Towards an Hypothesis of an IPI in the clicks of Pilot Whales

A DISSERTATION PRESENTED
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TO
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Introduction

As part of the teaching in cetacean bioacoustics, this document reports all the results and analyzes made by the students of Marine Sciences (IPA). The main purposes of this study are, on the one hand, to characterize the clicks of pilot whales and sperms whales in order to identify the individuals monitored and, on the other hand, to give a spatial location of the sources in order to follow their movements and to assess their behavior.

The long-finned pilot whales (*Globicephala melas*) and the sperm whales (*Physeter macrocephalus*, L. 1758) are currently present in the deep waters of the Mediterranean Sea. However, there is a lack of robust information for both species[8,3]. Indeed, the Mediterranean sea pilot whale is classified as Data Deficient on the International Union for the Conservation of Nature (IUCN) Red List[8]. Their population status is thus not really known but their densities appear to be much lower than before and anthropogenic disturbing seem to increase, suggesting that we should be concerned about the conservation of both population. The first step is now to collect more data.

All recording come from the Sphyrna Odyssey mission supported by the Prince Albert II of Monaco Foundation, Explorations of Monaco, ACCOBAMS with the Italian Ministry of the Environnement, and by many other operational partners. This mission is part of the Sphyrna Odyssey Campaigns initiated by Sea Proven, the Marine & Oceans journal, the University of Toulon and Lemer Pax. It is placed under the scientific direction of Pr. Hervé Glotin of the University of Toulon/CNRS, world renowned specialist in underwater bioacoustics[10].

This oceanographic mission which takes place between the end of September 2019 and the end of March 2020, notably in the cetacean sanctuary Pelagos, in the western Mediterranean, has for main objective the listening and the monitoring of the populations of cetaceans great divers but also the collection of a large amount of data from various sensors on board drones. The Sphyrna Odyssey doesn't aim to approach cetaceans but, on the contrary, to follow them from a distance to listen to them, and therefore to study them, without ever disturbing them. This is part of the Pelagos Sanctuary code of conduct in which a large part of the research are conducted[10]. The Pelagos Sanctuary (Fig. 1) is a maritime area of 87500 km^2 subject to an agreement between Italy, Monaco and France for the protection of marine mammals[9].

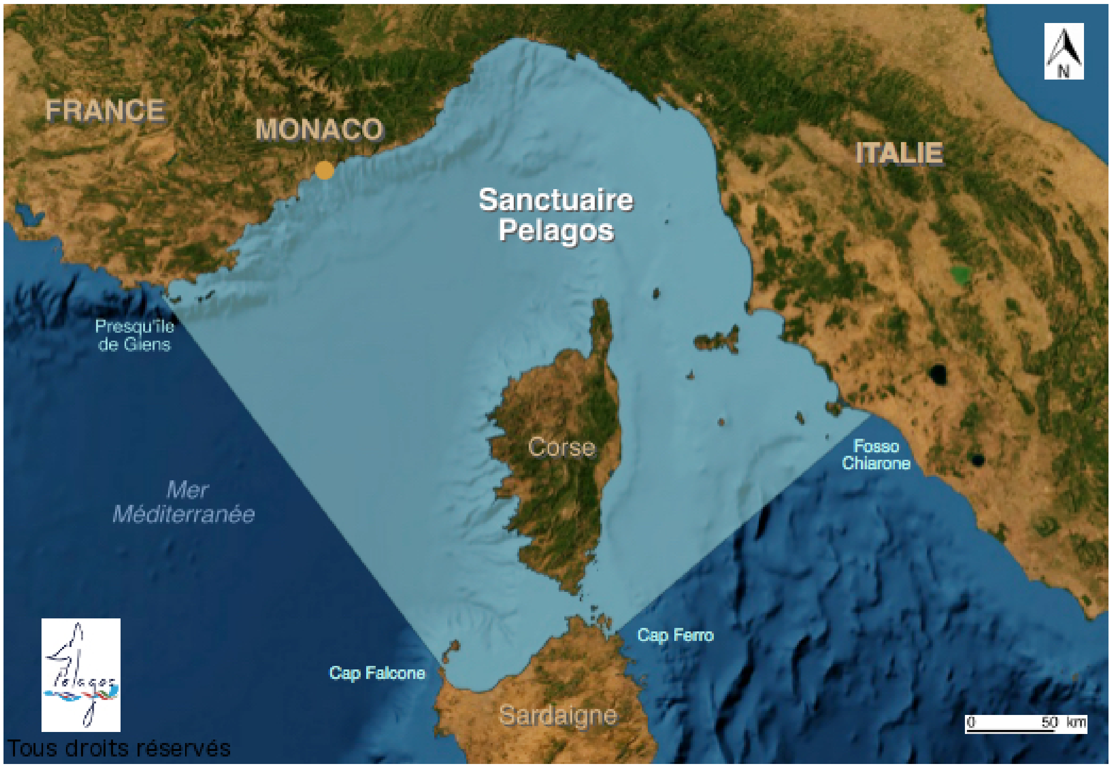

Figure 1: Location of the Pelagos Sanctuary which is a sea area of 87500 km². This area is subject to an agreement between Italy, Monaco and France for the protection of marine mammmals.

The Sphyrna Odyssey Mission implements two autonomous naval drones which are operated from a base ship, the OneCat, a 19-meter catamaran with mixed propulsion. This base ship hosts the scientific team and receive WIFI signals from drones in real time up to a distance of 13 kilometers[10]. Each drone has 5 hydrophones allowing the recording of sounds emitted by cetaceans (Fig. 2).

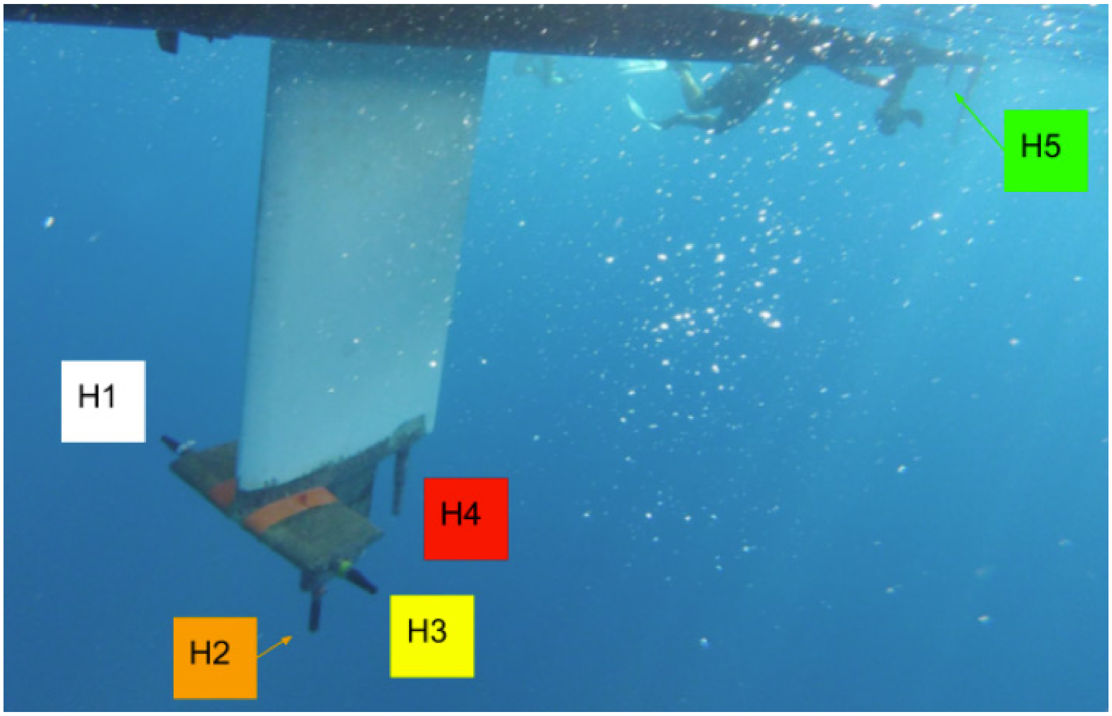

Figure 2: Acoustic antenna fixed under the keel of the drone and the five hydrophones position.

Thanks to Audacity software, every signal recorded can be studied. It allows to transform the analog signal into a numeric signal that can be visualized and manipulated. The various recording were used uniformly by setting the same basic parameters before each measurement. These parameters, such as high-pass and low-pass filter, are specified at the beginning of each chapter.

The sperm whale emits different vocalizations underwater to acoustically map the surrounding environment, to search for food and to communicate with conspecifics[2]. Each sound has its characteristics (frequency, amplitude, etc.), but for the most part, a similar structure is recorded by hydrophones.

The species produces a short multi-pulse signal, named "click", with time delays of few milliseconds between the pulses[2,1,6,5]. The anatomy of the head of a sperm whale is very complex and advanced, containing several compartments filled with an enormous skull and a complex system of soft organs (known as "spermaceti"), air sacs and nasal passages[2,11,7]. The nasal passages are asymmetrical, with the right side (Rn) closed and specialized in the production of sound, and the left (Ln) functional for the respiratory system (Fig. 3a). The spermaceti organ (So) is a sac filled with a complex mass of oil, the rear of which is in contact with a frontal air sac (Fr). This works as a great 'sound mirror'resting on the wide and frontal part of the skull[2,6,7]. In the forefront of the skull, the spermaceti organ ends in a pair of black lips of connective tissue (monkey lips, Mo) that produce sounds by way of a pneumatic action[2 2,6,4]. The monkey lips are also connected to the right side of the nasal passage and to the distal air sac (Di), another'sound mirror'at the front end of the head (Fig. 3a).

The time interval between these pulses, called "IPI" for Inter-Pulses Interval, depends among other parameters on the size of the animal. To produce a click, the sperm whale puts air under pressure which will pass through channels while producing sound energy. Part of this energy is diffused directly in the water and corresponds to the pulse P0, while the other part is reflected by a frontal air bag corresponding to the pulses P1 and sometimes P2 (Fig. 3b). The IPI is constant for a given individual.

Researchers have shown that there is a link between the size of an individual and the measured IPI. They characterized the nominal IPI which is measured between P1 and P2 of an individual: the nominal IPI is stable during all dives but increases over the years, certainly due to the increase in the size of the individual. The IPI can then give a measure of the size of an individual and estimate its growth precisely.

The inter-pulse interval (IPI) is constant for a given individual, with each click of the same type and within the same click. The inter-click interval (ICI) corresponds to the interval between the last pulse of a click n and the first pulse of a click n+1. This analysis of inter-click intervals will allow us to differentiate the individuals in the registered group by their sizes.

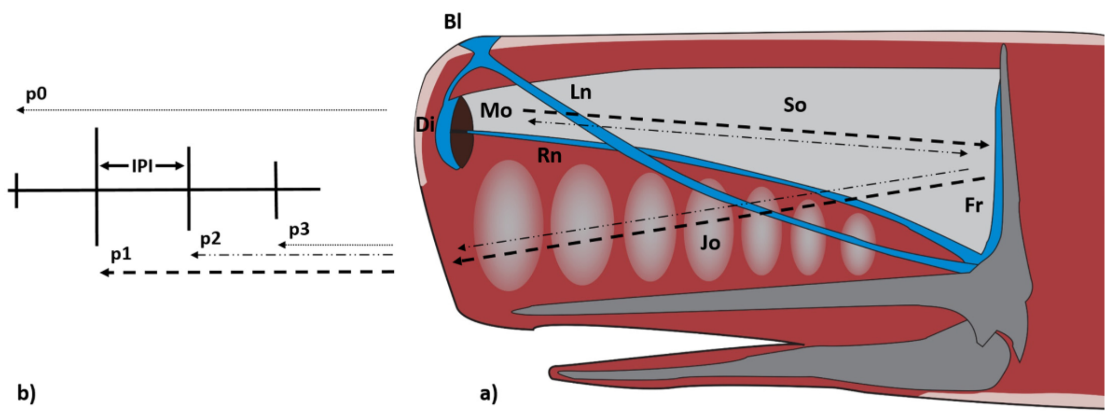

Figure 3: Scheme of the sperm whale's head and sound production (a) Bl: Blow hole;Di: Distal air sac;Fr: Frontal air sac;Jo: Junk organ;Ln: Left naris;Mo: Monkey lips;Rn: Right naris;So: Spermaceti organ. (b) According to the bent horn model, the production of a click generates multiple pulses (p0, p1, p2,p3 etc.).

1

Spatial location of pilot whales

In the same way as with sperm whales (chapter 2 and 3), we tried to indentify the different individuals of a pilot whales group. We also studied the location of the sources by calculating the pulse shift between the 5 channels given by the 5 hydrophones of the boat.

The high-pass filter applied was 15000 Hz and the low-pass filter was 30000 Hz. Each signal were amplified.

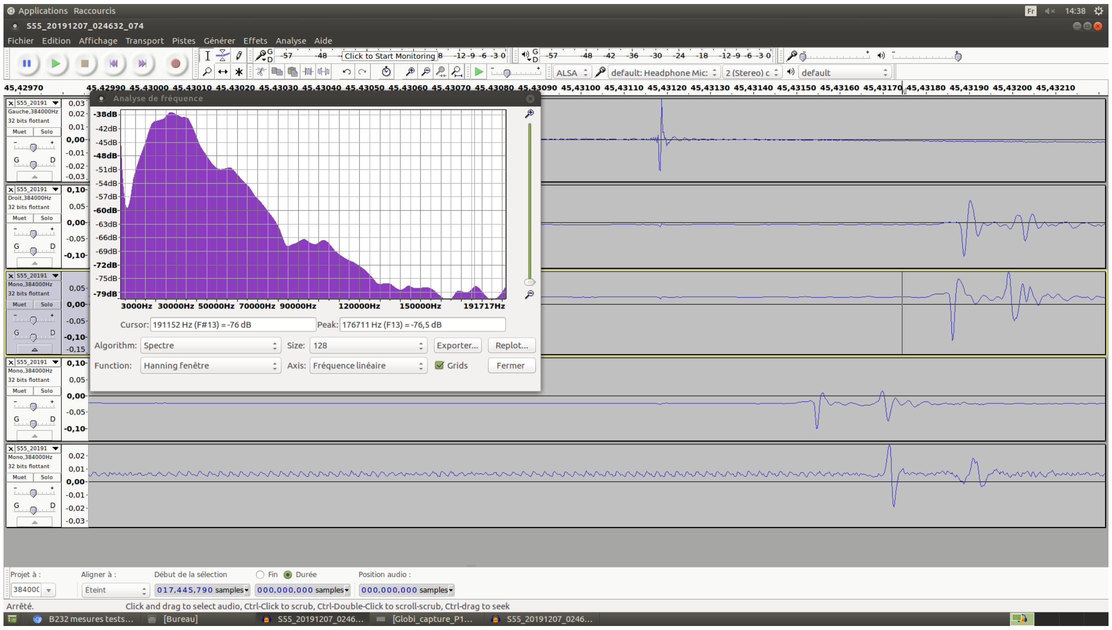

Figure 1.1: Example of a spectrum where we can see on channel 1 a frequency pulse of 43kHz. The animal sends its pulse in the axis of the hydrophone. On the contrary, on channel 2 we see a pulse with a much lower frequency of 27kHz. It's an "on axis" emission.

1.1 Théo BOUTELEUX

Globicephalus

Globicephala melas

Lenght: 6 m Weight : 1 ton

All of us are working with same pass filter to do not making mistakes on samples mesures.

It's important to remind that the sound is propagated faster in oil than water: in oil the sound speed is approximately 1600 m/s

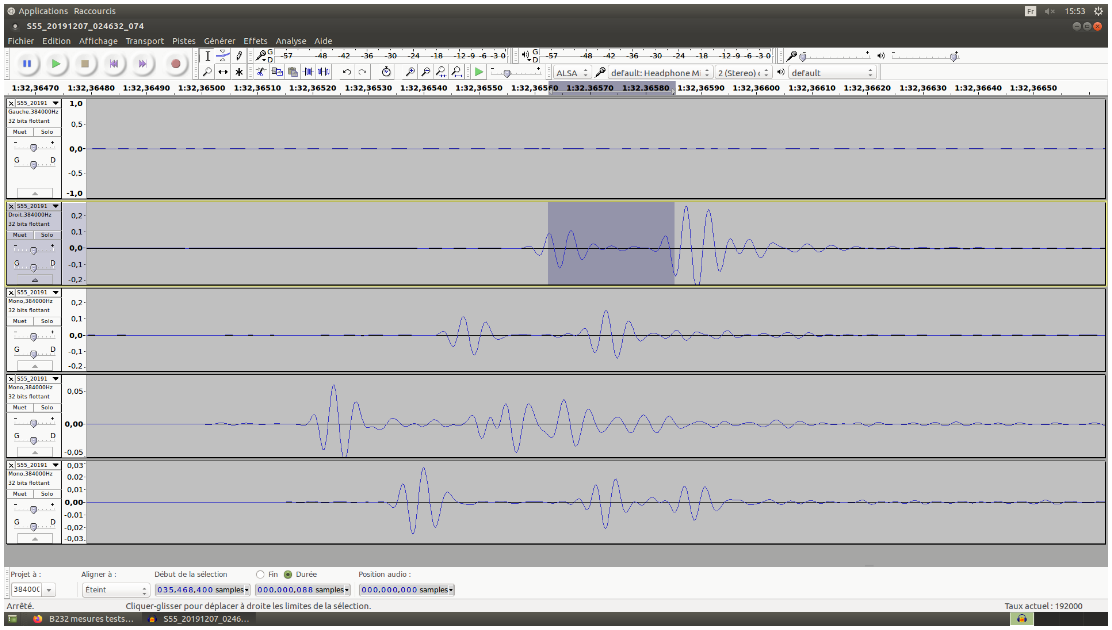

Figure 1.2: We can see here the maximum of amplitudes of P0. It represents the reflection of the sound on the little air bags of globi. It can be interpreted by a mask of sound. We can refer us on the globi's skeleton photography.

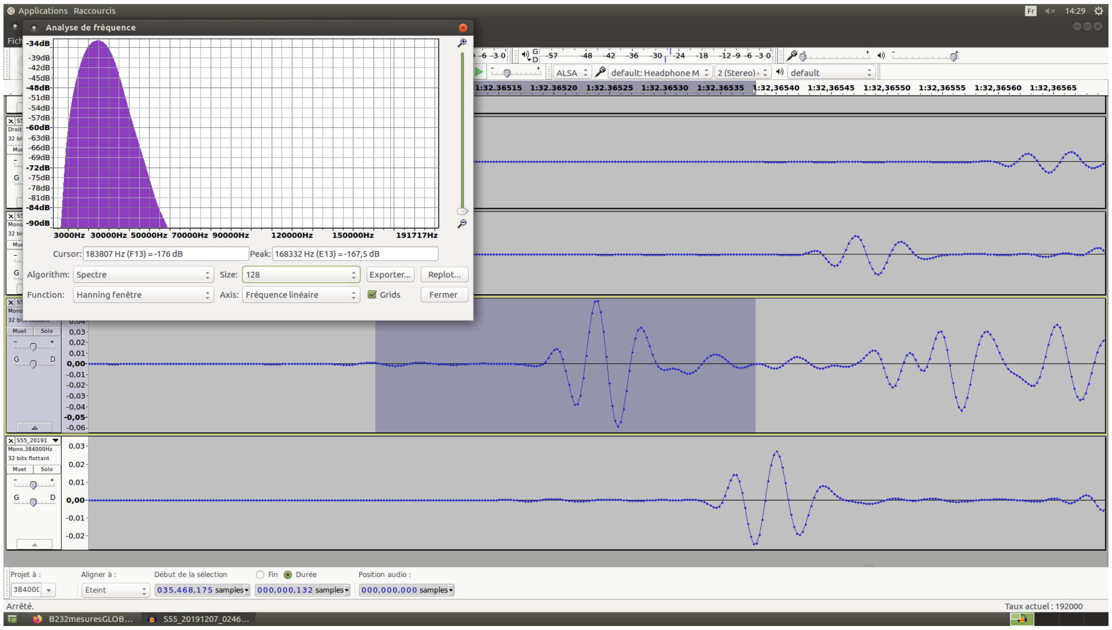

Figure 1.3: Example of frequency mesure on hydrophone 4. The angle's values of sound propagation are smaller in high frequencies than low frequencies. Indeed, according to the sound physical proprieties, the angle's value theta are near 0: this kind of called on axis. For the opposite (angle -180°), it's called off axis

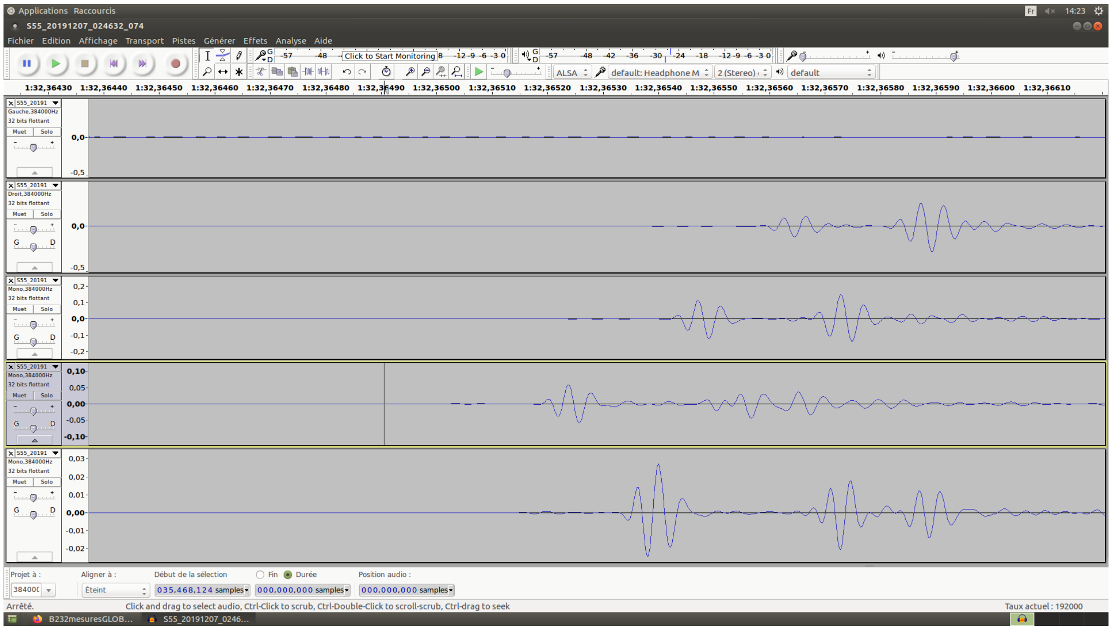

Figure 1.4: representation of clicks in hydrophones 2, 3, 4 and 5. We can see both pulses in figures (P0 and P1). We can also see the delay between hydrophones which with we can deduce the position of animal relative the drone

Figures of frequencies: Spectrum of analysis

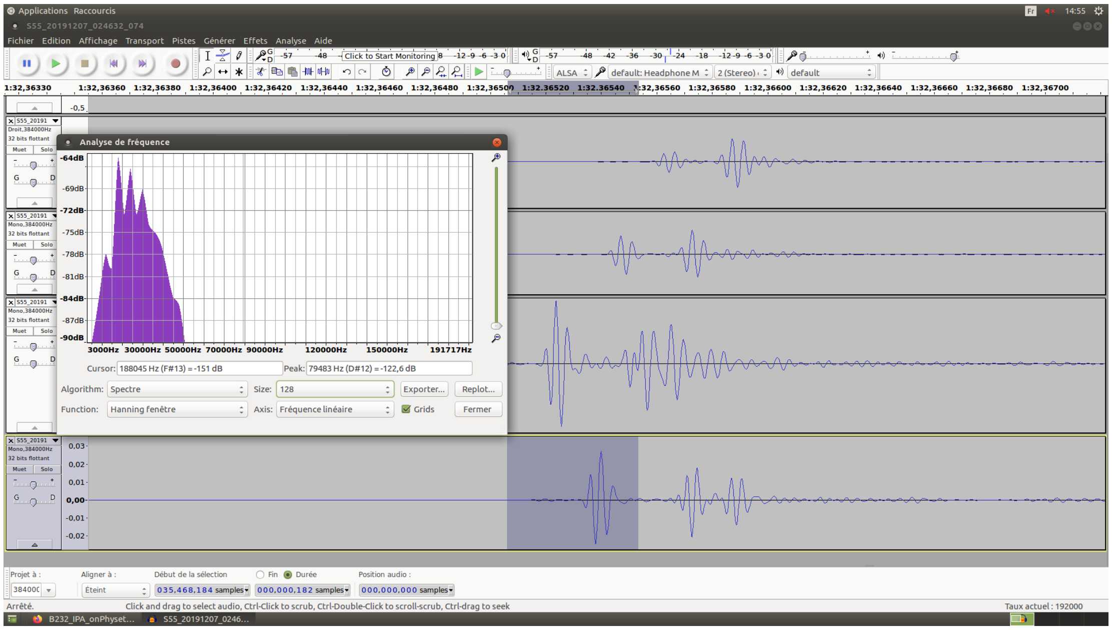

Figure 1.5: Frequency value of hydrophone 5

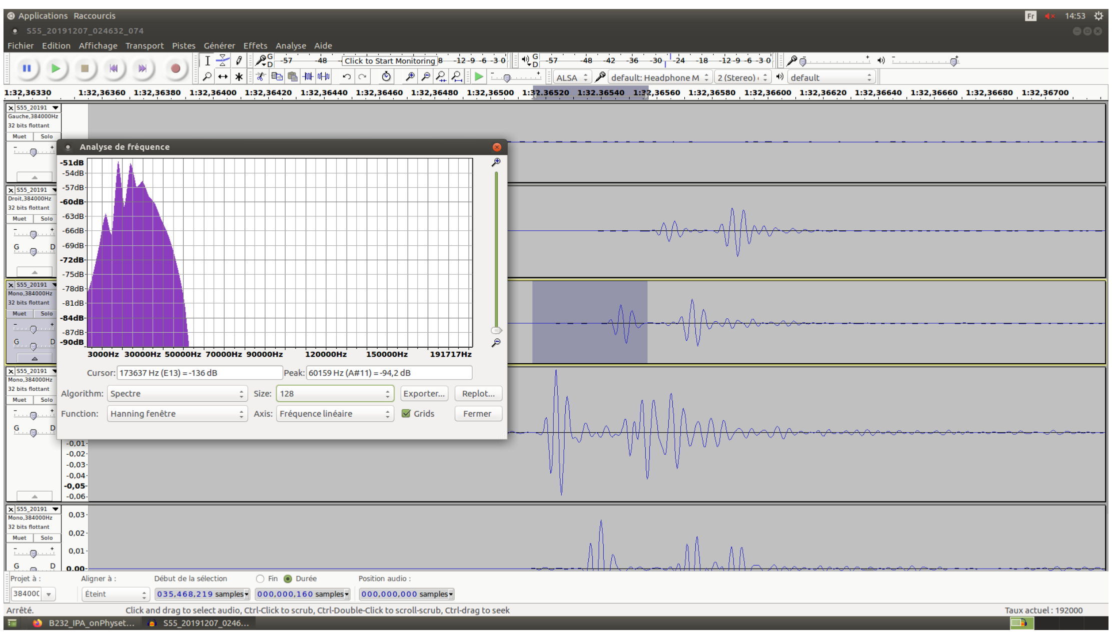

Figure 1.6: Frequency value of hydrophone 3

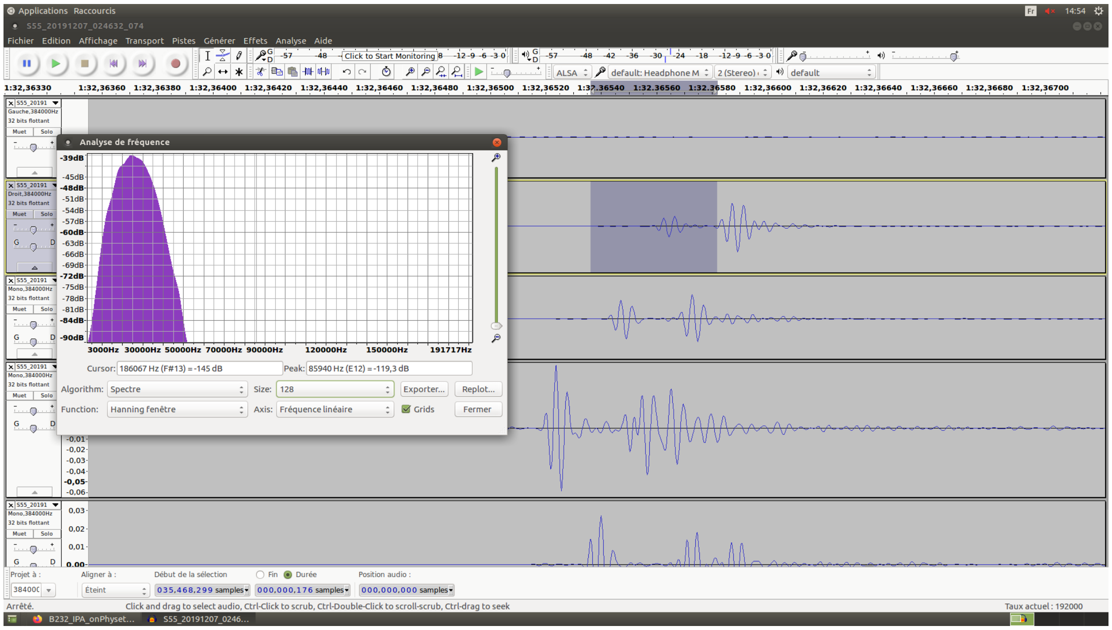

Figure 1.7: Frequency value of hydrophone 2

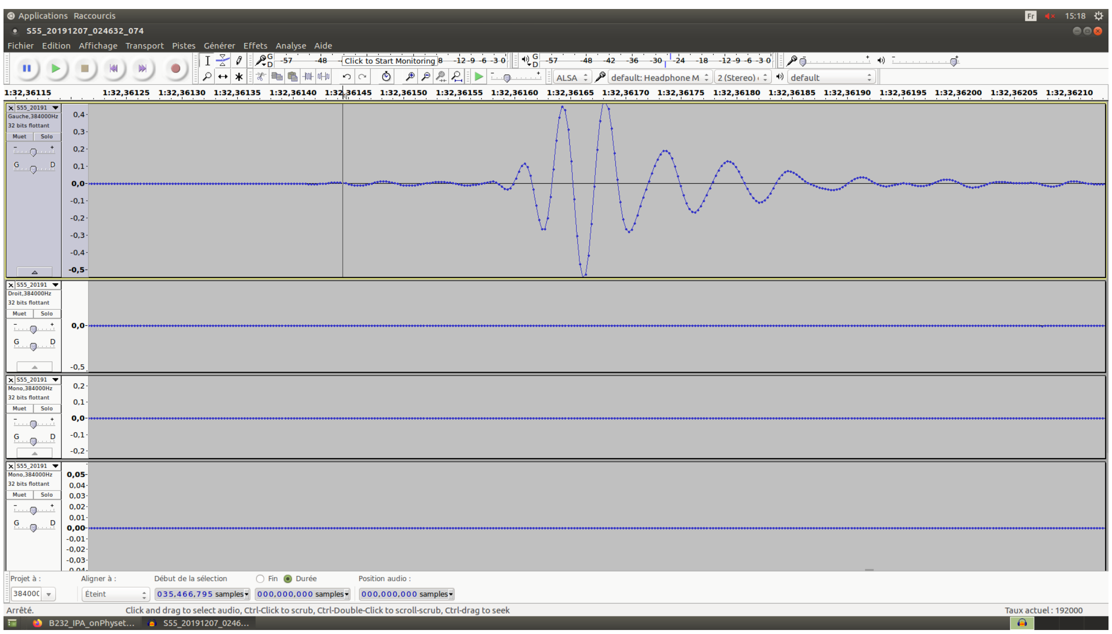

Figure 1.8: we can observe there is not rebound on the hydrophone 1. P1 is crushed

