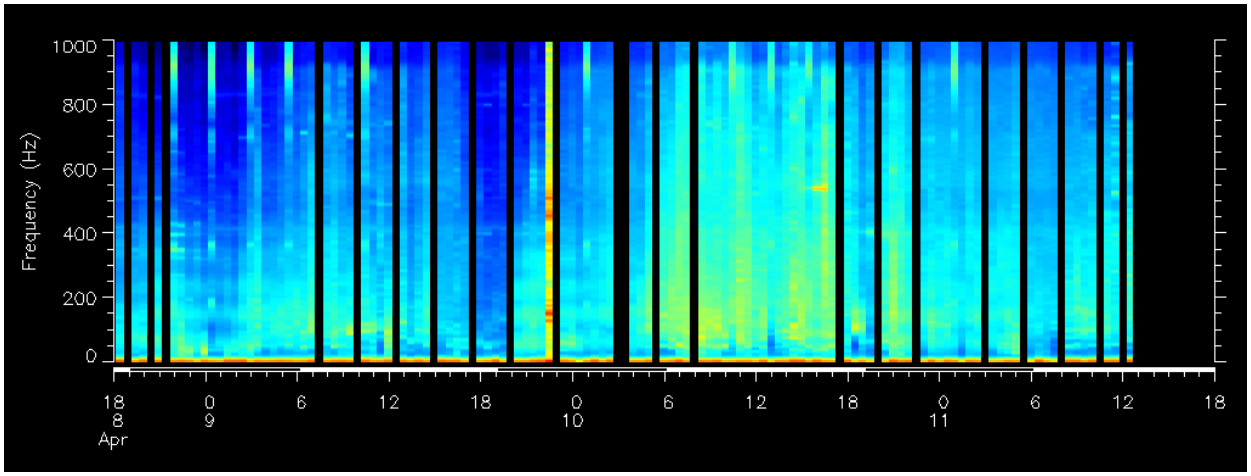


Figure 94. Recent Background Noise Spectra on a sample project page on Robots4Whales website.

Oceanographic Observations

Below the Recent Background Noise spectra, there are plots of oceanographic information from that deployment including chlorophyll fluorescence, turbidity, temperature, and salinity.

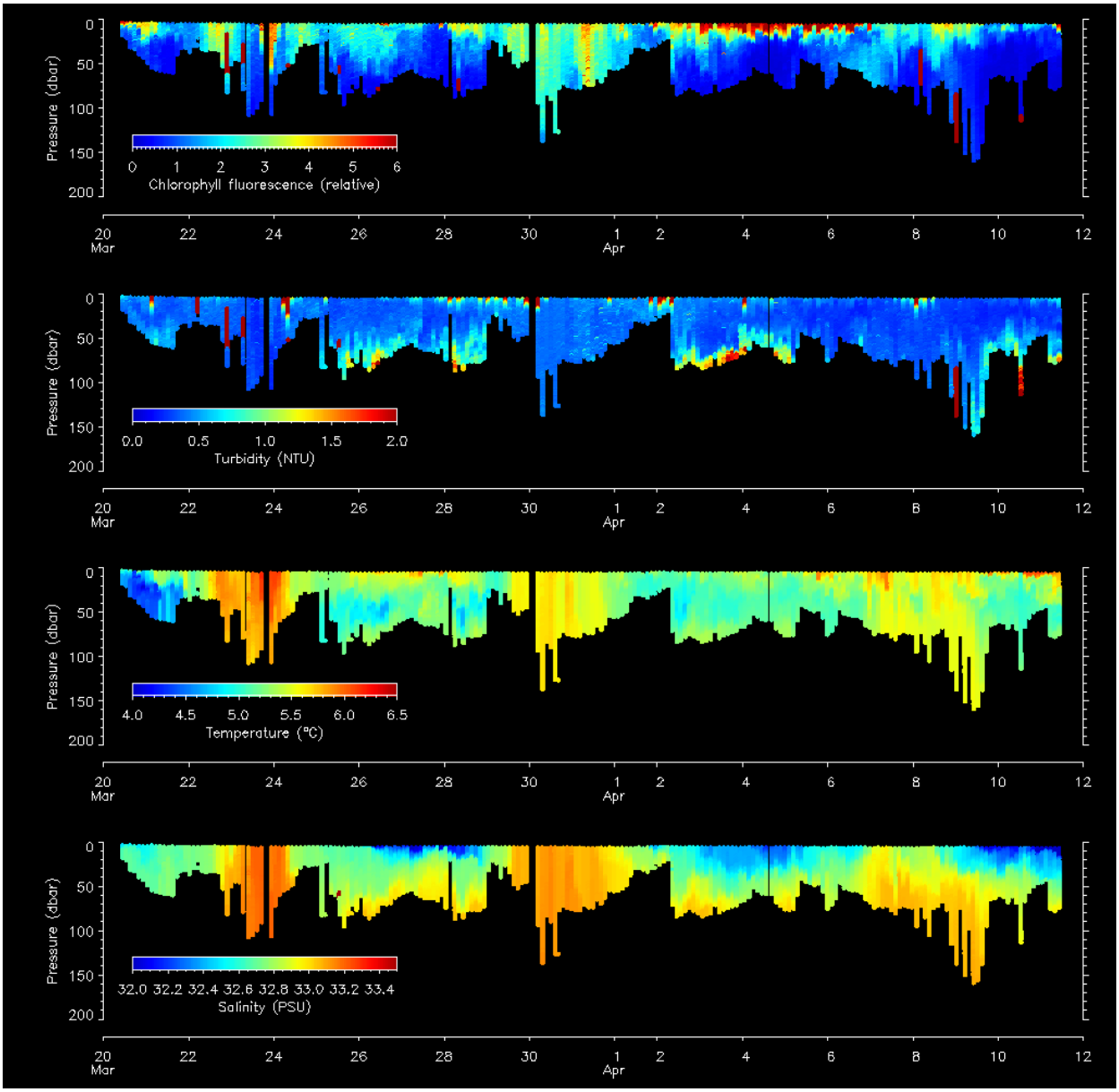


Figure 95. Oceanic Observations plots on a sample project page on Robots4Whales website.

Links to Detailed Information

At the bottom of each project page there is a section titled “Links to detailed information” that contains links to the automated detection data, DMON/LFDCS diagnostics, and platform diagnostics for that deployment. The Automated Detection Data page will be the most useful to the analyst, as it leads to a page with further raw detection output as well as the Daily Tally tables for each day of the deployment.

Automated Species Call Counts

At the top of the Automated Detection Data page, you will see a series of plots of depicting the number of autodetections that the LFDCS classifier identified as a given species per 15- minute tally period. All other pitch tracks that are not classified as a species are assigned to the "Other sounds" category at the bottom. These are *not* the species scores confirmed by a human analyst, but are the species/categories automatically assigned by the classifier based on the characteristics of each pitch track.

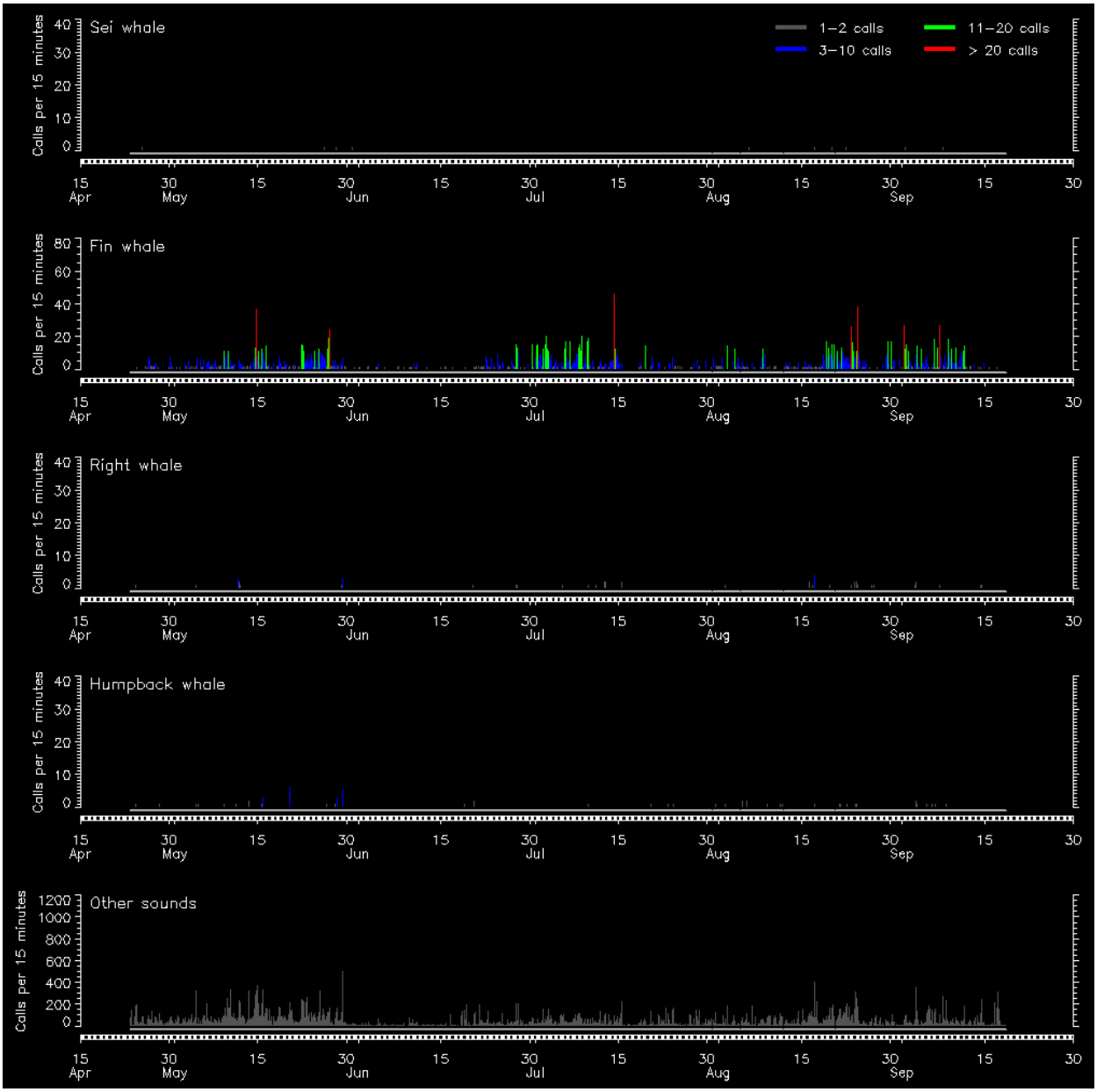


Figure 96. The Species Call Counts plots displaying the number of autodetections that the classifier identified as a given species per tally period.

Background Noise Spectrograms

As you scroll down the Automated Detection Data page, you will see three long-term spectrograms displaying the background noise for the selected platform. The top spectrogram shows the background noise for the entire deployment, the middle spectrogram shows approximately the last week, and the bottom spectrogram shows the last three days of background noise.

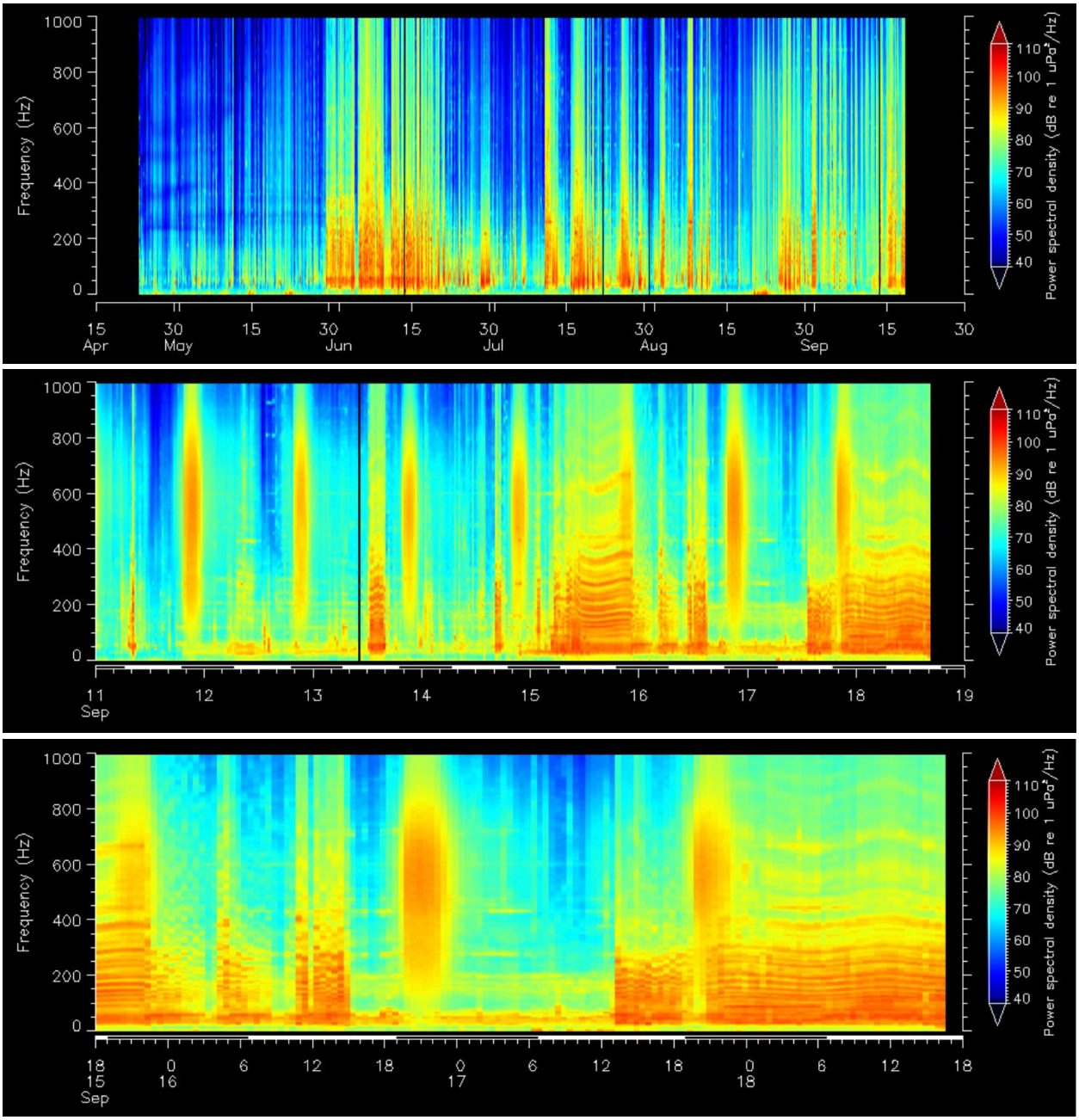


Figure 97. The background noise spectrograms for one of the New York Bight buoy deployments, depicting what is likely vessel noise over varying time periods.

Daily Tally Tables

Near the bottom of the Automated Detection Data page, you will find the Daily Tally tables. The incoming data is separated by days, and you can access data from a particular day by clicking on the link. The data for the current day will be displayed right there on the Automated Detection Data page (without a day link).

Each row in the table corresponds to a nominal 15-minute summary period, and the date/time displayed for a row corresponds to the date/time of the end of the 15-minute period (in local time). This is followed by the number of calls the DMON/LFDCS has classified per species. There is also an "Other" column for those sounds that did not match any calls in the call library. The "Duration" column refers to the duration in the summary period (in seconds); this should typically be 900 seconds (15 minutes) unless pitch tracking was turned off for a glider surfacing (Slocum glider only) or the DMON audio was muted to assess noise conditions and produce a time mark in the audio recording.

The "Tracks" column will show you which summary periods contain pitch track information (noted by a "PT"). Note that a maximum of 8 KB of pitch track data per hour is transmitted to shore via Iridium satellite to minimize cost, so not all summary periods have associated pitch track data available. To evaluate a summary period with pitch tracks, click on the "PT" link; this is further explained in the Using the "Pitch Track" Page section of this document. If there are "Map" and "Latitude/Longitude" columns, those will indicate the position of the glider at that particular point in time.

05/20/25

05/21/25

Date/time	Sei whale	Fin whale	Right whale	Humpback whale	Other	Duration	Tracks			
05/22/25 00:04:33	0	0	0	0	72	900	PT	Map	42.7591	-68.2948
05/22/25 00:19:33	1	0	0	1	59	900	PT	Map	42.7604	-68.2950
05/22/25 00:34:33	0	3	0	0	77	900	PT	Map	42.7618	-68.2951
05/22/25 00:47:41	0	0	0	0	57	788	PT	Map	42.7632	-68.2952
05/22/25 01:00:40	0	0	0	0	0	0		Map	42.7635	-68.2953
05/22/25 01:04:33	0	0	0	0	11	232	PT	Map	42.7635	-68.2953
05/22/25 01:19:33	0	0	0	0	63	900	PT	Map	42.7653	-68.2966
05/22/25 01:34:33	1	1	1	0	80	900	PT	Map	42.7683	-68.2981
05/22/25 01:49:33	0	0	1	0	98	900	PT	Map	42.7713	-68.2996
05/22/25 02:04:33	0	0	0	0	51	900		Map	42.7743	-68.3011
05/22/25 02:19:33	0	0	0	0	73	900		Map	42.7773	-68.3026
05/22/25 02:34:33	1	0	2	0	118	900	PT	Map	42.7803	-68.3041
05/22/25 02:49:33	0	0	0	0	46	900	PT	Map	42.7833	-68.3056
05/22/25 03:04:33	0	0	3	0	51	900	PT	Map	42.7863	-68.3071
05/22/25 03:07:35	0	0	0	0	33	182		Map	42.7884	-68.3082
05/22/25 03:23:44	0	0	0	0	0	0		Map	42.7899	-68.3105
05/22/25 03:34:33	0	0	0	0	39	648	PT	Map	42.7899	-68.3105
05/22/25 03:49:33	1	1	0	0	28	900	PT	Map	42.7933	-68.3124
05/22/25 04:04:33	0	2	0	0	31	900	PT	Map	42.7967	-68.3143
05/22/25 04:19:33	0	1	1	0	47	900	PT	Map	42.8001	-68.3162
05/22/25 04:34:33	0	1	2	0	26	900	PT	Map	42.8035	-68.3181

Note:
Tallies of classified calls are reported by the DMON every 15 minutes
Pitch tracks of individual calls are reported at a maximum rate of 8 KB per hour
While all detected calls are tallied in the table above, they are not all reported as pitch tracks
Only calls with an average amplitude of 11 dB above background or higher are tallied and reported as pitch tracks
Only calls with a Mahalanobis distance less than 3 are tallied
Other indicates all calls/sounds not found in the call library
Listening duration is period over which calls were detected (seconds)
All dates/times in EDT time zone

Figure 98. Daily Tally table on a sample project page on Robots4Whales website.

Real-Time Analysis Protocol

Using the "Pitch Track" Page

Click on the first "PT" in the tally table. This will bring you to a page that will have pitch tracks for that summary period (previously described in the document as "pitch track tally periods,"

henceforth known as the “Pitch Track” page). The transmission time information and species counts will be displayed at the top of the page (which is identical to the row from the tally table). Next, you should see 15 1-minute figures containing the pitch tracks. There may be dotted vertical lines with a code above that will indicate when pitch tracks are being generated or transmitted by the DMON/LFDCS. The codes and their definitions are as follows:

- MUTEON:

  The hydrophone is muted to assess system noise and to provide a time mark in the audio recording.

- MUTEOFF:

  The hydrophone is unmuted and normal recording has resumed.

- ADDET_OFF:

  A maximum of 8 KB of pitch track data per hour is transmitted by the glider. The ADDET_OFF message indicates that this limit has been reached.

- ADDET_ON:

  Transmission of pitch track data has resumed.

- $ADRUN, 0:

  The glider has reached the surface and will begin data transmission home, so pitch tracking is terminated (Slocum glider only).

- $ADRUN, 3:

  The glider has finished data transmission at the surface and is initiating a dive, so pitch tracking has resumed (Slocum glider only).

