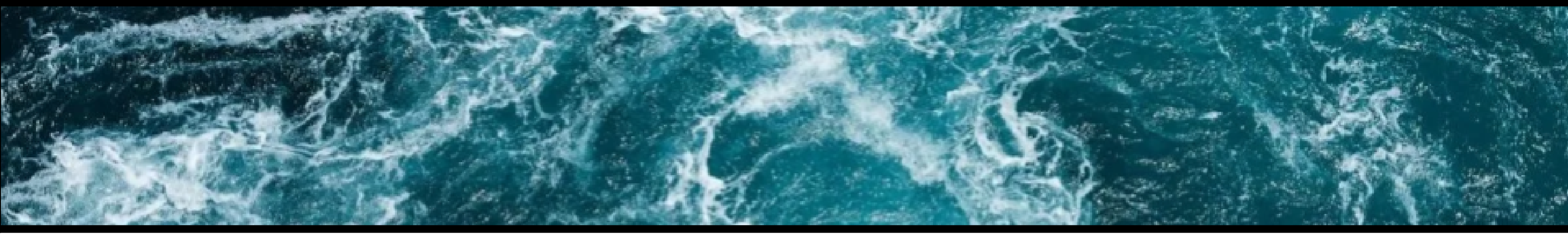

NOAA NEFSC Passive Acoustics Research Group

LFDCS Reference Guide

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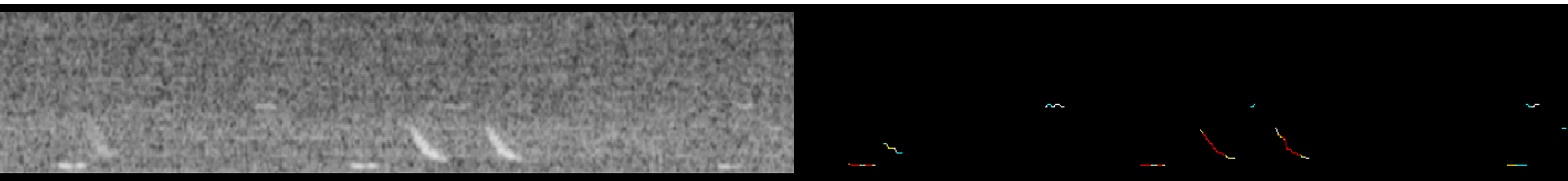

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Introduction to LFDCS

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, see Baumgartner and Mussoline 2011.

Part 1: Introduction to LFDCS Desktop of this reference guide includes instructions for installing the desktop version of the LFDCS 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 utilizing LFDCS to detect multiple species' acoustic occurrence from recordings collected along the eastern seaboard by many collaborators, see Davis et al. 2017 and 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, sei, humpback, blue, and North Atlantic right 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. 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 review 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, see Baumgartner et al. 2020. The uses of the near real-time system include monitoring shipping lanes, fishing grounds, wind energy construction areas (see 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, see Baumgartner et al. 2019.

Using the LFDCS 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, and customize the criteria used to process those datasets. 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 organized into two parts: [Introduction to LFDCS 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 version. This includes detailed descriptions and instructions for creating/managing call libraries, processing archival acoustic data, reviewing data, and exporting data. See the example below of the description of the [Building a Call Library]() program.

As shown in the example below, most program descriptions have a ***Code*** section with the basic code for the program. Depending on the program being used in the LFDCS Desktop, the code may have some commands that are helpful (and sometimes necessary) additions for specifying how you want the program to run. If applicable, these additional commands will be listed under the ***Commands*** column to the right of the code. The ***Code*** sections also have at least one example that shows the program code with file pathways and added commands. Most program descriptions will also include terminal window and LFDCS output screenshots to show what each program should look like when opened.

Example of Program Description with Code & Commands

Building a Call Library

Below are directions for how to build a new call library by adding exemplars of calls to create distinct call types within the library. This can be used from the start of creating a call library, or to add new call types to a pre-existing call library. This step requires you to have processed the deployment you wish to get exemplars from with LFDCS, as you will select pitch tracks and assign them to a designated call type.

You can specify parameters for the pitch tracks to narrow down what you have to browse through. This is helpful if you don't know if or where target calls are in the dataset you want to choose exemplars from, and to also help scroll more quickly to possible exemplars by leaving out pitch tracks that are not suitable for the target call types.

Code	***Commands***
1. Open terminal, launch IDL in lfdcs/process (hit return after typing each line of text in the command line below). **1% cd ~/Projects/Detectors/lfdcs/process** **2% idl** **IDL> find_exemplars, 'lfdcs_index_file', 'call_library_file'** *Example:* find_exemplars, '/Volumes/HARDDRIVE_NAME/NEFSC_SC_201511/NEFSC_SC_201511_site4/lfdcs/lfdcs_files_index.nc', '../call_library/clnb_gom/call_library.nc' *Note:* If there are more than eight call types in a call library not all of them will display as buttons along the right-hand side of the desktop window. Use the "call_type_buttons" keyword to specify which call types you would like to display as buttons.	start= 'MM/DD/YY HH:MM:SS' call_family=2 *(*1=broadband, 2=narrowband)* **LFDCS has the capacity to process broadband data, but it is still under development and not yet functional with the software.* call_type=[5,6,7] *(the numbers in the brackets are the call types from your call library that you want to browse through)* max_mdist=3

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 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
- For inquiries about setting up a real time platform for your research

Part 1
Introduction to LFDCS Desktop

Introduction to LFDCS Desktop

The LFDCS, or Low-Frequency Detection and Classification System (Baumgartner and Mussoline 2011), is an acoustic detection software system that was written by Dr. Mark Baumgartner at the Woods Hole Oceanographic Institution. It is used to scan sound files and identify marine mammal calls by analyzing frequency modulated signals and producing pitch tracks of sounds, 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, humpback, etc.) to classify the pitch track to the species' vocalization. The call library that each dataset is processed 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 (e.g., 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.

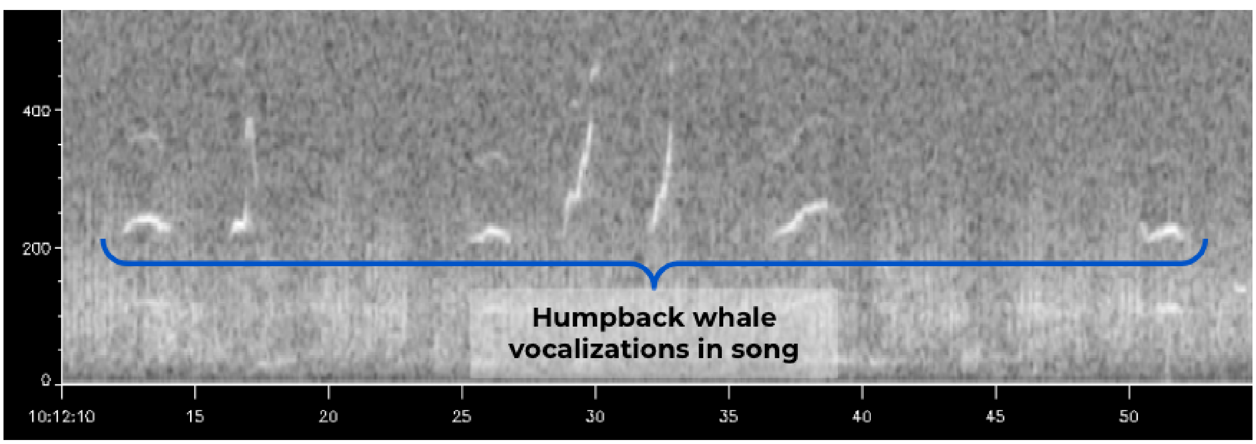


Image 1: Spectrogram of humpback song with Hz on the y-axis and seconds on the y-axis.

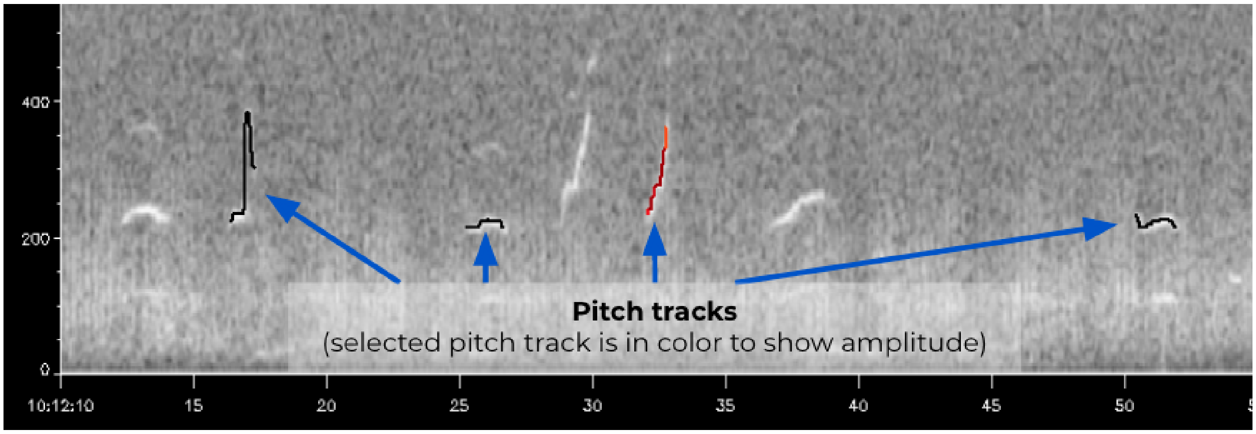


Image 2: Spectrogram showing the pitch tracks (black and color lines) tracing the humpback whale vocalizations. As the analyst clicks between pitch tracks, the LFDCS will highlight the selected pitch track in color showing the amplitude of that sound (warmer colors are louder, cooler colors are quieter). 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

Installing LFDCS

The instructions for how to install the LFDCS and additional software on a computer (must be a Mac) are below. The instructions can also be found on the Robots4Whales website.

Install the software packages below to run the desktop LFDCS. The LFDCS and it's supported programs can be found in the LFDCS program google drive folder. For NOAA/NEFSC users, files can be found on the server under: Z:\DETECTORS\LFDCS_programs.

Install IDL (required)

Obtain a license and install IDL following installation instructions from the Harris Geospatial ITT (the IDL software distribution company) downloads center, if not already installed. Use the "Native" version for gui-friendly download. The UNIX version is a terminal-based download.

Note: You may need to install XQuartz separately after installing IDL.

Install LFDCS for the first time using the lfdcs distribution file

1. Set up Terminal environment

    a. Find the Terminal application in the Applications/Utilities folder (it may be helpful to drag the application icon to the dock at the bottom of the screen to always have easy access to it)

    b. Launch Terminal

    c. Open Preferences (in the menu under "Terminal" in upper left-hand corner)

    d. Under the General tab, set "Shells open with:" to "Command" and write the following in the dialog box /bin/tcsh in the dialog box:

    /bin/tcsh

    e. In Settings, select the "Shell" tab, and set "When the shell exits" to "Close if shell exited cleanly"

2. Copy the following two LFDCS installation files to your home directory: lfdcs_v1_2.tar.gz and install_lfdcs. Your home directory is usually a folder named the same as your username (e.g., if your username is "Mark", then your home directory is /Users/Mark).

    a. In the Terminal window, type the following to install the LFDCS software:

    cd ~

    source install_lfdcs lfdcs_v1_2.tar.gz

    Note: You may have to leave out the ".gz" extension if you get the notification that "lfdcs_v1_2.tar.gz does not exist".

b. The install_lfdcs program should end with “**Installed LFDCS!**”

c. Exit the Terminal window by typing the following at the prompt:

exit

3. Configure XQuartz

a. Open another terminal window by selecting “New Window” from the Shell menu in the Terminal application (you must close the old window and open a new window to use the terminal configuration settings you just installed with install_lfdcs)

b. In the Terminal window, type the following to launch IDL:

idl

Note: If, when you type “idl” the terminal responds with “idl command not found”, then you need to do one more step:

From the Terminal menu bar, open Preferences. Go to the Profiles ↠ Shell.

Under startup, check the box for “Run command” and “Run inside shell” and type in the space after the Run command:

source ~/.cshrc

Note: After successfully loading IDL within the terminal, the terminal should spit out the IDL version information and installation/license information. If you see the line “%Program caused arithmetic error: Floating illegal operand” this is normal and fine to ignore, it will not affect the processing.

c. At the IDL prompt (IDL >), type the following to launch XQuartz:

window, 0

d. You will now see the XQuartz application in the dock at the bottom of the screen (the icon looks like this:). Click on that icon, then select Preferences (in the menu under “XQuartz” in the upper left-hand corner).

e. In the Input tab, select “Emulate three button mouse”, “Follow system keyboard layout” and “Enable key equivalents under X11”

f. In the Windows tab, select “Click-through Inactive Windows”

4. You’re ready to use the LFDCS!

Getting started on your first dataset

1. In the Finder, navigate to Projects/Detectors/lfdcs/paramfiles/test_dataset

2. Open testparam.txt in TextEdit

3. Change the Indir, Outdir, CallLibraryFile and CallLibraryFileBB directories to reflect your username (i.e., replace "Mark" with your username)

4. In a Terminal window type the following:

   cd ~/Projects/Detectors/lfdcs/process

   idl

5. In IDL, type the following:

   reformat_detect_classify, '../paramfiles/test_dataset/testparam.txt'

   The terminal asks you:

   "Are you sure you want to convert the recorder data to NetCDF? (y/n)"

   Type **"y"** and hit enter

   Note: You may get a pop up window with an error the first time running this that says: **"call_tracking_lfdcs_dlm.so" cannot be opened because the developer cannot be verified.** To resolve this, go into Privacy and Security and change permissions to allow that to be opened:

   System Preferences ↠ Security & Privacy ↠ General

   Click on the Lock button on the bottom left to make changes

   Under "Allow apps downloaded from:" click on "App store and identified developers"

   Sometimes the application pops up below in this window for the terminal program and it asks you if you want to allow to run this application anyways? Click "Allow Anyways".

   You can then run the line of code again. You may get a second question from the terminal that says:

   "LFDCS index file exists. Overwrite? (y/n)"

   Type **"y"** and hit enter.

6. This program should run for less than 15 seconds and will end with the following message:

   ****
   LFDCS processing completed!

****

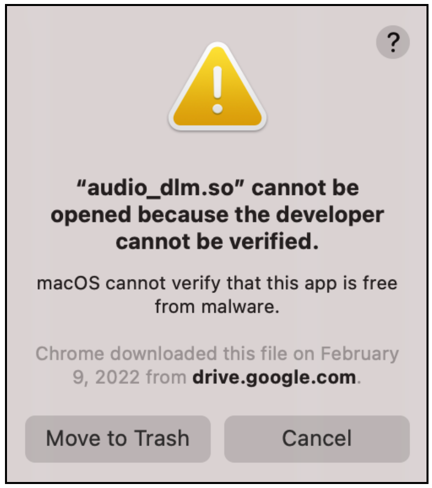
7. Congratulations, you just processed your first dataset with the LFDCS! Now type the following in IDL to view spectrograms and detections (see Viewing/Browsing Automated Detections section for more information):

   browse_autodetections, '../test_dataset/processed/lfdcs'

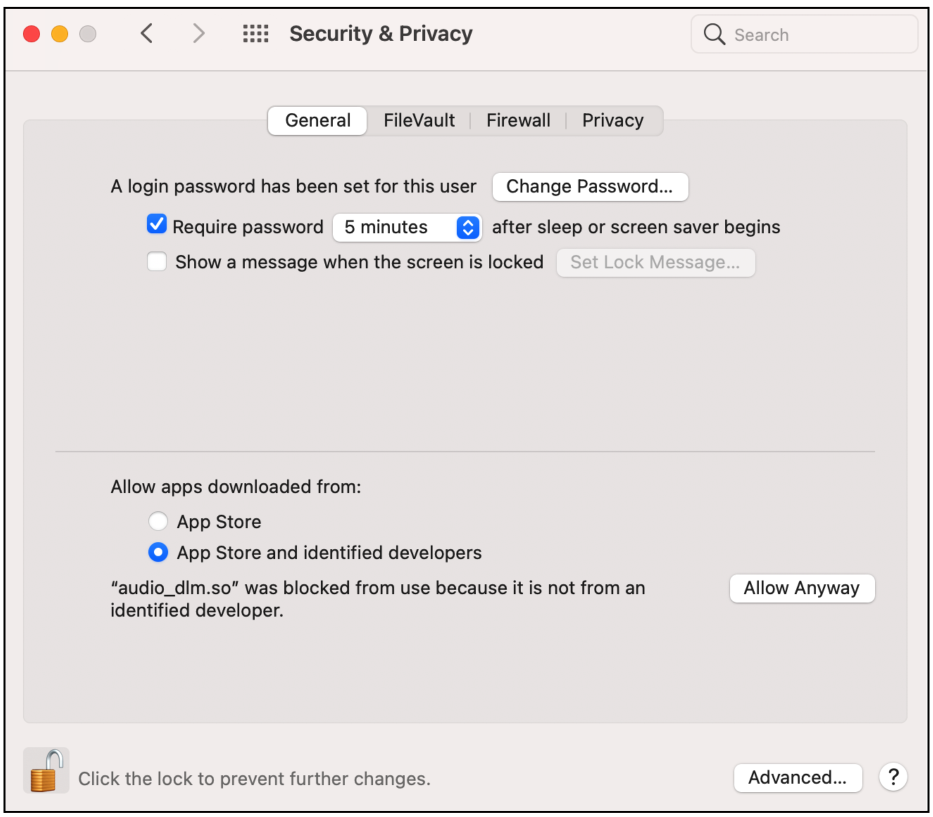
   Note: The first time you try to play a clip in processed data, you have to "allow" the two audio program files to run in System Preferences. See screenshots on the following page for directions on how to do this.

   In the terminal, you'll see the following text error as well as the following window pop up the first time you try to play a sound:

```
IDL> browse_autodetections, '../test_dataset/processed/lfdcs'
% Compiled module: BROWSE_AUTODETECTIONS.
% Compiled module: SYMBOL_CIRCLE.
% Compiled module: READ_LFDCS_FILE_INDEX.
% Compiled module: READ_ASCII_DATA.
% Compiled module: NCDF_FILL_FLOAT.
% Compiled module: READ_LFDCS_AUTODETECTIONS.
% Compiled module: TIME_TICKS.
% Compiled module: PLOT_MINOR_DATE_TICKS.
% Compiled module: READ_RECORDER.
% Compiled module: DISPLAY_IMAGE.
% Compiled module: CUSTOMCT.
% Compiled module: HOME_DIRECTORY.
% Compiled module: XPERC.
% Compiled module: YPERC.
% Compiled module: WINDOW_BUTTONS.
% Compiled module: WHICH_BUTTON.
% Compiled module: AVG.
% PLAY_AUDIO: Error loading sharable executable.
      Symbol: IDL_Load, File =
      /Users/username/idl_dlm/audio_dlm.sodlopen(/Users/username/idl_dlm/
      audio_dlm.so, 1): no suitable image found.
      Did find: /Users/username/idl_dlm/audio_dlm.so: code signature in
      (/Users/username/idl_dlm/audio_dlm.so) not valid for use in process
      using Library Validation: library load disallowed by system policy
% Execution halted at: BROWSE_AUTODETECTIONS  424
      /Users/username/Projects/Detectors/lfdcs/process/
      browse_autodetections.pro
% $MAIN$
```



You then have to go into System Preferences ↠ Security and Privacy. Here, the file should be listed under the “Allow apps downloaded from:” section. Click “Allow Anyway”.



You may have to repeat this process twice the <u>first</u> time you try playing a sound. These are two files Mark wrote to allow you to listen to the audio through LFDCS. Once the computer has allowed these two files to execute, you should not have any issues playing a sound.

Call Libraries

Note: This section may be skipped if using an existing call library.

Creating a Call Library

Below are directions for how to create a new call library that can be used to process datasets.

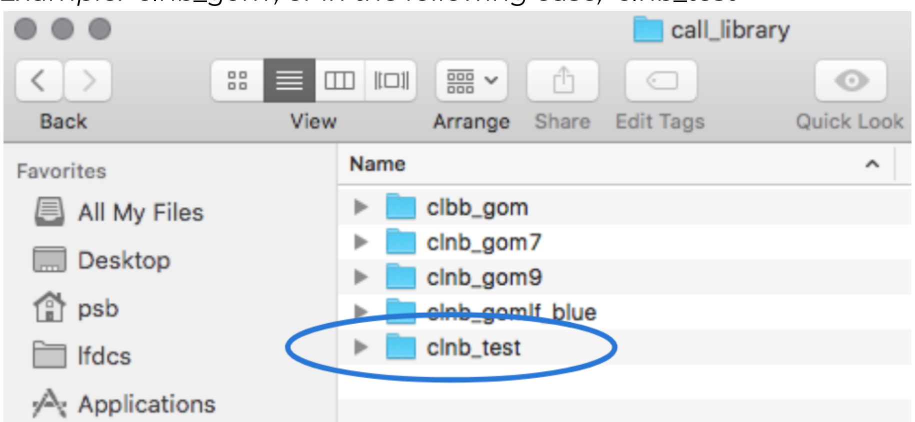
Code

1. Within lfdcs/call_library folder, create a new folder clXX_ZZZZ

   Note: XX = nb for narrowband call library or *bb for broadband call library; ZZZZ = call library name (e.g. gom)

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

   Example: 'clnb_gom', *or in the following case,* 'clnb_test'



2. Open terminal, launch IDL in lfdcs/process (hit return after entering each line of entered in the terminal below).

   1% cd ~/Projects/Detectors/lfdcs/process
   2% idl
   IDL> create_call_library

3. Follow prompts to create and annotate the new call library (see screenshot for previous step)

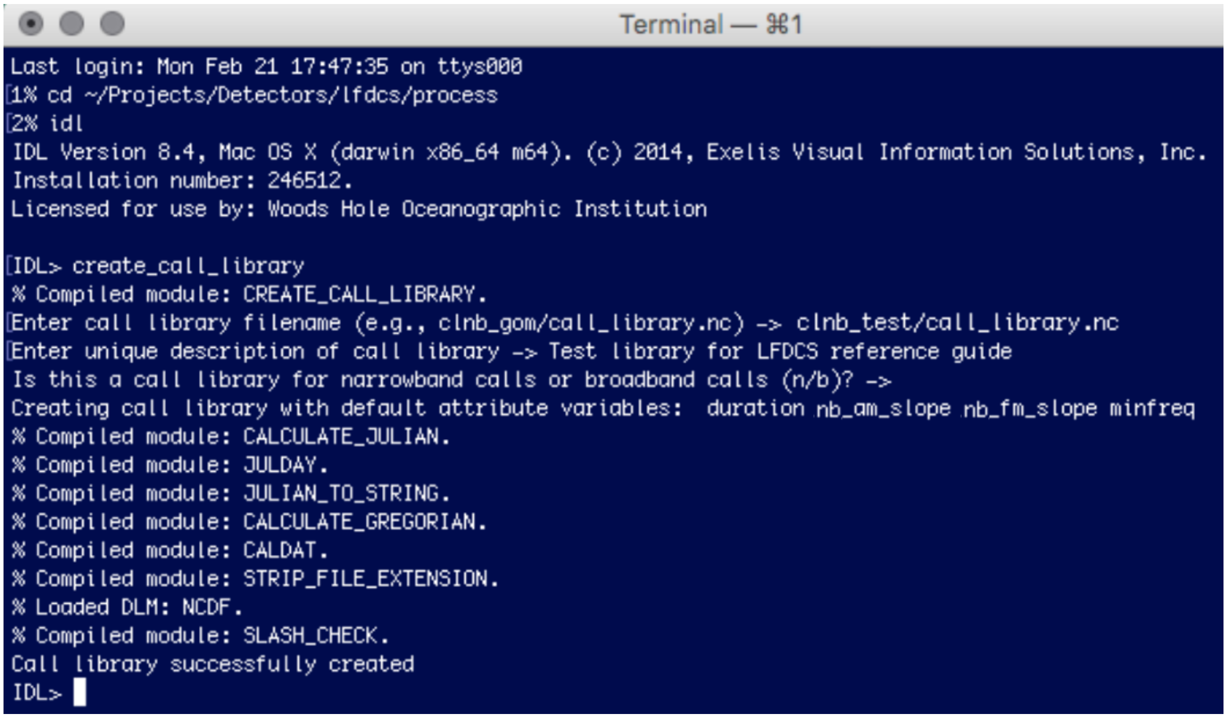
   a. Enter the call library file name. The first part of this will be the name of the folder you created in step #1. Follow that folder name with /call_library.nc

   b. Enter a unique description of the call library. This is metadata text for however you want to describe your call library.

   c. Enter "n" or "b" to define if the call library is a narrow band or *broadband call library (at the moment, only "n" should be entered.

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

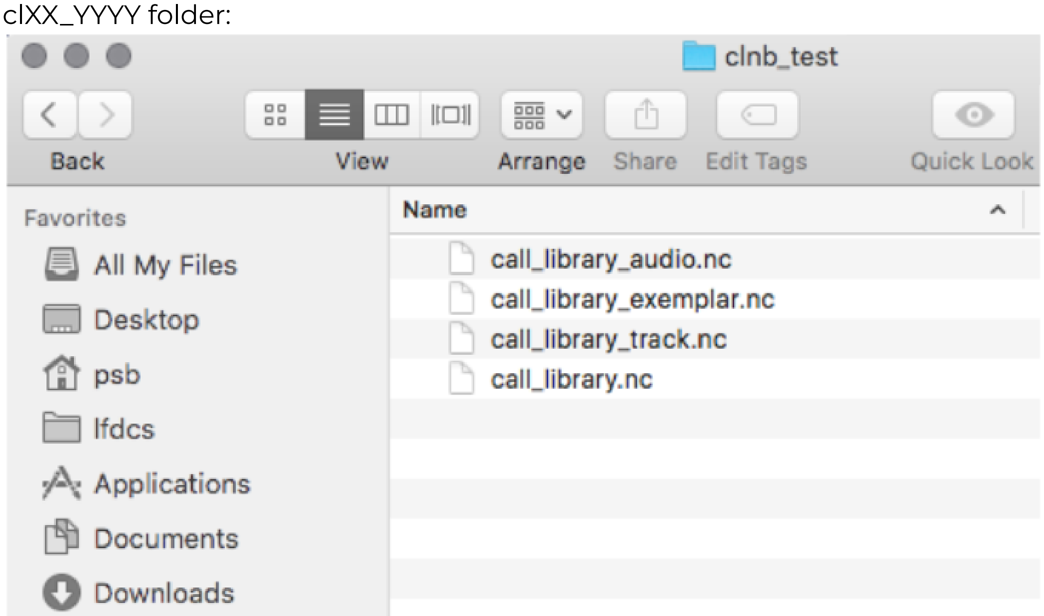
Terminal Window



```
Last login: Mon Feb 21 17:47:35 on ttys000
1% cd ~/Projects/Detectors/lfdcs/process
2% idl
IDL Version 8.4, Mac OS X (darwin x86_64 m64). (c) 2014, Exelis Visual Information Solutions, Inc.
Installation number: 246512.
Licensed for use by: Woods Hole Oceanographic Institution

IDL> create_call_library
% Compiled module: CREATE_CALL_LIBRARY.
Enter call library filename (e.g., clnb_gom/call_library.nc) -> clnb_test/call_library.nc
Enter unique description of call library -> Test library for LFDCS reference guide
Is this a call library for narrowband calls or broadband calls (n/b)? ->
Creating call library with default attribute variables:  duration nb_am_slope nb_fm_slope minfreq
% Compiled module: CALCULATE_JULIAN.
% Compiled module: JULDAY.
% Compiled module: JULIAN_TO_STRING.
% Compiled module: CALCULATE_GREGORIAN.
% Compiled module: CALDAT.
% Compiled module: STRIP_FILE_EXTENSION.
% Loaded DLM: NCDF.
% Compiled module: SLASH_CHECK.
Call library successfully created
IDL>
```

Resulting File Setup

Once these three steps have been completed, the following files should populate the new clXX_YYYY folder:



Building a Call Library

Below are directions for how to build a new call library by adding exemplars of calls to create distinct call types within the library. This can be used from the start of creating a call library, or to add new call types to a pre-existing call library. This step requires you to have processed the deployment you wish to get exemplars from with LFDCS, as you will select pitch tracks and assign them to a designated call type.

You can specify parameters for the pitch tracks to narrow down what you have to browse through. This is helpful if you don't know if or where target calls are in the dataset you want to choose exemplars from, and to also help scroll more quickly to possible exemplars by leaving out pitch tracks that are not suitable for the target call types.

Code	***Commands***
1. Open terminal, launch IDL in lfdcs/process (hit return after typing each line of text in the command line below). **1% cd ~/Projects/Detectors/lfdcs/process** **2% idl** **IDL> find_exemplars, 'lfdcs_index_file', 'call_library_file'** *Example:* find_exemplars, '/Volumes/ExternalHD/NEFSC_SC_201511_site4/lfdcs/lfdcs_files_index.nc', '../call_library/clnb_gom/call_library.nc' *Note:* If there are more than eight call types in a call library not all of them will display as buttons along the right-hand side of the desktop window. Use the "call_type_buttons" command to specify which call types you would like to display as buttons. *Example for call library with eight or more call types:* '/Volumes/ExternalHD/NEFSC_SC_201511_site4/lfdcs', '../call_library/clnb_gom9/call_library_gom9.nc', call_type_buttons=[1,2,3,4,6,7,8,10] See example terminal window on pg. 21.	**start= 'MM/DD/YY HH:MM:SS'** To specify the date/time to start browsing for exemplars in MM/DD/YY HH:MM:SS format (e.g., start='01/20/15 19:30:00') **call_family** To view all autodetections in a call family (*1=broadband, 2=narrowband) (e.g., call_family=2) **LFDCS has the capacity to process broadband data, but it is still under development and not yet functional with the software.* **call_type** To specify which call types you want to browse for and use in your current call library (e.g., call_type=[1, 2, 3]). If you have multiple call type values in order you can enter the range using a colon (e.g., instead of call_type=[1,2,3,4,5,6], use call_type=[1:6]). **call_type_buttons** To specify which call types you would like to specify as buttons in the desktop view (e.g., call_type_buttons=[1,2,3,4,6,7,8,10])

	min_amplitude To view all autodetections greater than or equal to a specified minimum amplitude (in dB above background) (e.g., min_amplitude=12) **max_amplitude** To view all autodetections less than or equal to a specified maximum amplitude (in dB above background) (e.g., max_amplitude=20) **min_mdist** To view all autodetections greater than or equal to a specified minimum Mahalanobis distance (e.g., min_mdist=1.0) **max_mdist** To view all autodetections less than or equal to a specified maximum Mahalanobis distance (e.g., max_mdist=3.0) **min_freq** To view all autodetections greater than or equal to a specified minimum frequency (in Hz) (e.g., min_freq=200) **max_freq** To view all autodetections less than or equal to a specified maximum frequency (in Hz) (e.g., max_freq=800) **min_duration** To view all autodetections greater than or equal to a specified minimum duration (in seconds) (e.g., min_duration=1.0) **max_duration** To view all autodetections less than or equal to a specified maximum duration (in seconds) (e.g., max_duration=4.0)

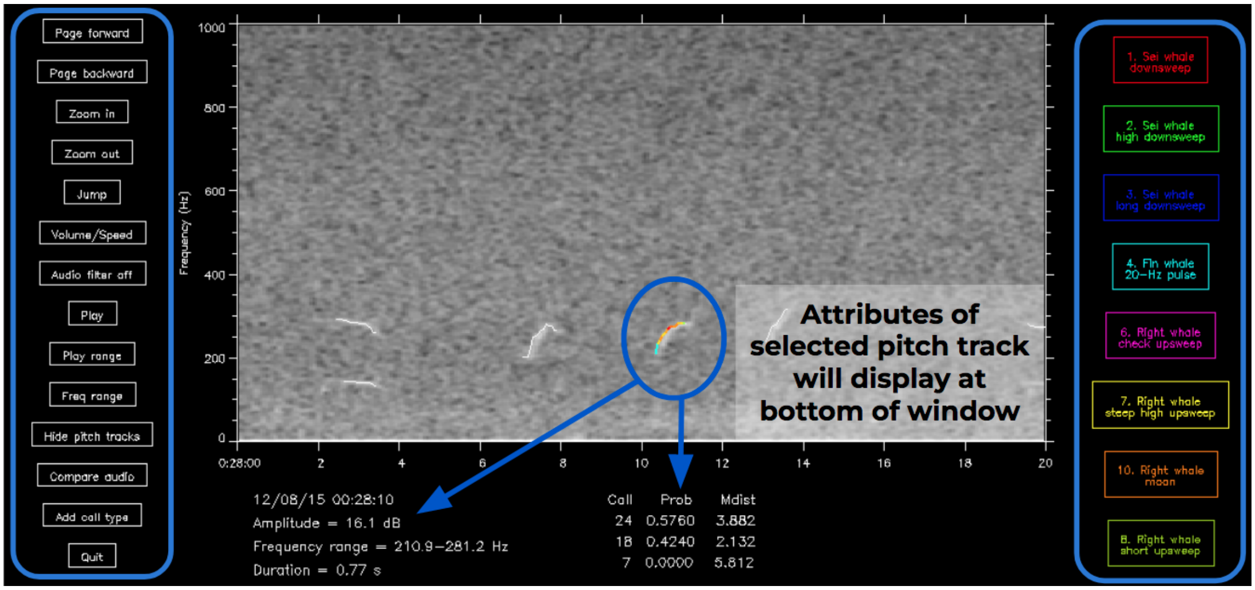
Terminal Window

Terminal — ⌘1

```
[1% cd ~/Projects/Detectors/lfdcs/process
[2% idl
 IDL Version 8.4, Mac OS X (darwin x86_64 m64). (c) 2014, Exelis Visual Information Solutions, Inc.
 Installation number: 246512.
 Licensed for use by: Woods Hole Oceanographic Institution

[IDL> find_exemplars, '/Volumes/NEFSC_22/NEFSC_SC_201511/NEFSC_SC_201511_CH4/', '../call_library/clnb_gom9/
call_library_gom9.nc', call_type_buttons=[1,2,3,4,6,7,8,10]
% Compiled module: FIND_EXEMPLARS.
% Compiled module: SLASH_CHECK.
% Compiled module: READ_LFDCS_CALL_LIBRARY.
% Compiled module: STRIP_FILE_EXTENSION.
% Loaded DLM: NCDF.
% Compiled module: GET_NCDF_VARIABLE.
% Compiled module: CALCULATE_JULIAN.
% Compiled module: JULDAY.
% Compiled module: FIND_NCALL.
% Compiled module: FIND_NEXEMPLAR.
% Compiled module: CHECK_AND_BACKUP_CALL_LIBRARY.
% Compiled module: READ_LFDCS_FILE_INDEX.
% Compiled module: READ_RECORDER_INDEX.
% Compiled module: READ_LFDCS_AUTODETECTIONS.
% Compiled module: STRING_TO_JULIAN.
% Compiled module: READ_RECORDER.
% Compiled module: NCDF_FILL_FLOAT.
% Compiled module: SYMBOL_CIRCLE.
% Compiled module: TIME_TICKS.
% Compiled module: CALCULATE_GREGORIAN.
% Compiled module: CALDAT.
% Compiled module: PLOT_MINOR_DATE_TICKS.
% Compiled module: DISPLAY_IMAGE.
% Compiled module: COMBOCT.
% Compiled module: TEK_COLOR.
% Compiled module: CUSTOMCT.
% Compiled module: HOME_DIRECTORY.
% Compiled module: MONOTONIC.
% Compiled module: JULIAN_TO_STRING.
% Compiled module: TEXT_BOX.
% Compiled module: QDFA_PREDICT_SINGLE.
% Compiled module: XPERC.
% Compiled module: YPERC.
% Compiled module: WINDOW_BUTTONS.
```

Desktop Buttons

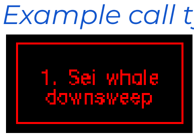
The following image and descriptions explain the basic functions available when building a call library. The buttons along the left-hand side of the window are standard in most LFDCS programs, the buttons along the right-hand side of the window are specific to the find_exemplars function.



The functions of the white buttons and the call type buttons along the right side are described below.

Button	Function
Select next detection/pitch track (not a visible button in the image above)	Click on (or hover cursor over the spectrogram window and scroll) the black background anywhere on the right-hand side of the window to navigate to the next automated detection (pitch track).
Select previous detection/pitch track (not a visible button in the image above)	Click on (or hover cursor over the spectrogram window and scroll) the black background anywhere on the left-hand side of the window to navigate to the next automated detection (pitch track).
'Page forward'	Click on (or hover cursor over button and scroll) 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 (or viewing window) 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, navigate back to the terminal window and enter the desired date and time in the MM/DD/YY HH:MM:SS format. *Example:* **Jump to date (mm/dd/yy hh:mm:ss) -> 01/29/16 04:13:58**
'Volume/Speed'	Adjusts volume and playback speed of audio file. After clicking, navigate back to the terminal window and enter the desired volume (on a scale of 1-10) and desired speed. Default values are both 1 whenever a processed deployment is opened from the terminal. *Example:* **Volume -> 7** **Speed -> 2**
'Audio filter off'	Click on the 'Audio filter off' button to apply 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 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 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, navigate back to the terminal window and enter the desired maximum frequency in Hz. The minimum frequency will remain 0 Hz. *Example:* **Maximum frequency: 600**
'Hide pitch 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.
'Compare audio'	Click on the 'Compare audio' button to listen to the selected pitch track audio and the audio of the exemplars of the call type to which you are comparing it.

	When you click the 'Compare audio' button, you will be prompted in the terminal window to select the call type you'd like to compare it to. 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. To stop the audio, click 'q' and it will quit the function.
'Add call types'	Click on the 'Add call types' button to add a new call type to the call library. Once the button is clicked, follow the prompts in the terminal window to complete the necessary information for that call type.
'Quit'	Quits the LFDCS program, allowing the analyst to then close out of the desktop window and terminal. **Use this button first to properly exit the program, then click on the "x" button on the top left corner of the window.** The LFDCS window will not close properly if the “Quit” button is not clicked before the “x” button.
Call type buttons along the right-hand 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.* *Example call type button:* 	Once the pitch track of interest is selected (colored) in the desktop window, click on the target call type button along the right-hand side of the window to add the pitch track as an exemplar for that call type. Click on (or hover cursor over and scroll) the black background anywhere on the left- or right-hand 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

Below are directions for 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 seven call type attributes are amplitude-weighted (AW) statistics.

Code

1. Open terminal, launch IDL in lfdcs/process (hit return after typing each line of text in the command line below).

   1% cd ~/Projects/Detectors/lfdcs/process
   2% idl
   IDL> manage_call_library, 'call_library_file'

Program will list call types within the call library, and prompt you to select which call type to open specs on. Once a call type is entered, a series of windows (see screenshots and descriptions below) will pop up. A list of commands in the terminal window is given for actions you can take relating to the call type (e.g., play, view in spectrogram, delete exemplar, move exemplar to different call type, etc.). Commands are listed in the terminal window with the correct letter key in () to press to execute command. You can use the different commands to view and manage exemplars and distribution of attributes for that call type.

Example:
manage_call_library, '../call_library/clnb_gom9/call_library_gom9.nc'

See example terminal windows on following pages.

Terminal Window

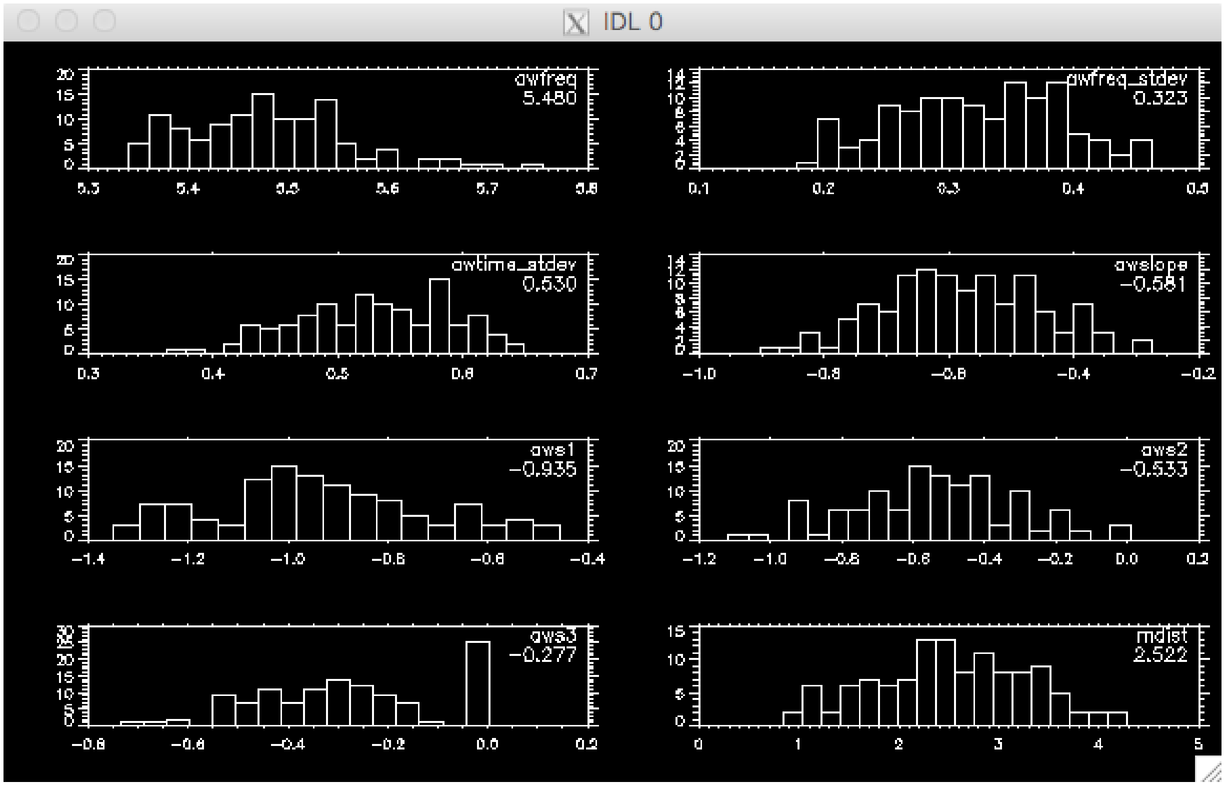
Terminal — ⌘1

```
Last login: Mon Feb 21 18:35:34 on ttys000
[1% cd ~/Projects/Detectors/lfdcs/process
[2% idl
IDL Version 8.4, Mac OS X (darwin x86_64 m64). (c) 2014, Exelis Visual Information Solutions, Inc.
Installation number: 246512.
Licensed for use by: Woods Hole Oceanographic Institution

[IDL> manage_call_library, '../call_library/clnb_gom9/call_library_gom9.nc'
% Compiled module: MANAGE_CALL_LIBRARY.
% Compiled module: READ_LFDCS_CALL_LIBRARY.
% Compiled module: STRIP_FILE_EXTENSION.
% Loaded DLM: NCDF.
% Compiled module: GET_NCDF_VARIABLE.
% Compiled module: CALCULATE_JULIAN.
% Compiled module: JULDAY.
% Compiled module: FIND_NCALL.
% Compiled module: FIND_NEXEMPLAR.
% Compiled module: CHECK_AND_BACKUP_CALL_LIBRARY.
% Compiled module: SLASH_CHECK.
Call
Type      n          Species                               Name                                    Description
   1     74        Sei whale                          downsweep                             80-30 Hz downsweep
   2     26        Sei whale                     high downsweep                            130-70 Hz downsweep
   3    117        Sei whale                     long downsweep              80-30 Hz long duration downsweep
   4    120        Fin whale                        20-Hz pulse                                    20-Hz pulse
   5    205      Right whale                             upcall                               100-200 Hz upcall
   6    144      Right whale                     check upsweep   attack with slight downsweep, then rapid upsweep
   7    186      Right whale                steep high upsweep                rapid upsweep ending around 200 Hz
   8    104      Right whale                     short upsweep                          short duration upsweep
   9     83      Right whale                      long upsweep                           90-250Hz long upsweep
  10     39      Right whale                              moan                    long duration quasi-tonal call
  15     71   Humpback whale                           upsweep 100-150 Hz upsweep similar to right whale upsweep
  16     31   Humpback whale                             tonal              2 second tonal with slight downsweep
  17    181   Humpback whale         low-frequency downsweep100-50 Hz downsweep similar to sei whale downsweep
  18    123   Humpback whale                           upsweep100-500Hz rapid upsweep similar to right whale upc
  19    100   Humpback whale                         downsweep              long "straight" 300-100 Hz downsweep
  20    128   Humpback whale                   short downsweep             short "straight" 300-100 Hz downsweep
  23    192   Humpback whale Mid-frequency downsweep (new)                             350-200 Hz downsweep
  24    151   Humpback whale              Inverted "U" (new)       Inverted 100-150 Hz "U" call w upper harmonic
  25    211   Humpback whale Variable downsweep arch (new)      Variations of a 550-200 Hz downsweeping arch
  26    146      Hard drive     HF hard drive upsweep (new)      800-1000Hz upsweeping PT of hard drive noise
  27    132      Hard drive      Hard drive downsweep (new)              Downsweeping PT of hard drive noise
  28    188      Hard drive          Hard drive tonal (new)          Long tonal component of hard drive noise
  29    162      Hard drive     MF hard drive upsweep (new)      100-400Hz steep upsweep from hard drive noise
Call type ->
```

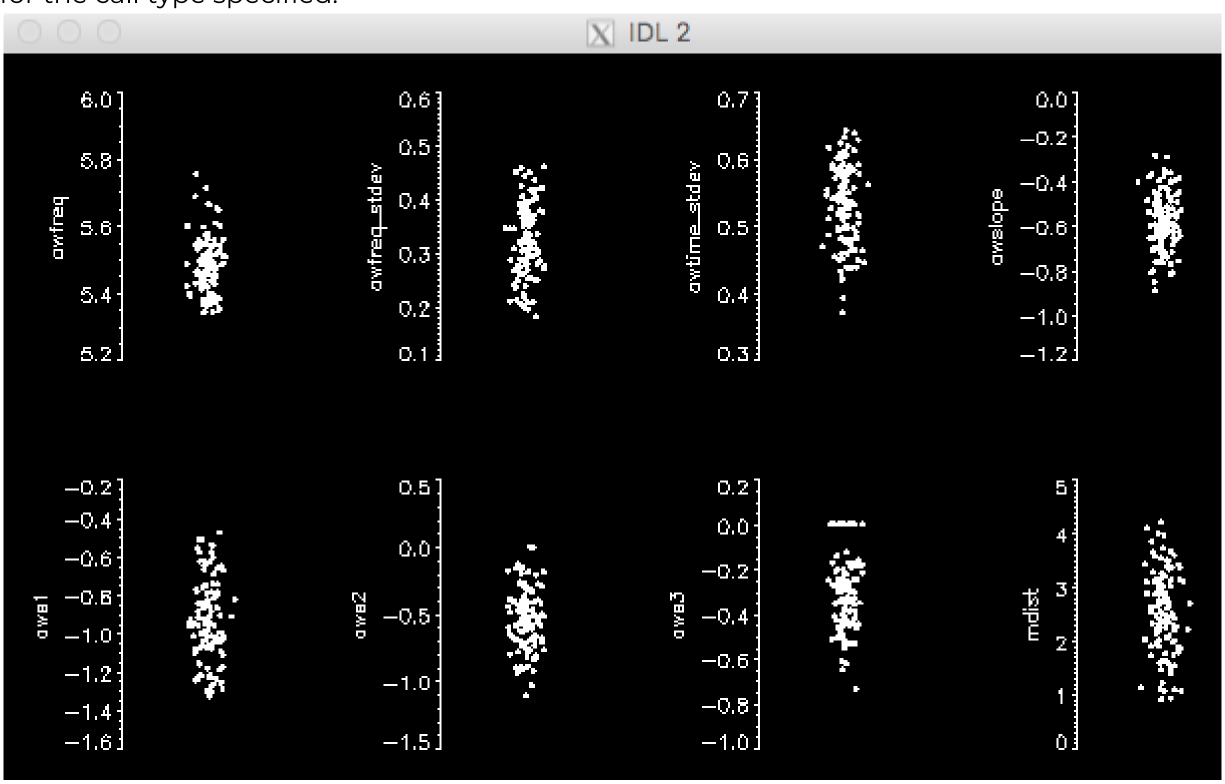
Key for 7 Call Type Attributes:
awfreq = Average frequency
awfreq_stdev = Frequency variation
awtime_stdev = Duration
awslope = Time-frequency slope
aws1 = Slope of the beginning (first third) of the call/pitch track
aws2 = Slope of the middle (second third) of the call/pitch track
aws3 = Slope of the end (last third) of the call/pitch track