Click Trains: analysis of delay between channels

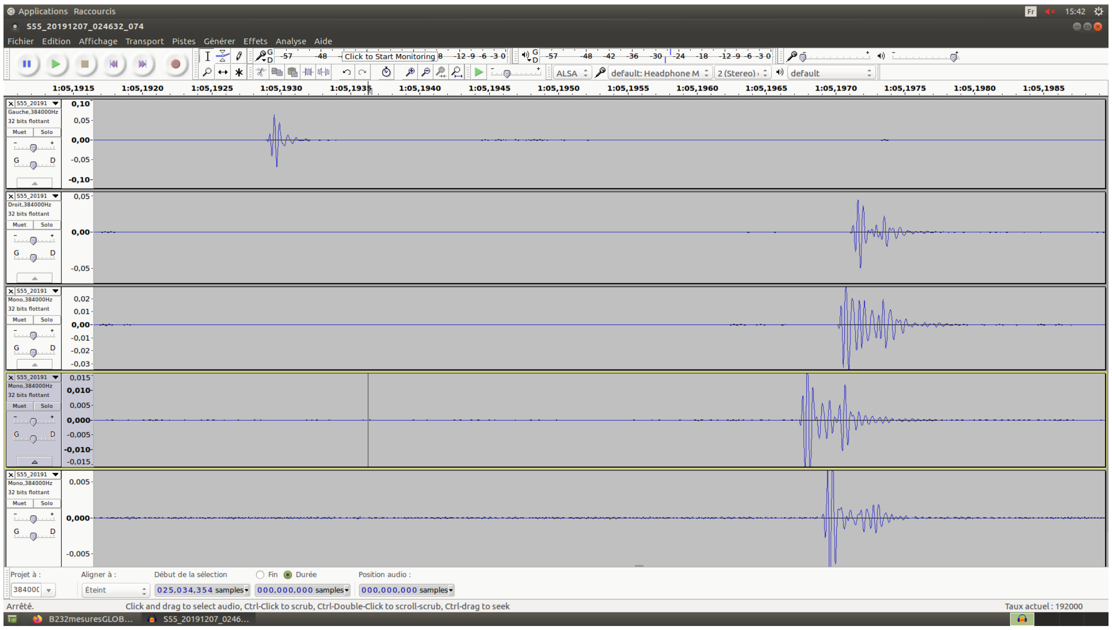

Figure 1.9: Globicephalus Click train on 1:05:19. We can see that the delay between the two first channels are bigger than the others

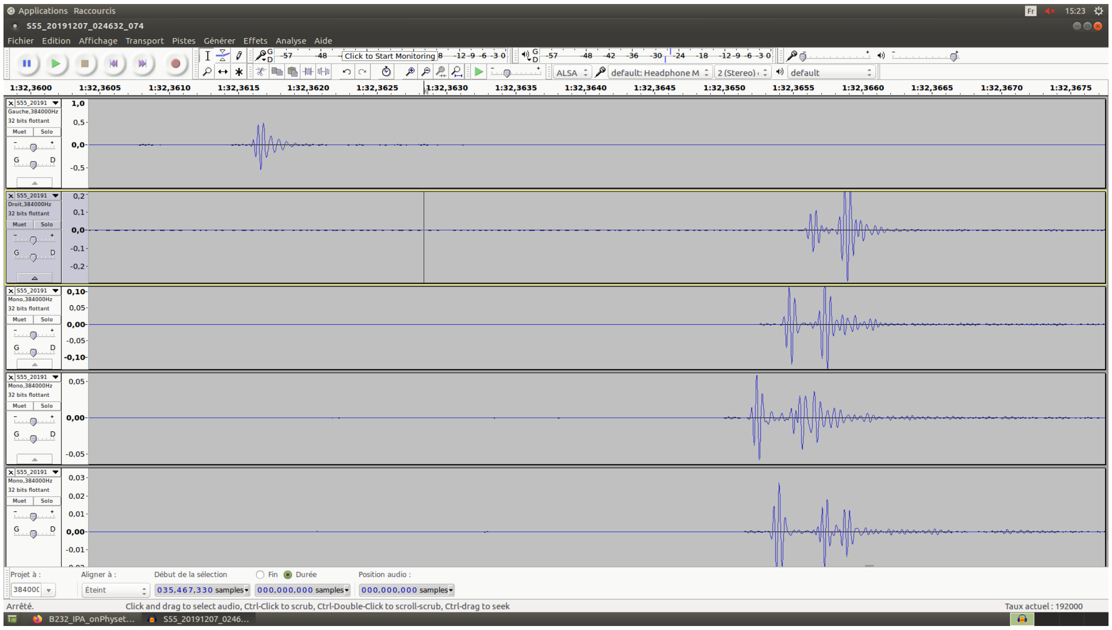

Figure 1.10: Globicephalus Click train on 1:32:36. We can observe that the pulse P0 on channel 5 starting negatively. We can also see that the delay between the two first channels are bigger than the others. So we can deduce the relative animal position.

1.2 Caroline VALMORI

Date of clic : 00:44:25 min / 169905863 samples

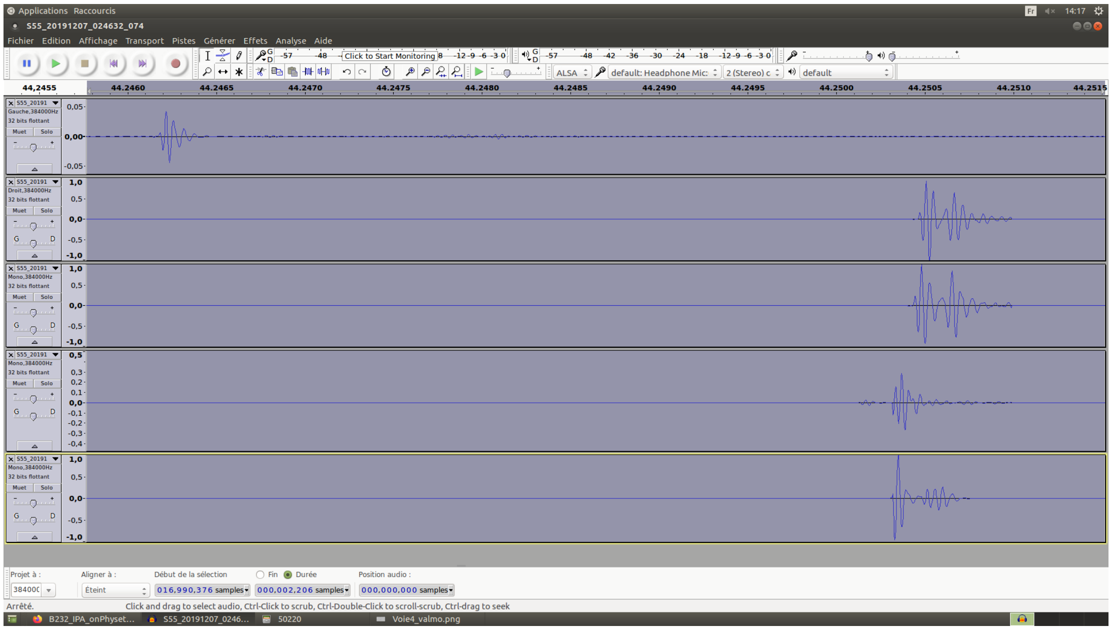

Figure 1.11: Signal studied on our 5 channels.

We have analysed one signal from different channel to verify if it provide from differences sources and to localize the individual. We can observe that the signal from the first channel is far from the other signals and we noticed that channel 5 was upside down.

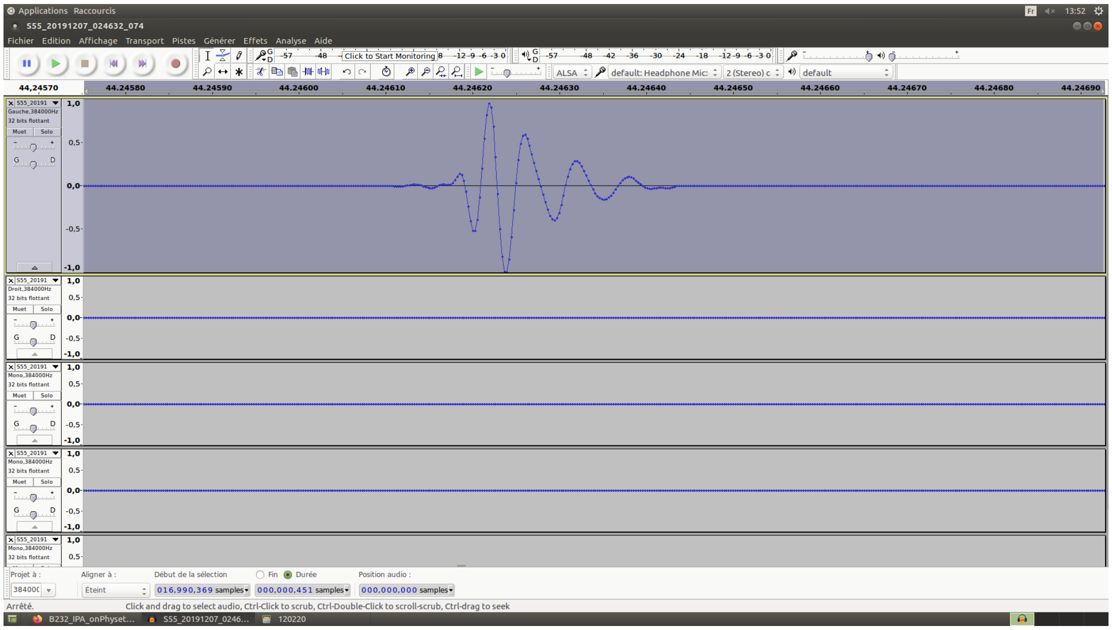

Figure 1.12: Signal studied on the first channel.

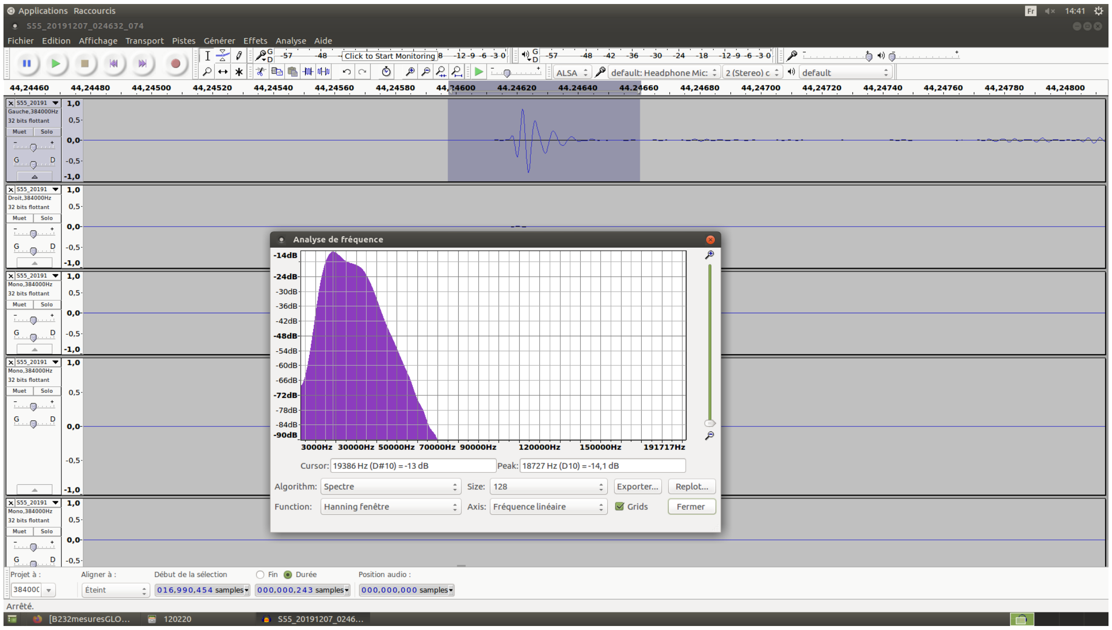

Figure 1.13: Graphic representing the frequency of our signal on the first channel.

For the first channel we cannot see the inter pulse P0-P1. We can supposed that it's because the animal is on axis with the hydrophone one. Frequences from this channel is equal to 18727 Hz.

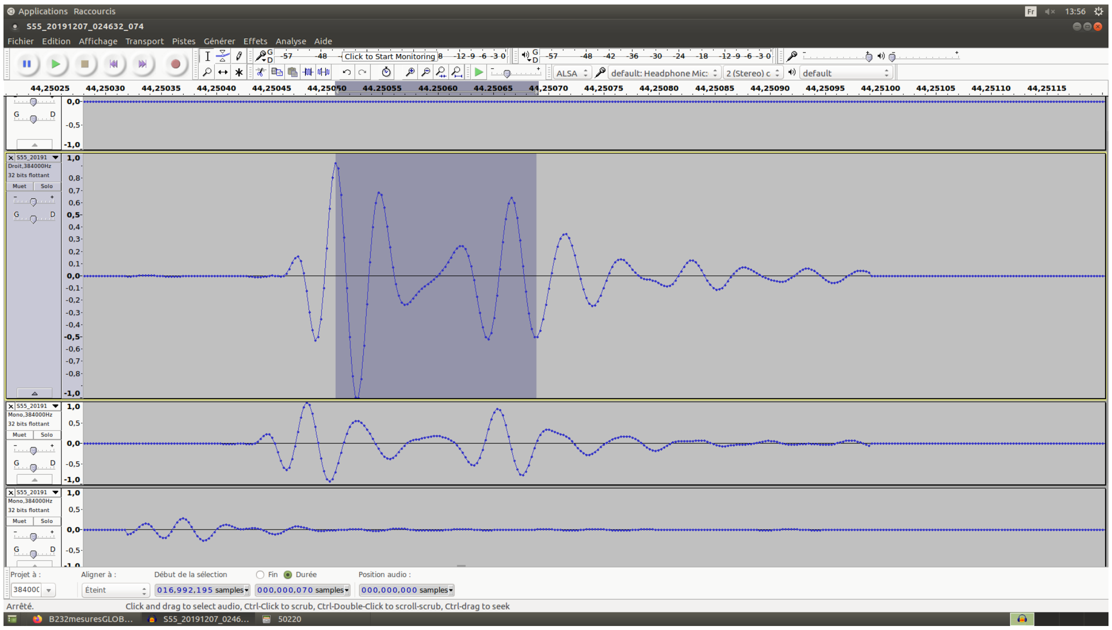

Figure 1.14: Signal studied on the second channel.

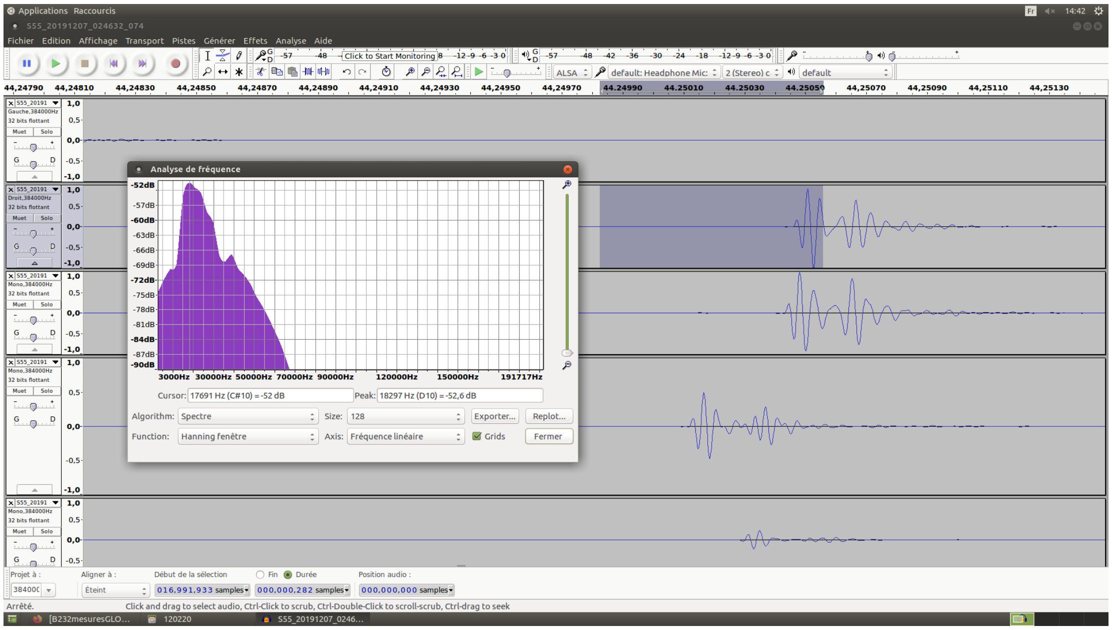

Figure 1.15: Graphic representing the frequency of our signal on the second channel.

For the second channel, the inter pulse is clear and it's equal to 70 samples. Frequences from this channel is equal to 18297 Hz.

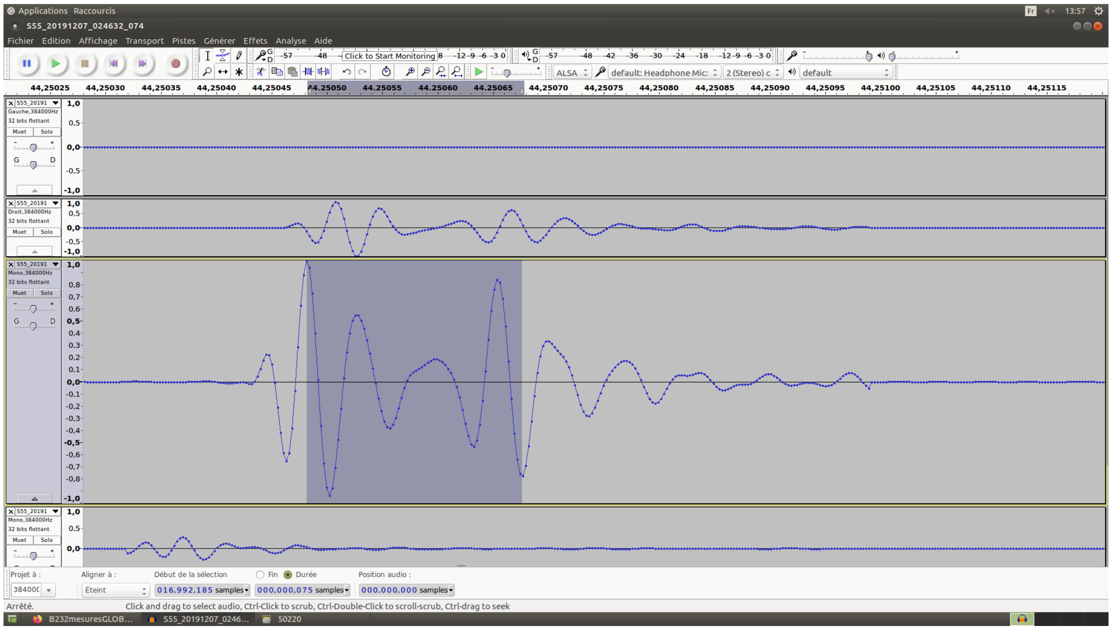

Figure 1.16: Signal studied on the third channel.

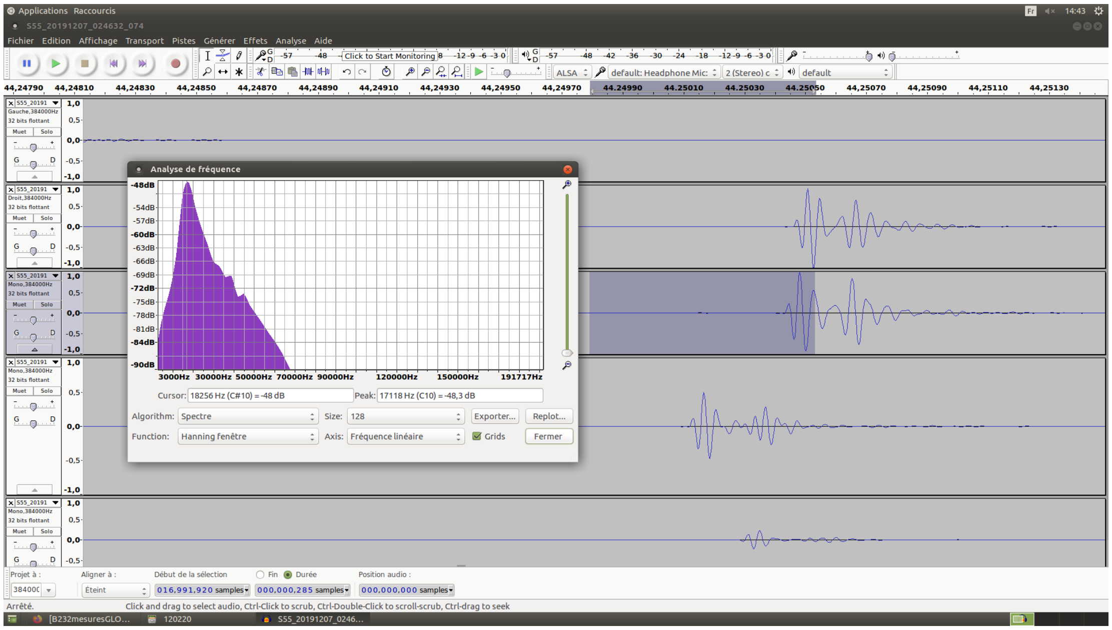

Figure 1.17: Graphic representing the frequency of our signal on the third channel.

Concerning the channel 3, the inter pulse is also clear and equal to 75 samples. Frequences is equal to 17118 Hz.

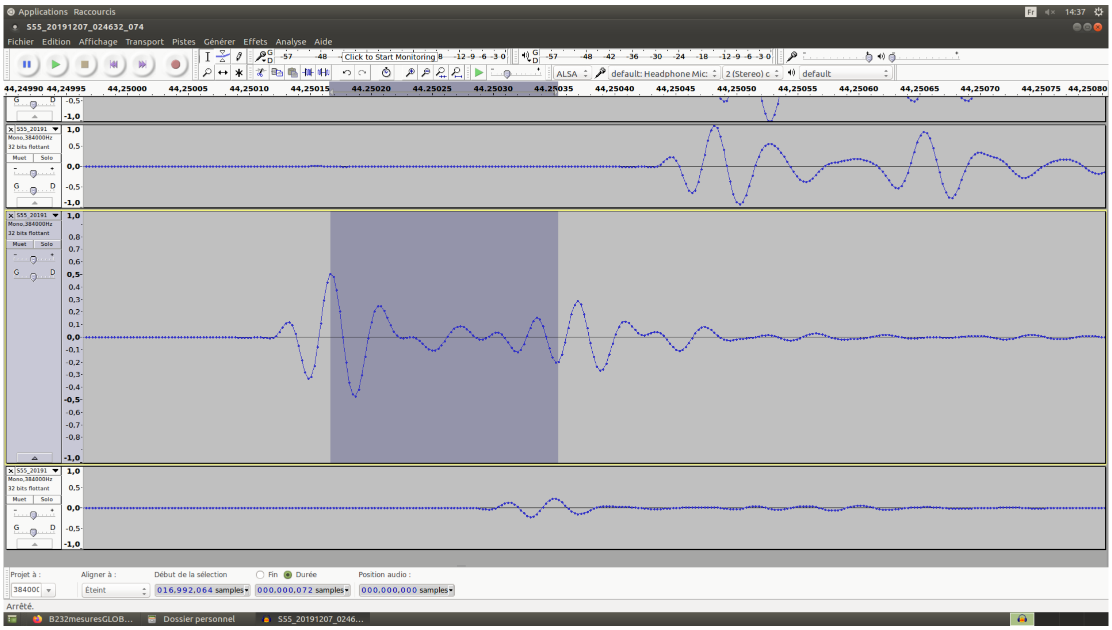

Figure 1.18: Signal studied on the fourth channel.

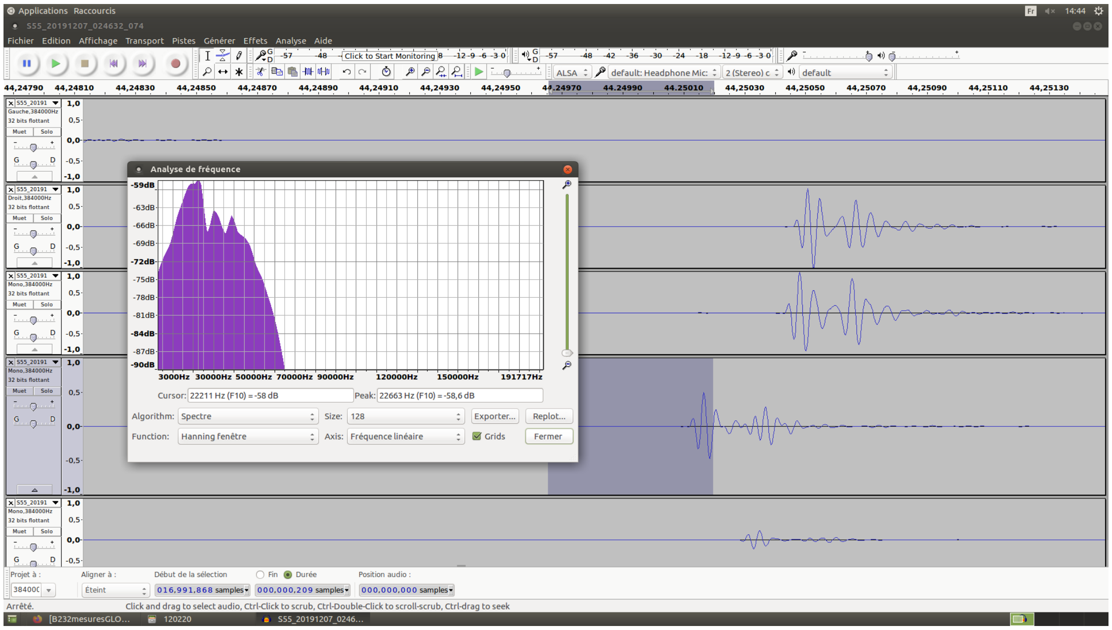

Figure 1.19: Graphic representing the frequency of our signal on the fourth channel.

For the fourth signal, the inter pulse is equal to 72 samples and frequences is equal to 22663 Hz.

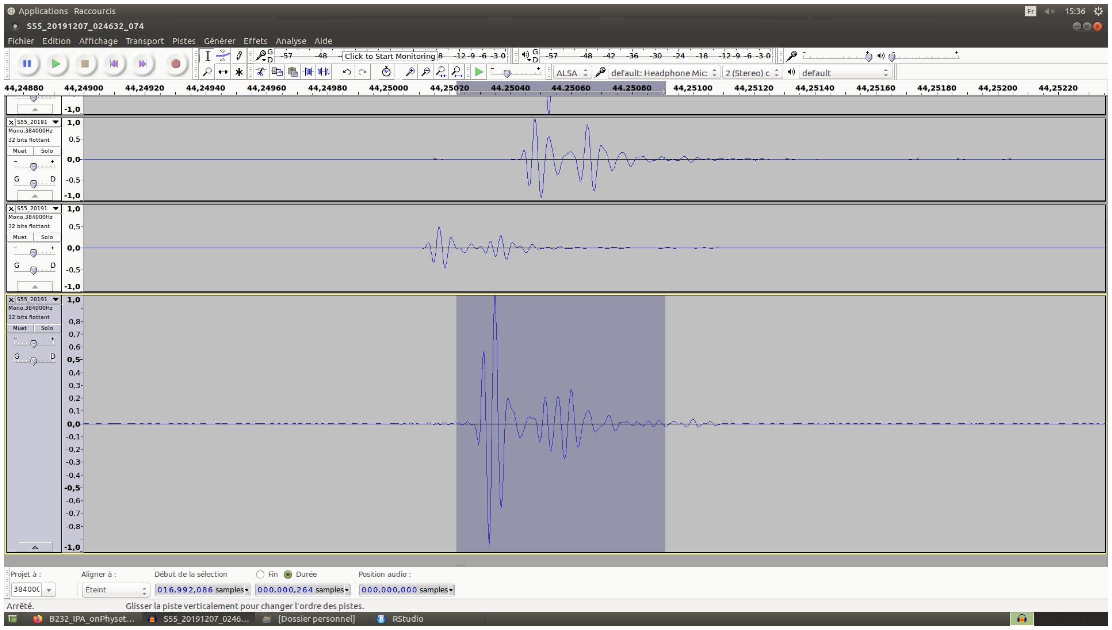

Figure 1.20: Signal studied on the fifth channel.

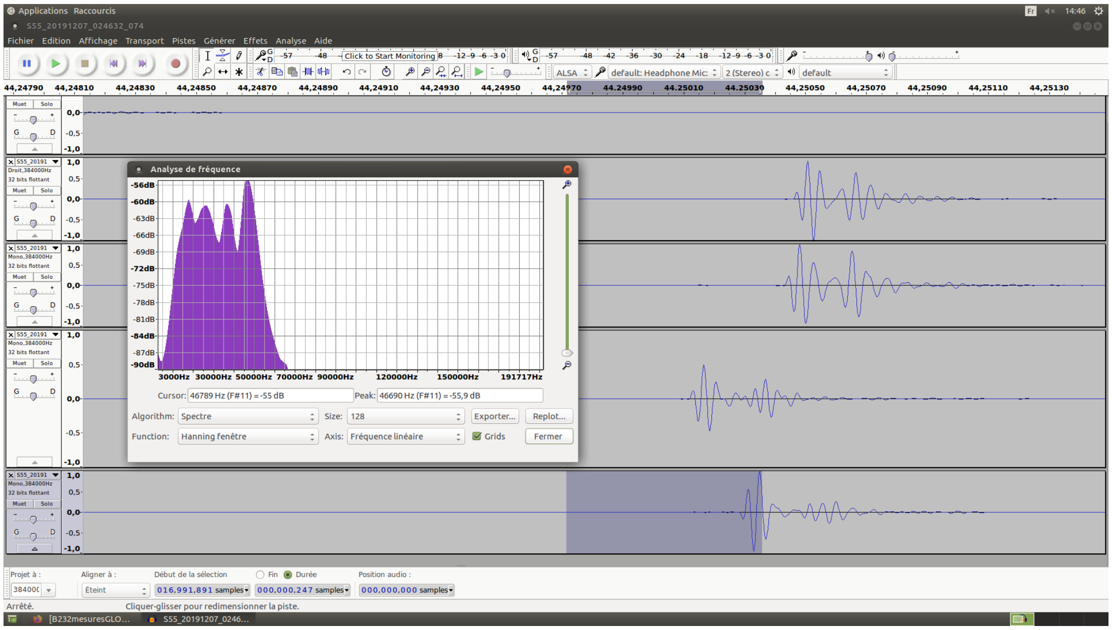

Figure 1.21: Graphic representing the frequency of our signal on the fifth channel.

Like for the first channel we cannot see the inter pulse P0-P1. We can supposed that it's because the animal is on axis with this hydrophone. Frequences from the channel 5 is equal to 46690 Hz. This high value can be explain by the directivity effect. Indeed, it's corresponding with the lack of data for the inter pulse between P0 and P1. We can suggest that animal look the hydrophone number 5, it's means that it on axis with the hydrophone 5.

We have calculated the mean and standard deviation of the inter click P0P1 for each channel: Mean = 72,33 +/- 2,52 samples.