The pitch tracks will be color coded; cooler colors (blue) represent quieter signals, and warmer colors (red) represent louder signals. Sounds that the DMON/LFDCS classifies as a known call type (from the call library) will have 2 white numbers displayed below the call. The top number represents the species ID, and the bottom number represents the Mahalanobis distance. The latter is not typically used in the evaluation process, but the former is very important. For the northeast United States call library, the species call types are as follows:

- Sei whale downsweep: Call types 1-3
- Fin whale 20-Hz pulse: Call type 4
- Right whale upcall: Call types 5-8
- Humpback whale downsweep and upcall: Call types 17 and 18

Note: Call type 17 is a low-frequency humpback downsweep, similar to a sei whale downsweep. Call type 18 is a steep upsweep, similar to a right whale upcall.

If you want to know what the species IDs are for your project, go to any Pitch Track page and scroll down to the bottom. Your species IDs and vertical line codes will be recorded there (the bullets previously listed are a common example of what you might see).

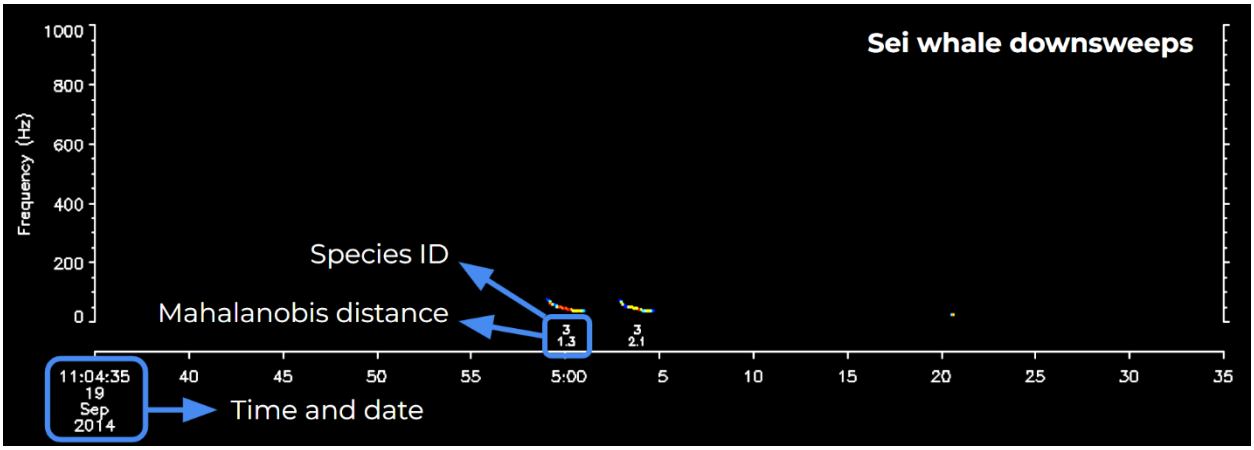


Figure 99. Example of pitch track data with feature labels.

Below the pitch tracks is the form that will be filled out after reviewing the pitch tracks. There are 3 choices per species: "Detected," "Possibly Detected," and "Not Detected" (default). When to assign a category to a species is covered in the Determining Species section of this document. Below the table is a text field ("Notes") where you can enter comments about what you observed. Things to write down include unknown signals that could be of interest, or signals that could belong to a species but there was not enough evidence to label as "Possibly Detected," and documentation (evidence) of species presence. Essentially, you would want to have notes of the times of interest such that once the platform is out of the water and the data are back at the lab, you can go through the spectrograms and listen to signals to confirm/reject what you originally thought it was.

Once you have completed the form, click on the "Submit" button. This will prompt you for a username and password. Each analyst will receive their own unique username and password from Mark Baumgartner. You will only be prompted for these credentials once during a session unless you close out of your browser window mid-analysis.

Once the form has been filled out and you click the "Submit" button, the website will bring you to the next Pitch Track page. You can also maneuver between Pitch Track pages by either the "Back" or "Next" buttons at the bottom of the page. If you want to change a previous form submission, just navigate to that Pitch Track's page, re-fill the form, and press "Submit." Selecting the "Back" or "Next" buttons will not save any new notes or species presence scores.

Determining Species

The most important thing to keep in mind is to be conservative when determining the detection of a species. There are 4 main criteria for determining species acoustic presence from pitch track data: amplitude, shape, isolation, and classification. Each species has a different variation of these criteria for it to be considered "Detected," "Possibly Detected," or "Not Detected." The following sections describe the criteria used for determining the detection score for each species. If you are still in doubt, please refer to the Roseway Basin study to see how Mark Baumgartner has classified those pitch tracks (Baumgartner, n.d.b).

The Four Main Criteria for Determining Species

1. Amplitude of the signal
2. Shape of the pitch track
3. Isolation from other pitch tracks (context)
4. Classification of species based on the detector's call library (species ID)

Amplitude

The amplitude of a signal (i.e., how loud or quiet it is) can sometimes be helpful in assessing pitch tracks. Faint (light to dark blue) pitch tracks can be produced either by faint whale calls or, in some circumstances, by noise. For example, spurious pitch tracks can be produced by the low-frequency whooshing sound produced by breaking waves as a Slocum glider nears the surface. On rare occasions, these spurious pitch tracks can resemble actual whale calls. These pitch tracks are often quiet, so quiet calls should always be eyed with some suspicion.

Use the criteria described in the following sections of this document for each species and if the context, pattern, or accompanying calls lead you to believe a quiet call is genuinely produced by a whale, then score it as such. Loud tonal or frequency modulated sounds that are not at the very base of the spectrogram, in contrast, are typically not spurious, and they are usually well pitch-tracked. These should be viewed with much less suspicion.

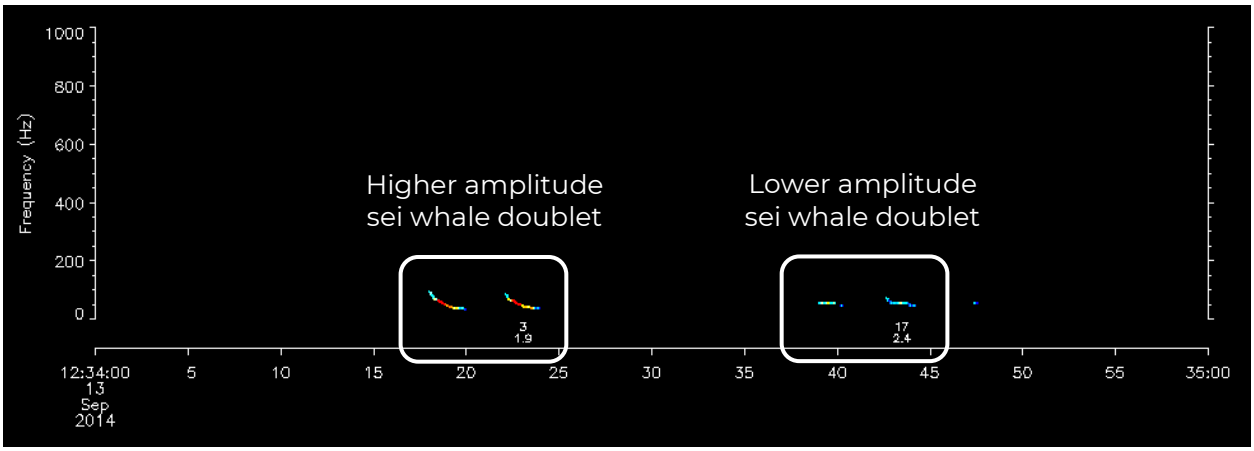


Figure 100. Example of higher and lower amplitude sei whale calls in the pitch track data. Note that, in this case, the higher amplitude calls have a smoother, more defined shape and the lower amplitude calls still appear but are partially pitch tracked and have a more jagged shape.

Shape

The shape of a pitch track can be used to assess whether it is a true call or just noise. A call is easier to identify if it has "good shape," meaning it is smooth and/or has a form that is characteristic of the species in question. A pitch track that has poor shape may be broken or jagged (see comparison between shapes of louder versus quieter sei whale doublets in Fig. 98). Sometimes the pitch tracks will have straight lines connecting it to other calls or noise. This is because the algorithm that produces the pitch tracks believes that those two sounds belong together, even if they do not. When this happens, we use the term "artifact." These artifacts can distort pitch tracks and make it difficult to determine whether the call is real or if it is just noise.

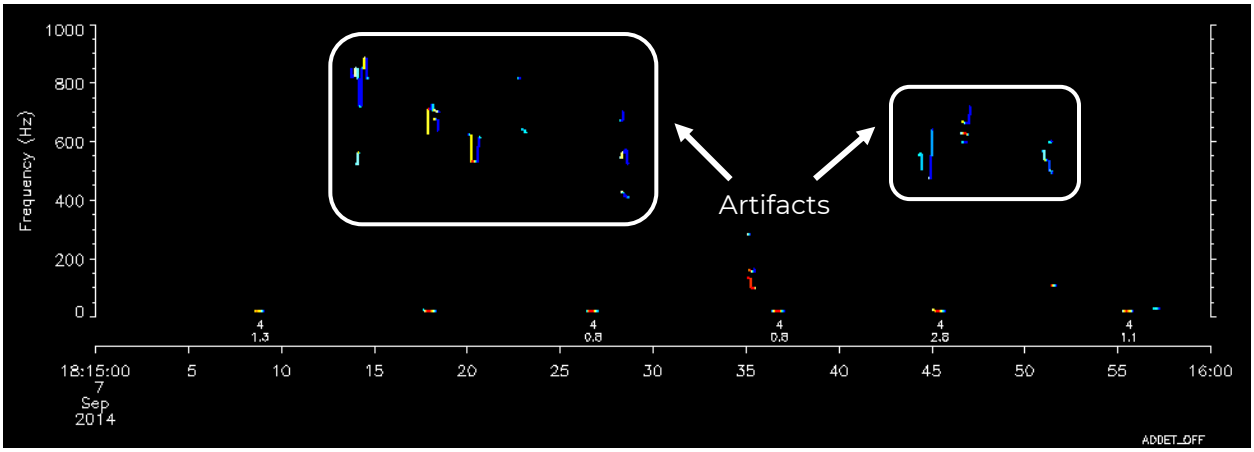


Figure 101. Example of artifacts (the straight vertical lines in the white boxes) in the pitch track data.

Isolation or Context

The degree of isolation of a call from spurious pitch tracks or calls made by another species can be helpful in determining its source. Usually assessing the 5 seconds before and after the call can clue the analyst into possible noise or biological sources that could have produced a deceiving

pitch track. For example, if the call is surrounded by pitch tracks that look relatively similar and appear to be produced by random noise, the analyst should be more skeptical.

In other cases, it may be helpful to assess longer periods of time surrounding the call. Analyzing a full minute before and after a call or occasionally the entire 15-minute period can provide contextual information about other species present in the area that may be producing similar calls. For example, if there is a potential right whale upcall but humpback calling is also observed in the same period, the analyst should be cautious and assess whether the upcall appears to be "in rhythm" with the humpback song pattern or similar to calls that are in pattern or whether it is sufficiently isolated and dissimilar to be considered as a right whale. This situation is further described in the right whale General section of this document.

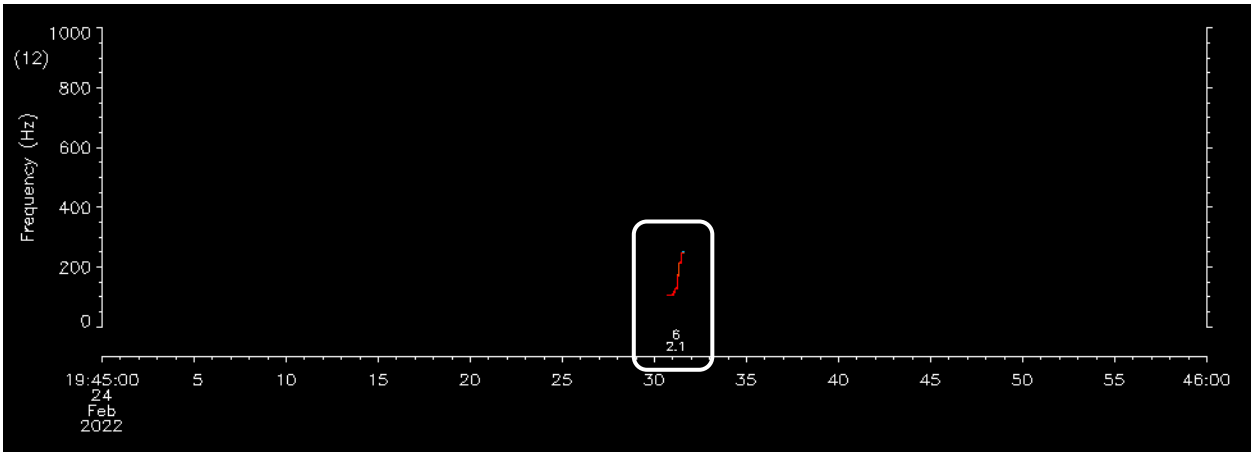


Figure 102. Example of a classified North Atlantic right whale upcall that is well-isolated from any potential background noise or possible humpback calls. It is also loud with a very nice shape.

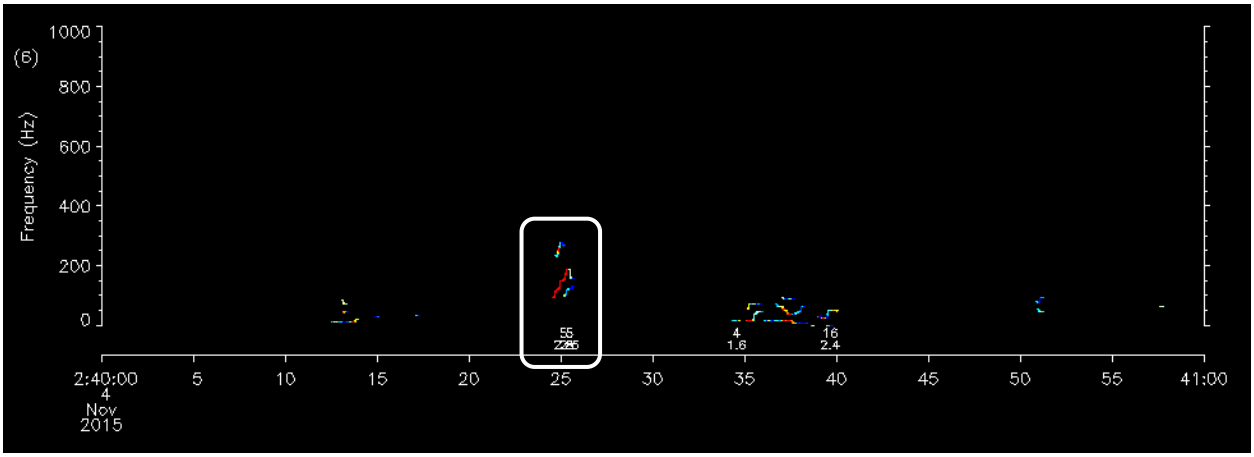


Figure 103. Example of a classified North Atlantic right whale upcall that is not as well-isolated from background noise. It may be a true call given its characteristic shape and louder amplitude, but should be approached with caution due to the faint spurious pitch tracks directly above and below it (potentially harmonics or echoes of the upcall) as well as the other clusters of spurious pitch tracks which are indicative of low-frequency background noise throughout the panel.

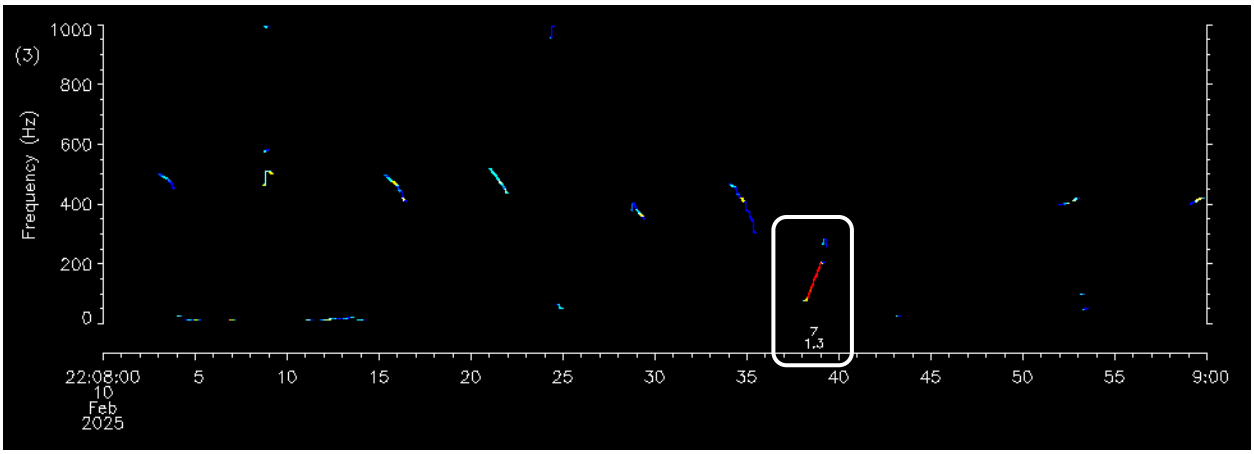


Figure 104. Example of a classified North Atlantic right whale upcall that has faint humpback song and low-frequency noise nearby, but can still be considered as isolated because it does not fall into the humpback song pattern. The good shape, classification, and amplitude difference between the louder upcall and faint humpback and noise are also good indicators that it is a true right whale call.

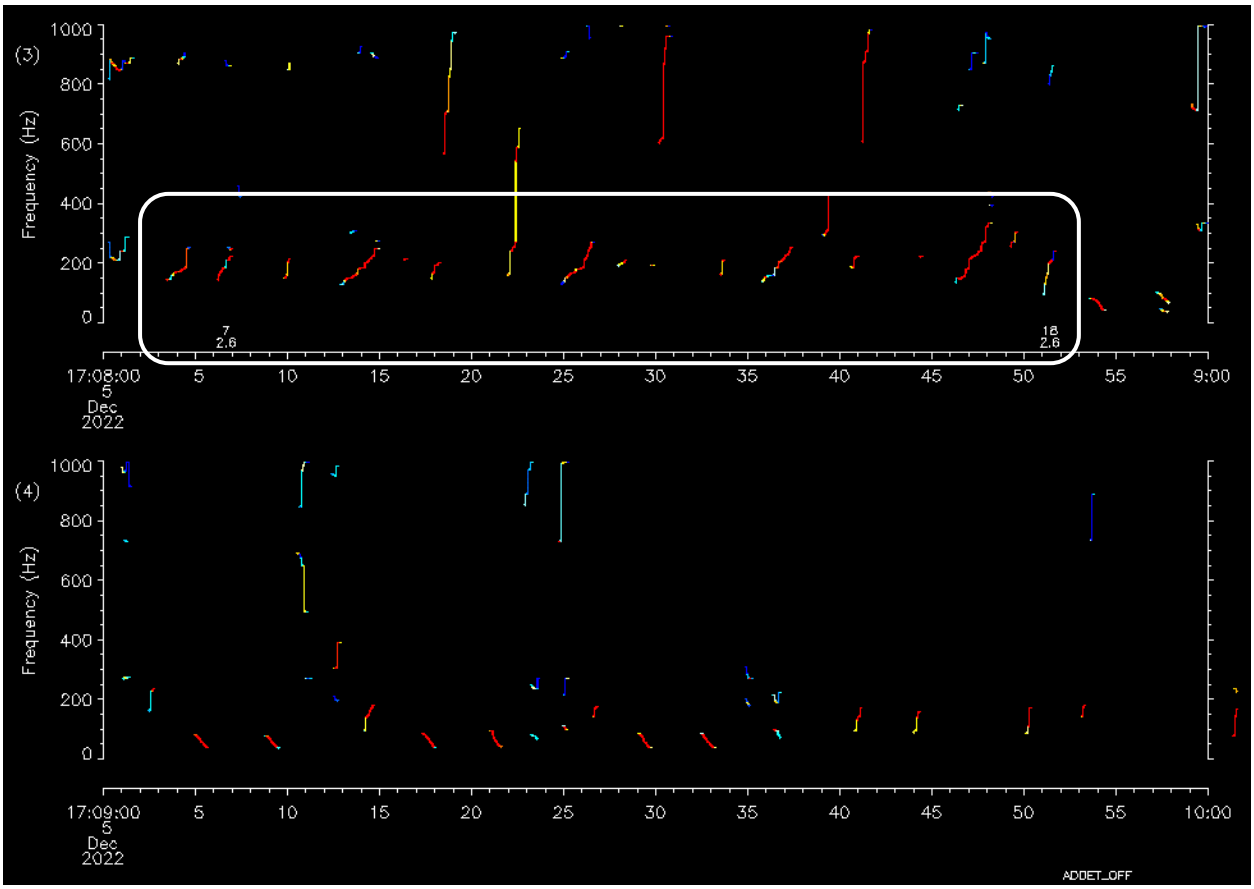


Figure 105. Example of classified and unclassified upsweeps that are not isolated given that they fall into the humpback song pattern as one of the themes (i.e., alternating with other patterned call types and shifting into a second theme of downsweep doublets in the second panel). This period would be scored as Not Detected for right whales and Detected for humpbacks. In the white box, one upsweep is misclassified as right whale likely due to its shape being similar. Another upcall is classified as the humpback call type 18, which is a longer, steeper upcall than most right whale upsweeps (but may be used interchangeably as a

right whale call type if the classified upcall is well-isolated from any potential humpback calls). In this case, both classified upsweeps are considered to be humpback since they are incorporated into a song pattern.