Call Type Terminal Window

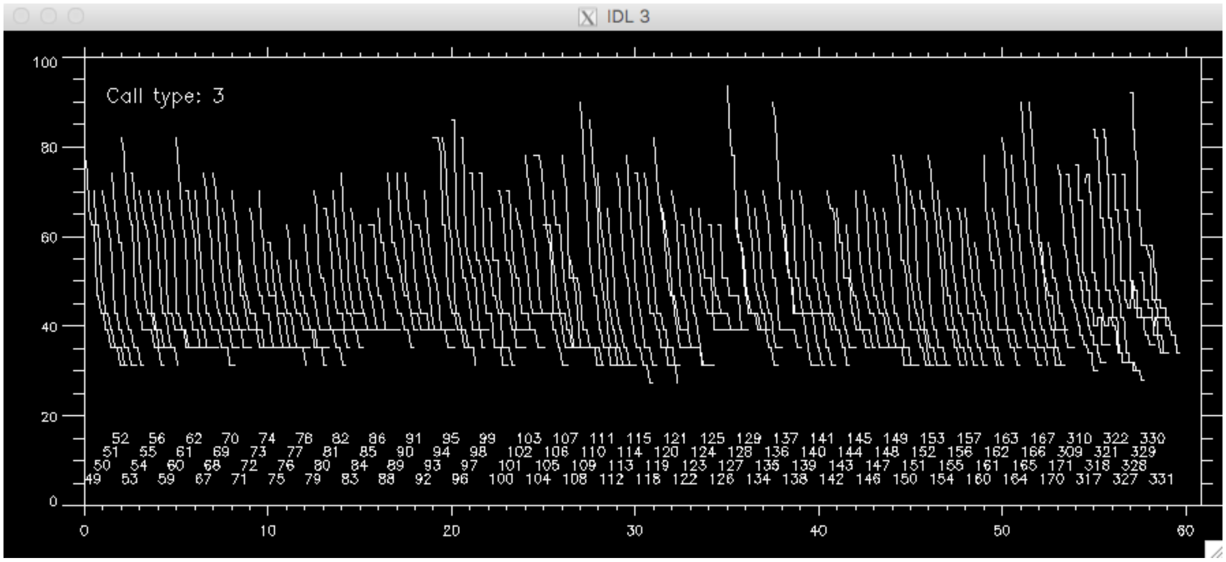
```
Terminal — ⌘1
Call type -> 3
% Compiled module: TEK_COLOR.
                                Start        Start
                awfreq      awtime
Index       Date       Time          Time        Freq
     awfreq       stdev       stdev     awslope       aws1        aws2        aws3      MDist      Index
% Compiled module: JULIAN_TO_STRING.
% Compiled module: CALCULATE_GREGORIAN.
% Compiled module: CALDAT.
   49  09/21/07 09:10:03  4439403.250      78.125     5.4111     0.3738     0.5911    -0.6003    -1.0261    -0.5450    -0.2975       1.46        49
   50  09/21/07 09:10:07  4439407.474      70.312     5.4190     0.3214     0.4686    -0.6531    -1.1528    -0.5816    -0.2201       1.97        50
   51  09/21/07 09:18:43  4439923.250      70.312     5.4367     0.3837     0.5147    -0.7206    -1.0268    -0.5658    -0.3447       1.71        51
   52  09/21/07 09:18:47  4439927.090      74.219     5.5082     0.3937     0.4799    -0.8012    -0.6486    -1.1093    -0.3824       3.26        52
   53  09/21/07 07:34:25  4433665.842      82.031     5.4885     0.3959     0.6223    -0.5971    -0.9119    -0.3185    -0.4449       2.90        53
   54  09/21/07 07:34:29  4433669.938      74.219     5.5416     0.3443     0.5131    -0.6524    -0.9416    -0.4536    -0.4861       1.78        54
   55  09/21/07 09:37:37  4441057.714      70.312     5.4714     0.3494     0.4955    -0.6533    -0.9650    -0.3226    -0.2087       3.39        55
   56  09/21/07 09:37:41  4441061.682      70.312     5.5468     0.3616     0.4381    -0.8101    -0.6352    -0.8373    -0.5046       4.10        56
   59  09/21/07 10:10:16  4443016.050      70.312     5.4211     0.3172     0.5806    -0.4891    -1.2288    -0.1859    -0.2048       2.37        59
   60  09/21/07 10:10:20  4443020.018      70.312     5.4287     0.3494     0.4954    -0.6437    -1.2812    -0.4191     0.0000       3.14        60
   61  09/21/07 10:12:30  4443150.386      82.031     5.4151     0.3808     0.5769    -0.5881    -1.3017    -0.4068     0.0000       3.41        61
   62  09/21/07 10:12:34  4443154.354      70.312     5.4616     0.3868     0.5333    -0.6699    -1.0038    -0.5746     0.0000       3.06        62
   67  10/04/07 16:01:38  5587298.756      70.312     5.3810     0.3180     0.6095    -0.4865    -1.0190    -0.3202    -0.2814       1.91        67
   68  10/04/07 16:01:42  5587302.724      74.219     5.4834     0.3340     0.5492    -0.5724    -1.0849    -0.4088    -0.2971       0.92        68
   69  10/04/07 16:03:48  5587428.484      74.219     5.4520     0.3025     0.5625    -0.4952    -1.0932    -0.3347    -0.2965       1.54        69
   70  10/04/07 16:03:52  5587432.708      66.406     5.5453     0.2669     0.3916    -0.6438    -0.9968    -0.6887    -0.0000       3.20        70
   71  10/04/07 16:05:44  5587544.196      70.312     5.4334     0.3050     0.5780    -0.4808    -1.0405    -0.3070    -0.1821       1.50        71
   72  10/04/07 16:05:48  5587548.548      54.688     5.3942     0.1947     0.4954    -0.3814    -0.6277    -0.2775    -0.2488       2.24        72
   73  10/04/07 16:08:18  5587698.948      66.406     5.4245     0.2760     0.5756    -0.4500    -0.8452    -0.5401    -0.0000       2.27        73
   74  10/04/07 16:08:23  5587703.044      70.312     5.5021     0.3002     0.5253    -0.5462    -0.9602    -0.4881    -0.1824       0.90        74
   75  10/04/07 16:10:48  5587848.580      58.594     5.3496     0.2512     0.6017    -0.3891    -0.8217    -0.4855    -0.1704       3.36        75
   76  10/04/07 16:10:52  5587852.804      54.688     5.3403     0.2125     0.5405    -0.3688    -0.5446    -0.6824     0.0000       3.50        76
   77  10/04/07 16:31:59  5589119.108      62.500     5.3617     0.2484     0.6325    -0.3640    -0.7506    -0.1614    -0.4467       3.60        77
   78  10/04/07 16:32:03  5589123.332      54.688     5.3421     0.2091     0.5363    -0.3639    -0.5402    -0.5806     0.0000       3.10        78
   79  10/04/07 16:35:18  5589318.468      62.500     5.3548     0.2366     0.6189    -0.3537    -0.7810    -0.0000    -0.4490       3.65        79
   80  10/04/07 16:35:22  5589322.436      70.312     5.4698     0.2874     0.5707    -0.4564    -0.9245    -0.3937    -0.2680       1.40        80
   81  07/26/07 13:01:52  2206912.768      66.406     5.4724     0.2839     0.6075    -0.4301    -0.9272    -0.2776    -0.2453       2.03        81
   82  07/26/07 13:01:56  2206916.992      70.312     5.5412     0.2765     0.5234    -0.4879    -0.9342    -0.4109     0.0000       2.00        82
   83  07/26/07 16:58:17  2221097.216      74.219     5.5230     0.2591     0.5566    -0.3998    -1.1928    -0.0000    -0.1602       3.14        83
   84  07/26/07 16:58:20  2221100.800      66.406     5.5290     0.2673     0.4381    -0.5688    -1.0198    -0.6256    -0.0000       2.36        84
   85  08/10/07 15:58:32  3513512.732      62.500     5.4648     0.2163     0.5090    -0.3812    -0.6629    -0.5176    -0.0000       2.45        85
   86  08/10/07 15:58:36  3513516.828      62.500     5.5094     0.2628     0.4969    -0.4774    -0.9165    -0.4999     0.0000       2.07        86
   88  08/17/07 23:03:04  4143784.256      66.406     5.5407     0.2476     0.5486    -0.4438    -0.5799    -0.4653    -0.4247       2.61        88
   89  08/17/07 23:03:07  4143787.712      74.219     5.6499     0.2594     0.4903    -0.5174    -0.7991    -0.4141    -0.5483       3.01        89
   90  08/17/07 23:14:39  4144479.040      74.219     5.5591     0.2867     0.4975    -0.5297    -1.0223    -0.1794    -0.1901       2.91        90
   91  08/17/07 23:14:42  4144482.368      74.219     5.6001     0.2935     0.4449    -0.6235    -0.9955    -0.4503    -0.3544       2.22        91

  322  05/10/05 00:34:52   779692.594      84.000     5.4251     0.4566     0.5825    -0.7584    -1.2577    -0.9027    -0.2937       3.15       322
  327  05/10/05 11:28:54   818934.250      74.000     5.5143     0.2696     0.6161    -0.3990    -1.0582    -0.1531    -0.3710       3.09       327
  328  05/10/05 11:28:57   818937.813      74.000     5.5429     0.2876     0.5844    -0.4535    -1.0495    -0.2634    -0.4366       2.42       328
  329  05/10/05 11:45:56   819956.500      92.000     5.7132     0.3256     0.5568    -0.5591    -1.0666    -0.6916    -0.1407       3.54       329
  330  05/10/05 16:52:23   838343.375      52.000     5.3750     0.1802     0.4374    -0.4024    -0.5079    -0.3963    -0.4019       3.72       330
  331  05/10/05 16:52:26   838346.938      58.000     5.4459     0.2224     0.4638    -0.4668    -0.7963    -0.2651    -0.4608       2.20       331
% Compiled module: PLOT_HISTOGRAM.
% Compiled module: STDEV.
% Compiled module: COMPUTE_HISTOGRAM.
% Compiled module: XPERC.
% Compiled module: YPERC.
% Compiled module: AVG.
% Compiled module: JITTER_PLOT.
% Compiled module: SYMBOL_CIRCLE.
% Compiled module: SET_SYMBOL.
(Q)uit, (D)elete exemplar, d(E)lete call type, change (M)ax/min
modify call type (I)nformation, change call (T)ype, (A)dd call type
select (C)ase, (N)ext case, (B)ack one case, spect(R)ogram view of case
m(O)ve case to a different call type
(S)peed, (V)olume, (P)lay case, (L)oop through calls to compare
```



Window IDL 0: This window shows the distribution of each attribute for all of the exemplars for the call type specified.



Window IDL 2: This window shows the distribution of each attribute for all of the exemplars for the call type specified.



Window IDL 3: This window shows all of the exemplar pitch tracks for the call type selected, with the exemplar's identification number below.

You can then browse through exemplars using the commands in the terminal window 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, and there will be a vertical line on the bar plots in window IDL 0 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. See the next section about evaluating your call library further.

Evaluating a Call Library

Below are directions for how to evaluate a call library. Quadratic discriminant function analysis relies on the assumption that the distribution of the seven attributes for a particular call type are multivariate normal (or nearly so). Visualizing data from tens to hundreds of exemplars in seven 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

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 <u>not</u> 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). Follow the directions below to check the Mahalanobis distribution of each call type in a call library.

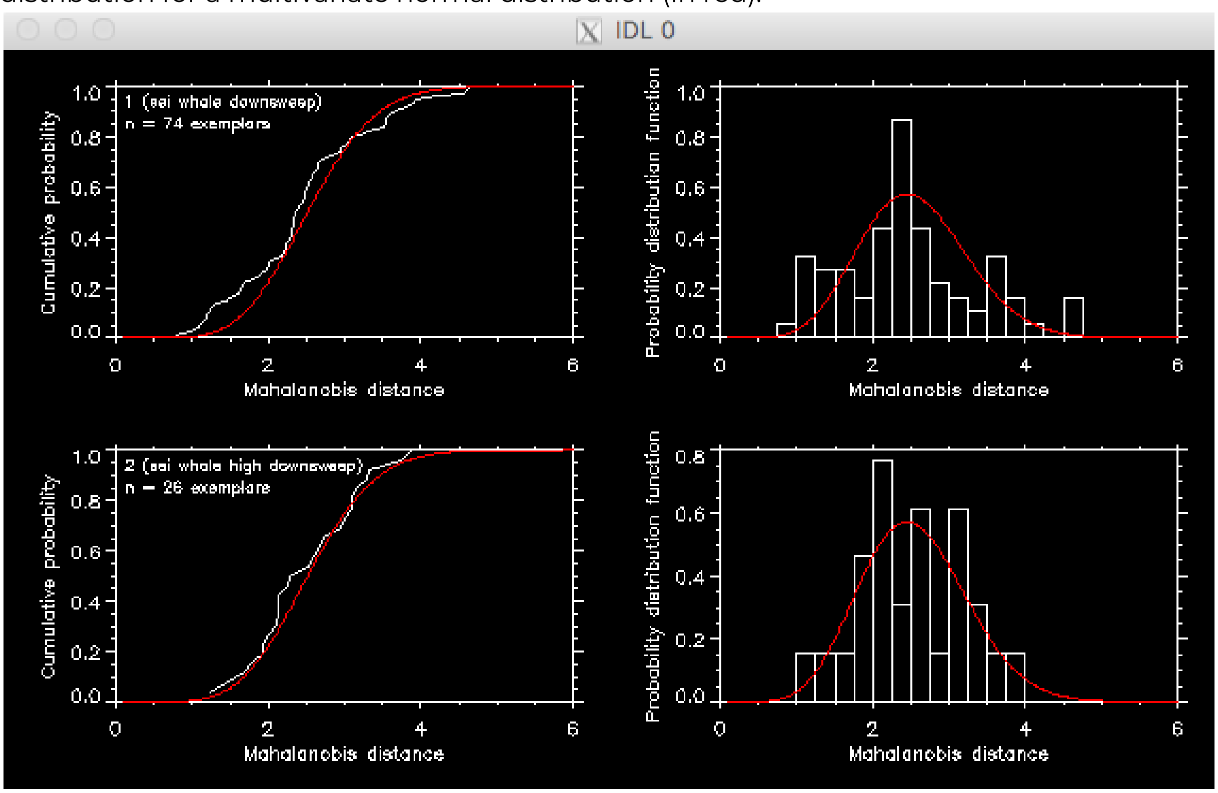
Code	***Commands***
1. Open terminal, launch IDL in lfdcs/process (hit return after typing each line of text in the command line below). **1% cd ~/Projects/Detectors/lfdcs/process** **2% idl** **IDL> plot_mdist_distribution, 'call_library_file'** *Example:* plot_mdist_distribution, '../call_library/clnb_gom9/call_library_gom9.nc', call_type=[5,6,7], /ps See example terminal window on the following page.	**call_type** To look at a subset of call types (e.g., call_type=[5,6,7]) **/ps** To export the results as a Postscript file that can be opened with a PDF reader; this will give you a larger view and allows you to zoom in on the figures in the LFDCS output

Terminal Window

```
Terminal — ⌘1
Last login: Mon Feb 21 18:38:17 on ttys000
[1% cd ~/Projects/Detectors/lfdcs/process
[2% idl
IDL Version 8.4, Mac OS X (darwin x86_64 m64). (c) 2014, Exelis Visual Information Solutions, Inc.
Installation number: 246512.
Licensed for use by: Woods Hole Oceanographic Institution

[IDL> plot_mdist_distribution, '../call_library/clnb_gom9/call_library_gom9.nc'
% Compiled module: PLOT_MDIST_DISTRIBUTION.
% Compiled module: TEK_COLOR.
% Compiled module: READ_LFDCS_CALL_LIBRARY.
% Compiled module: STRIP_FILE_EXTENSION.
% Loaded DLM: NCDF.
% Compiled module: GET_NCDF_VARIABLE.
% Compiled module: CALCULATE_JULIAN.
% Compiled module: JULDAY.
% Compiled module: COMPUTE_CDF.
% Compiled module: MONOTONIC.
% Compiled module: CHISQR_PDF.
% Compiled module: IGAMMA.
% Compiled module: TEXT_BOX.
% Compiled module: COMPUTE_HISTOGRAM.
```

LFDCS Output

The following images show an example of the plot_mdist_distribution output. Each plot shows the distribution of Mahalanobis distances for a call type (cumulative probability distribution on left, probability distribution function on right) compared to the ideal distribution for a multivariate normal distribution (in red):



Multivariate Distributions with Scatterplots

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

Code	***Commands***
1. Open terminal, launch IDL in lfdcs/process (hit return after typing each line of text in the command line below). **1% cd ~/Projects/Detectors/lfdcs/process** **2% idl** **IDL> compare_call_types_scatter, 'call_library_file'** *Example:* compare_call_types_scatter, '../call_library/clnb_gom9/call_library_gom9.nc', call_type=[5,6,7], /ps See example terminal window on the following page.	**call_type** To look at a subset of call types (e.g., call_type=[5,6,7]) **/ps** To export the results as a Postscript file that can be opened with a PDF reader; this will give you a larger view and allows you to zoom in on the figures in the LFDCS output

Terminal Window

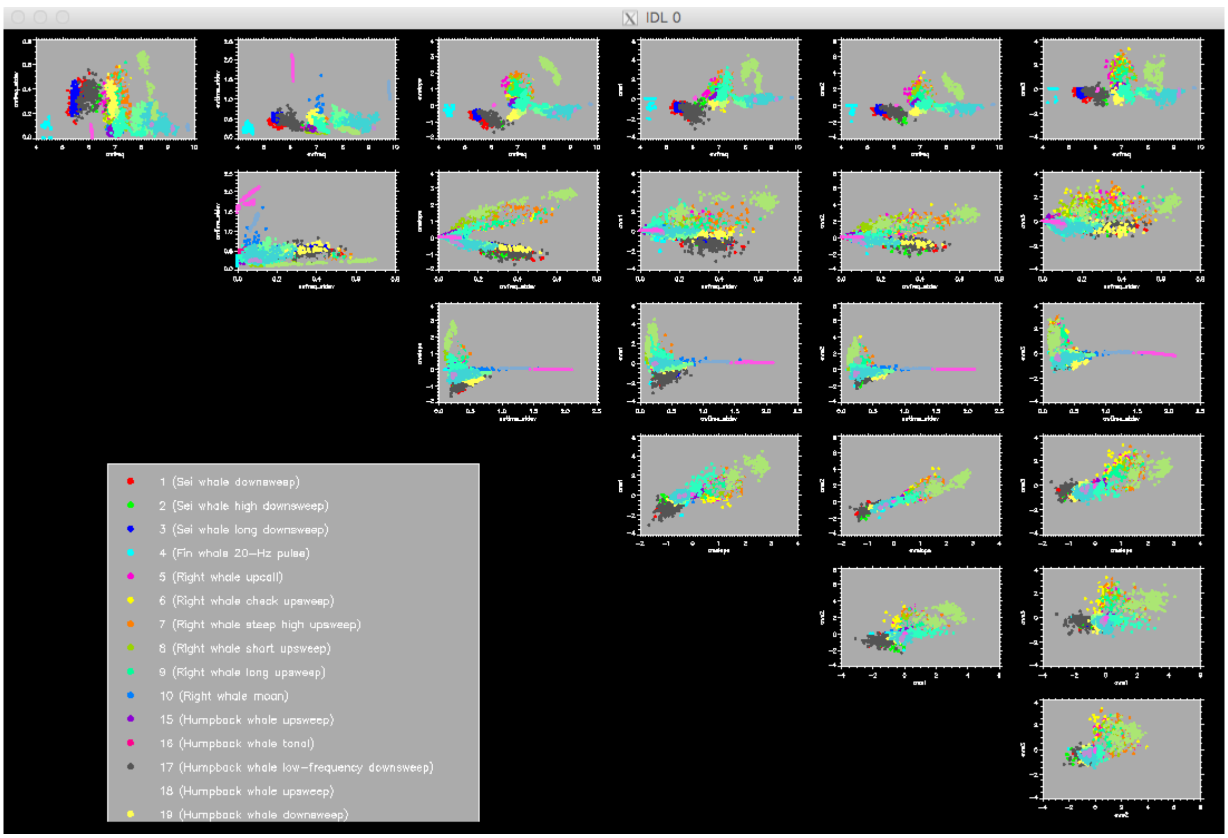
Terminal — ⌘1

```
Last login: Mon Feb 21 18:52:17 on ttys000
[1% cd ~/Projects/Detectors/lfdcs/process
[2% idl
IDL Version 8.4, Mac OS X (darwin x86_64 m64). (c) 2014, Exelis Visual Information Solutions, Inc.
Installation number: 246512.
Licensed for use by: Woods Hole Oceanographic Institution

[IDL> compare_call_types_scatter, '../call_library/clnb_gom9/call_library_gom9.nc'
% Compiled module: COMPARE_CALL_TYPES_SCATTER.
% Compiled module: TEK_COLOR.
% Compiled module: SYMBOL_CIRCLE.
% Compiled module: READ_LFDCS_CALL_LIBRARY.
% Compiled module: STRIP_FILE_EXTENSION.
% Loaded DLM: NCDF.
% Compiled module: GET_NCDF_VARIABLE.
% Compiled module: CALCULATE_JULIAN.
% Compiled module: JULDAY.
% Compiled module: FIND_NEXEMPLAR.
% Compiled module: LEGEND_MFB.
% Compiled module: SET_SYMBOL.
IDL>
```

Key for 7 Call Type Attributes:
awfreq = Average frequency
awfreq_stdev = Frequency variation
awtime_stdev = Duration
awslope = Time-frequency slope
aws1 = Slope of the beginning (first third) of the call/pitch track
aws2 = Slope of the middle (second third) of the call/pitch track
aws3 = Slope of the end (last third) of the call/pitch track

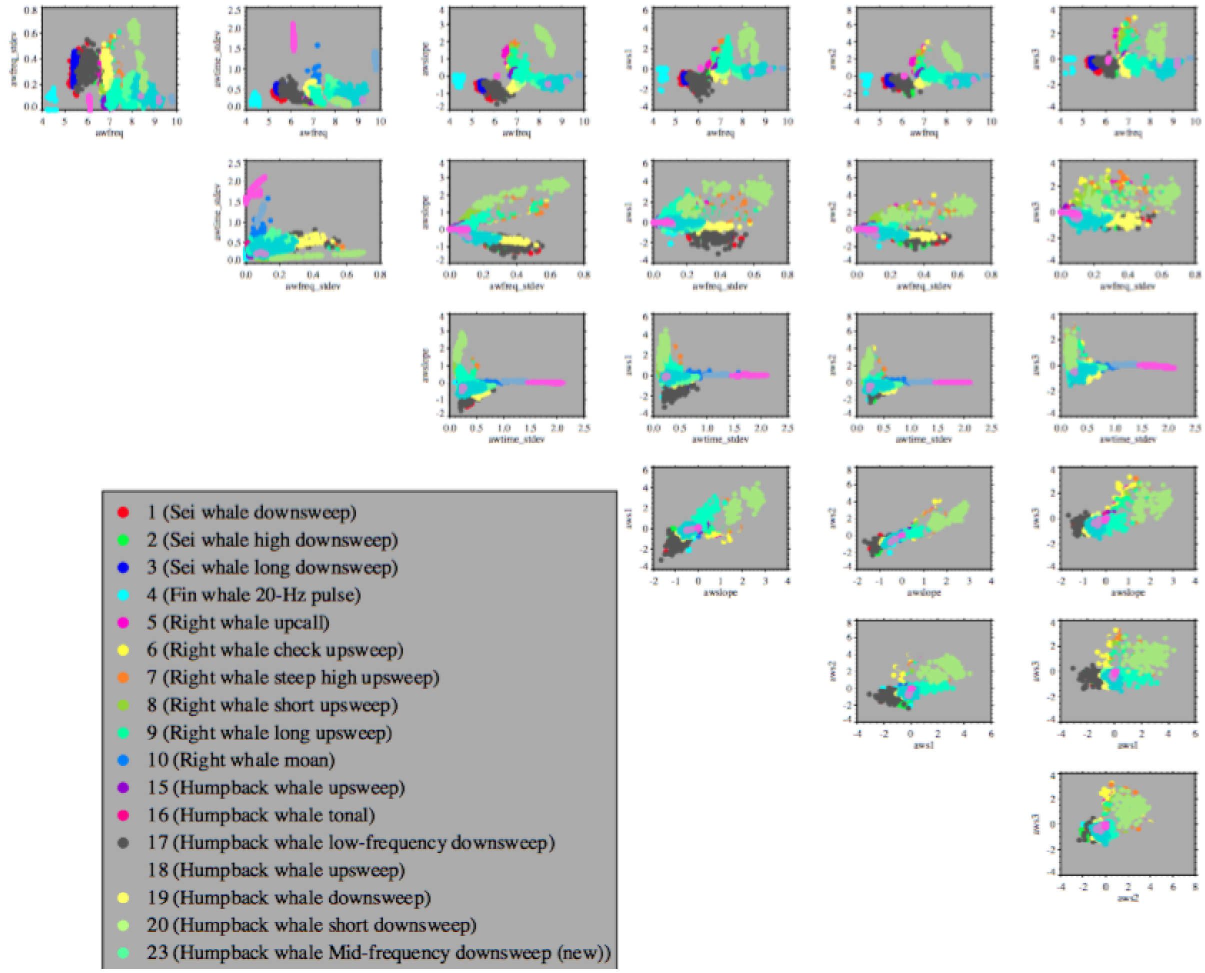
LFDCS Output

Note: The resulting LFDCS output window that appears once you enter this code may be very small and difficult to view. To expand the window, click and drag the bottom right-hand corner of the window outward. Then go back to the terminal window and re-enter the last line of code.



LFDCS Output as a Postscript File

Using the /ps command with your code will export a Postscript file (compare_call_types_scatter.ps) to your lfdcs/process folder that you can open as a PDF. This will allow you to view a larger version of the LFDCS output and zoom in as needed.



Multivariate Distributions with Canonical Discriminant Function Analysis

To assess overlap in multivariate distributions, canonical discriminant function analysis (CDFA) can be used to reduce the seven attribute dimensions down to two so that the distributions can be directly visualized using scatterplots. CDFA seeks to find linear combinations of the seven variables that best discriminates between the call types. By plotting the first two 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.

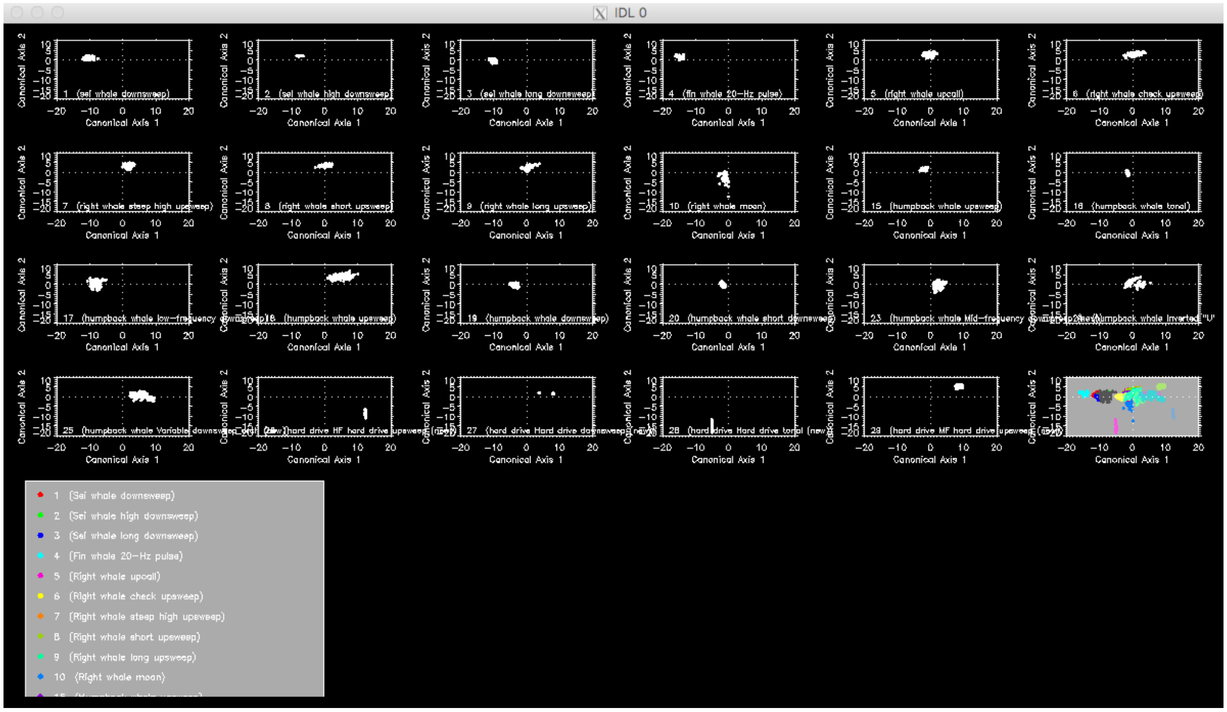
Code	***Commands***
1. Open terminal, launch IDL in lfdcs/call_library (hit return after typing each line of text in the command line below). **1% cd ~/Projects/Detectors/lfdcs/call_library** **2% idl** **IDL> compare_call_types_canonical, 'call_library_file'** *Example:* compare_call_types_canonical, '../call_library/clnb_gom9/call_library_gom9.nc', call_type=[5,6,7], /ps See example terminal window on the following page.	**call_type** To look at a subset of call types (e.g., call_type=[5,6,7]) **/ps** To export the results as a Postscript file that can be opened with a PDF reader; this will give you a larger view and allows you to zoom in on the figures in the LFDCS output

Terminal Window

```
Terminal — ⌘1
Last login: Mon Feb 21 19:12:14 on ttys000
[1% cd ~/Projects/Detectors/lfdcs/process
[2% idl
IDL Version 8.4, Mac OS X (darwin x86_64 m64). (c) 2014, Exelis Visual Information Solutions, Inc.
Installation number: 246512.
Licensed for use by: Woods Hole Oceanographic Institution

[IDL> compare_call_types_canonical, '../call_library/clnb_gom9/call_library_gom9.nc'
% Compiled module: COMPARE_CALL_TYPES_CANONICAL.
% Compiled module: TEK_COLOR.
% Compiled module: SYMBOL_CIRCLE.
% Compiled module: READ_LFDCS_CALL_LIBRARY.
% Compiled module: STRIP_FILE_EXTENSION.
% Loaded DLM: NCDF.
% Compiled module: GET_NCDF_VARIABLE.
% Compiled module: CALCULATE_JULIAN.
% Compiled module: JULDAY.
% Compiled module: FIND_NEXEMPLAR.
% Compiled module: CANONICAL_DISCRIMINANT_ANALYSIS.
% Compiled module: AVG.
% Compiled module: STDEV.
% Compiled module: QRFAC.
% Compiled module: REAL_PART.
% Compiled module: CHISQR_PDF.
% Compiled module: IGAMMA.
% Compiled module: CORRELATE.
% Compiled module: XPERC.
% Compiled module: YPERC.
% Compiled module: LEGEND_MFB.
% Compiled module: SET_SYMBOL.
IDL>
```

LFDCS Output

Note: The resulting LFDCS output window that appears once you enter this code may be very small and difficult to view. To expand the window, click and drag the bottom right-hand corner of the window outward. Then go back to the terminal window and re-enter the last line of code.



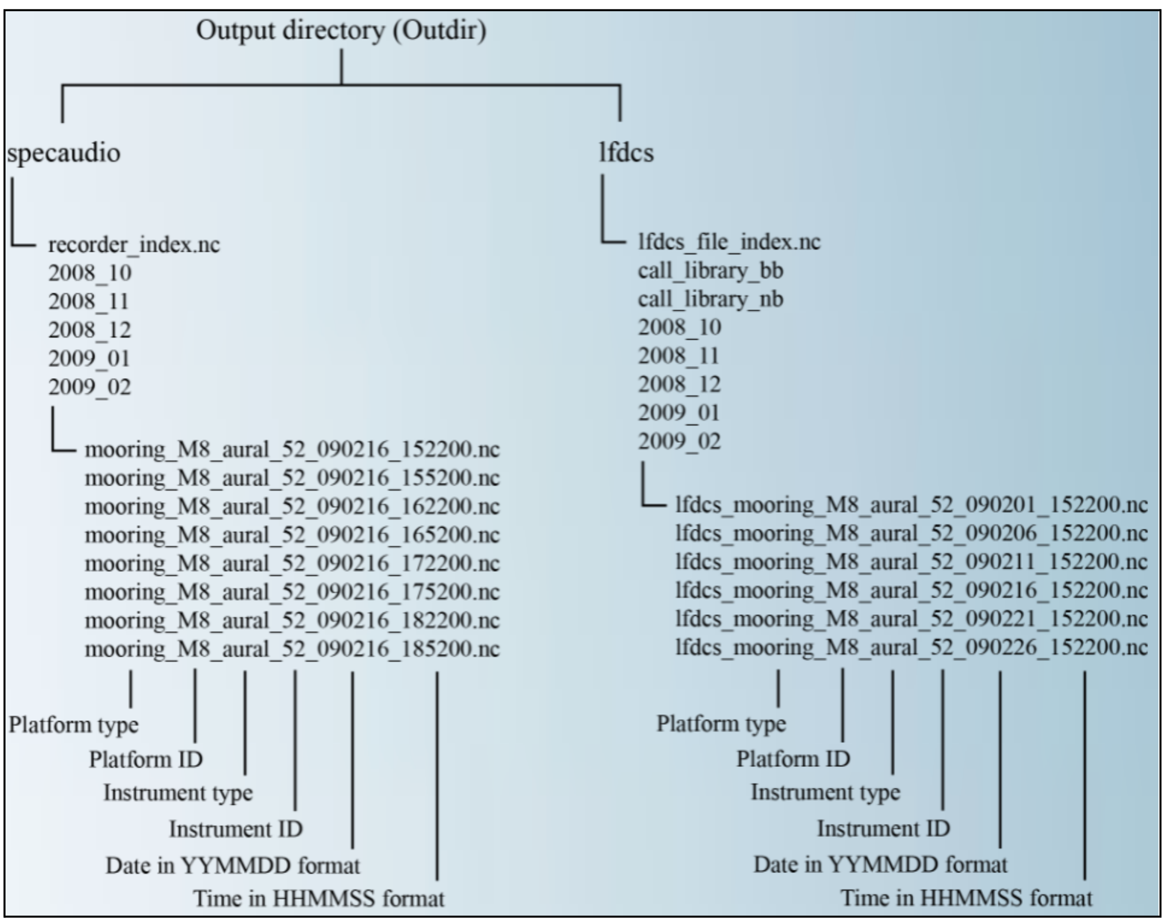
Data Processing

Processing Datasets

Below are directions for how to run audio files through the LFDCS to prepare for analysis. You must create a parameter file (in the directory /Users/username/Projects/Detectors/lfdcs/paramfiles) for each dataset (unique recorder) you want to process. See testparam.txt in the lfdcs/paramfiles folder, and Appendix A for an example and explanation of the parameters.

There are two 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 paramfile. 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. The output directory structure is as follows:



Note: NEFSC processes and resamples datasets with two different sample rates and call libraries (for humpback, sei, and NARW, acoustic data is resampled in the processing stage to 2000Hz; for fin and blue whales, datasets are resampled to 128Hz). Once specaudio is created for the 2kHz sample rate, you can use that specaudio to resample for lower frequencies, rather than having to re-process the original audio. See example in paramfiles/Davis_etal 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 one 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 (see above Note), it is good practice to add a specification in the parameter name (e.g., _2kHz, _LF).

<table>
<tr>
<th>Code</th>
<th>Commands</th>
</tr>
<tr>
<td>

In lfdcs/paramfiles, create and edit a new parameter file with your processing parameters (see testparam.txt example in Appendix A)
Open terminal, launch IDL in lfdcs/process (hit return after typing each line of text in the command line below)

1% cd ~/Projects/Detectors/lfdcs/process
2% idl
Process new recordings:

IDL> reformat_detect_classify, 'parameter_file'

Example:
reformat_detect_classify, '../paramfiles/NEFSC_SC_201511_site4.txt', start_date='02/01/10 00:00:00', end_date='02/15/10 00:00:00', /nolfdcs, /verbose
Confirm to process data.

The terminal asks you:

"Are you sure you want to convert data to NetCDF? (y/n)"

Type "y" and hit enter

</td>
<td>
/nolfdcs
To only convert raw audio to specaudio files without running LFDCS

/noconvert
To only run LFDCS without converting raw audio to specaudio files. Note: The specaudio files must already exist to use this command.

start_date= 'MM/DD/YY HH:MM:SS'
To specify the date/time to start reformatting and processing in MM/DD/YY HH:MM:SS format (e.g., start_date='02/01/10 00:00:00')

end_date= 'MM/DD/YY HH:MM:SS'
To specify the date/time to end reformatting and processing in MM/DD/YY HH:MM:SS format (e.g., end_date='02/15/10 00:00:00')

/verbose
To output extra information about processing
</td>
</tr>
</table>

Note: If you have already processed this dataset and are reprocessing, or restarting due to it halting, another prompt will pop up saying: **"LFDCS files already exist, do you want to overwrite? (y/n)"** Type **"y"** and hit enter	

Terminal Window

Terminal — ⌘1

```
Last login: Wed Feb 16 12:30:59 on ttys000
[1% cd ~/Projects/Detectors/lfdcs/process
[2% idl
IDL Version 8.4, Mac OS X (darwin x86_64 m64). (c) 2014, Exelis Visual Information Solutions, Inc.
Installation number: 246512.
Licensed for use by: Woods Hole Oceanographic Institution

[IDL> reformat_detect_classify, '../paramfiles/test_dataset/testparam.txt'
% Compiled module: REFORMAT_DETECT_CLASSIFY.
% Compiled module: READ_PARAM_FILE.
% Compiled module: STRING_TO_JULIAN.
% Compiled module: CALCULATE_JULIAN.
% Compiled module: JULDAY.
% Compiled module: CHECK_LFDCS_PARAMS.
Creating /Users/psb/Projects/Detectors/lfdcs/test_dataset/processed
% Compiled module: SLASH_CHECK.
Are you sure you want to convert the recorder data to NetCDF? (y/n) y
% Compiled module: CONVERT_RECORDER_TO_NETCDF.
Creating /Users/psb/Projects/Detectors/lfdcs/test_dataset/processed/specaudio/recorder_index.nc
% Loaded DLM: NCDF.
% Compiled module: PARAMETER_EXISTS.
% Compiled module: FIND_DATE_IN_FILENAME.
Reading /Users/psb/Projects/Detectors/lfdcs/test_dataset/raw/NOPP6_EST_20090330_000000_CH10.wav
% Compiled module: WRITE_RECORDER_NETCDF.
% Compiled module: CALCULATE_GREGORIAN.
% Compiled module: CALDAT.
Writing
/Users/psb/Projects/Detectors/lfdcs/test_dataset/processed/specaudio/2009_03/moored_buoy_NOPP6_maru_6_090330_000000.nc
% Compiled module: JULIAN_TO_STRING.
% Compiled module: COMPUTE_SPECTROGRAM.
% Compiled module: HANNING.
Reading /Users/psb/Projects/Detectors/lfdcs/test_dataset/raw/NOPP6_EST_20090330_010000_CH10.wav
Expected next file date: 03/30/09 01:00:00 0.0000000
  Actual next file date: 03/30/09 01:00:00 0.0000000
Gap between audio files is negative: 0.0000000 seconds
Setting date to what it *should* be based on the length of the last file...
Writing
/Users/psb/Projects/Detectors/lfdcs/test_dataset/processed/specaudio/2009_03/moored_buoy_NOPP6_maru_6_090330_003000.nc
Writing
/Users/psb/Projects/Detectors/lfdcs/test_dataset/processed/specaudio/2009_03/moored_buoy_NOPP6_maru_6_090330_010000.nc
Reading /Users/psb/Projects/Detectors/lfdcs/test_dataset/raw/NOPP6_EST_20090330_020000_CH10.wav
Expected next file date: 03/30/09 02:00:00 0.0000000
  Actual next file date: 03/30/09 02:00:00 0.0000000
Gap between audio files is negative: 0.0000000 seconds
```

```
Setting date to what it *should* be based on the length of the last file...
Writing
/Users/psb/Projects/Detectors/lfdcs/test_dataset/processed/specaudio/2009_03/moored_buoy_NOPP6_maru_6_090330_013000.nc
Writing
/Users/psb/Projects/Detectors/lfdcs/test_dataset/processed/specaudio/2009_03/moored_buoy_NOPP6_maru_6_090330_020000.nc
Writing
/Users/psb/Projects/Detectors/lfdcs/test_dataset/processed/specaudio/2009_03/moored_buoy_NOPP6_maru_6_090330_023000.nc
% Compiled module: GET_NCDF_VARIABLE.

% Compiled module: READ_RECORDER_INDEX.
Creating /Users/psb/Projects/Detectors/lfdcs/test_dataset/processed/lfdcs/lfdcs_file_index.nc
% Compiled module: CREATE_LFDCS_INDEX_FILE.
Creating /Users/psb/Projects/Detectors/lfdcs/test_dataset/processed/lfdcs/call_library_nb/
Creating /Users/psb/Projects/Detectors/lfdcs/test_dataset/processed/lfdcs/call_library_bb/
% Compiled module: STRIP_FILE_EXTENSION.
% Compiled module: REFORMAT_PARAMETERS_FOR_LFDCS.
% Compiled module: REFORMAT_CALL_LIBRARY_FOR_LFDCS.
% Compiled module: READ_LFDCS_CALL_LIBRARY.
% Compiled module: CREATE_LFDCS_FILES.
% Loaded DLM: CALL_TRACKING_LFDCS_DLM.
% Compiled module: CONSOLIDATE_DETECTION_FILES.
% Compiled module: COPY_NCDF.
Time elapsed for 2009_03/lfdcs_moored_buoy_nopp6_maru_6_090330_000000.nc: 0 hours, 0 minutes, and 22 seconds

***************************
LFDCS processing completed!
***************************
```

Reclassifying Autodetections

Below are directions for 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 and call classifications, you can reprocess the datasets with a parameter file (directing to the new call library) and add the command “/noconvert” to the code 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 (see the parameter file example for LF processing above) to reflect the specaudio files, not the original audio files.

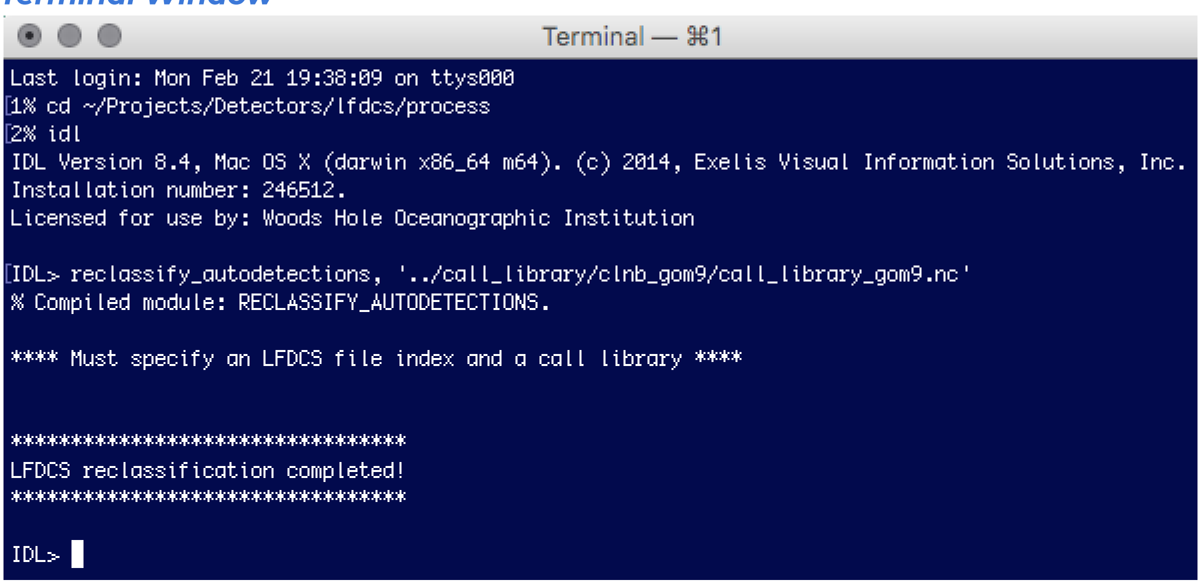
Code

1. Open terminal, launch IDL in lfdcs/process (hit return after typing each line of text in the command line below).

   1% cd ~/Projects/Detectors/lfdcs/process
   2% idl
   IDL> reclassify_autodetections, 'lfdcs_index_file', 'call_library_file'

Example:
reclassify_autodetections,
'/Volumes/ExternalHD/NEFSC_SC_201511_site4/lfdcs/lfdcs_files_index.nc',
'../call_library/clnb_gom9/call_library_gom9.nc'

Terminal Window



Data Review

Manually Reviewing Data

Below are directions for 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 and assign them to a species which you can later export. The species and codes can be found in the ***Manual Species Codes*** table below, as well as in the manual_classes.csv document, found in your lfdcs/process folder. In this document, the “Species Code” value is what you can specify in the manual_species=[] parameter. Here, we have added Incorrect, Correct, Unknown, and Unclassified values in the "Species" column to allow for a Correct/Incorrect/Unknown manual analysis scoring (this is the method used in NEFSC daily presence analyses, see protocols described in Appendix B for more information). Likewise, the manual_classes.csv also has a “Call Type Code" column (specified below in the manual_call_type=[] parameter), 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.

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
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

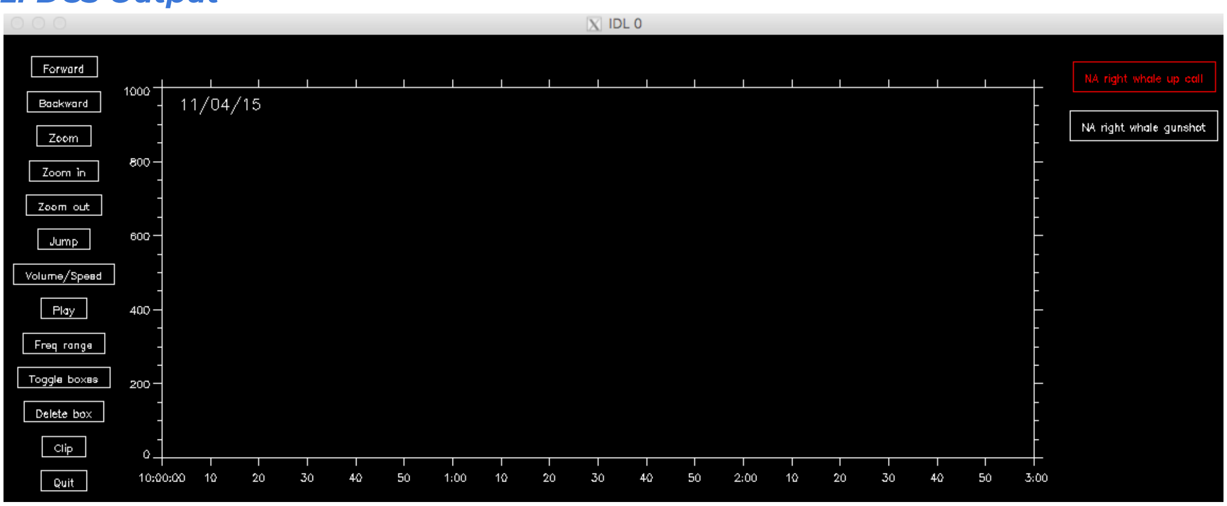
Code	*Commands*
1. Open terminal, launch IDL in lfdcs/process (hit return after typing each line of text in the command line below). **1% cd ~/Projects/Detectors/lfdcs/process** **2% idl** 2. Manually review data: **IDL> manual_detections, 'processed_specaudio_folder', 'log_index_file'** *Example:* manual_detections, '/Volumes/ExternalHD/NEFSC_SC_201511_site4/processed/specaudio', '/Volumes/ExernalHD/NEFSC_SC_201511_site4/missed_validation/RW_missed_validation_log_JW.nc', manual_species=[7,7], manual_call_type=[1,3]	**manual_species** To enter species code values that will appear as classification buttons to allow for manual classification of species (e.g., manual_species=[7] as 7 is the code value for North Atlantic right whale **OR** manual_species=[9999,-9999,0,-32767] which are the four code values for the “Correct”, “Incorrect”, “Unknown” and “Unclassified” buttons, respectively, that you can use instead of species buttons) **manual_call_type** To specify the call type within a given species category (e.g., manual_call_type=[1,3] as 1 is the code value for a North Atlantic right whale upcall and 3 is the code value for a North Atlantic right whale gunshot). If no call type is needed (i.e., you are only identifying species or correct/incorrect), you can omit this command).