Thanks to this mean, we calculate the distance P0P1 between the emitter and the front of the animal:

$$d(emitter - front) = (Mean * distance(cm))/2/Numberofsamplebyseconds * 100$$

Distance is calculated by the hypothesis that the propagation speed of the wave is 150 m/s which correspond to 1m50 by milliseconds.

$$d(emitter - front) = 72,33 * 15000/2/384000 * 100$$

$$d(emitter - front) = 14,13cm$$

1.3 Kiara LANGE

In this chapter we will work on a single click of a pilot whale from a recording named S55-13083492 using Audacity software. Date of click studied : 00:34:06 min / 13082085 samples

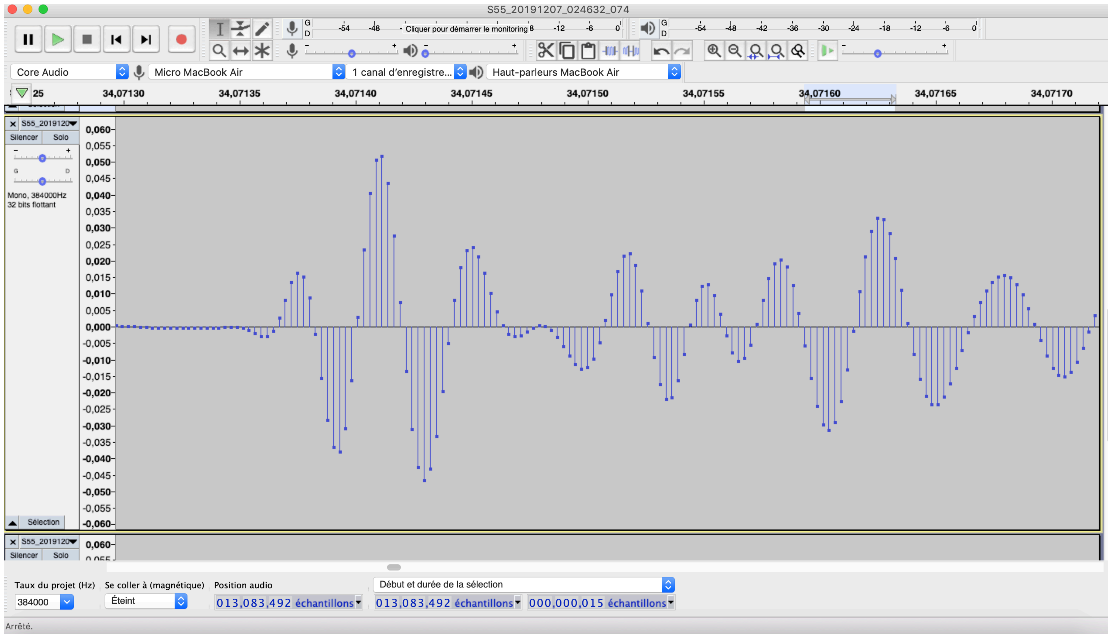

Figure 1.22: Example of a break in the wave curve by addition of energy which highlights P0P1

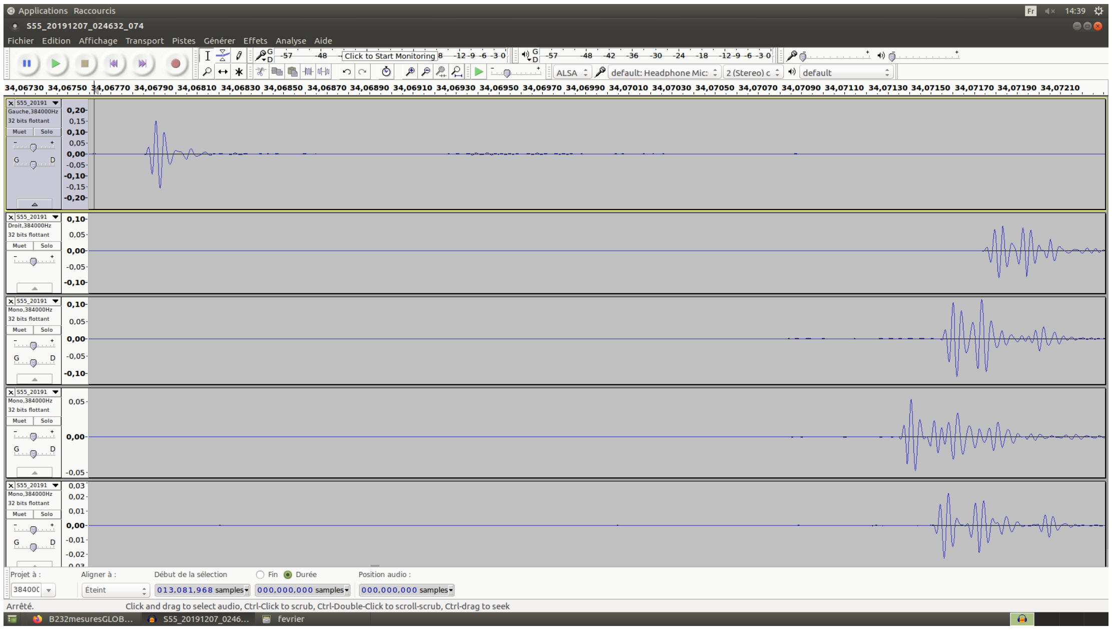

Figure 1.23: Pilot whale click at 34:06s from the five hydrophones.

Figure including the clicks studied on the 5 different channels, after using the high and low pass filters. We can observe the different delays, from which we will be able to deduce the location of the animal in space. Hydrophones 4 and 5 are connected upside down and therefore the observed figures will be reversed. After observation of the delays for each channel, it is clear that the animal is closer to the first hydrophone than the other 4 hydrophones given the small delay for hydrophone 1.

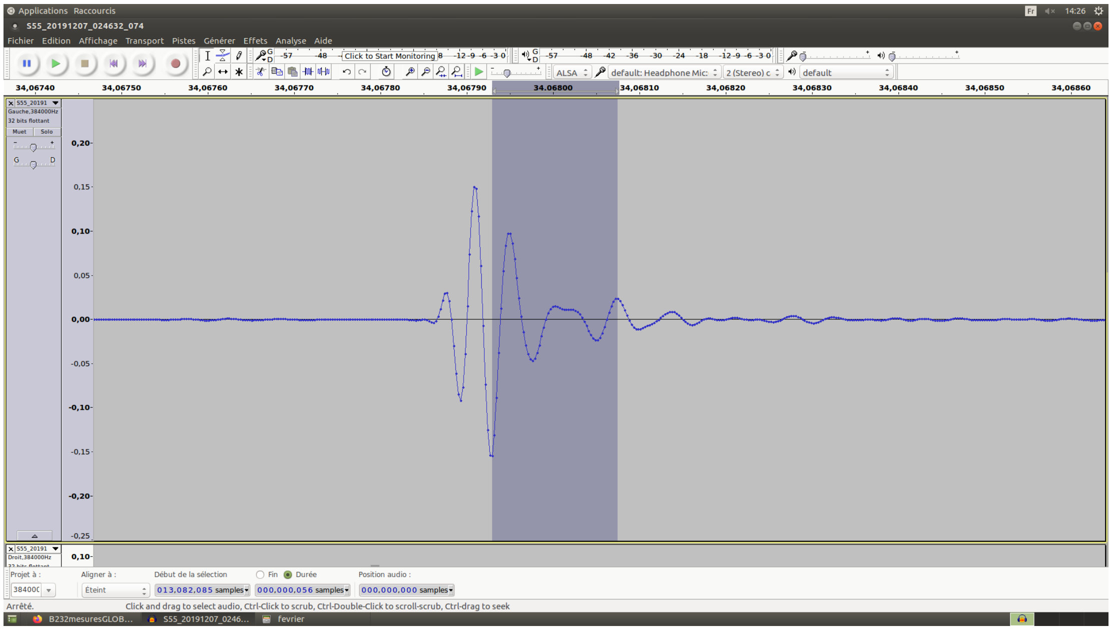

Figure 1.24: Pilot whale click at 34s in the hydrophone 1. P0P1 = 56 samples

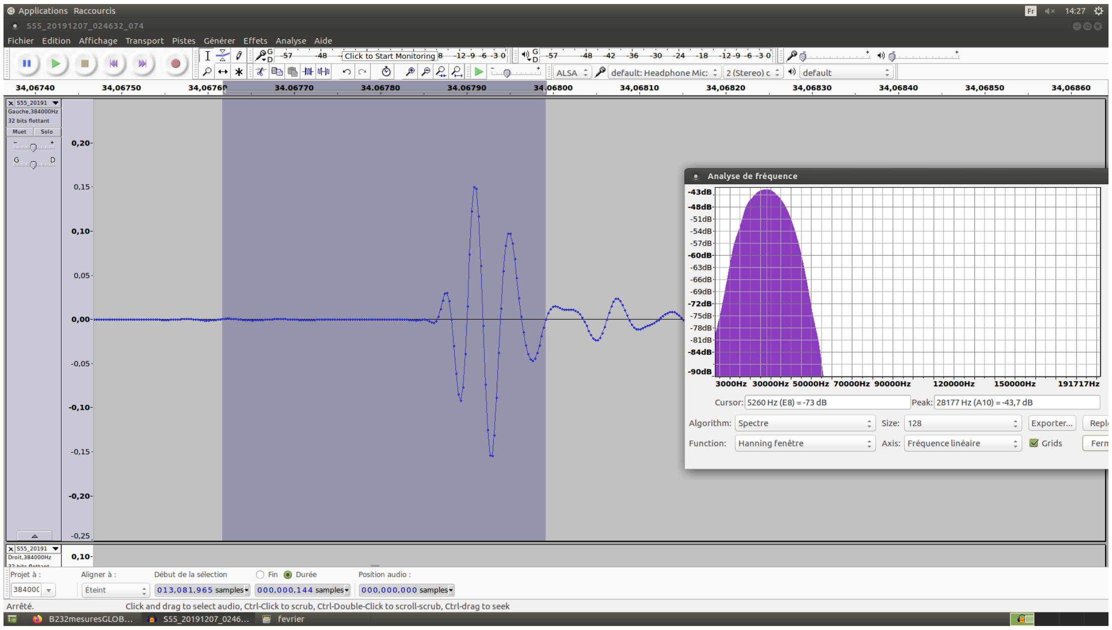

Figure 1.25: Spectrum analysis of P0 at 34s from hydrophone 1.

As there are not enough points to plot the spectrum, we shift the selection to the left which will not distort the analysis because there is no additional sound selected. Peak at 28177 Hz, with - 43,7 dB

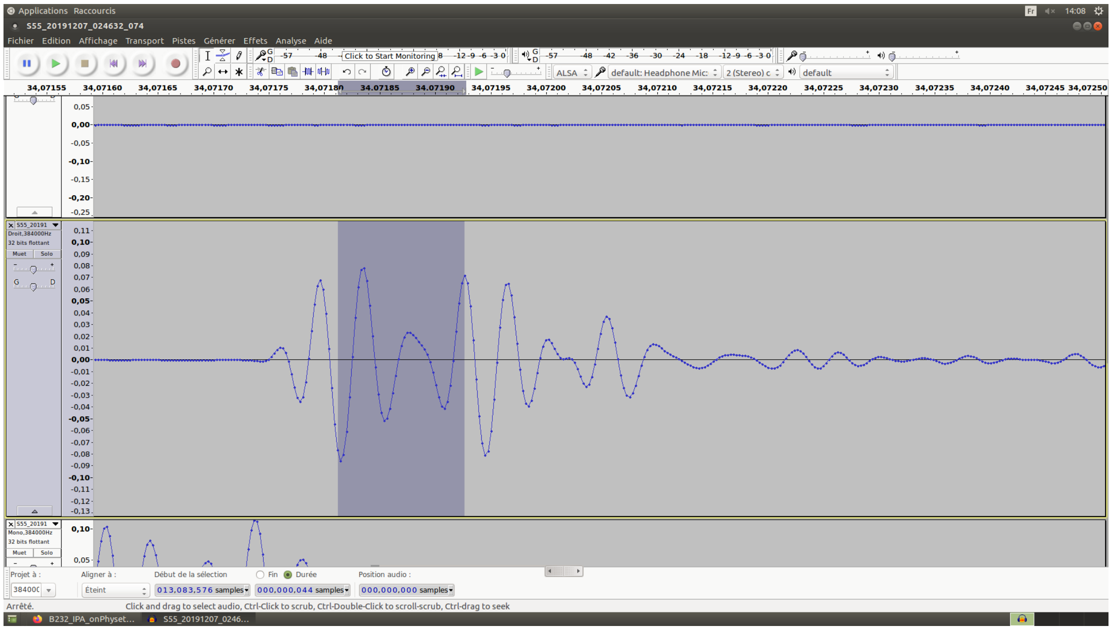

Figure 1.26: Pilot whale click at 34s in the hydrophone 2 by Kiara Lange. We probably have the presence of a P2, formed by a wave which rebounded twice. So we have P0P1 approximately equal to P1P2. P0P1 = 44 samples

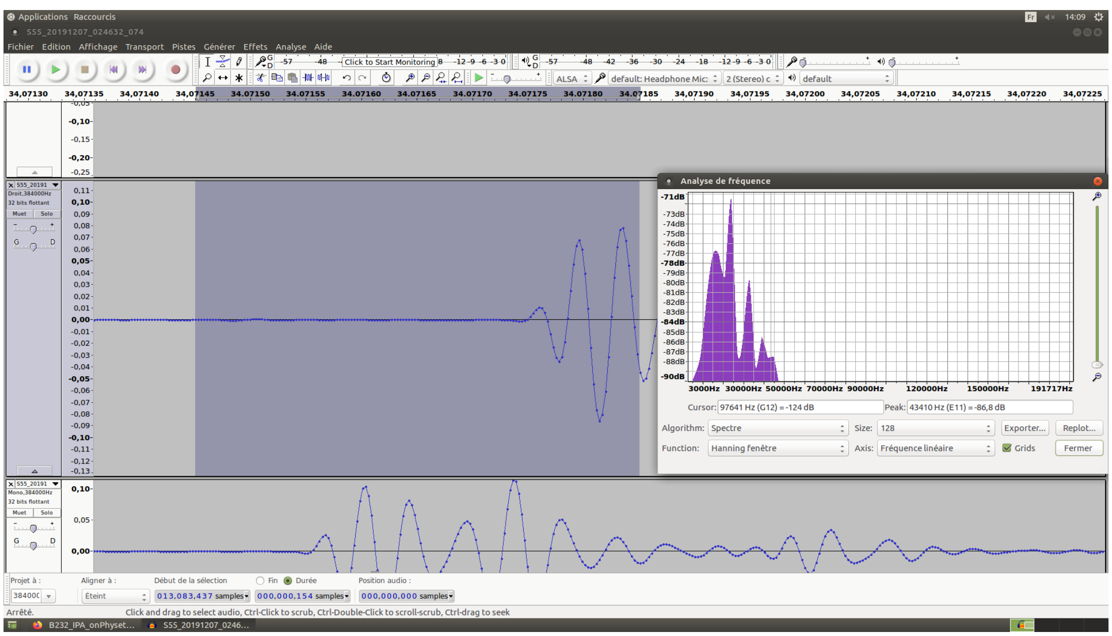

Figure 1.27: Spectrum analysis of P0 at 34s from hydrophone 2. There is a great peak at 23 kHz, with - 71,5 dB

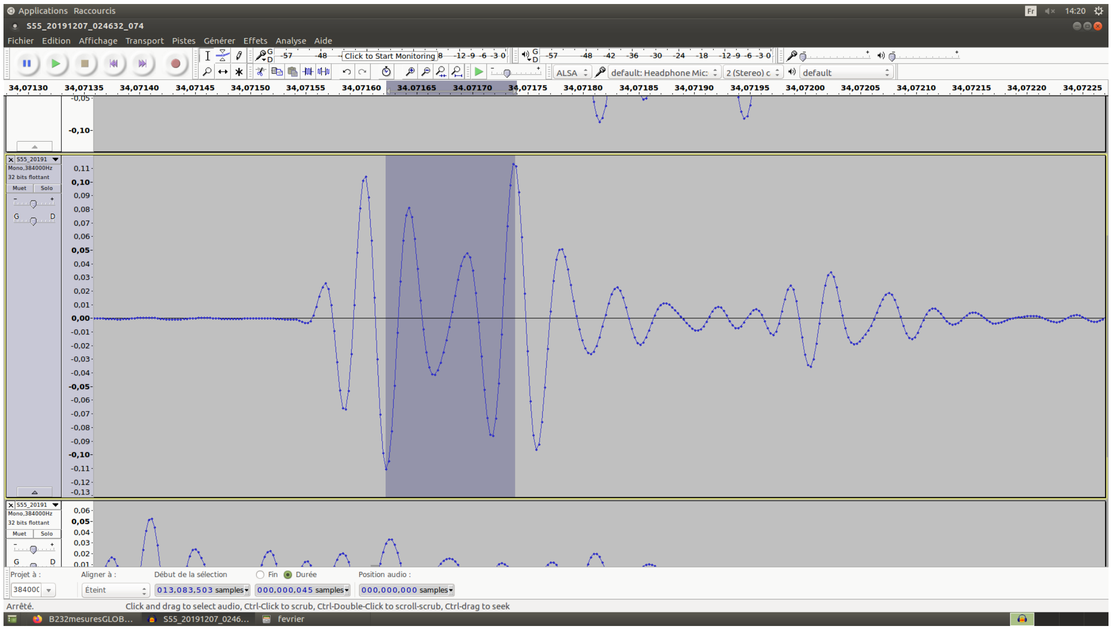

Figure 1.28: Pilot whale click at 34s in the hydrophone 3. P0P1 = 45 samples

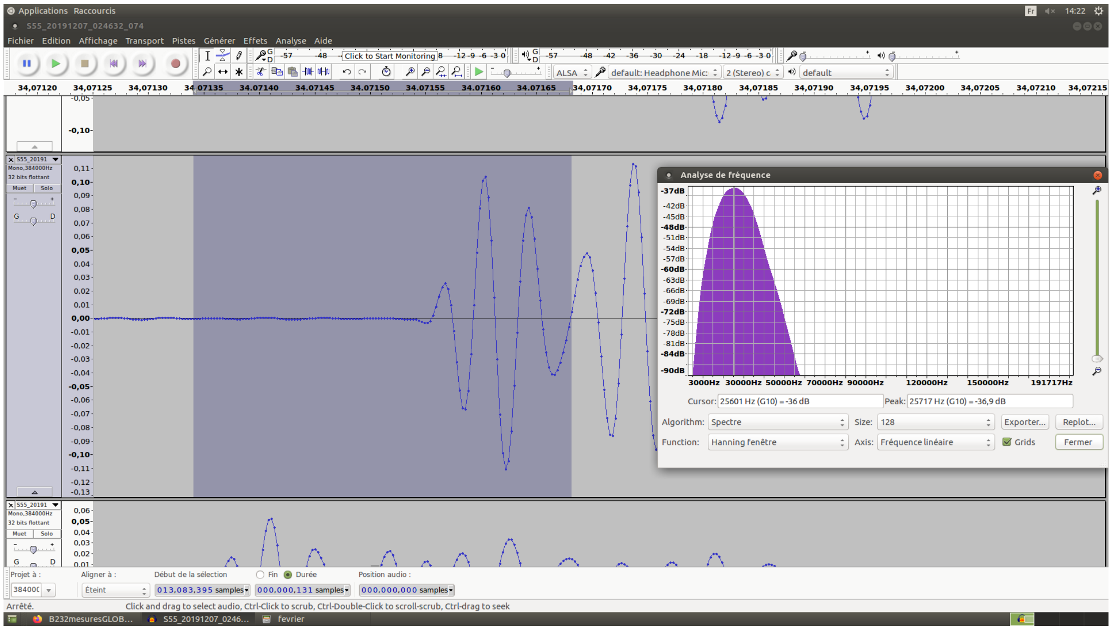

Figure 1.29: Spectrum analysis of P0 at 34s from hydrophone 3. Peak at 25717 Hz, with - 36,9 dB

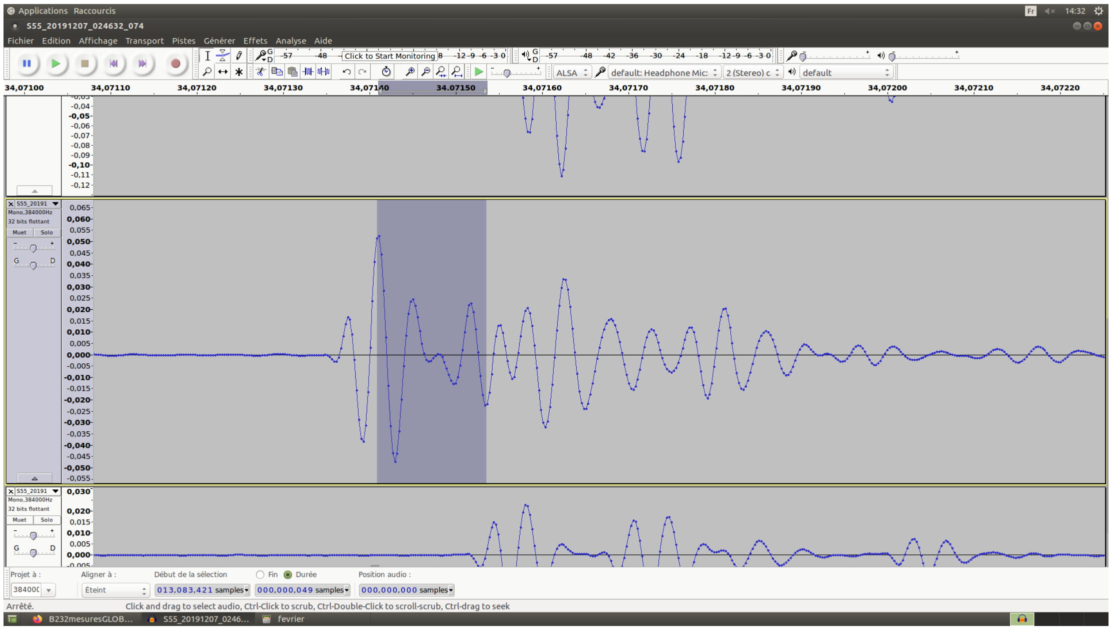

Figure 1.30: Pilot whale click at 34s in the hydrophone 4. The hydrophone is plugged upside down. P0P1 = 49 samples

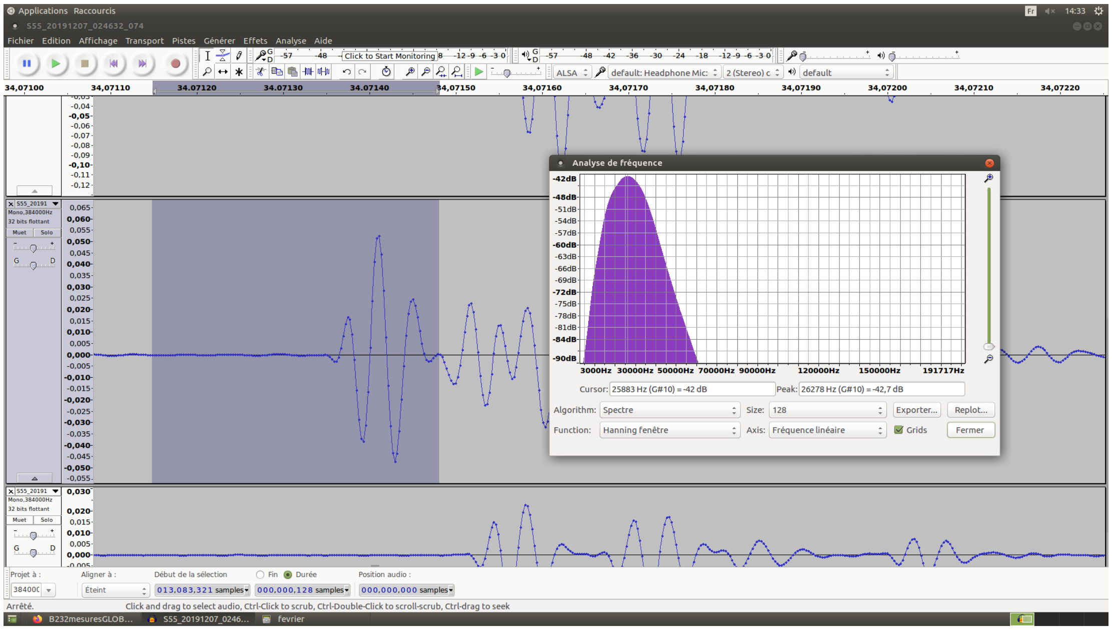

Figure 1.31: Spectrum analysis of P0 at 34s from hydrophone 4. Peak at 26278 Hz, with - 42,7 dB

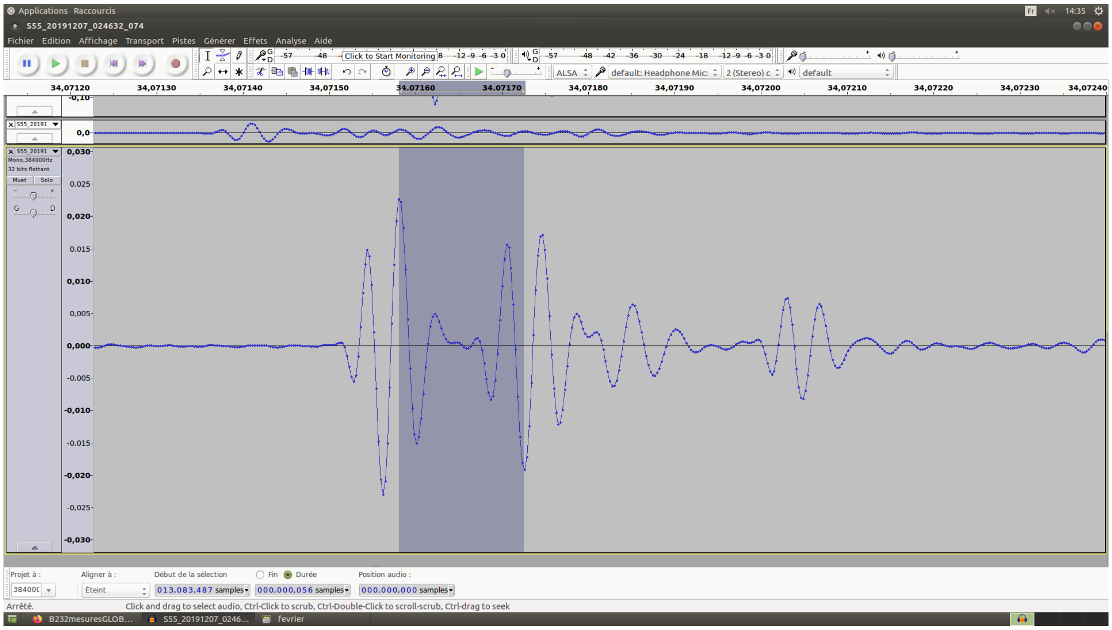

Figure 1.32: Pilot whale click at 34s in the hydrophone 5. The hydrophone is plugged upside down. P0P1 = 56 samples

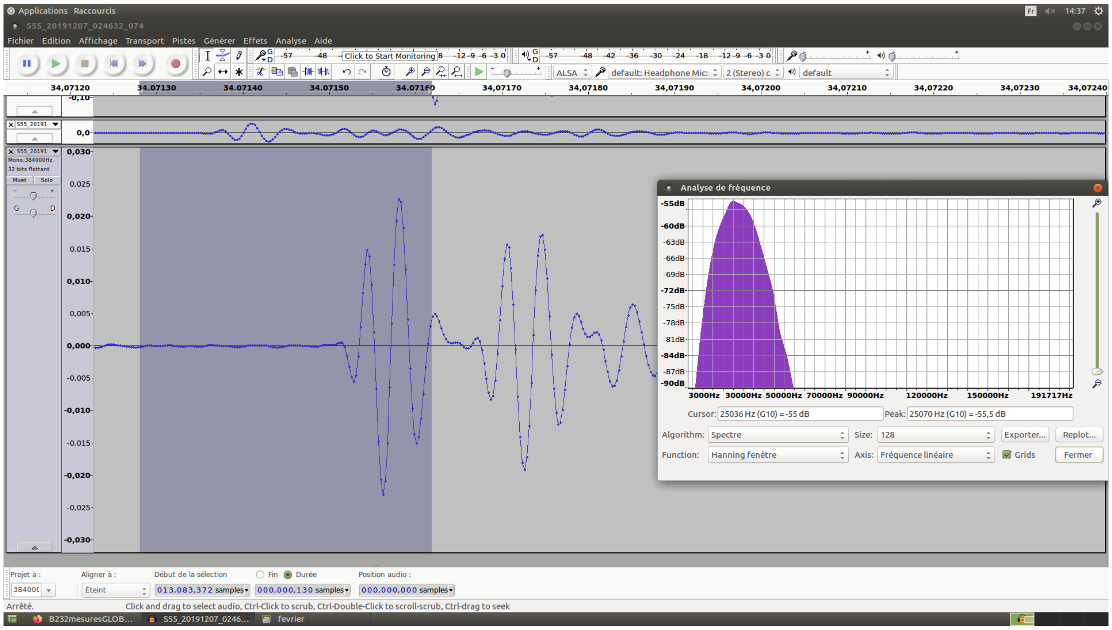

Figure 1.33: Spectrum analysis of P0 at 34s from hydrophone 5. Peak at 25070 Hz, with - 55,5 dB

After calculating the mean of PoP1 for the 5 different channels, we can deduce the distance between the airbag and the phonic lips of the pilot whale which gives us information about the size of its head and therefore an idea of the size of the animal. Here the mean of PoP1 = 49.6 samples. By multiplying this mean by the speed of the sound in water (approximately 1500 ms), dividing it by two and then dividing it by the number of samples per second (here 384000), we can determine the distance between the airbag and the phonic lips of the pilot whale. For the click studied in this section, the distance between the transmitter and the front of the animal's head is 9.69 cm.

Regarding the spectrum analysis, the frequencies give us information about the position of the animal in space. The higher frequency for our click is on the channel 1 with 28177 Hz which suggests that the animal's head is probably turned in that direction.

1.4 Louise VILLAC

We are analysing a signal coming from 5 channels, to localise as more as we can the animal. The frequency of the first channel, begin a little time after the others, and the fourth one, begin a little time before the others.

