AWdF Acoustic Literature Review

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Introduction

In the underwater world, light propagation is limited, contrasting with sound which travels five times faster than in air (Tyack and Clark, 2000). Therefore, sound is the primary sensory cue for most marine mammals (Mooney *et al*., 2012). This is especially true for the Cetacea order, formed of whales, dolphins, and porpoises who use sound both for communication and acquiring environmental information (Tyack and Clark, 2000). Cetacean communication appears to be affected by the increasing levels of anthropogenic ocean noise (Nabi *et al*., 2018). Therefore, there is a clear need to understand cetacean acoustic communication for the future conservation of the species (Nowacek *et al*., 2016).

Within the Cetacea order, forms of communication are extremely diverse (Sayigh, 2014). For example, the Odontocete family (toothed whales) has evolved elaborate echolocation systems enabling sophisticated vocalisation exchanges between conspecifics as well as the ability to navigate, detect predators and sense the presence of prey (Hildebrand, 2004). The communication sounds produced by Odontocetes can be divided into two forms, pulse sounds and narrow-band tonal sounds (whistles) (Morisaka, 2012). Pulse sounds are used for both echolocation and communication and can be split into two subgroups, clicks trains and burst-pulsed sounds. Click trains are related to echolocation and consist of sequences of acoustic pulses (50µsec, 5-150kHz) (Dudzinski *et al*., 2009). Burst-pulsed sounds (20-100kHz) consist of a high repetition rate with a pulse produced less then every 5µsecond. The function of the burst pulse has been shown to be for communicative and social purposes (Overstrom, 1983). The narrow-band tonal sounds are believed to be used for only communication purposes. As a result of the low frequency of the whistles (5-85kHz) they can travel greater distances than pulsed sounds (Berta *et al*., 2005).

Knowledge of Odontocete communication has been gained through extensive scientific research, some of which was carried out in the Canary Islands, due to the archipelago harbouring extremely high cetacean diversity and abundance levels. Twenty eight species have been recorded in the area, four of which are resident; the Bottlenose Dolphin (*Tursiops truncates*), Short-Finned Pilot Whale (*Globicephala macrorhynchus*), Risso's Dolphin (*Grampus griseus*) and the Sperm Whale (*Physeter macrocephalus*) (Pérez-Vallazza *et al*., 2008). In terms of communication Short-finned pilot whales whistles operate at a frequency of 2 to 14kHz and Bottlenose dolphins have an acoustic range of 0.2 to 150 kHz (Simard *et al*., 2011; Weilgart and Whitehead, 1990). The AWdF is based in South Tenerife, therefore the acoustic research programme will primarily focus on the resident Short-Finned Pilot Whales and Bottlenose Dolphins, with the methodology used being passive acoustic monitoring (PAM).

For the AWdF acoustic research programme to be a success, current literature has been extensively reviewed. Research papers along with case studies have been discussed, including different methodologies, reviewing the various models and analysis software available, and the application of the data collected. The concluding section will discuss the scope of what the AWdF acoustic programme can achieve when considering the reviewed literature.

1. Different Acoustic Methodologies

There are two main types of passive acoustic equipment that are used by the scientific community for recording underwater sounds: cabled hydrophones and autonomous recorders. Cabled hydrophones can be deployed as permanent/semi-permanent installations, e.g. fixed to the hull of a boat, or placed in the water for set amount of time (Wiggins, 2003). The cabled hydrophones are widely used by the navy/governmental agencies and for research, due to the equipment providing continuous data in real-time (Rankin *et al*., 2005).

Autonomous recorders typically consist of a recording device such as a hydrophone being moored on the seafloor and a buoy to suspend the hydrophone if placed in deeper water channels, normally for a period of 2 years (Clark *et al.,* 2007). The recording devices can be configured to capture sound continuously or intermittently according to a sampling method. Autonomous hydrophones are deployed in clusters of 3 to 10 instruments to give a vast coverage of the designated area of interest, whilst allowing for the localisation of sound sources (Wiggins, 2003). For both these systems the data is stored within the device and cannot be transmitted, therefore the devices need to be recovered for subsequent analysis.

Another method of marine mammal acoustic survey is through the means of radio-linked hydrophones. This technique incorporates a hydrophone sensor upon a mooring (Clark *et al.,* 2007) with a link to a station upon the shore through radio transmission (Rankin *et al*., 2005). The data for radio-linked hydrophones is still recorded in real-time and continuously, with the capability to transmit the data without retrieval of the recording equipment.

A further method for marine mammal acoustic monitoring involves using the marine mammals themselves as the physical platform, rather than using a fixed position on a stationary platform like a mooring. This method uses a scaled down version of the acoustic sensor and recording instrument in the form of an attachable tag. The attachable tag allows audible data to be collected in areas where the animal itself is exposed. This methodology has been successfully tested on both whales (Madsen *et al*., 2002) and elephant seals (Burgess *et al*., 1998). The main advantages of using fixed passive cetacean acoustics methods is that they can be implemented all year round in various weather conditions (Mellinger *et al*., 2007), with relatively low cost to the researchers (Thompson 1982) and can be carried out in the most remote areas (Stafford *et al.,* 1999). However, these methods are error prone when recording vocal behaviour to estimate pod size/abundance (Parks and Tyack, 2005), whilst also being vulnerable to anthropogenic noise pollution in the open sea.

The decision into which methodology should be used for the research is dependent on the desired measured unit and where the hydrophones will be deployed. For the AWdF research programme the hydrophone will be placed into the water at the point in which an interaction with the selected cetacean species occurs. Once a visual observation of Pilot Whales / Bottlenose Dolphins is confirmed by the observers on the Rib, the boat will come to a stop at a safe distance from the pods. Once the vessels engine has ceased, the hydrophone (Dolphin Ear 200) is activated and lowered off the side of the boat into the water. Audible data will be recorded for each individual interaction that occurs with the vessel each day, allowing for further subsequent analysis and providing more time for other interactions to be documented.

2. Reviewing the Different Models and Analysis Software Available

Acoustic analysis involves displaying sound in a visual format using specialised software, followed by categorisation of the soundbite through visual inspection and calculation of measurable features. An acoustic spectrogram is the visualisation format typically used. The acoustic spectrogram displays a time-frequency representation which is a display of changes in frequency overtime (TFR; Figure 1).The spectrogram is vital to the understanding of the marine mammal species of Tenerife, as marine vocalisations have a significant role in individual or group cetacean identification (Mallawaarachchi *et al.*, 2008). Mallawaarachchi *et al* study showed that spectrograms are also useful in identification of whistle sounds as well as potential meanings when paired with an existing database. The biggest hurdle in acoustic analysis through spectrograms is the underwater background noise and its presence in the spectrograms (Mellinger and Clark, 2000). To minimise the backscatter and background noise, the engine of the rib should be off and sound from the boat should be minimal. Vocalisations of the target species can be detected manually through visually looking at the sounds (Mellinger and Clark, 2000). However, it may be potentially useful to automate the detection process of whales on the spectrogram to reduce processing time and increase the amount of time available to analysis the recorded vocalisations (Miller and Dawson, 2009).