Terminal Window

Terminal — ⌘1

```
[1% cd ~/Projects/Detectors/lfdcs/process
[2% idl
 IDL Version 8.4, Mac OS X (darwin x86_64 m64). (c) 2014, Exelis Visual Information Solutions, Inc.
 Installation number: 246512.
 Licensed for use by: Woods Hole Oceanographic Institution

[IDL> manual_detections, '/Volumes/NEFSC_22/NEFSC_SC_201511/NEFSC_SC_201511_CH4/specaudio', '/Volumes/NEFSC_22/NE
FSC_SC_201511/NEFSC_SC_201511_CH4/missed_validation/RW_missed_validation_log_JW.nc', manual_species=[7,7], manua
l_call_type=[1,3]
% Compiled module: MANUAL_DETECTIONS.
% Compiled module: SLASH_CHECK.
% Compiled module: READ_RECORDER_INDEX.
% Loaded DLM: NCDF.
% Compiled module: GET_NCDF_VARIABLE.
% Compiled module: READ_RECORDER.
% Compiled module: NCDF_FILL_FLOAT.
% Compiled module: STRING_TO_JULIAN.
% Compiled module: CALCULATE_JULIAN.
% Compiled module: JULDAY.
% Compiled module: READ_ASCII_DATA.
% Compiled module: TIME_TICKS.
% Compiled module: CALCULATE_GREGORIAN.
% Compiled module: CALDAT.
% Compiled module: PLOT_MINOR_DATE_TICKS.
% Compiled module: DISPLAY_IMAGE.
% Compiled module: TEK_COLOR.
% Compiled module: JULIAN_TO_STRING.
% Compiled module: XPERC.
% Compiled module: YPERC.
% Compiled module: WINDOW_BUTTONS.
```

LFDCS Output



Viewing/Browsing Automated Detections

Below are directions for how to open a dataset in LFDCS that has already been processed through the detector with a specific call library. The browse_autodetections function 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".

The 'lfdcs_index_file' in the ***Code*** section below refers to the index file found in the "lfdcs" subdirectory in the output directory (e.g., /Volumes/ExternalHD/NEFSC_SC_201511_site4/lfdcs/lfdcs_file_index.nc). As a shortcut, you may also just provide the lfdcs subdirectory (e.g., /Volumes/ExternalHD/NEFSC_SC_201511_site4/lfdcs) or the output directory (e.g., /Volumes/ExternalHD/NEFSC_SC_201511_site4).

You may include numerous commands to specify exactly the kind of calls you want to examine, see the ***Commands*** section below. For example, to look for fin whale 20-Hz calls on or after 12/10/09, you might use the following commands: start='12/10/09 00:00:00', min_freq=15, max_freq=25, min_duration=0.25, max_duration=1.25.

If you would like to manually classify autodetections, set the "classify" command (e.g., /classify), and specify which species and call types you intend to classify using the "manual_species'' and "manual_call_type" commands (e.g., manual_species=[1, 2, 3], manual_call_type=[99, 99, 99]). 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 the Manual Species Codes table 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, you can use just manual_species=[9999,-9999,0,-32767] and should omit the manual_call_type command.

<table>
<tr><th>Code</th><th>Commands</th></tr>
<tr><td>
1. Open terminal, launch IDL in lfdcs/process (hit return after typing each line of text in the command line below).

1% cd ~/Projects/Detectors/lfdcs/process
2% idl

2. Browse autodetections:

IDL> browse_autodetections, 'lfdcs_index_file'

This opens detections from the start of a specified month/channel.

Example:
</td><td>
start= 'MM/DD/YY HH:MM:SS'
To specify the date/time to start browsing autodetections in MM/DD/YY HH:MM:SS format (e.g., start='01/20/15 19:30:00')

call_family
To view all autodetections in a call family (*1=broadband, 2=narrowband) (e.g., call_family=2)

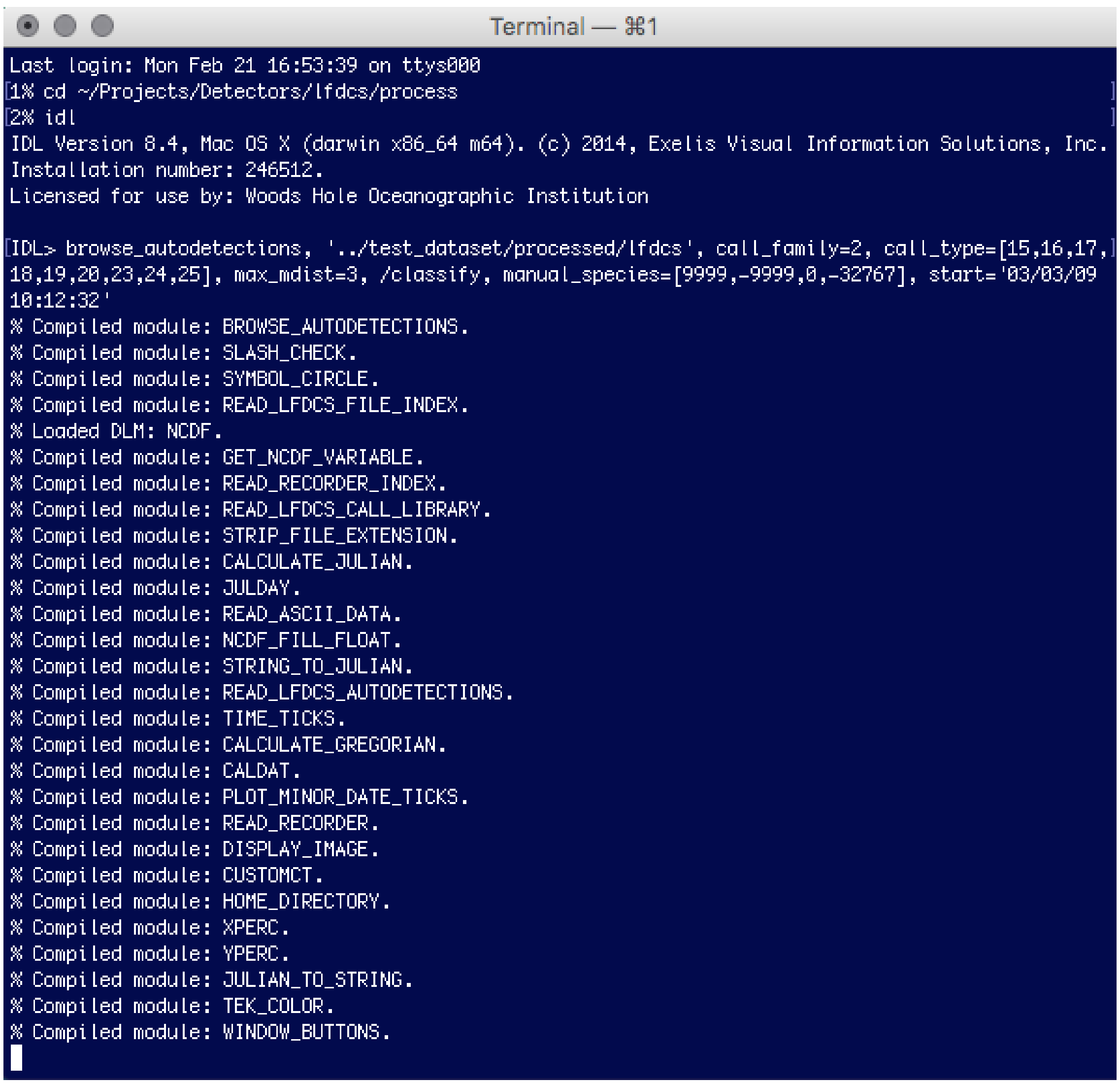
*LFDCS has the capacity to process broadband data, but it is still under development and not yet functional with the software.

call_type
To view all autodetections of a particular call type (e.g., call_type=[1, 2, 3]). If you have multiple call type values in order you can enter the
</td></tr>
</table>

browse_autodetections, '/Volumes/ExternalHD/NEFSC_SC_201511_site4/lfdcs', call_family=2, call_type=[15:25], max_mdist=3, /classify, manual_species=[9999,-9999,0,-32767], start='02/01/21 10:12:32'	range using a colon (e.g., instead of call_type=[1,2,3,4,5,6], use call_type=[1:6]). **min_amplitude** To view all autodetections greater than or equal to a specified minimum amplitude (in dB above background) (e.g., min_amplitude=12) **max_amplitude** To view all autodetections less than or equal to a specified maximum amplitude (in dB above background) (e.g., max_amplitude=20) **min_mdist** To view all autodetections greater than or equal to a specified minimum Mahalanobis distance (e.g., min_mdist=1.0) **max_mdist** To view all autodetections less than or equal to a specified maximum Mahalanobis distance (e.g., max_mdist=3.0) **min_freq** To view all autodetections greater than or equal to a specified minimum frequency (in Hz) (e.g., min_freq=200) **max_freq** To view all autodetections less than or equal to a specified maximum frequency (in Hz) (e.g., max_freq=800) **min_duration** To view all autodetections greater than or equal to a specified minimum duration (in seconds) (e.g., min_duration=1.0) **max_duration** To view all autodetections less than or equal to a specified maximum duration (in seconds) (e.g., max_duration=4.0) **/classify** To enable manual classification of each autodetection **manual_species** To enter species code values that will appear as classification buttons to allow for manual classification of species (e.g., manual_species=[7] as 7 is the code value for

	North Atlantic right whale **OR** manual_species=[9999,-9999,0,-32767] which are the four code values for the “Correct”, “Incorrect”, “Unknown” and “Unclassified” buttons, respectively, that you can use instead of species buttons) **manual_call_type** To specify the call type within a given species category (e.g., manual_call_type=[1,3] as 1 is the code value for a North Atlantic right whale upcall and 3 is the code value for a North Atlantic right whale gunshot). If no call type is needed (i.e., you are only identifying species or correct/incorrect), you can omit this command).

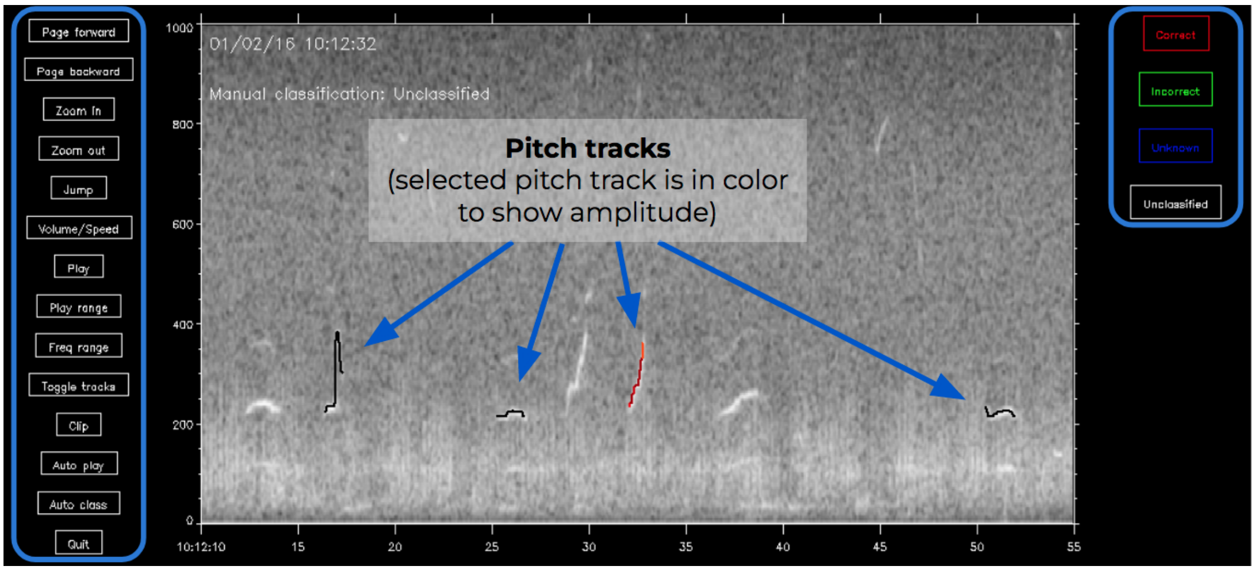
Terminal Window



Desktop Buttons

The following image and descriptions explain the basic functions available once an audio file has been processed with the LFDCS and is opened in the desktop version in order to view automated detections (based on a specified call library). The buttons along the left-hand side of the window are standard in most LFDCS programs, the buttons along the right-hand side of the window are specific to the browse_autodetections function.

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). 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.



Button	Function
Select next detection/pitch track (not a visible button in the image above)	Click on (or hover cursor over the spectrogram window and scroll) the black background anywhere on the right-hand side of the window to navigate to the next automated detection (pitch track).
Select previous detection/pitch track (not a visible button in the image above)	Click on (or hover cursor over the spectrogram window and scroll) the black background anywhere on the left-hand side of the window to navigate to the next automated detection (pitch track).
'Page forward'	Click on (or hover cursor over button and scroll) 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 (or viewing window) 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, navigate back to the terminal window and enter the desired date and time in the MM/DD/YY HH:MM:SS format. *Example:* **Jump to date (mm/dd/yy hh:mm:ss) -> 01/29/16 04:13:58**
'Volume/Speed'	Adjusts volume and playback speed of audio file. After clicking, navigate back to the terminal window and enter the desired volume (on a scale of 1-10) and desired speed. Default values are both 1 whenever a processed deployment is opened from the terminal. *Example:* **Volume -> 7** **Speed -> 2**
'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 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, navigate back to the terminal window and enter the desired maximum frequency in Hz. The minimum frequency will remain 0 Hz. *Example:* **Maximum frequency: 600**
'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, 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. Navigate back to the terminal window and enter the desired playback speed/volume and file name (must type out the .wav file extension at the end of the file name for it to save correctly). Selecting 'N' for Normal speed/volume will automatically save the sound file at Speed = 1 and Volume = 1. Selecting 'S' for Selected speed/volume will automatically save the sound file at the speed/volume the analyst set using the 'Volume/Speed' button (e.g., Speed = 2 and Volume = 8). Once the file name has been entered in the terminal window, the file is saved in your lfdcs/process directory. To save to an alternate location, the file path can be inserted in the file name (i.e. /Users/CompuerName/Desktop/Clips/WaveName.wav) *Example:* **Save a (N)ormal speed/volume or currently (S)elected speed/volume? (N/S) N** **Name of WAV file -> SBNMS_humpback-upsweeps_021416_053947.wav**
'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 then close out of the desktop window and terminal. **Use this button first to properly exit the program, then click on the "x" button on the top left corner of the window.** The LFDCS window will not close properly if the “Quit” button is not clicked before the “x” button.
'Correct'	Click on (or hover cursor over and scroll) the red 'Correct' button on the right-hand side of the window to mark the currently selected (colored) pitch track as a correct detection for that call type. The program will then automatically move forward to the next automated detection (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) the green 'Incorrect' button on the right-hand side of the window to mark the currently selected (colored) pitch track as an incorrect detection for that call type. The program will then automatically move forward to the next automated detection (pitch track).
'Unknown'	Click on (or hover cursor over and scroll) the blue 'Unknown' button on the right-hand side of the window to mark the currently selected (colored) pitch track as an unknown detection for that call type. The program will then automatically move forward to the next automated detection (pitch track). 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.
'Unclassified'	Click on (or hover cursor over and scroll) the white 'Unclassified' button on the right-hand side of the window to mark the currently selected (colored) pitch track as an unclassified detection for that call type. The program will then automatically move forward to the next automated detection (pitch track). 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'.

Note: If you have already analyzed a dataset and want to browse through detections that you have only marked correct or unknown, for example, you can add select_manual_species with the correct/incorrect/unknown/unclassified classification codes you want to look through (e.g., select_manual_species=[9999, 0]). This command only works in conjunction with manual_species also being included (can choose to have all buttons included in manual_species, if you want to change the classification of what you are browsing)

Example of full line of code to view only correct or unknown marked detections for the call types specified:

browse_autodetections, '/Volumes/ExternalHD/NEFSC_SC_201511_site4/lfdcs', call_family=2, call_type=[15,16,17,18,19,20,23,24,25], max_mdist=3, /classify, manual_species=[9999,-9999,0,-32767], select_manual_species=[9999,0]

Data Export

Exporting Automated Detections

Below are directions for 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, as well as a description of each of the columns. Following the header, there is one 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, the detection start time (as seconds since the start date given in the original parameter file to process the data), the detection end time (as seconds since the start date), times of the pitchtrack, duration (seconds), minimum frequency (Hz), maximum frequency (Hz), bandwidth (Hz), amplitude (dB relative to background), and mahalanobis distance.

You may include several commands to specify exactly the kind of calls you want to export (see Basic Commands below). For example, you can specify the call type numbers you want to export (e.g., [1, 2, 3]), and any classification provided from the call library.

<table>
<tr><th>Code</th><th>Commands</th></tr>
<tr><td>
1. Open terminal, launch IDL in lfdcs/process (hit return after typing each line of text in the command line below).

1% cd ~/Projects/Detectors/lfdcs/process
2% idl

2. Process autodetection table as a .csv file:

IDL> export_autodetections, 'lfdcs_index_file', call_type, 'exported_autodetections_sheet_name.csv'

lfdcs_index_file refers to the index file found in the "lfdcs" subdirectory in the output directory (e.g., /Volumes/ExternalHD/NEFSC_SC_201511_site4/lfdcs/lfdcs_file_index.nc). As a shortcut, you may also just provide the lfdcs subdirectory (e.g., /Volumes/ExternalHD/NEFSC_SC_201511_site4/lfdcs) or the output directory (e.g., /Volumes/HARDDRIVE_NAME/NEFSC_SC_201511/NEFSC_SC_201511_site4).

Sheets automatically export to your lfdcs/process directory; if you would like this to go into another directory, specify the path in the output file name.
</td><td>
sdate= ‘MM/DD/YY HH:MM:SS’
To specify the date/time to start exporting autodetections in MM/DD/YY HH:MM:SS format (e.g., sdate='01/20/15 19:30:00')

edate= ‘MM/DD/YY HH:MM:SS’
To specify the date/time to end exporting autodetections in MM/DD/YY HH:MM:SS format (e.g., edate='01/20/15 23:30:00')

/narrowband
To export only narrowband autodetections (call family = 2); this is the default behavior

*/broadband
To export only broadband autodetections (call family = 1)

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

[5,6,7]
To export specific call types using the respective code values. Note: Call types are specified without a command label in this program.

max_mdist
</td></tr>
</table>

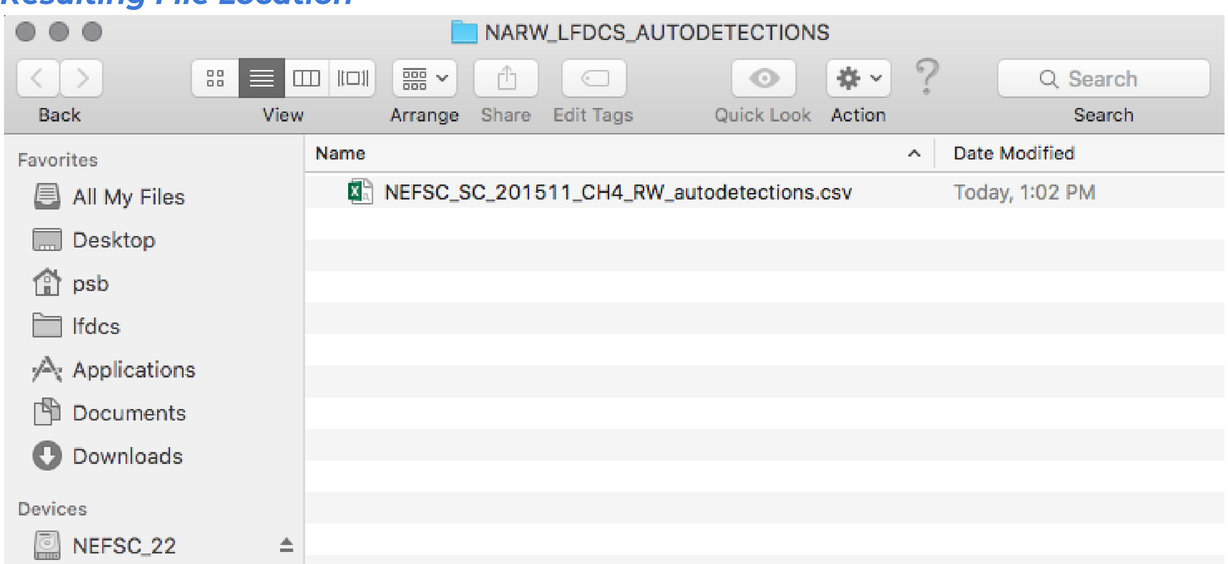
	To export all autodetections less than or equal to a specified maximum Mahalanobis distance (e.g., max_mdist=3.0) **/manual** To also export associated manual classification information for all automated detections that are exported **/textdate** To export date/time in text format with fractional seconds **/list** To export the top 3 call types; this command adds additional columns to the output which give the posterior probability and Mahalanobis distance for the first three call types for that pitch track. Without /list you get just the top (first) call type.
North Atlantic Right Whale Example: export_autodetections, '/Volumes/ExternalHD/NEFSC_SC_201511_site4/', [5,6,7,8,9], '/Users/Desktop/NARW_LFDCS_AUTODETECTIONS/NEFSC_SC_201511_site4_RW_autodetections.csv', /list ***Sei Whale Example:*** export_autodetections, '/Volumes/ExternalHD/NEFSC_SC_201511_site4/', [1,2,3], '/Users/Desktop/SEI_LFDCS_AUTODETECTIONS/NEFSC_SC_201511_site4_SW_autodetections.csv' ***Fin Whale Example (decimated data):*** export_autodetections, '/Volumes/ExternalHD/NEFSC_SC_201511_site4/', [1], '/Users/Desktop/FIN_LFDCS_AUTODETECTIONS/NEFSC_SC_201511_site4_FW_autodetections.csv' ***Blue Whale Example (decimated data, higher mdist):*** export_autodetections, '/Volumes/ExternalHD/NEFSC_SC_201511_site4/', [2,3,4], '/Users/Desktop/BLUE_LFDCS_AUTODETECTIONS/NEFSC_SC_201511_site4_BW_autodetections.csv'	*Note:* Call types for humpback, sei, and right whales are specific to the 'clnb_gom9' call library. Call types for fin and blue whales are specific to the 'clnb_gomlf_blue' call library.

Humpback Example: export_autodetections, '/Volumes/ExternalHD/NEFSC_SC_201511_site4/', [15,16,17,18,19,20,23,24,25], '/Users/Desktop/HUMPBACK_LFDCS_AUTODETECTIONS/NEFSC_SC_201511_site4_HW_autodetections.csv'	

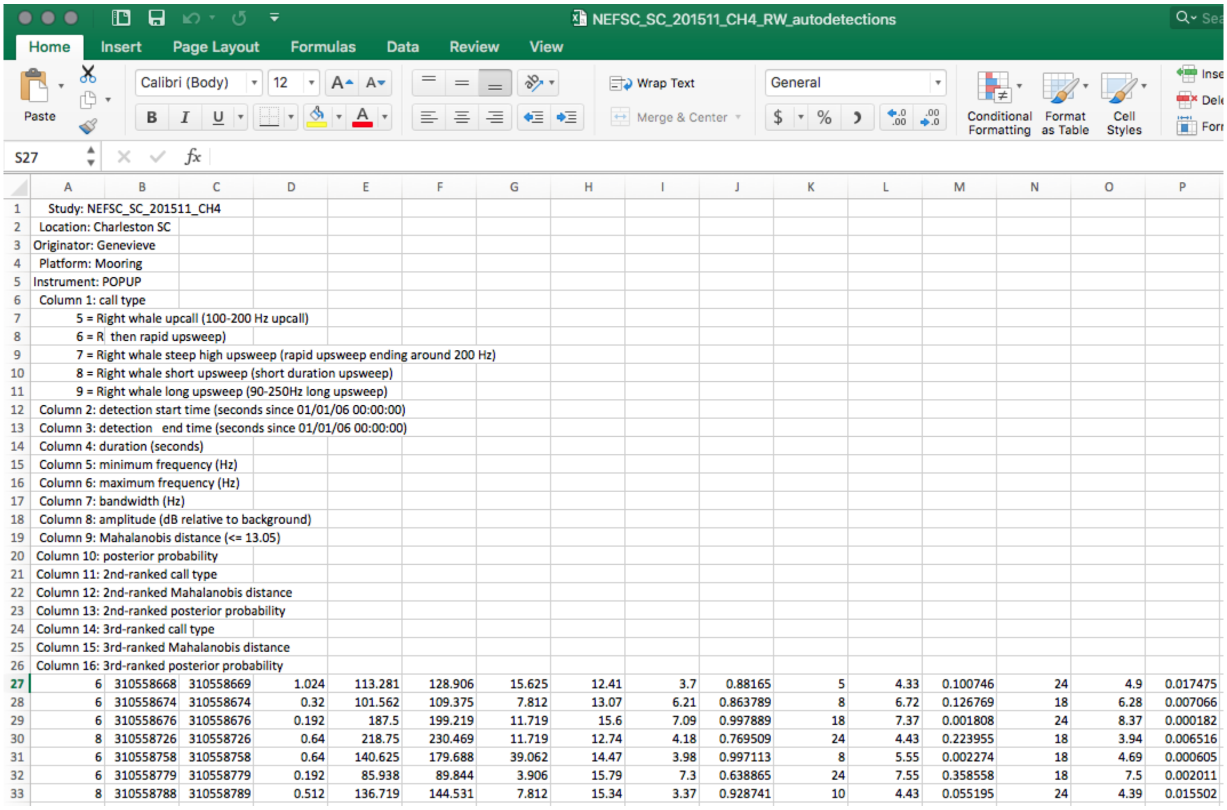
Terminal Window

```
Terminal — ⌘1
Last login: Fri Feb 25 12:19:42 on ttys000
[1% cd ~/Projects/Detectors/lfdcs/process
[2% idl
IDL Version 8.4, Mac OS X (darwin x86_64 m64). (c) 2014, Exelis Visual Information Solutions, Inc.
Installation number: 246512.
Licensed for use by: Woods Hole Oceanographic Institution

[IDL> export_autodetections, '/Volumes/NEFSC_22/NEFSC_SC_201511/NEFSC_SC_201511_CH4/', [5,6,7,8,9], '/Users/psb/D
esktop/NARW_LFDCS_AUTODETECTIONS/NEFSC_SC_201511_CH4_RW_autodetections.csv', /list
% Compiled module: EXPORT_AUTODETECTIONS.
% Compiled module: SLASH_CHECK.
% Compiled module: READ_LFDCS_FILE_INDEX.
% Loaded DLM: NCDF.
% Compiled module: GET_NCDF_VARIABLE.
% Compiled module: READ_LFDCS_CALL_LIBRARY.
% Compiled module: STRIP_FILE_EXTENSION.
% Compiled module: CALCULATE_JULIAN.
% Compiled module: JULDAY.
% Compiled module: READ_LFDCS_ALL_AUTODETECTIONS.
% Compiled module: JULIAN_TO_STRING.
% Compiled module: CALCULATE_GREGORIAN.
% Compiled module: CALDAT.
Reading autodetections:     0%% Compiled module: READ_LFDCS_AUTODETECTIONS.
% Compiled module: STRING_TO_JULIAN.
   10%   20%   30%   40%   50%   60%   70%   80%   90%  100%
IDL>
```

Resulting File Location



Exported Automated Detections



NEFSC_SC_201511_CH4_RW_autodetections

	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

Exporting Summary Sheets of Autodetections

Below are directions for 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. With the correct code, 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., max_mdist=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.

Note: 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).

<table>
<tr><th>Code</th><th>Commands</th></tr>
<tr><td>

Open terminal, launch IDL in lfdcs/process (hit return after typing each line of text in the command line below).

1% cd ~/Projects/Detectors/lfdcs/process
2% idl
Process new summary sheet as a .csv file:

IDL> export_summary_autodetections, 'lfdcs_index_file', [call_types], 'exported_autodetections_sheet_name.csv', sdate='MM/DD/YY HH:MM:SS', edate='MM/DD/YY HH:MM:SS', BinNumber, /timeBin

You may include other commands (in addition to the ones listed in the column to the right) to correspond to and have summary sheets that only include detections used for a daily presence analysis. For example, call types (e.g., [5,6,7,8]) and maximum mahalanobis distance (e.g., max_mdist=3.0).
</td><td>
sdate= 'MM/DD/YY HH:MM:SS'
To specify the date/time at which to start summarizing the data (e.g., sdate= '01/15/20 00:00:00')

edate= 'MM/DD/YY HH:MM:SS'
To specify the last date/time to be included in the summary sheet (e.g., edate= '04/25/20 00:00:00'). The 'edate' command must be included to avoid an endless exported sheet for dates over which there is no data (file will never finish writing).

BinNumber
This represents the amount of units to summarize the specified time bin (e.g., 24.0 when used with the /timeBin code '/hours' means a 24 hour period, 30 when used with /timeBin code '/minutes' would look at 30 minute summaries)

/timeBin
To specify the time period over which the data is summarized. This command can be written as /seconds, /minutes, /hours, /days, or /months and the number of these to summarize over can be specified using the BinNumber command (e.g., /days, 5.0 would summarize detections for every 5 days).
</td></tr>
</table>

Note: The following examples will export <u>daily</u> presence summary sheets which were most commonly used for analyses conducted at NEFSC/WHOI. ***North Atlantic Right Whale Example:*** export_summary_autodetections, '/Volumes/ExternalHD/NEFSC_SC_201511_site4/lfdcs', [5,6,7,8,9], 'NEFSC_SC_201511_site4_right_daily_det.csv', 24.0, max_mdist=3.0, sdate= '11/01/15 00:00:00', edate = '04/30/16 0:00:00', /hours ***Sei Whale Example:*** export_summary_autodetections, '/Volumes/ExternalHD/NEFSC_SC_201511_site4/lfdcs', [1,2,3], 'NEFSC_SC_201511_site4_sei_daily_det.csv', 24.0, max_mdist=3.0, sdate= '11/01/15 00:00:00', edate = '04/30/16 0:00:00', /hours ***Fin Whale Example (decimated data):*** export_summary_autodetections, '/Volumes/ExternalHD/NEFSC_SC_201511_site4/lfdcs', [1], 'NEFSC_SC_201511_site4_fin_daily_det.csv', 24.0, max_mdist=3.0, sdate= '11/01/15 00:00:00', edate = '04/30/16 0:00:00', /hours ***Blue Whale Example (decimated data, higher mdist):*** export_summary_autodetections, '/Volumes/ExternalHD/NEFSC_SC_201511_site4/lfdcs', [2,3,4], 'NEFSC_SC_201511_site4_blue_daily_det.csv', 24.0, max_mdist=5.0, sdate= '11/01/15 00:00:00', edate = '04/30/16 0:00:00', /hours ***Humpback Example:*** export_summary_autodetections, '/Volumes/ExternalHD/NEFSC_SC_201511_site4/lfdcs', [15,16,17,18,19,20,23,24,25], 'NEFSC_SC_201511_site4_humpback_daily_det.csv', 24.0, max_mdist=3.0, sdate= '11/01/15 00:00:00', edate = '04/30/16 0:00:00', /hours	*Note:* Call types for humpback, sei, and North Atlantic right whales are specific to the 'clnb_gom9' call library. Call types for fin and blue whales are specific to the 'clnb_gomlf_blue' call library.

Terminal Window

```
Terminal — ⌘1
Last login: Mon Feb 21 21:11:38 on ttys000
1% cd ~/Projects/Detectors/lfdcs/process
2% idl
IDL Version 8.4, Mac OS X (darwin x86_64 m64). (c) 2014, Exelis Visual Information Solutions, Inc.
Installation number: 246512.
Licensed for use by: Woods Hole Oceanographic Institution

IDL> export_summary_autodetections, '/Volumes/NEFSC_22/NEFSC_SC_201511/NEFSC_SC_201511_CH4', [5,6,7,8,9], 'NEFSC_SC_201511_site4_right_daily_det.csv', 24.0, max_mdist=3.0, sdate= '11/01/15 00:00:00', edate = '04/30/16 0:00:00'
,  /hours
% Compiled module: EXPORT_SUMMARY_AUTODETECTIONS.
% Compiled module: SLASH_CHECK.
% Compiled module: READ_LFDCS_FILE_INDEX.
% Loaded DLM: NCDF.
% Compiled module: GET_NCDF_VARIABLE.
% Compiled module: READ_LFDCS_CALL_LIBRARY.
% Compiled module: STRIP_FILE_EXTENSION.
% Compiled module: CALCULATE_JULIAN.
% Compiled module: JULDAY.
% Compiled module: READ_LFDCS_ALL_AUTODETECTIONS.
% Compiled module: STRING_TO_JULIAN.
% Compiled module: JULIAN_TO_STRING.
% Compiled module: CALCULATE_GREGORIAN.
% Compiled module: CALDAT.
Reading autodetections:     0%% Compiled module: READ_LFDCS_AUTODETECTIONS.
   10%   20%   30%   40%   50%   60%   70%   80%   90%  100%
IDL>
```

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). See Appendix B for more information. The examples below shows the following added columns:

- ‘Manual_Review’ (0=not present, 1=present, 2=possibly present)
- ‘True_Tally’ (number of positive detections determined for a given day)
- ‘True_Tally_Timestamp’ (exact timestamp of the true detection(s))
- ‘Unknown_Timestamp’ (exact timestamp of unknown detection(s))
- ‘Suggested_Daily_Presence’ (if conservative protocol for daily presence 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.)
- ‘Notes’ (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 five species. These are examples of columns manually entered to the summary autodetection sheets that are exported by lfdcs.

Note: The following suggestions and examples correspond with daily presence summary sheets which were most commonly used for analyses conducted at NEFSC/WHOI.

North Atlantic right whale

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_Tally_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					
8/15/2020	5:00:00	8/16/2020	5:00:00	18	33	6	100	0	157	1	3	00:02; 00:03; 00:04			
8/16/2020	5:00:00	8/17/2020	5:00:00	11	20	3	102	1	137	2	2	00:01; 00:02		YES	undetected upcall at 00:03
8/17/2020	5:00:00	8/18/2020	5:00:00	4	10	1	68	0	83	2			00:05;		
	EST time zone for recorder set for GMT														

Sei whale

LFDCS_SEI_PRESENCE-SHEET-GUIDE .XLSX

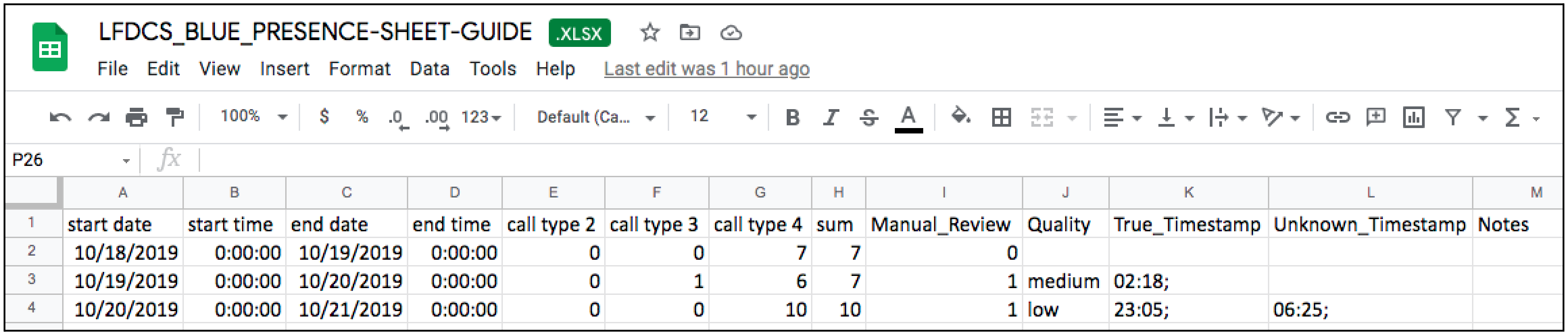
start date	start time	end date	end time	call type 1	call type 2	call type 3	sum	Manual_Review	True_Timestamp	Singles?	Unknown_Timestamp	Suggested_Daily_Presence	Notes
12/8/2017	0:00:00	12/9/2017	0:00:00	0	0	0	0	0					
12/9/2017	0:00:00	12/10/2017	0:00:00	24	2	0	26	2		YES		YES	singlets very likely sei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

Fin whale

LFDCS_FIN_PRESENCE-SHEET-GUIDE .XLSX

start date	start time	end date	end time	call type 1	sum	Manual_Review	True_Timestamp	Unknown_Timestamp	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			
10/6/2019	12:00:00	10/6/2019	13:00:00	65	65	2		12:31;	

Blue whale



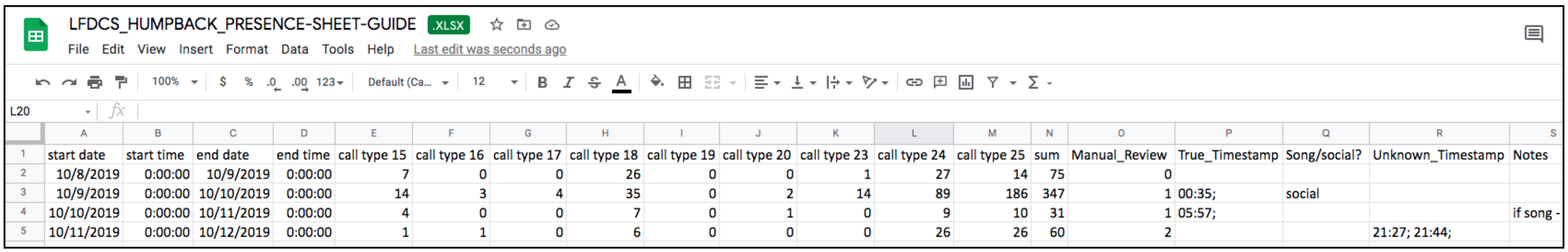
LFDCS_BLUE_PRESENCE-SHEET-GUIDE .XLSX

File Edit View Insert Format Data Tools Help Last edit was 1 hour ago

P26

	A	B	C	D	E	F	G	H	I	J	K	L	M
1	start date	start time	end date	end time	call type 2	call type 3	call type 4	sum	Manual_Review	Quality	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	medium	02:18;		
4	10/20/2019	0:00:00	10/21/2019	0:00:00	0	0	10	10	1	low	23:05;	06:25;	

Humpback whale



LFDCS_HUMPBACK_PRESENCE-SHEET-GUIDE .XLSX

File Edit View Insert Format Data Tools Help Last edit was seconds ago

L20

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S
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				
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;	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;			if song -
5	10/11/2019	0:00:00	10/12/2019	0:00:00	1	1	0	6	0	0	0	26	26	60	2			21:27; 21:44;	

How To Score Daily Presence for Different Species

Appendix B

Exporting Metadata from Processed LFDCS Datasets

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 QA/QC.

The same line of code can be used to pull metadata from an .nc file from the specaudio folder or the lfdcs folder (note, enter your first line of code to direct into the lfdcs folder instead of the specaudio 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.

Code for exporting specaudio metadata

1. Plug in drive that the LFDCS outputs were processed onto.

2. Open terminal, but do not put in normal starting code (cd ~/Projects/Detectors/lfdcs/process). Instead, type the following code – filling in the correct drive and file names for the target dataset:

   1% cd /Volumes/ExternalHD/NEFSC_SC_201511_site4/specaudio/2015_11
   2% idl

3. Pick any .nc file in the specaudio folder that was specified in the previous line of code and insert it into this code between the straight quotation marks:

   IDL> ncdf_info, 'mooring_NEFSC_SC_201511_site4_151104_000000.nc'

A lot of information will come up – some things to find particularly useful are 'original_file' (specifies the original sound file that was used to create the .nc file). The project names should match. For multi-channel data (MARUs), 'original_channel' can also be important to make sure the right channel was processed.

See example terminal windows on the following pages.

Terminal Window for specaudio Output

Terminal — ⌘1

```
Last login: Mon Feb 21 21:13:35 on ttys000
[1% cd /Volumes/NEFSC_22/NEFSC_SC_201511/NEFSC_SC_201511_CH4/specaudio/2015_11
[2% idl
IDL Version 8.4, Mac OS X (darwin x86_64 m64). (c) 2014, Exelis Visual Information Solutions, Inc.
Installation number: 246512.
Licensed for use by: Woods Hole Oceanographic Institution

[IDL> ncdf_info, 'mooring_MARU105_popup_4_151104_100000.nc'
% Compiled module: NCDF_INFO.
% Loaded DLM: NCDF.
NetCDF File
-----------
Dimensions: 3
Variables: 4
Global attributes: 22
Unlimited dimension: NONE

Dimensions
----------
0: n (1800000)
1: nt (14062)
2: nf (256)

Global attributes
-----------------
comments: Recorder data and associated spectrogram
experiment: NEFSC_SC_201511_CH4
location: Charleston SC
originator: Genevieve
platform_type: Mooring
platform_id: MARU105
instrument_type: POPUP
instrument_id: 4
sampling_rate_Hz: 2000.0000
nsamples: 1800000
actual_start_datetime: 11/04/15 10:00:00 0.0000000
actual_end_datetime: 11/04/15 10:14:59 0.99950000
start_date: 01/01/06 00:00:00
start_time_seconds: 3.1055760e+08
end_time_seconds: 3.1055850e+08
time_zone: EST
original_file:
/Volumes/stellwagen/ACOUSTIC_DATA/BOTTOM_MOUNTED/NEFSC_SC/NEFSC_SC_201511/Charleston_AIFFs_EST/775
28_Charleston01_002K_M07_multi_UTCm5_20151104_101500.aif
original_channel: 1
spectrogram_frame: 512
spectrogram_overlap: 0.75000000
window_function: Hann
spectrogram_smoothing: Yes
```

```
Variables
---------
0: data (INT; n)
    long_name: audio data
    units: 16 bit signed digital value
1: time (DOUBLE; nt)
    long_name: spectrogram time
    units: seconds since start date
    start_date: 01/01/06 00:00:00
2: freq (FLOAT; nf)
    long_name: spectrogram frequency
    units: Hz
3: spectrogram (INT; nt, nf)
    long_name: spectrogram of recorder data
    units: dB
    comments: saved as signed 2 byte value - recast to unsigned integer when reading
    scale: 0.0017263603
    offset: -37.985537
    conversion: spectrogram = scale * (2 byte unsigned integer) + offset
IDL>
```

Code for exporting lfdcs metadata

1. Plug in drive that the LFDCS outputs were processed onto.

2. Open terminal, but do not put in normal starting code (cd ~/Projects/Detectors/lfdcs/process). Instead, type the following code – filling in the correct drive and file names for the target dataset:

   1% cd /Volumes/ExternalHD/NEFSC_SC_201511_site4/lfdcs/2015_11
   2% idl

3. Pick any .nc file in the specaudio folder that was specified in the previous line of code and insert it into this code between the straight quotation marks:

   IDL> ncdf_info, 'lfdcs_mooring_NEFSC_SC_201511_site4_151104_000000.nc'

A lot of information will come up – some things to find particularly useful are 'original_file' (specifies the original sound file that was used to create the .nc file). The project names should match. For multi-channel data (MARUs), 'original_channel' can also be important to make sure the right channel was processed.

See example terminal windows on the following pages.

Terminal Window for lfdcs Output

Terminal — ⌘1

```
Last login: Fri Feb 25 11:59:58 on ttys000
[1% cd /Volumes/NEFSC_22/NEFSC_SC_201511/NEFSC_SC_201511_CH4/lfdcs/2015_11
[2% idl
IDL Version 8.4, Mac OS X (darwin x86_64 m64). (c) 2014, Exelis Visual Information Solutions, Inc.
Installation number: 246512.
Licensed for use by: Woods Hole Oceanographic Institution

[IDL> ncdf_info, 'lfdcs_mooring_maru105_popup_4_151104_100000.nc'
% Compiled module: NCDF_INFO.
% Loaded DLM: NCDF.
NetCDF File
-----------
Dimensions: 3
Variables: 28
Global attributes: 47
Unlimited dimension: NONE

Dimensions
----------
0: n (120204)
1: nsave (5)
2: ntrack (892700)

Global attributes
-----------------
comments: LFDCS-generated pitch tracks, call attributes, and classifications for all automated call detections
narrowband_detector: Baumgartner, M.F. and S.E. Mussoline, 2011, JASA 129:2889-2902.
broadband_detector: Baumgartner, M.F. and S.E. Mussoline, 2012, JASA
experiment: NEFSC_SC_201511_CH4
location: Charleston SC
originator: Genevieve
platform_type: Mooring
platform_id: MARU105
instrument_type: POPUP
instrument_id: 4
time_zone: EST
index_file: specaudio/recorder_index.nc
sampling_rate_Hz: 2000.00
frame: 512
overlap: 0.75000000
spectrogram_duration_seconds: 30.000000
pitch_tracking_window_seconds: 25.000000
detection_threshold_dB: 10.000000
cost_gradient_threshold_dB: 15.000000
distance_weighting_dB: 20.000000
min_call_duration_seconds: 0.25000000
min_avg_amplitude_dB: 10.000000
blanking_time_seconds: 0.25000000
blanking_frequency_Hz: 20.000000
noise_reduction_window_seconds: 60.000000
bb_detection_threshold_dB: 9.6000000
bb_min_segment_span_Hz: 150.00000
```

```
bb_min_total_span_Hz: 200.00000
bb_min_broadband_duration_seconds: 0.12500000
bbp_in_threshold_dB: 5.0000000
bbp_in_duration_seconds: 1.5000000
bbp_out_threshold_dB: 5.0000000
bbp_out_duration_seconds: 4.0000000
bbp_max_duration_seconds: 300.00000
avg_fft_low_threshold_dB: -999.00000
avg_fft_high_threshold_dB: 999.00000
avg_fft_duration_limit_seconds: 300.00000
call_library_bb_file: lfdcs/call_library_bb/call_library_broadband.nc
call_library_bb_description: Gulf of Maine broadband call library
call_library_bb_last_mod_date_GMT: 01/20/15 21:02:09
call_library_bb_attribute_names: duration bb_am_slope bb_fm_slope minfreq
processed_date_GMT: 08/11/16 01:48:30
call_library_nb_file: lfdcs/call_library_nb/call_library_gom9.nc
call_library_nb_description: Gulf of Maine narrowband call library
call_library_nb_last_mod_date_GMT: 04/03/18 16:33:23
call_library_nb_attribute_names: awfreq awfreq_stdev awtime_stdev awslope aws1 aws2 aws3
reclassification_date_nb_GMT: 06/15/18 19:14:44

Variables
---------
0: detection_time (DOUBLE; n)
    long_name: start time of call
    units: seconds since start date
    start_date: 01/01/06 00:00:00
1: call_family (INT; n)
    long_name: family of call
    units: none
    value1: broadband sound
    value2: frequency modulated or tonal sound
2: call_start (LONG; n)
    long_name: starting index of call in track file
    units: none
3: call_n (INT; n)
    long_name: number of pitch track points
    units: none
4: duration (FLOAT; n)
    long_name: duration of call
    units: seconds
5: minfreq (FLOAT; n)
    long_name: minimum frequency of call
    units: Hz
6: maxfreq (FLOAT; n)
    long_name: maximum frequency of call
    units: Hz
7: avg_amplitude (FLOAT; n)
    long_name: average amplitude of call
    units: dB relative to running average
```

```
8: awfreq (FLOAT; n)
     long_name: amplitude-weighted average frequency
     units: Hz base 2
9: awfreq_stdev (FLOAT; n)
     long_name: amplitude-weighted frequency variation (sweep proxy)
     units: Hz base 2
10: awtime_stdev (FLOAT; n)
     long_name: amplitude-weighted time variation (duration proxy)
     units: seconds
11: awslope (FLOAT; n)
     long_name: amplitude-weighted slope of call
     units: octaves per second
12: aws1 (FLOAT; n)
     long_name: amplitude-weighted slope of first third of call
     units: octaves per second
13: aws2 (FLOAT; n)
     long_name: amplitude-weighted slope of middle third of call
     units: octaves per second
14: aws3 (FLOAT; n)
     long_name: amplitude-weighted slope of last third of call
     units: octaves per second
15: bb_am_slope (FLOAT; n)
     long_name: slope of average amplitude of broadband sound after peak amplitude
     units: dB per second
16: bb_fm_slope (FLOAT; n)
     long_name: slope of change in amplitude with frequency between first and last FFT in broadband sound
     units: dB per octave
17: call_group_auto (INT; n)
     long_name: automatic classification of call type group
     units: none
18: mdist (FLOAT; n)
     long_name: mahalanobis distance from autoclassified group
     units: none
19: prob (FLOAT; n)
     long_name: relative posterior probability of membership in autoclassified group
     units: none
20: call_group_auto_saved (INT; nsave, n)
     long_name: top automated classification groups
     units: none
21: mdist_saved (FLOAT; nsave, n)
     long_name: mahalanobis distances from top autoclassified groups
     units: none
22: prob_saved (FLOAT; nsave, n)
     long_name: relative posterior probabilities of membership in top autoclassified groups
     units: none
23: manual_species (INT; n)
     long_name: manually classified species producing call
     units: none
     value00: Unclassified
     value01: Blue whale
     value02: Fin whale
     value03: Sei whale
```

```
     value04: Brydes whale
     value05: Minke whale
     value06: Gray whale
     value07: North Atlantic right whale
     value08: North Pacific right whale
     value09: Southern right whale
     value10: Humpback whale
     value11: Bowhead whale
24: manual_call_type (INT; n)
     long_name: manually classified within-species call type
     units: none
25: call_time (DOUBLE; ntrack)
     long_name: pitch track time
     units: seconds since start date
     start_date: 01/01/06 00:00:00
26: call_freq (FLOAT; ntrack)
     long_name: pitch track frequency
     units: Hz
27: call_amplitude (FLOAT; ntrack)
     long_name: amplitude of call along pitch track
     units: dB relative to running average
IDL>
```

Appendices

Appendix A: Parameter File

To process a dataset with 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 two 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.