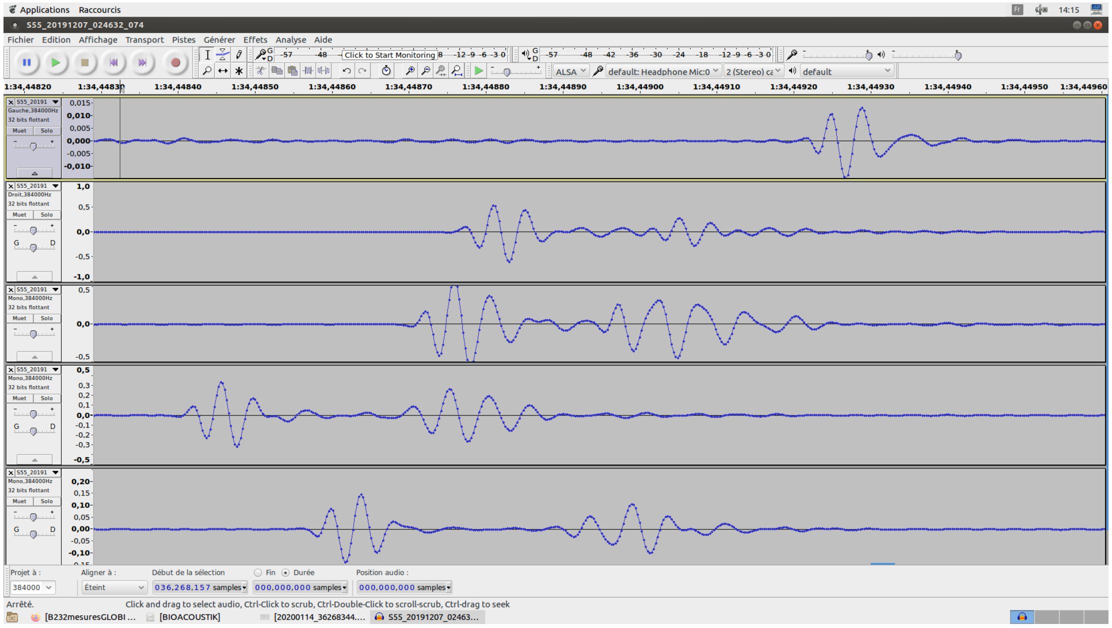

Figure 1.34: Picture of analysis of a Pilot Whale click, all ways at 1:34

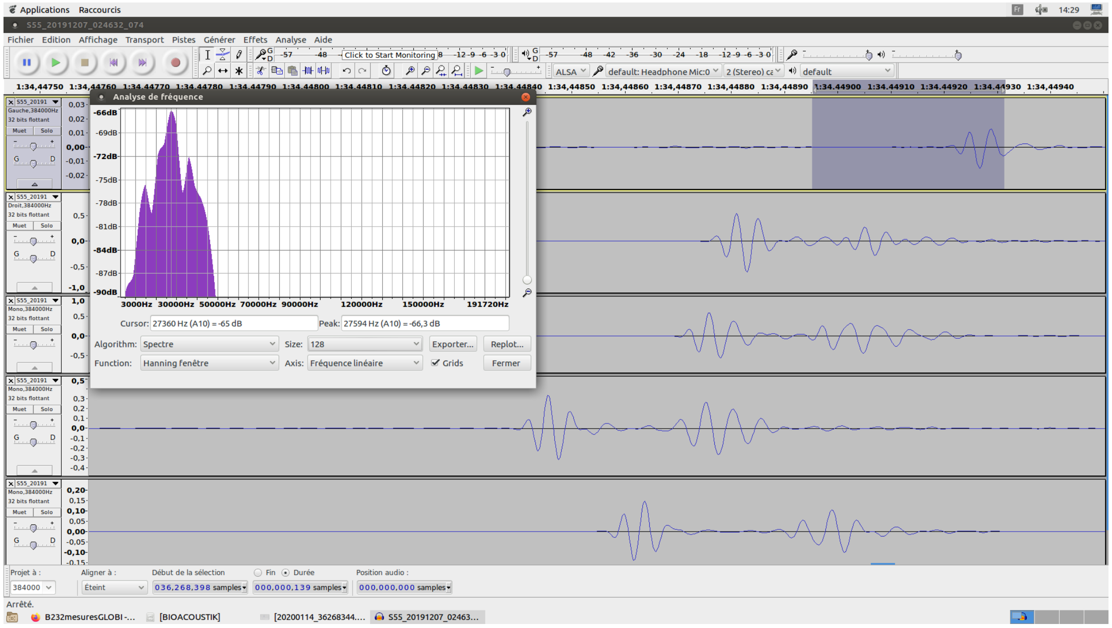

Figure 1.35: Spectral analysis of the first way. There is no P0P1 for this way, P1 is crash

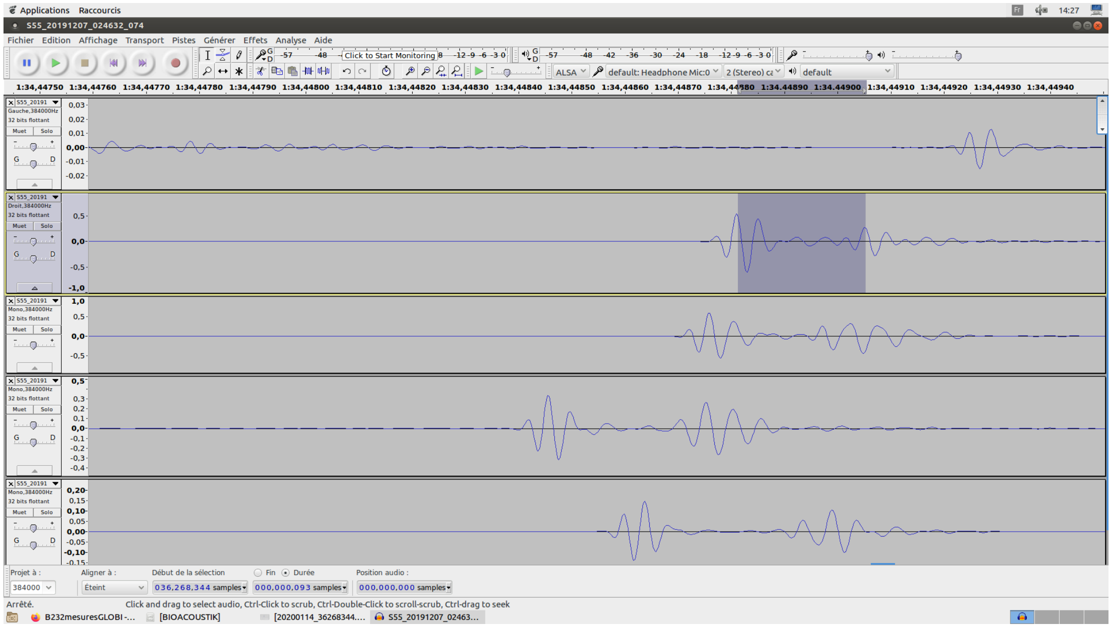

Figure 1.36: Picture of POP1 for the second way at 1:34

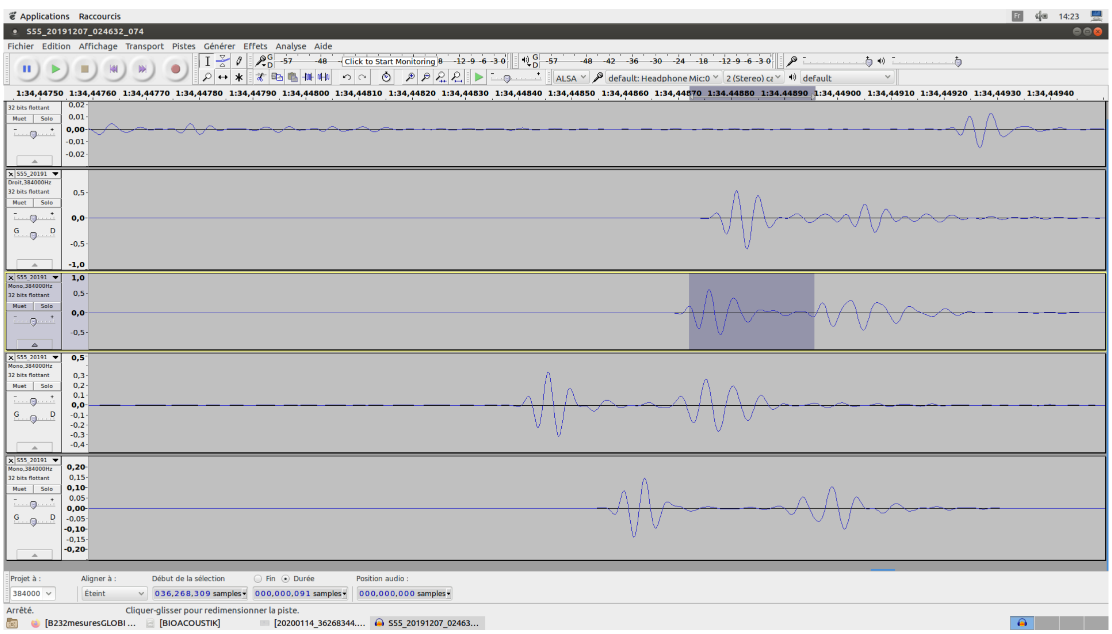

Figure 1.37: Picture of POP1 for the third way at 1:34

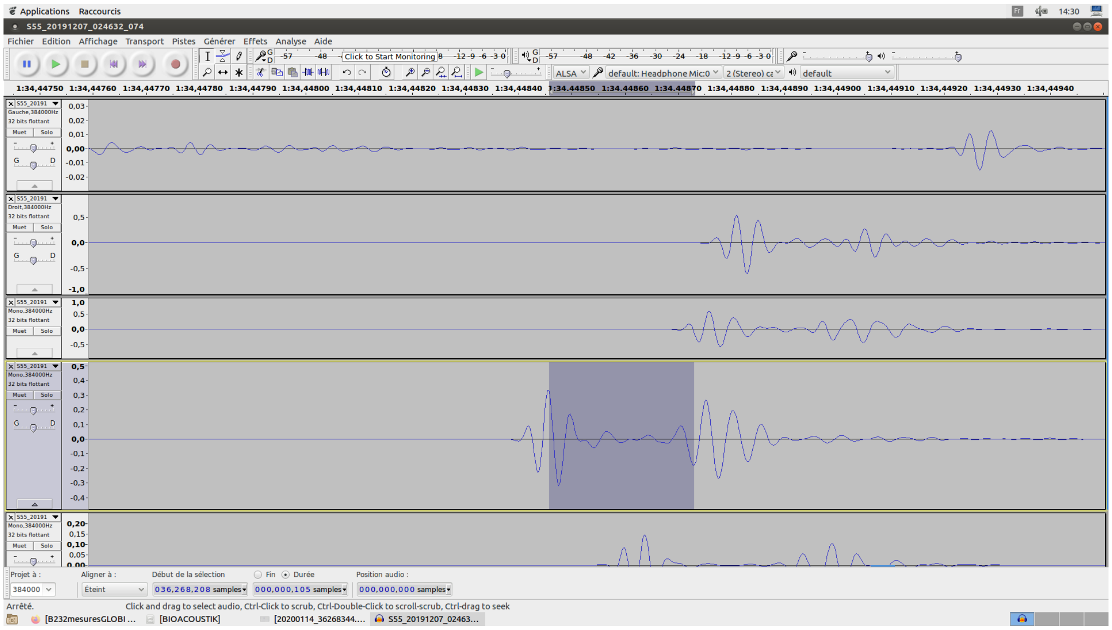

Figure 1.38: Picture of POP1 for the way 4 at 1:34

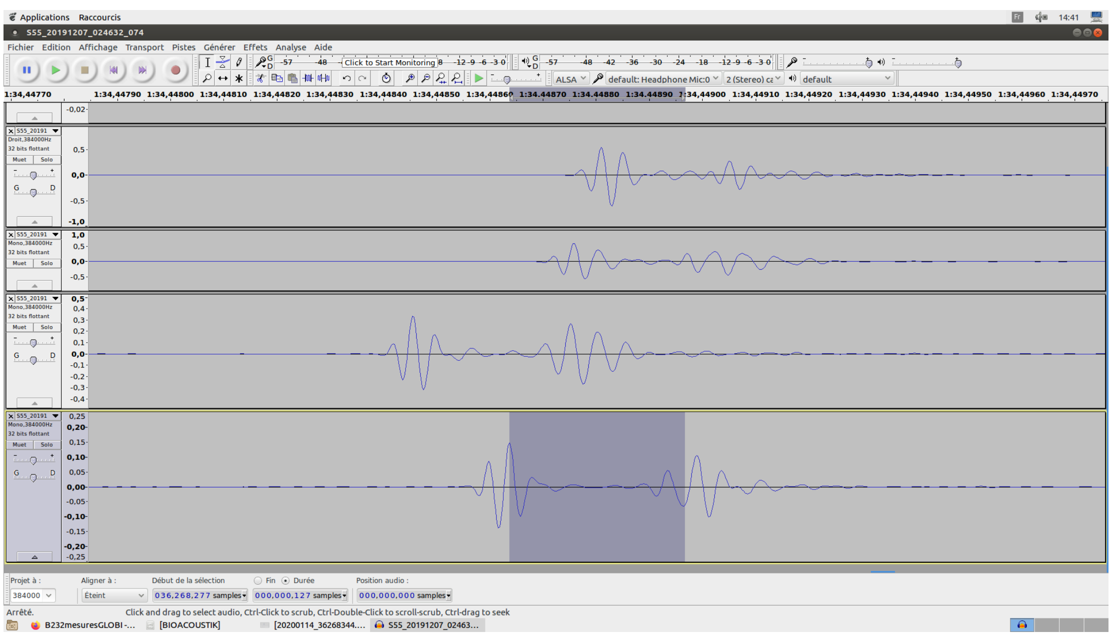

Figure 1.39: Picture of POP1 for the way 5 at 1:34. It could be a big Pilot Whale, with a distance between the phonetic lips and the frontal air bag about 15cm.

This click was obtained from an audio track viewed using Audacity software. We we first equalized. Then We passed on the original signal a high pass filter (wavelet) at 15 kHz allowing to encode the information in the form of wavelet coefficients, and a low pass filter (scaling function) at 30 kHz, all for 48dB.

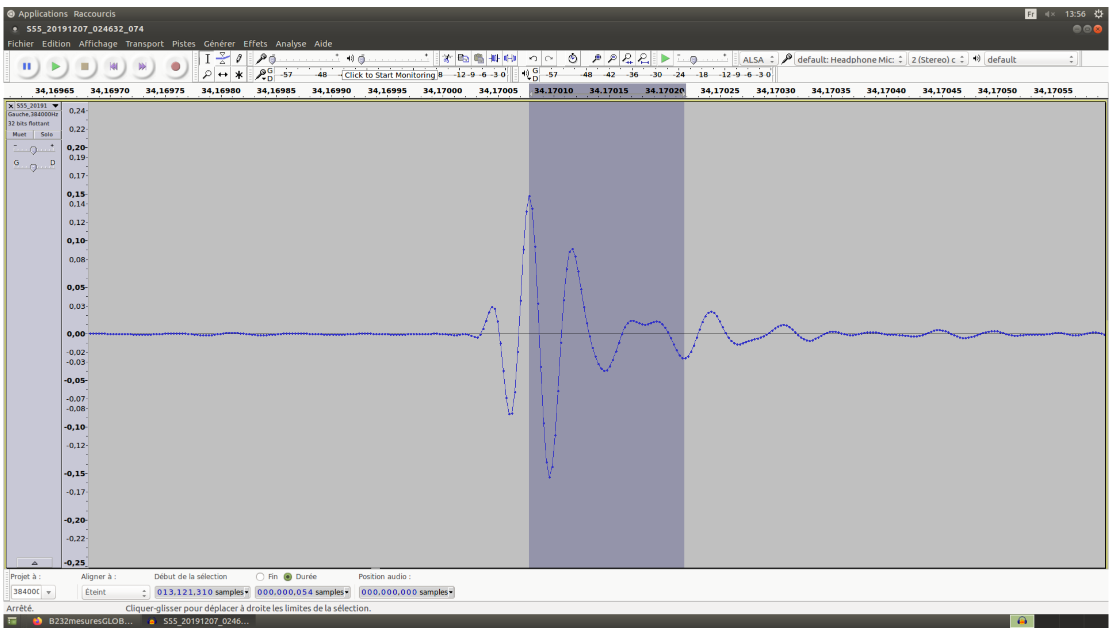

Figure 1.40: Distance between P0 and P1 with the hydrophone 1. Click size is 54 samples.

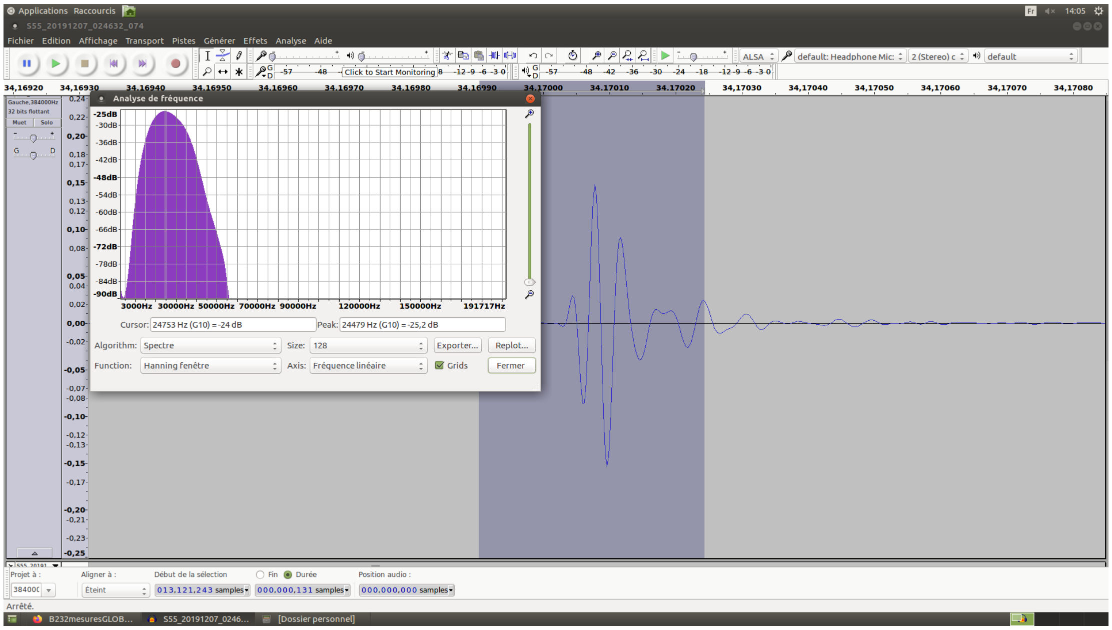

Figure 1.41: Spectrum analysis of P0 with the hydrophone 1. We can see that the frequency peak of P0 is equal to 22479 Hz

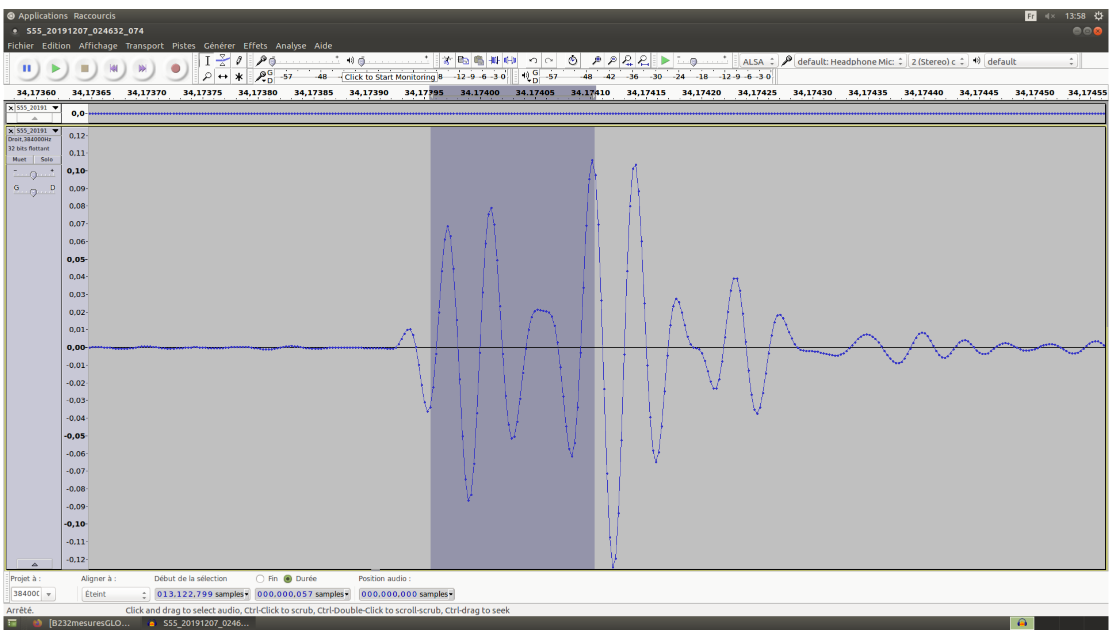

Figure 1.42: Distance between P0 and P1 with the hydrophone 2. Click size is 57 samples.

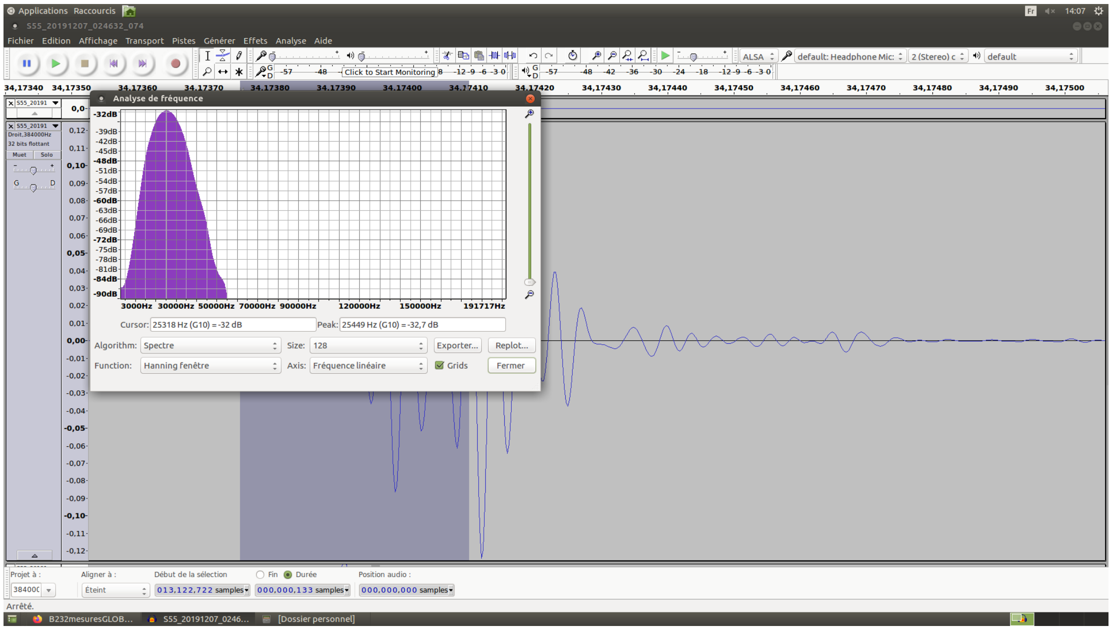

Figure 1.43: Spectrum analysis of P0 with the hydrophone 2. The frequency peak of P0 is equal to 25449 Hz.

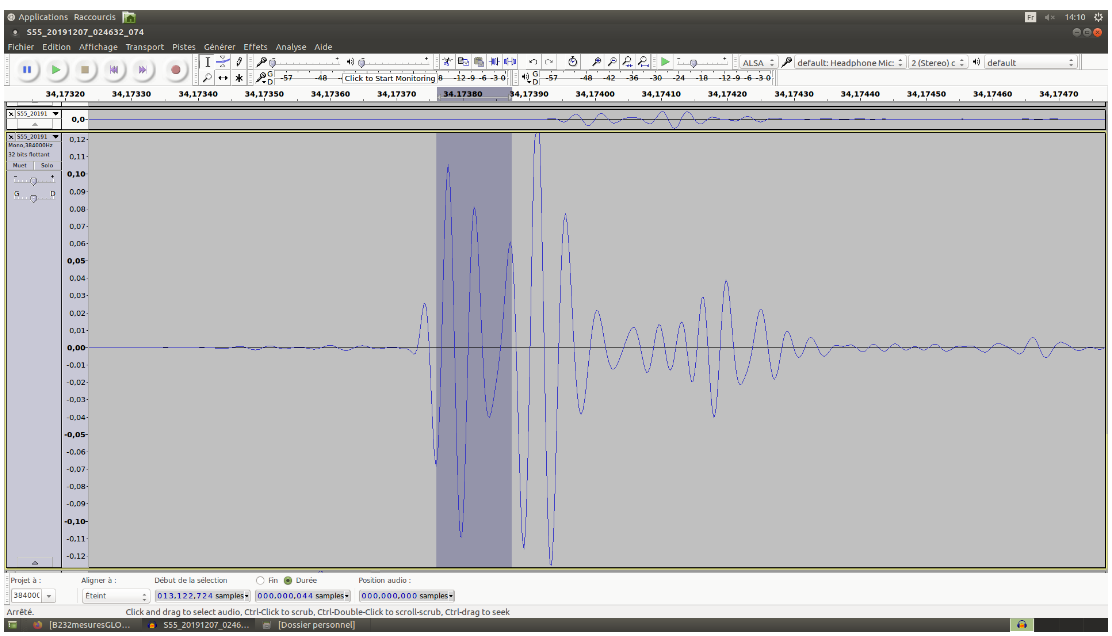

Figure 1.44: Distance between P0 and P1 with the hydrophone 3. Click size is 44 samples

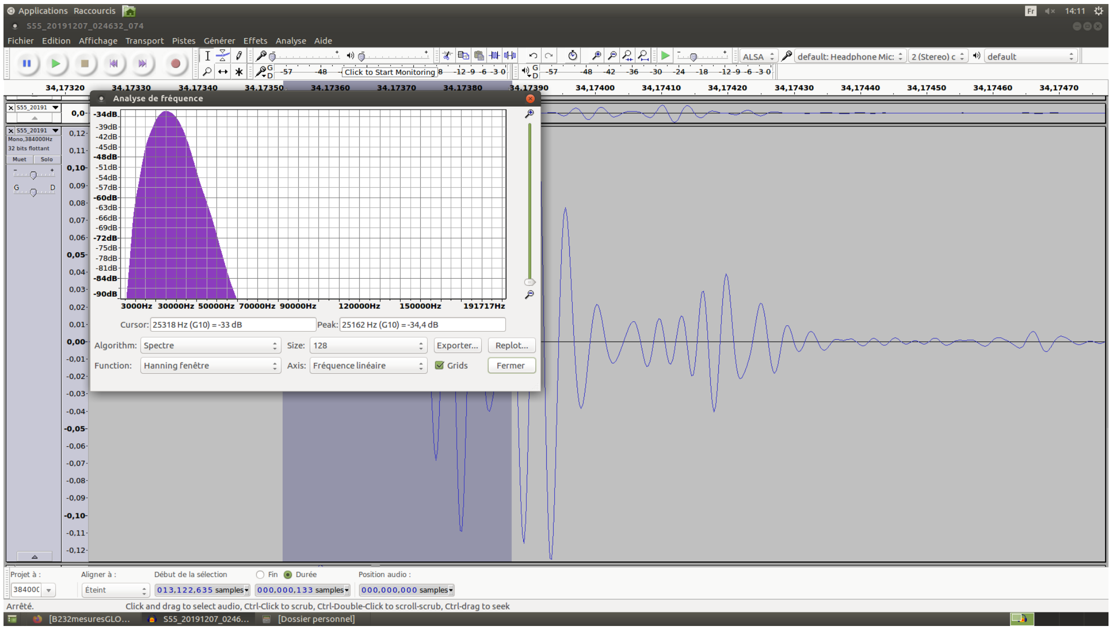

Figure 1.45: Spectrum analysis of P0 with the hydrophone 3. The frequency peak of P0 is equal to 25162 Hz.

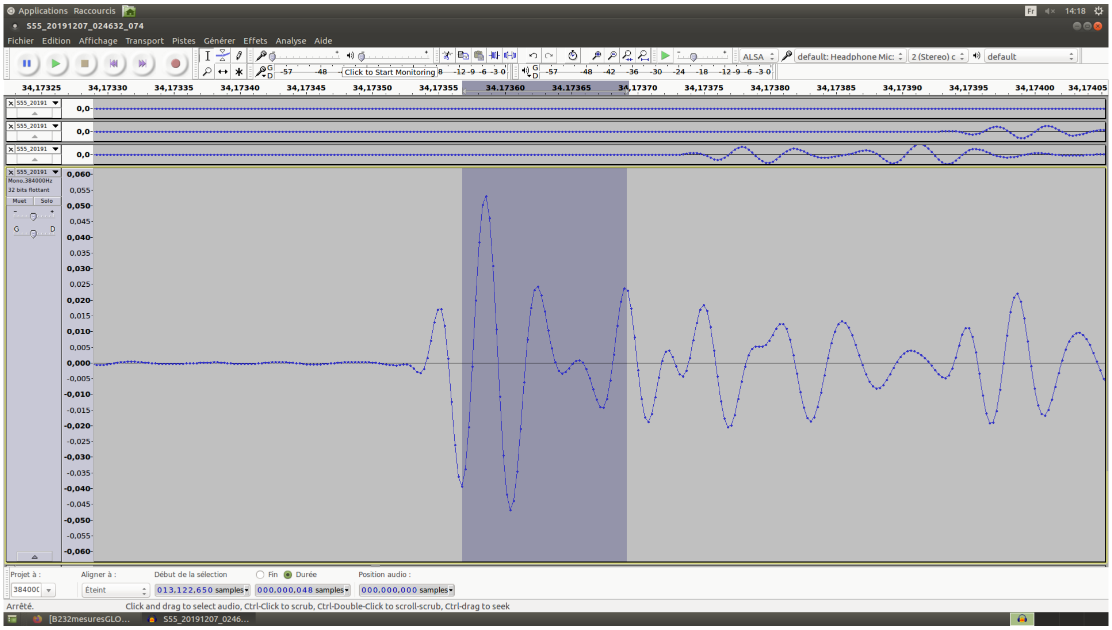

Figure 1.46: Distance between P0 and P1 with the hydrophone 4. It is observed that the pulse P0 on this hydrophone begins negatively because the hydrophone has been connected backwards. Click size is 47 samples.

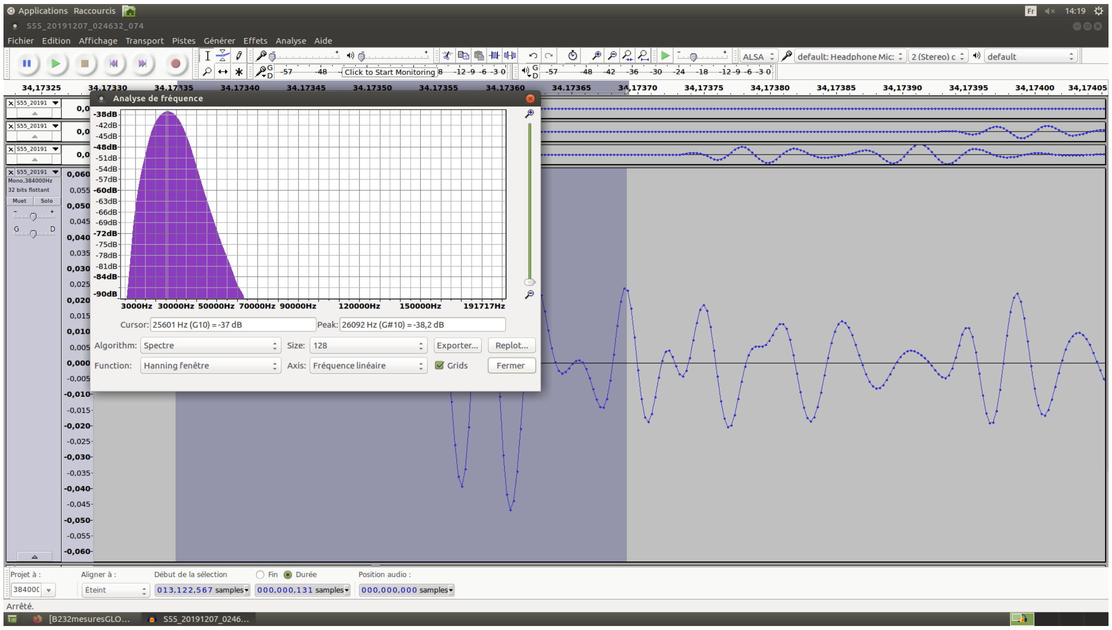

Figure 1.47: Spectrum analysis of P0 with the hydrophone 4. The frequency peak of P0 is equal to 26092

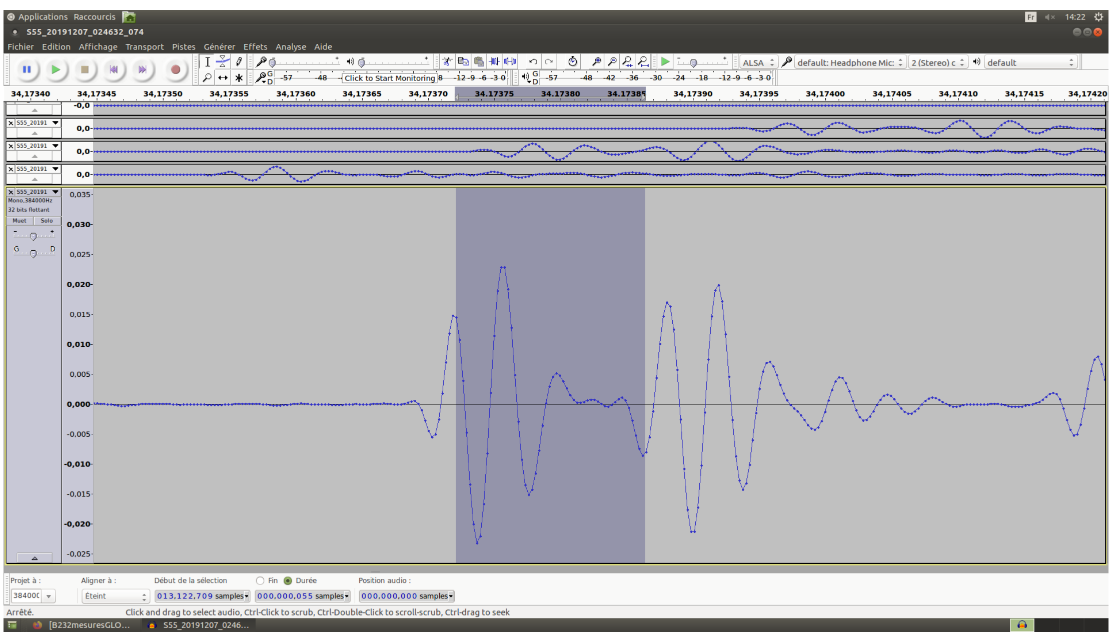

Figure 1.48: Distance between P0 and P1 with the hydrophone 5. Like hydrophone 4, the P0 pulse on hydrophone 5 starts negatively because it has been connected backwards. Click size is 55 samples.