Classification

If the call has been classified by the DMON/LFDCS classification system and assigned a Species ID number (see the Using the "Pitch Track" Page section), that classification can be used to support whether a species is present or not. For sei, fin, and right whales, a summary period can be scored as "Detected" only if there are classified calls present. If there are no classified calls for these species in a period, then it can only be scored as "Possibly Detected" or "Not Detected." This is not true of humpback whales, however, since humpback calls change often and are typically not well represented in the call library. There may be cases when there is clear humpback song in a period but none of the calls are classified as humpback. In these cases, it may be appropriate to still score the period as "Detected" for humpback since the song pattern is easily identified.

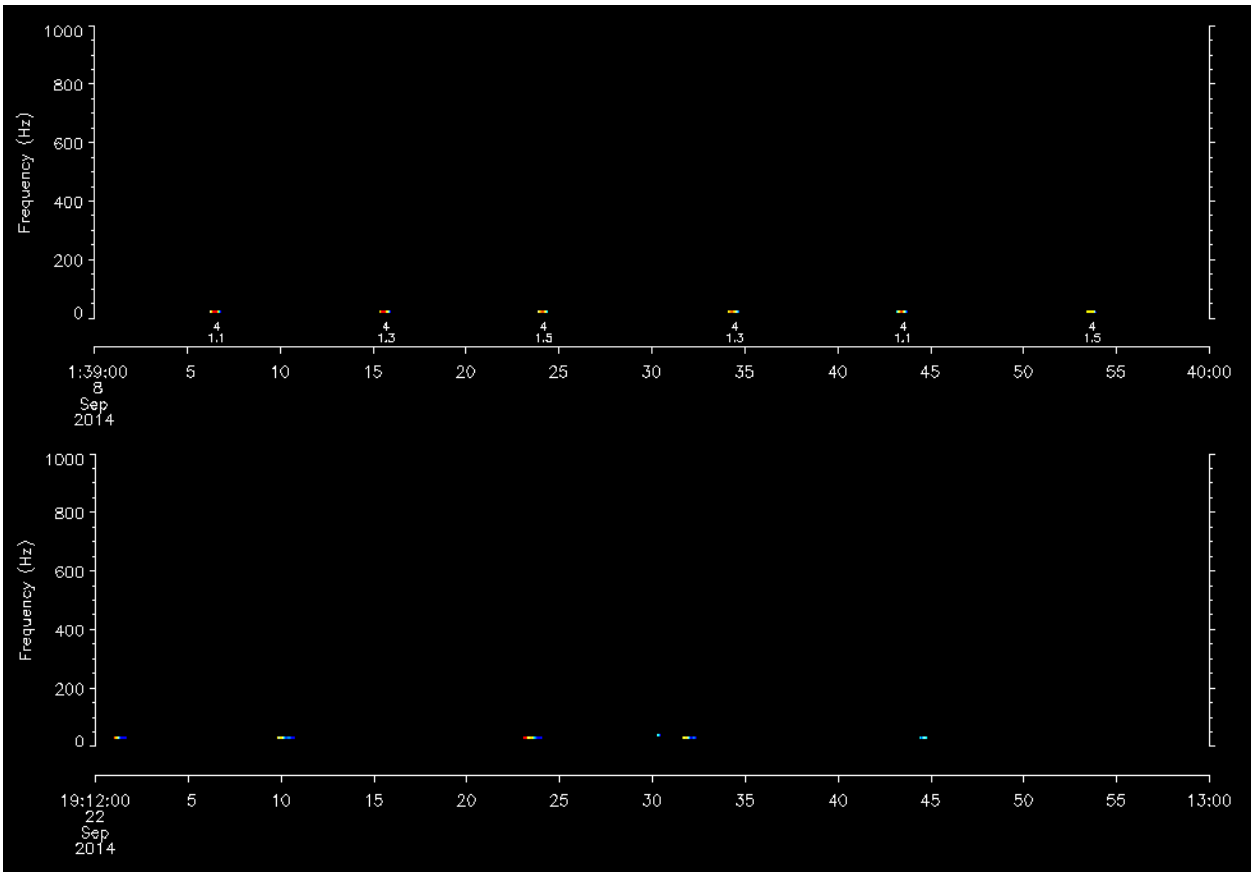


Figure 106. Example of classified fin whale pulses in the top panel and unclassified pulses that are likely just noise in the bottom panel. The classifications are especially helpful for species like fin whales because it is difficult to determine if the pulses are at exactly 20 Hz with the human eye. The clear, consistent pattern between the pulses in the top panel is also a helpful indicator that they are true fin whale pulses.

Distinguishing Between Noise and Biological Calls

All acoustic recorders pick up noise to varying degrees depending on the platform type and environment. This could be background noise from the surrounding environment, anthropogenic noise, or flow noise created by currents or a mobile platform moving through the water. Noise can make identifying biological calls difficult when analyzing both the real-time pitch track data or the archival audio recordings. In the real-time pitch track data, we can use our 4 main criteria for determining species presence to help identify pitch tracks that are just noise versus pitch tracks of true calls.

For example, pitch tracks that should be considered as background noise often appear faint (light to dark blue, i.e., with low amplitude). The pitch track shape should be considered because noise will usually appear messy with a lot of jagged pitch tracks and artifacts (think of a tangled ball of yarn or a child scribbling with a marker, versus a carefully drawn contour line). The context and classification should be considered because occasionally the classifier will try to identify calls incorrectly within the noise. Caution should be exercised if a classified sound or just a sound that resembles one of the characteristic species call types appear surrounded by "messy" spurious pitch tracks. It could just be noise that had similar characteristics to a known call type.

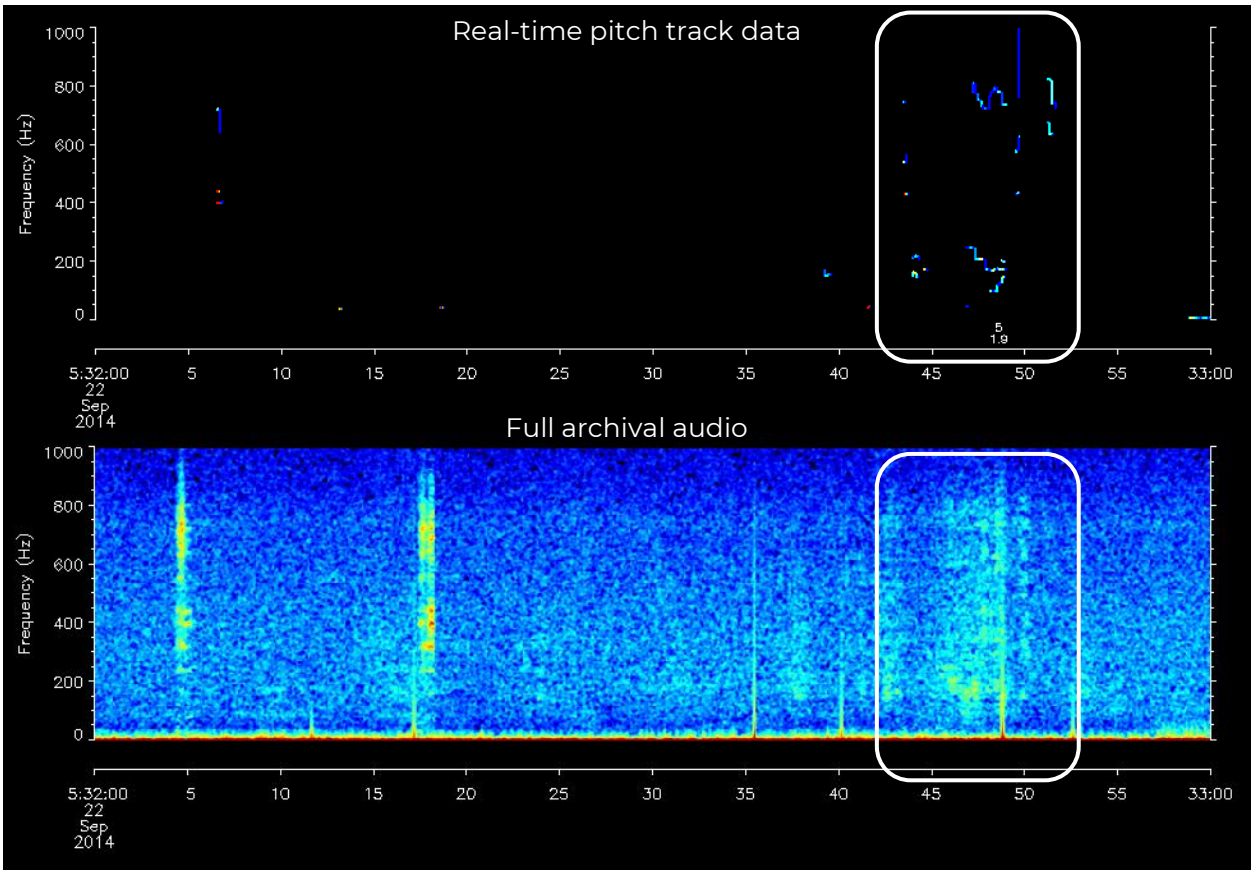


Figure 107. Example of pitch tracks generated in real-time of lower amplitude background noise in the white box in the top panel. The corresponding spectrogram from the archival audio (available after the real-

time platform has been retrieved) is in the bottom panel to provide insight into what is going on “behind the scenes”. Note there is a sound that was classified as a North Atlantic right whale upcall (call type 5), which can be identified by the real-time analyst as a false classification by considering the amplitude, shape, and context of the pitch track which is surrounded by other faint, jagged spurious pitch tracks.

Right Whale

Quick Guide

Table 2. Quick Guide for scoring North Atlantic right whale (*Eubalaena glacialis*) presence.

	LFDCS Classified (Y/N)	Pattern	Context	Number of calls needed
Detected	Y	None	If humpbacks present, assess for off-rhythm and/or different amplitude	3+, 1+ must be classified
Possibly detected	Y/N	None	If humpbacks present, assess for off-rhythm and/or different amplitude	1-2 classified or 3+ unclassified
Not detected	N	None	N/A	N/A

General

Right whales produce an upsweep between 50 and 300 Hz called the "upcall." For a detailed description of right whale call characteristics, see Parks et al. 2011 and Clark et al. 2010. In contrast to fin and humpback whale patterned calling (song), the upcall is not produced as often and typically does not occur in any recognizable pattern. The upcall is most often confused with a similar call sometimes produced by humpback whales, so context is particularly important when determining if right whales are present. Any upcalls observed concurrent with humpback-like pitch tracks should be treated with suspicion. Only upcalls that are "off-rhythm" with a humpback song or of different amplitude (e.g., humpback song is loud, upsweep is quiet) might be considered as produced by a right whale. Upcalls in complete isolation (i.e., without any evidence of humpback presence) are much more likely to be produced by right whales.

Detected

Right whales can be scored as "Detected" when 3 or more upcalls are detected, 1 or more of which is classified as a right whale upcall by the DMON/LFDCS, and there is no evidence of humpback whale presence. Please refer to the Roseway Basin project if you are unsure.

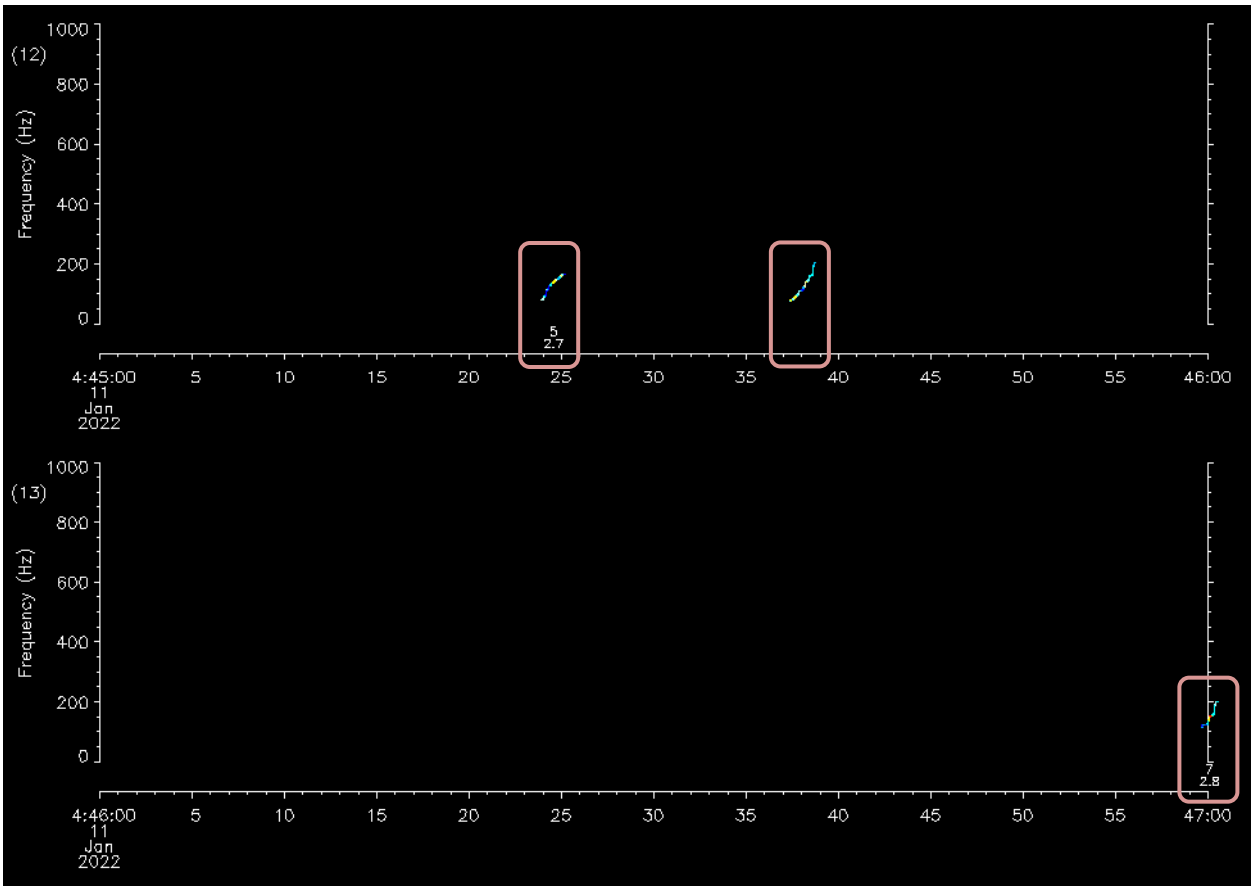


Figure 108. North Atlantic right whale (*Eubalaena glacialis*) "Detected" example 1: Multiple calls are present; no humpback whales (*Megaptera novaeangliae*) are present in the 15-minute summary period; the digital acoustic monitoring (DMON) instrument/ Low-Frequency Detection and Classification System (LFDCS) was able to classify two of the calls. Some calls may appear to extend past the edge of the spectrogram but are still legitimate, such as the upcall at the end of the second panel. Occasionally, a pitch-tracked call will appear entirely outside of the spectrogram but then is repeated in the next panel. In those cases, only the copy of the call that is included within the spectrogram in the next panel should be factored into the scoring criteria for species presence.

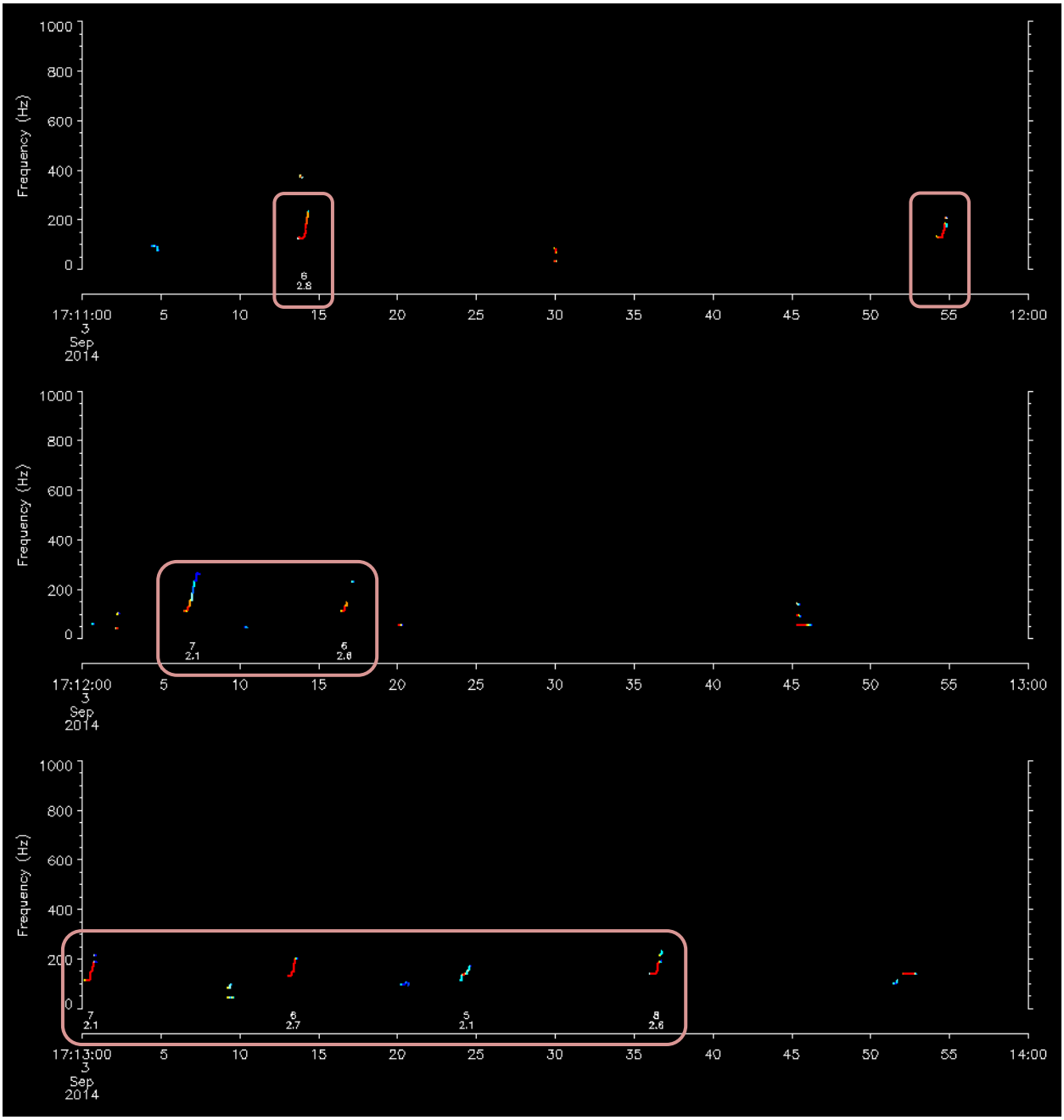


Figure 109. North Atlantic right whale (*Eubalaena glacialis*) "Detected" example 2: Many calls are present, all of which are loud; no humpback whales (*Megaptera novaeangliae*) are present in the 15-minute summary period; the digital acoustic monitoring (DMON) instrument/ Low-Frequency Detection and Classification System (LFDCS) was able to classify almost all calls.