On the following page, you'll find a screenshot of an example parameter file. Following that is the list of parameters with their definitions.

Example of Parameter File

This is an example of a parameter file that a user would build prior to processing a new dataset in LFDCS. See Processing Datasets section for more detail.

```
          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)
```

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. Recommended to use a generic start date such as 01/01/70 00:00:00. You may use any time that predates the recordings, but best to keep 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., HARU, AMAR, AURAL, DMON, POPUP). 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 three parameters. This parameter is primarily for legacy recorders such as the ones listed in e.g. 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 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.

Frame: Number of samples over which a single 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 zero. 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 three 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 one 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 zero.

BlankingFreq (Hz): Frequency band above and below a time step in the pitch track to be blanked or set to zero.

Appendix B: Suggested Species Daily Presence Scoring Criteria

These are the criteria that the NEFSC PA Group uses for analysis of daily presence of various baleen whale species. Terms such as 'Manual_Review', 'True_Tally', etc. correspond to the column titles within the exported Daily Presence Sheets (see Exporting Summary Sheets of Autodetections section) where analysis results are recorded. These are the protocols established and used in Davis et al. 2017 and 2020.

Right whale

2 kHz sample rate, call types [5, 6, 7, 8, 9], max_mdist = 3
All call types are included in the clnb_gom9 call library. All detections that are browsed are marked as Correct, Incorrect, or Unknown.

Manual_Review = 1:
Manually view detections for right whales. A day is marked "Present" (Manual_Review = "1") if there are three or more true detections in a day. Keep a tally of how many true upcall detections are in the day in the "True_Tally" column, and note the times in "True_Tally_Timestamps". Once 3 true detections have been found in a given day, mark Manual_Review with 1 and move on to the next day.

Manual_Review = 2:
Days with one or two detections will be marked as "Possibly present" (Manual_Review = "2"), with the number of upcalls noted in the "True_Tally" column, and times noted in "True_Tally_Timestamps". If the 1-2 upcalls are convincingly right whale, mark the "Suggested_Daily_Presence" column = "YES". Days with only unknown detections, and therefore, unclear if right whales are present, receive Manual_Review = 2. Times can be noted in the "Unknown_TimeStamps" column.

Manual_Review = 0:
A day is marked as "Not Detected" (Manual_Review = "0") if no detections on that day are "correct" or possibly correct ("unknown").

Sei whale

2 kHz sample rate, call types [1, 2, 3], max_mdist = 3
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 (downsweeps separated by 2-4 seconds from the start 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. All detections that are browsed are marked as Correct, Incorrect, or Unknown.

Manual_Review = 1:
Manually view detections for sei whales. A day is marked "Present" (Manual_Review = "1") if there is one true doublet or triplet present, with at least one of the calls pitch tracked in the doublet/triplet. The time stamp of the correct detection (HH:MM) should be noted in the "True_TimeStamp" column.

Manual_Review = 2:

A day is marked as “Possibly present” (Manual_Review = “2”) if the day has only single downsweeps and/or all unknown calls. Singlet detections will all be marked as “unknown” in the LFDCS program. Days with singlet detections (and no true detections) receive a “YES” in the “Singles” column. When only singlets are present, zoom out to a 5 minute window for each detection to see if any doublets or triplets are present and not detected. If a doublet or triplet is present but not pitchtracked, mark “Suggested_Daily_Presence” = “YES”, and in the notes column say, e.g., “Undetected doublet at HH:MM”. If the day has only singlets and the analyst thinks they should be considered for sei whale presence, the “Suggested_Daily_Presence column = “YES”, with a note stating, e.g., “singlets very likely sei whales”.

Unknown detections that should be looked at more closely should have the time stamp (HH:MM) marked in the “Unknown_Timestamp” column.

Manual_Review = 0:
A day is marked as “Not Detected” (Manual_Review = “0”) if no detections on that day are “correct” or possibly correct (“unknown”).

Fin whale

Decimated data (resampled at 120 Hz), call type 1, max_mdist = 3
All detections that are browsed are marked as Correct, Incorrect, or Unknown.

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 on 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). When one detection in a bout of 4 total calls (only one needs to be pitchtracked) is correct, that hour will be given a “1” for truly present in the “Manual_Review” column. Time does not have to be noted. The analyst can then skip to the first hour with 29 or more detections on the **next/new date**.

Manual_Review = 1:
A day is marked as “Present” (Manual_Review = “1”) if there is an hour with 29 or more detections, and there is at least one true detection within a bout of 4 or more 20 Hz pulses.

Manual_Review = 2:
A day is marked as “Possibly present” (Manual_Review = “2”) if the only hours with 29 or more detections have only 3 or less 20 Hz pulses present (with at least 1 pulse pitchtracked).

Manual_Review = 0:
A day is marked as “Not Detected” (Manual_Review = “0”) if no detections on that day are “correct” (none of the hours with 29 or more detections are correct).

Further details from the logistic regression: Days that have hours with at least 29 detections/hour (for 90% confidence of fin whale presence) will be given a “1” for truly present.

For the manual evaluation, hours marked present were determined by having at least one true detection within a bout that had 4 or more pulses present (at least three other 20Hz pulses including those not pitch-tracked).

Humpback whale

2 kHz sample rate, call types [15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25], max_mdist = 3

Manually view detections for humpback whales.

Manual_Review = 1:
A day is marked "Present" (Manual_Review = "1") if there are three or more true humpback whale vocalizations in a 10 minute period (window zoom max), with at least one of the vocalizations pitch-tracked. Time of the true detection (HH:MM) should be marked in the "True_TimeStamp" column. Due to the number of incorrect detections, there is no need to mark every incorrect detection as "Incorrect", just page through detections until a "Correct" or "Unknown" detection is found.

Keep track of whether presence is determined by song or social sounds. In the "Song/Social?" column, enter "SOCIAL" if the detections are social sounds, or "UNKNOWN" if it is hard to determine. 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 write "UNKNOWN".

Manual_Review = 2:
Days with only one or two vocalizations will be marked as "Possibly present" (Manual_Review = "2"), and can be noted in the notes column. Unknowns that need to be reviewed or looked at again should have the time stamp noted in the "Unknown_Timestamp" column.

Manual_Review = 0:
A day is marked as "Not Detected" (Manual_Review = "0") if no detections on that day are "correct" or possibly correct ("unknown").

Blue whale

Decimated data, call types [2, 3, 4], max_mdist = 5
All detections that are browsed are marked as Correct, Incorrect, or Unknown.

Manual_Review = 1:
All days will be verified for blue whale song presence. Presence (Manual_Review = "1") will be determined by having one true detection, with at least 3 song units present with detection (at least two other units not pitch tracked). A unit is either an A, B, or AB call "packet". Note the "Quality" column as either Low, Medium, or High, determined as the number of units within an 11-12 minute period that can be distinguished as:

Low= 3
Medium= 4-7 units
High = 8 or more units

To be able to count the number of packets/units within the song, zoom out to an 11 minute period within LFDCS. As long as there are the number of above defined units within the song bout, the song quality can be defined as Low, Medium, or High.

Note the time of the true detection in the "True_Timestamp" HH:MM.

Manual_Review = 2:
Blue whales will be marked as “Possibly present” (Manual_Review = “2”) if there are unknown detections, or only 1 or 2 “packets” present in the 11-12 minute distinguishable window. Mark the time in the “Unknown_Timestamp” column.

Blue whale detections will be viewed with a max_mdist = 5.0 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 = 0:
A day is marked as “Not Detected” (Manual_Review = “0”) if no detections on that day are “correct” or possibly correct (“unknown”).

Appendix C: Tips, Tricks & Common Errors

Code Tips

- Prepare a code document (.txt file) on your desktop with all the commands necessary for your analysis for a quick guide and to help eliminate errors when typing in the terminal (so you can copy + paste). This can also be a place to enter the time and date where you left off in your analysis to save your place.

- Only use 'straight' (' not ‘) quotation marks in the code. If you copy and paste from another document, some code may paste with curved quotation marks which will need to be corrected in the terminal before running the code (otherwise will produce an error).

- File and folder names should not have any spaces or special characters, dashes “-” and underscores “_” may be used for separation of text.

- For FileDateSpec in the parameter file, if there are characters that may change or vary in front or after a date, use *. The asterisk means “any combination of 1 or more alphanumeric characters”.

- Typing **cd ~** in the terminal brings you to your home directory, which should be /Users/Username. To check what folder you are currently in, type **pwd** in the terminal (for “path working directory”).

- You may get this message (and can ignore it, it has no effect) anytime you open IDL in the terminal:

  % Program caused arithmetic error: Floating overflow

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.

Part 2
Introduction to LFDCS Real-Time Analysis Protocol

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** webpage under the Active Studies category, then the project's title. 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 Northeast Fisheries Science Center (NEFSC), Woods Hole Oceanographic Institution (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, as that was annotated by Mark. 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?

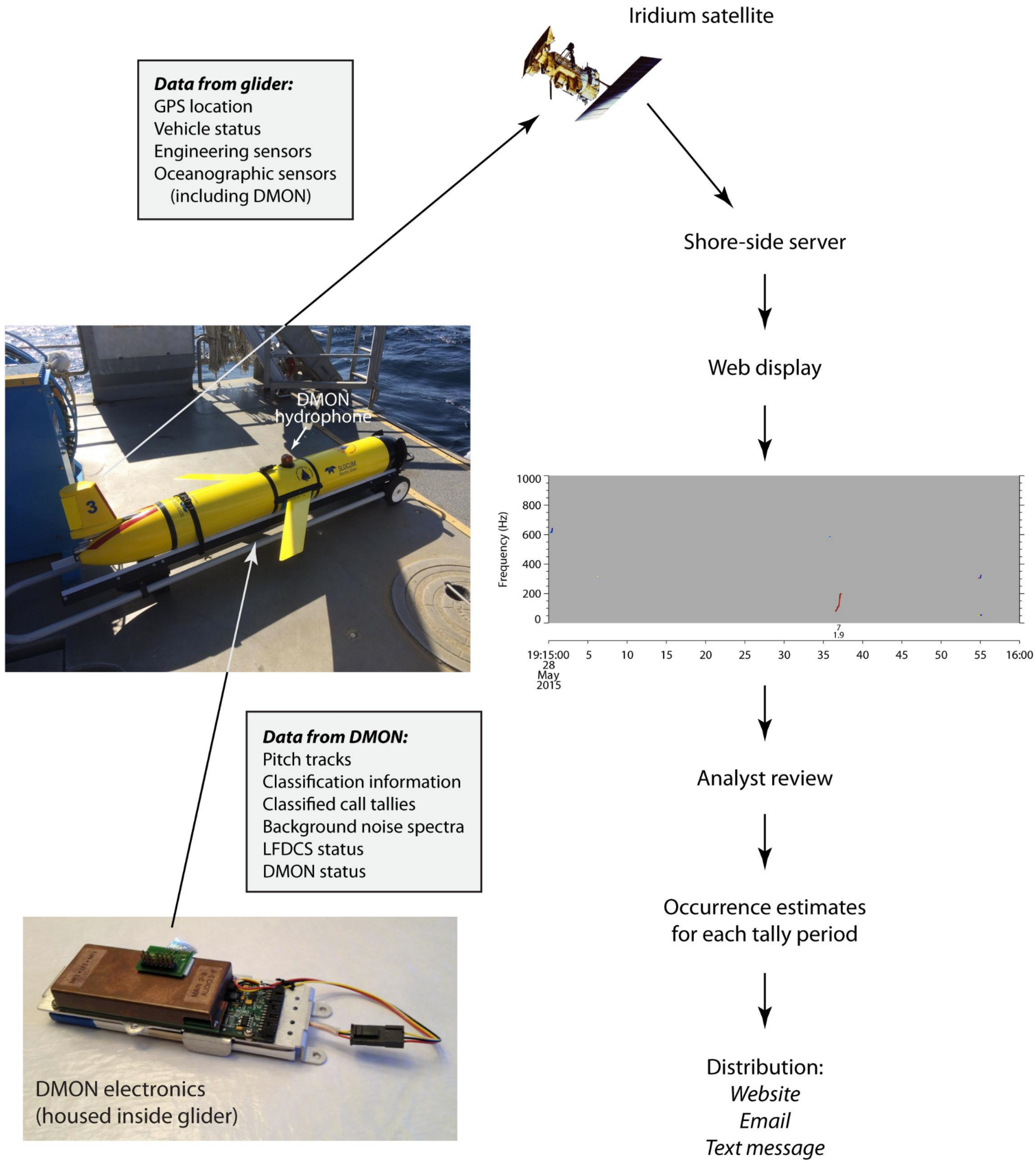


Image 1: Diagram of data flow from the DMON integrated in a Slocum glider to a shore-side server via the Iridium satellite service. These data are displayed on the Robots4Whales website, and pitch tracks and classification information are reviewed by an analyst to produce species-specific occurrence 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 upcall (Baumgartner et al. 2020).

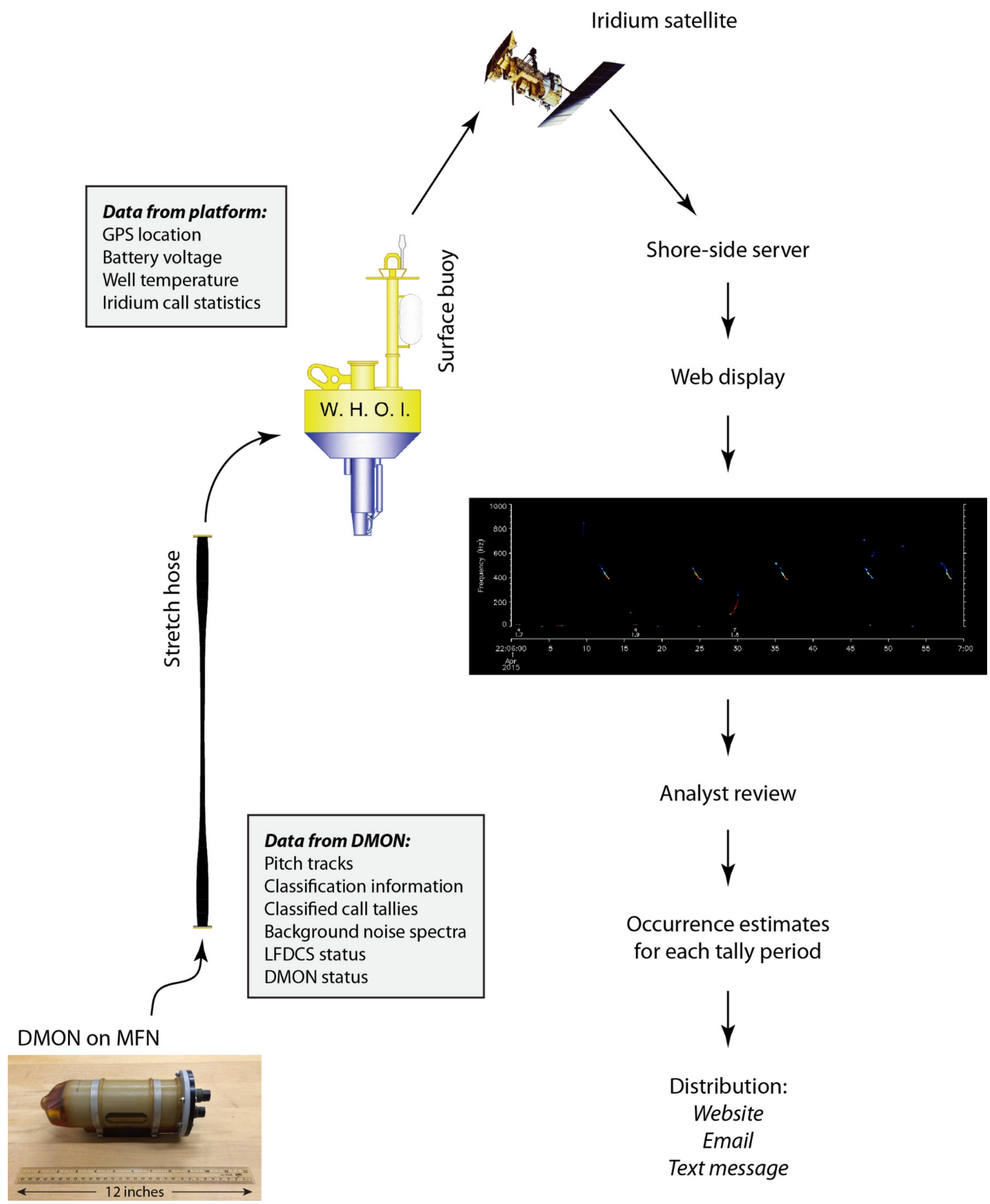


Image 2: Diagram of data flow from the DMON mounted on the multi-function node (MFN) to a shore-side server via the stretch hoses, surface buoy and Iridium satellite service. These data are displayed on the Robots4Whales website, and pitch tracks and classification information are reviewed by an analyst 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 upcall, patterned downsweeps in a humpback song, and two possible 20-Hz fin whale 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.

Robots4Whales Website

Main Page

Latest Detections Table

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

Platform	Species detected in last 3 days	Operator(s)*
San Francisco buoy	No detections in the last 3 days	Woods Hole Oceanographic Institution
Santa Barbara buoy	Fin and humpback whales	Woods Hole Oceanographic Institution
Stellwagen Slocum glider	Sei, fin and humpback whales	Woods Hole Oceanographic Institution and NOAA Northeast Fisheries Science Center
Martha's Vineyard buoy	Fin and humpback whales	Woods Hole Oceanographic Institution
Cox Ledge Slocum glider	No detections in the last 3 days	Woods Hole Oceanographic Institution and NOAA Northeast Fisheries Science Center
New York Bight SE buoy	Humpback whale	Woods Hole Oceanographic Institution
Coastal New Jersey Slocum glider	Fin and humpback whales	Rutgers University and Woods Hole Oceanographic Institution
Atlantic City buoy	Humpback whale	Woods Hole Oceanographic Institution
Ocean City buoy	Humpback whale	Woods Hole Oceanographic Institution and University of Maryland Center for Environmental Science
Cape Hatteras buoy	No detections in the last 3 days	Woods Hole Oceanographic Institution and NAVFAC Atlantic

**Includes organizations serving as platform operators and near real-time acoustic analysts. Other collaborators and sponsors are listed on each platform webpage.*

Active Deployments Map

Scroll down further and you will find a map showing all of the current active deployments.

Projects Menu

Below the map under Projects 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 (March 2022)

Slocum Glider G3, Stellwagen Bank (March 2022)

Slocum Glider G3, Cox Ledge (February 2022)

Moored Buoy, San Francisco, California (February 2021)

Moored Buoy, Cape Hatteras, North Carolina (October 2021)

Moored Buoy, Martha's Vineyard, Massachusetts (July 2021)

Moored Buoy, Atlantic City, New Jersey (July 2021)

Moored Buoy, Ocean City, Maryland (May 2021)

Moored Buoy, New York Bight SE (May 2021)

Moored Buoy, Santa Barbara Channel (May 2021)

Archived missions

Slocum Glider G2, Gulf of Maine (December 2021)

Slocum Glider G3, Stellwagen Bank (December 2021)

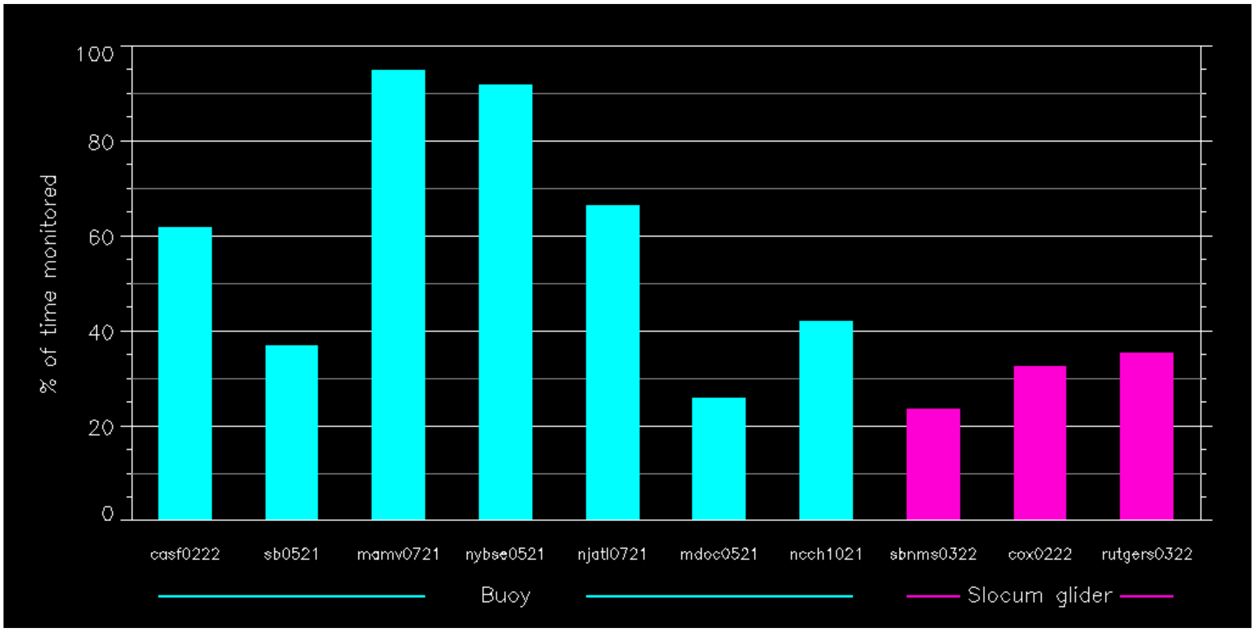
Operations, Sounds, & Platforms

Additional sections below Projects include Operations, Sounds, and Platforms which provide a basic description of the pitch tracking algorithm, recordings of the species and their respective call types that we are listening for, and descriptions and images of the autonomous platforms used for real time deployments (most common being the Slocum glider and moored buoy).

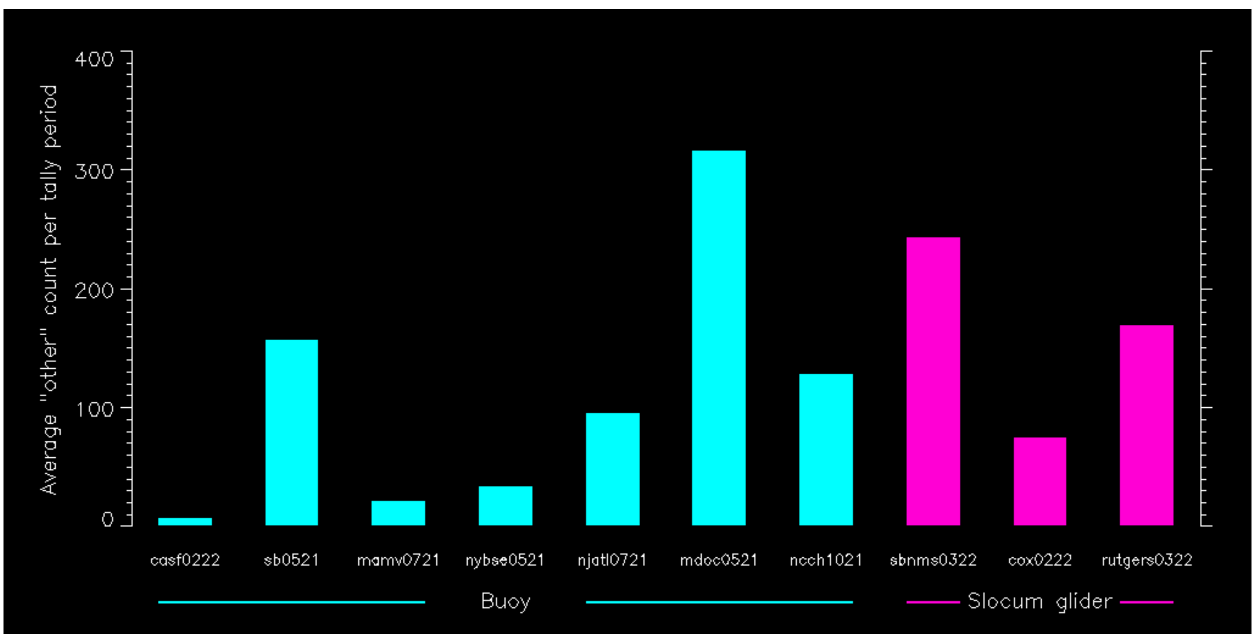
Real-Time Acoustic Diagnostics

Near the bottom of the main page, there is a section titled Real-time Acoustic Diagnostics 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 is 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 Diagnostics page.

Percentage of time that pitch track data is available for different platforms over the last 3 days:

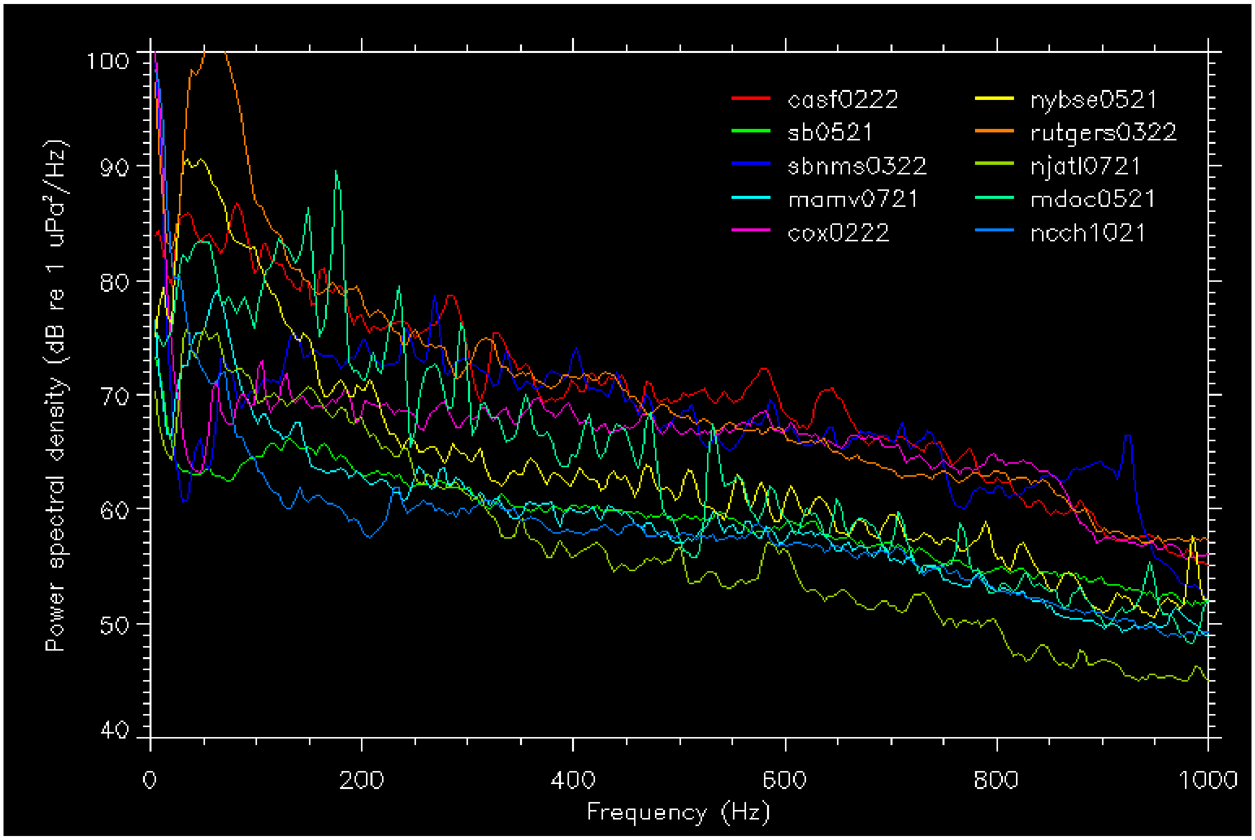


Average count of "other" detections per nominal 15-minute tally period over the last 3 days:



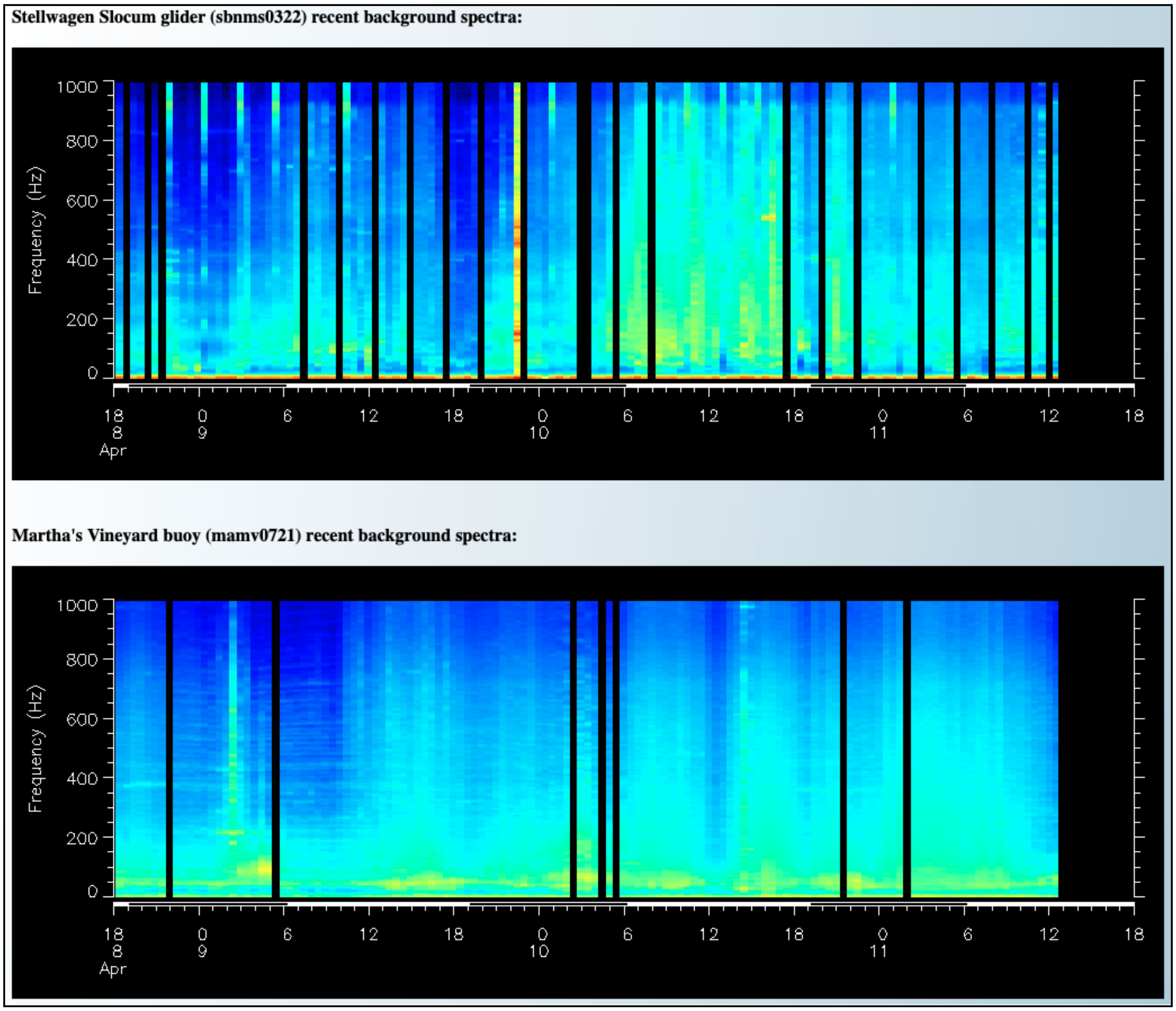
Latest power spectra from all platforms:

This is also shown in separate graphics on the Diagnostics webpage that isolate the power spectra from the moored buoys and the gliders.



Recent background spectra examples 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.



Reference Guide to LFDCS, Tutorials, & Other Information

At the bottom of the main page on the Robots4Whales website, there is another section which contains a link to the latest version of the Reference Guide to LFDCS. Versions will be indicated clearly at the beginning of the document by version number (e.g., Version 1.1, 1.2, etc.) and revision date so you can be sure you are using the latest version.

Recordings of the LFDCS Tutorial from the DCLDE 2022 conference can also be found here, along with references and Mark's contact information.

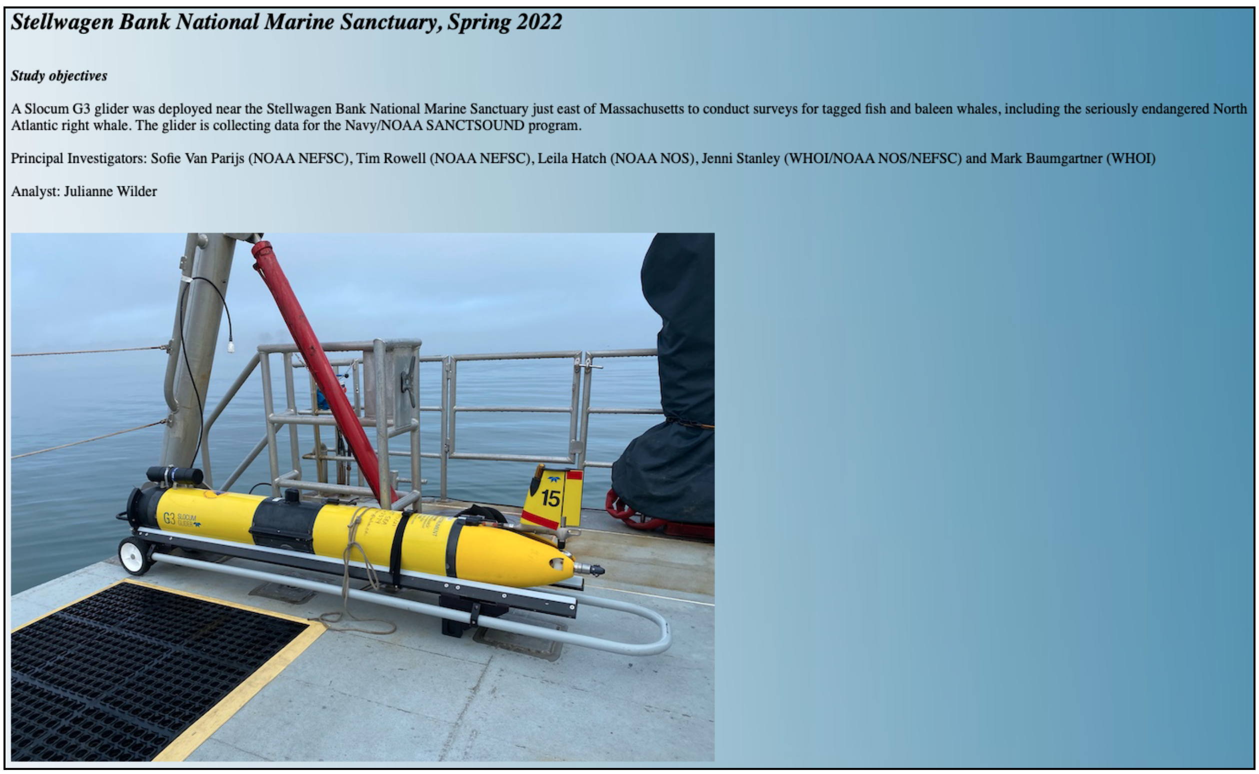
Project Pages

You can access the individual project web pages via the links in the Latest Detections table or the Projects 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 that you can find on the individual project pages.

Note: The example of the Stellwagen Bank National Marine Sanctuary, Spring 2022 Slocum glider deployment is used in the following sections. 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.



Stellwagen Bank National Marine Sanctuary, Spring 2022

Study objectives

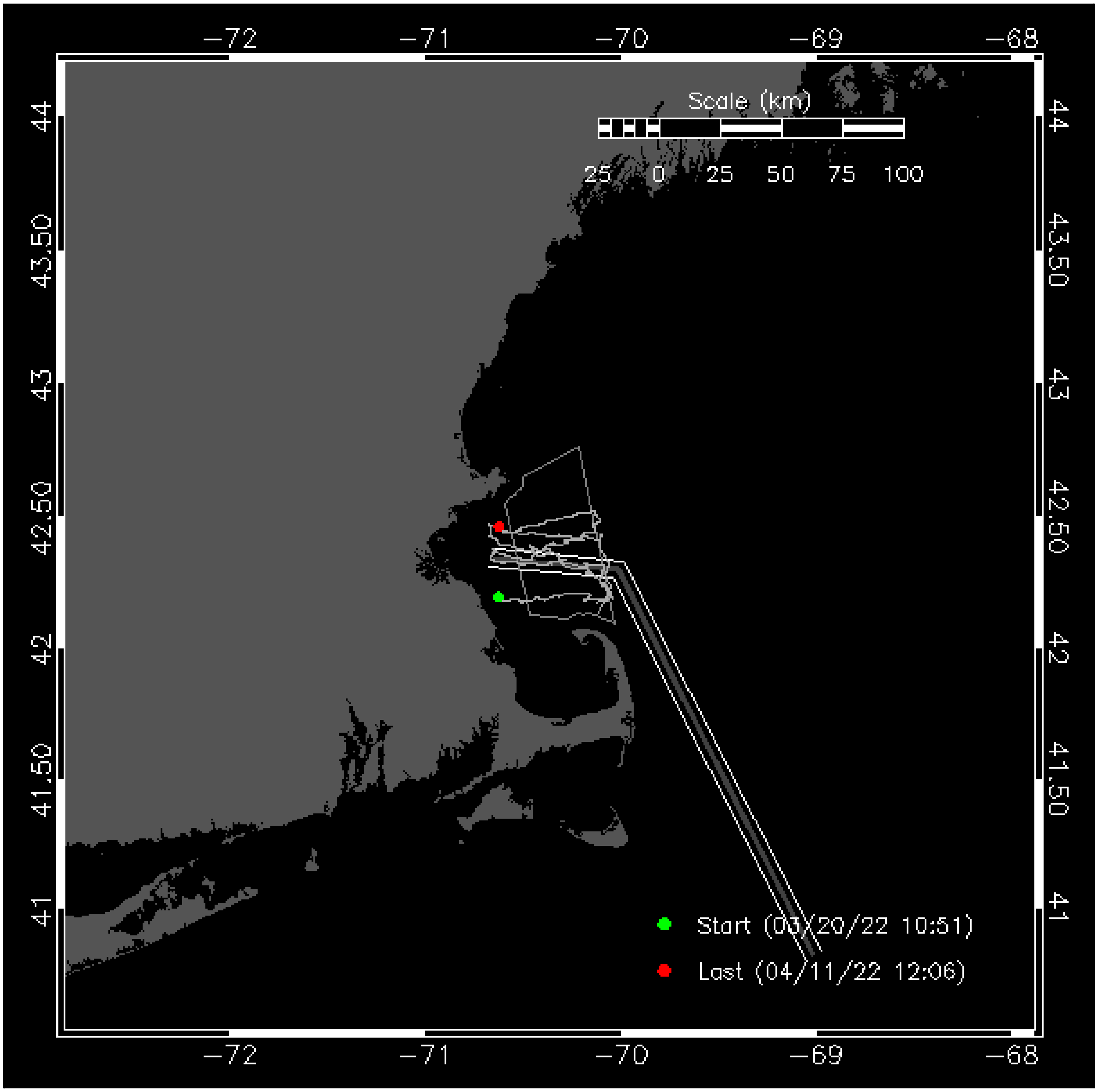
A Slocum G3 glider was deployed near the Stellwagen Bank National Marine Sanctuary just east of Massachusetts to conduct surveys for tagged fish and baleen whales, including the seriously endangered North Atlantic right whale. The glider is collecting data for the Navy/NOAA SANCTSOUND program.

Principal Investigators: Sofie Van Parijs (NOAA NEFSC), Tim Rowell (NOAA NEFSC), Leila Hatch (NOAA NOS), Jenni Stanley (WHOI/NOAA NOS/NEFSC) and Mark Baumgartner (WHOI)

Analyst: Julianne Wilder

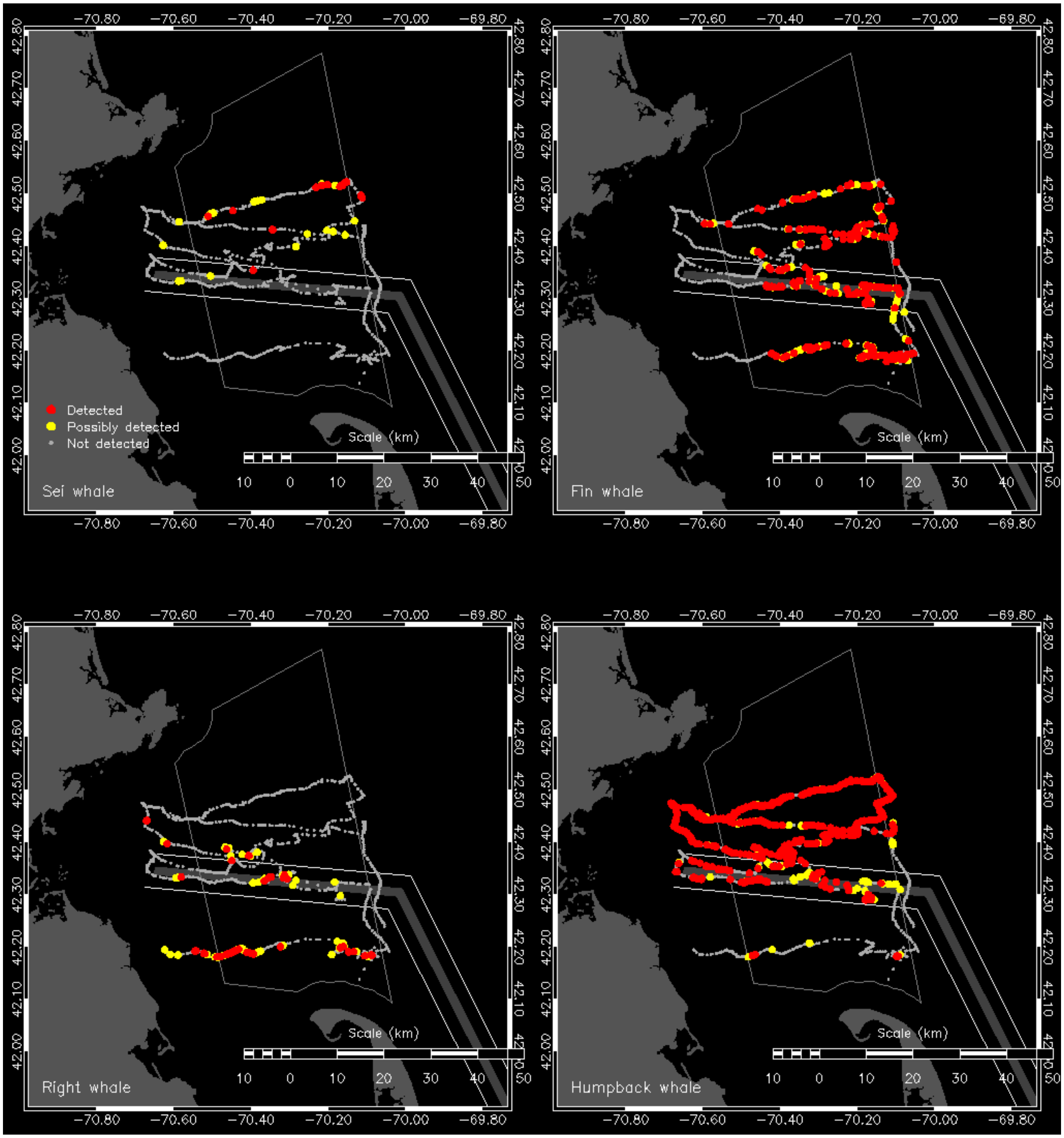
Platform Location

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 location of the last transmission.