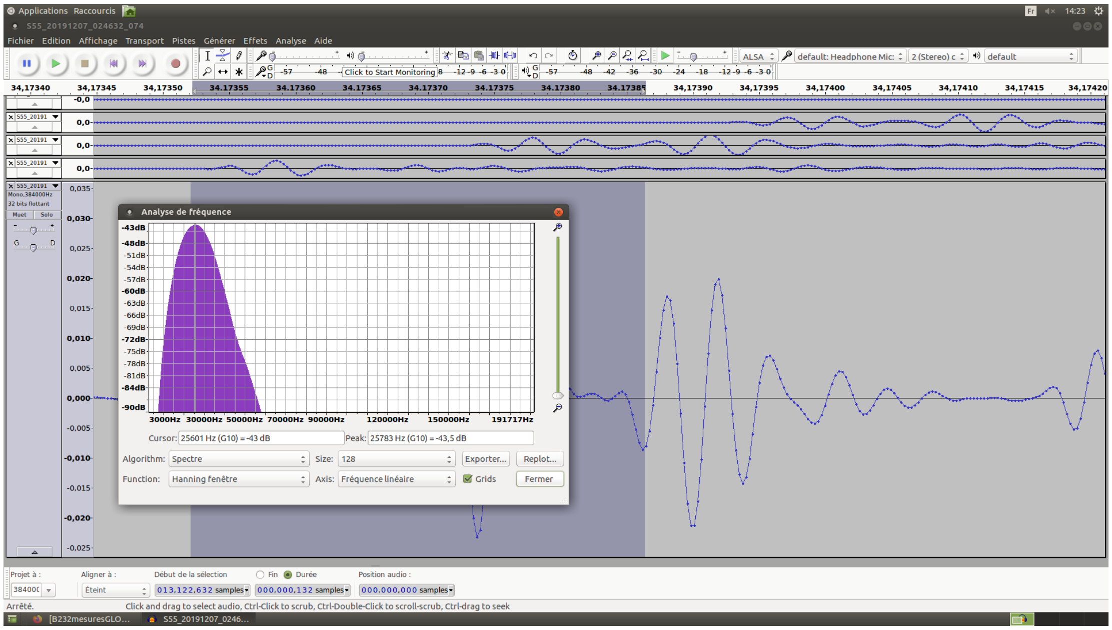

Figure 1.49: Spectrum analysis of P0 with the hydrophone 5. The frequency peak of P0 is equal to 25783.

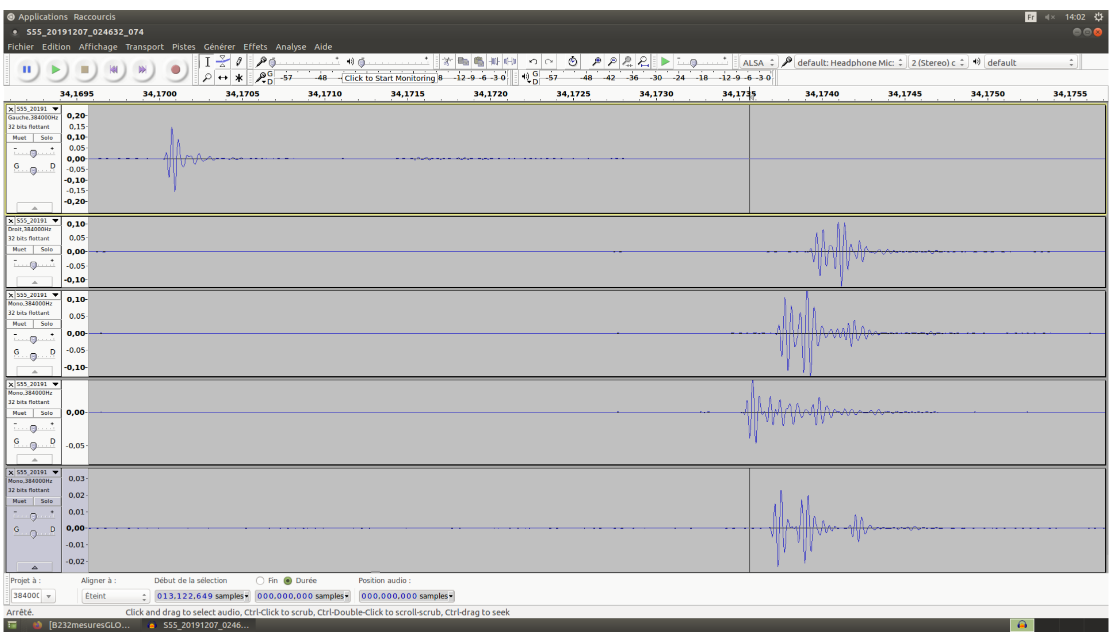

Figure 1.50: Figure showing a click of pilot whale and its arrival time offset on each of the 5 hydrophones (hydrophone 1 to 5 from top to bottom). The earliest arrival date is on hydrophone 1, the latest on hydrophone 2.

Conclusion for Pilot whale click : The pulse propagates through the melon when decompressed. The emission of P0 on the air bag can be re-emitted and pass back through the melon P1 (equal to the second pulse). It depends on the size of the animal. As a result, the pulse twice makes its way to the melon. To cross the melon, the pulse takes 1600 m/s. We worked with the order of magnitude of 380000 samples/second. So we can calculate the distance between the phonic lip and the airbag. For my click, we find a distance of 10.04 cm between the airbag and the phonic lip and this is an average distance that we can find in the literature for the pilot whales.

Conclusion for the spectrum analysis : The frequency of sound emission between each hydrophone will make it possible to find the position of the animal in space. The maximum frequency is 26090 Hz with the hydrophone 4 and the minimum frequency is 24479 Hz with the hydrophone 1 which makes a difference of 1611 Hz. There is not much difference between each hydrophone, so the animal is about the same distance between each hydrophone. However, the transmission frequency is slightly higher with hydrophone 4, which may indicate that the animal's head is slightly turned towards this hydrophone.Thus, we can suppose that the animal has its back slightly turned towards the hydrophone 1 whose frequency is the lowest.

1.6 Louise DALISSON

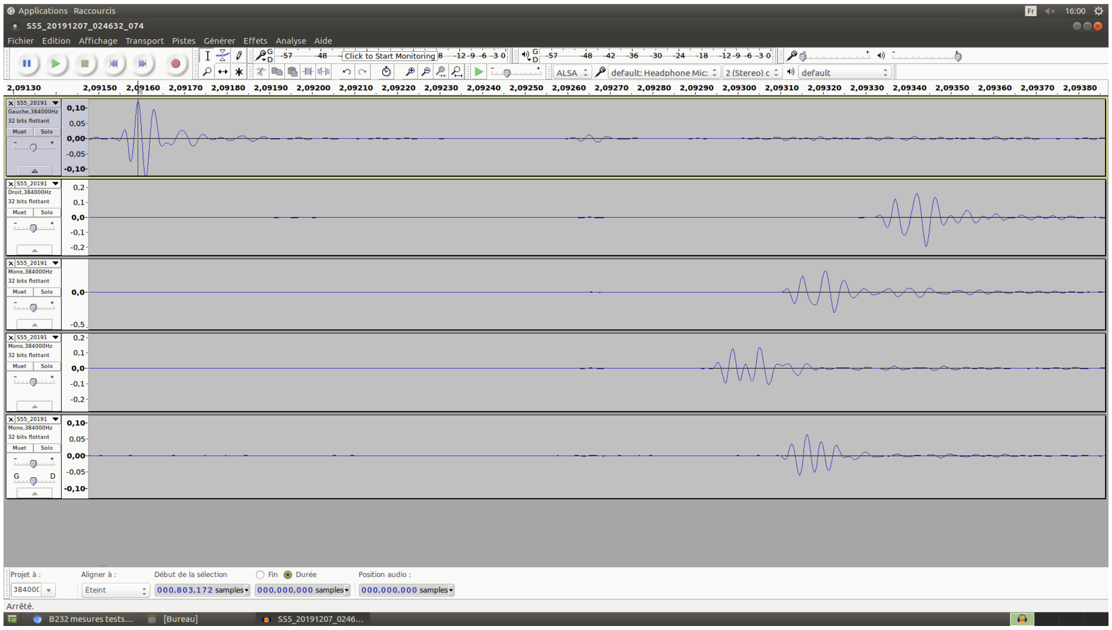

Figure 1.51: Clicks on the five channels at 2.09 seconds by Louise DALISSON

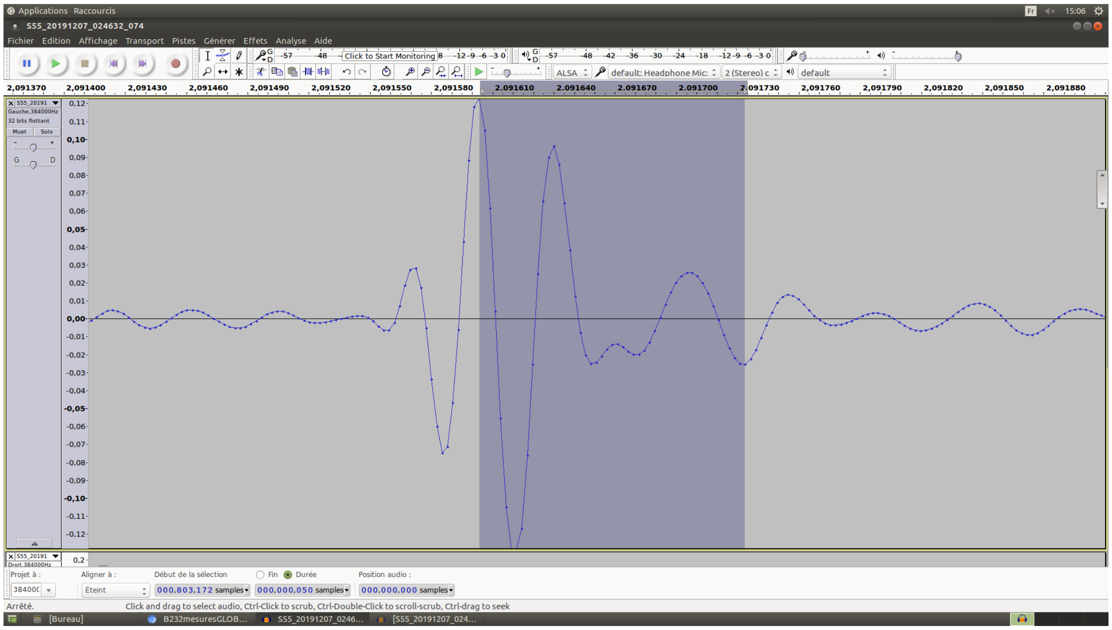

Figure 1.52: Click on the hydrophone 1 at 2.09 seconds by Louise DALISSON

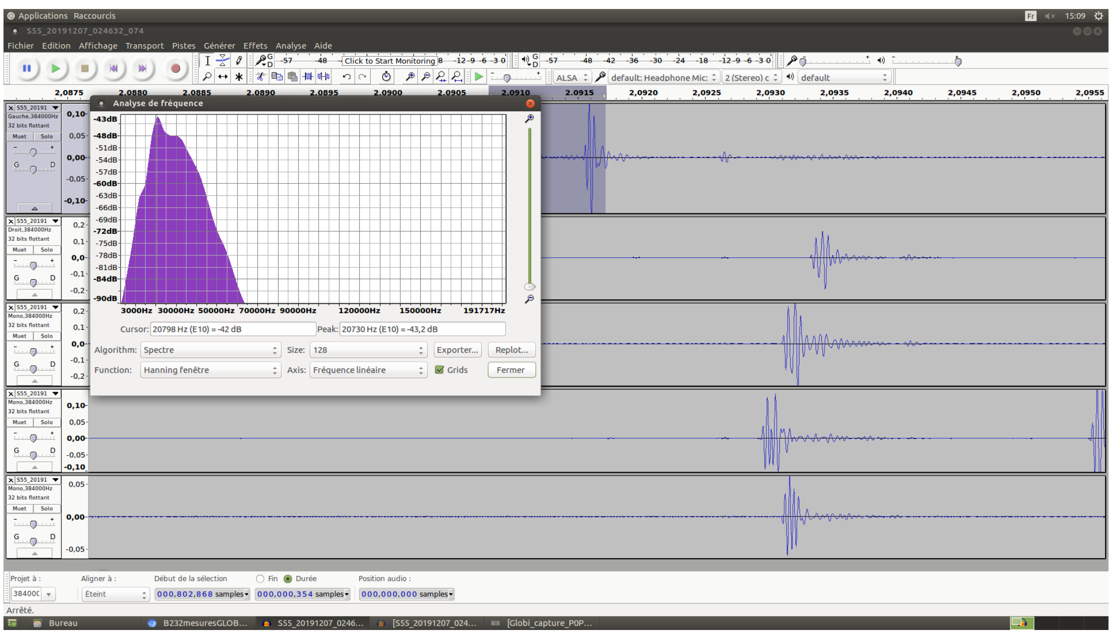

Figure 1.53: Spectral analysis for the hydrophone 1 at 2.09 seconds by Louise DALISSON

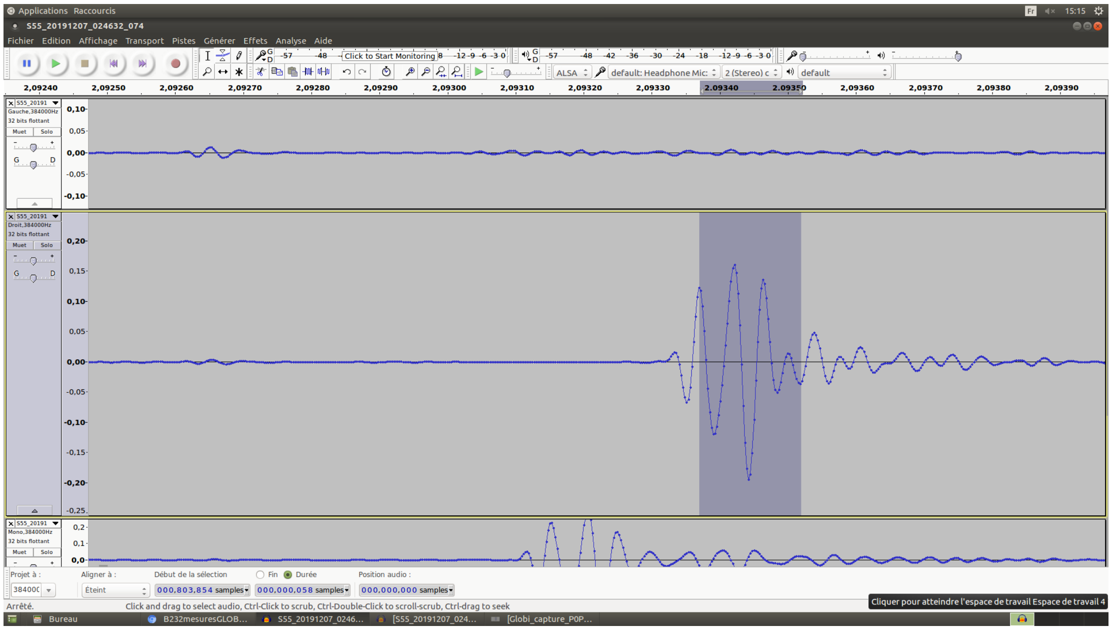

Figure 1.54: Click on the hydrophone 2 at 2.09 seconds by Louise DALISSON

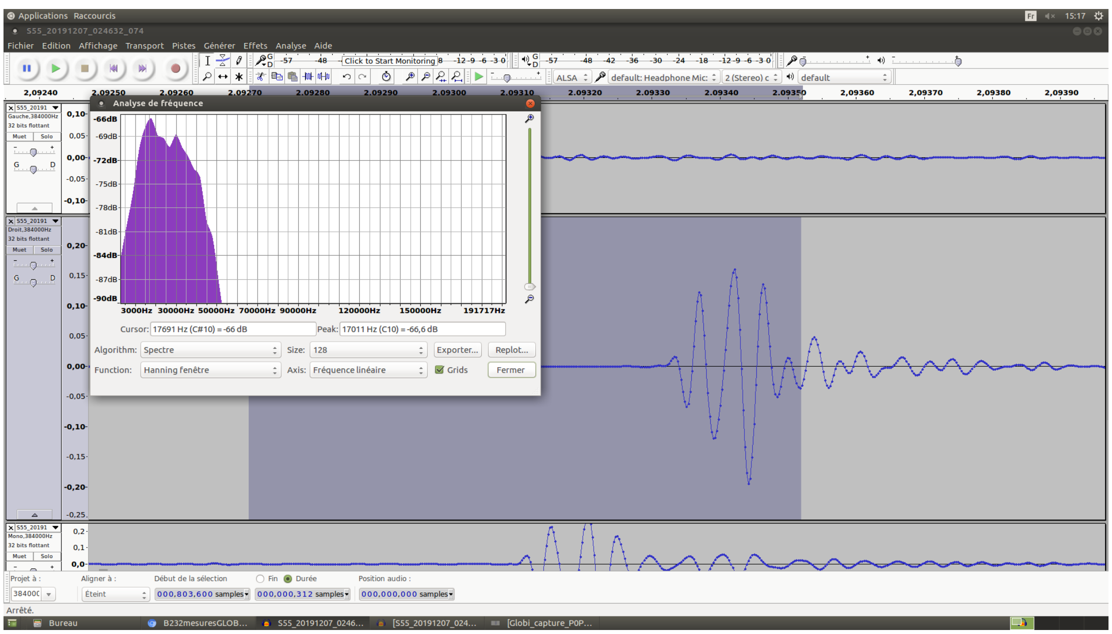

Figure 1.55: Spectral analysis for the hydrophone 2 at 2.09 seconds by Louise DALISSON

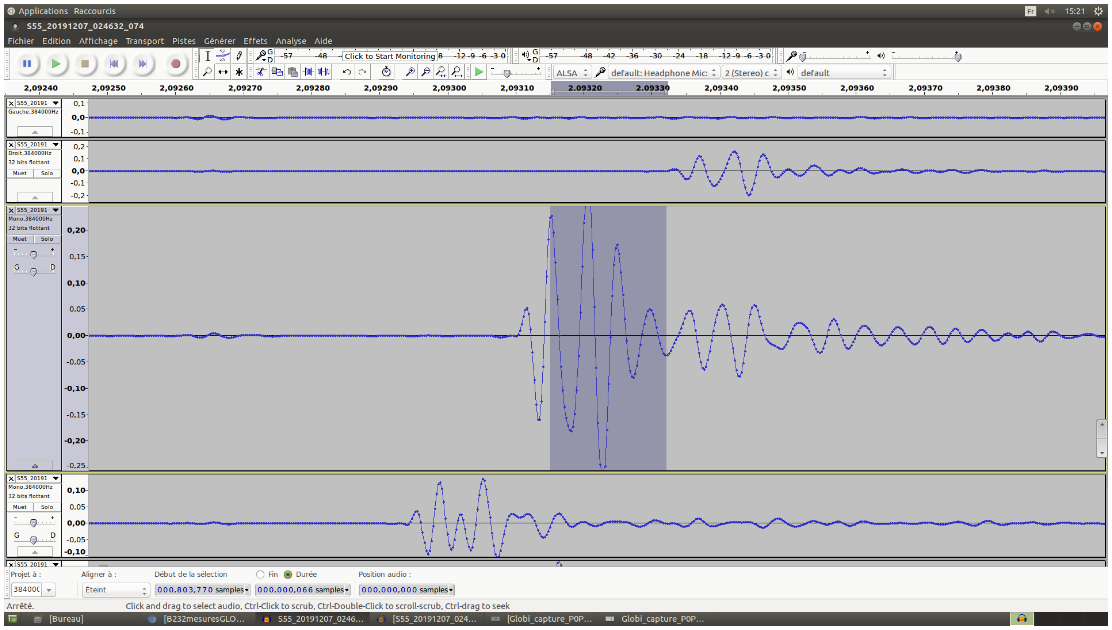

Figure 1.56: Click on the hydrophone 3 at 2.09 seconds by Louise DALISSON

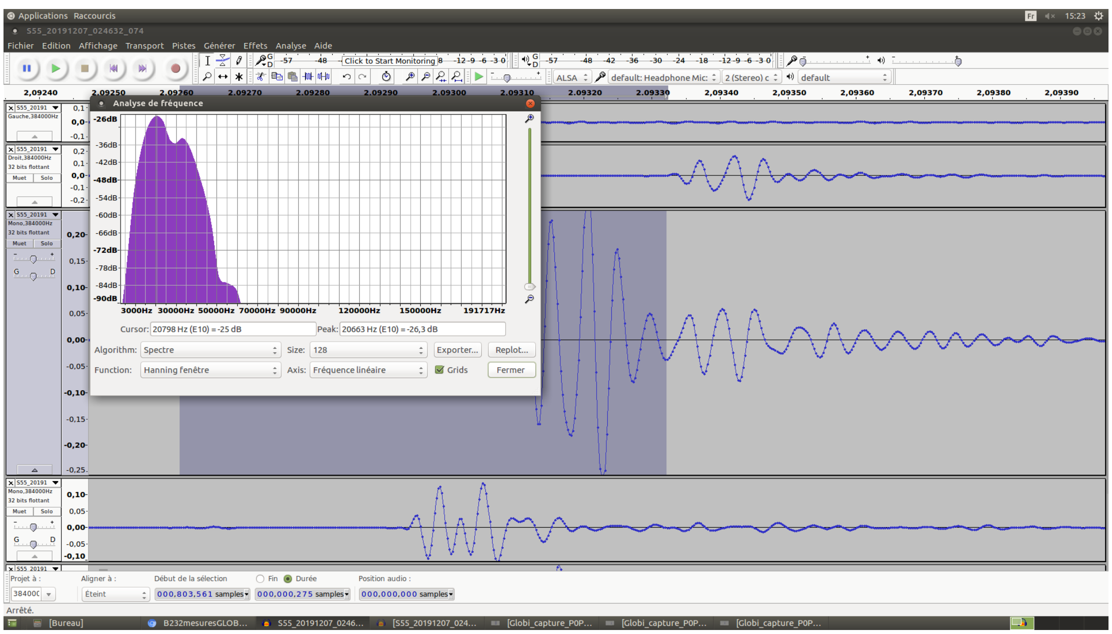

Figure 1.57: Spectral analysis for the hydrophone 3 at 2.09 seconds by Louise DALISSON

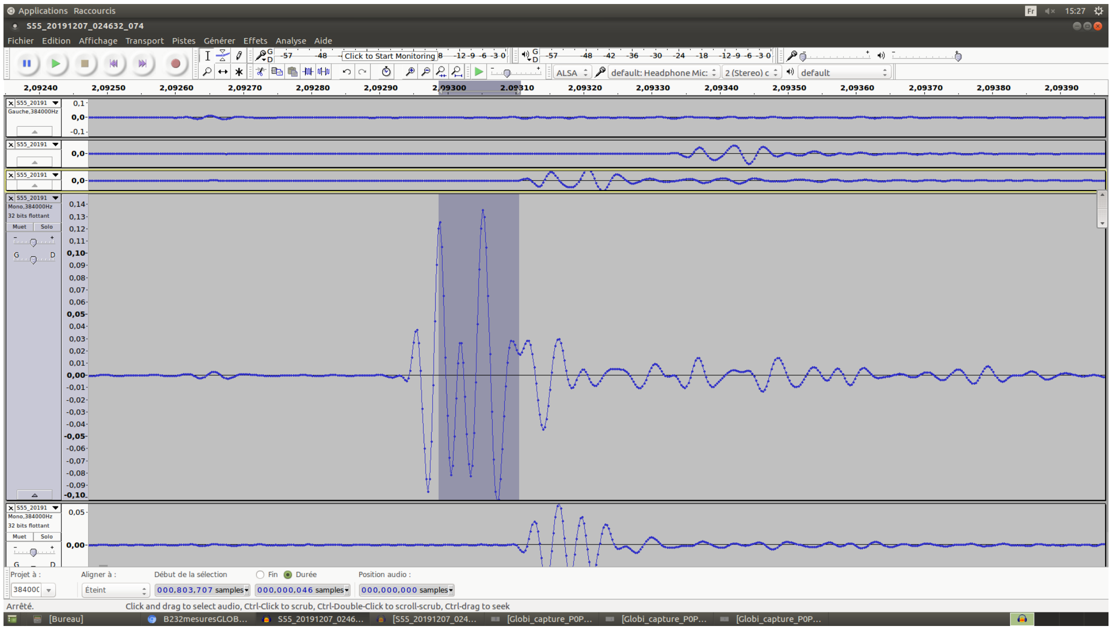

Figure 1.58: Click on the hydrophone 4 at 2.09 seconds by Louise DALISSON

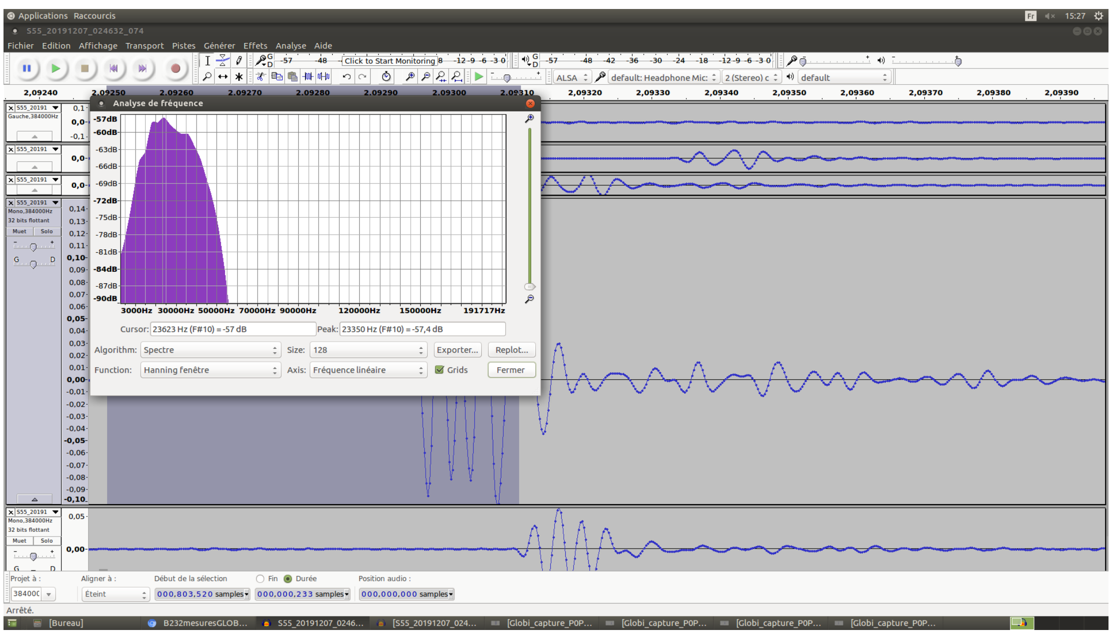

Figure 1.59: Spectral analysis for the hydrophone 4 at 2.09 seconds by Louise DALISSON

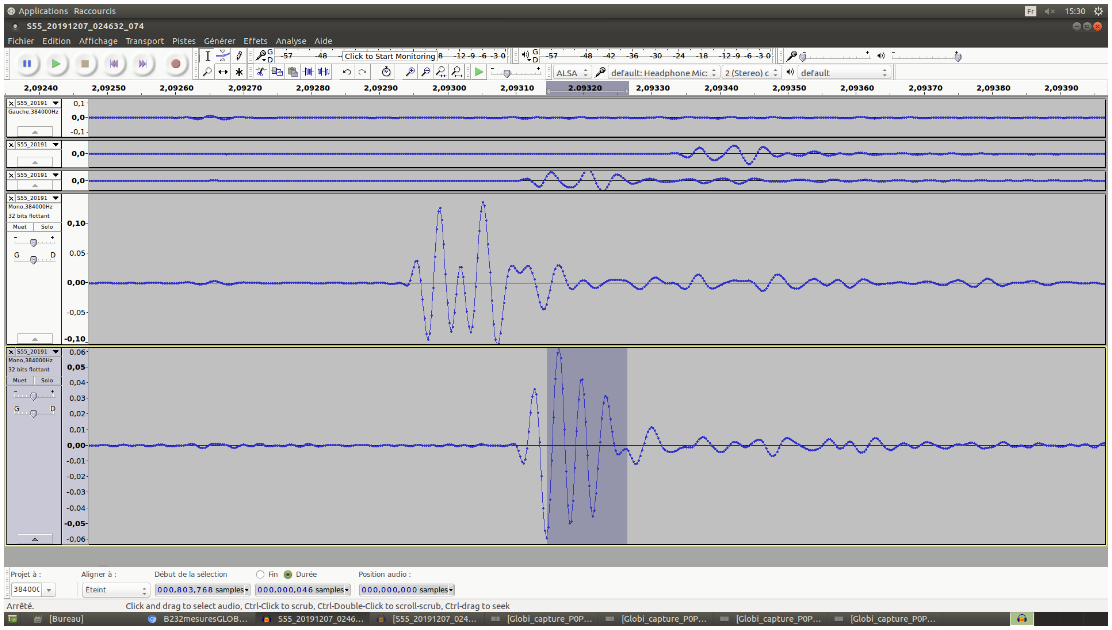

Figure 1.60: Click on the hydrophone 5 at 2.09 seconds by Louise DALISSON

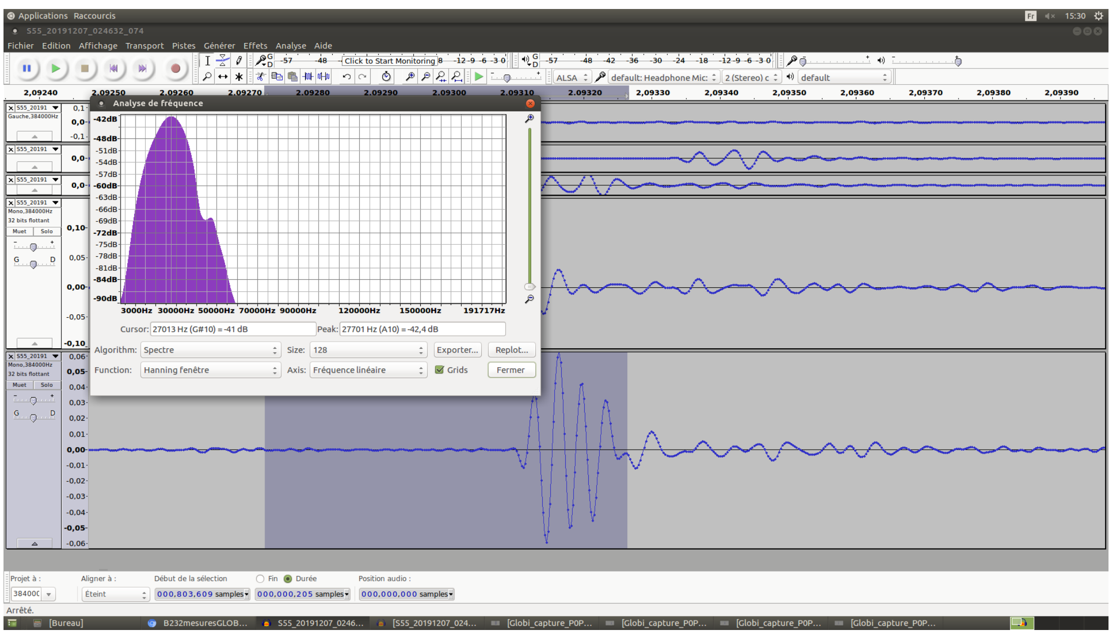

Figure 1.61: Spectral analysis for the hydrophone 5 at 2.09 seconds by Louise DALISSON