Possibly Detected

If there are only 1 or 2 upcalls in a 15-minute summary period and they are both classified as right whale upcalls, then score as “Possibly Detected.” If there are 3 or more unclassified calls, score as “Possibly Detected.”

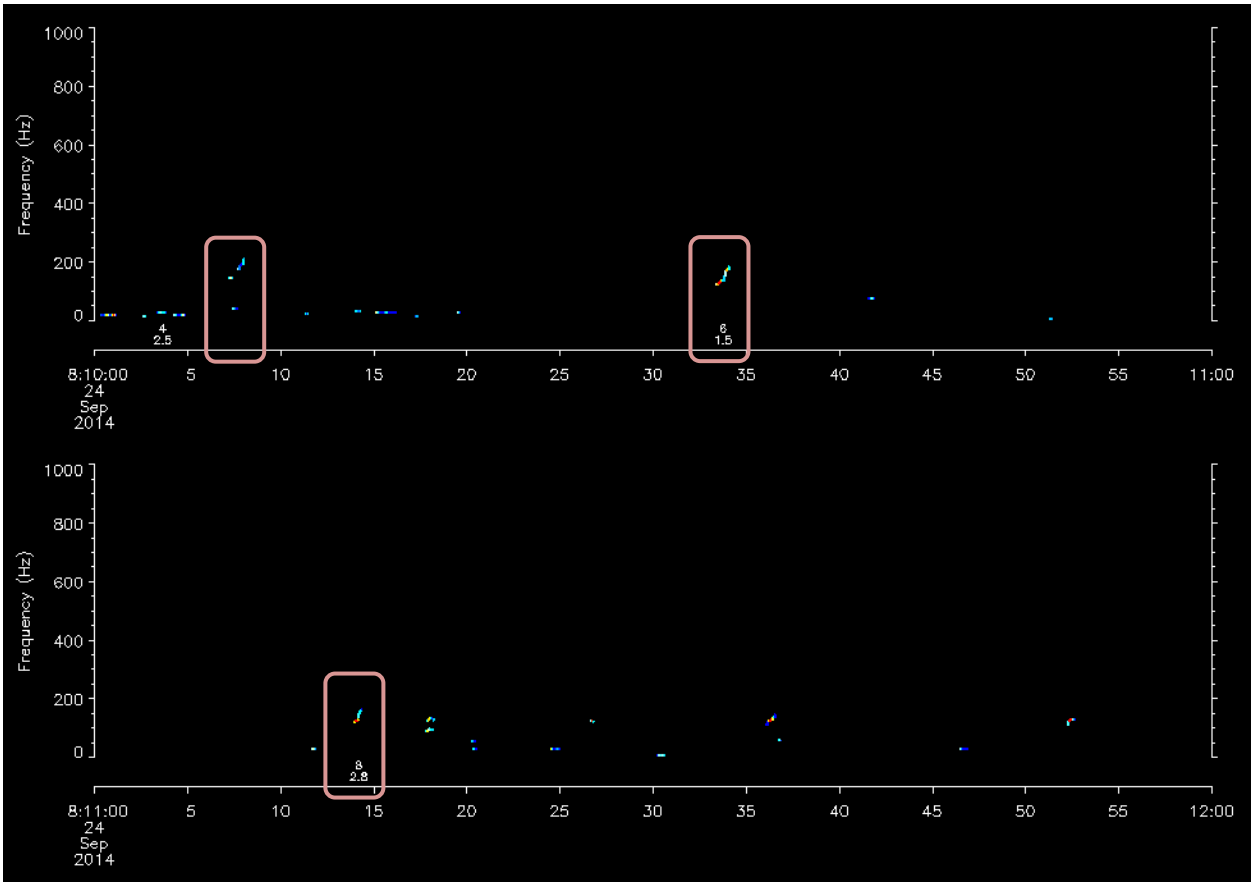


Figure 110. North Atlantic right whale (*Eubalaena glacialis*) "Possibly Detected" example 1: Multiple calls are present; no humpback whales (*Megaptera novaeangliae*) are present in the 15-minute summary period; the digital acoustic monitoring (DMON) instrument/ Low-Frequency Detection and Classification System (LFDCS) was able to classify two of the calls. Context should be considered here though, as there is low-frequency noise creating spurious pitch tracks in both panels. The first classified upcall (second red box) has relatively good shape and is somewhat isolated from the noise, however the upcalls in the first and third red boxes are shorter, fainter, and have spurious pitch tracks nearby. The overall quality and isolation of the three possible upcalls here are not good enough to score this period as “Detected” for right whales.

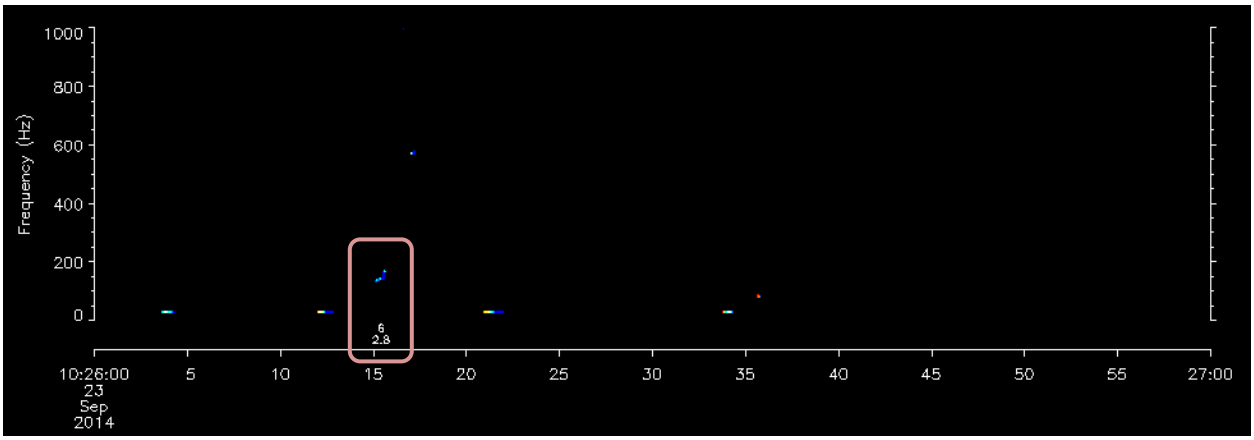


Figure 111. North Atlantic right whale (*Eubalaena glacialis*) "Possibly Detected" example 2: Faint call classified as a right whale is the only upcall in the 15-minute summary period.

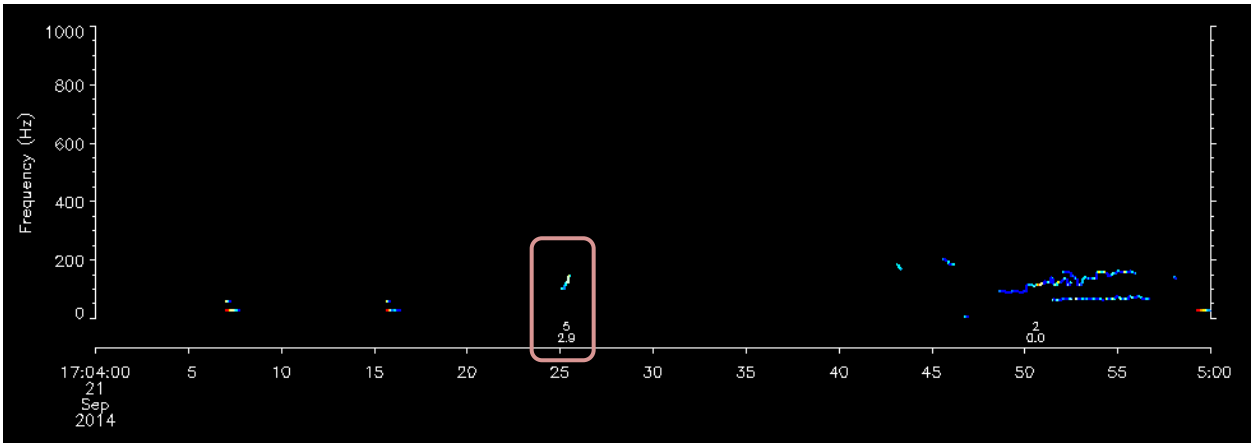


Figure 112. North Atlantic right whale (*Eubalaena glacialis*) "Possibly Detected" example 3: Faint call classified as a right whale is the only upcall in the 15-minute summary period.

Not Detected

If there are only 1-2 unclassified upcalls, mark the summary period as “Not Detected.” If there are singing humpbacks, be cautious. It is helpful to comment in the Notes section of the web form about your suspicions about possible right whale calls.

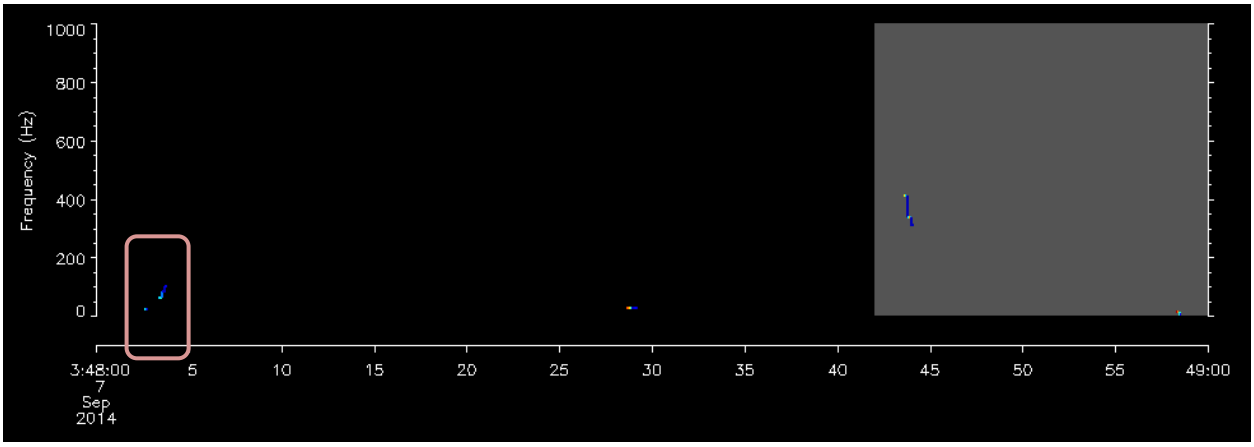


Figure 113. North Atlantic right whale (*Eubalaena glacialis*) "Not Detected" example: Not classified and is very faint; it is the only upcall in the summary period.

Sei Whale

Quick Guide

Table 3. Quick Guide for scoring sei whale (*Balaenoptera borealis*) presence.

	LFDCS Classified (Y/N)	Pattern	Context	Number of calls needed
Detected	Y	Doublets/triplets	If humpbacks present, exercise caution	3+ classified singles 1+ classified within doublet/triplet
Possibly detected	Y	No observed pattern	If humpbacks present, exercise caution	1-2 classified singles
Not detected	N	N/A	N/A	N/A

General

Sei whales emit downsweeps between 80 and 30 Hz that are produced in singles, doublets, or triplets. For a detailed description of sei whale call characteristics, see Baumgartner et al. 2008. Doublets or triplets are believed to be diagnostic of species presence. Low-frequency downsweeps in singles or singles in uniform succession can also be produced by humpback whales, so care must be exercised in the presence of other humpback whale sounds. However, the presence of clear doublets or triplets that are “out of rhythm” with a humpback whale song can be scored as sei whale downsweeps.

Sei whale downsweeps can have subtle variations in time-frequency characteristics that can be difficult to glean from viewing the pitch tracks. If the DMON/LFDCS has classified the call as a sei whale (call types 1-3), you can be confident that the shape, frequency range, and

duration of the call all conform to what is expected for a known sei whale downsweep. This can be helpful, particularly when other low-frequency downsweeps of dubious origin are present. Note that some sei whale downsweeps can be classified as call type 17 (humpback whale low-frequency downsweep). If calls of call type 17 are present (particularly in doublets or triplets) and there is no evidence of humpback presence, you should consider the possibility that sei whales are producing the calls.

Detected

To score a summary period as "Detected" for sei whales, several downsweeps should be present. As few as 2 downsweeps can be used to justify a "Detected" score if they are present in a doublet and at least 1 of the calls in the doublet is classified by the DMON/LFDCS as a sei whale call (call types 1-3). If there are many unclassified calls arranged in doublets with no evidence of humpback whale presence, the summary period can be marked as "Detected." Doublets or triplets are diagnostic of species presence; be sure that the calls that comprise doublets or triplets are ~3.5 seconds apart (Baumgartner et al. 2008). Exercise caution when only single calls are present; however, 3 or more classified single calls (not in a regular pattern) can be scored as "Detected."

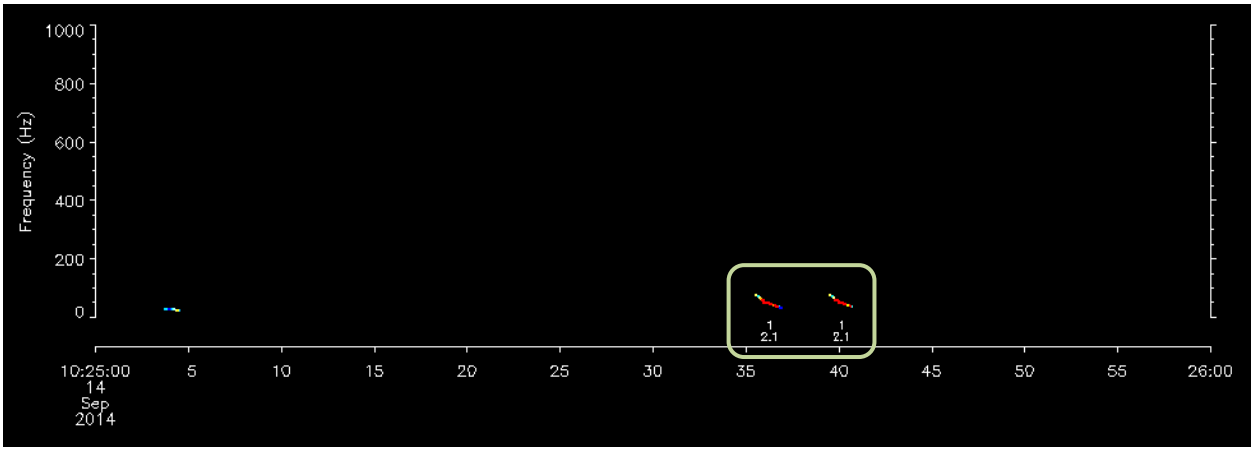


Figure 114. Sei whale (*Balaenoptera borealis*) "Detected" example 1: The digital acoustic monitoring (DMON) instrument/ Low-Frequency Detection and Classification System (LFDCS) has classified at least 1 (in this case, both) downsweeps within a doublet as sei whale, indicated by the small call type "1" underneath each downsweep.

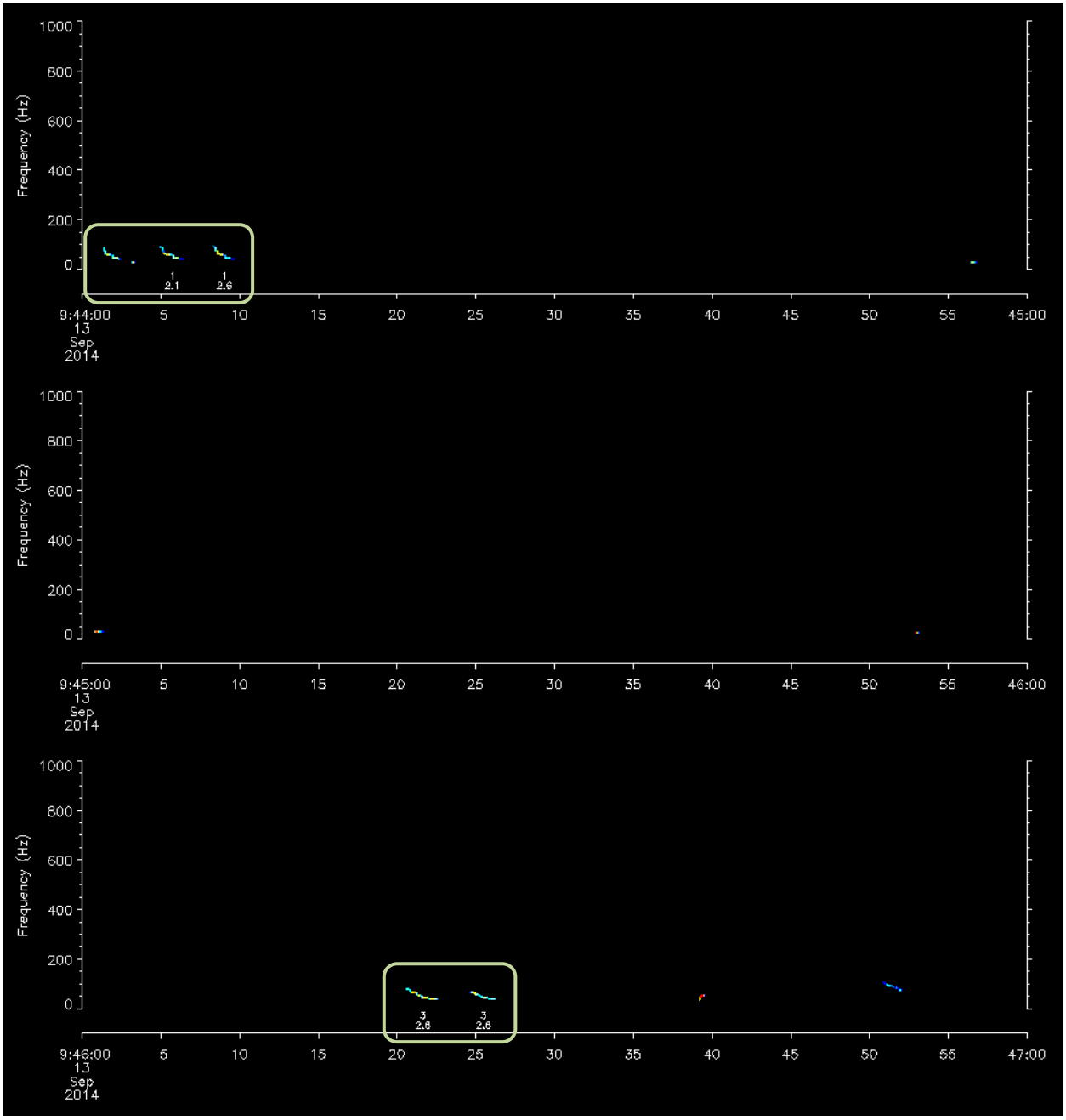


Figure 115. Sei whale (*Balaenoptera borealis*) "Detected" example 2: More than 1 call has been detected in a 15-minute summary period; the digital acoustic monitoring (DMON) instrument/ Low-Frequency Detection and Classification System (LFDCS) has classified most of the calls as sei whale and the downsweeps are in triplets/doublets.

Possibly Detected

If 1-2 single calls within the 15-minute summary period have been classified by the LFDCS as “sei,” then it can be considered “Possibly Detected” (other unclassified downsweeps could be present). If only a doublet is present but neither of the calls has been classified as sei whale

downsweeps, the summary period can be considered “Possibly Detected.” If humpbacks are present, exercise caution (see sei whale General section).