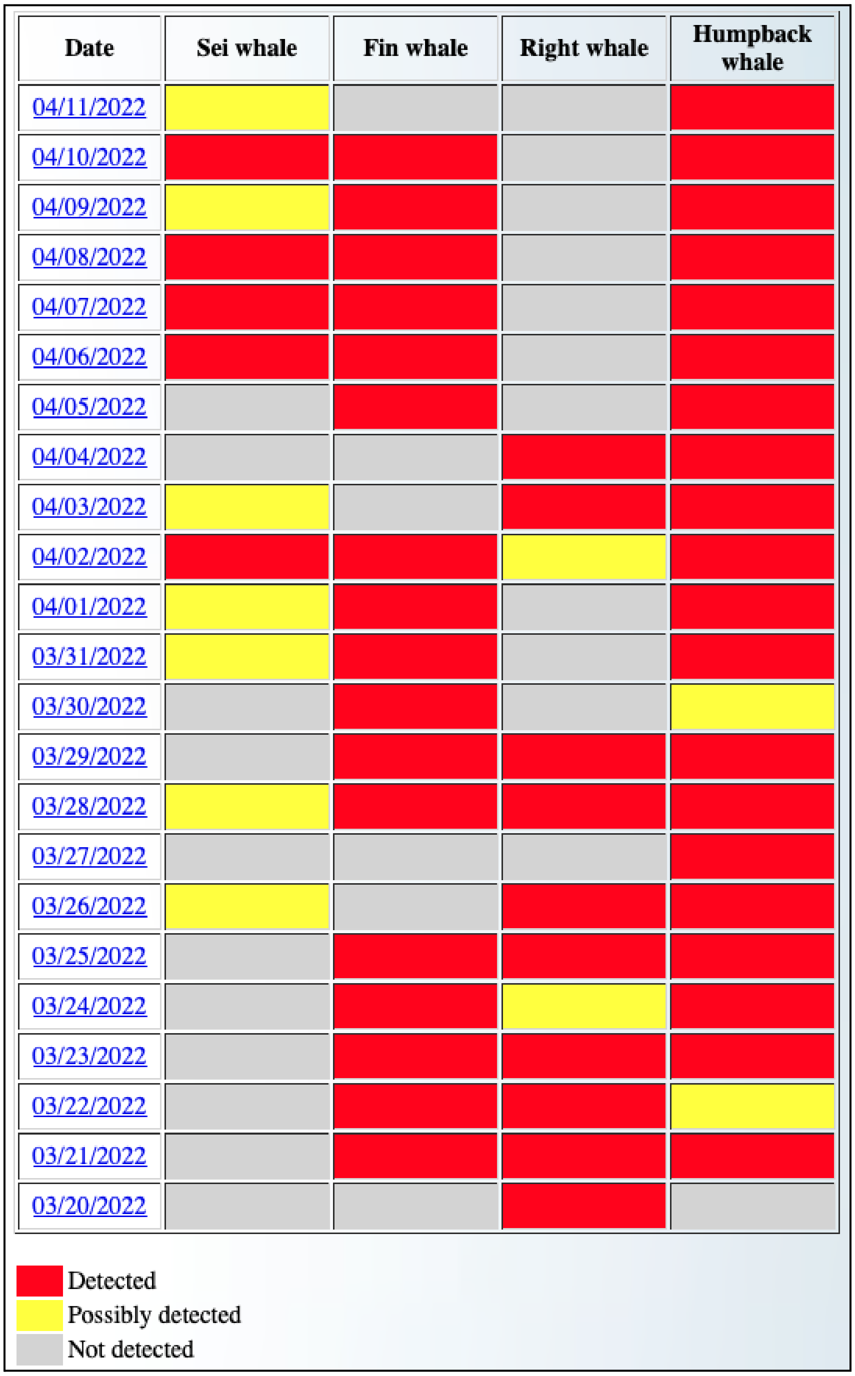
Analyst-Reviewed Species Occurrence Maps

On any project pages for glider deployments, below the Platform Location map you will find maps of occurrence by species. These are based on the analyst's scoring of species presence from the pitch track data. The small gray dots indicate where there is 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](#).



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 one 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
04/11/2022				
04/10/2022				
04/09/2022				
04/08/2022				
04/07/2022				
04/06/2022				
04/05/2022				
04/04/2022				
04/03/2022				
04/02/2022				
04/01/2022				
03/31/2022				
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				

Detected
Possibly detected
Not detected

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:

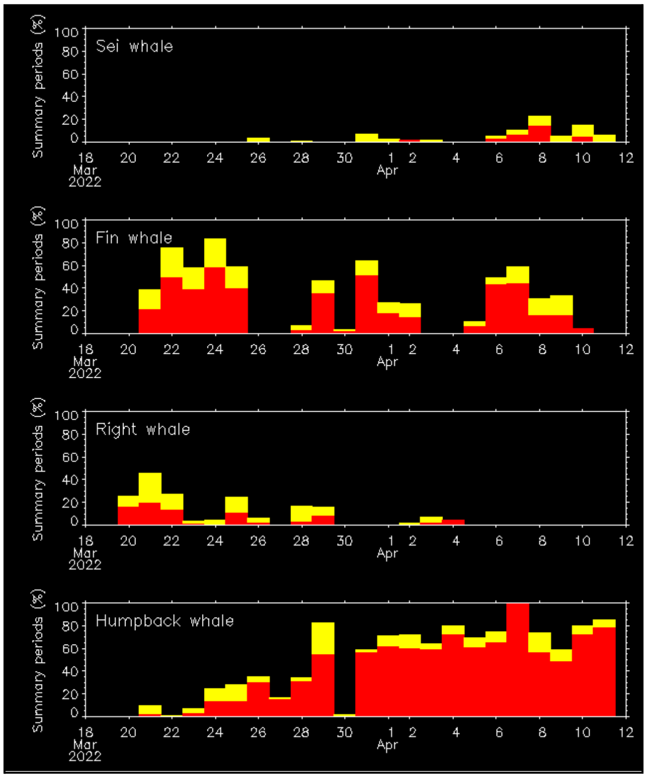
Date/time (local)	Occurrence	Latitude	Longitude	Notes
04/03/22 13:07:44	Detected	42.3970	-70.6169	Faint classified and unclassified upcalls throughout the period. All upcalls are isolated from any of the HW song in the period.
04/03/22 15:07:44	Possibly detected	42.4004	-70.6248	Two possible faint upcalls 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.

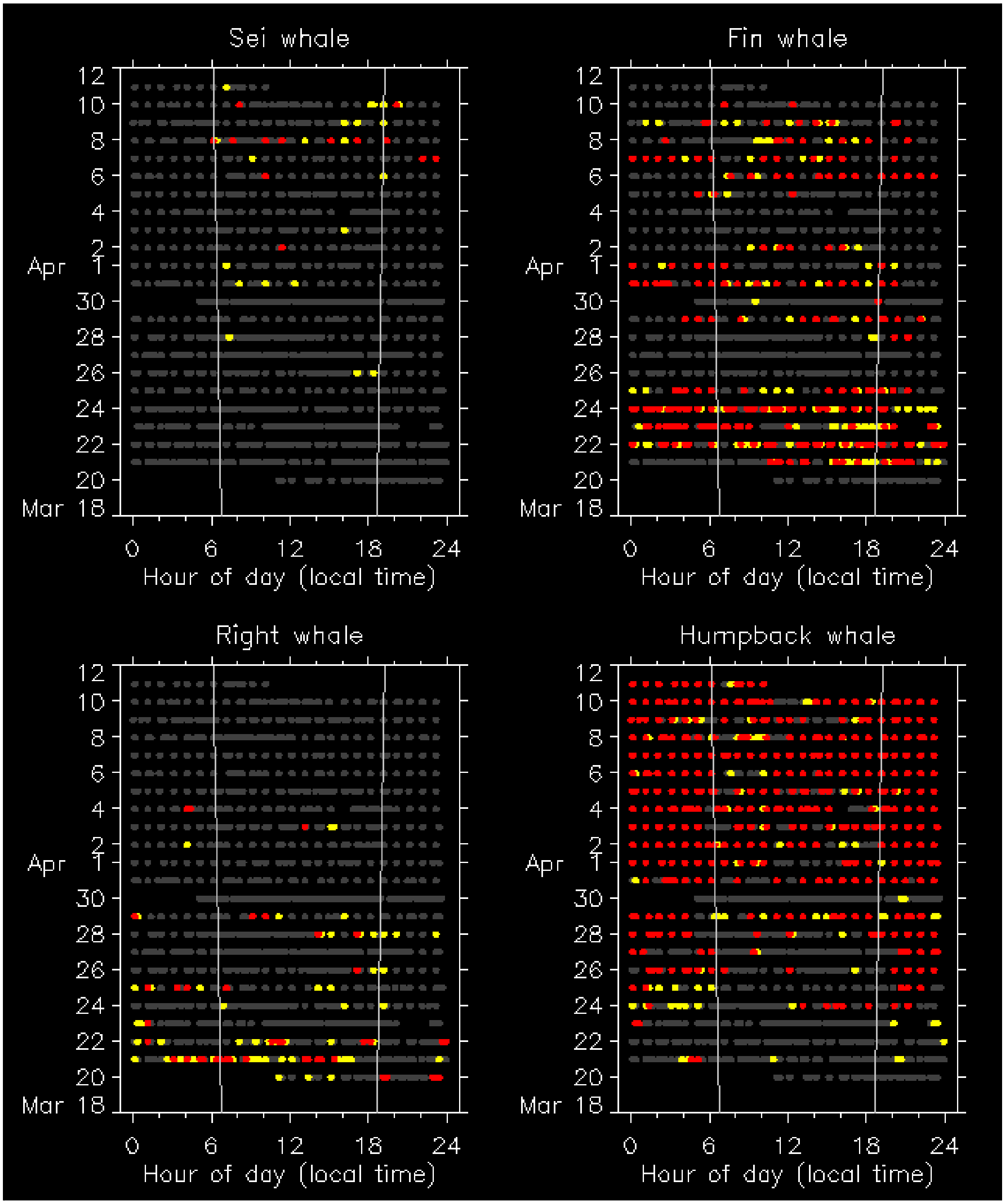
Time Series of Analyst-Reviewed Species Occurrence

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 acoustically present (red) or possibly present (yellow) for each day of the deployment.



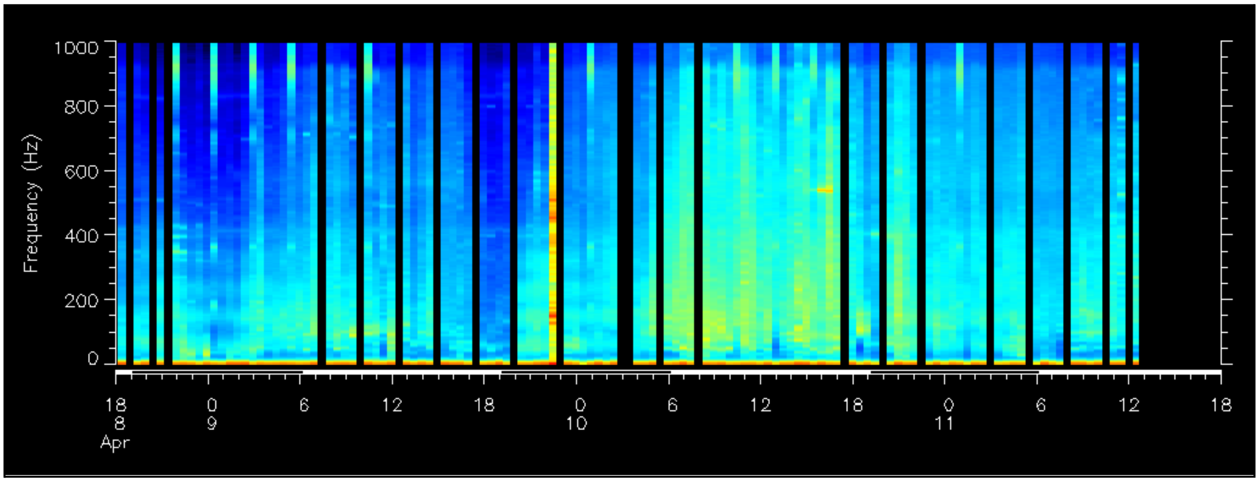
Diel Plots of Analyst-Reviewed Species Occurrence

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 one 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.



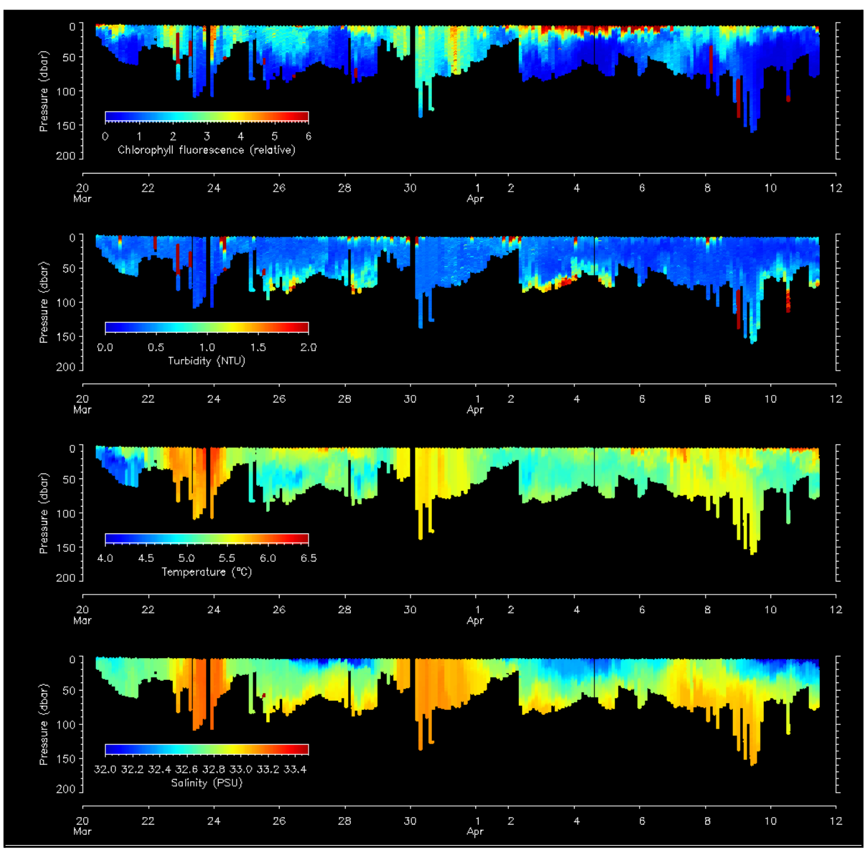
Recent Background Noise Spectra

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



Oceanographic Observations

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



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.

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 is a "Map" and "Latitude/Longitude" columns, those will indicate the position of the glider at that particular point in time.

An example of what the Daily tally tables section looks like is included on the following page.

04/07/22

04/08/22

04/09/22

04/10/22

Date/time	Sei whale	Fin whale	Right whale	Humpback whale	Other	Duration	Tracks			
04/11/22 00:07:44	5	22	15	36	825	900	PT	Map	42.4503	-70.5210
04/11/22 00:22:44	0	30	10	20	701	900		Map	42.4503	-70.5218
04/11/22 00:32:15	0	8	6	13	497	571		Map	42.4502	-70.5224
04/11/22 00:52:01	0	0	0	0	0	0		Map	42.4460	-70.5225
04/11/22 00:52:44	0	0	0	0	1	42		Map	42.4460	-70.5225
04/11/22 01:07:44	0	25	1	11	399	900	PT	Map	42.4459	-70.5242
04/11/22 01:22:44	2	30	7	16	481	900		Map	42.4461	-70.5265
04/11/22 01:37:44	0	28	0	6	599	900		Map	42.4462	-70.5287
04/11/22 01:52:44	1	30	6	34	855	900		Map	42.4464	-70.5310
04/11/22 02:07:44	0	22	15	39	932	900	PT	Map	42.4466	-70.5332
04/11/22 02:22:44	4	24	10	29	781	900		Map	42.4467	-70.5355
04/11/22 02:37:44	0	26	14	42	756	900		Map	42.4469	-70.5377
04/11/22 02:51:13	0	13	2	7	517	809		Map	42.4470	-70.5399
04/11/22 03:12:29	0	0	0	0	0	0		Map	42.4437	-70.5419
04/11/22 03:22:44	0	7	3	11	289	614	PT	Map	42.4421	-70.5442
04/11/22 03:37:44	0	25	4	18	617	900		Map	42.4425	-70.5473
04/11/22 03:52:44	0	13	3	18	573	900		Map	42.4430	-70.5504
04/11/22 04:07:44	5	17	3	15	603	900	PT	Map	42.4434	-70.5535
04/11/22 04:22:44	1	18	5	22	698	900		Map	42.4439	-70.5566

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

Real-Time Analysis Protocol

Using the “Pitch Track” page

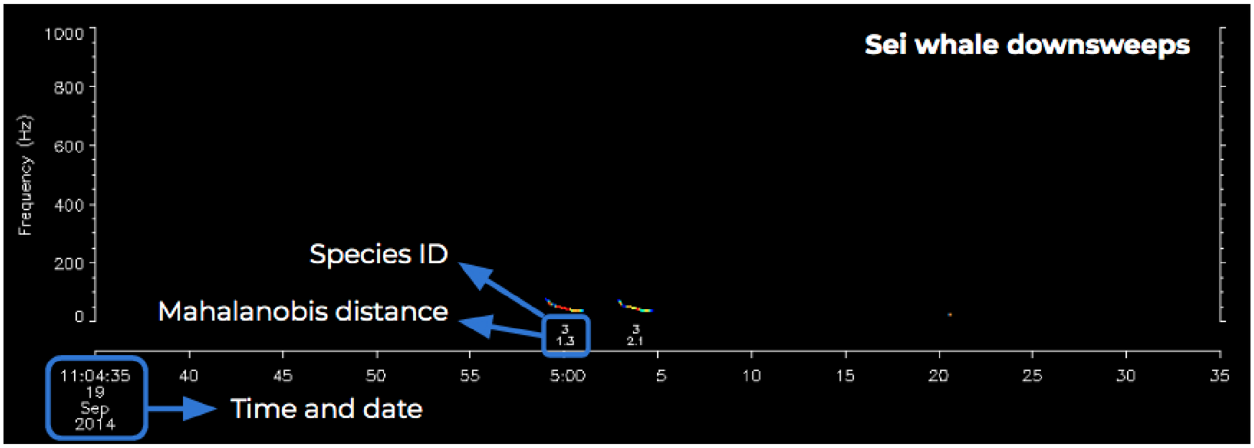
Click on the first “PT” in the tally table. This will bring you to a page that will have pitch tracks for that summary period (previously described in the document as "pitch track tally periods", henceforth known as the “Pitch Track” page). The transmission time information and species counts will be displayed at the top of the page (which is identical to the row from the tally table). Next you should see fifteen 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 two 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 (various calls): Call types 15-20
    - *Note: Call type 17 is a low-frequency humpback downsweep very similar to a sei whale downsweep.*

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).



Below the pitch tracks is the form that will be filled out after reviewing the pitch tracks. There are three 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, 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. 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 four 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 has classified his pitch tracks.

The Four Main Criteria for Determining Species

- **Amplitude of the signal**
- **Shape of the pitch track**
- **Isolation from other pitch tracks (context)**
- **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 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.

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. 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. Examples of artifacts are shown in the humpback whale "Possibly detected" section of this document.

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.

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 one or more classified calls. If there are no classified calls for these species, then only “Possibly detected” or “Not detected” can be scored. 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.

Species Quick Guides

The four tables below are included in each of the following sections detailing the real-time analysis protocol for determining presence of sei, fin, humpback, and right whales in the North Atlantic Ocean. This page is a quick reference guide for those protocols. The following protocols should be read in full before proceeding with analysis.

Right whale

	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+ calls, 1+ must be classified
Possibly detected	Y/N	None	If humpbacks present, assess for off-rhythm and/or different amplitude	1-2 classified calls or 3+ unclassified calls
Not detected	N	None	N/A	N/A

Sei whale

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

Fin whale

	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 (see 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 pulses in pattern (2+ must be classified as fin)
Not detected	N	No pattern or irregular pattern	N/A	N/A

Humpback whale

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

Right whale

Quick guide

	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+ calls, 1+ must be classified
Possibly detected	Y/N	None	If humpbacks present, assess for off-rhythm and/or different amplitude	1-2 classified calls <u>or</u> 3+ unclassified calls
Not detected	N	None	N/A	N/A

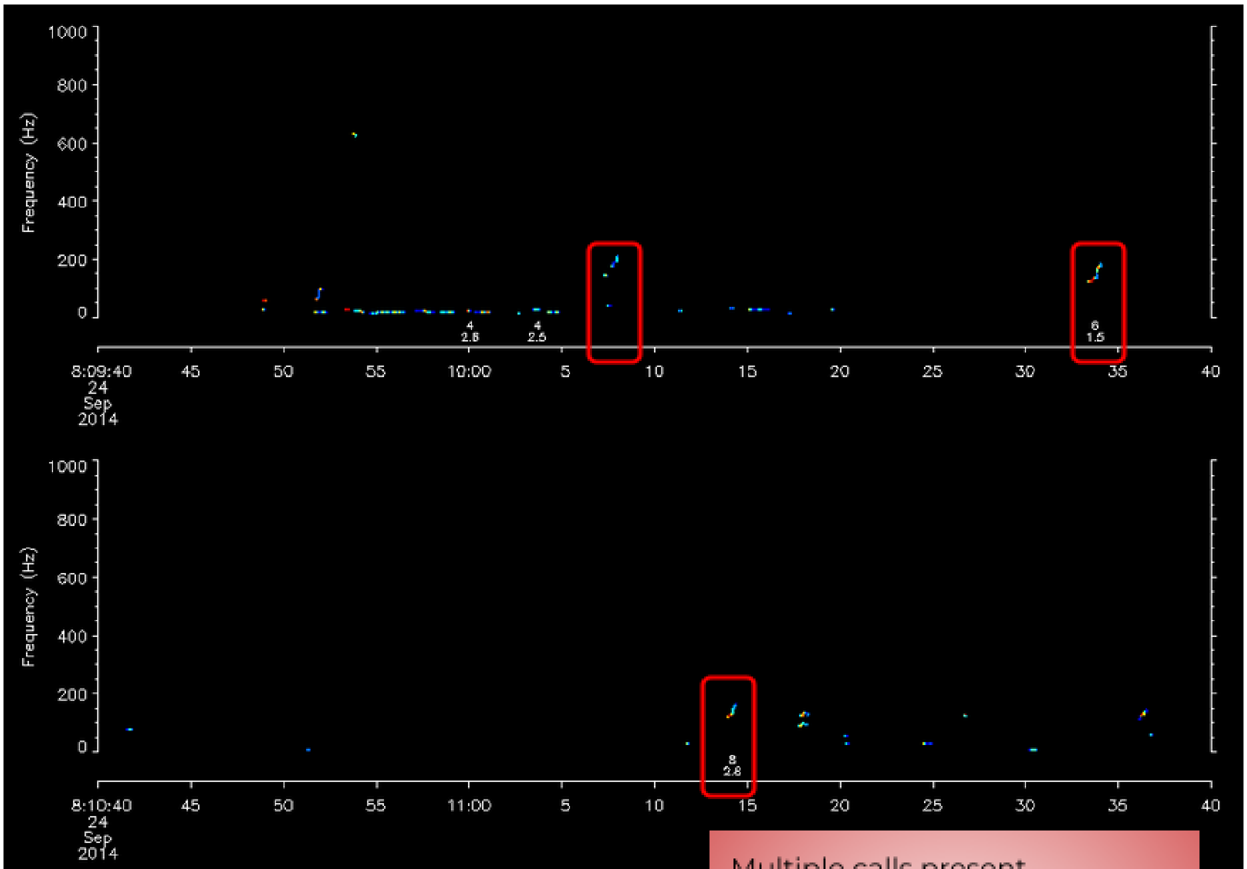
General

North Atlantic 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, one or more of which is classified as a right whale upcall by the DMON/LFDCS, and there is no evidence of humpback whale presence. If there is evidence of humpback whale presence, detected upcalls must be off-rhythm or have different amplitude (i.e., loudness) than the humpback whale calls.

The following figures are examples of when a right whale could be considered “Detected”. Please refer to the Roseway Basin project if you are unsure.

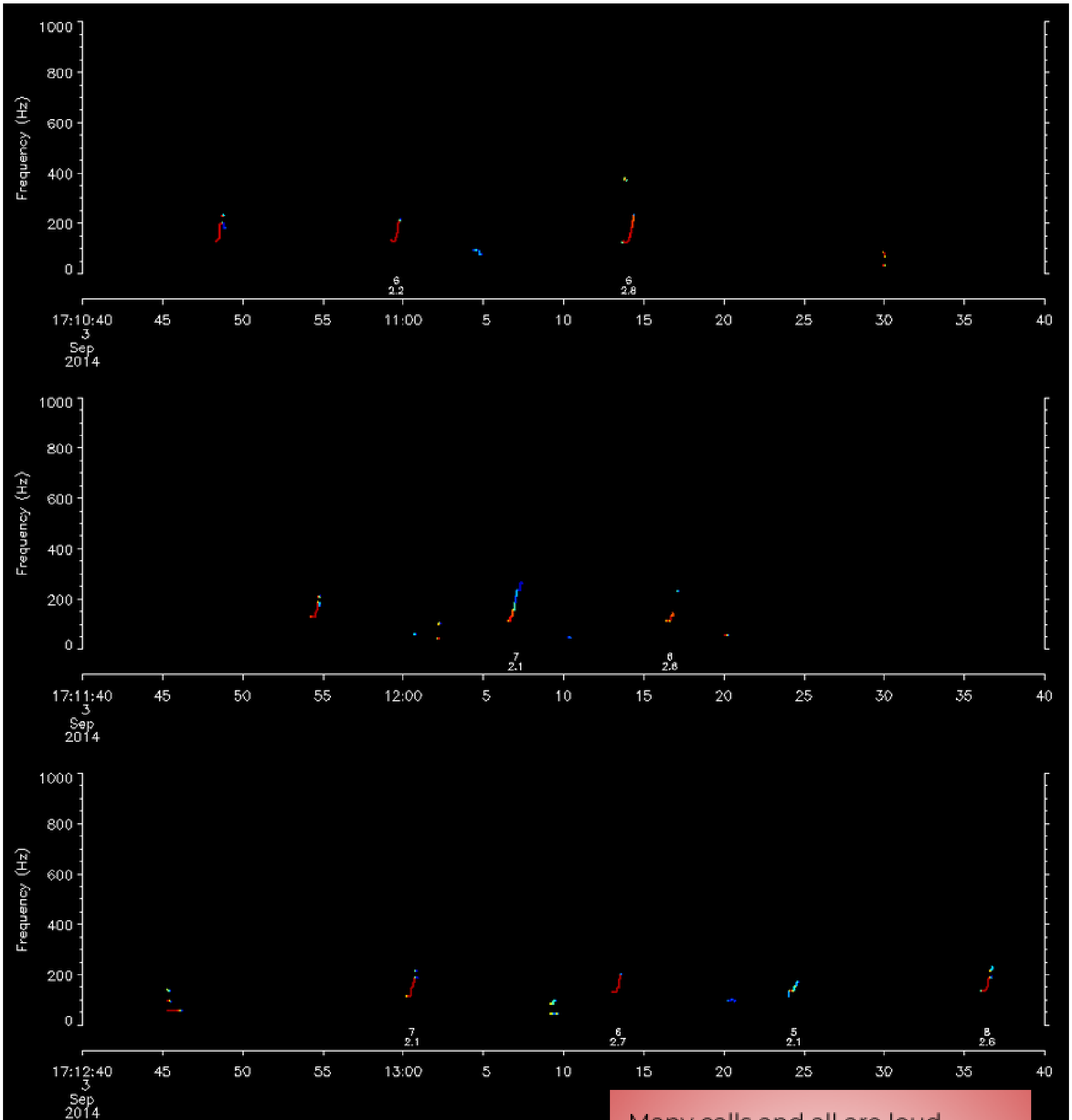


Multiple calls present

No humpbacks are present in the 15-minute summary period

LFDCS was able to classify some of the calls

= right whale “Detected”



Many calls and all are loud

No humpbacks are present in the 15-minute summary period

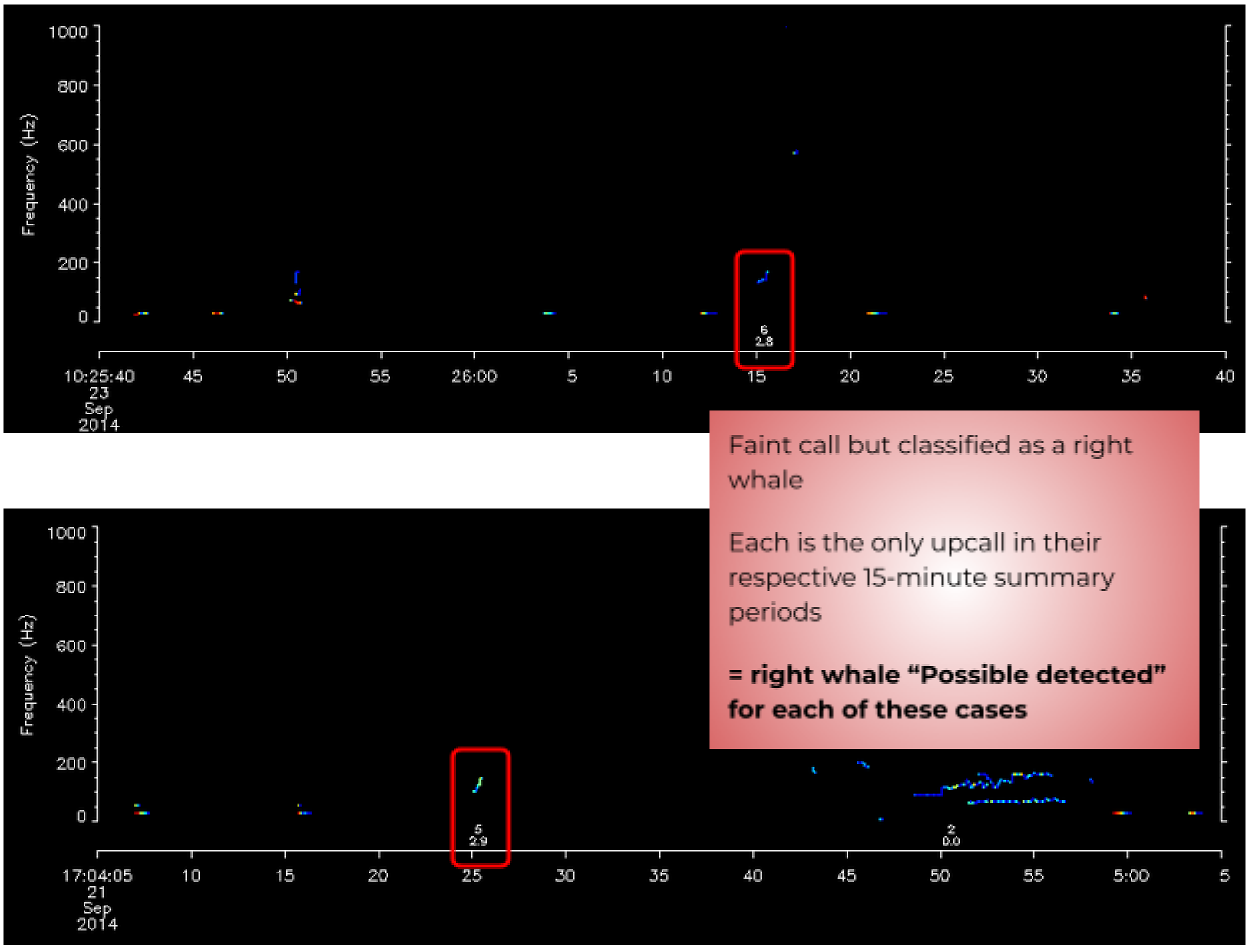
LFDCS was able to classify almost all calls

= right whale "Detected"

Possibly detected

If there are only one or two upcalls in a 15-minute summary period, but 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”.

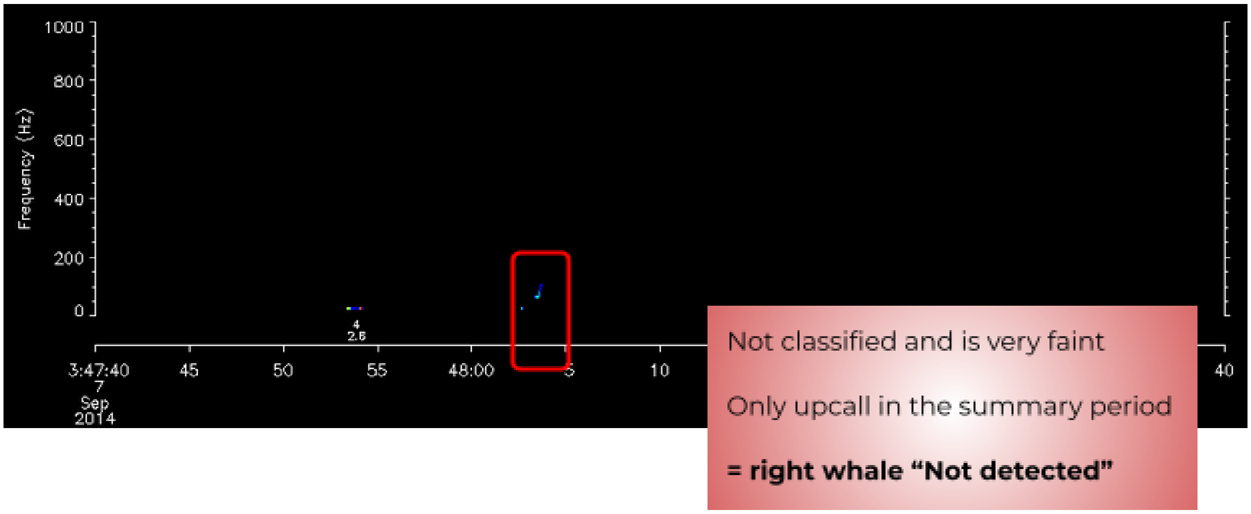
The following figures are examples of when a right whale could be considered “Possibly detected”.



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.

The following figure is an example of when a right whale could be considered “Not detected”.



Sei whale

Quick guide

	LFDCS Classified (Y/N)	Pattern	Context	Number of calls needed
Detected	Y	Doublets/triplets	If humpback or blue whales present, exercise caution	3+ classified singles <u>or</u> 1+ classified within doublet/triplet
Possibly detected	Y	No observed pattern	If humpback or blue whales 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.

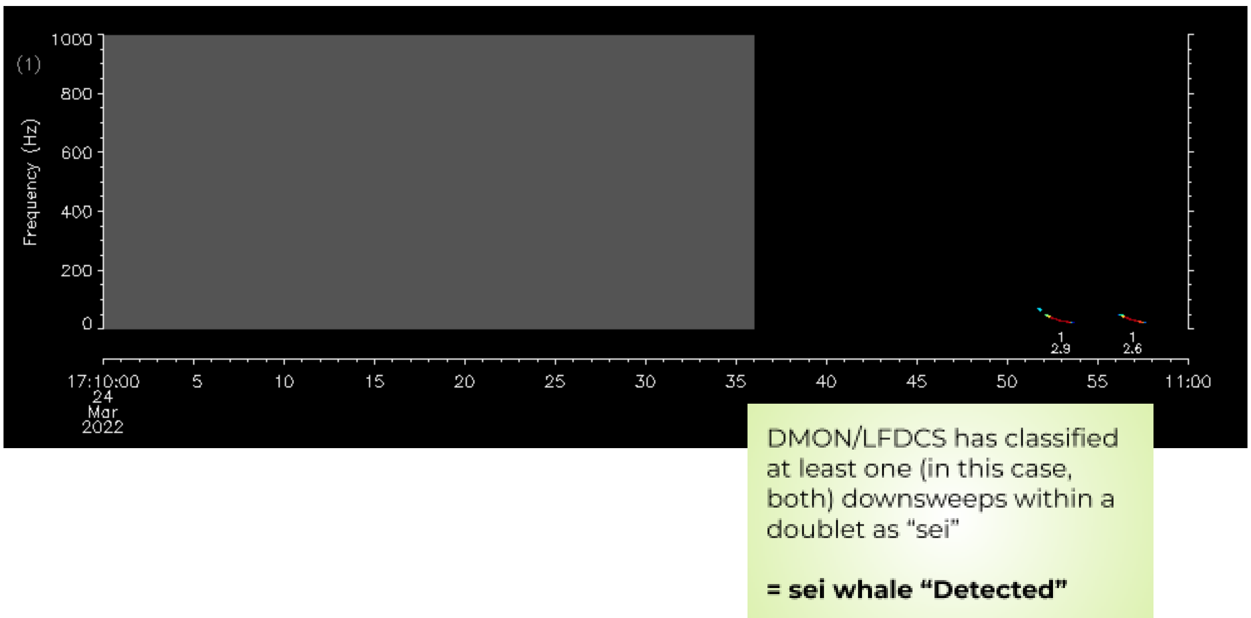
Blue whales have also been known to produce low-frequency 'downsweeps' called a D call, so be cautious if there are signs of other blue whale calls. Concave up blue whale D calls regularly set off the sei whale detector. These downsweeps can occur in doublets and triplets, but usually the inter-pulse interval is longer than 3.5 sections (closer to 5-6 seconds, see example in the Northwest Atlantic blue whale "Not detected" section).

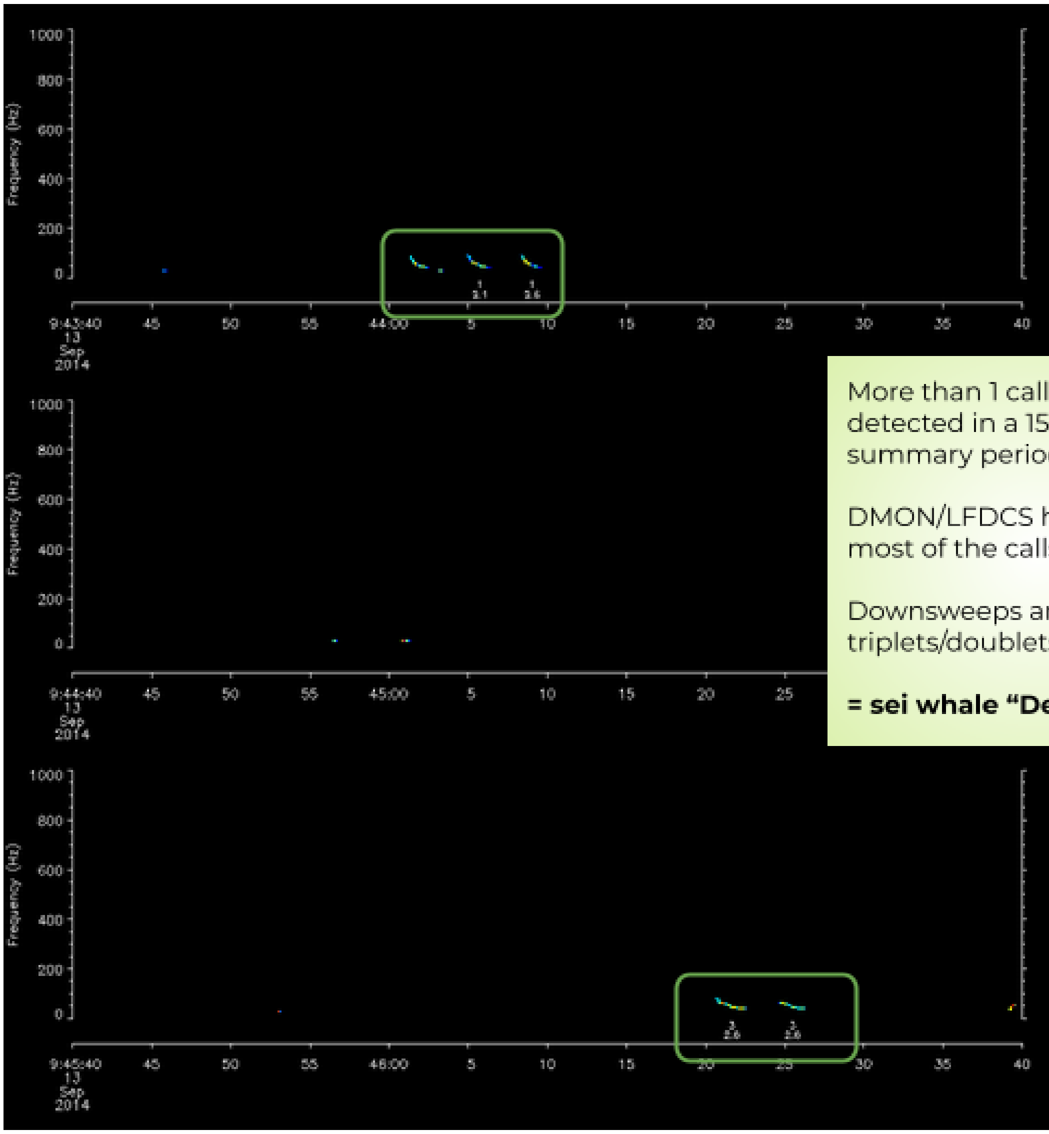
Sei whale downsweeps can have subtle variations in time-frequency characteristics that can be difficult to glean from viewing the pitch tracks. If the LFDCS has classified the call as a sei whale (call types 1-3), you can be confident that the shape, frequency range, and duration of the call all conform 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 two downsweeps can be used to justify a “Detected” score if they are present in a doublet and at least one 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” (see Roseway Basin example 09/20/14 18:48:42). Doublets or triplets are diagnostic of species presence; be sure that the calls that comprise doublets or triplets are ~3.5 seconds apart (i.e., 3.5 seconds between the start of one call and the start of the next call; see 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”.

The following figures are examples of when a sei whale could be considered “Detected”.





More than 1 call has been detected in a 15-minute summary period

DMON/LFDCS has classified most of the calls as “sei”

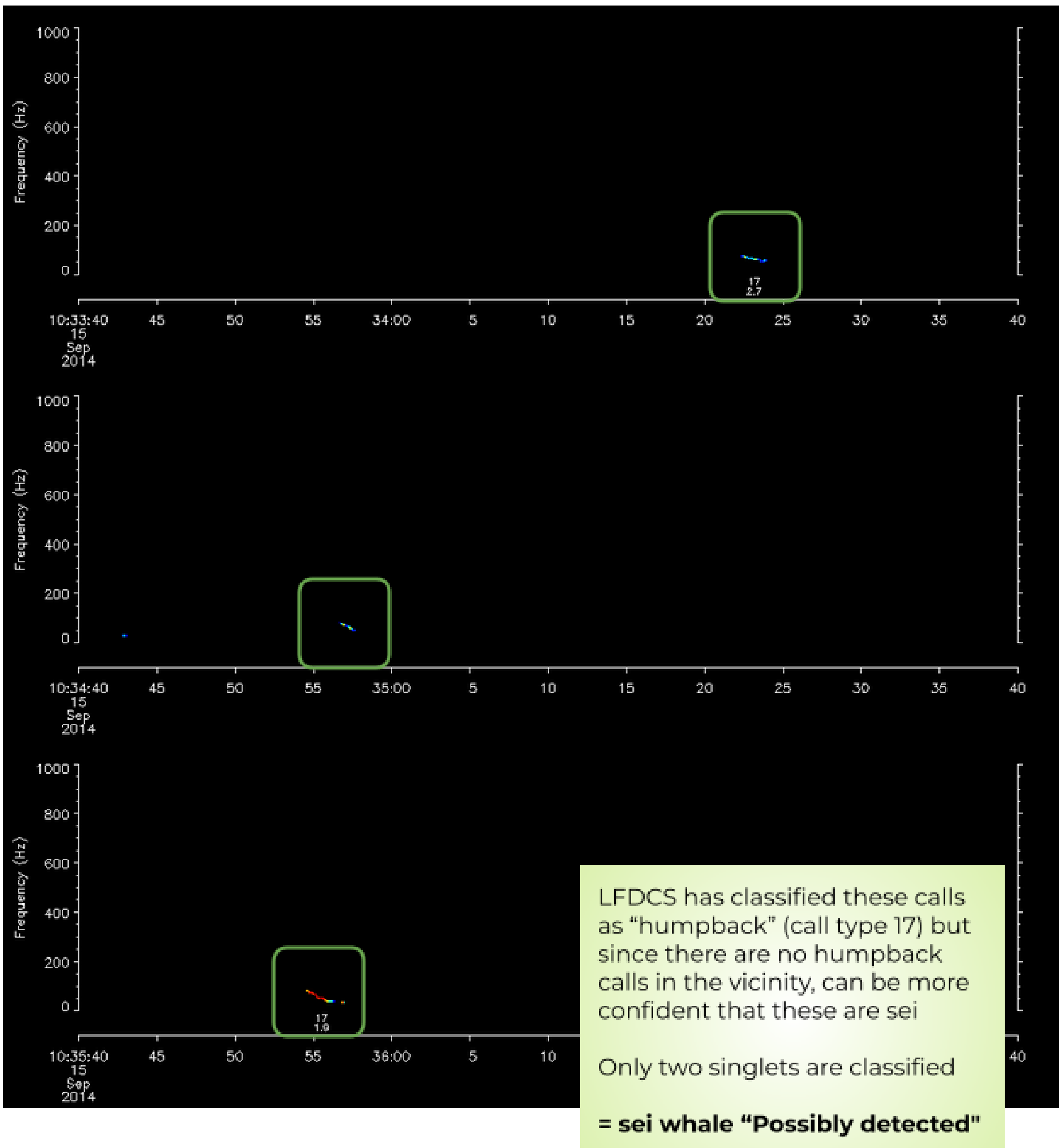
Downsweeps are in triplets/doublets

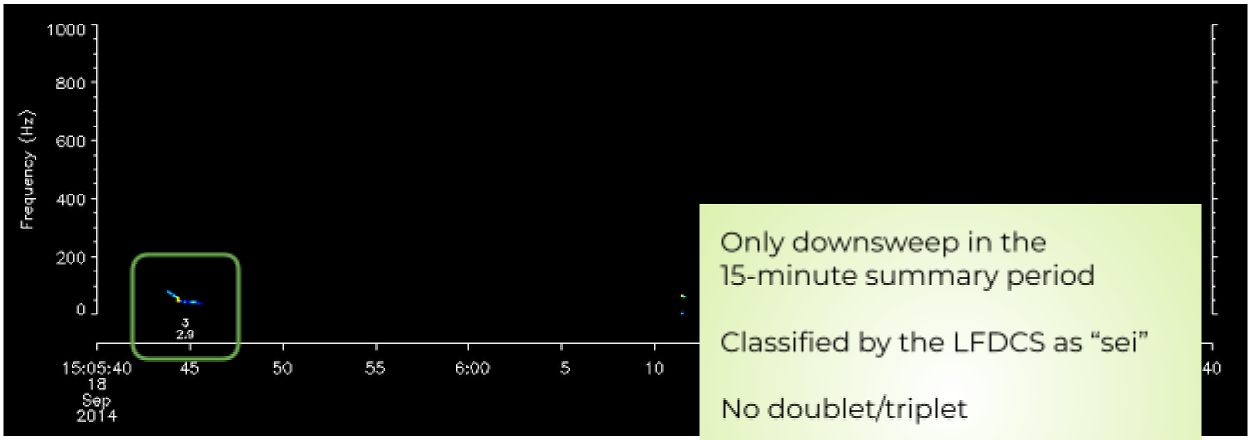
= sei whale “Detected”

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 General above).

The following figures are examples of when a sei whale could be considered “Possibly detected”.





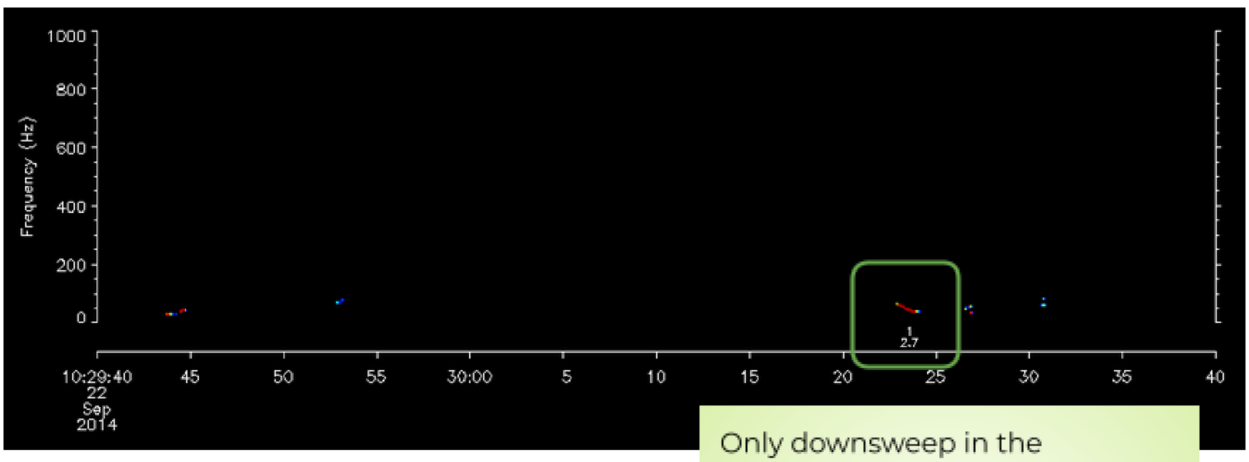
Only downsweep in the 15-minute summary period

Classified by the LFDCS as “sei”

No doublet/triplet

Faint call

= sei whale “Possibly detected”



Only downsweep in the 15-minute summary period

Classified by the LFDCS as “sei”

No doublet/triplet

Loud call

= sei whale “Possibly detected"

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

	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 (see [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 pulses in pattern (2+ must be classified as fin)
Not detected	N	No pattern or irregular pattern	N/A	N/A

General

Fin whales in the western North Atlantic Ocean emit 20-Hz pulses (downsweeps) that occur in regular patterns (song). Internote intervals 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.

The figure to the right is from the Morano et al. 2012 paper which describes in detail the seasonal shifts in fin whale INIs in the western North Atlantic. In general, fin whale INIs may be in the longer 15-16 second range in March-May, and in the shorter 8-9 second range in September-January. During the "transitional months" of February and June-August, it may be more common to observe variation in the INI duration.