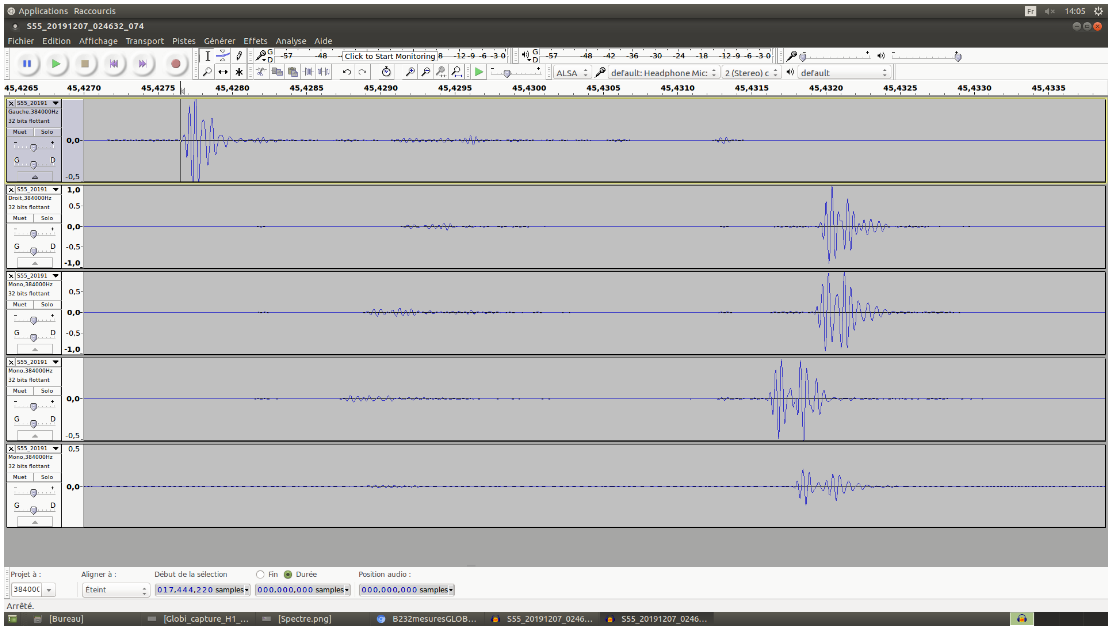

Figure 1.62: Clicks on the five channels at 45.42 seconds by Louise DALISSON

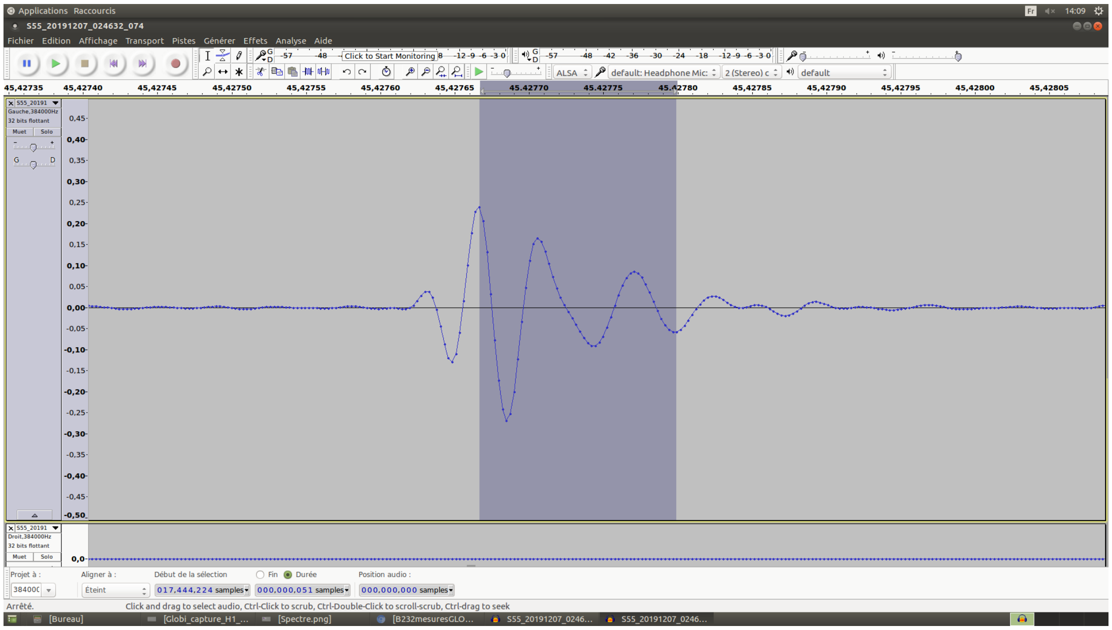

Figure 1.63: Click on the hydrophone 1 at 45.42 seconds by Louise DALISSON

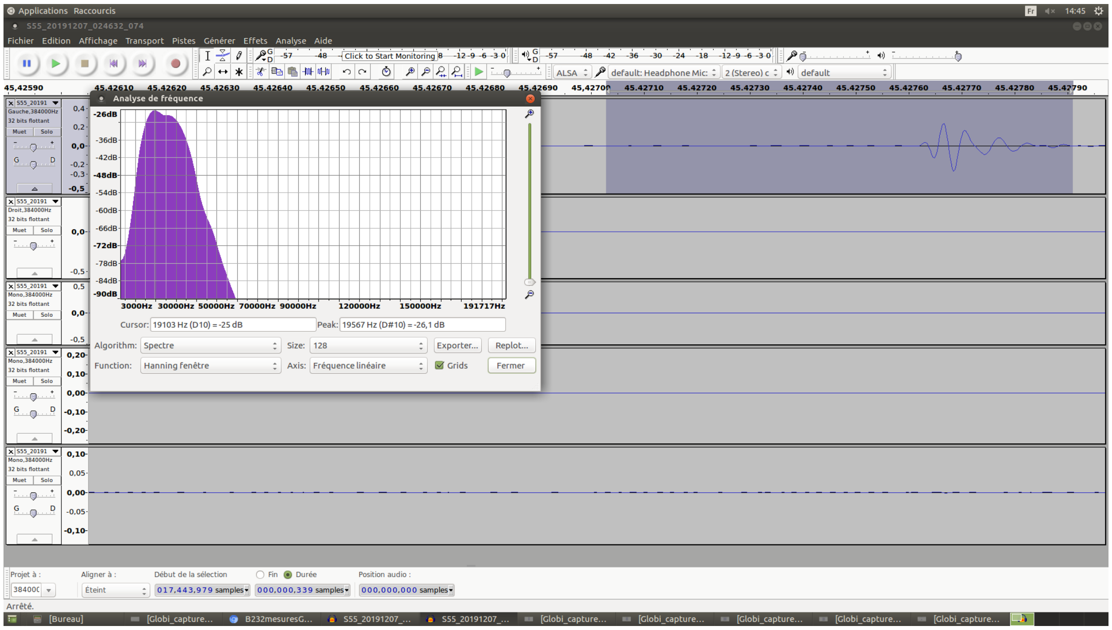

Figure 1.64: Spectral analysis for the hydrophone 1 at 45.42 seconds by Louise DALISSON

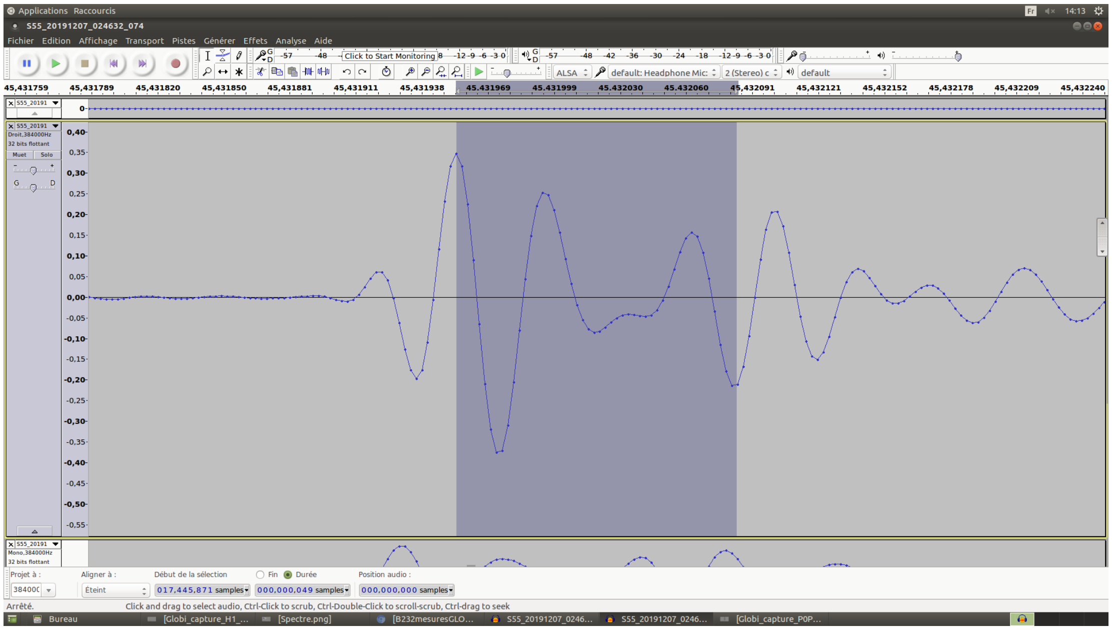

Figure 1.65: Click on the hydrophone 2 at 45.42 seconds by Louise DALISSON

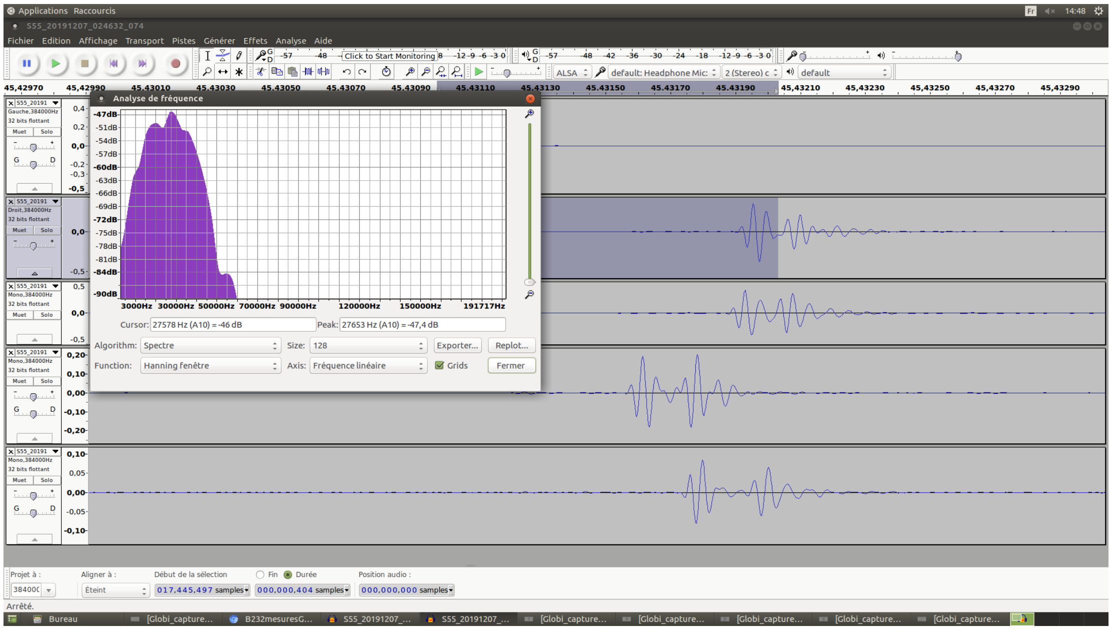

Figure 1.66: Spectral analysis for the hydrophone 2 at 45.42 seconds by Louise DALISSON

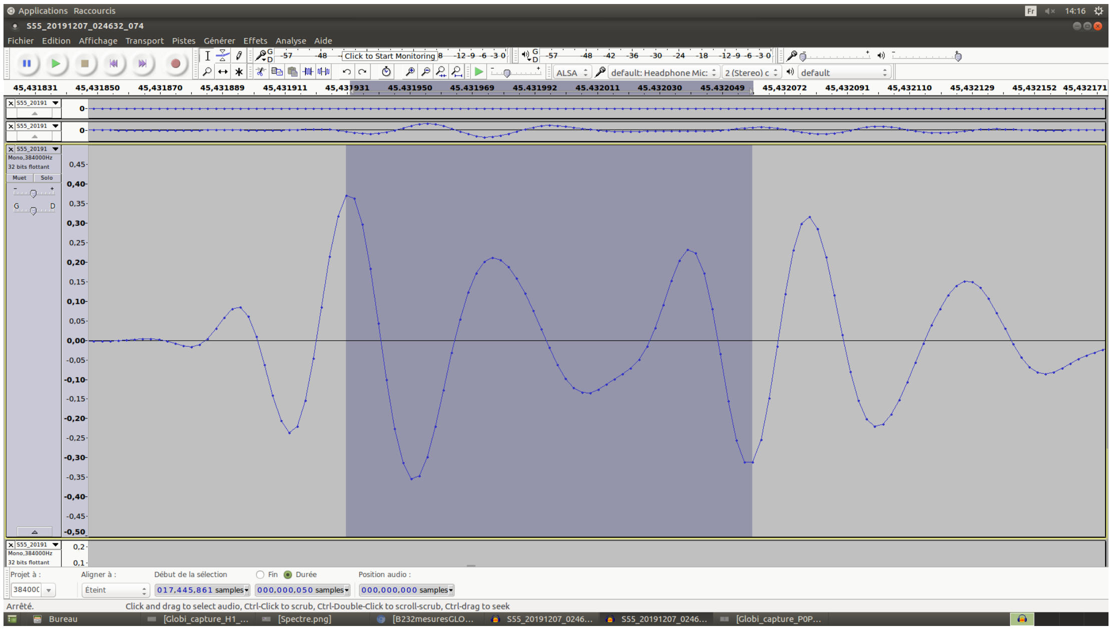

Figure 1.67: Click on the hydrophone 3 at 45.42 seconds by Louise DALISSON

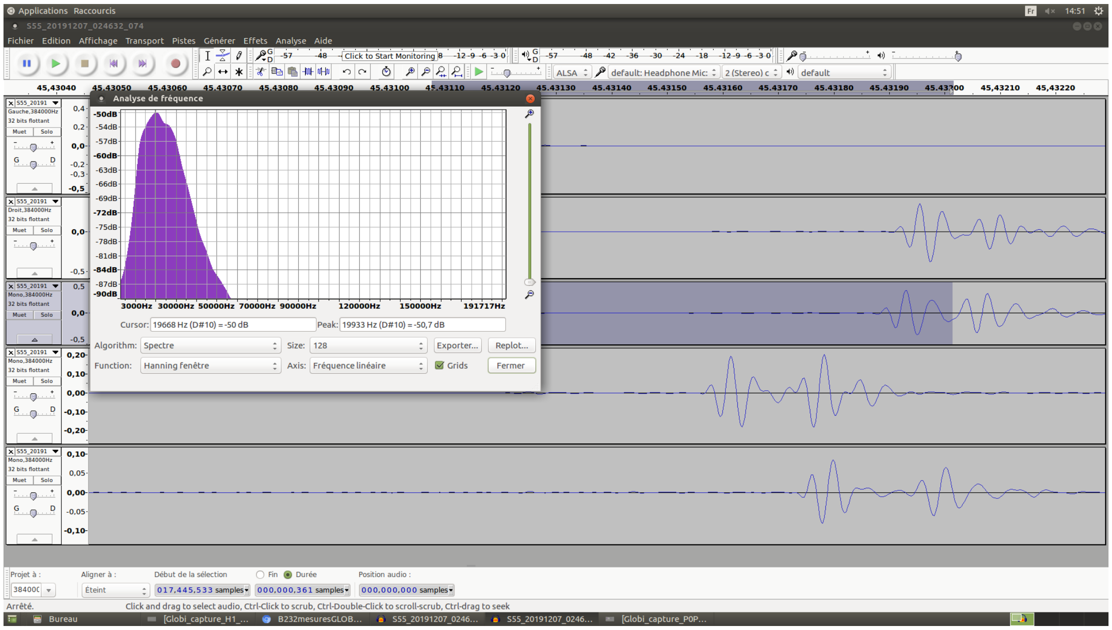

Figure 1.68: Spectral analysis for the hydrophone 3 at 45.42 seconds by Louise DALISSON

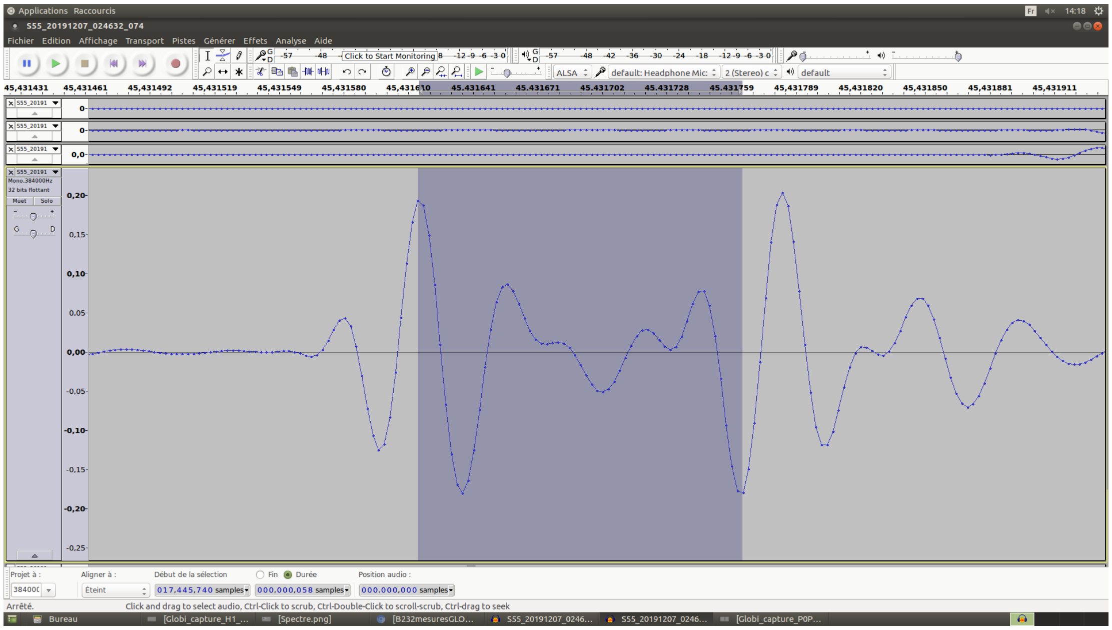

Figure 1.69: Click on the hydrophone 4 at 45.42 seconds by Louise DALISSON

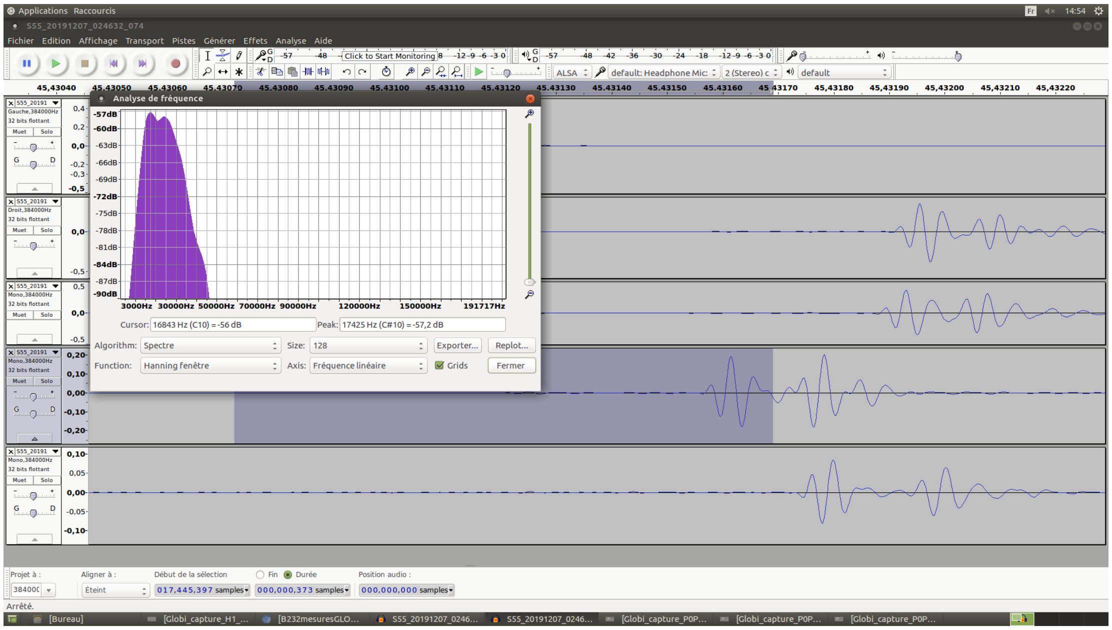

Figure 1.70: Spectral analysis for the hydrophone 4 at 45.42 seconds by Louise DALISSON

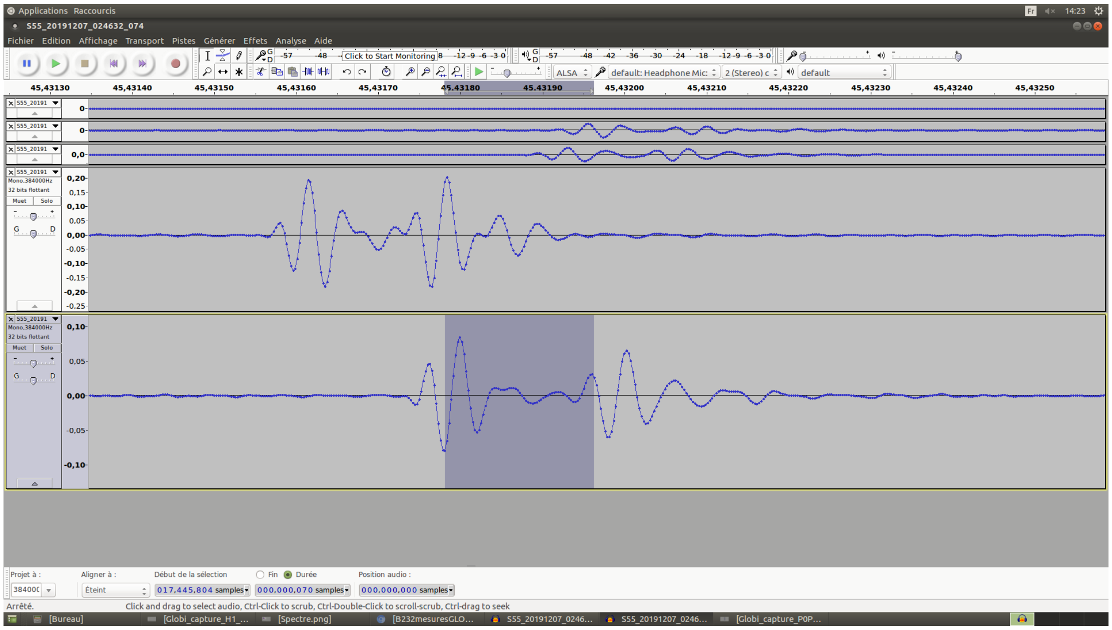

Figure 1.71: Click on the hydrophone 5 at 45.42 seconds by Louise DALISSON

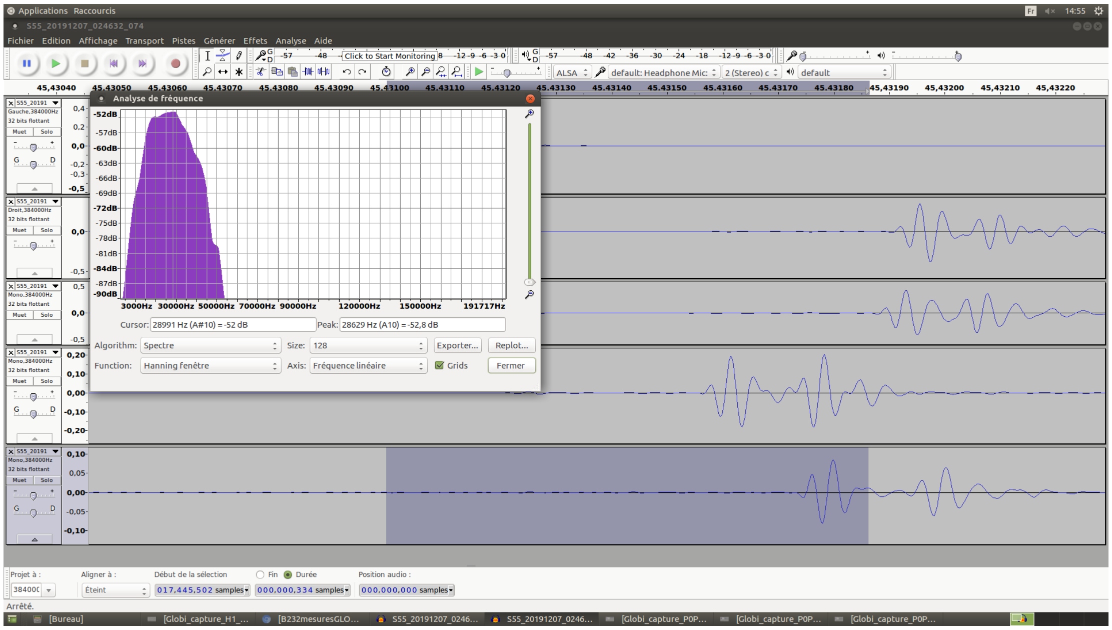

Figure 1.72: Spectral analysis for the hydrophone 5 at 45.42 seconds by Louise DALISSON

1.7 Measurements at 2.36 seconds by Estelle BERGONZOLI

As we can see by comparing these 5 hydrophones, the POP1 measurements are very close (32, 33, 33, 32, 33). After having measured the differences in signal reception times between the 5 channels, these delays are also very short, even insignificant. From this, we can describe the position of the animal and deduce that it is equidistant from the 5 hydrophones.