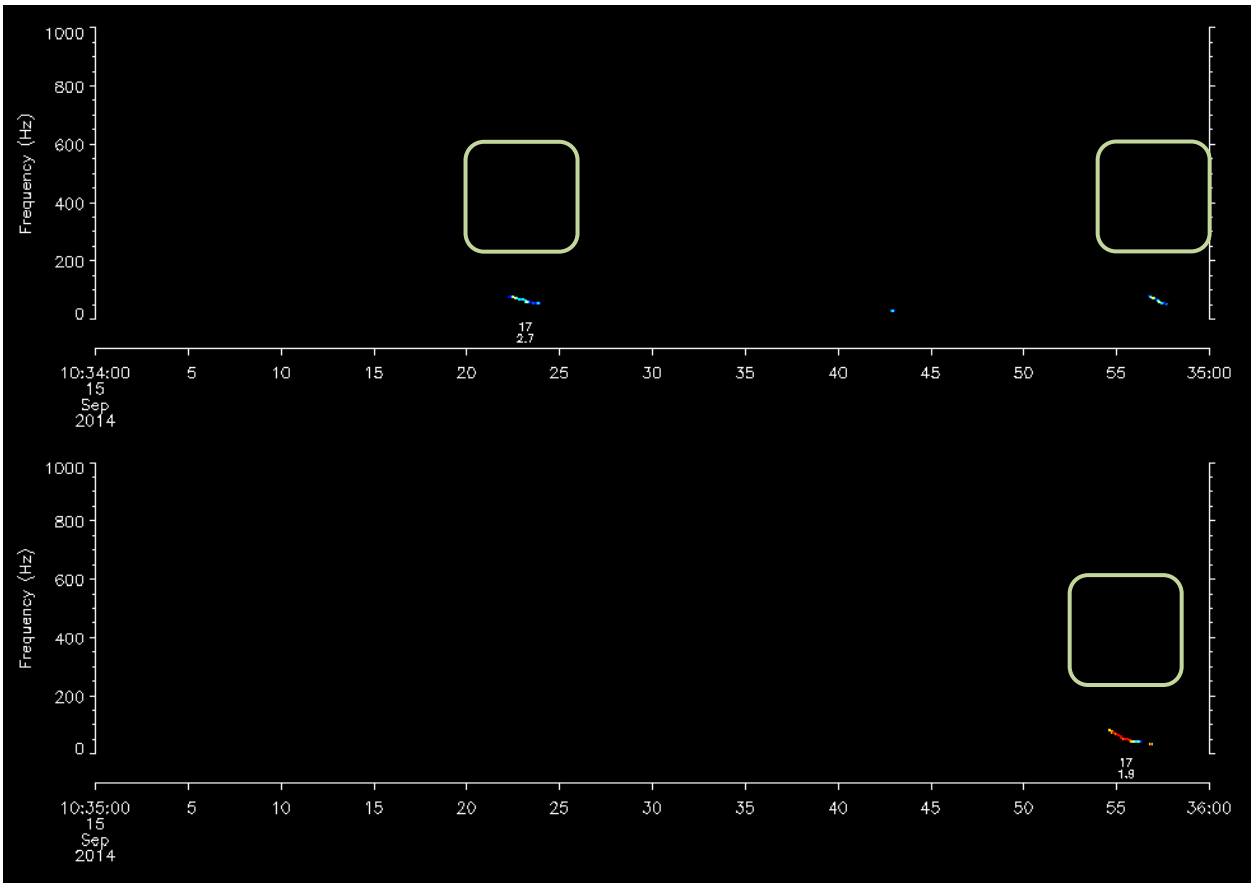


Figure 116. Sei whale (*Balaenoptera borealis*) "Possibly Detected" example 1: The digital acoustic monitoring (DMON) instrument/ Low-Frequency Detection and Classification System (LFDCS) has classified these calls as humpback whale (call type 17), but since there are no humpback whale (*Megaptera novaeangliae*) calls in the vicinity, the user can be more confident that these are sei whale calls; only 2 singlets are classified.

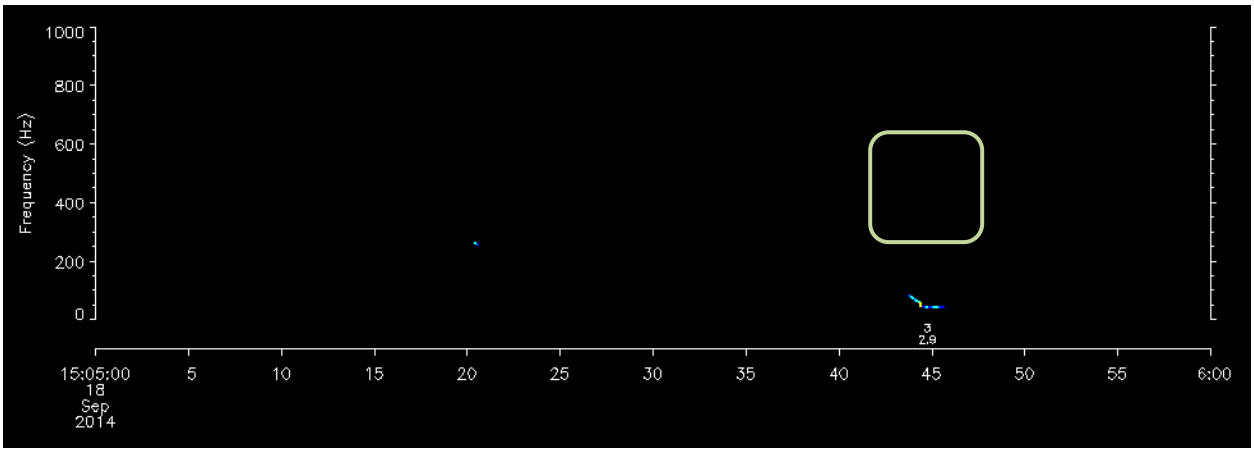


Figure 117. Sei whale (*Balaenoptera borealis*) "Possibly Detected" example 2: Only downsweep in the 15-minute summary period classified by the digital acoustic monitoring (DMON) instrument/ Low-Frequency **Detection and Classification System (LFDCS) as sei whale, no doublet/triplet, and the call is faint.**

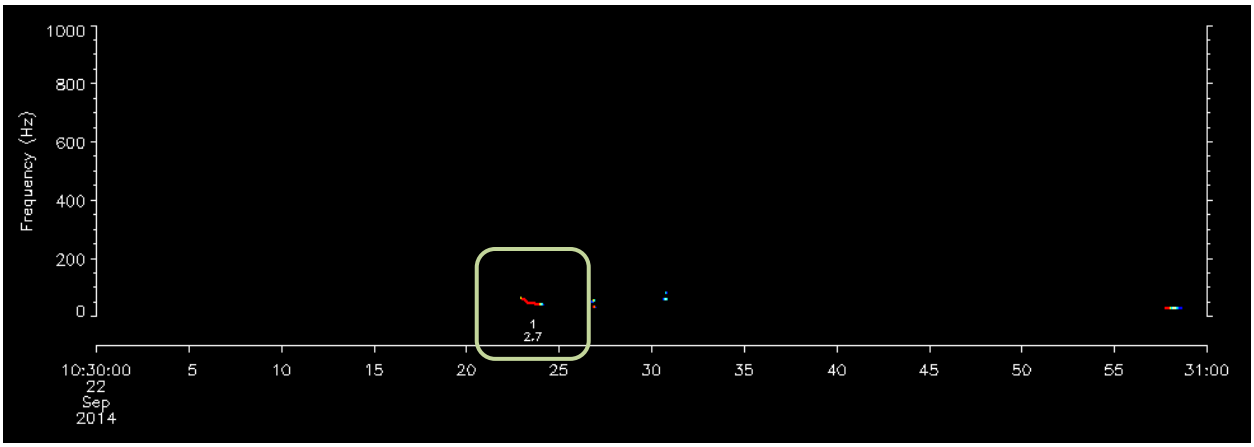


Figure 118. Sei whale (*Balaenoptera borealis*) "Possibly Detected" example 3: Only downsweep in the 15-minute summary period classified by the digital acoustic monitoring (DMON) instrument/ Low-Frequency Detection and Classification System (LFDCS) as sei whale, no doublet/triplet, and the call is loud.

Not Detected

If there is only one downsweep present within the 15-minute summary period but it is not classified, then it can be considered "Not Detected." If there are unclassified calls that look like they could be sei whales, but they are not in doublets/triplets, too long in duration, or not in the expected frequency band of 30-100 Hz, then score it as "Not Detected." It may be helpful to comment in the notes why you chose "Not Detected" if there are signals present.

Fin Whale

Quick Guide

Table 4. Quick Guide for scoring fin whale (*Balaenoptera physalus*) presence.

	LFDCS Classified (Y/N)	Pattern	Context	Number of calls needed
Detected	Y	Repeated with constant 8-16 s interval (do not count missing calls as part of pattern)	N/A	4+ consecutively classified calls with seasonally appropriate internote intervals (Morano et al. 2012)
Possibly detected	Y	3 calls in pattern with constant 8-16 s interval (do not count missing calls as part of pattern)	N/A	3 in pattern (2+ must be classified as fin)
Not detected	N	No pattern or irregular pattern	N/A	N/A

General

Fin whales emit 20-Hz pulses (downsweeps, but they often appear as short tonals in the pitch track data) that occur in regular patterns (song). Internote intervals (INIs) can be between 8 and 16 seconds. For a detailed description of fin whale call characteristics, see Delarue et al. 2008 and Morano et al. 2012. The DMON/LFDCS usually does a good job classifying these calls, so if you see a call that looks like a 20-Hz pulse but is not classified as one, be suspicious; it may be in the wrong frequency band, which is hard to judge at the scale you are typically viewing the pitch tracks. Calls comprising pulse trains should have similar amplitudes.

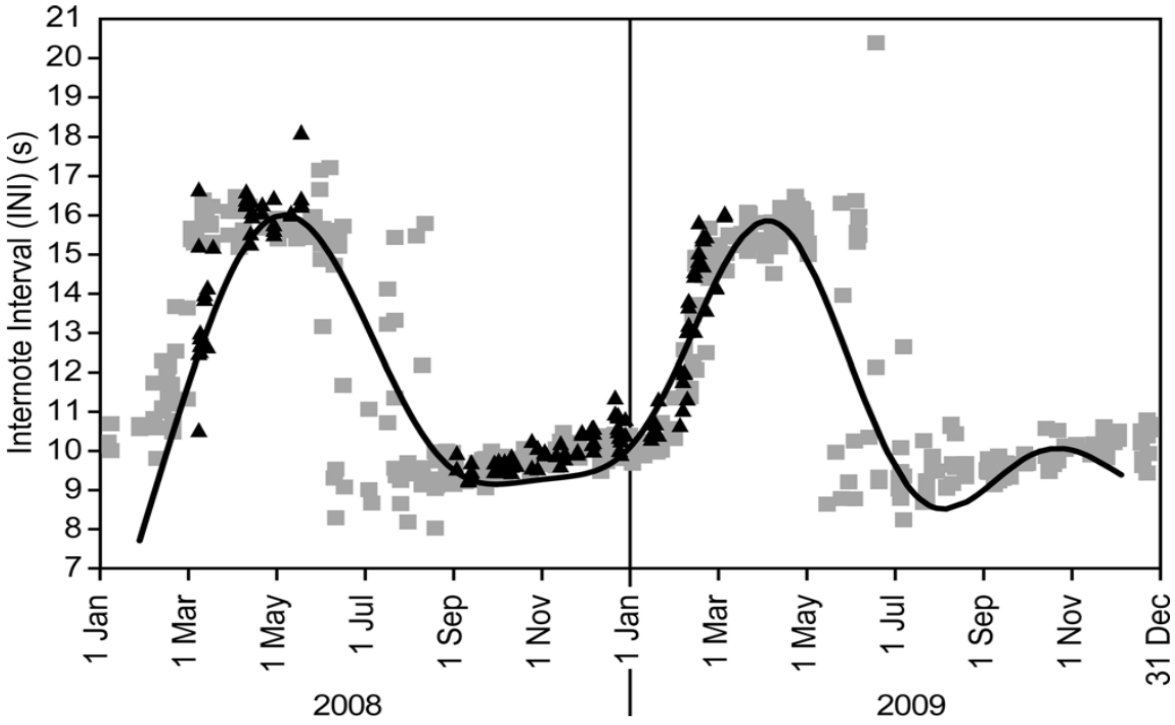


FIG. 3. INI of fin whale 20 Hz song notes measured for 1 January 2008–31 December 2009 in Massachusetts Bay (gray squares, $N = 481$ songs) and New York Bight (black triangles, $N = 129$ songs). The generalized additive model (black line) explains the seasonal changes in INI, where the short-INI season occurs in September–January, the long-INI season occurs in March–May, and February and June–August are transitional months.

Figure 119. Morano et al. (2012) figure which describes the seasonal shifts in fin whale (*Balaenoptera physalus*) internote intervals (INIs) in the western North Atlantic. In general, fin whale INIs may be in the longer 15-16 second range from March-May and in the shorter 8-9 second range from September-January. During the "transitional months" of February and June-August, it may be more common to observe variation in the INI duration.

Detected

Fin whales can be considered “Detected” if a pulse train comprised of 4 or more consecutively classified 20-Hz pulses with a constant INI of 8-16 seconds occurs in a 15-minute summary period (e.g., 4 pulses between which the INI is equal to 8 seconds, or 4 pulses between which the INI is equal to 12 seconds). Ideally, the INI will follow the trend specified in the Morano et al. 2012 paper. However, there may be some variation, especially in the transitional months.

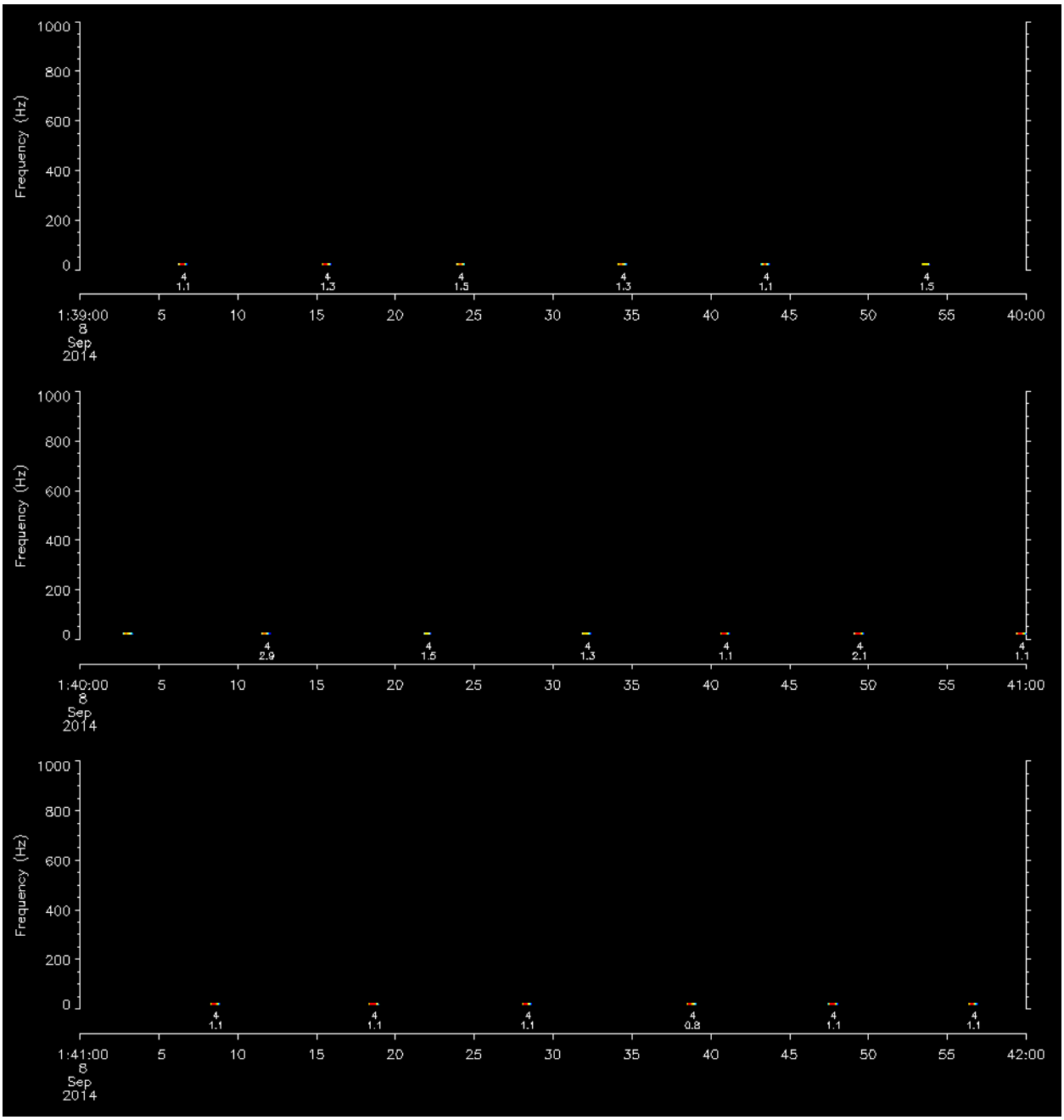


Figure 120. Fin whale (*Balaenoptera physalus*) "Detected" example: Many 20-Hz pulses regularly spaced every 10 seconds; this period was observed in September when fin whales in the western North Atlantic tend to transition down to 8-9 second internote intervals (INIs), so the shorter 10 second INIs make sense here; the digital acoustic monitoring (DMON) instrument/ Low-Frequency Detection and Classification System (LFDCS) classified most pulses.

Possibly Detected

When there are only 3 pulses in a pattern (2 or more of which have been classified by the LFDCS as a “fin whale”) and that is the only pattern of pulses in the 15-minute summary period, then it should be marked as “Possibly Detected.” Be careful that song bouts can be “broken,” particularly when the calls are faint (i.e., there is a silent period where a pulse should be based on the INI). Do not count missing pulses (i.e., “phantom” pulses) as part of the song bout. Exercise caution when there is an abundance of low-frequency noise that is being pitch tracked; some low-frequency sounds may look like fin whale calls, but it is difficult to discriminate frequencies by eye near the bottom of the spectrogram.

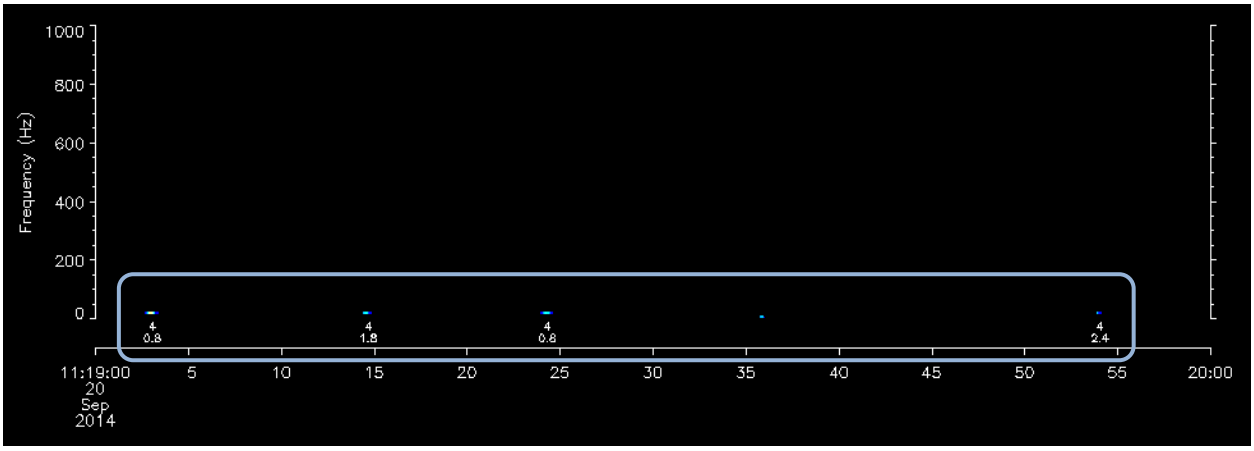


Figure 121. Fin whale (*Balaenoptera physalus*) "Possibly Detected" example 1: Multiple faint 20-Hz pulses showing regular internote intervals (INIs); however, at least 1 pulse is missing; the digital acoustic monitoring (DMON) instrument/ Low-Frequency Detection and Classification System (LFDCS) classified most pulses but there are not 4 consecutively classified pulses.