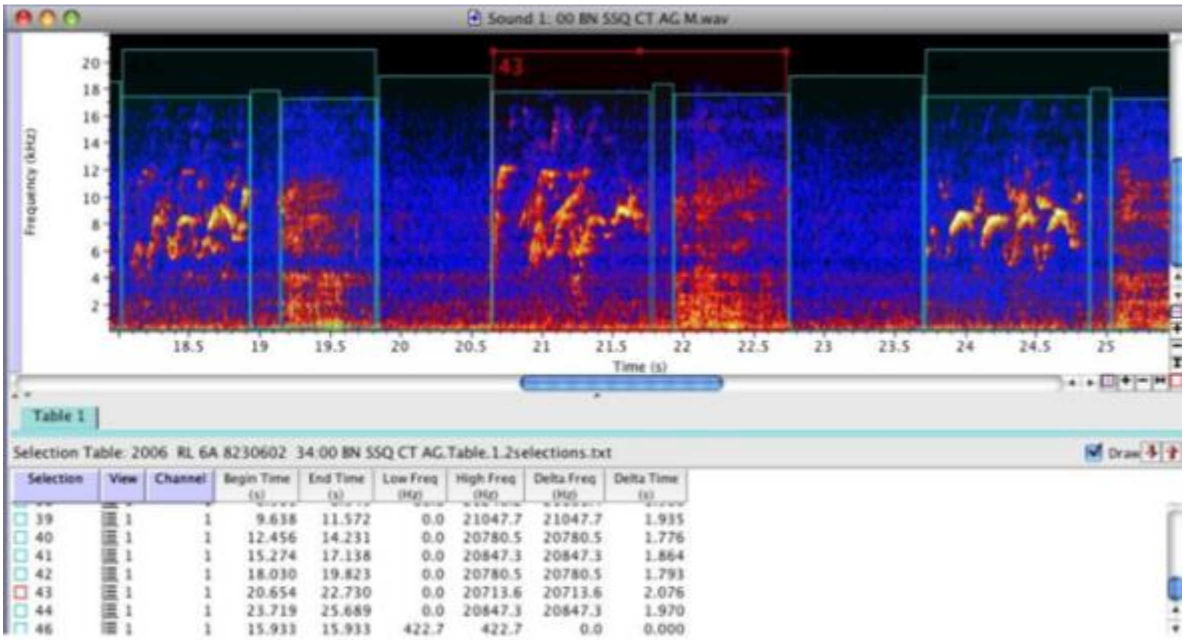

Figure 1: A Raven Pro spectrogram displaying a series of bottlenose dolphin whistles and buzz separated by inter-signal-intervals, forming a repeated motif (e.g. 43). (Herzing, D.L., 2015)

Recent studies on Delphinid acoustic communication have utilized a wide range of software to generate spectrograms for subsequent call analysis and classification. Although there is no single piece of software researchers universally select for sound analysis, MATLAB (Mathworks, 2020) has been of particular importance in recent studies on Bottlenose Dolphins and Pilot Whales (e.g. Sayigh *et al*., 2013; Perez *et al*., 2017; Quick *et al*., 2018). MATLAB is a multi-paradigm programming language with a broad array of functions, from analysing a variety of dataset types to developing algorithms. The software is used by personnel in the fields of engineering, science, and economics (Mathworks, 2020). Due to its multisector applicability, its unsurprising research institutions appear to favour the programme, however, given the specificity of the work conducted by the AWdF, such a programme may not be necessary.

If MATLAB is at one extreme of a spectrum of potential software, then programmes such as Avisoft (Avisoft, 2020) and Raven Pro (Ravensoundsoftware, 2019) are at the other. Scheer, Hofmann and Behr (2003) previously used Avisoft to study the vocalisations of Short-Finned Pilot Whales off the southern coast of Tenerife, using data obtained from a hydrophone of similar capacity and frequency range of that currently available to the AWdF. Whilst Herzing (2015) also used a similar category of hydrophone, the author analysed data on Bottlenose Dolphin vocalisations collected in the Bahamas through Raven Pro (Figure 1). Both software's have been specifically developed for bioacoustics analysis and so would be better suited to the specialist aims of the research conducted at the AWdF.

Given that a multitude of software can be used to produce spectrograms visualising the same features, it is spectrogram interpretation rather than spectrogram generation that is arguably of greater importance. As with acoustic software selection, how best to classify Delphinid vocalisations based on spectrogram outputs lacks a broad consensus, although similar features are often taken into consideration. Initially, vocalisations can be split between pulse sounds and narrow-band tonal sounds, but further partitioning beyond this is highly subjective and variable between studies.

Some authors choose to initiate spectrographic interpretation by classifying calls based on their quality, before omitting low quality calls from subsequent analysis (e.g. Scheer, 2013; Quick *et al*., 2018). Scheer (2013) adopted Chmelnitsky and Ferguson's (2012) signal-to-noise (S/N) quality ranking system during his study on Pilot Whales off Tenerife, with calls deemed to have low or very low S/N ratios being excluded, since they were not sufficiently clear. Quick *et al*. (2018) also ranked calls of the same species based on S/N ratio, but dependent on more specific and less subjective features, while also only retaining high quality calls with completely visible fundamental frequencies, start and end times, and high amplitude.

Early studies often focused entirely on the shape of the fundamental frequency spectrographic contour to classify vocalisations (Sayigh *et al*., 2013), however, an increasing number of acoustic features are now being taken into consideration. Common parameters calculated include call duration, start, end minimum and maximum frequency (Scheer, Hofmann and Behr, 2003; Scheer, 2013; Herzing, 2015; Perez *et al*., 2017; Quick *et al*., 2018). Other features which have recently been taken into consideration when studying Bottlenose Dolphins and Pilot Whales are the occurrence of biphonation (two independent contours in a single call; Sayigh *et al*., 2013; Perez *et al*. 2017), harmonics and transitions between apparent pulsed and tonal components of the calls (Sayigh *et al*., 2013) and inter-signal intervals (Herzing, 2015).

In addition to the features used for categorising calls, the way in which these features are interpreted also varies. To interpret spectrograms, studies have used a single specialist observer, multiple independent specialist observers reaching a consensus and multiple lay-observers with no prior acoustic knowledge (Scheer, Hofmann and Behr, 2003; Scheer, 2013; Herzing, 2015; Perez *et al*., 2017; Quick *et al*., 2018). Sayigh *et al*. (2013) evaluated the consistency of their groupings using the "Whale FM" website, which although no longer active, has archives available for download from GitHub (Github, 2020). Whale FM has an extensive database of whale calls and associated spectrograms, which can be listened to and viewed to "match" personal recordings.

It is clear bioacoustics monitoring of Delphinids lacks specific, universal protocols for vocalisation analysis and interpretation, meaning it is highly subjective. Given the specific focus of the research conducted at the AWdF, software solely developed for and restricted to bioacoustics analysis, which is also comparatively simple and user-friendly such that it can be navigated by non-experts (e.g. students), such as Raven Pro, would be most optimal. Additionally, any call analysis procedure should consist of an initial filtering stage to isolate calls of a suitable quality, followed by categorisation of calls using at minimum the shape of the fundamental frequency contour line, duration, and the start, end, minimum and maximum frequency, into groups for future interpretation.

3. Application of the Acoustic Data Collected

Passive acoustic monitoring (PAM) data can be used to answer several different scientific questions. The main applications of PAM data include linking cetacean behaviours with different signals/calls, estimating population size, determining distributions along with identifying and mitigating anthropogenic threats. PAM data has been shown to support management and conservation strategies, helping to protect endangered cetacean species.

PAM data is commonly used to understand the acoustic behaviours of cetaceans. For passive acoustic monitoring (PAM) strategies to be used in conservation management there needs to be an understanding of the acoustic behaviour of a species as well as a sufficient description of their acoustic repertoire (Van Parijs et al., 2009; Stimpert et al., 2011). There is often variability in acoustic repertoires between seasons and over geographical areas, in terms of vocalization for both individual and group calling behaviours. It is important to understand this variability when using acoustics to implement management and mitigation strategies for a species (Van Parijs et al., 2009; Holt et al., 2013). Vocalization patterns correlated with specific behaviours allowing behaviours to be analysed using PAM data. For example, certain vocalisation patterns could be correlated with foraging events and breeding behaviours. Such correlations enable PAM data to be utilised in the identification of important foraging habitats and breeding areas. This can have important implications in the management of endangered or threatened species (Holt et al., 2013; Van Parijs et al., 2009). Understanding the role of different acoustic signals and vocalisation patterns is also important when assessing the potential effects of anthropogenic noise pollution (Van Parijs et al. 2009; Holt et al., 2013). Furthermore, Pam can be used to classify, predict, and record surface behaviours when visual data is not available (Henderson 2012).