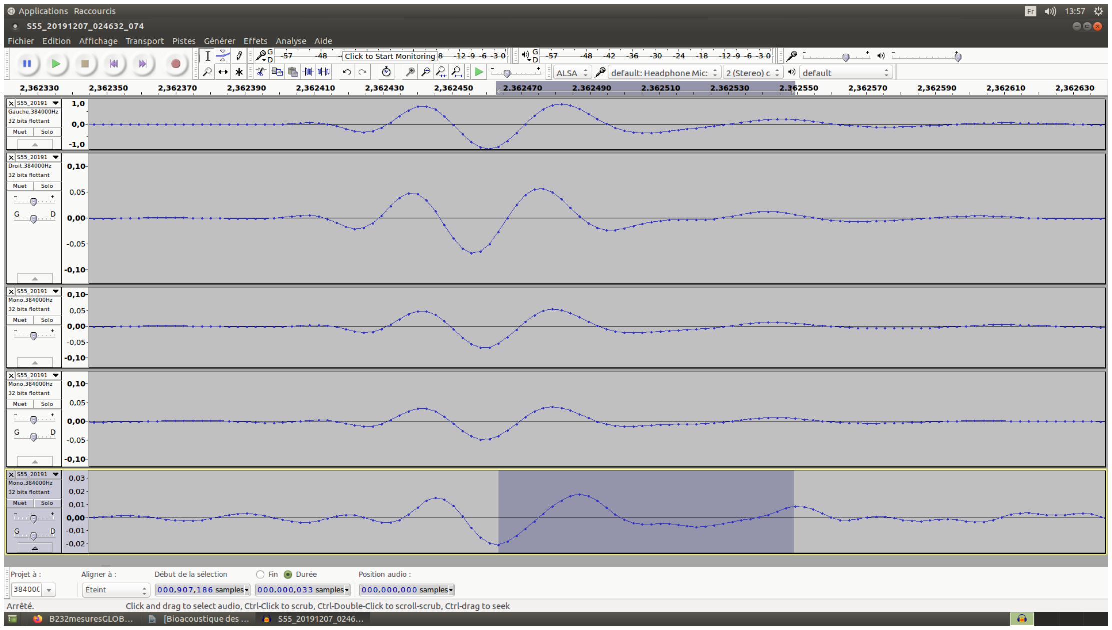

Figure 1.73: Pilot whale click at 2,36 seconds between the five hydrophones

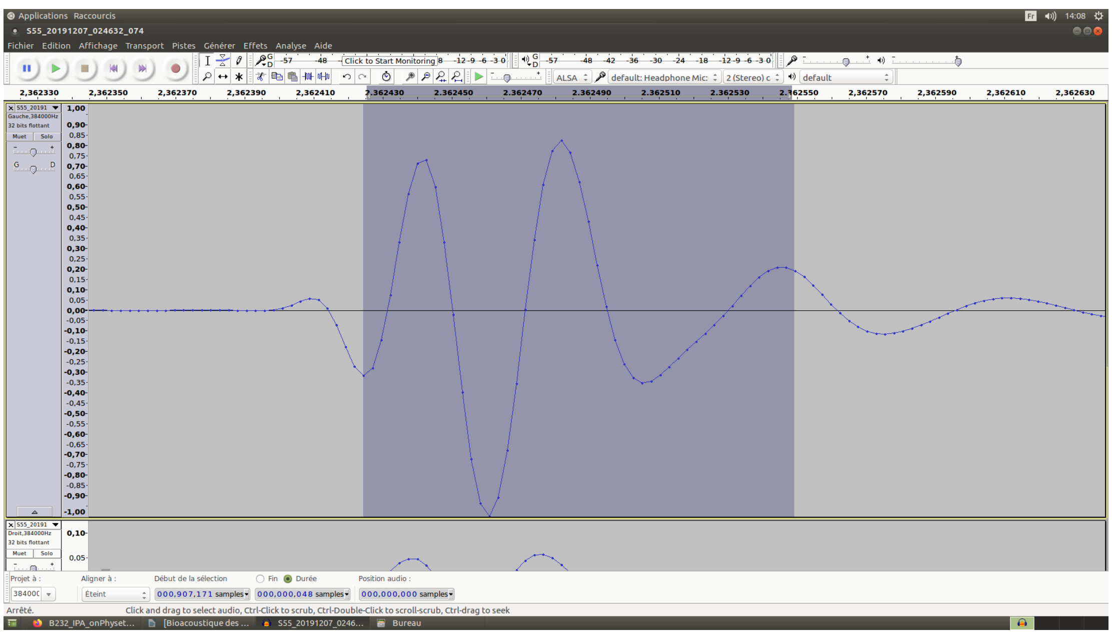

Figure 1.74: Pilot whale clic with hydrophone 1 at 2 seconds 36 (P0P1 = 32 samples)

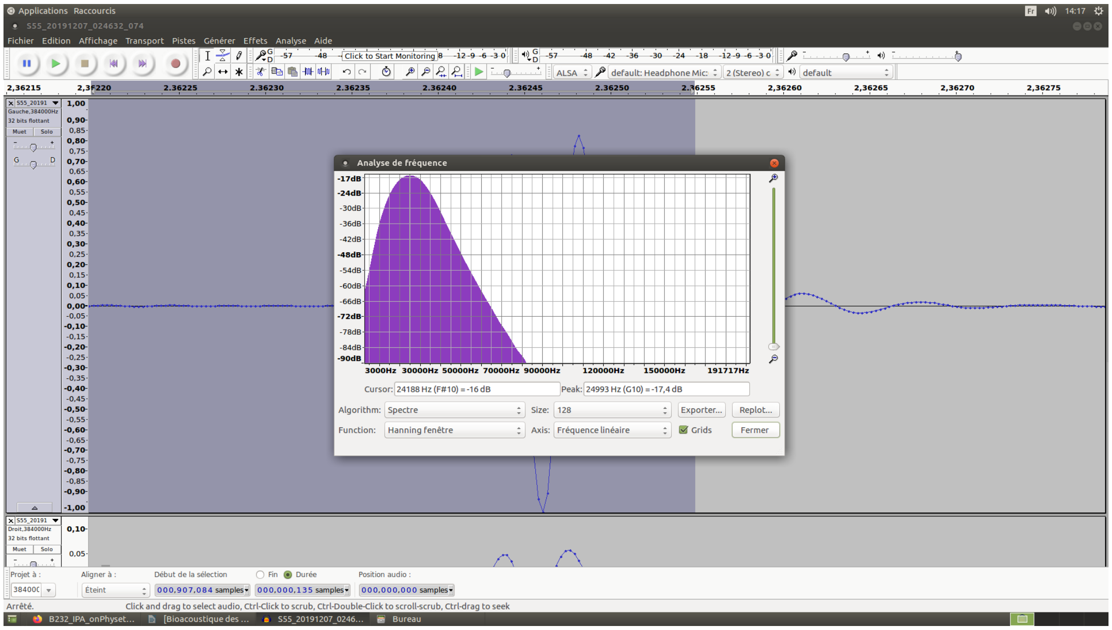

Figure 1.75: Frequency spectrum with hydrophone 1 at 2 seconds 36 (Freq = 24993 Hz).

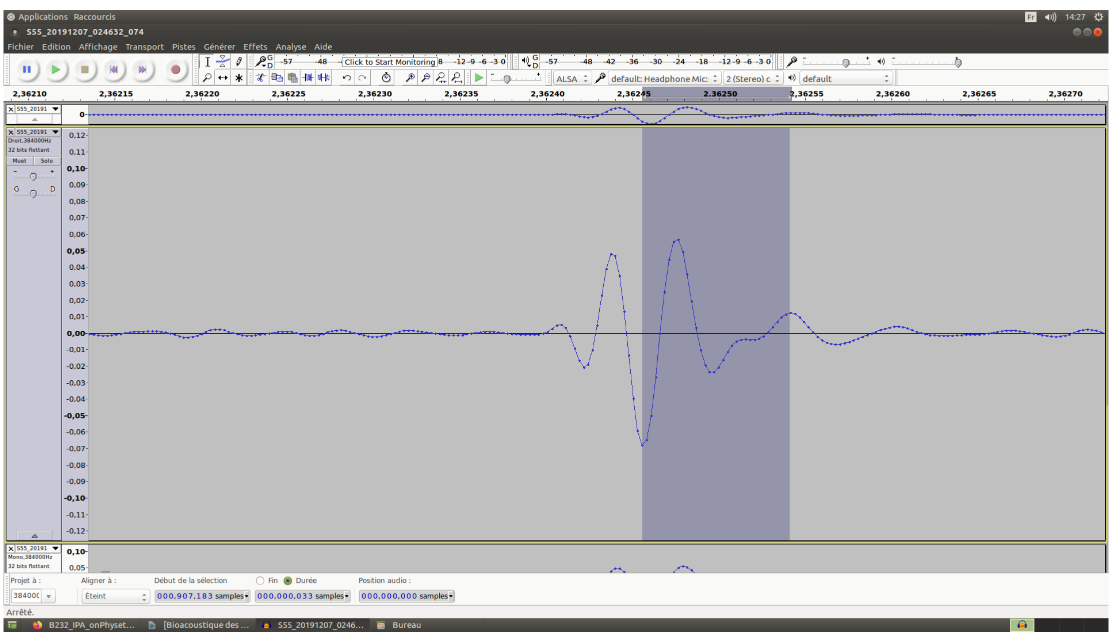

Figure 1.76: Pilot whale clic with hydrophone 2 at 2 seconds 36 (P0P1 = 33 samples)

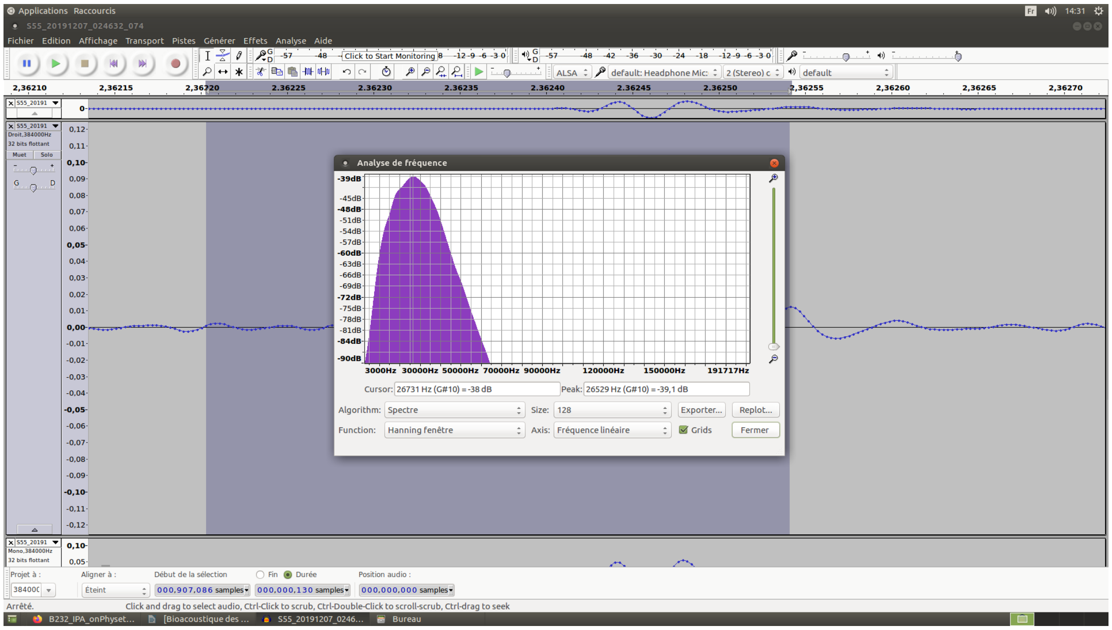

Figure 1.77: Frequency spectrum with hydrophone 2 at 2 seconds 36 (Freq = 26529 Hz)

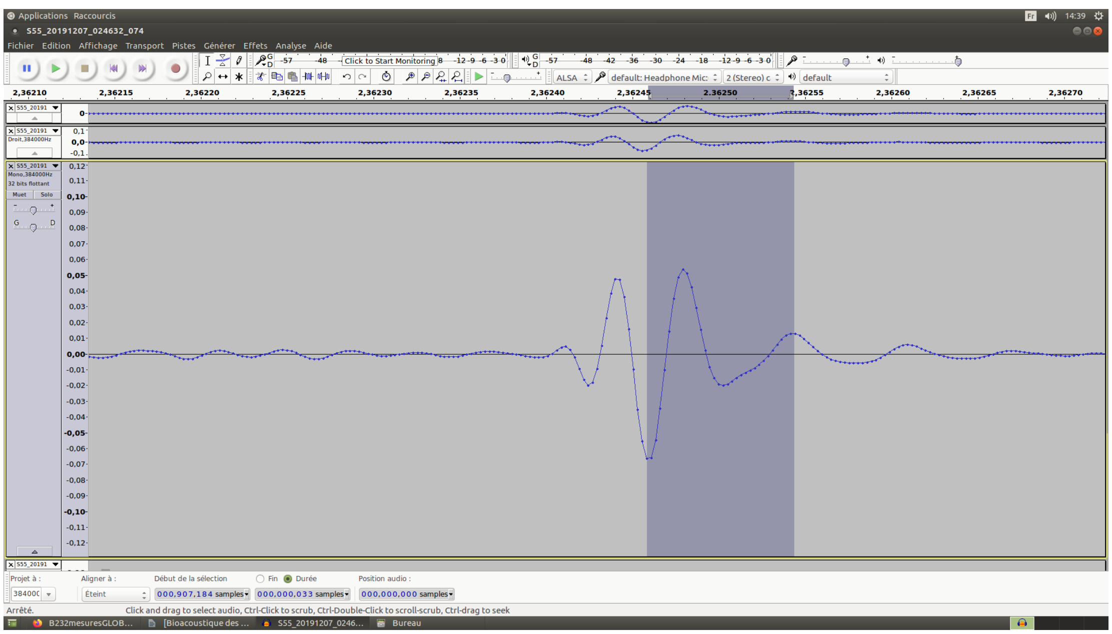

Figure 1.78: Pilot whale clic with hydrophone 3 at 2 seconds 36 (P0P1 = 33 samples)

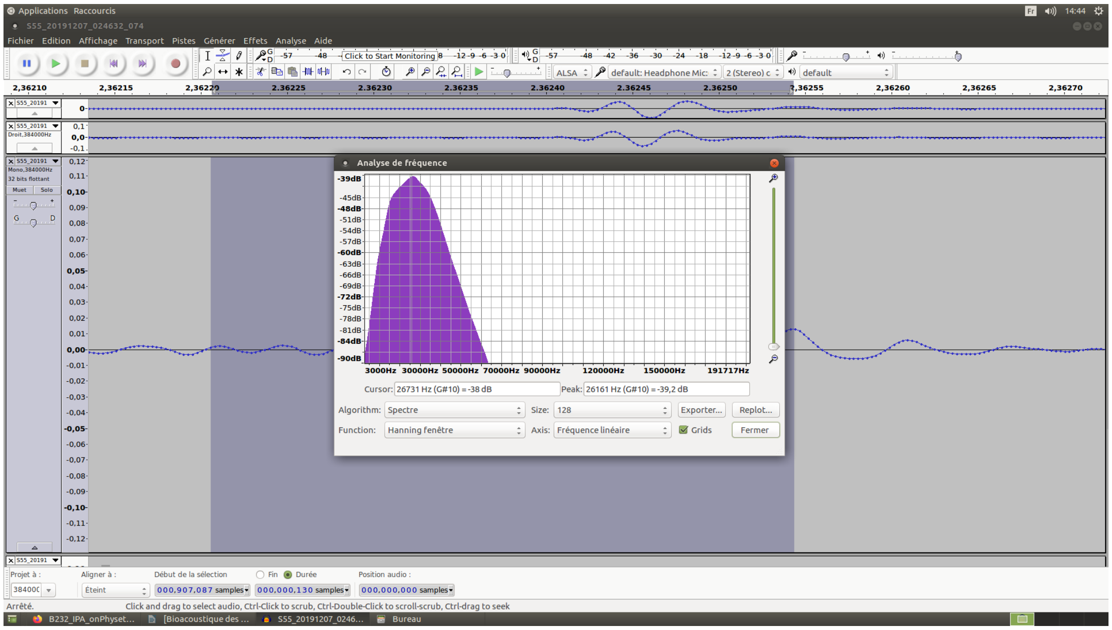

Figure 1.79: Frequency spectrum with hydrophone 3 at 2 seconds 36 (Freq = 26161 Hz)

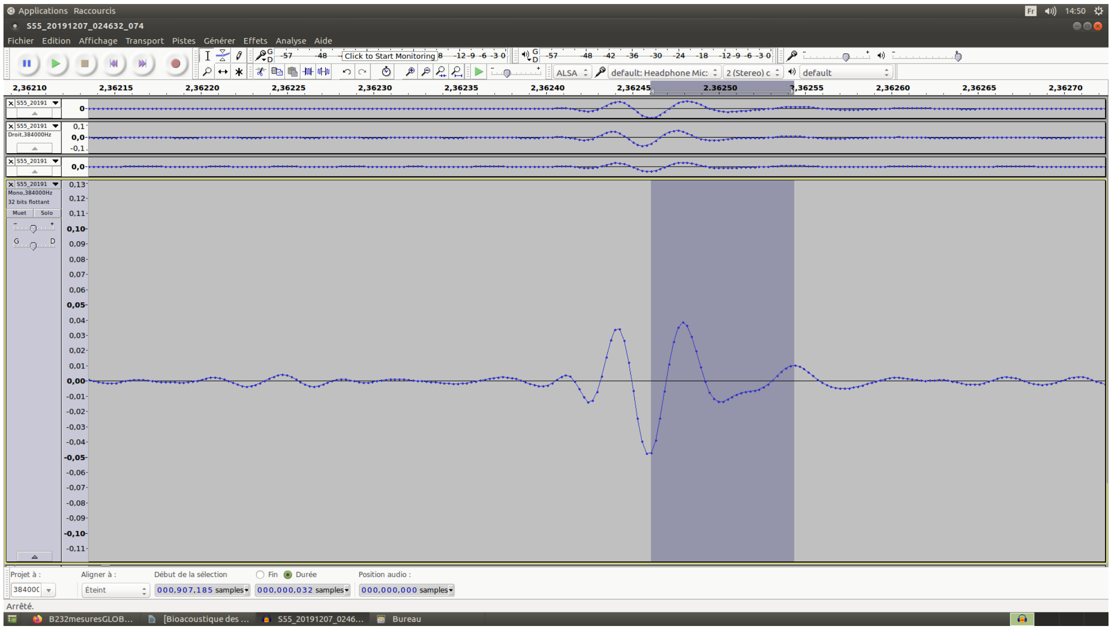

Figure 1.80: Pilot whale clic with hydrophone 4 at 2 seconds 36 (P0P1 = 32 samples)

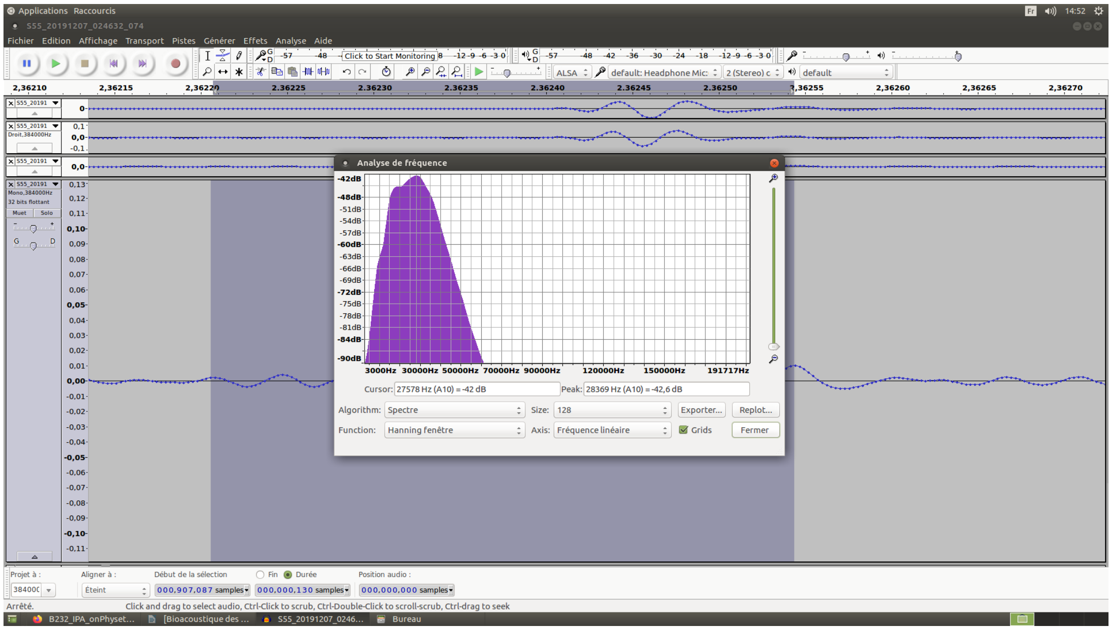

Figure 1.81: Frequency spectrum with hydrophone 4 at 2 seconds 36 (Freq = 28369 Hz)

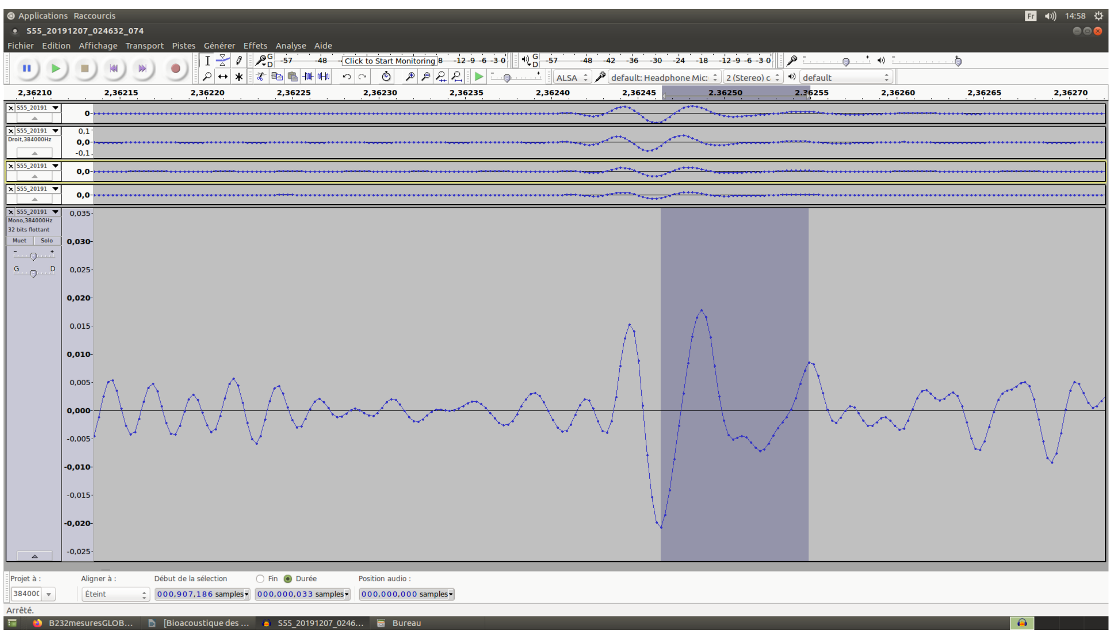

Figure 1.82: Pilot whale clic with hydrophone 5 at 2 seconds 36 (P0P1 = 34 samples)

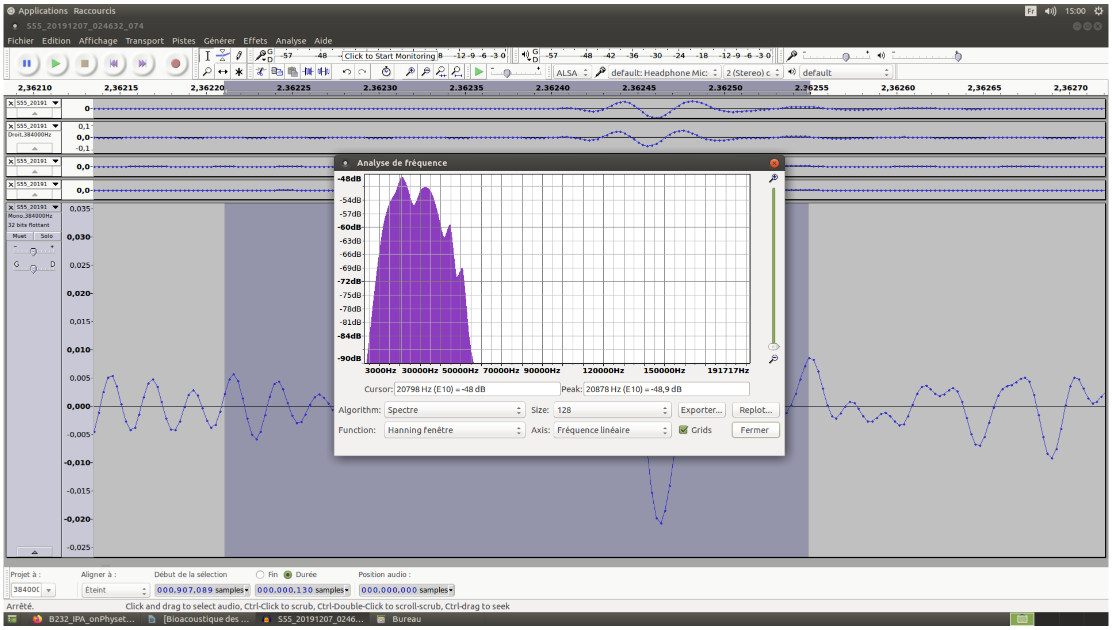

Figure 1.83: Frequency spectrum with hydrophone 5 at 2 seconds 36 (Freq = 20878 Hz)

1.8 Measurements at 39.10 seconds by Orava ATIU

The aim being to characterize the individual at 39.10 seconds and to be able to determine his position soon, the Po pulse observed on the 5 different channels is measured. These 5 channels correspond to the 5 recording hydrophones. The Po shift is already noticeable with an overall view of this 5 channels (Fig. 1.84).

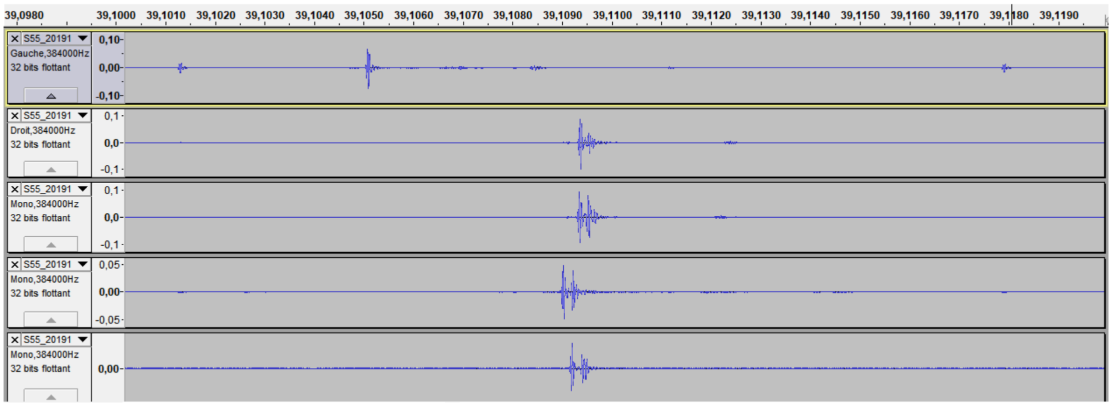

Figure 1.84: Pilot whale clicks at 39 seconds between the five hydrophones.

1.8.1 Results with the channel 1

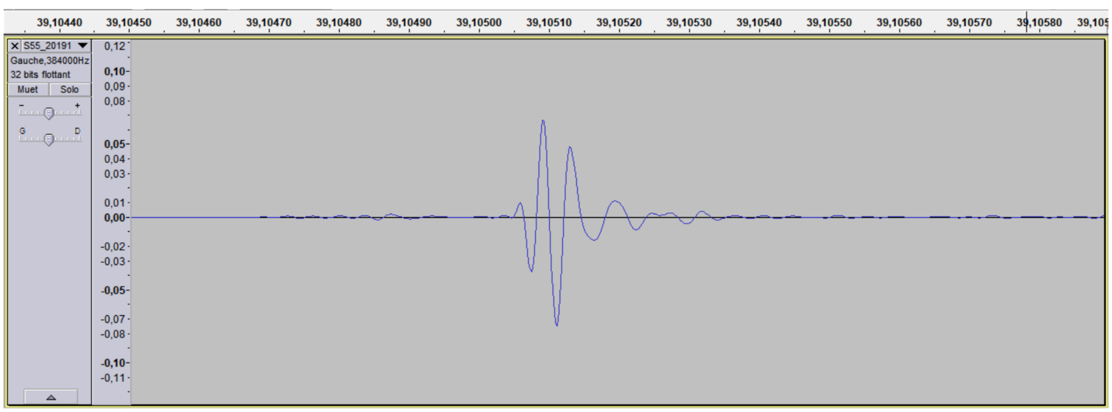

Figure 1.85: Pilot whale click at 39 seconds in the hydrophone 1.

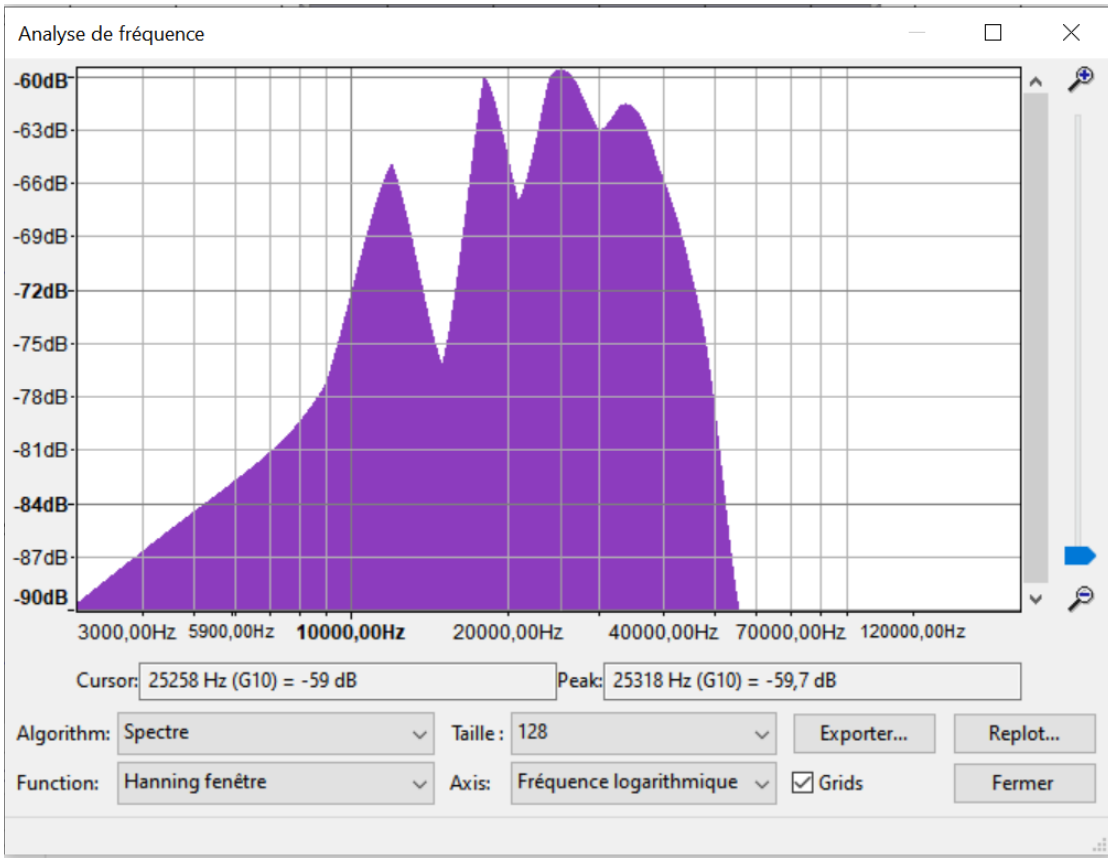

Figure 1.86: Spectrum analysis of P0 in the hydrophone 1 at 39 seconds.

By analyzing channel 1 (Fig. 1.85) at the given time of 39.10 seconds, we note that P1 is not visible and that therefore P0P1 IPI cannot be determined. Regarding the frequency spectrum (Fig. 1.86), it shows a peak at 25318 Hz.

1.8.2 Results with the channel 2

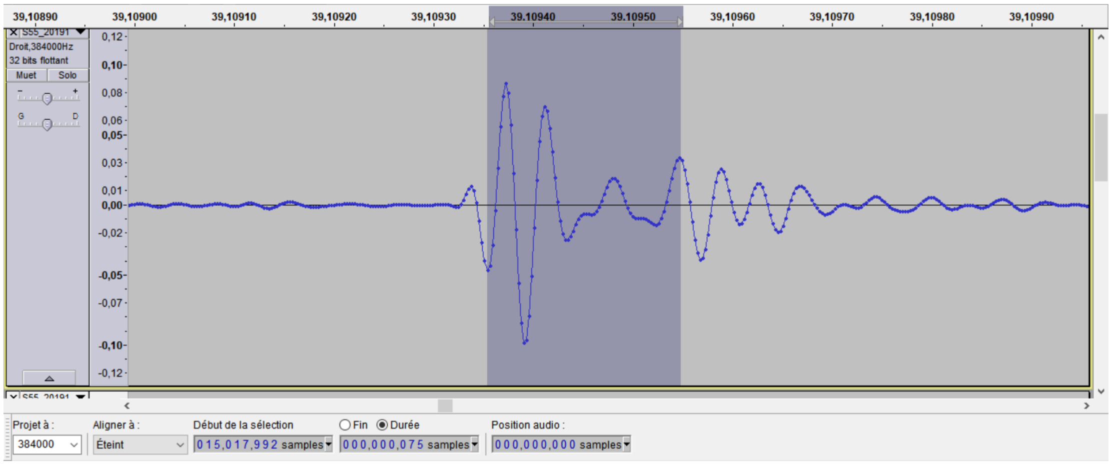

Figure 1.87: Pilot whale click at 39 seconds in the hydrophone 2.