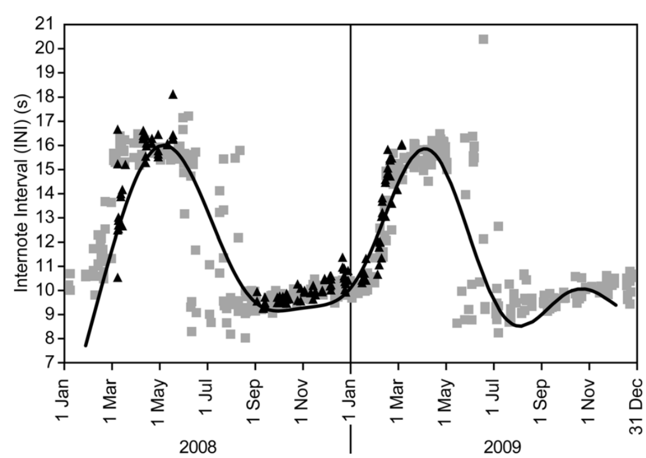
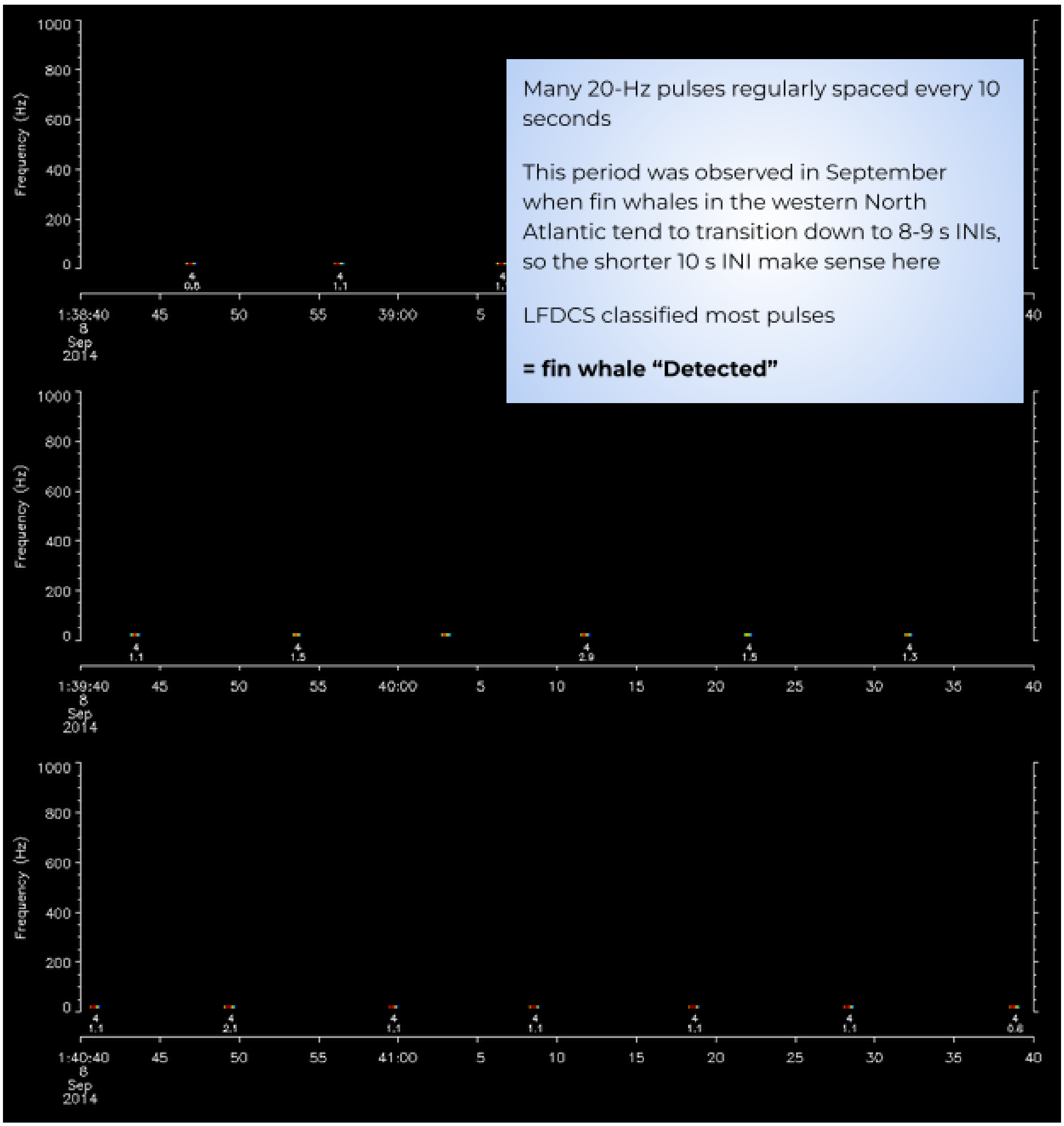


FIG. 3. INI of fin whale 20 Hz song notes measured for 1 January 2008–31 December 2009 in Massachusetts Bay (gray squares, $N = 481$ songs) and New York Bight (black triangles, $N = 129$ songs). The generalized additive model (black line) explains the seasonal changes in INI, where the short-INI season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

Detected

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

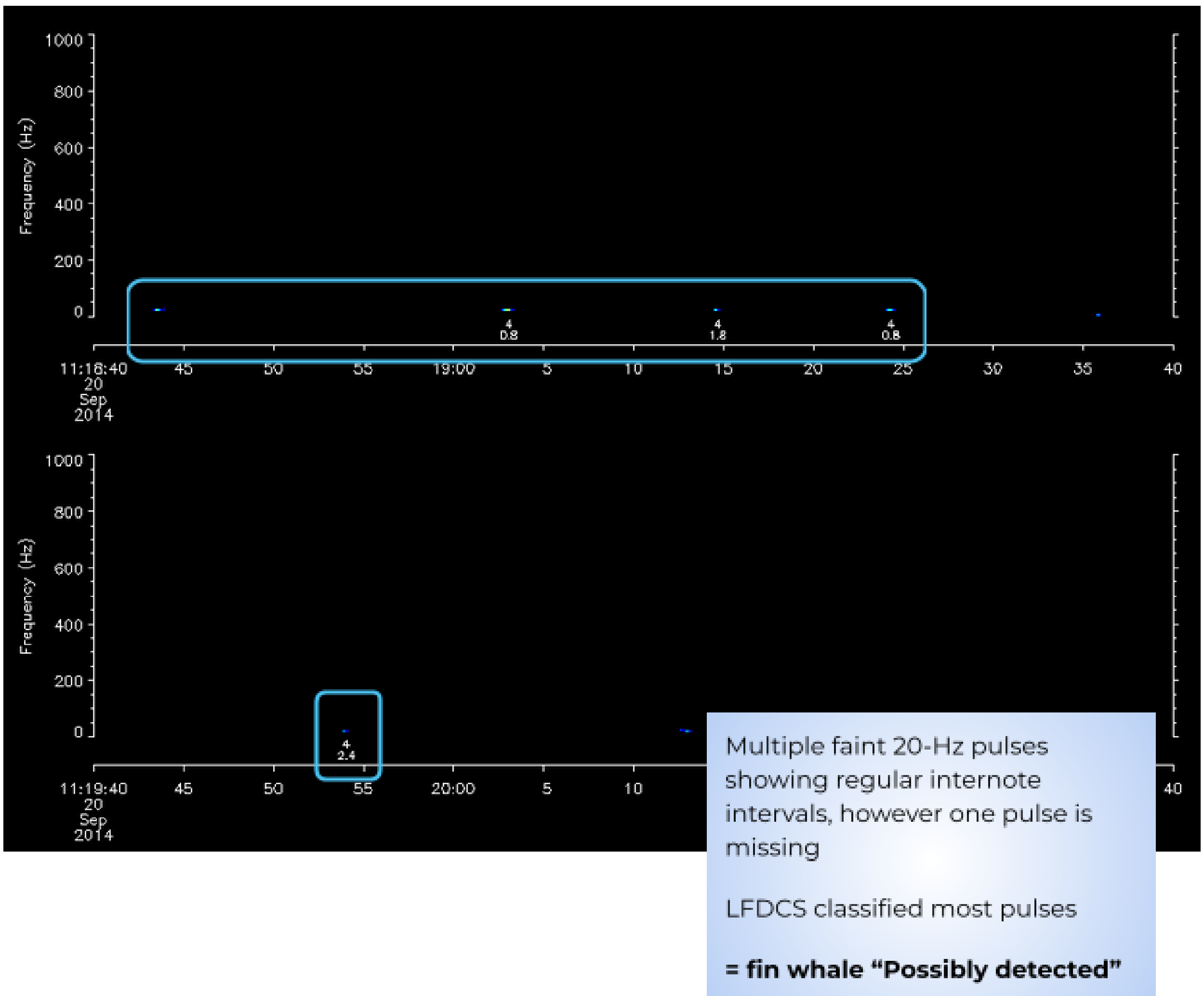
The following figure is an example of when a fin whale could be considered "Detected".

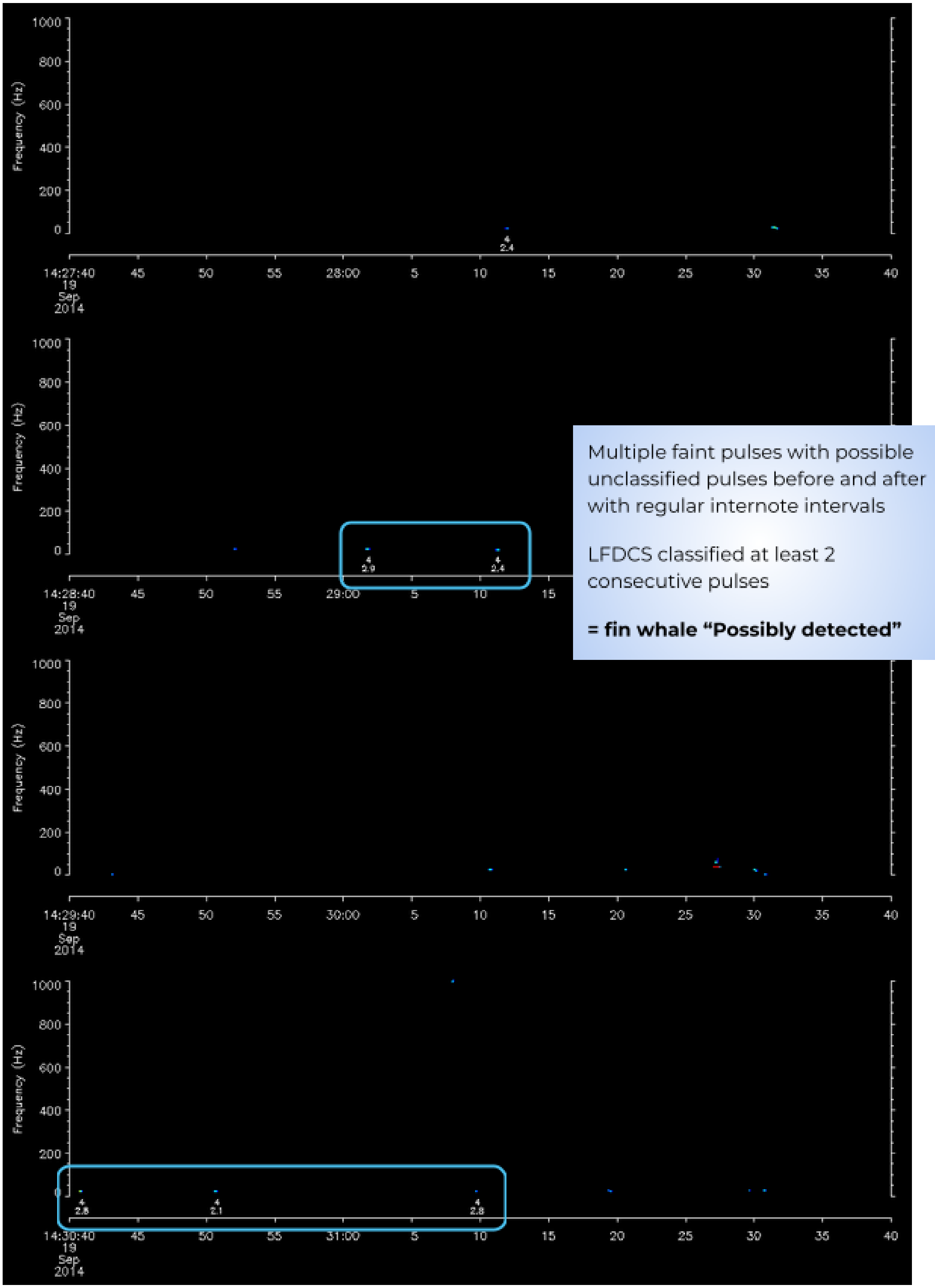


Possibly detected

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 internote interval). 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.

The following figures are examples of when a fin whale could be considered “Possibly detected”.

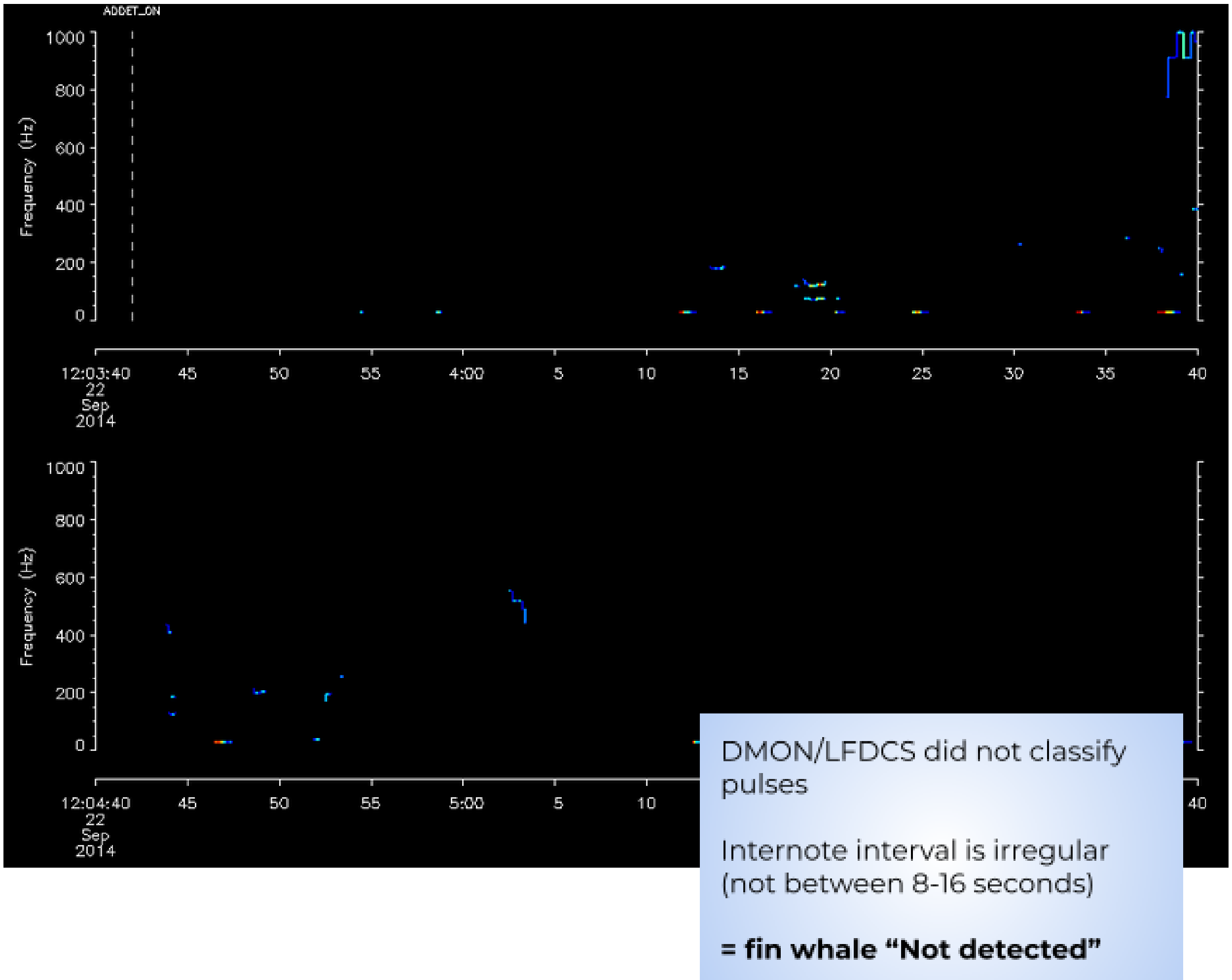


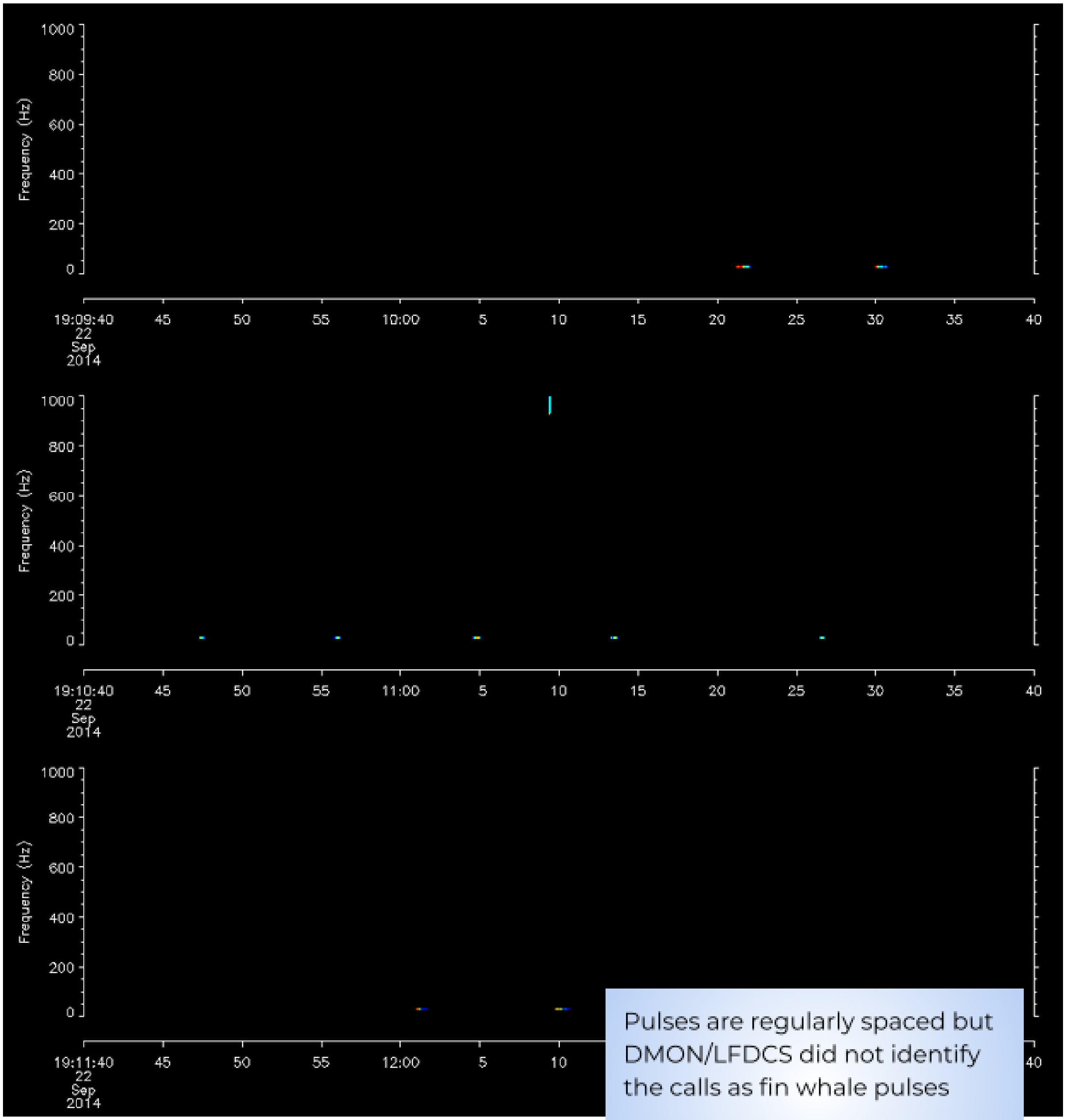

Multiple faint pulses with possible unclassified pulses before and after with regular internote intervals
LFDCS classified at least 2 consecutive pulses
= fin whale "Possibly detected"
Frequency (Hz)
14:27:40
19
Sep
2014
14:28:40
14:29:40
14:30:40

Not detected

For patterned pulses to be considered “Not detected”, none of the pitch tracks in the patterned pulses should be classified, the internote interval varies, or the internote interval is not within the 8-16 second bounds.

The following figures are examples of when a fin whale could be considered “Not detected”.





Pulses are regularly spaced but DMON/LFDCS did not identify the calls as fin whale pulses

= fin whale "Not detected"

Humpback whale

Quick guide

	LFDCS Classified (Y/N)	Pattern	Context	Number of calls needed
Detected	Y/N	Often many calls grouped together that are repeated	None	Many calls (5+)
Possibly detected	Y/N	Some calls in repetition or no pattern	None	Few calls (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 & McVay 1971, Payne & Payne 1985, and Winn & 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).

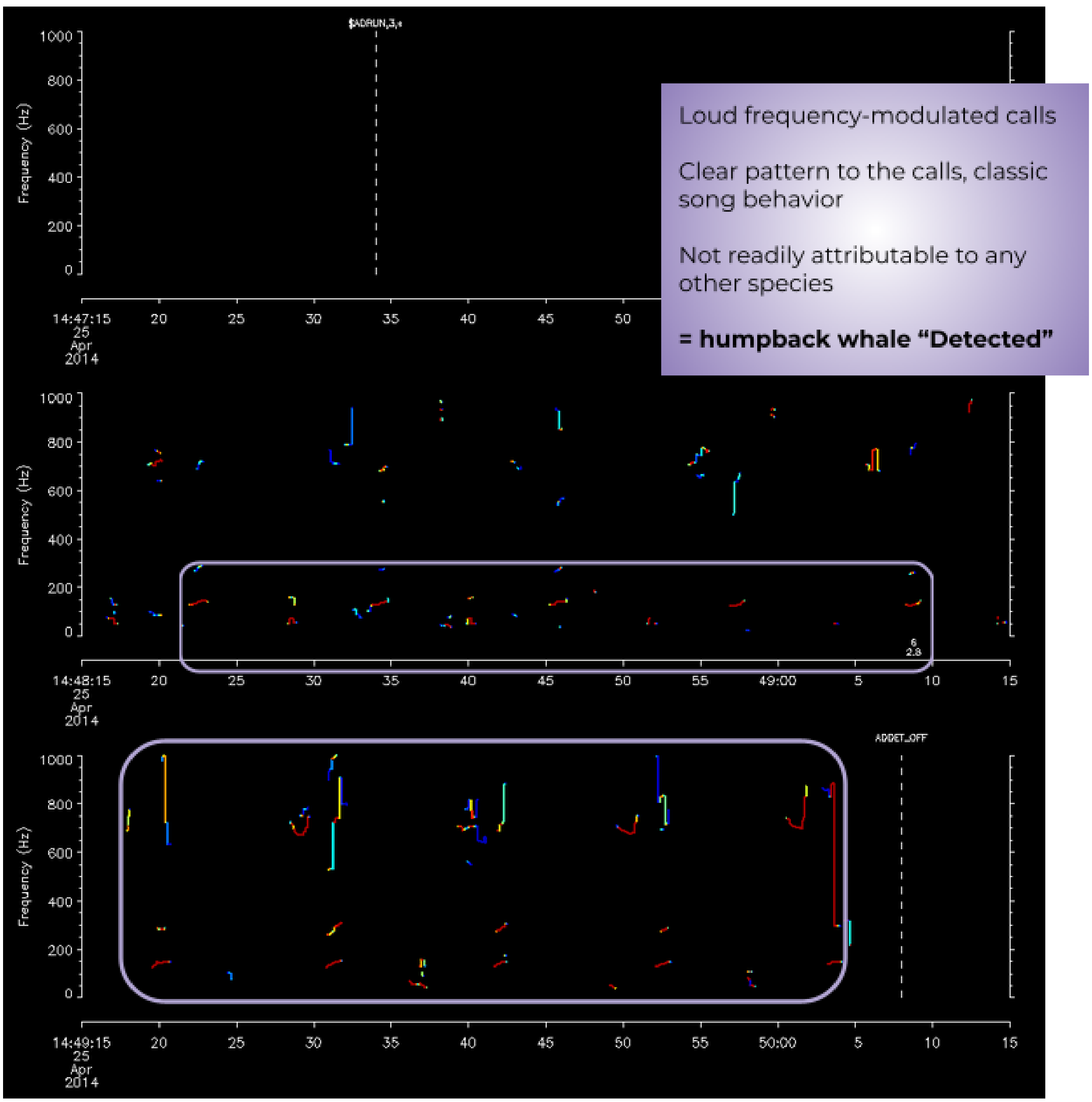
Off the U.S. and Canadian eastern seaboards, we often believe that many unknown sounds are produced by humpback whales. While there are little data to back up this belief, it is based upon the idea that humpback whales produce such a high variety of different sounds; so, when an unknown loud tonal sound 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 being conservative, so only mark a summary period as “Detected” if you are very sure of that species’ presence.

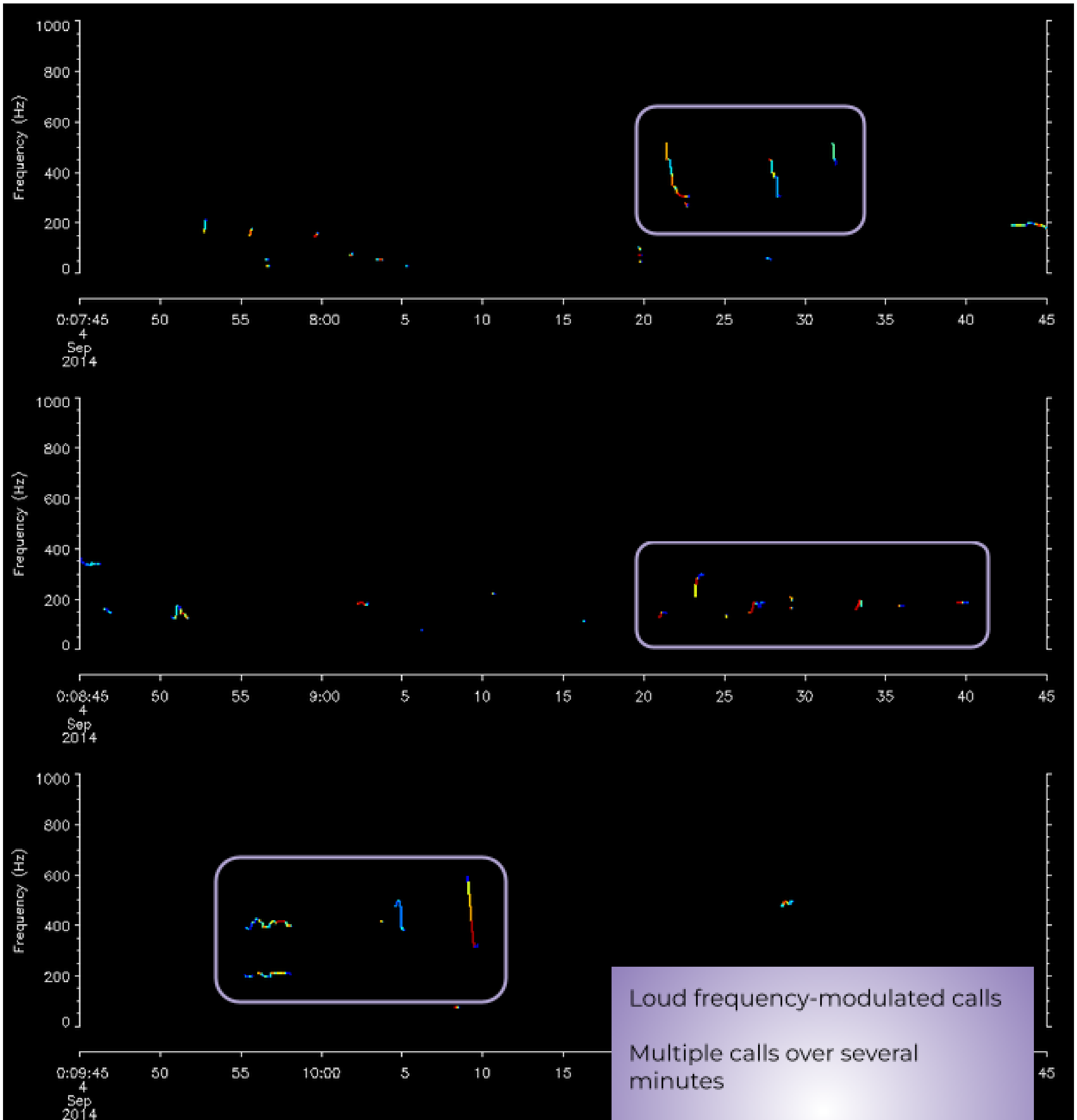
Noise in the upper half of the monitored frequency range can create spurious quiet pitch tracks that sometimes resemble faint humpback calling. Pitch tracks that are in the 500-1000 Hz band, are faint, and change frequency very quickly (making them look almost disjointed) should be viewed with some suspicion.

Detected

If you see patterned calling (e.g., 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.

The following figures are examples of when a humpback whale could be considered “Detected”.





Loud frequency-modulated calls

Multiple calls over several minutes

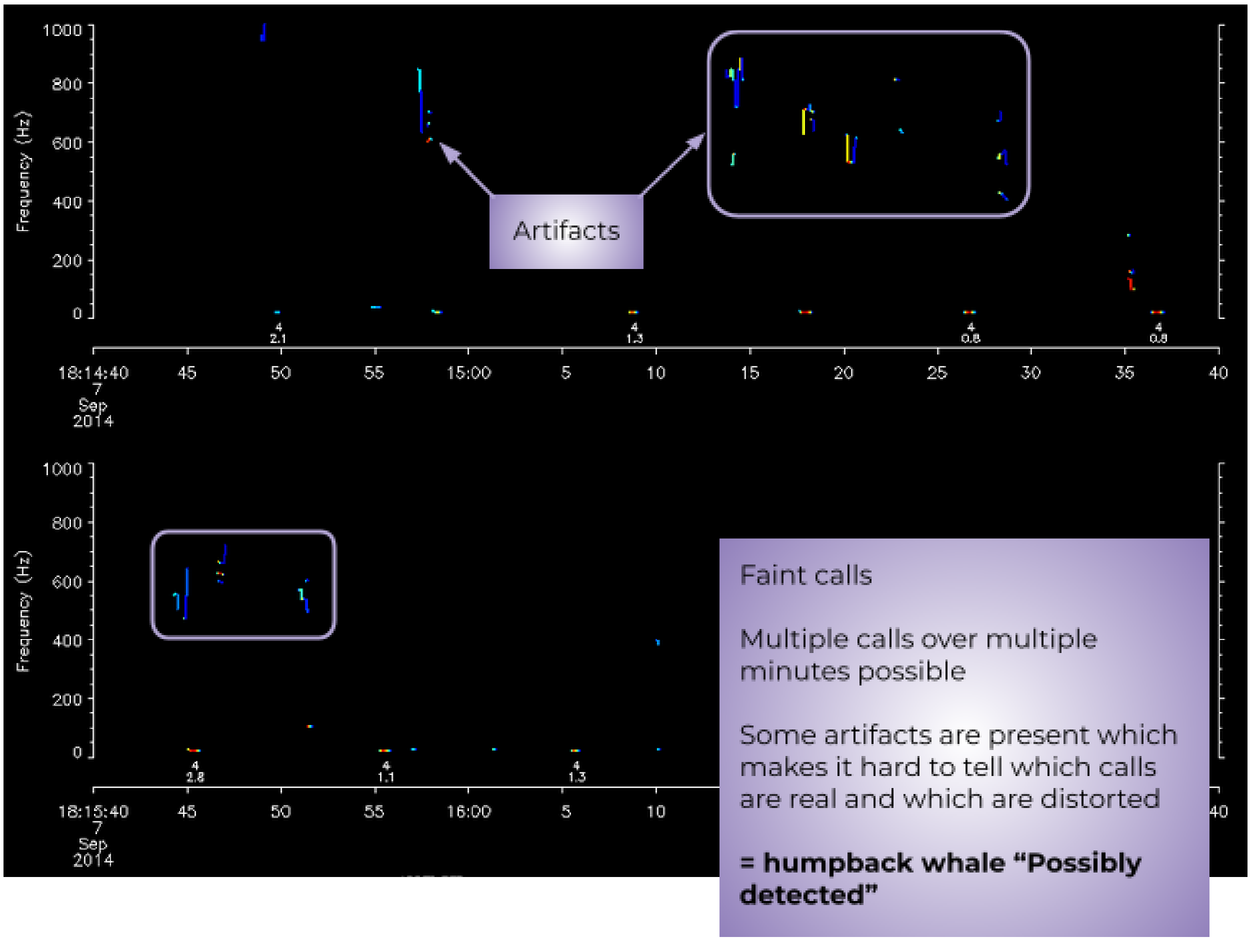
Not readily attributable to any other species

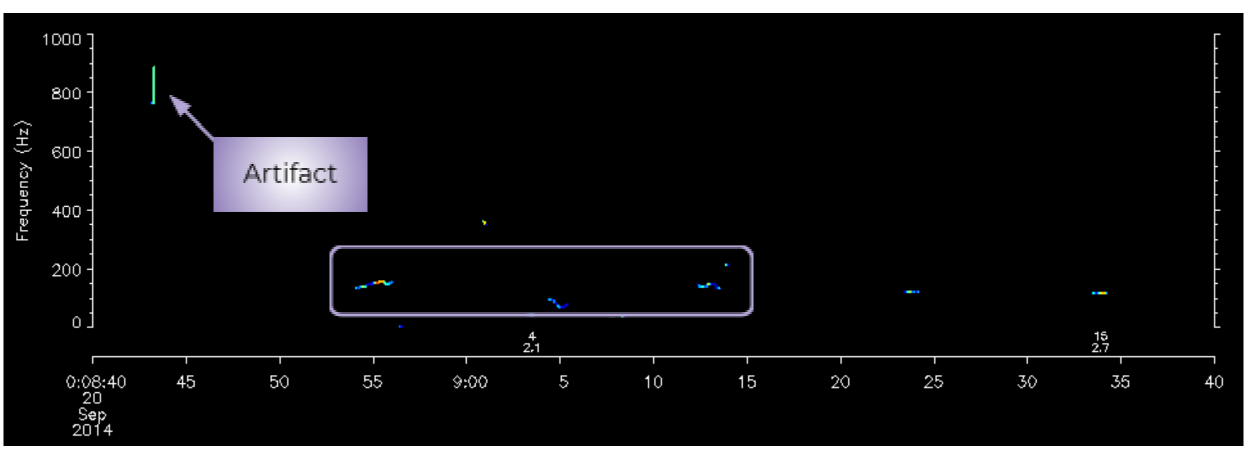
= humpback whale "Detected"

Possibly detected

Signals that are faint should be marked as “Possibly detected”. Sometimes the pitch tracks will have straight lines connecting calls. This is because it believes that those two calls belong together, even if they do not. When this happens, we will use the term “artifact”.

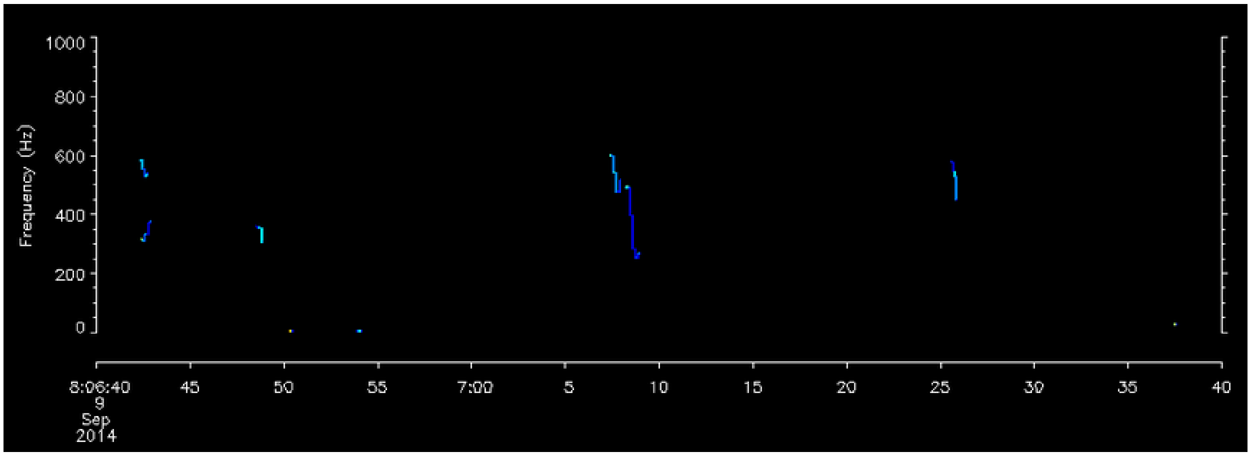
The following figures are examples of artifacts and faint humpback calls when a humpback whale could be considered “Possibly detected”.

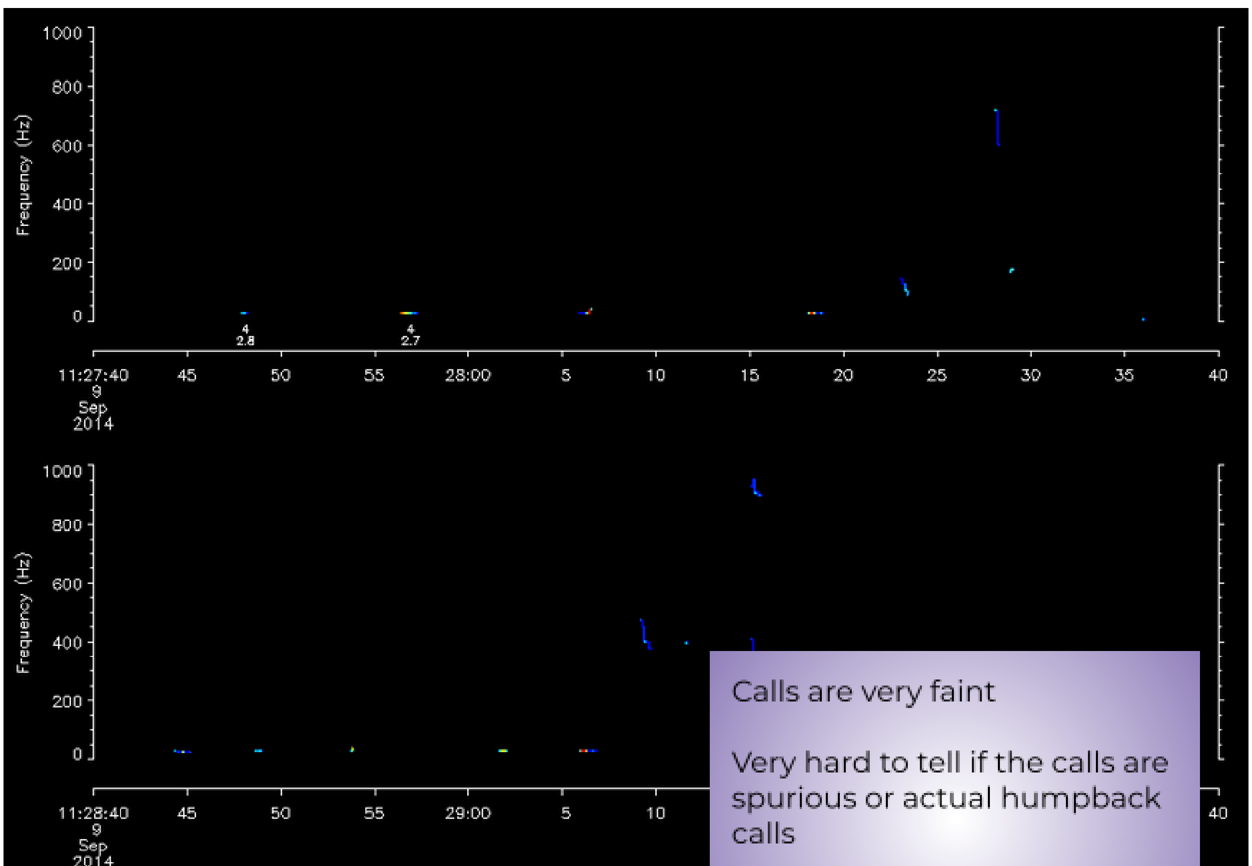




Not detected

When there are only a few faint calls, mark the 15-minute summary period as “Not detected”. Examples of this are shown in the following figures.





Calls are very faint

Very hard to tell if the calls are spurious or actual humpback calls

= humpback whale “Not detected”

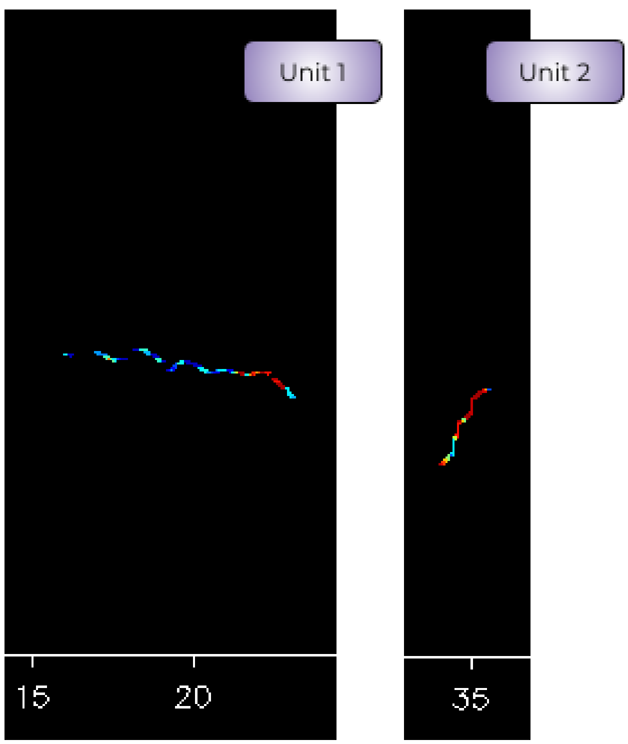
Supplementary Protocol: Identifying humpback whale song

Understanding Song Structure

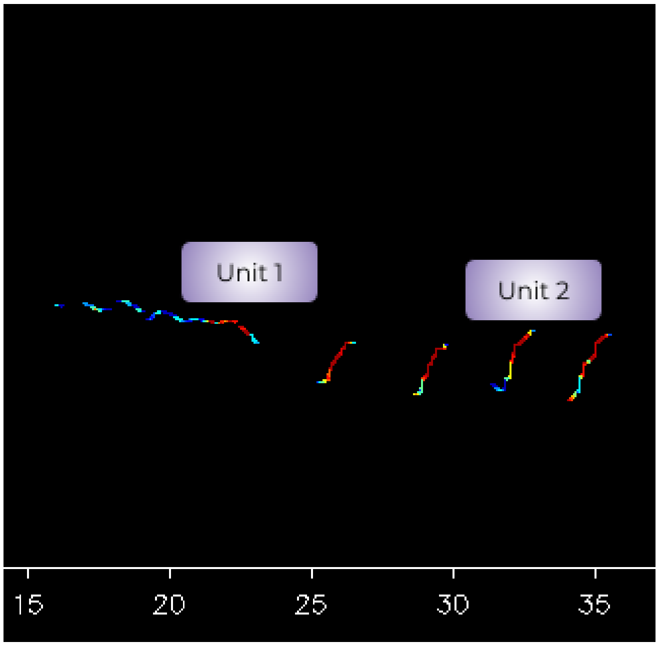
Identifying Unique Themes

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.

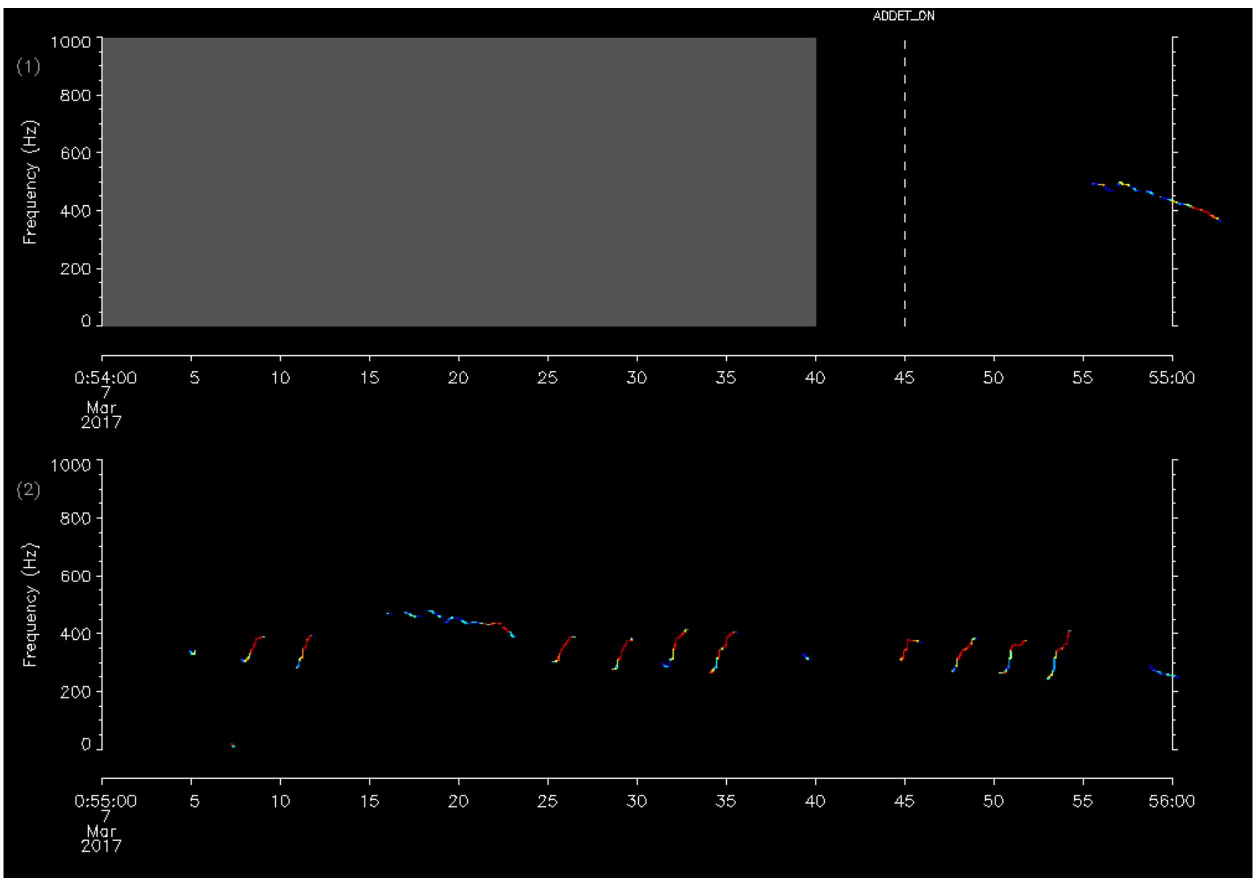
Example of humpback song units



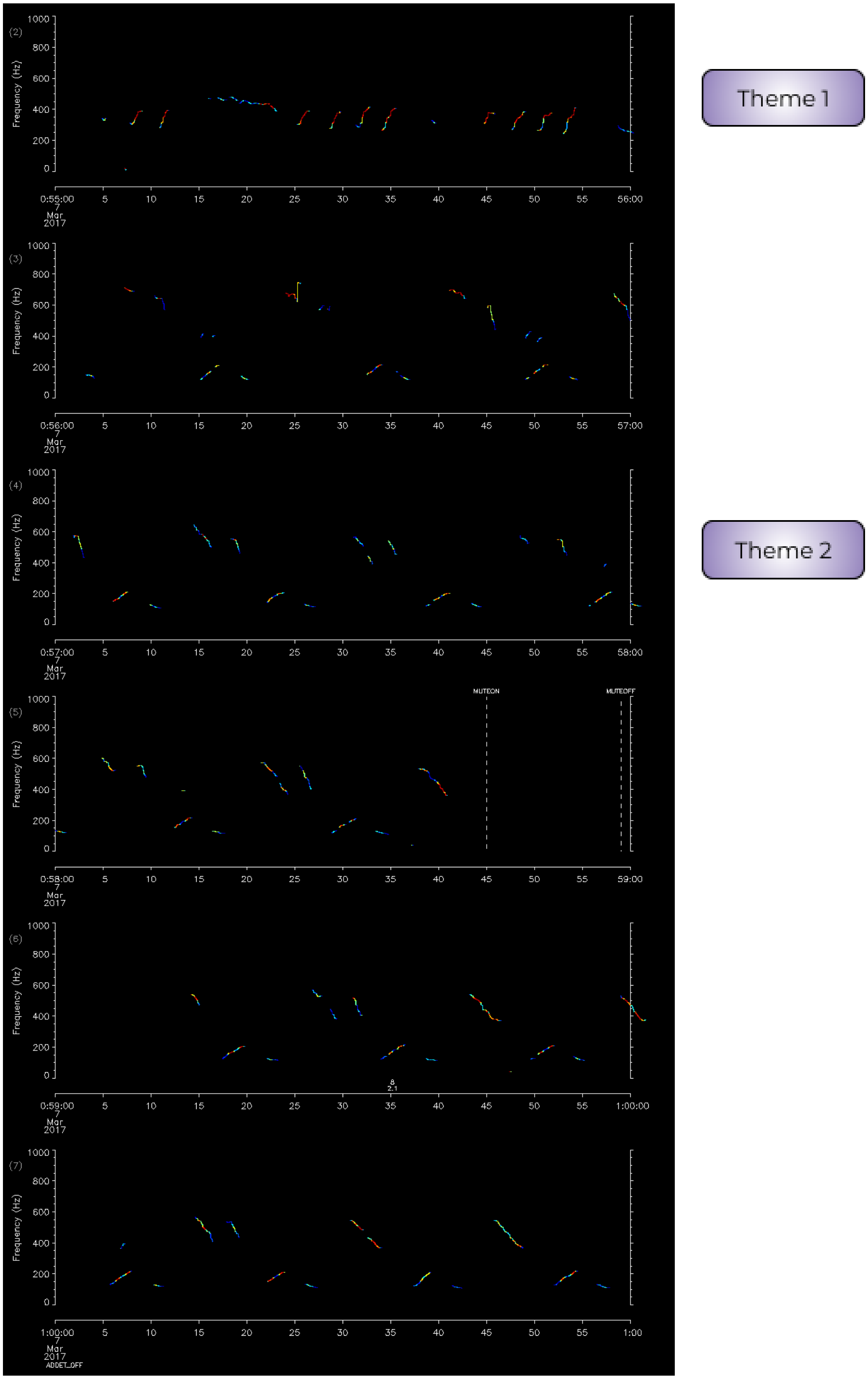
Example of humpback song phrase (patterned series of units)



Example of humpback song theme (repeating phrases)



Example of humpback song fragment (including two different themes)



Appendices

Appendix A: Known Idiosyncrasies

Artifacts of the pitch tracking algorithm

This has been explained, with examples, in the humpback whale "Possibly detected" section. It is important to note that not just humpbacks are susceptible to artifacts, but also right whale upcalls.