One of the fundamental requirements for the successful conservation and management of populations is an estimation of abundance (Van Parijs et al. (2002). Without this information the ability to successfully manage cetacean populations is limited. Many cetacean species are difficult to detect and monitor using visual observation methods and these methods are commonly labour intensive and logistically difficult (Kyhn et al., 2012; Van Parijs et al., 2002). PAM is often used as an alternative approach to determine the population and distribution of a species (Van Parijs et al., 2009). Hildebrand et al. (2015) estimated the density of beaked whales (*Mesoplodon europaeus*, *Ziphius cavirostris*, *Mesoplodon densirostri*s and an unknown *Mesoplodon sp*.) in the Gulf of Mexico using PAM data. Similarly, Van Parijs et al. (2002) estimated the abundance of Pacific humback dolphins (*Sousa chinesis*) off Stradbroke Island, Australia, using PAM methods. Understanding the distribution and movement patterns of cetaceans is also essential for their successful conservation and management (Davis et al., 2017). PAM data can provide detailed long-term information on the distribution and movement of multiple species to help inform management. PAM data can provide insights into where species are distributed at times of the year when the weather is usually too poor to conduct visual surveys (Davis et al., 2017). Davis et al. (2017) used PAM data to understand the distribution patterns of the endangered North Atlantic right whale (*Eubalaena glacialis*) between 2003 and 2014 throughout the western North Atlantic Ocean. PAM data such as that collected by Davis et al. (2017) can be used to define Seasonal Management Areas (SMAs) or Areas to be Avoided (ATBA) which can mitigate some of the anthropogenic threats facing these species. Continual monitoring of species distribution is critical for managing strategies to reflect new threats that arise when species move into regions outside of their normal range (Davis et al., 2017).

Once the baseline acoustic behaviour of a group or individual is understood, it can be used to assess potential anthropogenic impacts on a species (Van Parijs et al., 2009). One significant anthropogenic threat facing cetaceans is noise pollution which is increasing with mounting human activities (Brandt et al., 2011). Cetaceans are particularly vulnerable to noise pollution because of their reliance on sound for foraging, navigation, and communication. Thompson et al. (2010) used PAM to assess the impact of pile-driving noise during the installation of two 5 MW offshore wind turbines off NE Scotland in 2006 on cetaceans. Pile driving can physically injure animals or temporarily damage their hearing thresholds. This form of pipe instillation can also disturb foraging or social behaviour and in some cases, change the distribution of a species (Thompson et al., 2010). Thompson et al. (2010) found evidence that porpoises responded to disturbance from the installation activities. PAM is a reliable way of detecting the presence of cetaceans in an area, when detected, activities such as pile driving can be avoided to minimise disturbance. PAM data can also be used to reduce depredation of fish by cetaceans. Off the eastern Gulf of Alaska, sperm whales (Physeter macrocephalus) have learned to remove fish from demersal longline gear deployments. The sperm whales often arrive at a site after a haul begins, this suggests they are responding to potential acoustic cues. Thode et al. (2007) determined with PAM that cavitation arising from changes in ship propeller speeds acts the acoustic cue for the sperm whales. With an understanding of the acoustic cues used by the sperm whales, mitigation strategies can be developed to reduce depredation.

Scope of what the AWdF Acoustics Programme could Achieve

When considering the reviewed literature and the research programmes presently running, the acoustic programme has huge potential both in terms of accessible data and scientific output. Currently AWdF cetacean research centres around behaviour ecology, population dynamics and spatial ecology. The acoustic research can be easily integrated into the methodology of these programmes, aiding the potential for long term studies. The high level of cetacean interactions experienced will provide ample opportunity for the collection of acoustic recordings. With the expected high volume of data, an archive can be compiled of cetacean recordings open to the public, to be used both for science and art. This will allow AWdF to be globally recognised for acoustic cetacean recordings, aiding future research.

The cetacean recordings will be collected using the hydrophone DolphinEar DS200 (DolphinEar, 2014), with the methodology being passive acoustic monitoring. As mentioned above the software used will be Raven Pro (Ravensoundsoftware, 2019) or a similar programme. Therefore, long-term acoustic studies must consider these conditions along with the potential to incorporate with the other AWdF research programmes. As part of the behaviour research programme cetacean behaviours are recorded during interactions, meaning a long-term study associating the cetacean sounds with behaviours is very viable (Weilgart and Whitehead, 1990). The acoustic behavioural study can include both pilot whales and bottlenose dolphins, with comparisons between species being a possibility. Furthermore, due to the nature of the AWdF Fin Identification process linking specific vocalisations with individuals is another credible aim, as has been seen with bottlenose dolphin investigations in the past (Janik, 2013). The acoustic research will also aid the population dynamics and spatial ecology studies as further data will be gathered on the number of individuals present in an interaction and their distribution.

There is mounting evidence that cetacean populations and even pods have their own dialect (Dudzinski *et al*., 2009). Henceforth, there is scope for an investigation focusing on comparing the AWdF recordings with pilot whale and bottlenose dolphin recordings from around the globe. Through this comparison the dialects can be investigated allowing for a broader understanding of cetacean communication. Additionally, comparison will allow ties to be created between AWdF and other cetacean organisations involved in acoustic research, encouraging further cooperation in the future. The effect of anthropogenic noise on cetacean acoustics can also be fully investigated as south Tenerife experiences high levels of boat traffic (Constantine et al., 2004). A study focusing on maritime transport would be particularly relevant and Interesting.

As demonstrated by the potential long-term studies the acoustic programme at AWdF has scope to achieve significant scientific findings if the programme and time scale is set correctly**.**

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Weilgart, L.S. and Whitehead, H. (1990) Vocalisations of the North Atlantic pilot whale (Globicephala melas) as related to behavioural contexts. Behav Ecol Sociobol 26, 399-402

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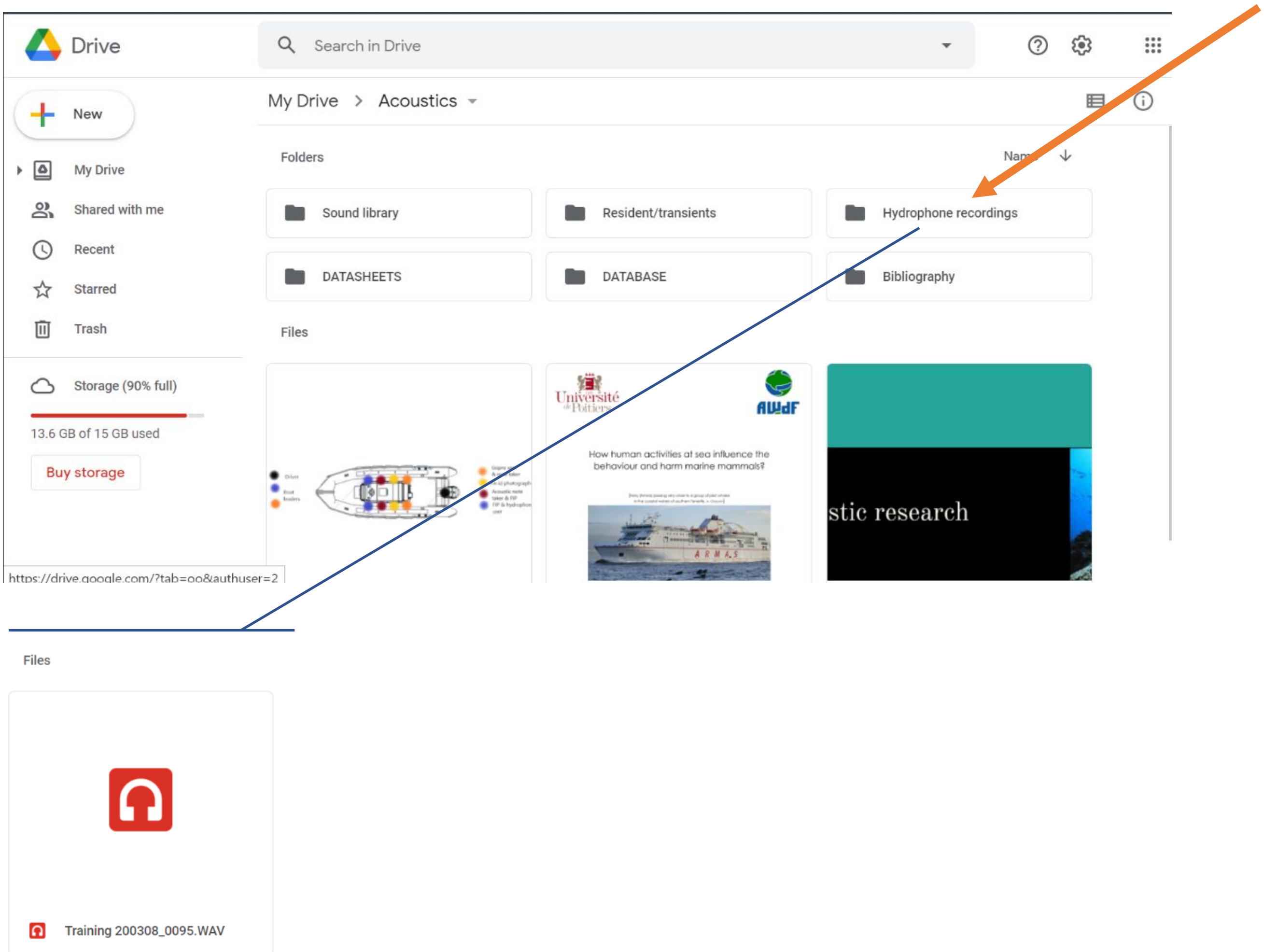
Explanatory sheet for taking care of acoustic data