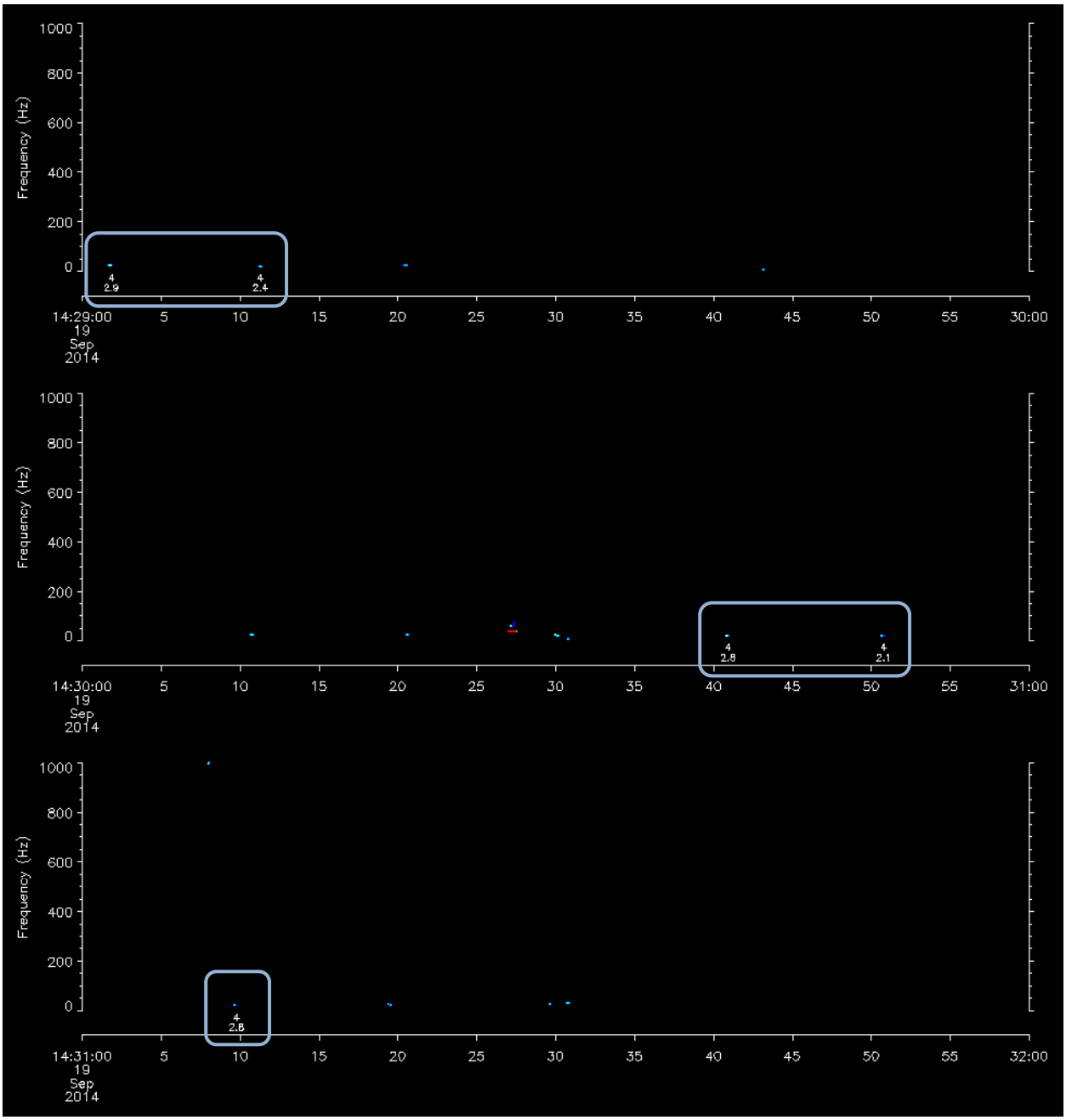


Figure 122. Fin whale (*Balaenoptera physalus*) "Possibly Detected" example 2: Multiple faint pulses with possible unclassified pulses before and after with regular internote intervals (INIs); the digital acoustic monitoring (DMON) instrument/ Low-Frequency Detection and Classification System (LFDCS) classified at least 2 consecutive pulses multiple times, but there are not 4 consecutively classified pulses.

Not Detected

For patterned pulses to be considered "Not Detected," none of the pitch tracks in the patterned pulses should be classified, the INI should vary, or the INI should not be within the 8-16 second bounds.

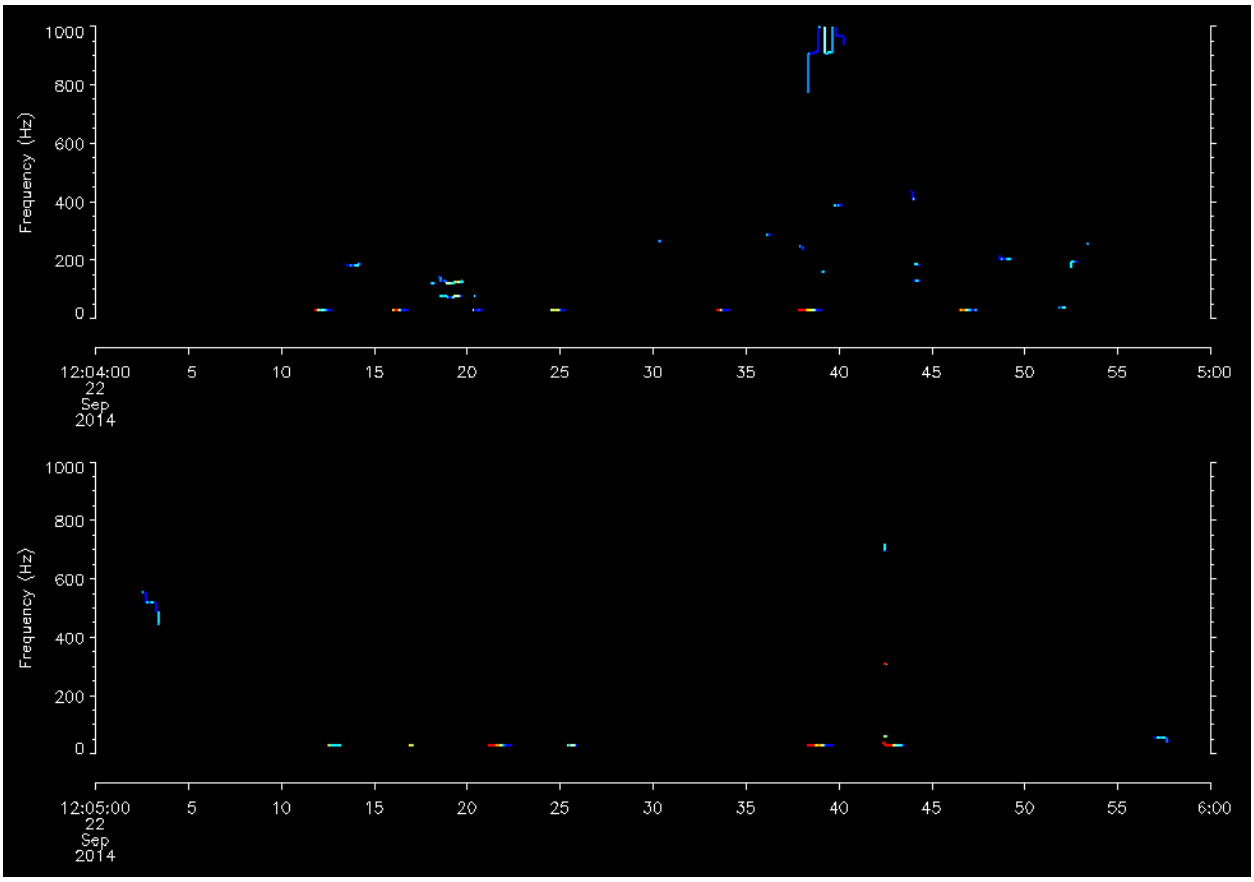


Figure 123. Fin whale (*Balaenoptera physalus*) "Not Detected" example 1: The digital acoustic monitoring (DMON) instrument/ Low-Frequency Detection and Classification System (LFDCS) did not classify pulses; internote interval (INI) is irregular (not between 8-16 seconds).

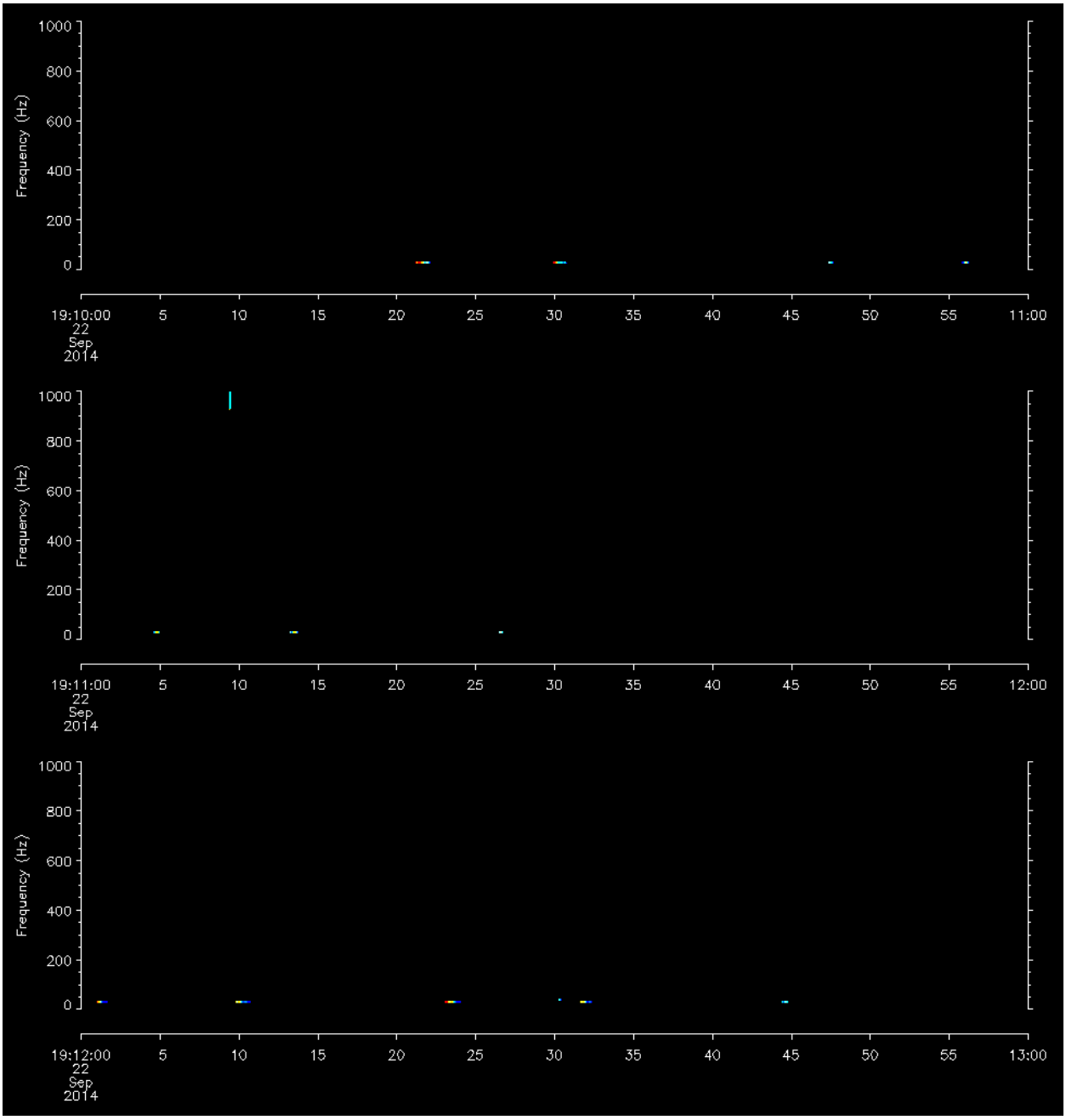


Figure 124. Fin whale (*Balaenoptera physalus*) "Not Detected" example 2: Pulses are regularly spaced, but digital acoustic monitoring (DMON) instrument/ Low-Frequency Detection and Classification System (LFDCS) did not identify the calls as fin whale pulses.

Humpback Whale

Quick Guide

Table 5. Quick Guide for scoring humpback whale (*Megaptera novaeangliae*) presence.

	LFDCS Classified (Y/N)	Pattern	Context	Number of calls needed
Detected	Y/N	Often many calls grouped together that are repeated	None	Many (5+)
Possibly detected	Y/N	Some calls in repetition or no pattern	None	Few (1-4)
Not detected	N	None	None	N/A

General

Humpback whale song is produced in identifiable patterns (unlike humpback social sounds, which have less patterned structure). Individual calls comprising these patterns can have frequencies ranging from 10s to 1000s of Hz. For a detailed description of humpback whale call and song characteristics, see Payne and McVay 1971, Payne and Payne 1985, and Winn and Winn 1978. These patterns are unambiguous in the pitch tracks when they are present and loud. The vast majority of humpback presence will be determined based on the presence of patterned song units, not from DMON/LFDCS classifications. Most humpback whale call types are not represented in the DMON/LFDCS call library, and those that are represented are many years old and may not be applicable to the sounds that humpbacks make today because humpbacks change their song from year to year, and their social sounds are not consistent over time or between populations. Therefore, DMON/LFDCS classification information for humpback whales should not be heavily relied upon (if at all).

Off the U.S. and Canadian eastern seaboards, we often believe that many unknown sounds are produced by humpback whales. While there are little data to back up this belief, it is based upon the idea that humpback whales produce such a high variety of different sounds; so, when an unknown loud tonal sound is encountered, it is assumed to be just another call in the vast humpback whale call repertoire. As such, you may encounter unknown, well pitch-tracked, loud frequency-modulated sounds in isolation (not accompanied by other sounds) that may or may not be produced with irregular intervals. These calls should be scored as "Detected" if you have other corroborating evidence of humpback presence (e.g., humpback singing in the previous 15-minute summary period), "Possibly Detected" if you have other evidence but there is still some doubt, or "Not Detected" if you have no additional evidence for species attribution. Whatever you score, be sure to explain your reasoning in the Notes section for these types of calls. To emphasize again, our overriding principle is to be conservative, so only mark a summary period as "Detected" if you are very sure of that species' presence.

Noise in the upper half of the monitored frequency range can create spurious quiet pitch tracks that sometimes resemble faint humpback calling. Pitch tracks that are in the 500-1000 Hz band, are faint, and change frequency very quickly (making them look almost disjointed) should be viewed with some suspicion.

Detected

If you see patterned calling (i.e., song), then mark the summary period as “Detected” for humpback whales. If patterned calling is not present, look for frequency-modulated calls of moderate to high amplitude (loudness) that are not attributable to any other species. Calls will not necessarily have a DMON/LFDCS classification as the system does not recognize all the types of calls a humpback can make. Most of the time, in the tally table, humpback calls will be classified as “Other” because of this reason.

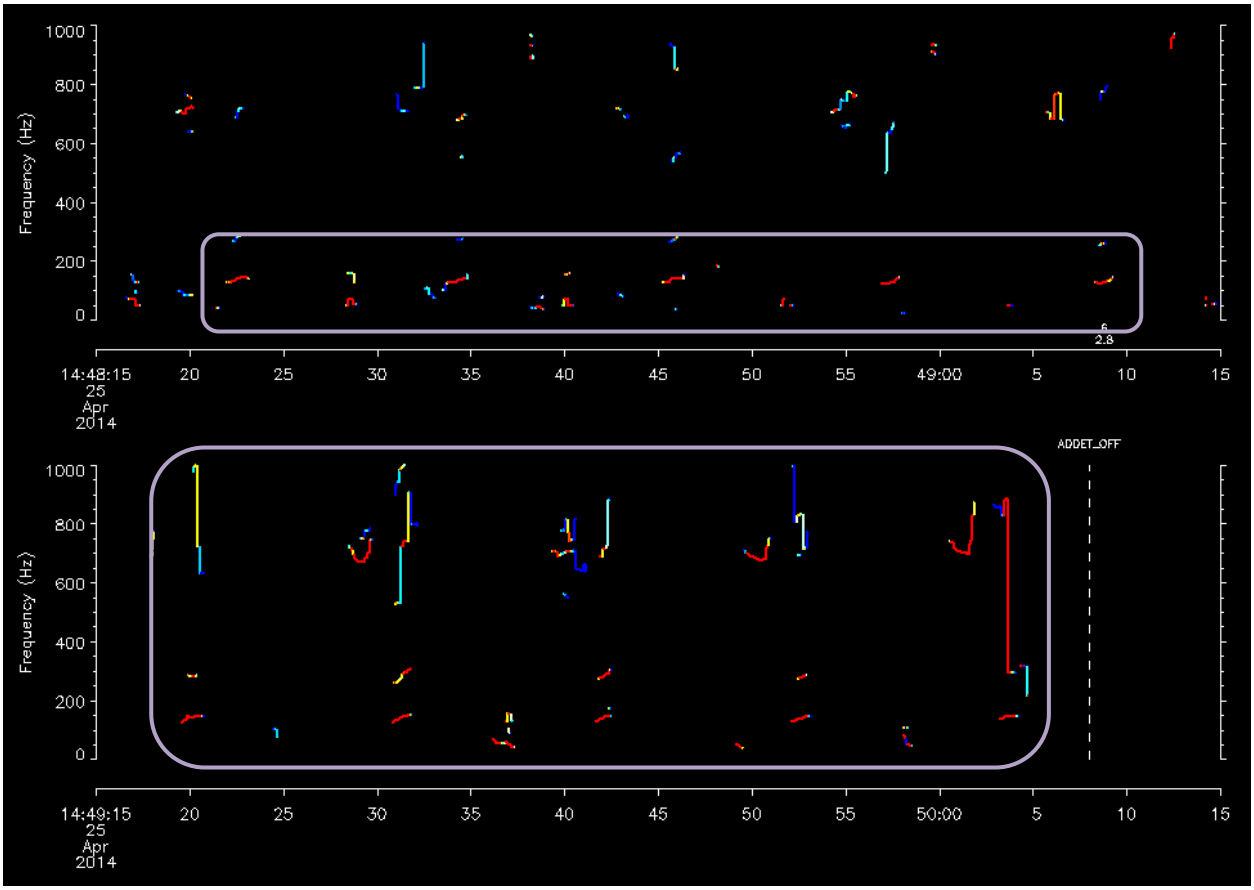


Figure 125. Humpback whale (*Megaptera novaeangliae*) "Detected" example 1: Loud frequency-modulated calls; clear pattern to the calls and classic song behavior; not readily attributable to any other species.