Webpage 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 between 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 click the "Reload" or "Refresh" button on your browser and the data that you entered into the form will be visible.

Appendix B: Additional Species Analysis Protocols

Note: If you have an additional real-time analysis protocol for another species or population that you would like to contribute to this reference guide, please email julianne.wilder@noaa.gov for more information.

Northwest Atlantic blue whale

Protocol written by Allison Richardson and Kimberley Davies (University of New Brunswick)
For questions about this protocol, please contact Allison Richardson at aricha13@unb.ca.

Quick guide

	LFDCS Classified (Y/N)	Pattern	Context	Number of calls needed
Detected	N	Can have pattern, but does not need to be in pattern	If sei whales present, exercise caution	3+ arch sounds <u>or</u> 3+ D calls with at least 2 being concave down
Possibly detected	N	Can have pattern, but does not need to be in pattern	If sei whales present, exercise caution	1-2 arch sounds <u>or</u> 2+ D calls with at least 1 being concave down
Not detected	N	None	N/A	N/A

General

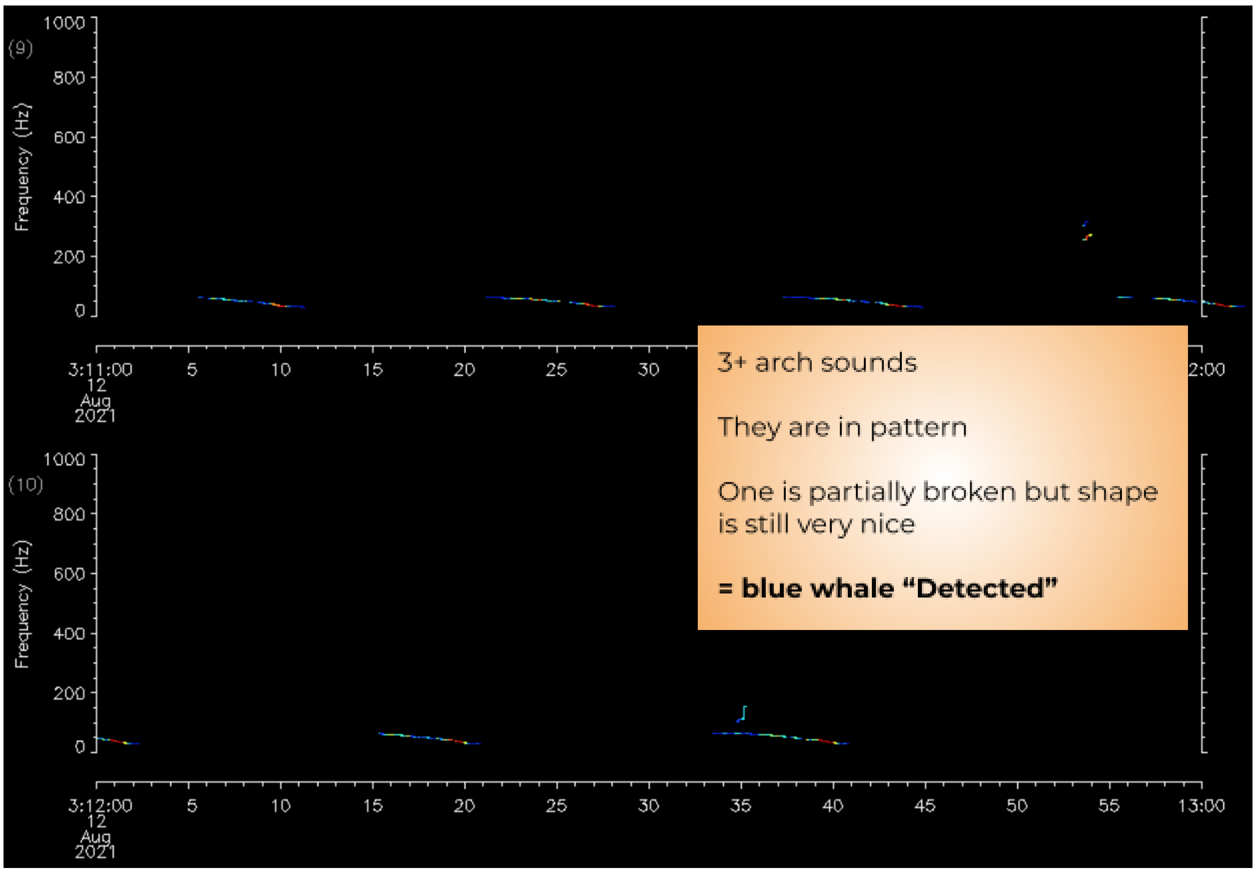
Northwest Atlantic blue whales emit two types of audible calls that can be used for real-time passive acoustic monitoring. Low-frequency downsweeps known as D calls that can be produced in singlets or in bouts. Arch sounds consist of a short ascending portion which plateaus for a few seconds, followed by a long downsweep, creating a characteristic arch shape on a spectrogram. The ascending portion is often quieter than the rest of the call or, as is regularly the case in the Gulf of St. Lawrence, not loud enough to be picked up by the LFDCS. Therefore, it is sometimes not present in LFDCS pitch tracks, which only show the plateau/downsweep portion. Arch sounds are usually produced in bouts. Arch sounds are diagnostic of this species presence because no other species makes this kind of call in the low-frequency range. Arch sounds are produced between 30 and 70 Hz while D calls are produced between 35 and 75 Hz but can be produced up to 150 Hz.

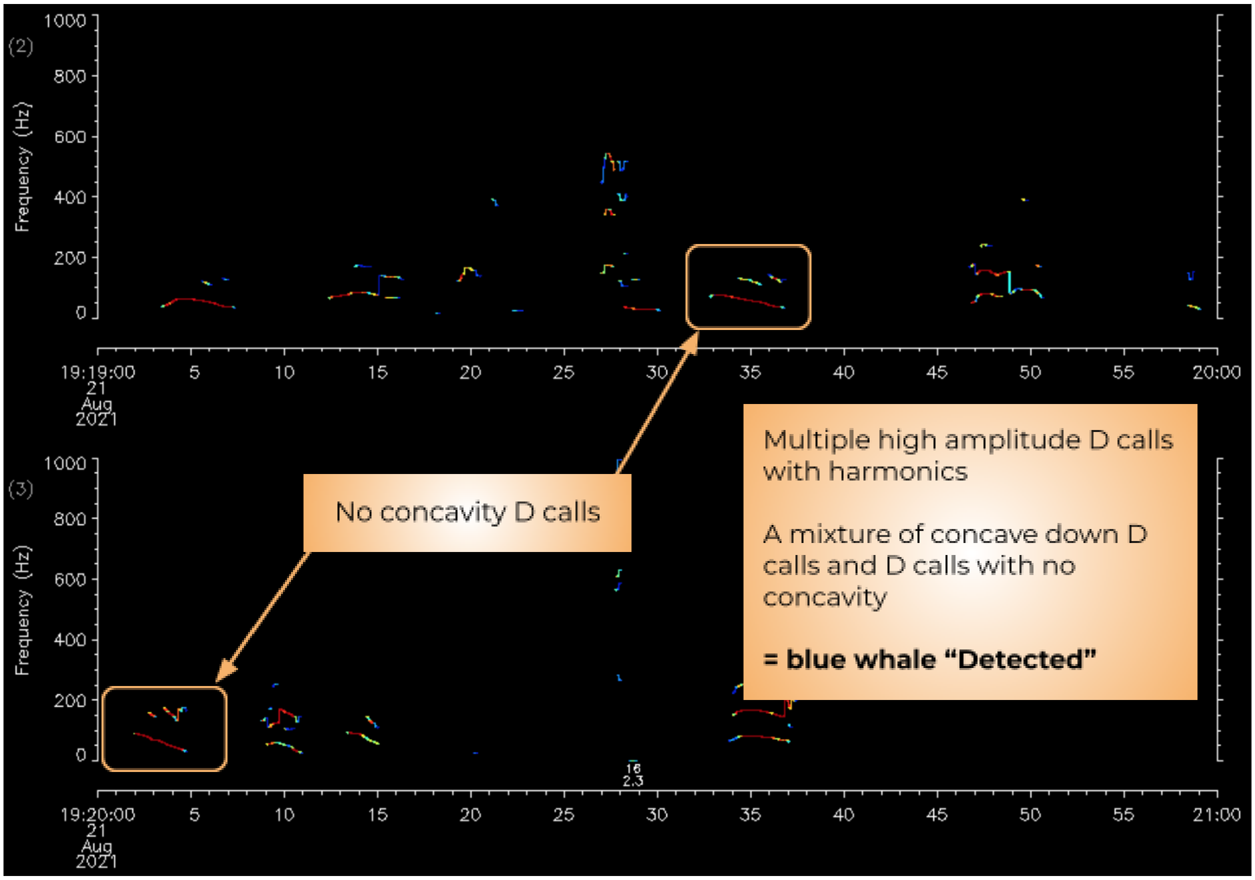
Blue whale calls can be produced in pattern, but don't have to be in pattern. The inter-pulse interval between calls can vary within a bout from 5-50 seconds. The number of calls in a bout is highly variable, with a single animal sometimes producing calls constantly over several tally periods. D calls can either be concave up, concave down, or have no concavity. Blue whale concave up D calls look very similar to sei whale downsweeps and can be misclassified by the LFDCS as a sei whale (call types 1-3). If there are only concave up D calls in a tally period, you should consider the possibility that sei whales are producing the calls. If there are concave down D calls, no concavity D calls, or arch sounds, you should consider that there is a blue whale present.

Detected

Blue whales can be scored as "Detected" when there are 3 or more nicely shaped arch sounds in a tally period. Arch sounds typically occur in bouts of 4-8 calls. If D calls are present, there should be at least 2 concave down D calls to be confident that it is a blue whale producing the calls. D calls can be produced in bouts or can be produced in singlets. If there are more than 3 calls, with 2 being concave down, the period can be scored as "Detected" for blue whales.

The following images depict examples of "Detected" Northwest Atlantic blue whales.



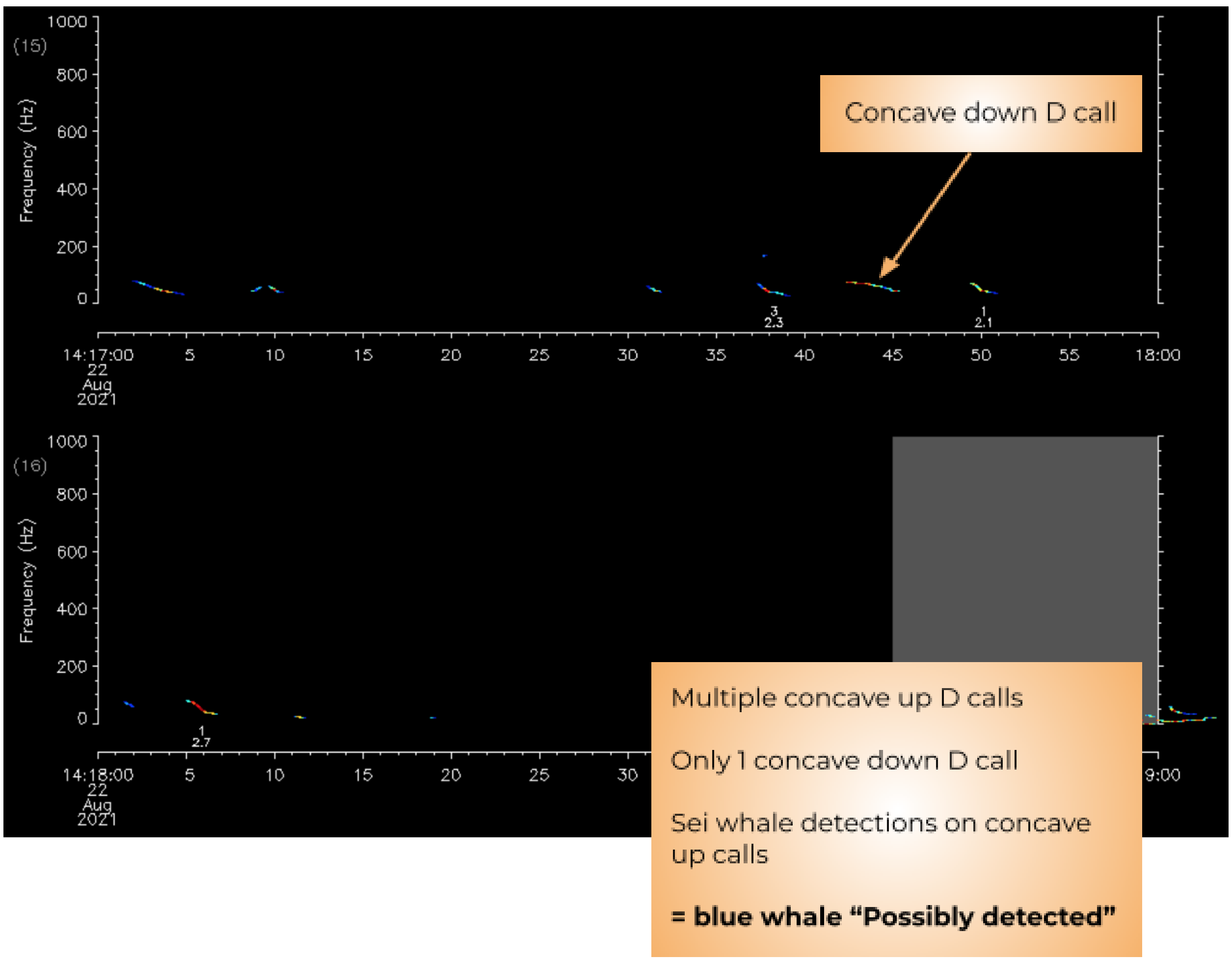


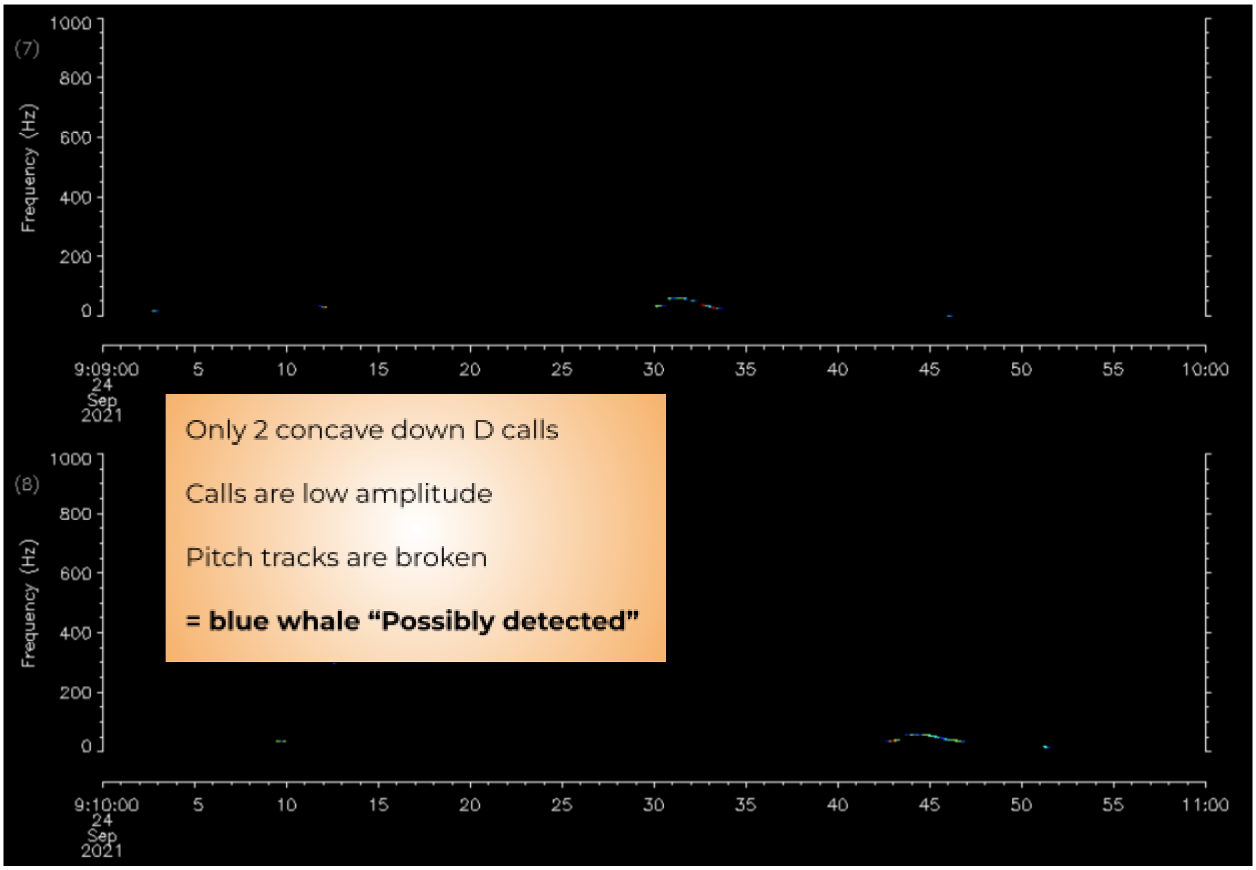
(2)
Frequency (Hz)
1000
800
600
400
200
0
19:19:00
21
Aug
2021
5
10
15
20
25
30
35
40
45
50
55
20:00
(3)
Frequency (Hz)
1000
800
600
400
200
0
19:20:00
21
Aug
2021
5
10
15
20
25
30
35
40
45
50
55
21:00
No concavity D calls
Multiple high amplitude D calls with harmonics
A mixture of concave down D calls and D calls with no concavity
= blue whale "Detected"

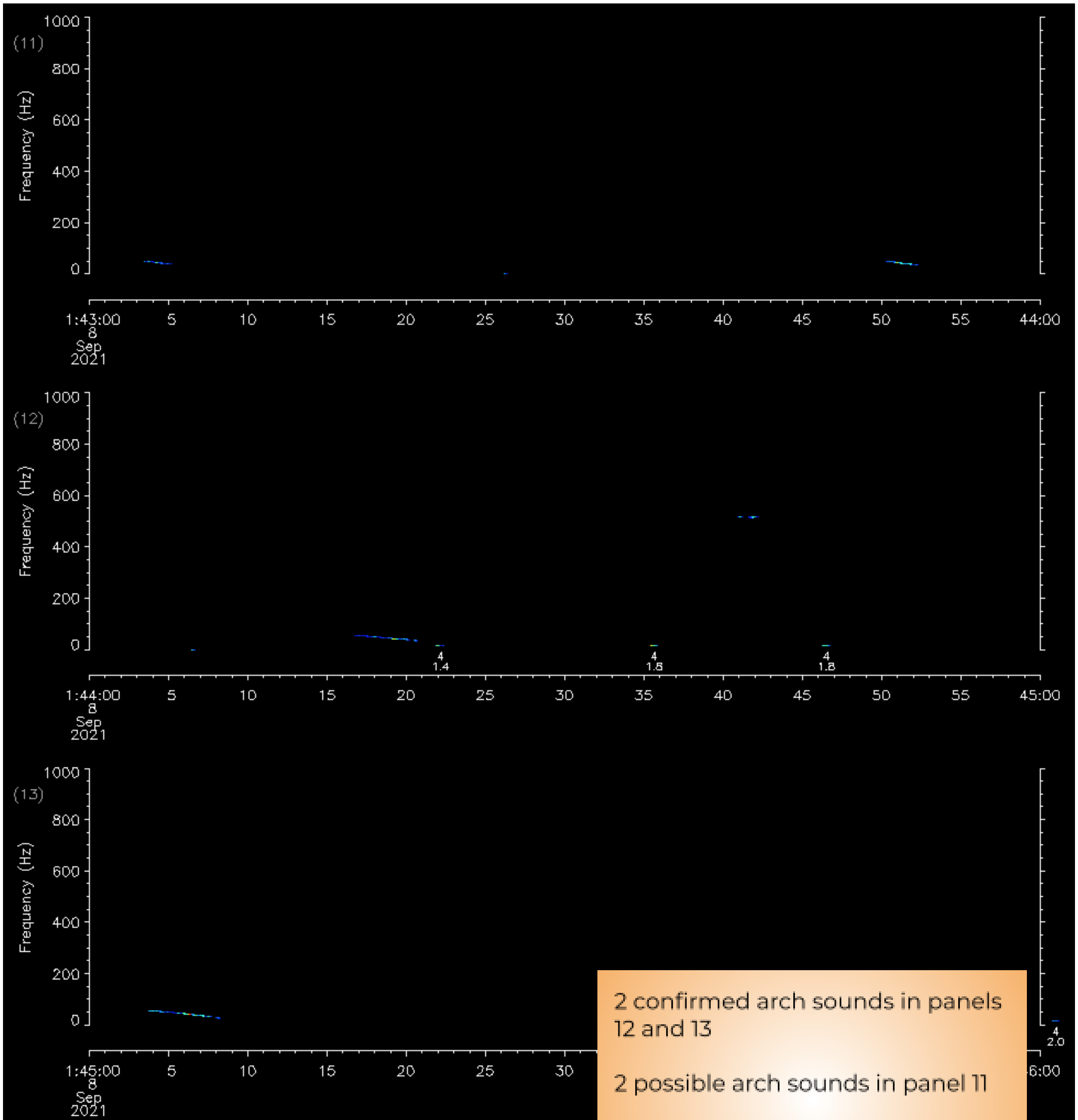
Possibly detected

If there are only one or two arch sounds or if there are broken or low amplitude arch sounds that are not in a bout, then the period should be scored as "Possibly detected". If there are concave up D calls with only one concave down D call within the same tally period, then the period should be considered "Possibly detected". If there are D calls with no concavity or concave down D calls that are broken or do not have the best shape, then the period should be scored as "Possibly detected". If there are high amplitude, long concave up downsweeps that have a shallow slope, then the period should be scored as "Possibly detected".

The following images depict examples of "Possibly detected" Northwest Atlantic blue whales.




(7)
Frequency (Hz)
1000
800
600
400
200
0
9:09:00
24
Sep
2021
5
10
15
20
25
30
35
40
45
50
55
10:00
Only 2 concave down D calls
Calls are low amplitude
Pitch tracks are broken
= blue whale "Possibly detected"
(8)
Frequency (Hz)
1000
800
600
400
200
0
9:10:00
24
Sep
2021
5
10
15
20
25
30
35
40
45
50
55
11:00

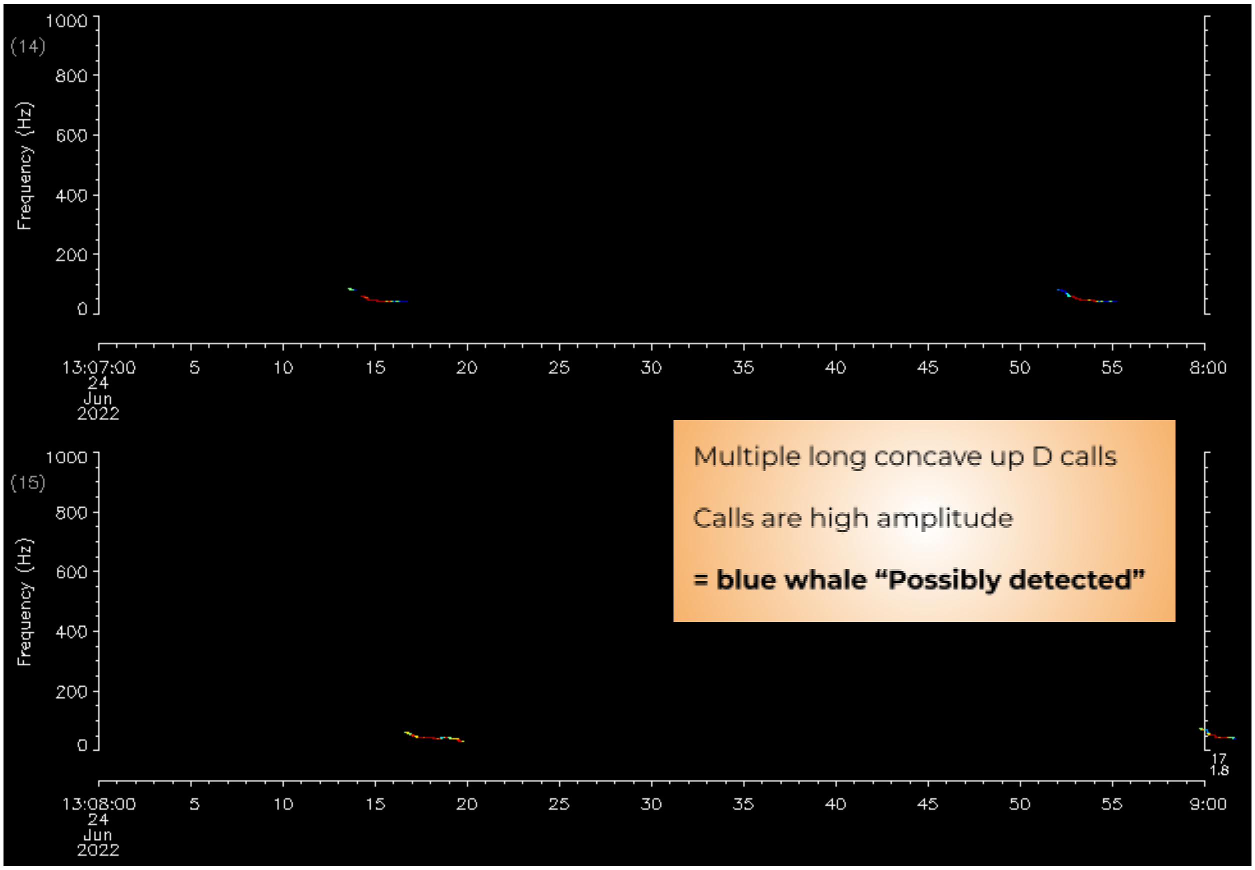


2 confirmed arch sounds in panels 12 and 13

2 possible arch sounds in panel 11

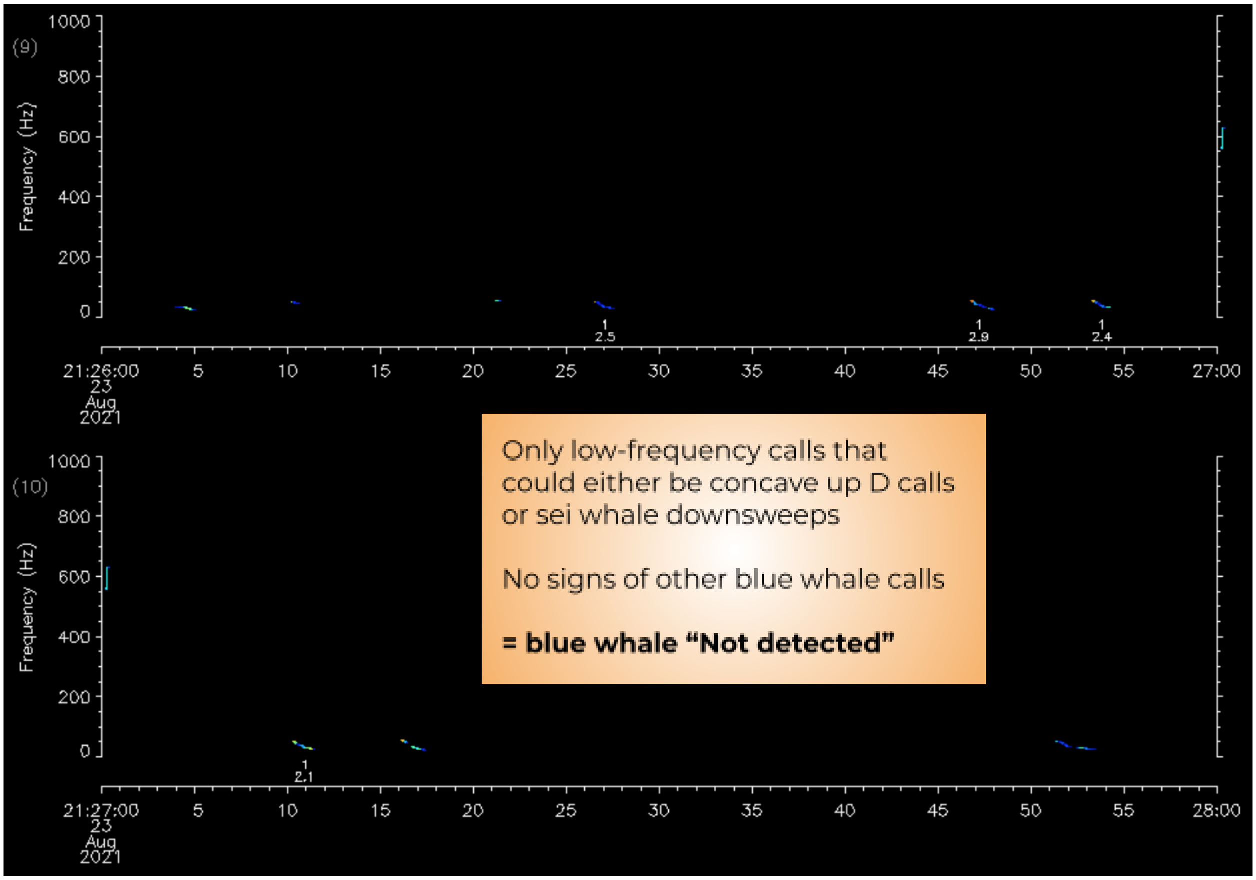
Calls are low amplitude

= blue whale "Possibly detected"


1000
(14)
800
Frequency (Hz)
600
400
200
0
13:07:00
24
Jun
2022
5
10
15
20
25
30
35
40
45
50
55
8:00
1000
(15)
800
600
400
200
0
13:08:00
24
Jun
2022
9:00
17
1.8
Multiple long concave up D calls
Calls are high amplitude
= blue whale "Possibly detected"

Not detected

If there are only concave up calls that look like blue whale concave up D calls or sei whale downsweeps without any signs of arch sounds, concave down D calls, or D calls with no concavity, then this period should be scored as "Not detected" and you should consider the possibility that there are sei whales present. See example below.



North Pacific blue whale

Protocol written by Ana Širović and Megan Wood (Texas A&M University Galveston)
For questions about this protocol, please contact Megan Wood at megan.wood@noaa.gov.
Note: This protocol has yet to be formally evaluated using archival data.

Quick guide

A/B Calls	LFDCS Classified (Y/N)	Pattern	Context	Number of calls needed
Detected	Y/N	A-B song	If only A calls, exercise caution when other noises around	1+ A-B sequence, classified or not <u>or</u> 2+ A or B calls at regular intervals, classified or not
Possibly detected	Y/N	No observed pattern		1 A or B, classified or not
Not detected	N	N/A	N/A	N/A

D Calls	LFDCS Classified (Y/N)	Pattern	Context	Number of calls needed
Detected	Y/N	No observed pattern, >1 second duration	If humpbacks or other low-frequency sounds are around, exercise caution	2+ D calls classified <u>or</u> 3+ D calls not classified
Possibly detected	Y/N	No observed pattern, >1 second duration		1 D calls classified <u>or</u> 2 unclassified
Not detected	N	N/A	N/A	N/A

General

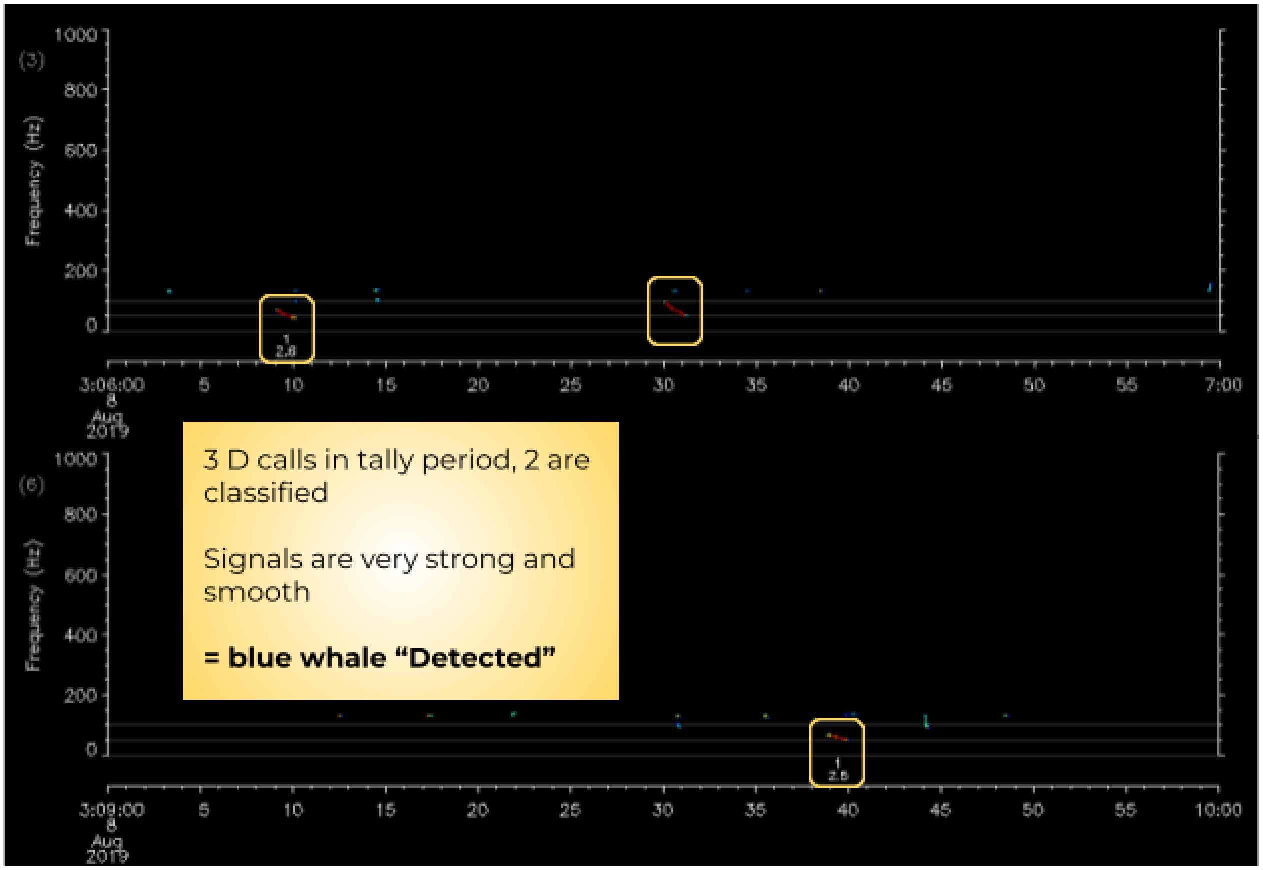
Blue whales of both sexes emit downsweeps (also called D calls), sweeping typically from as high as 100-120 Hz to as low as 25 Hz and lasting more than 1 second. While blue whale D calls are generally low-frequency, signals that begin below 50 Hz or approach/touch 0 Hz should be viewed with suspicion. Additionally, signals that are jagged are more likely to be a product of spurious noise rather than biological sourcing. Furthermore, humpback whales may also produce downsweeps that can be mistaken for blue whale D calls. Humpback calls are typically higher in frequency, usually above 150 Hz, but can occasionally approach the same frequencies as blue whale D calls. In these instances context can be an important cue for discerning species. If the downsweep occurs absent humpback calls, it is more likely to be a product of blue whale calling. Calls classified as blue whale downsweeps will be labeled as call type 1 calls when using the Pacific call library.

Male blue whales also produce stereotyped A and B calls which, when patterned in sequences, are considered song. In southern California, the A call is a series of rapid pulses with peak energy around 90 Hz. When produced as part of a song sequence, it is followed by a long tonal near 45 Hz, termed a B call, which has slight frequency modulation and often features an obvious downstep. The B call occasionally contains a step-down in frequency at the end of the call. When using the Pacific call library, calls classified by the detector as call A will be labeled as call type 40 while call B will be labeled as call 10 or 12 (depending on presence of step-down) and the step-down will be labeled as call type 20. For more information regarding blue whale calling behavior, consult Lewis & Širović 2017 and Oleson et al. 2007.

Detected

To score a tally period as "Detected" for North Pacific blue whales, at least three D calls should be present (only two needed if both are classified) or at least two A and/or B calls.

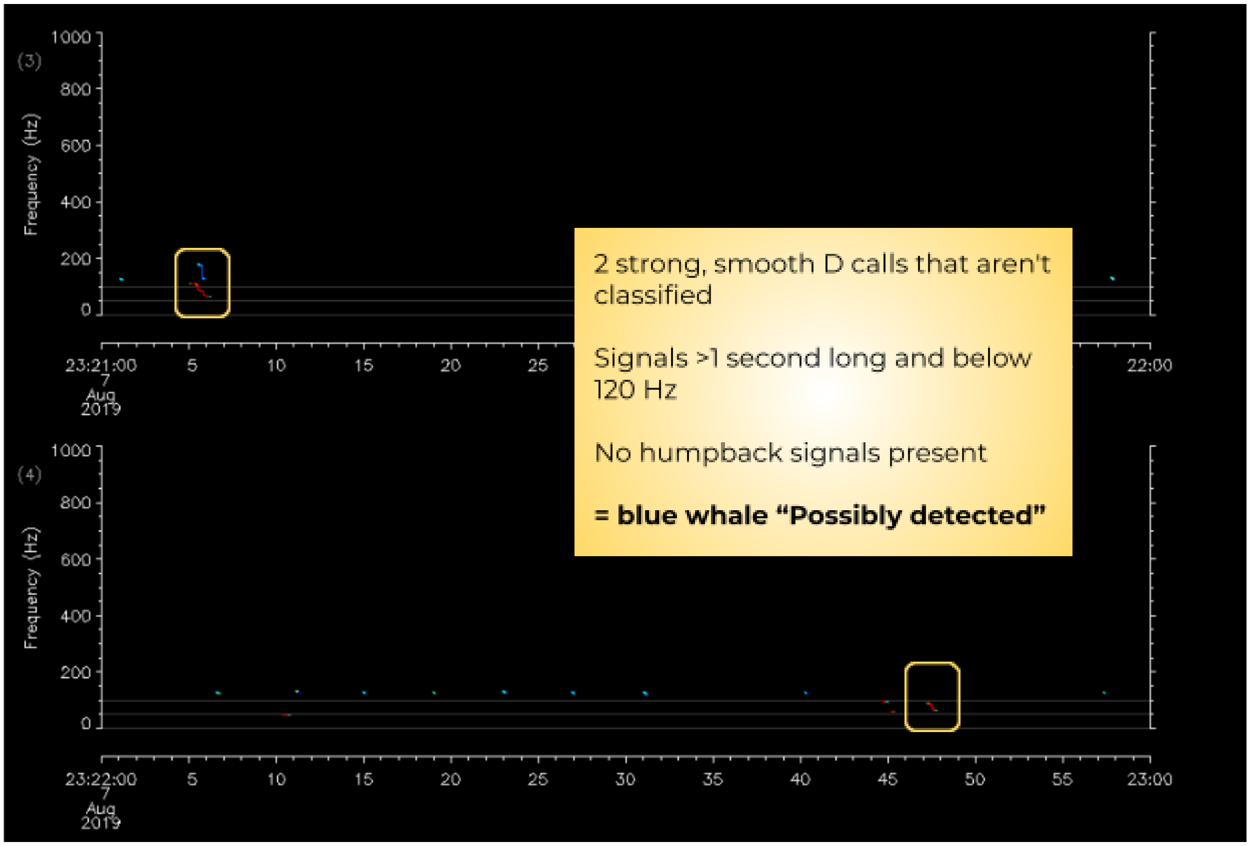
The following images depict examples of "Detected" North Pacific blue whales.

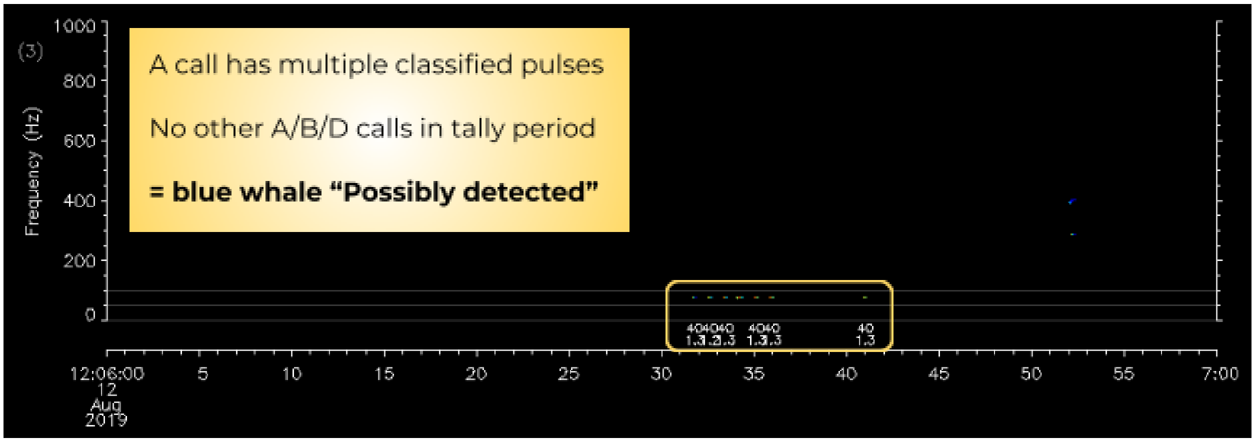

(3)
Frequency (Hz)
1000
800
600
400
200
0
2.8
3:06:00
8
Aug
2019
5
10
15
20
25
30
35
40
45
50
55
7:00
(6)
Frequency (Hz)
1000
800
600
400
200
0
2.5
3:09:00
8
Aug
2019
5
10
15
20
25
30
35
40
45
50
55
10:00
3 D calls in tally period, 2 are classified
Signals are very strong and smooth
= blue whale "Detected"

Possibly detected

If there is only a single classified D call in a tally period, or less than three quality unclassified D calls, that period should be scored as "Possibly detected" for North Pacific blue whales. If there is only a single A or B call in a tally period, it should also be scored as "Possibly detected".

The following images depict examples of "Possibly detected" North Pacific blue whales.

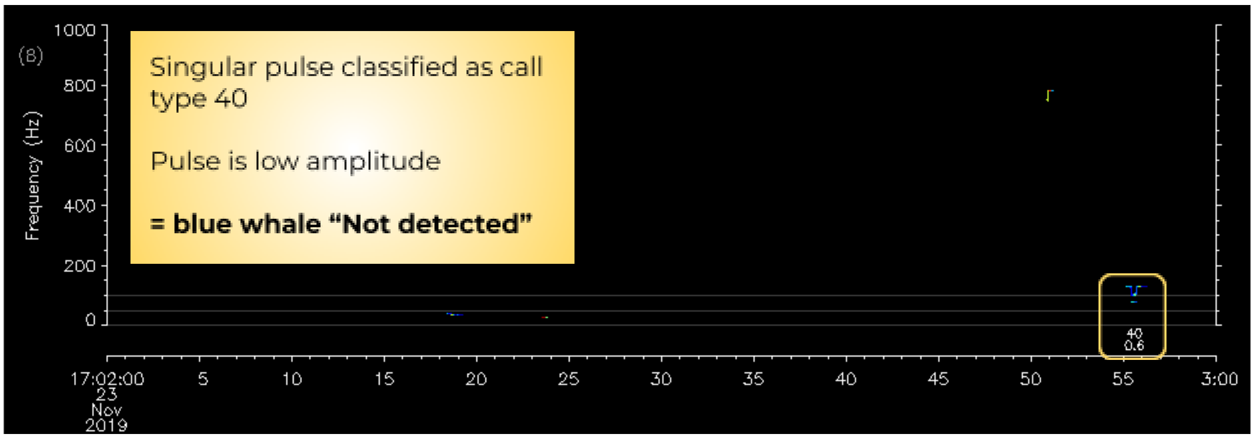


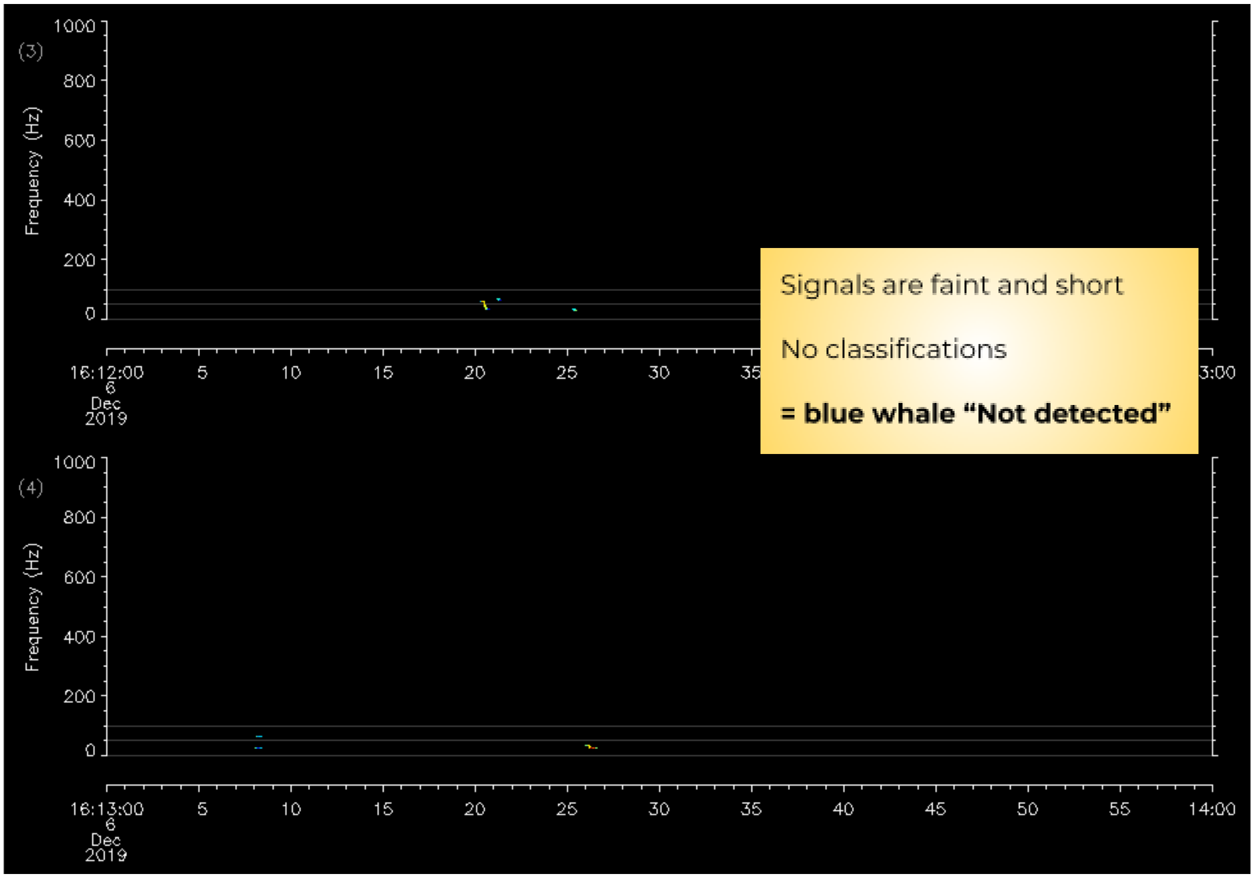

(3)
Frequency (Hz)
1000
800
600
400
200
0
A call has multiple classified pulses
No other A/B/D calls in tally period
= blue whale "Possibly detected"
12:06:00
12
Aug
2019
5
10
15
20
25
30
35
40
45
50
55
7:00

Not detected

If there is a singular unclassified downsweep in a tally period, then it can be considered "Not detected". If there are several possible downsweeps but they are too short, jagged, or not in the expected frequency range, then score it as "Not detected". Singular pulses classified as call type 40 should be viewed with suspicion, as spurious low-frequency noises can be classified thusly by the detector.