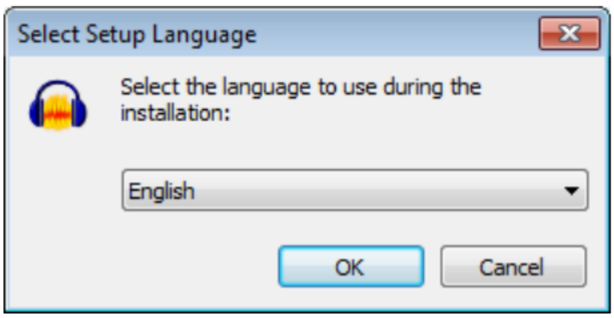
- First, go to the drive and get the recording to practice.



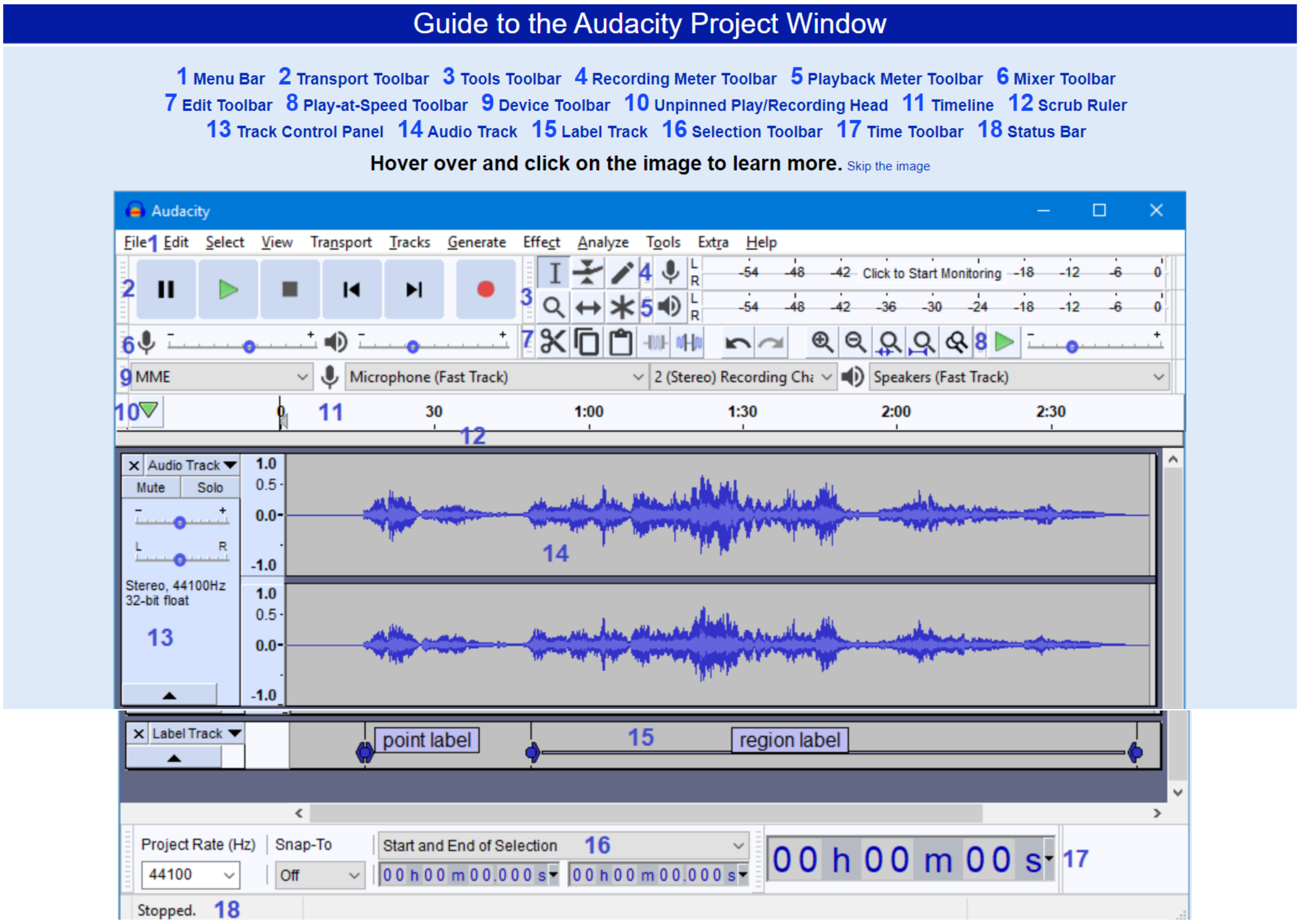
- Then you can open the software interface or download it if you don't have it.