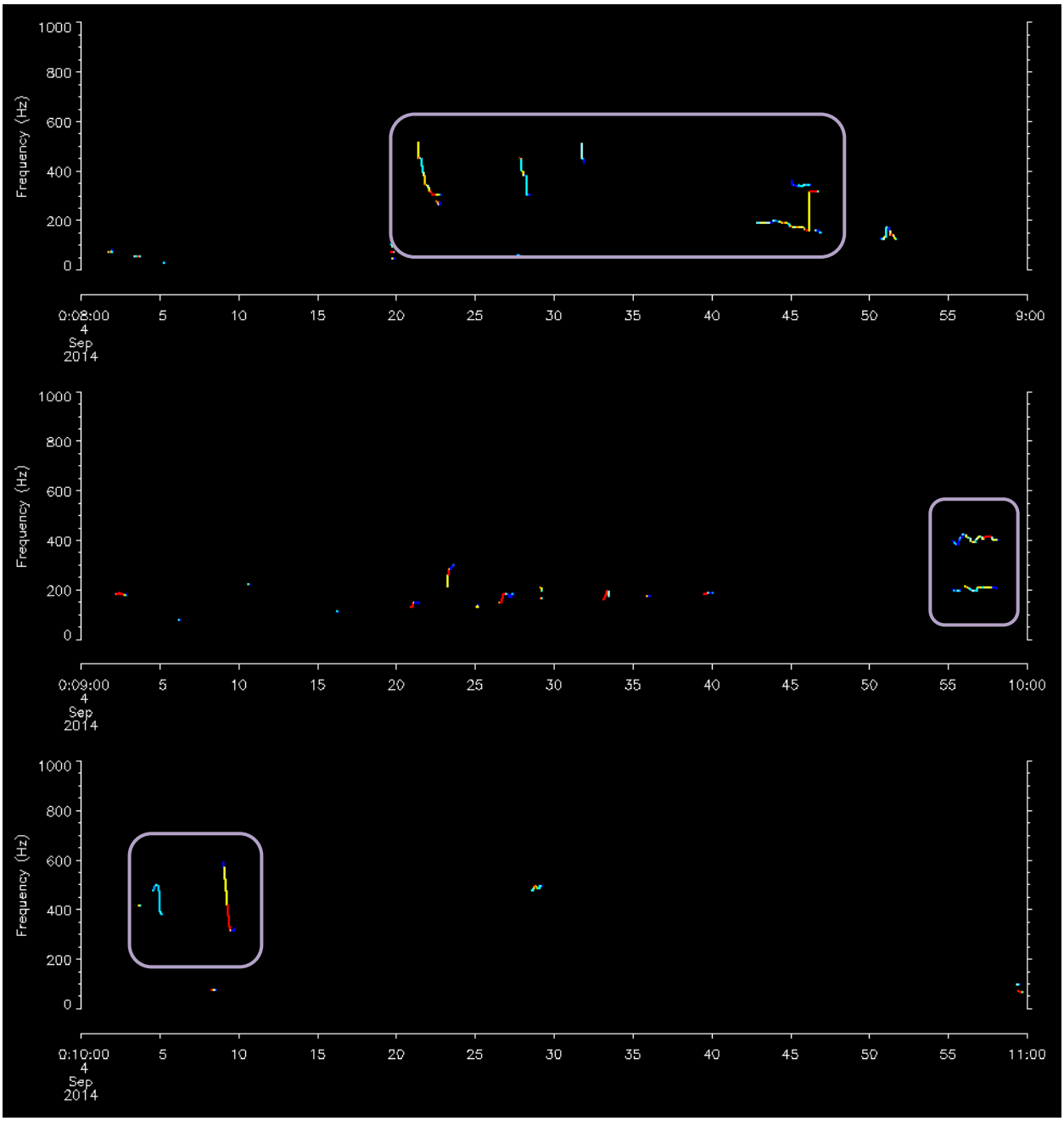


Figure 126. Humpback whale (*Megaptera novaeangliae*) "Detected" example 2: Loud frequency-modulated calls; 5+ semi-patterned calls over several minutes; not readily attributable to any other species.

Possibly Detected

Signals that are faint should be marked as “Possibly Detected.”

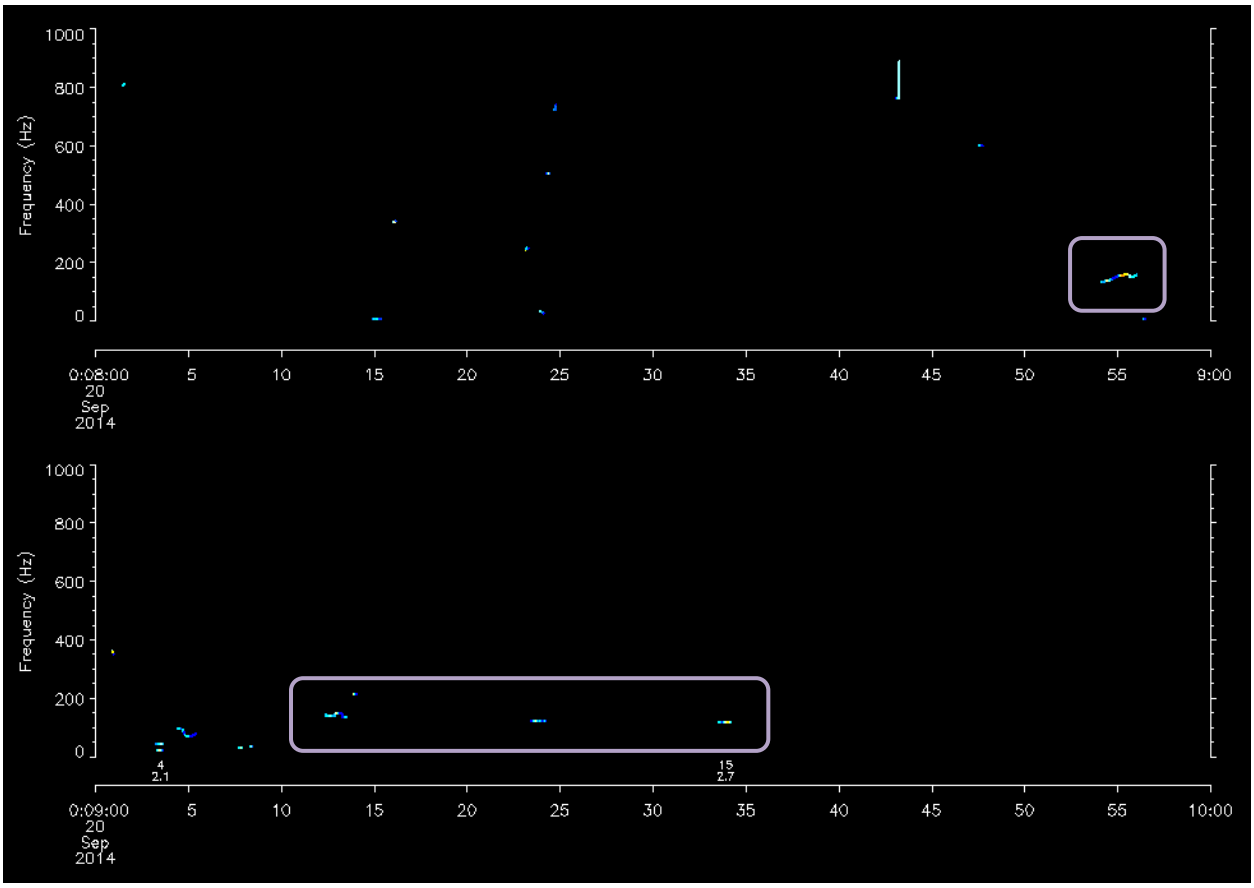


Figure 127. Humpback whale (*Megaptera novaeangliae*) "Possibly Detected" example: Multiple faint calls in a possible pattern.

Not Detected

When there are only a few possible faint calls, mark the 15-minute summary period as “Not Detected”, especially if artifacts are present.

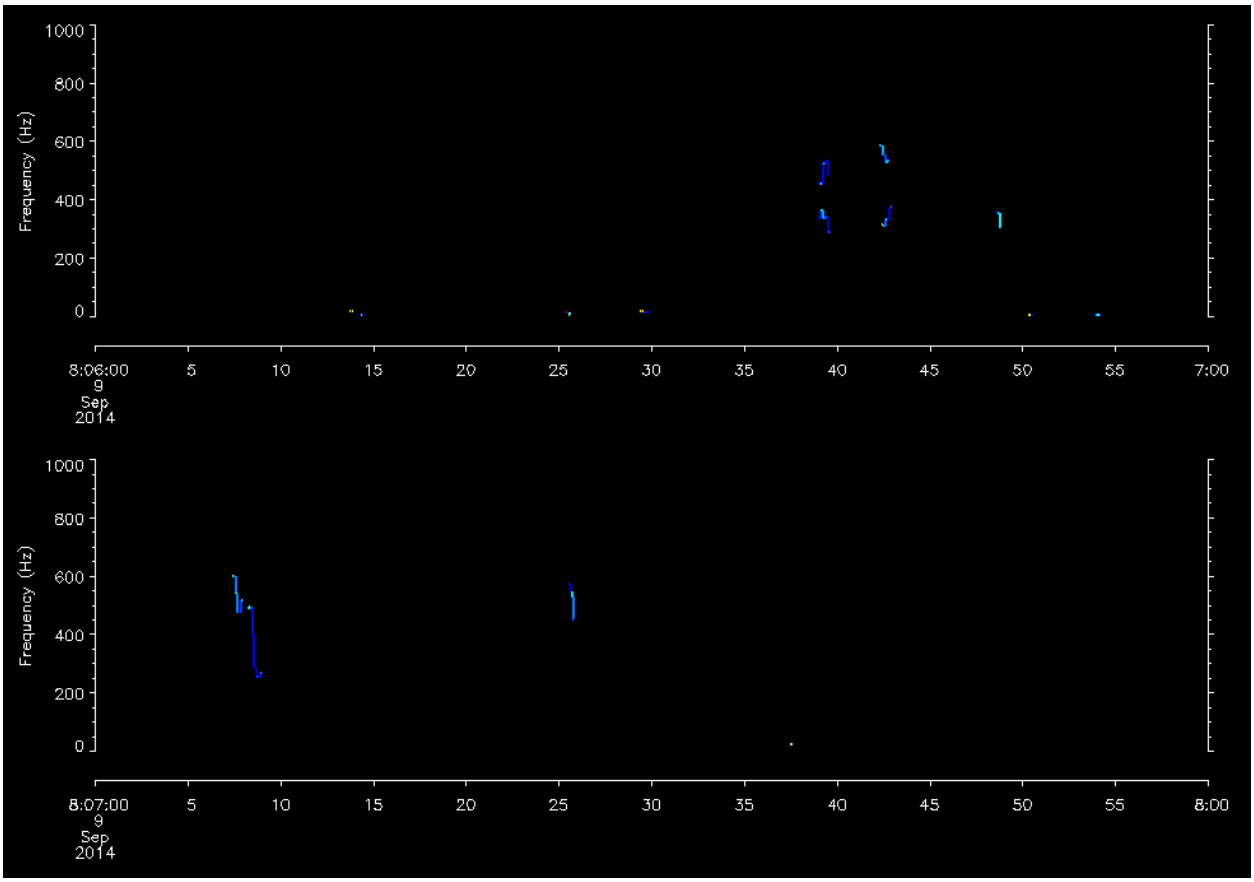


Figure 128. Humpback whale (*Megaptera novaeangliae*) "Not Detected" example: Possible calls are very faint and some have artifacts; difficult to tell if the calls are spurious or actual humpback calls.

Supplementary Protocol: Identifying Humpback Whale Song

Understanding Song Structure

Identifying Unique Themes

Humpback whale song has a hierarchical structure which is composed of units or “notes” (singular calls), phrases (short patterned series of units), themes (sections of repeating phrases), and multiple themes which make up a full song. While song patterns generally change from year to year, unique themes are often continued across years with some variation. Once a number of recognizable themes have been observed in a given year, those patterns can be used to help detect humpback whale presence for the remainder of that season.

Example of Humpback Song Units

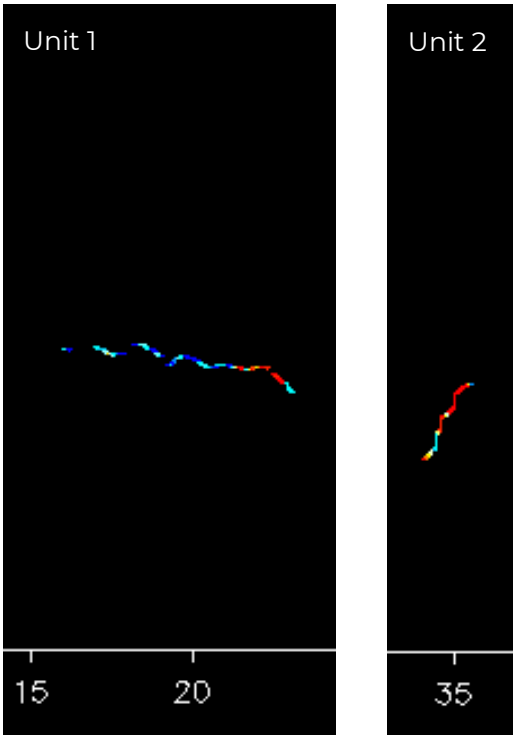


Figure 129. Example of 2 distinct humpback whale (*Megaptera novaeangliae*) song units.

Example of Humpback Song Phrase

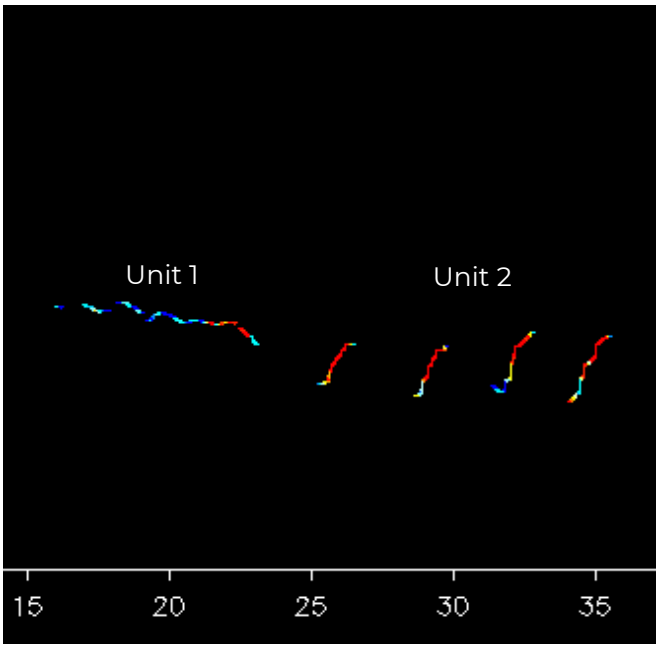


Figure 130. Example of a humpback whale (*Megaptera novaeangliae*) song phrase (patterned series of units).

Example of Humpback Song Theme

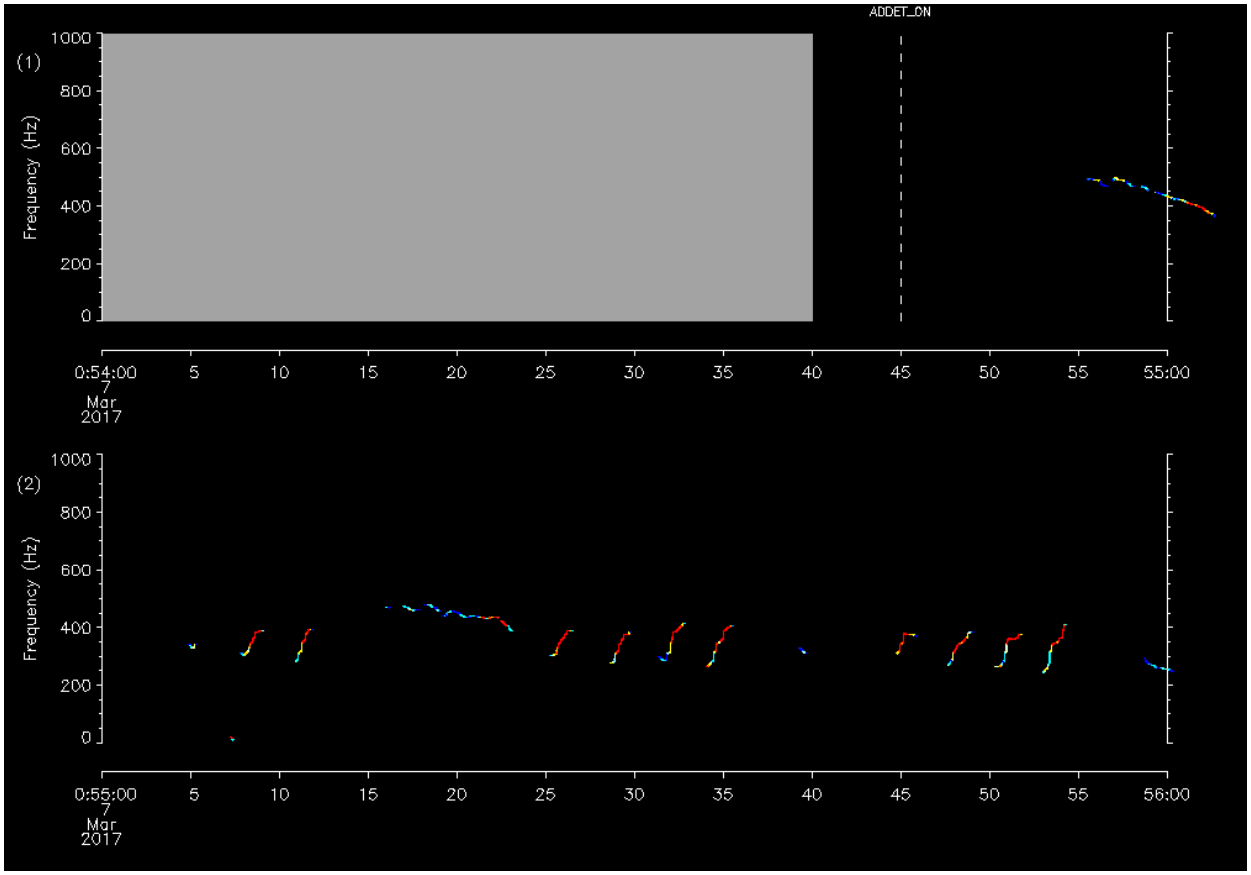


Figure 131. Example of humpback whale (*Megaptera novaeangliae*) song theme (repeating phrases).

Example of Humpback Song Fragment

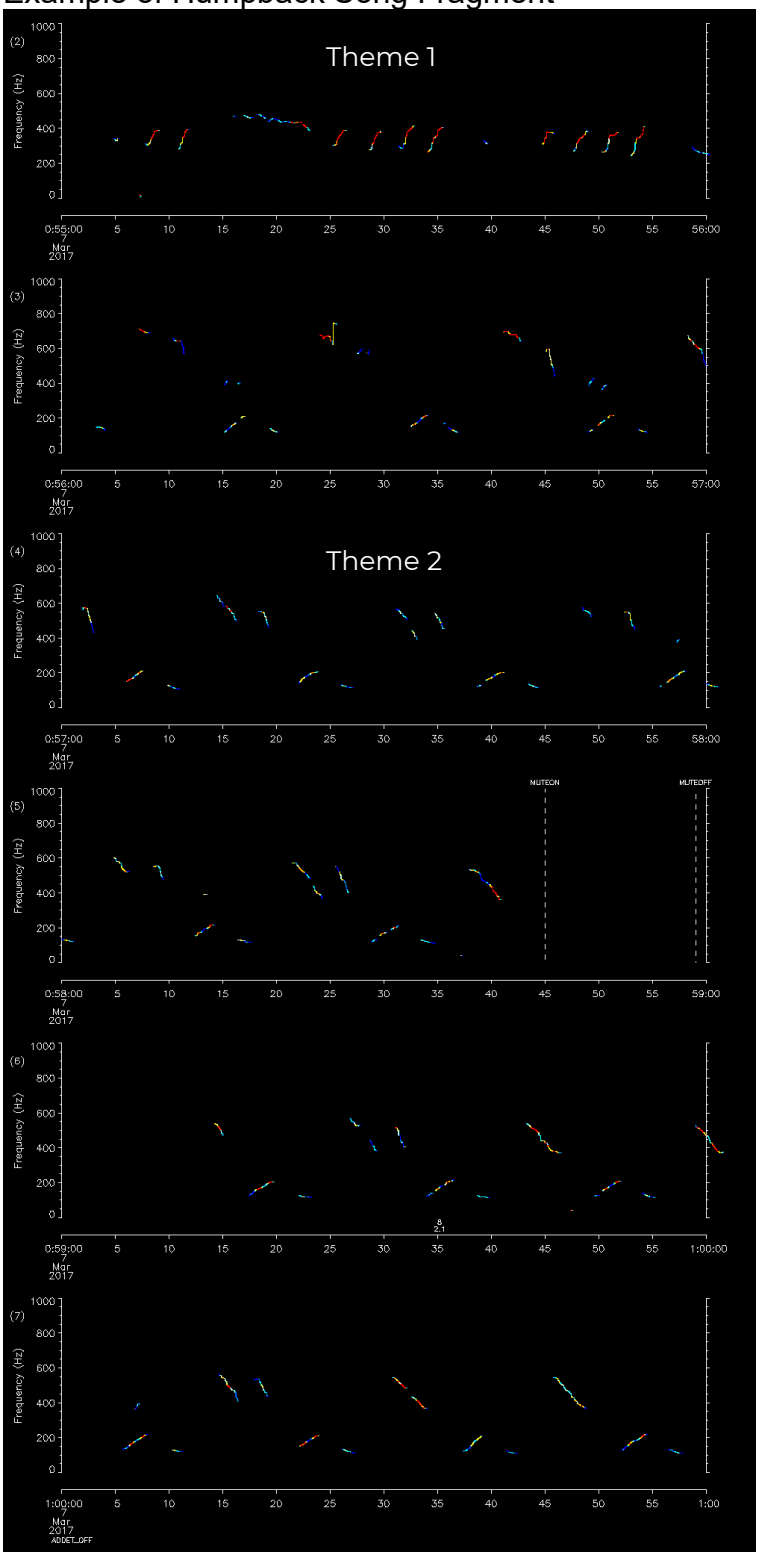


Figure 132. Example of humpback whale (*Megaptera novaeangliae*) song fragment, including 2 different themes.