The following images depict examples of periods that were scored as "Not detected" for North Pacific blue whales.

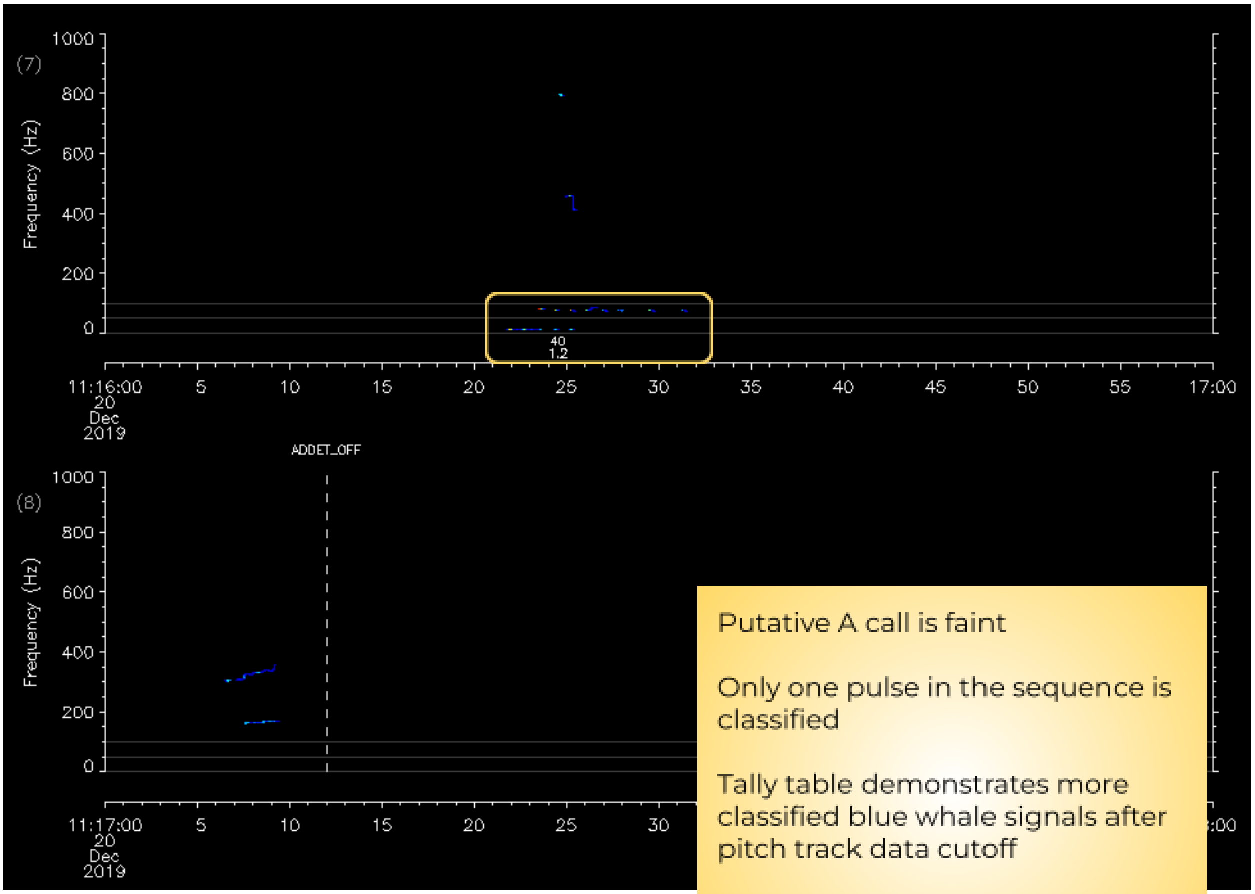




(3)
1000
800
600
400
200
0
Frequency (Hz)
16:12:00
6
Dec
2019
5
10
15
20
25
30
35
Signals are faint and short
No classifications
= blue whale "Not detected"
(4)
1000
800
600
400
200
0
Frequency (Hz)
16:13:00
6
Dec
2019
5
10
15
20
25
30
35
40
45
50
55
14:00

Unique situations

Date/time	Blue whale	Fin whale	Other	Duration
12/20/19 11:25:24	12	0	84	900



Putative A call is faint

Only one pulse in the sequence is classified

Tally table demonstrates more classified blue whale signals after pitch track data cutoff

= blue whale "Possibly detected" (with a note!)

North Pacific fin whale

Protocol written by Ana Širović and Megan Wood (Texas A&M University Galveston)
For questions about this protocol, please contact Megan Wood at megan.wood@noaa.gov.
Note: This protocol has yet to be formally evaluated using archival data.

Quick guide

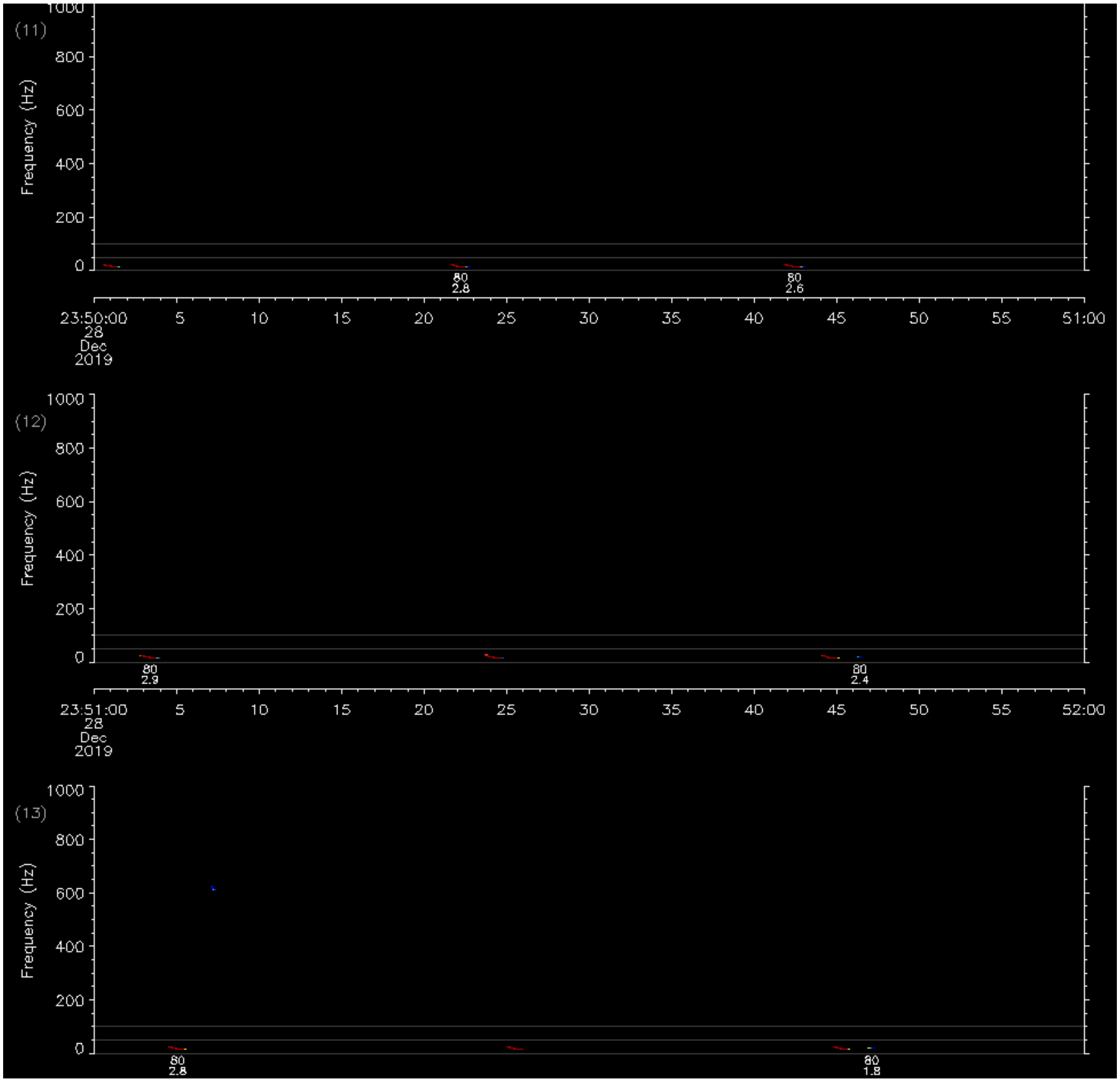
	LFDCS Classified (Y/N)	Pattern	Context	Number of calls needed
Detected	Y	Repeated with constant ~18-24 second intervals (do not count missing calls as part of pattern)	N/A	4+ calls in pattern (2+ must be classified as fin) with appropriate internote intervals (see Širović et al. 2017)
Possibly detected	Y	3 calls in pattern with constant 18-24 second intervals (do not count missing calls as part of pattern)	N/A	3 pulses in pattern (2+ must be classified as fin)
Not detected	N	No pattern or irregular pattern	N/A	N/A

General

Fin whales emit short (<1 second) 20 Hz pulses (downsweeps) that often occur in regular patterns as song although they can also occur intermittently. Interpulse or internote intervals in these songs can be between 18 and 24 seconds. This pattern will change interannually and seasonally, for a more detailed overview see Širović et al. 2017. Calls comprising sequences should have similar amplitudes. Spurious low-frequency noise can often be falsely classified by the detector as a fin whale pulse, so be sure to pay attention to the patterning. While 20 Hz pulses can occur singularly or not in a song-like pattern, detections will only be considered when patterned song is present because, in this context, the irregular signals are too difficult to distinguish from noise.

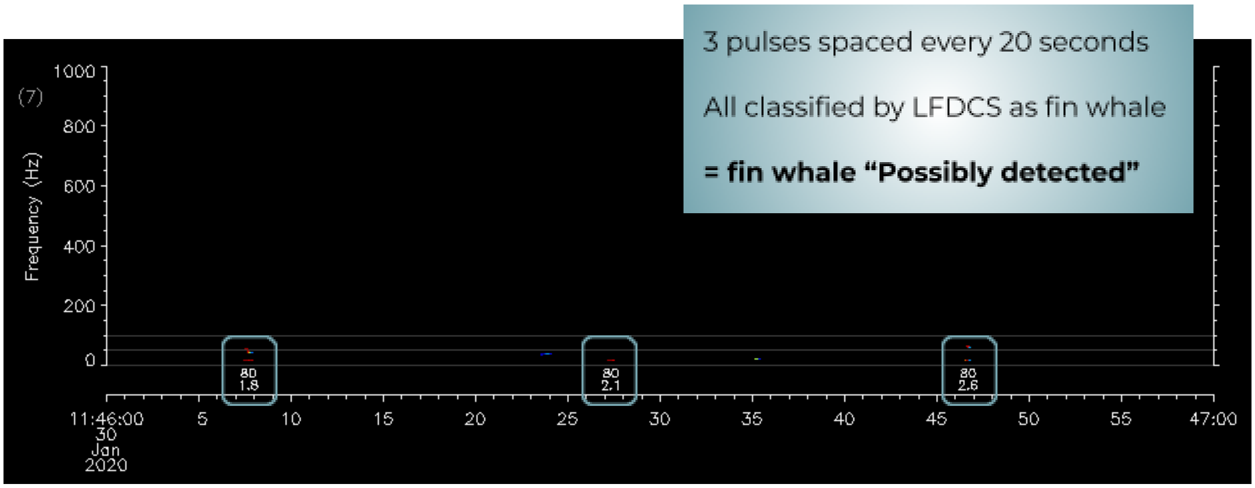
Detected

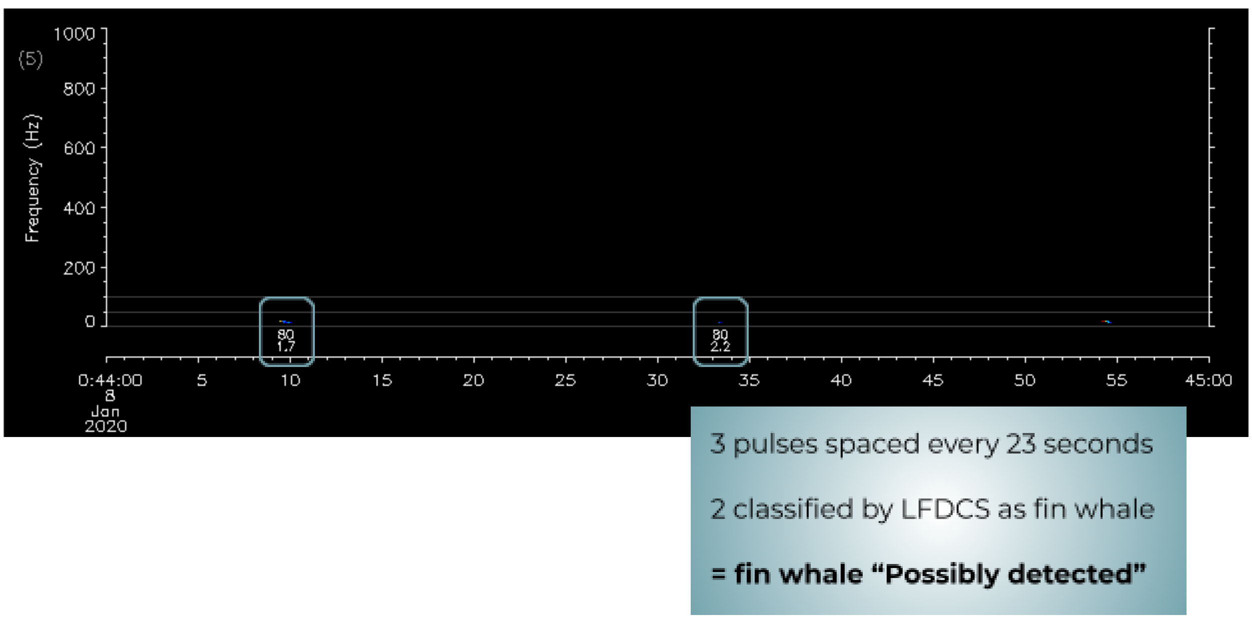
Fin whales can be considered "Detected" if a sequence comprising four or more 20 Hz pulses (two or more of which are classified as fin whales) with a constant internote interval of 18-24 seconds occurs in a 15-minute tally period. An example of this is shown below.



Possibly detected

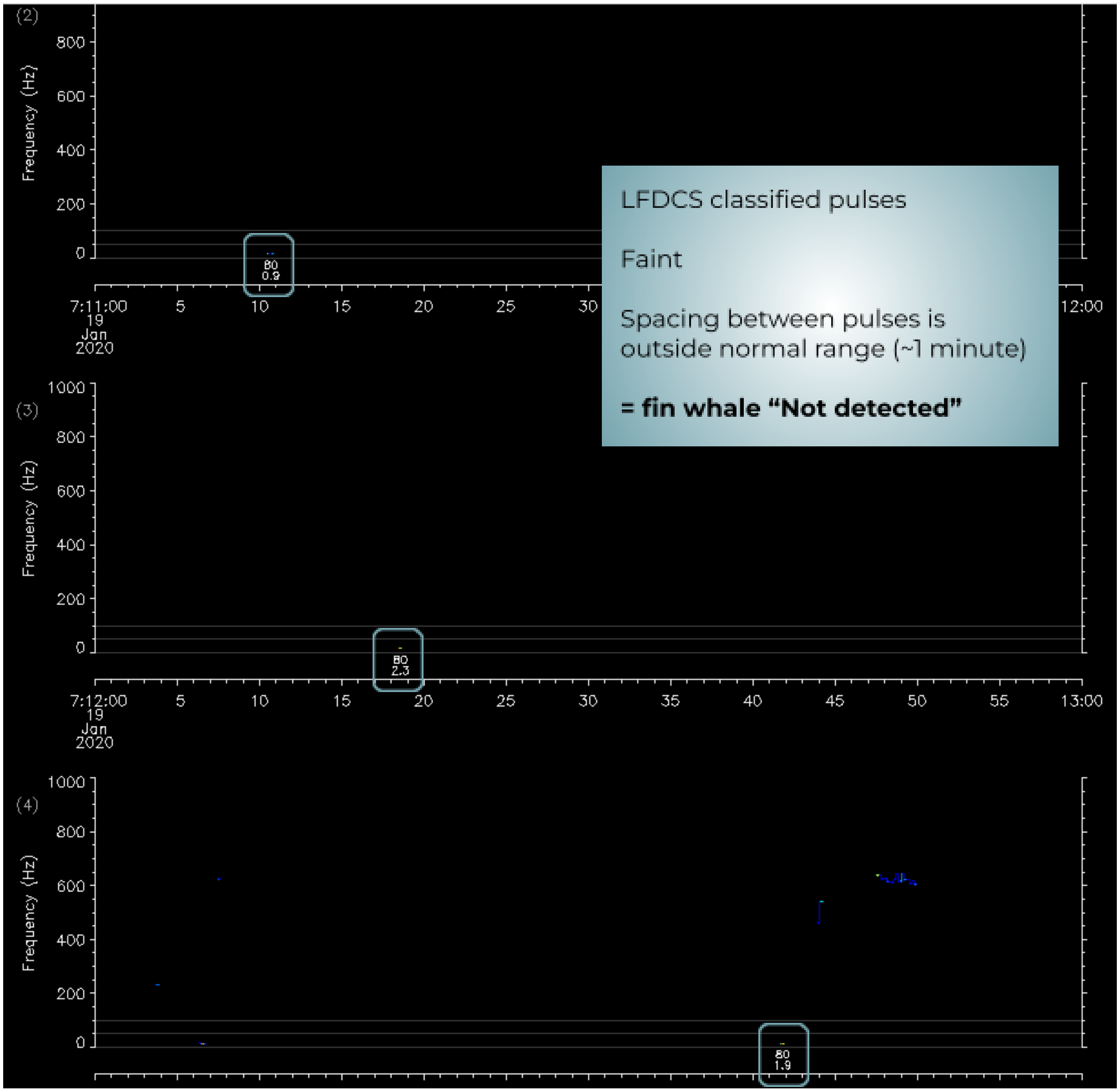
When there are only three pulses in a sequence (two or more of which have been classified by the LFDCS as a "fin whale"), then it should be scored as "Possibly detected". Be careful that pulse trains can be "broken", particularly when the calls are faint (i.e., there is a silent period where a pulse should be based on the internote interval). Do not count missing pulses (i.e., "phantom" pulses) as part of the pulse train. 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.





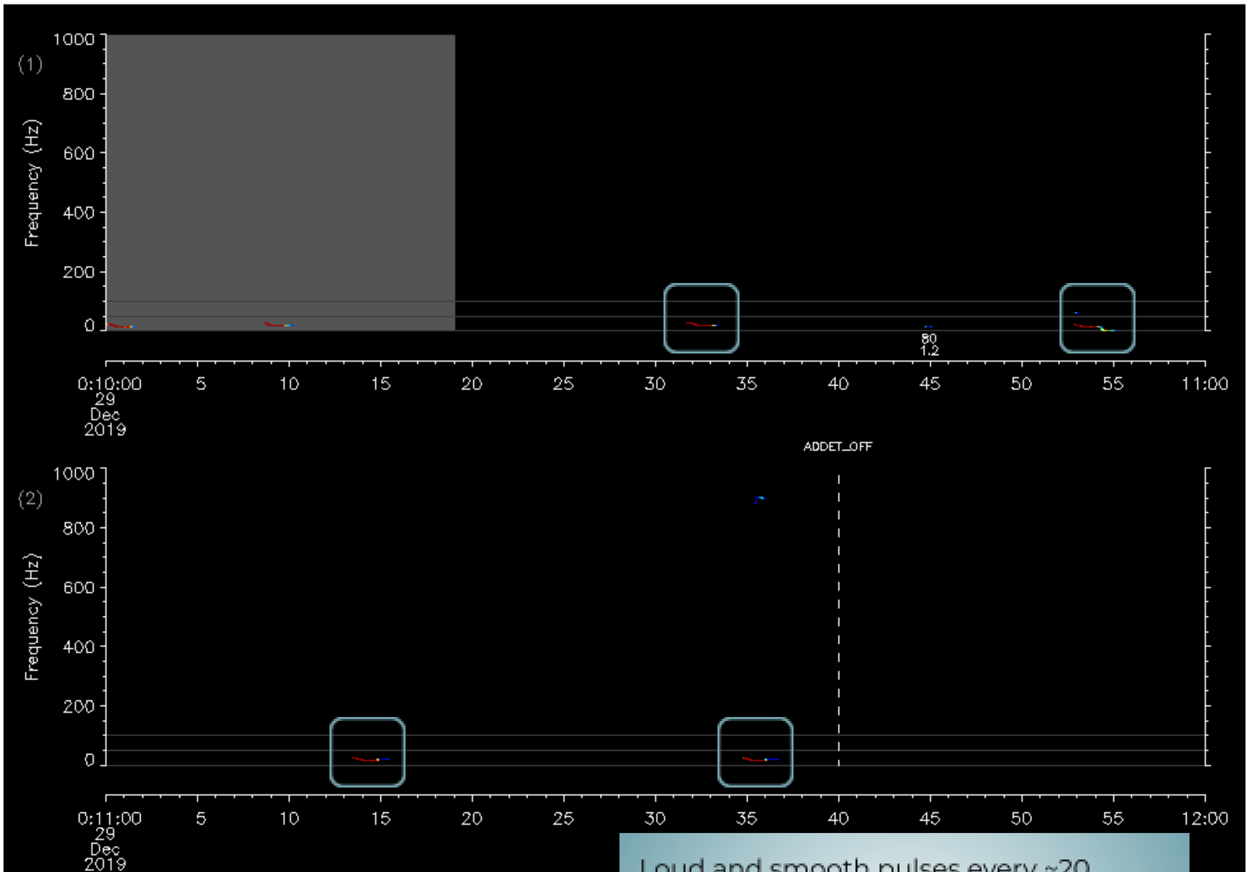
Not detected

For a pulse train to be considered "Not detected", none of the calls in the pulse train are classified or the internote interval varies, or the internote interval is not within the 18-24 second bounds.



Unique situations

Date/time	Blue whale	Fin whale	Other	Duration
12/29/19 00:25:24	0	10	43	900



Loud and smooth pulses every ~20 seconds

None of the strong calls are classified

Classified fin calls occur after addet_off

= fin whale "Detected" (with note!)

North Pacific humpback whale

Protocol written by Ana Širović and Megan Wood (Texas A&M University Galveston)
For questions about this protocol, please contact Megan Wood at megan.wood@noaa.gov.
Note: This protocol has yet to be formally evaluated using archival data.

Quick guide

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

General

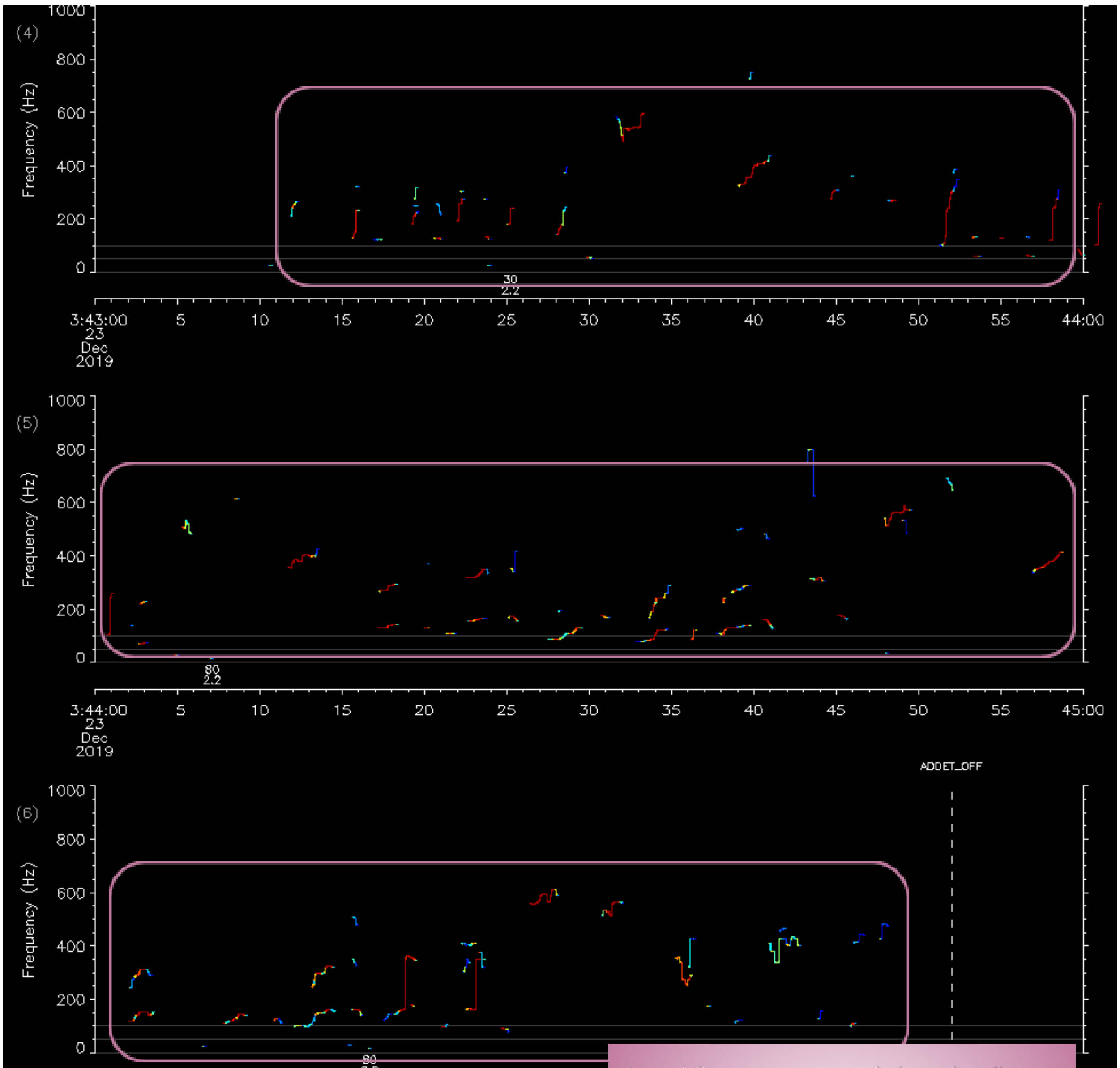
Humpback whale song is produced in identifiable patterns (unlike humpback social sounds, which have less patterned structure). Individual calls comprising these patterns can have frequencies ranging from 10s to 1000s of Hz. These patterns are unambiguous in the pitch tracks when they are present and loud. Humpback whale call types from California are currently not integrated into the LFDCS call library, therefore humpback whale calls are grouped in the 'Other' category of the classifier.

Off the California coast, we often believe that many unknown pitch-tracked sounds are produced by humpback whales. While there are little hard 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 and unknown loud tonal sound is encountered, it is evaluated against the possibility of being another call in the vast humpback whale call repertoire. As such, you may encounter unknown, well-pitch-tracked, high intensity 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 being 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 (e.g., 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.

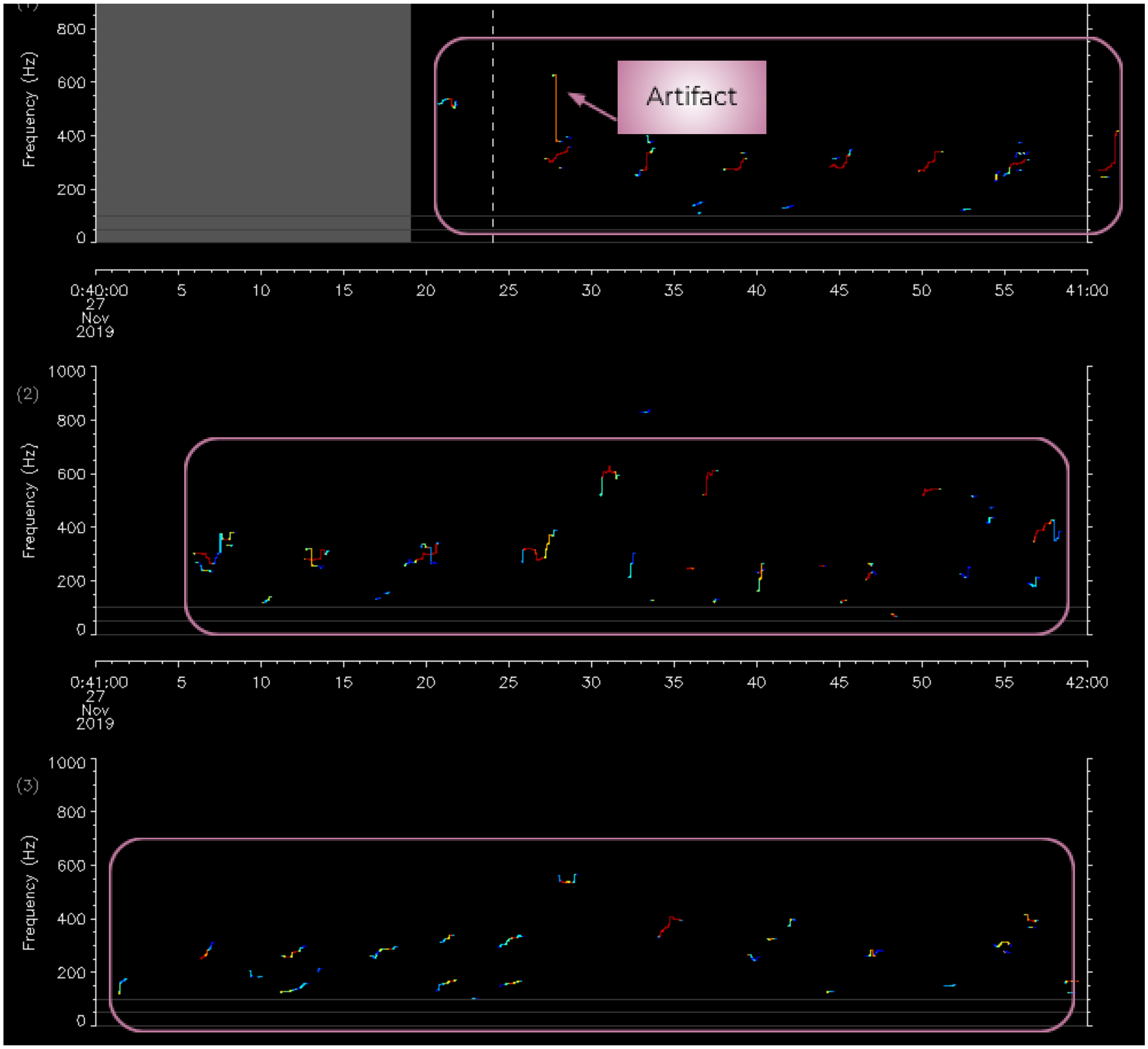


Loud frequency-modulated calls

Multiple calls over several minutes

Large variability in signal shape but signals relatively smooth

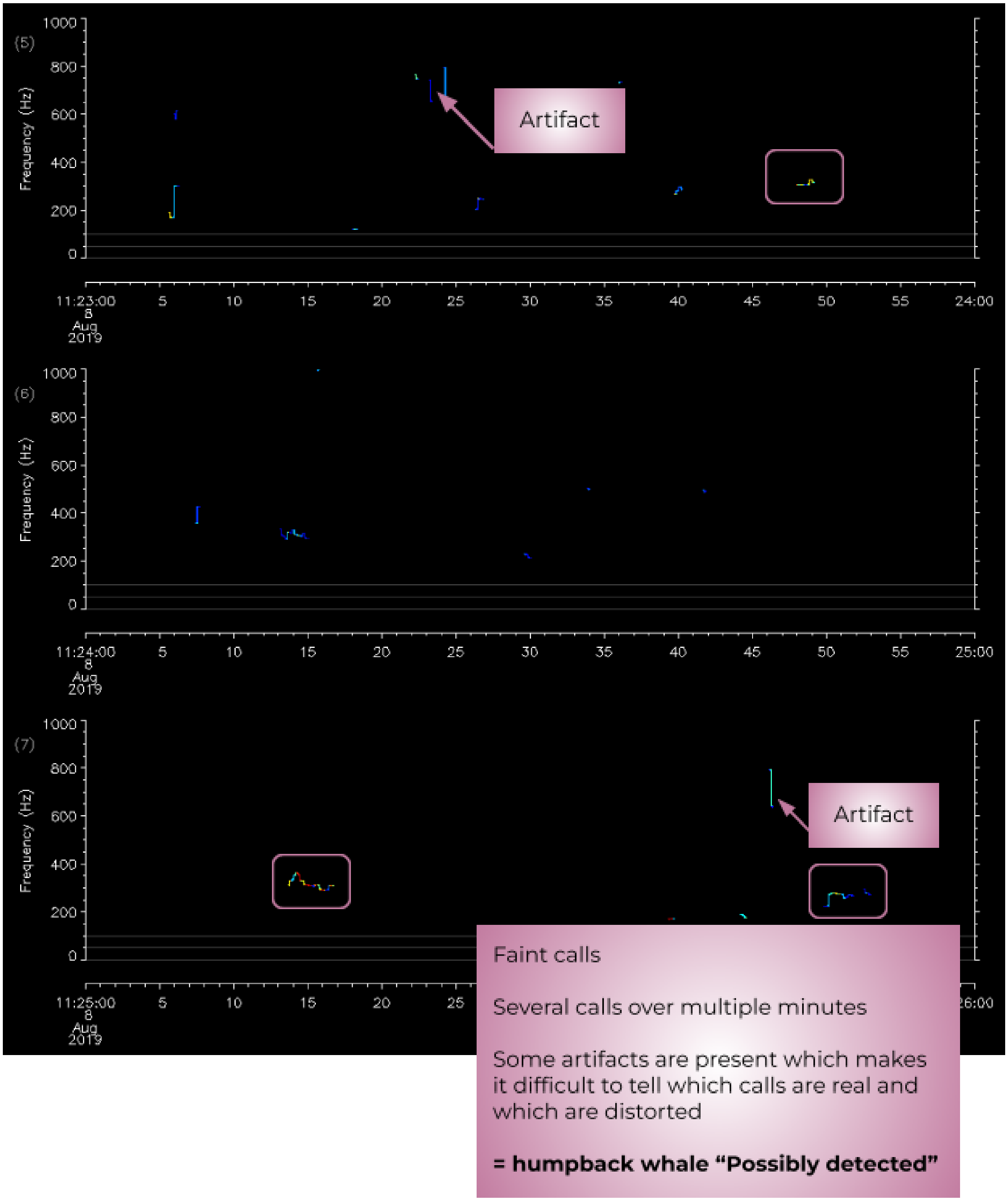
= humpback whale "Detected"



Artifact
(2)
(3)
Frequency (Hz)
0:40:00
27
Nov
2019
41:00
0:41:00
27
Nov
2019
42:00

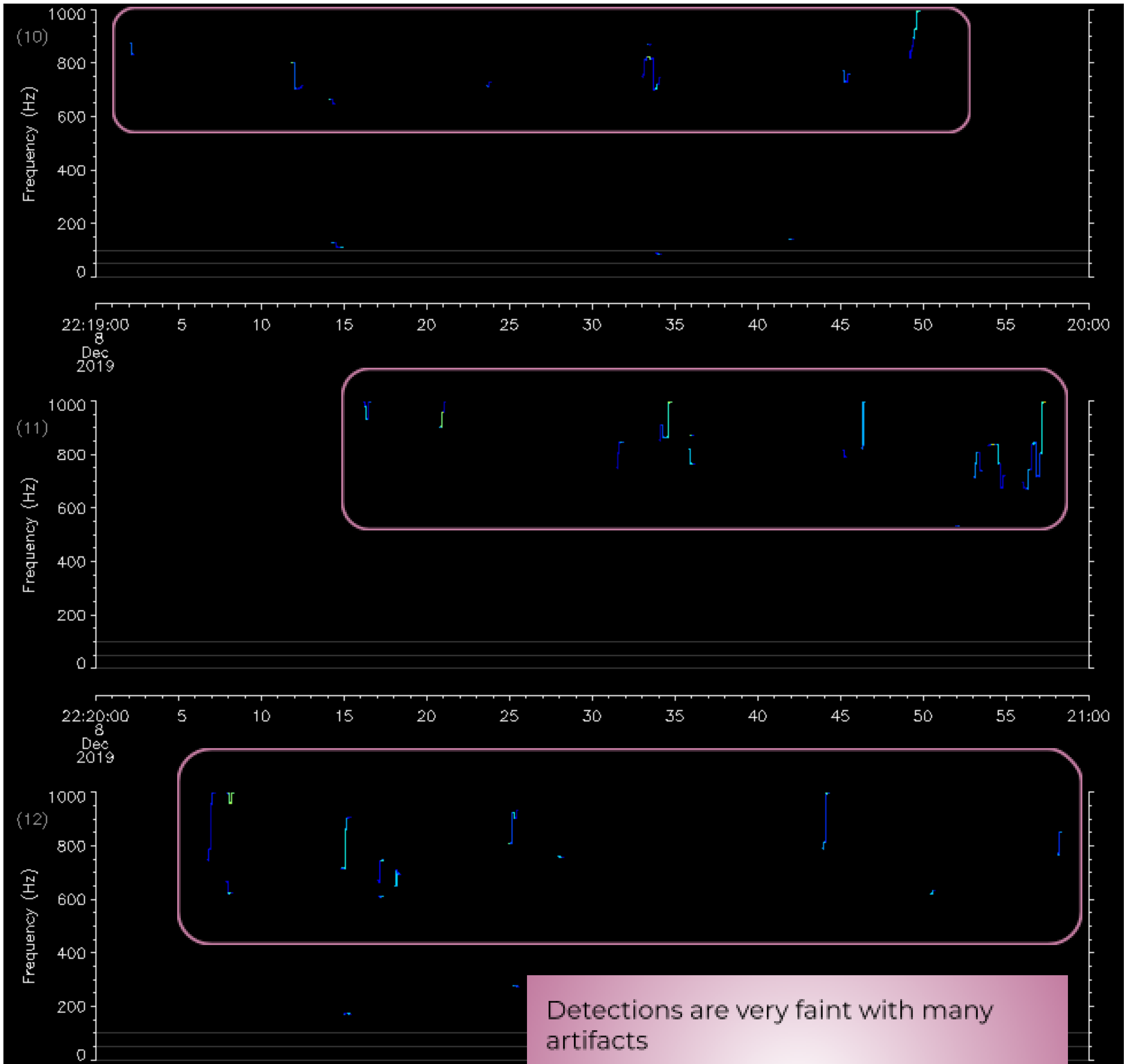
Possibly detected

Signals that are faint should be marked as "Possibly detected". Some signals may also have connecting artifacts which can increase the difficulty when determining whether a pitch track is depicting a real call or just noise. This is explained in more detail in The Four Main Criteria: Shape section of this document.



Not detected

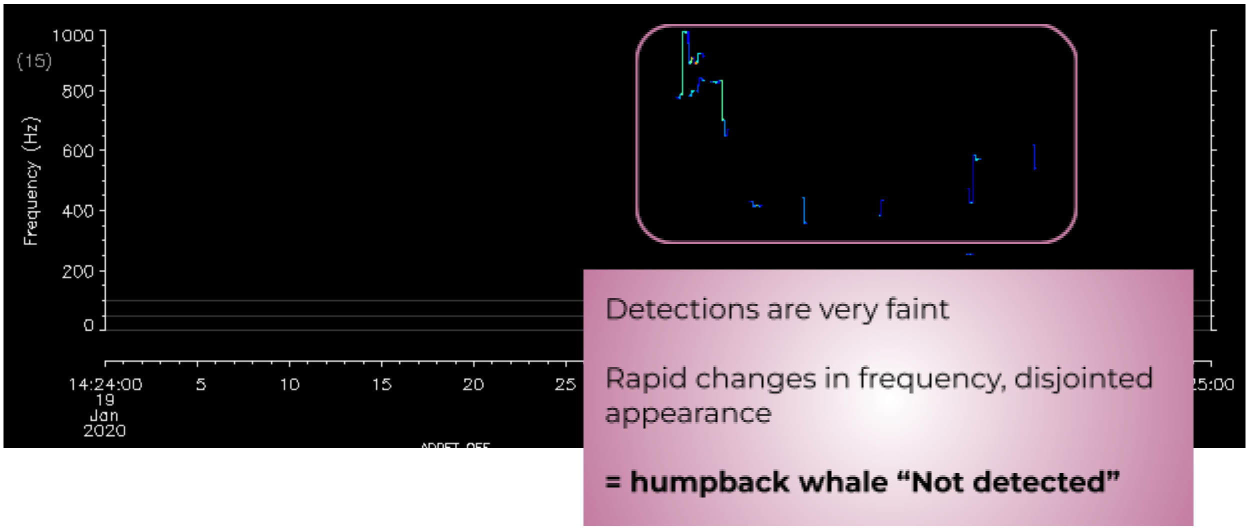
When there are only a few faint calls, score the 15-minute tally period as "Not detected". Calls that are very spurious should also be considered as "Not detected".



Detections are very faint with many artifacts

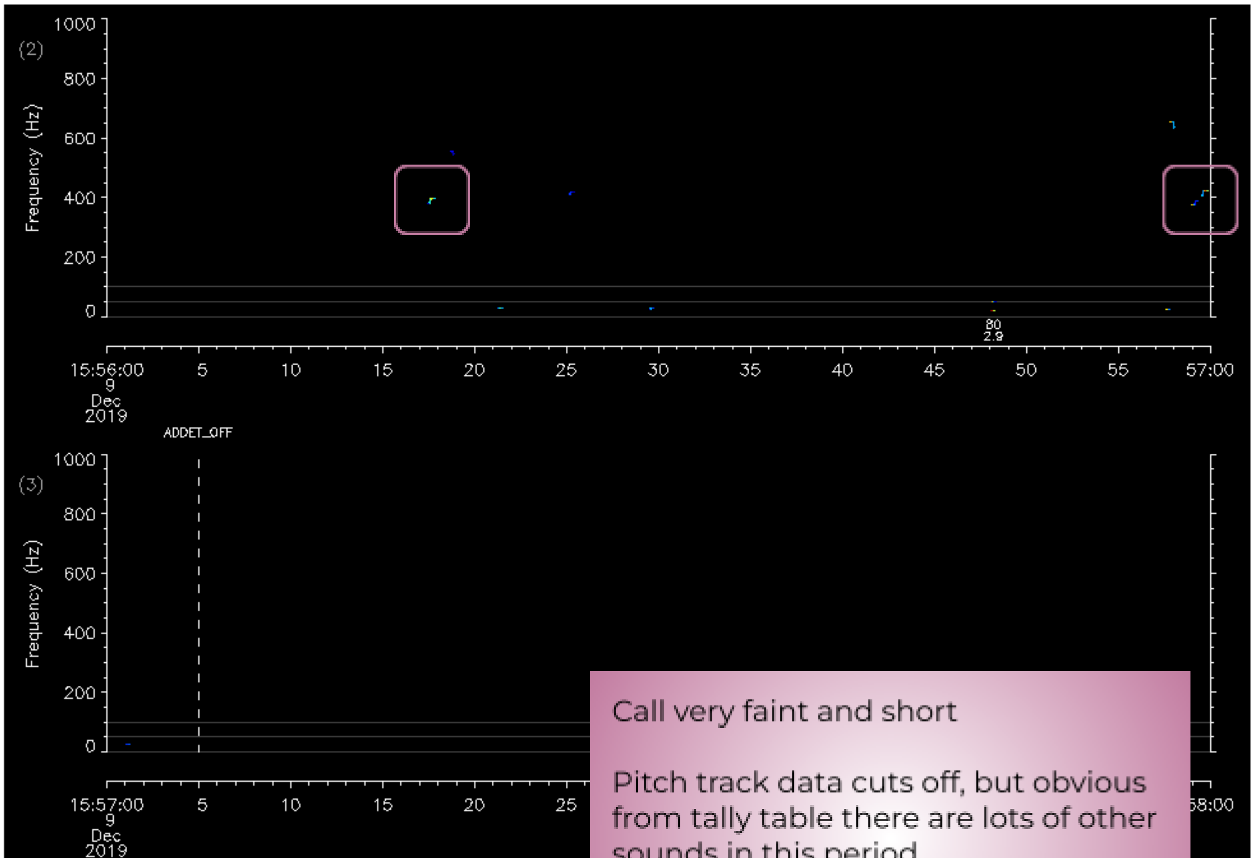
Very difficult to tell if the detections are spurious or actual humpback calls

= humpback whale "Not detected"


1000
(15)
800
600
400
200
0
Frequency (Hz)
14:24:00
19
Jan
2020
5
10
15
20
25
Detections are very faint
Rapid changes in frequency, disjointed appearance
= humpback whale “Not detected”

Unique situations

Date/time	Blue whale	Fin whale	Other	Duration
12/09/19 16:10:24	1	10	295	900



Call very faint and short

Pitch track data cuts off, but obvious from tally table there are lots of other sounds in this period

= humpback whale “Not detected” (but note)

Appendix C: Known Idiosyncrasies of the North Pacific Species

Call types 40 and 80

The LFDCS classification may label spurious pitch tracks of low-frequency noise with either blue whale call type 40 or fin whale call type 80. These classifications should be disregarded when analyzing pitch tracks for species presence. This situation can be seen in the blue whale "Not detected" and fin whale "Not detected" sections.

Artifacts of the pitch tracking algorithm

This has been explained, with examples, in the humpback whale “Possibly detected” section. It is important to note that not just humpbacks are susceptible to artifacts, but also right whale upcalls.

Webpage 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 between 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 click the “Reload” or “Refresh” button on your browser and the data that you entered into the form will be visible.

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