https://www.audacityteam.org/download/

- You can now choose the language in which you want to use this software



Getting use to the interface

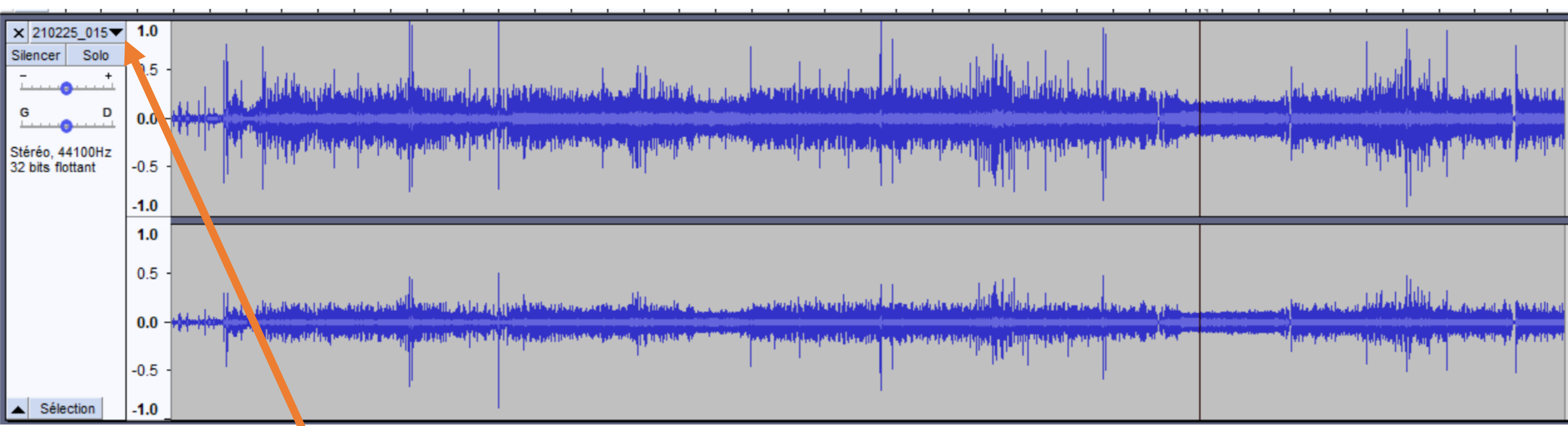


https://manual.audacityteam.org

- first, load the recording

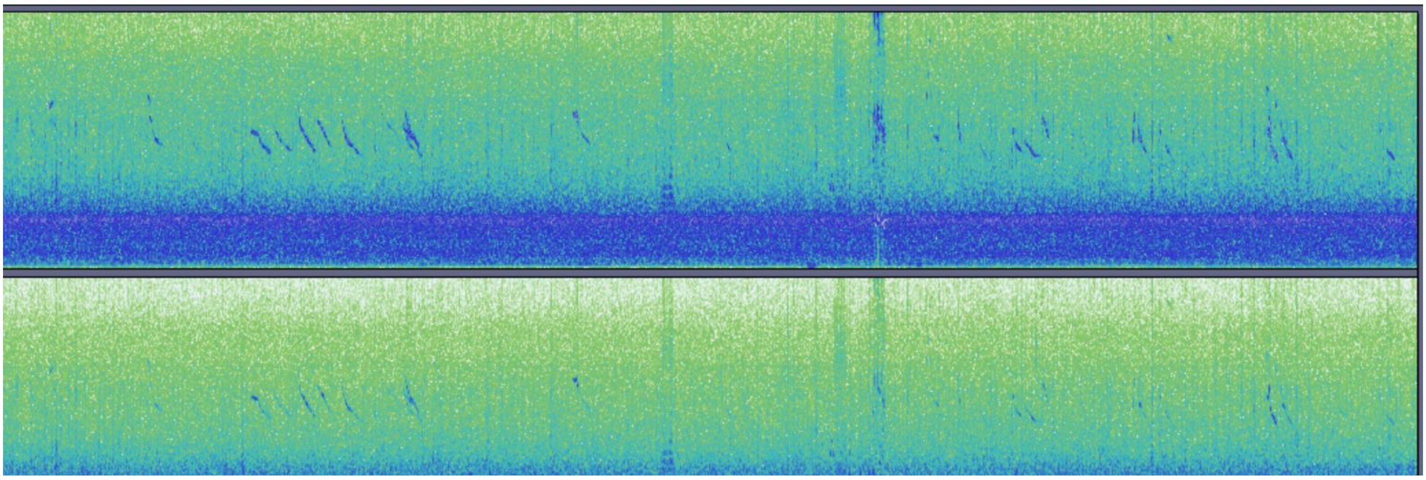
Either drag the files into the current project window, or choose **File > Import > Audio...**.

Files can be imported into a new project window with **File > Open...**.



select multi-view to activate spectrogram view

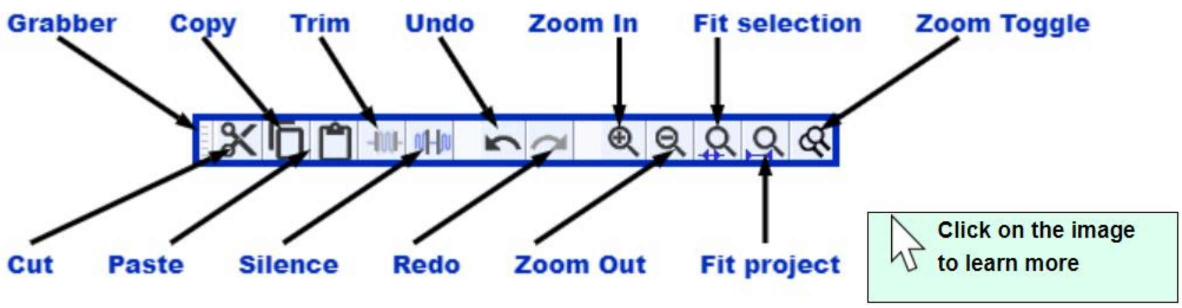
If Selection tool is not selected (default setting), choose I from Tools Toolbar, below:



Selecting the entire project

You can select the **entire length** of all tracks on screen with **Select > All** or use the shortcut ***Ctrl + A*** *(or* ***⌘ + A*** *on a Mac).*

- now that you have a better understanding of the software, it may be time to start the scientist's groundwork



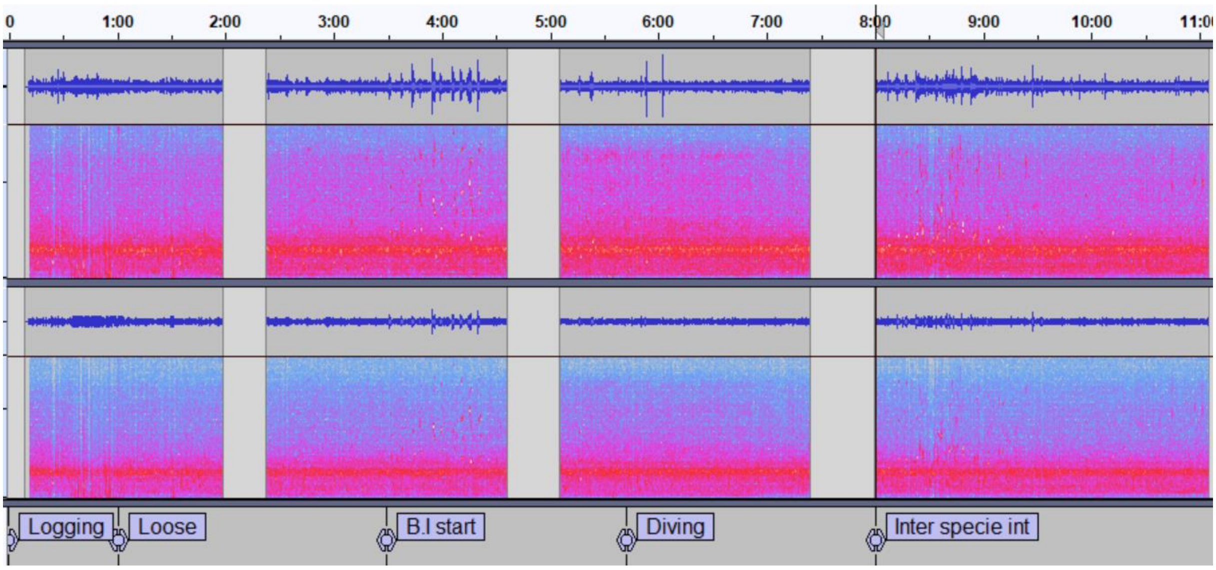
Cut **Edit > Cut** or ***Ctrl + X***

The objective here is described in several steps:

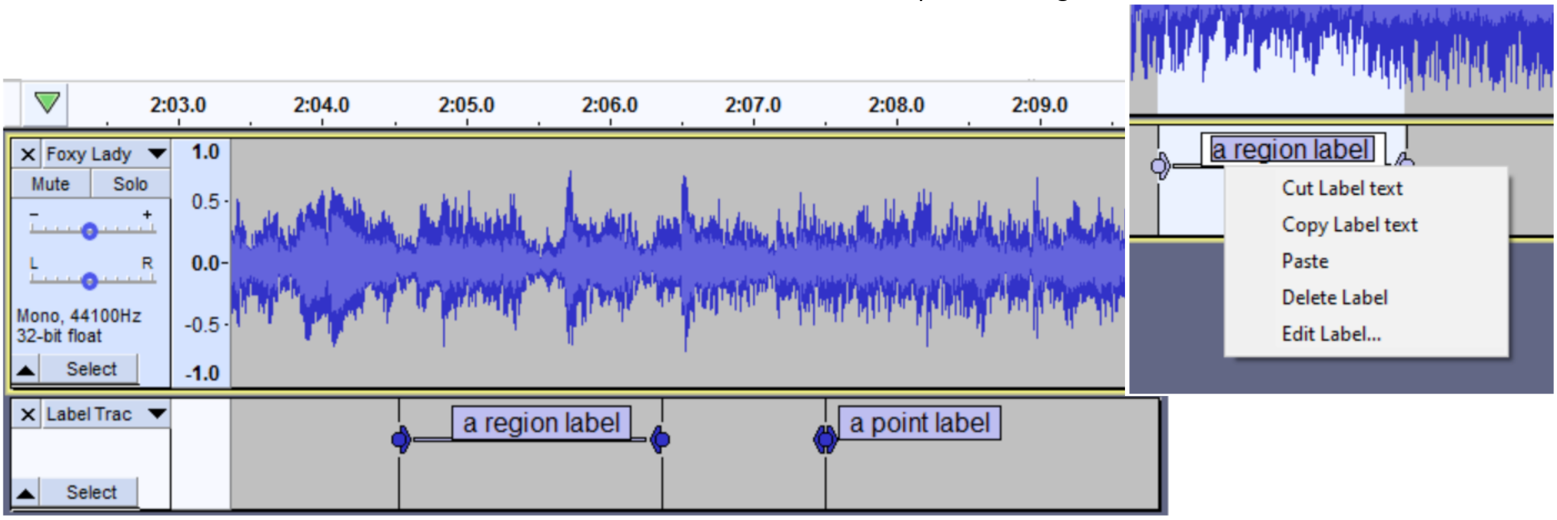
1. Check if there are anthropogenic sounds: if so: check the database for boat interaction.
2. Calculate the vocalization times starting from the first click or whistle and stopping only from a pause > 60 seconds according to the workflow.
3. In the case of a boat interaction, count the duration of the total silences.

Go to page 4 to learn more about it

- it is a matter of placing the observed behaviours at the right moment of the recording concerned



- To do so : use label tracks: it can be used to reference points or regions.



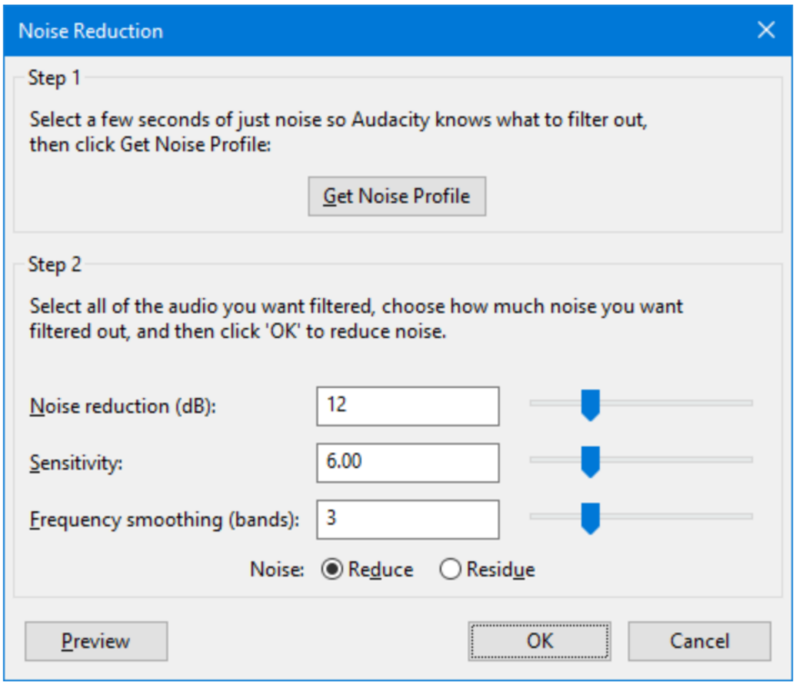
- if you select the label, you will be able to see the duration, according to different criteria that you can modify. IT IS REALLY IMPORTANT FOR THE REST OF THE PROCESSING. In fact, part of the workflow following is about it, so this step need to be very accurate and done as seriously.

When working data, coming back from the rib, use start time and end time, to have the correct time of recordings so it fits with behaviours related. Use hours.

When taking duration, switch to duration and something else. Use seconds.

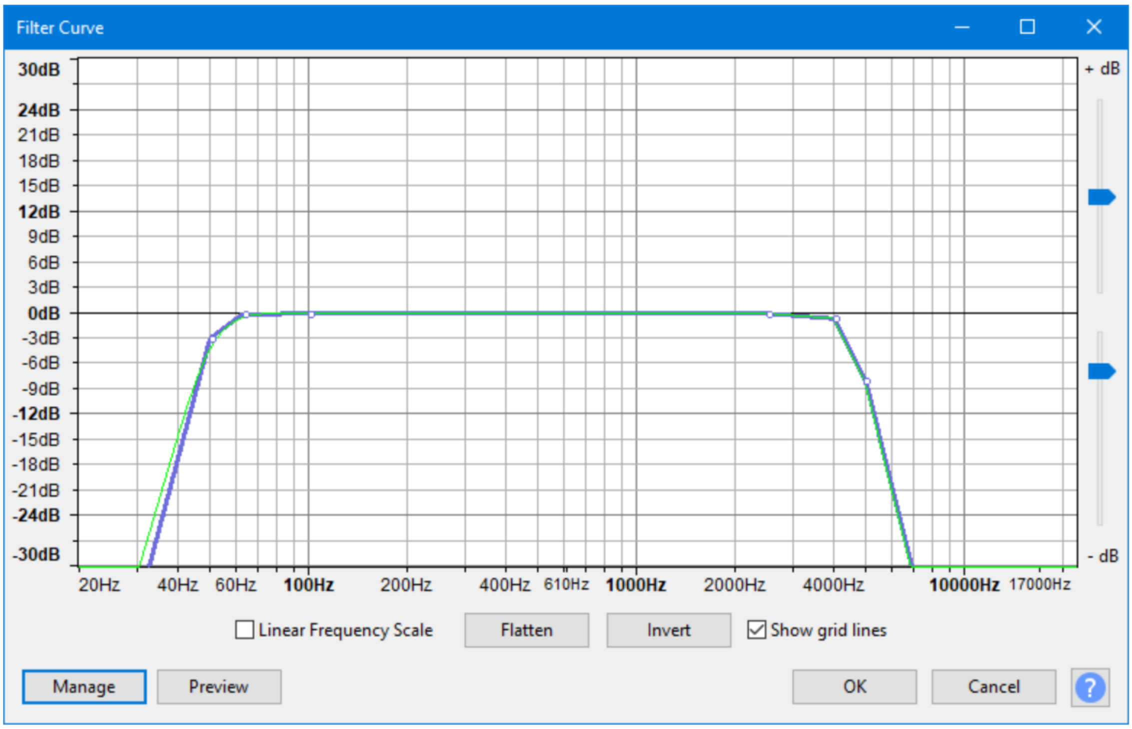
- then on each part where the vocalizations of cetaceans are interesting, it is a question of getting the best out of them thanks to the effects, and of cleaning the parasitic noises. For that, you need to use the tool "select"

Accessed by: **Effect > Noise Reduction...**



- If you want to get rid of a specific range or frequency of sound, there are multiple tools that I'm going to explain you.
- the most general and flexible is the **filter curve**, look at the extract you want to modify, the frequency where the vocalisations are found, and edit it as you think is best.

Accessed by: **Effect > Filter Curve EQ...**



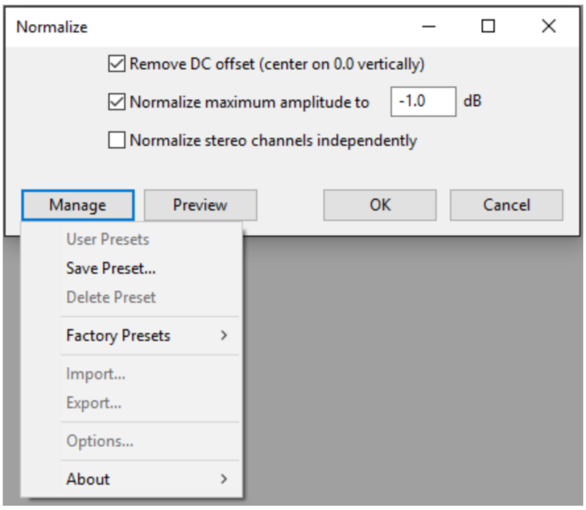
Graph Scale and Sliders

- **Vertical Scale:** This scale is in ***dB*** and shows the amount of ***gain*** (amplification above 0 dB or attenuation below 0 dB) that will be applied to the audio at any given ***frequency***.
- **Horizontal Scale:** This shows the frequencies in ***Hz*** to which volume adjustments will be applied. Dragging the Equalization window wider displays some additional points on the scale and makes it easier to plot the graph accurately.
- **Vertical scale sliders:** By default the vertical scale reads from + 30 dB to - 30 dB, but these two sliders to left of the scale let you adjust the upper and lower dB values so as to change the visible range on the graph. Note that moving either slider changes the horizontal position of the 0 dB line. Reducing the visible range lets you make a finer adjustment to how loud the frequencies sound, but the changes will be more subtle because the volume adjustment will be less.