APPENDIX A: PARAMETER FILE

To process a dataset with the LFDCS, you must create a parameter file that contains the metadata and parameters on how to process. This must be created for any processing run on a recorder. The parameter file has 2 main sections; the first half leading up to "CallLibraryFileBB" contains parameters that you may change in order to process your files correctly with the appropriate metadata. The parameters below "CallLibraryFileBB" contain all of the settings that have been tested and selected for the best results for the LFDCS. It is not recommended to change these, unless you are processing lower frequency data (in which case, see the "testparam_davis_et_al_LF_original_audio.txt" example parameter file under parameter_files\davis_et_al_examples in your LFDCS distribution files; also see the following Parameter File Processing Settings for 2 kHz and Low-Frequency Datasets section).

Example of Parameter File

```
            Experiment: Stellwagen Bank test dataset
                 Indir: /Users/psb/Projects/Detectors/lfdcs/test_dataset/raw
                Outdir: /Users/psb/Projects/Detectors/lfdcs/test_dataset/processed
             StartDate: 01/01/70 00:00:00
          PlatformType: moored_buoy
            PlatformID: NOPP6
        InstrumentType: MARU
          InstrumentID: 6
         FileExtension: wav
            FileFormat: WAV
          FileDateSpec: _YYYYMMDD_hhmmss
            Originator: Sofie Van Parijs
              Location: Stellwagen Bank National Marine Sanctuary
          ResampleRate: 2000.0
          FileDuration: 1800.0
                 Frame: 512
               Overlap: 0.75
                Smooth: 1

       CallLibraryFile: /Users/psb/Projects/Detectors/lfdcs/call_library/clnb_gom7/call_library_gom7.nc
     CallLibraryFileBB: /Users/psb/Projects/Detectors/lfdcs/call_library/clbb_gom/call_library_broadband_gom.nc
DetectionFileDuration: 5.0     ; how many days worth of autodetections to put in each detection file

                Scale: 0.0030  ; conversion parameters for spectrogram (dB -> unsigned short int)
               Offset: -100.0

   SpectrogramDuration: 30.0    ; duration of the spectrogram window to be processed (seconds); choose based on how
                                ; long longest call is expected to be
   PitchTrackingWindow: 25.0    ; duration of the window where pitch tracking will occur (seconds)
                                ; make a few seconds shorter than SpectrogramDuration because that time is used to
                                ; identify and remove transient and persistent broadband signals before a spectrum
                                ; can be moved into the spectrogram

  NoiseReductionWindow: 60.0    ; duration of the window over which spectrogram equalization will take place (seconds)
                                ; equalization occurs by subtracting an exponentially-weighted running mean from each
                                ; frequency band in the spectrogram; results are deviations in amplitude from the
                                ; background noise

    AvgFFTLowThreshold: -10.0   ; minimum level for how quiet the average FFT value can be relative to background to be
                                ; included in the exponentially-weighted running means; helps keep very quiet periods out
                                ; of the running mean used for spectrogram normalization (really specific to DMON1
                                ; hydrophone mute periods)
   AvgFFTHighThreshold:  10.0   ; maximum level for how loud the average FFT value can be relative to background to be
                                ; included in the exponentially-weighted running means; helps keep very loud broadband
                                ; noise out of the running mean used for spectrogram equalization
   AvgFFTDurationLimit: 300.0   ; indicates how long to tolerate running mean *not* being updated; after this period,
                                ; running mean is forced to reset

        BBP_InThreshold: 5.0    ; minimum level in spectrogram to indicate a persistent broadband sound - defines "loud"
                                ; broadband sound (dB)
         BBP_InDuration: 1.5    ; minimum duration of loud sound before ending pitch tracking (seconds)
       BBP_OutThreshold: 5.0    ; maximum level of spectrogram to indicate quiet after a persistent broadband sound (dB)
        BBP_OutDuration: 4.0    ; minimum duration of quiet period after a persistent broad sound to resume pitch
                                ; tracking (seconds)
        BBP_MaxDuration: 300.0  ; maximum duration of a persistent broadband sound - after this duration, the running mean
                                ; is reset and the persistent sound is considered part of the background

  BB_DetectionThreshold: 9.6    ; minimum level in spectrogram to trigger transient broadband detection (dB)
      BB_MinSegmentSpan: 150.0  ; minimum frequency range of a transient broadband segment (Hz)
        BB_MinTotalSpan: 200.0  ; minimum accumulated frequency range of all transient broadband segments of a broadband
                                ; signal (Hz)
BB_MinBroadbandDuration: 0.125  ; minimum duration of a transient broadband signal (seconds); min and max frequency of each
                                ; broadband segment is saved, then lowest min and the highest max are used to box out entire
                                ; transient broadband sound

     DetectionThreshold: 10.0   ; minimum amplitude in a spectrogram to trigger the DCS/pitch tracking (dB)
                                ; pitch track forward to locate the end of the call and pitch track backwards to identify
                                ; the start of the call (backward pitch track is final pitch track)
                                ; do it this way because the call will likely start earlier in time than when it is first
                                ; detected with the amplitude threshold (call ramps up at beginning and ramps down at end)
  CostGradientThreshold: 15.0   ; used to decide when to stop pitch tracking (i.e., to identify the start or end of the
                                ; call) (dB)
      DistanceWeighting: 20.0   ; weight associated with "jumping" an octave in frequency in successive time slices (dB)

        MinCallDuration: 0.25   ; minimum duration of a pich track to be kept as a legitimate call (seconds)
        MinAvgAmplitude: 10.0   ; minimum average amplitude of the pitch track to be kept as a legitimate call (dB)
           BlankingTime: 0.25   ; time before and after a time slice in the pitch track to be blanked or set to zero (seconds)
           BlankingFreq: 20.0   ; frequency above and below a time slice in the pitch track to be blanked or set to zero (Hz)
```

Figure 133. Example of a parameter file that a user would build prior to processing a new dataset in Low-Frequency Detection and Classification System (LFDCS). See Processing Datasets section for more detail.

Parameters (In Order as They Appear in Parameter File)

Note: Parameters that have "(metadata)" after the explanation indicate parameters that contain text to help you identify information about the dataset being processed and do not have any effect on how the detector is run.

- Experiment:

  A description of the study from which the recorder data comes (metadata).

- Indir:

  Input directory where all raw audio data resides.

- Outdir:

  Output directory in which subdirectories "specaudio" and "lfdcs" will be created and into which all output NetCDF files will be placed.

- StartDate:

  Reference date in MM/DD/YY HH:MM:SS text format giving date/time from which all times will be measured. It is recommended to use a generic start date such as "01/01/06 00:00:00". You may use any time that predates the recordings, but it is best to stay consistent.

- PlatformType:

  The type of platform from which the data come (e.g., mooring, glider; metadata).

- PlatformID:

  An identifier for the specific platform used (metadata).

- InstrumentID:

  An identifier for the channel to read. For multichannel data, this directs which channel to process (e.g., "5" in multichannel data will process the 5th channel). For single channel data, this can be set to "1".

- InstrumentType:

  The type of instrument with which the data was collected (e.g., Haruphone [HARU], Autonomous Multichannel Acoustic Recorder [AMAR],

Autonomous Underwater Recorder for Acoustic Listening [AURAL], digital acoustic monitoring [DMON] instrument, Marine Autonomous Recording Unit [MARU]). For the instrument types listed, this tells LFDCS how to read the audio format, and you do not need to include the FileExtension, FileFormat, or FileDateSpec parameters below. If you have a generic wave or aiff file, use the following 3 parameters. This parameter is primarily for legacy recorders such as the ones listed above. This can be considered metadata if the FileExtension, FileFormat, and FileDateSpec parameters are specified.

- FileExtension:

  The file extension listed for the raw audio being read (e.g., if raw audio files end with ".wav," then set FileExtension to wav).

- FileFormat:

  The format of the raw audio files. These are specific to file formats and identify which audio reader file LFDCS should use. In most cases, possibilities are: WAV (for 16-bit wave files), AIF (for aiff files), WAV24 (for 24-bit wave files), WAV32 (for 32-bit wave files), or NETCDF (for specaudio files). If you have additional formatted audio files that are unable to be processed, get in touch with Mark Baumgartner to see if he can create a custom script to read your files.

- FileDateSpec:

  A string indicating the format of the date/time encoded in the raw audio filenames; see list below for values. For special characters or any leading numeric/alphabetic characters to ignore, use an asterisk (*). You may include any separating digits such as a period, underscore, or dash (as it appears in the sound file name) to help direct lfdcs to the correct character stream; see examples of file names below. A string may contain any of the following values:

  - Y: year
  - M: month
  - D: day
  - h: hour
  - m: minute
  - s: second
  - f: fractions of seconds expressed in milliseconds
  - u: fractions of seconds expressed in microseconds
  - N: abbreviated month name (e.g., Jan, Feb, Mar)
  - S: seconds since midnight, January 1, 1970
  - X: any single character

- x: any single character
- *: any group of characters

Example:
For raw audio files that are in WAV format and have a filename that looks like this: audio_012015_131500-gom.wav, use the following:
FileExtension: wav
FileFormat: WAV
FileDateSpec: _MMDDYY_HHMMSS-
The date/time in the filename above would be interpreted as January 20, 2015 at 13:15:00.

Example:
For raw audio files that are in 24-bit WAV format and have a filename that looks like this: audio$jan20-2015-1315$gom.wav, use the following:
FileExtension: wav
FileFormat: WAV24
FileDateSpec: $NNNDD-YYYY-HHMM$
The date/time in the filename above would be interpreted as January 20, 2015 at 13:15:00.

- Originator:

  Person providing/collecting the data (metadata).

- Location:

  Location of the study. Should not contain any commas (,) or special characters as this might produce an error in the processing (metadata).

- TimeZone:

  Time zone in which date/times encoded in raw audio filenames are reported (e.g., UTC; metadata).

- ResampleRate (optional; samples per second):

  Specify resample rate if desired. Original sample rate is taken from the input audio files. A low-pass anti-alias filter is also used when resampling.

- FileDuration (seconds):

  Duration of a single NetCDF file audio/spectrogram file in the specaudio subdirectory. If original recorder files are longer than this, they will be broken up into smaller NetCDF files. Will not allow small raw files to be

compiled into larger NetCDF files. It is recommended to use a longer FileDuration setting such as “3600” because it will create fewer breaks in your specaudio files (if you try to create a clip of a sound that spans a specaudio file break, the clip will not work).

- Frame:

  Number of samples over which a single Fast Fourier Transform (FFT) will be calculated. See examples in paramfiles/Davis_etal folder for best settings found for the _2kHz and _LF processing.

- Overlap:

  Fraction of overlap of audio data between each successive FFT. See examples in paramfiles/Davis_etal folder for best settings found for the _2kHz and _LF processing.

- Smooth:

  Set to “1” to use 3´3 smoothing operator on each spectrogram; otherwise, set to 0. See examples in paramfiles/Davisetal folder for best settings found for the _2kHz and _LF processing.

- CallLibraryFile:

  Input NetCDF file containing narrowband call library.

- CallLibraryFileBB:

  Input NetCDF file containing broadband call library.

- DetectionFileDuration (days):

  Number of days’ worth of autodetection information to be stored in a single NetCDF file in the “lfdcs” subdirectory.

- Scale:

  Scale for converting the floating point spectrogram (units of dB) to unsigned short integer (default = 0.003).

- Offset:

  Offset for converting the floating point spectrogram (units of dB) to unsigned short integer (default = -100.0).

- SpectrogramDuration (seconds):

  Duration of spectrogram that is saved in memory. This should be many seconds greater than the longest anticipated call.

- PitchTrackingWindow (seconds):

  Duration of "window" over which pitch tracking is conducted. This should be many seconds greater than the longest anticipated call. Typically just a few seconds shorter than SpectrogramDuration.

- NoiseReductionWindow (seconds):

  Time scale over which exponentially weighted running mean is calculated to reduce tonal noise in each FFT frequency band (T in section IIB of Baumgartner and Mussoline [2011]; note e = 1 – exp(ln(0.02)Dt/T) in LFDCS – value 0.15 changed to 0.02 from equation 5 in Baumgartner and Mussoline [2011]).

- AvgFFTLowThreshold (dB):

  Minimum value of the average FFT relative to background that can be included in the exponentially-weighted running means. This parameter is included to keep unusually quiet periods out of the running mean used for spectrogram equalization (e.g., during DMON hydrophone shut-off).

- AvgFFTHighThreshold (dB):

  Maximum value of the average FFT relative to background that can be included in the exponentially-weighted running means. This parameter is included to keep unusually loud periods out of the running mean used for spectrogram equalization.

- AvgFFTDurationLimit (seconds):

  If the running mean is not updated for a period of time specified with this parameter, the running mean is forced to reset.

- BBP_InThreshold (dB):

  Minimum level of the average FFT to indicate the start of a persistent broadband sound. This parameter defines how loud the average FFT must be to consider it potentially the start of a persistent broadband sound.

- BBP_InDuration (seconds):

Minimum duration of a loud broadband sound (i.e., average FFT > BBP_InThreshold) before considering it a persistent broadband sound.

- BBP_OutThreshold (dB):

  Maximum level of the average FFT to indicate the end of a persistent broadband sound. This parameter defines how quiet the average FFT must be to consider it potentially the end of a persistent broadband sound.

- BBP_OutDuration (seconds):

  Minimum duration of quiet period after a persistent broad sound (i.e., average FFT < BBP_OutThreshold) to consider a persistent broadband sound is over.

- BBP_MaxDuration (seconds):

  Maximum duration of a persistent broadband sound. After this duration, the running mean is forced to reset, and the persistent sound is considered part of the background.

- BB_DetectionThreshold (dB):

  Minimum amplitude of an element in the spectrogram to trigger broadband sound processing (a_{bb} in section IIC of Baumgartner and Mussoline [2011]).

- BB_MinSegmentSpan (Hz):

  Minimum span of over-threshold elements in a single FFT to be considered a segment of a broadband sound (f_{bbseg} in section IIC of Baumgartner and Mussoline [2011]).

- BB_MinTotalSpan (Hz):

  Minimum total span of all segments combined in a single FFT to consider the FFT potentially "inside" a broadband sound (fS_{bbseg} in section IIC of Baumgartner and Mussoline [2011]).

- BB_MinBroadbandDuration (seconds):

  Minimum duration of sound to be considered a broadband sound (t_{bb} in section IIC of Baumgartner and Mussoline [2011]).

- DetectionThreshold (dB):

Minimum amplitude of an element in the spectrogram to trigger pitch tracking (a_{pt} in section IID of Baumgartner and Mussoline [2011]; default = 10.0).

- CostGradientThreshold (dB):

  Minimum gradient of cost function over 3 spectrogram time steps to end pitch tracking (g in section IID of Baumgartner and Mussoline [2011]; default = 15.0).

- DistanceWeighting (dB):

  Penalty in cost function applied for a frequency "jump" of 1 octave over 1 spectrogram time step (w in section IID of Baumgartner and Mussoline [2011]; default = 20.0).

- MinCallDuration (seconds):

  Minimum duration a pitch-tracked sound can last to be considered a legitimate call.

- MinAvgAmplitude (dB):

  Minimum average amplitude a sound can have to be considered a legitimate call.

- BlankingTime (seconds):

  Time before and after a time step in the pitch track to be blanked or set to 0.

- BlankingFreq (Hz):

  Frequency band above and below a time step in the pitch track to be blanked or set to 0.

Parameter File Formatting Tips

If you are using a Windows computer, you may need to include the hard drive letter in your file pathways in your parameter file (e.g., C:\Users\julianne.wilder\Documents\LFDCS\call_library\clnb_gom9\call_library_gom9.nc).

Parameter File Processing Settings for 2 kHz and Low-Frequency Datasets

If you are processing any deployments using the original LFDCS or the LFDCS 2.0 (on a Mac, Windows, Linux, virtual machine, or container), please check that your parameter files have the following values. There are different settings that you will need to have in your parameter file if you are processing low-frequency data (e.g., <128 Hz) versus if you are processing data at a 2 kHz sampling rate.

For both 2kHz and LF processing:
AvgFFTLowThreshold: -999.0; (unless processing glider data or DMON1 data. If so, use -10);
AvgFFTHighThreshold: 999.0; (unless processing glider data or DMON1 data. If so, use 10)

For 2kHz processing:
BB_MinSegmentSpan: 150.0;
BB_MinTotalSpan: 200.0;
BlankingFreq: 20.0;

For LF processing:
BB_MinSegmentSpan: 20.0;
BB_MinTotalSpan: 30.0;
BlankingFreq: 4.0

It is recommended that you make a copy of the correct parameter file from the examples that are included in your distribution file used to install the LFDCS, and then edit the top fields from there. That way, you ensure that your settings fit the sampling rate at which you process your data.

Example of parameter file for processing data at 2 kHz sampling rate:
supplemental\parameter_files\soundtrap_examples\testparam_soundtrap_2kHz.txt

Example of parameter file for processing data at 128 Hz sampling rate:
supplemental\parameter_files\soundtrap_examples\testparam_soundtrap_LF_from_2kHz.txt

It is important to note that there may be differences in the way your data will process and be pitch tracked if you process it from raw audio that has a higher sampling rate (e.g., 48 kHz) versus processing it from specaudio that was already resampled at 2 kHz. It is currently recommended that you process your higher sampling rate data down to 2 kHz with LFDCS first (see supplemental\parameter_files\soundtrap_examples\testparam_soundtrap_2kHz.txt in the distribution file), then reprocess it using a parameter file with the correct low-frequency settings (see supplemental\parameter_files\soundtrap_examples\testparam_soundtrap_LF_from_2kHz.txt in the distribution file).

Note: The InstrumentType, InstrumentID, ResampleRate, Overlap, and CallLibraryFile fields of the parameter files vary when processing 2 kHz sampled data versus when processing low-frequency data processed from 2 kHz specaudio. The FiledateSpec, FileExtension, FileFormat fields can be removed when processing low-frequency data from 2 kHz specaudio.

APPENDIX B: TIPS, TRICKS & COMMON ERRORS

Desktop Window Tips

Hover cursor over any button in the LFDCS window and scroll forward or back to select that button. This function can be used (rather than repeatedly clicking the mouse or touchpad on the computer) to scroll or page through the detections more easily. Note: If you are not paying attention, it is possible that your cursor might drift off the button you are scrolling on, causing your to incorrectly score sounds.

APPENDIX C: KNOWN IDIOSYNCRASIES

Artifacts of the Pitch Tracking Algorithm

This has been explained with examples in The Four Main Criteria for Determining Species section. It is important to note that not just humpbacks are susceptible to artifacts, but right whale upcalls and other frequency-modulated calls may have them as well.

Web Page Updates

If there is a “Daily analyst review” table in your project, it is important to note that after you have reviewed a pitch track (or multiple pitch tracks), it will take 5-10 minutes for your classifications to be shown on that table. This is also generally true for filling out forms; if you go back to review a recently modified form, you may see that the form has not been filled out. That is not true but rather that the web browser has not automatically refreshed the page. Simply refresh your browser page and the data that you entered into the form will be visible.

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