Equalization settings

- Flatten : A quick way to set a "level response curve". This means the curve on the graph is drawn from left to right at 0 dB on the vertical scale, so that no frequencies will have their volume level modified.
- Invert : Turns the current curve in the window upside down, changing positive gains at a particular frequency into negative, and vice versa.
- ☑ **Show Gridlines:** draws the gridlines on the window aiding accurate positioning of control points. Default setting is "on".

- Then do not forget to save your setting to spare your time.
- Go to → manage → save.



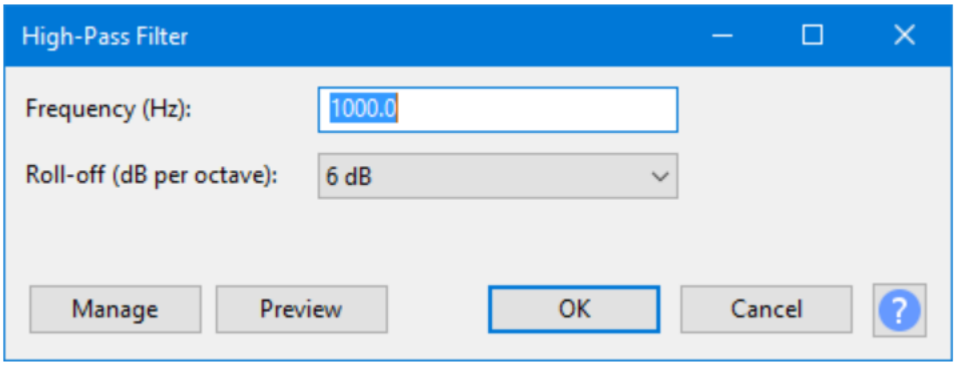
High-pass filter

Frequency (Hz)

Sound below this cutoff frequency in ***Hz*** is not eliminated but increasingly attenuated as the frequency falls further below the cutoff.

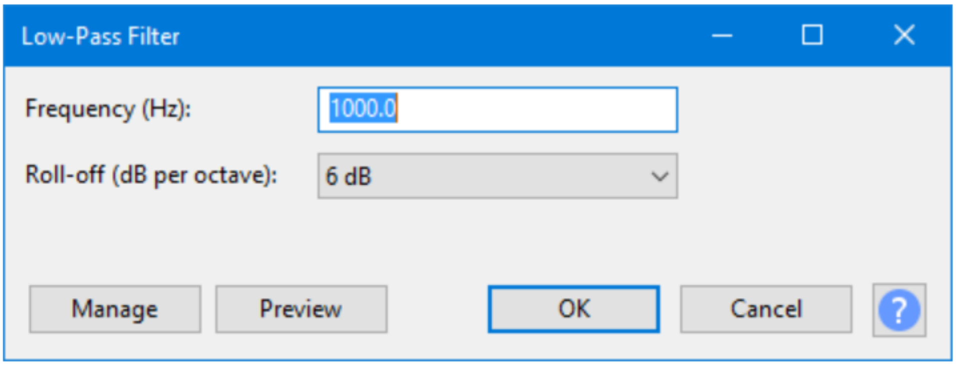
The cutoff frequency (sometimes also called *corner frequency*) defines the point at which the audio is reduced by 3 dB. Thus there will also be a small and decreasing amount of attenuation just above the cutoff frequency as in the following image.

Accessed by: Effect > High-Pass Filter...



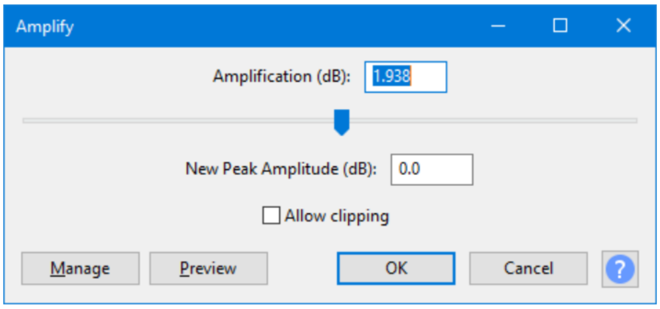
- This one is very very useful. It can be doubled with the low-pass filter.

Accessed by: Effect > Low-Pass Filter...

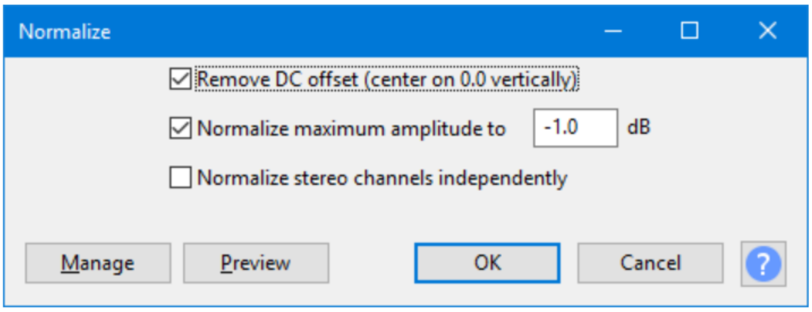


- This allows you to isolate the two extreme frequencies of your recording very quickly. However, it sometimes lacks precision and the filter curve is recommended.
- Once you have completed all these steps, you can save your project again. And if some sequences are too weak, you can increase them with the Amplify or Normalize effect.

Accessed by: Effect > Amplify...



Accessed by: Effect > Normalize...



- Use the Normalize effect to set the peak amplitude of a single track, make multiple tracks have the same peak amplitude and equalize the balance of left and right channels of stereo tracks.

References:

Audacity 3.0.0 Manual

https://manual.audacityteam.org/index.html

That's it! You know the basics of Audacity software! Well done buddy !!

Acoustic RIB

How do you get the data right when you are the acoustic assistant in a rib or if you have to manage your assistant?

Datasheet on RIB

- Once you have checked your equipment, as explained in the guide book "**How to use hydrophone**", prepare yourself before the interaction with pilot whales begins.

- Look at how many boats are present in the surveyed area and what type. Are they ferries or commercial fishing boats? If so, the interaction will be directly with a boat.

- If they are all types of sailing boats, only count as a boat interaction if they interact closely enough with the animals you are trying to listen to.

Boat interaction code date/location/int/rec	Time	Type of boats	Proximity (1very close_2close_3quite far_4very far)	Whales stop vocalise?

BOAT INTERACTION CODE date/Location/int/rec	TIME	TYPE OF BOAT	PROXIMITY 1-close 2-less close 3-Far 4-very far	Whales Stop Vocalize
01042021 LC 2 1	0:00	Ferry (both)	4	NO

Example of a boat interaction

Interaction Code (date/location/int.rec)	Species	Travelling	Logging	Milling	Diving	Direction change

Interaction code	Species	Tight	Loose	Groups Tight	Groups Loose

- To enter the data, you have to pay close attention to what the team members are saying. You can't always listen and see all around you at the same time. By the time the hydrophone and recording starts, you have a few minutes to spot the first group behaviour and the first group formation.

- Once the observed animals change their behaviour, indicate the recorder's time in the corresponding box. Remember, if we change interaction, we change line. Be very careful, the more information we have, the better.

- On the second page are the comments. Here you can indicate anything that does not fit in the boxes. **Also important information like the different types of dives**. For example, if only adults or some individual's dive. If you can observe it, note the beginning and the end. Don't write down anything you are not sure alone, *always discuss it with your teammate*. This is also where you can indicate, if possible, the **length** of the line of the **hydrophone** you are using.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	
1	Date	Species	Interaction No.	Recording No.	Volunteers		Match time				Hydrophone	Timing Behaviour (LMTD + time in min when it starts)			Timing Formation (TLGTGL + time in min when it starts)			Direction 1	
2					Note taker	Hydrophone user	Total Recording duration (min)	Start time of recording	Start time of interaction	End time of interaction	hydrophone length (m)	Recording 1	Recording 2	Recording 3	Recording 1	Recording 2	Recording 3	number of time group changed direction	Vessel's names
3	01.04.2021	PW	1	174/175	Cato	Nycolin	8.31	8:31	8:25	8:45	5	T0-3.45	L0-0.05		GT0-3.45	GT0		3.55	
4	01.04.2021	PW	3	176	Cato	Nycolin	7.29	9:21	9:16	9:27	21	T0-5.20 D5.20-7.30			GT0-3.00 L3.00-7.30				Armas and Fred Olsor
5	01.04.2021	PW	4	177	Cato	Nycolin	6.12	9:45	9:31	9:40		T0			GT0-4.30 T4.30-6.12				

Database like

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
1	Date	Rec_n	Total_rec_durati	Location	Hydrophone_lgth_	n_behavior (s)	n_formation (s)	d_behavior_T_normal (s)	d_behavior_L_normal (	d_behavior_M_normal (	d_behavior_F_normal (	d_behavior_D_normal (	d_formation_T_normal (	d_formation_L_normal(	d_formation_GT_normal
2	11/02/2021	143	8.05	LC	20	2	1		151			333		485	
3	11/02/2021	144	11.06	LC	20	1	1		345			321		666	
4	18/02/2021	148	3.58	LC	15	1	1	239					239		
5	18/02/2021	149	4.33	LC	20	1	1	273					273		
6	18/02/2022	150	6.51	LC	20	2	1								
7	22/02/2021	153/154	12.2	LG	20	6	3	422	235			84	460	280	
8	25/02/2021	155	6.25	LC	24.66666667	3	2	180				209		103	283
9	25/02/2021	156	17.2	LC	20	4	1								
10	25/02/2021	157	9.02	LC	25	6	1	285		44		193			542
11															
12	01.03.2021	159, 161	14.57	LG	5	2	2	162		234		136	234	162	
13	01.03.2021	160	5.94	LG	5	1	1								
14	04.03.2021	162, 163	14.52	LC	13										
15	11.03.2021	165	5.2	LC	9	2	1	67				100		320	
16	11.03.2021	166	8.03	LC	16.5	2	1	398				86		483	
17	11.03.2021	167	6.55	LC	11.5	2	1	124				292	415		
18	15.03.2021	168	5.3	LG	16.5										
19	15.03.2021	169	13.26	LG	23										
20	18.03.2021	170, 171	10.44	LC	20										
21															
22	01.04.2021	174/175	8.31	LC	13	6	1	399	6			108			513
23	01.04.2021	176	7.29	LC	13										
24	01.04.2021	177	6.12	LC	13	1	2	372					102		270

Excel sheet for statistical analysis (on software Audacity, behaviours&formations converted in seconds, used then to make plots on R studio)

ACOUSTIC ASSISTANTS: Caro

HYDROPHONE USER: Nico

AWdI

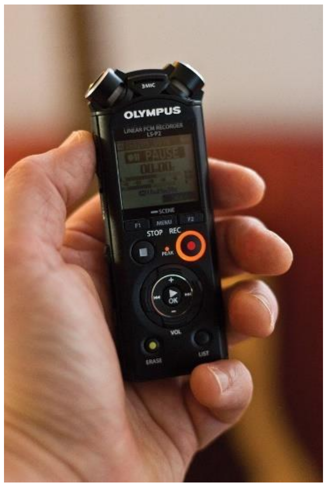
Interaction Code (date/location/int/rec)	Species	Travelling	Logging	Milling	Feeding	Diving	Direction change
1042021LC11	PW	0:00 3:45					
4:46 01042021LC12	PW	0:05 ~~[illegible]~~ 3:03	0:00			1:10	3:55
01042021LC21	PW	0:00				5:20	
01042021LC13	PW	0:00	~~[illegible]~~			~~[illegible]~~	

Interaction code	Species	Tight	Loose	Groups Tight	Groups Loose
01042021LC1 1	PW	~~[illegible]~~		0:00 3:45	
01042021LC1 2	PW			0:00	
01042021LC21			3:00	0:00	~~[illegible]~~
01042021Lc13	PW	4:30		0:00	

Example of a datasheet filled by one of the volunteer here in Tenerife.

DE200 Series: Complete

- DolphinEar DE200 Hydrophone your choice of cable length: 24 Metres.
- Headphone Amplifier.
- Olympus LS-P2



<u>What to prepare in advance?</u>

- *Batteries*

always have a spare lr6 battery in the green bag where the olympus is located in case it runs out of battery.

As for the amplifier, the battery is a bit more expensive and difficult to find, when the **red light** becomes weak and the quality of the recordings drops in quality, it is probably a matter of changing the battery (Status Zinc battery, 9v/6F22).

- *Datasheet*

make sure there is enough data sheet for your acoustic assistant or coordinator. If not, go and print some.

- *Before getting on the rib*

just before the rib, the day before, on the port while waiting for the skipper, whatever…

- connect your devices between them: cable jack 1 hydrophone with Olympus in the right hole (logo recorder) - big cable in rotating hook with amplifier.

This way, you will not be caught short in case of interaction with cetaceans, and you will save time when it comes to putting the equipment in the water.

Right in the middle of the action

- Here we go, the team has spotted pilot whales, get ready, talk to the skipper if he is available, watch him, observe the distance to the whales, the orientation of the boat with them.
- In general, the best orientation is the hydrophone oriented towards the direction the animals are heading, never behind them. Wait for the right moment. Generally, the skipper will tell you when he wants to stop, if you don't know him, get to know him first, tell him you are working for me and that you are going to take recordings.

Don't forget: a recording with the noise of our boat is a ruined recording. Never put the hydrophone on when the engines are still running.

- When you have unrolled the hydrophone, start listening immediately by pressing the red circle once. First you listen and then you record. Don't unroll the 24m if you don't need to, if the dolphins come to us, a few meters are enough, if they move away, unroll the wire.

- Don't forget to help your assistant to take his data, tell him the times when they observe changes in behaviour or formations, be attentive too, don't hesitate to ask the boat leader or the other scribe for information you might have missed.

- The key words? COOPERATION, RESPECT & COMPANIONSHIP

While recording data

- Now you are recording, tell your assistant which interaction it is, which recording and check what is happening.
- Avoid, unless necessary, multiplying the recordings, unless the interaction changes, it complicates the work. If you feel the need, you can pause the recording using the same button and resume immediately afterwards.
- Do not do this if the dolphins are still visible! it could falsify the results.

the tour ends

- Thank the skipper, store your equipment properly, once at the base, quickly soak the hydrophone in fresh water to remove the salt.

extract the data

- get the olympus, open the usb port by pressing on the side, connect it to your computer and transfer the data of the day.
- organize it in this way and finally as for the finID

-DAY/name of skipper folder one -interaction number folder two

in this form, put them on a drive with space, or directly as a backup on the external hard drive.

- Enter the data into the database, and use the audacity software with the help of the personal guide, organising the sequences according to the group behaviour of the animals.

- Once this is done, collect the duration of these sequences or absence and therefore silence in case of interactions and enter them in the corresponding excel provided to make statistics.

don't forget to store the material in its closed cabinet, correctly arranged, the olympus attached with elastics to the amplifier, with its spare battery and all the wires in the front pocket, to avoid that they are in contact with the wet hydrophone of the close main.

You are done, thank you and good job!!!