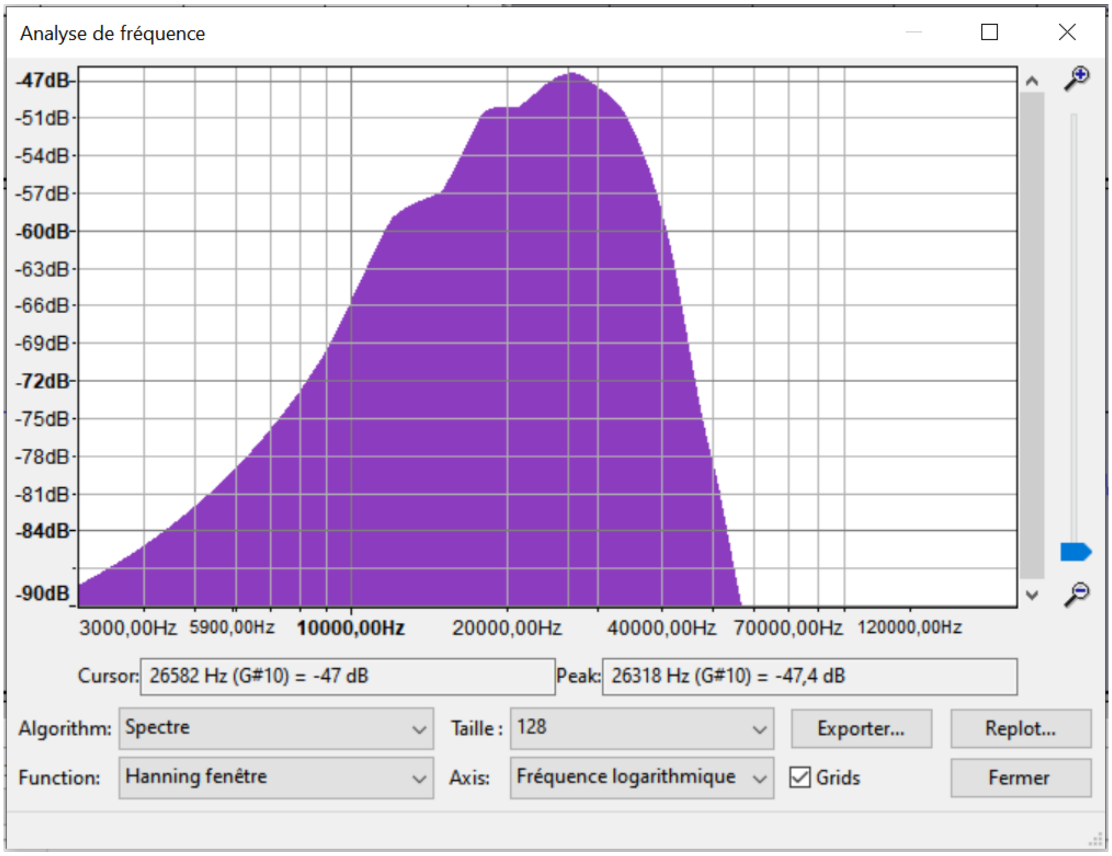

Figure 1.88: Spectrum analysis of P0 in the hydrophone 2 at 39 seconds.

The channel 2 (Fig. 1.87) offers us a P0P1 IPI of 75 samples and its spectral analysis gives a peak at 26318 Hz (Fig. 1.88).

1.8.3 Results with the channel 3

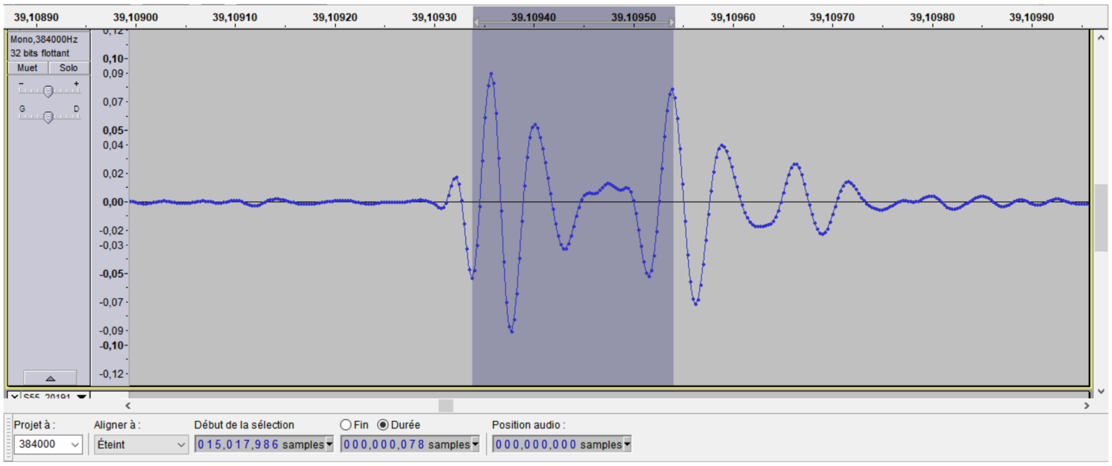

Figure 1.89: Pilot whale click at 39 seconds in the hydrophone 3.

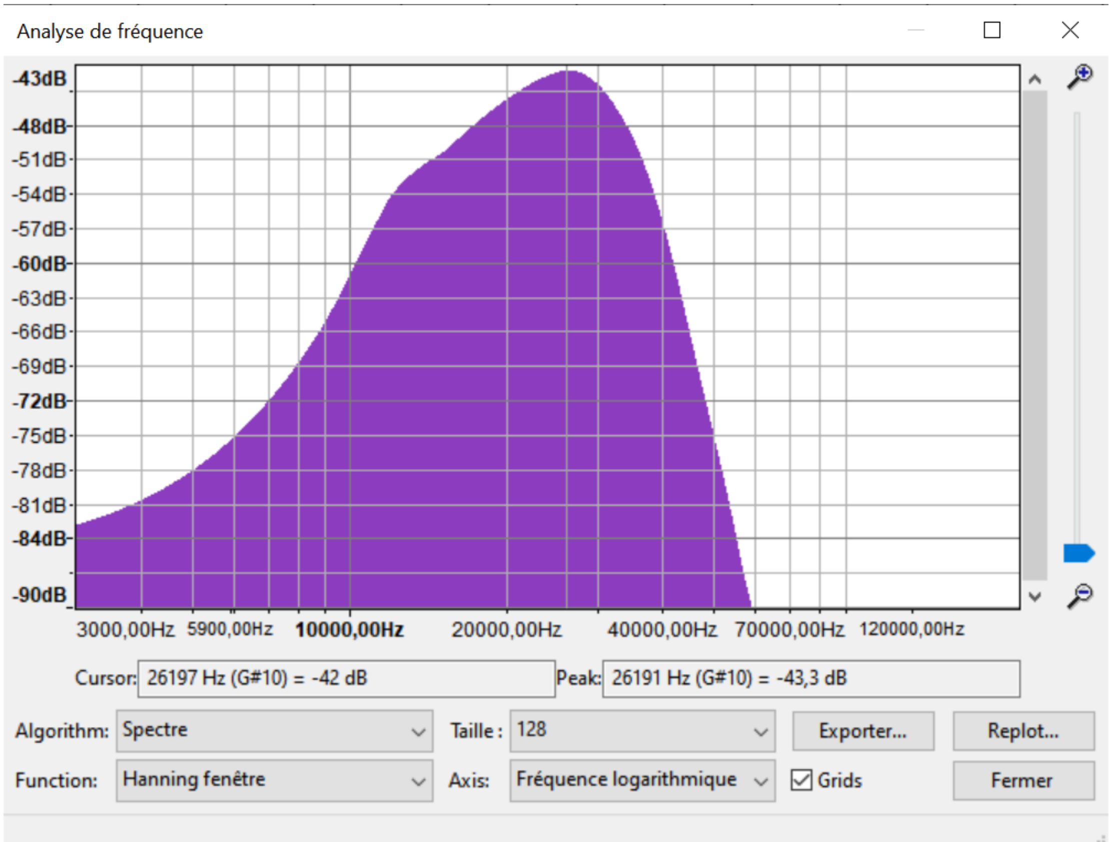

Figure 1.90: Spectrum analysis of P0 in the hydrophone 3 at 39 seconds.

The channel 3 (Fig. 1.89) presents a P0P1 IPI of 78 samples and its spectral analysis shows a peak at 26191 Hz (Fig. 1.90).

1.8.4 Results with the channel 4

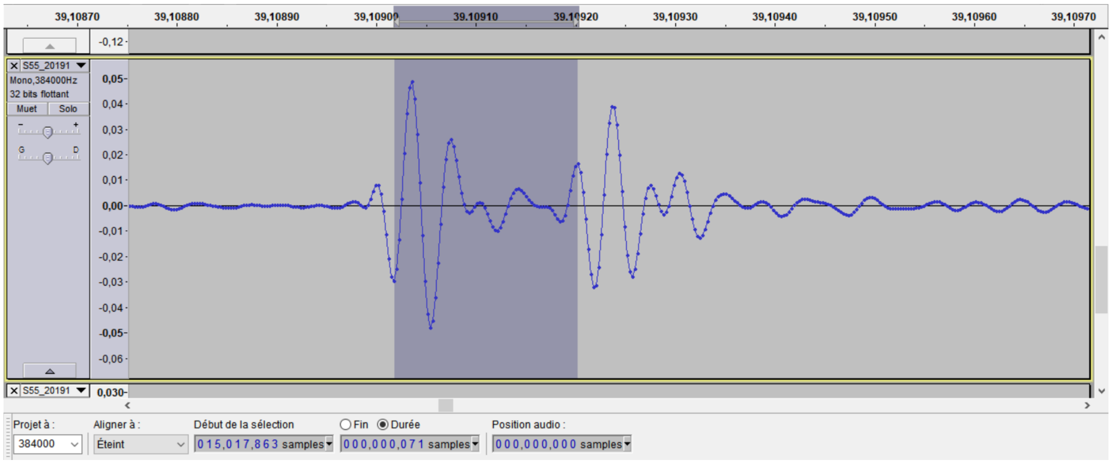

Figure 1.91: Pilot whale click at 39 seconds in the hydrophone 4.

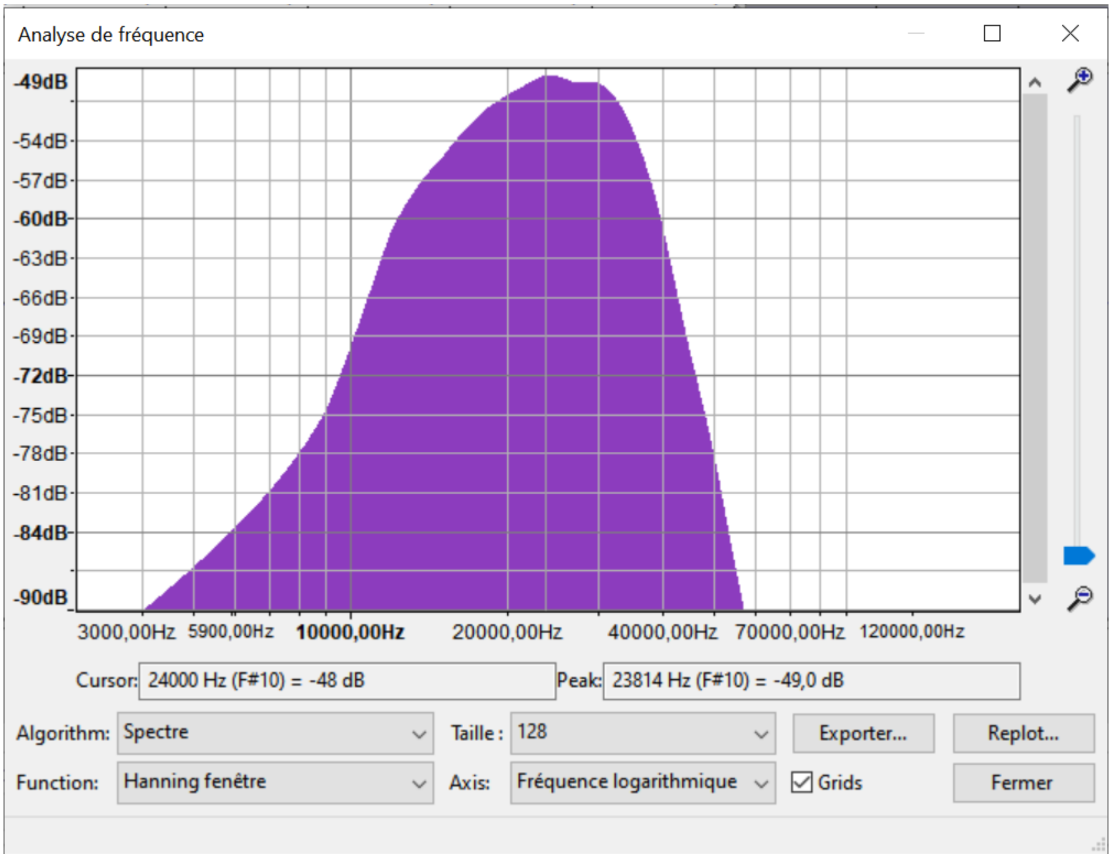

Figure 1.92: Spectrum analysis of P0 in the hydrophone 4 at 39 seconds.

The P0P1 IPI in the channel 4 (Fig. 1.91) is 71 samples and the spectral analysis gives its peak at 23814 Hz (Fig. 1.92).

1.8.5 Results with the channel 5

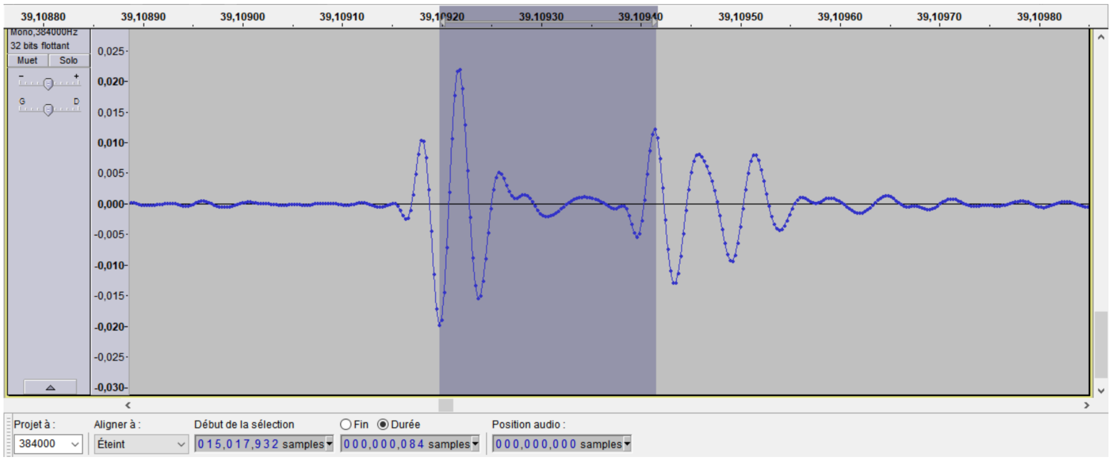

Figure 1.93: Pilot whale click at 39 seconds in the hydrophone 5.

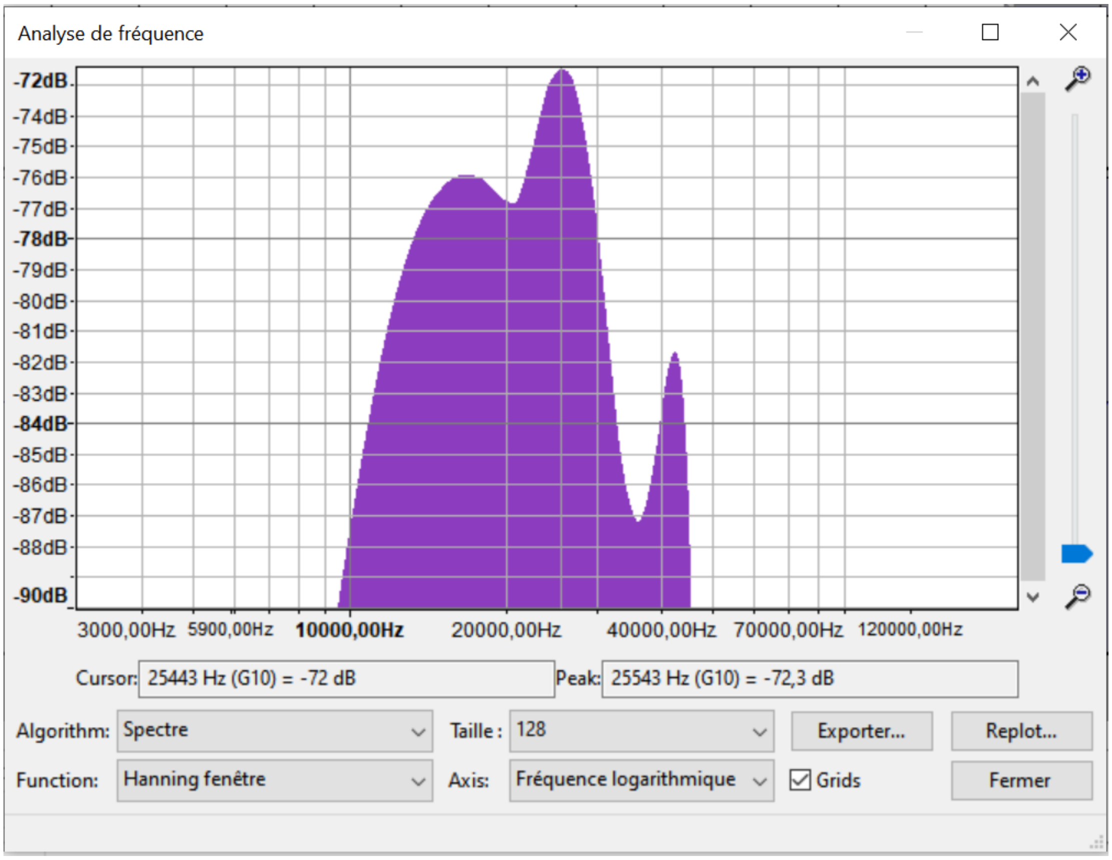

Figure 1.94: Spectrum analysis of P0 in the hydrophone 5 at 39 seconds.

For the last one, the channel 4 (Fig. 1.93), the PoP1 is 84 samples. The spectral analysis corresponding show a peak at 25543 Hz (Fig. 1.94).

1.9 Marina CAMPANA

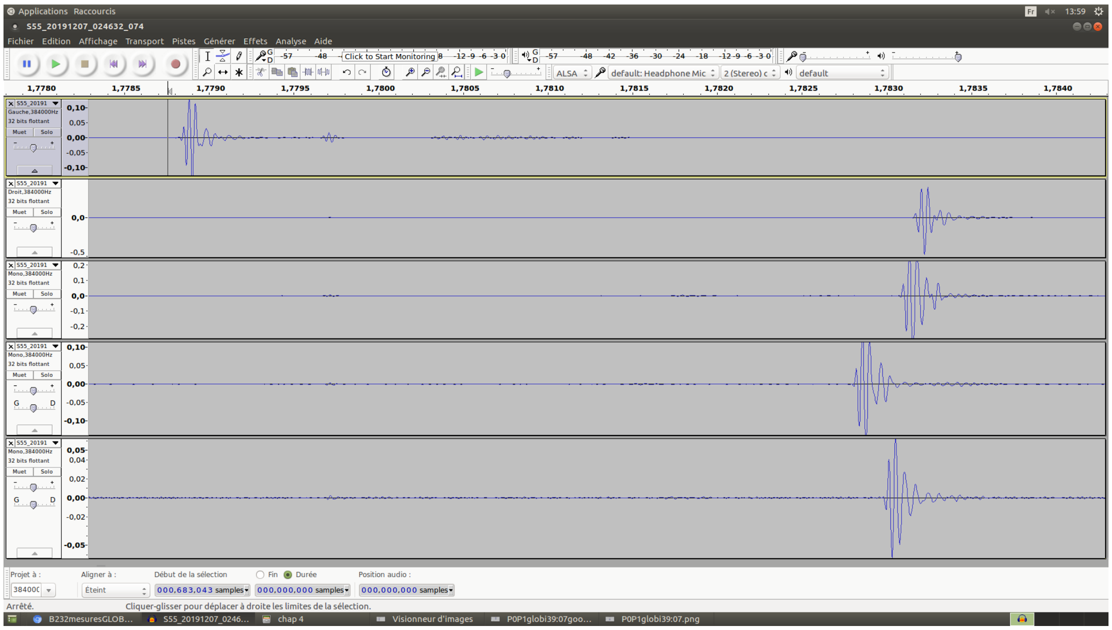

Figure 1.95: We can see the click on these fives channels and by comparing the delay between the hydrophones we can provide the localization of the individual. The sound came first at the hydrophone 1 so the individual is closer to this hydrophone than the others.

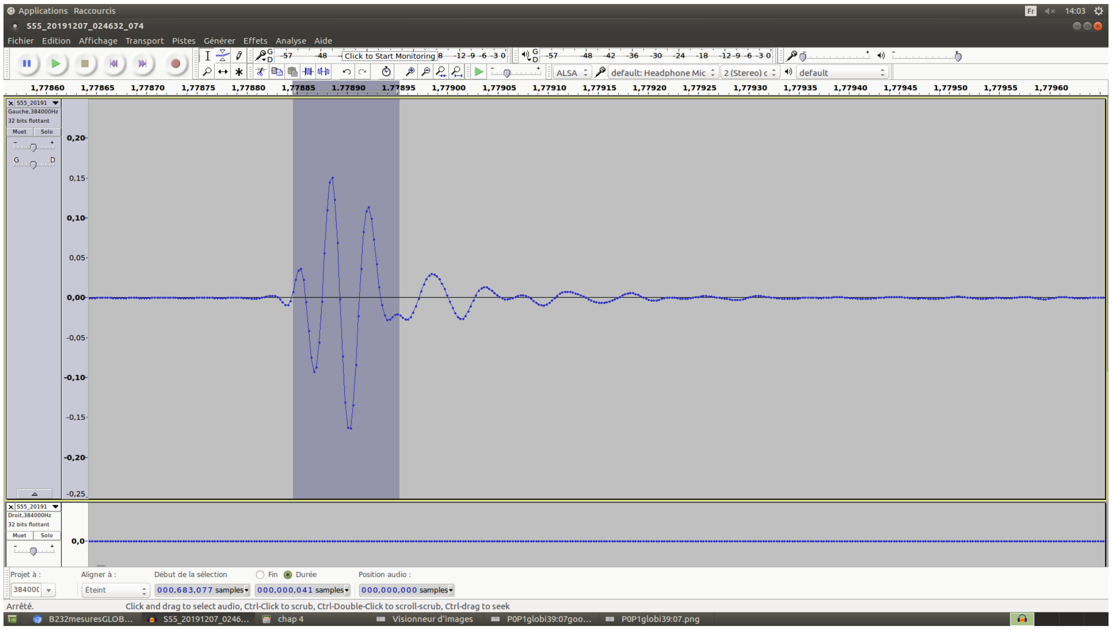

Figure 1.96: The number of samples between P0 and P1 is about 41.

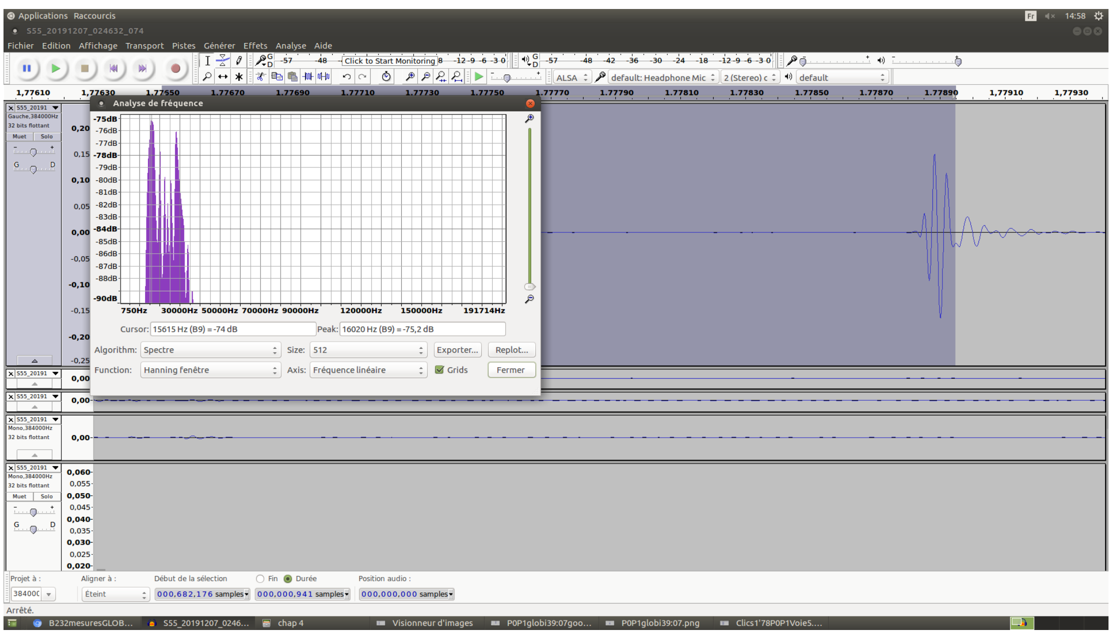

Figure 1.97: The frequency peak of P0 on the channel 1 is about 16020 Hz.

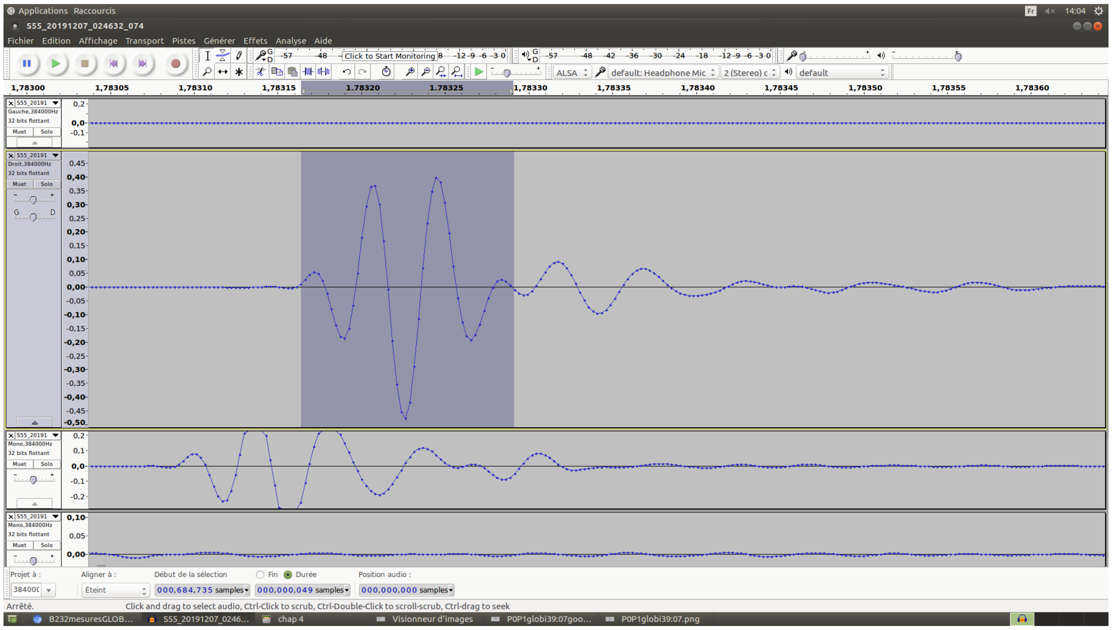

Figure 1.98: The number of samples between P0 and P1 is about 49

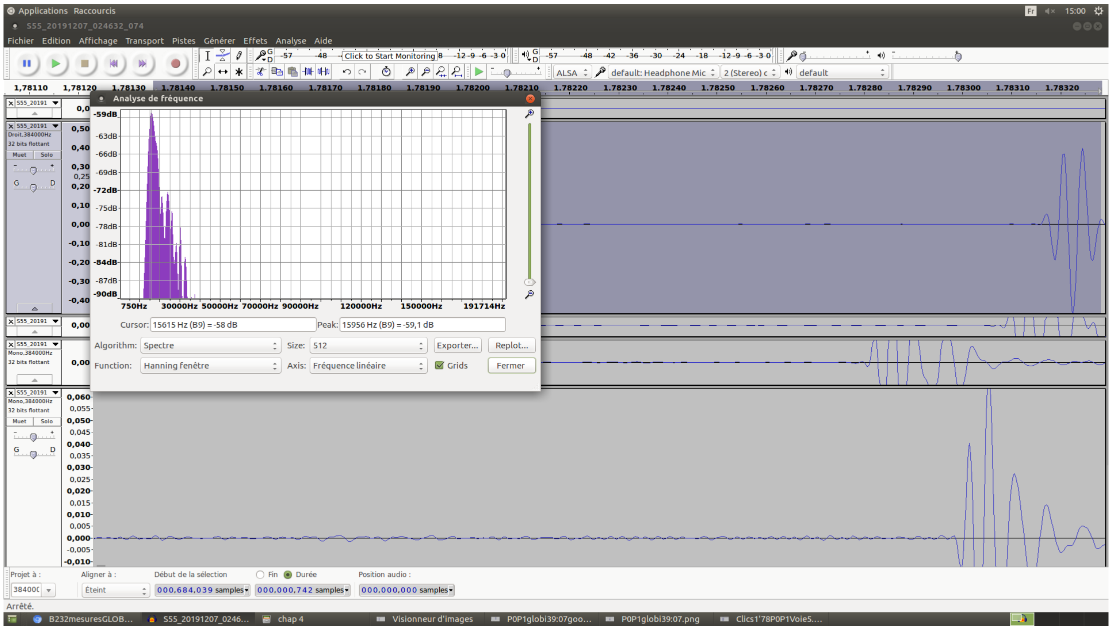

Figure 1.99: The frequency peak of P0 on the channel 2 is about 15956 Hz.

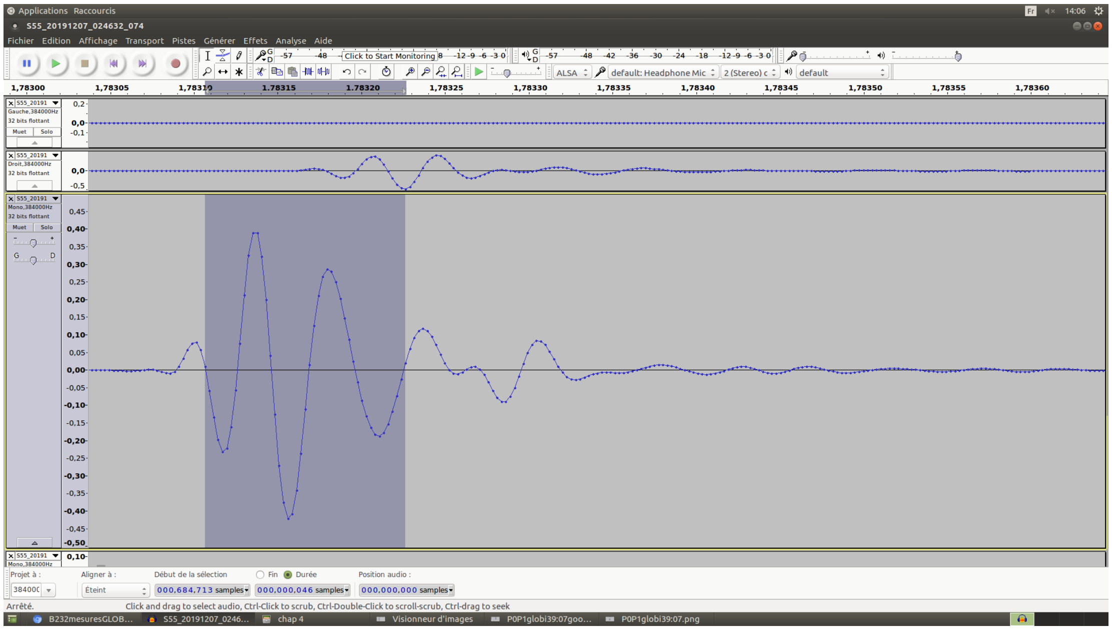

Figure 1.100: The number of samples between P0 and P1 is about 46

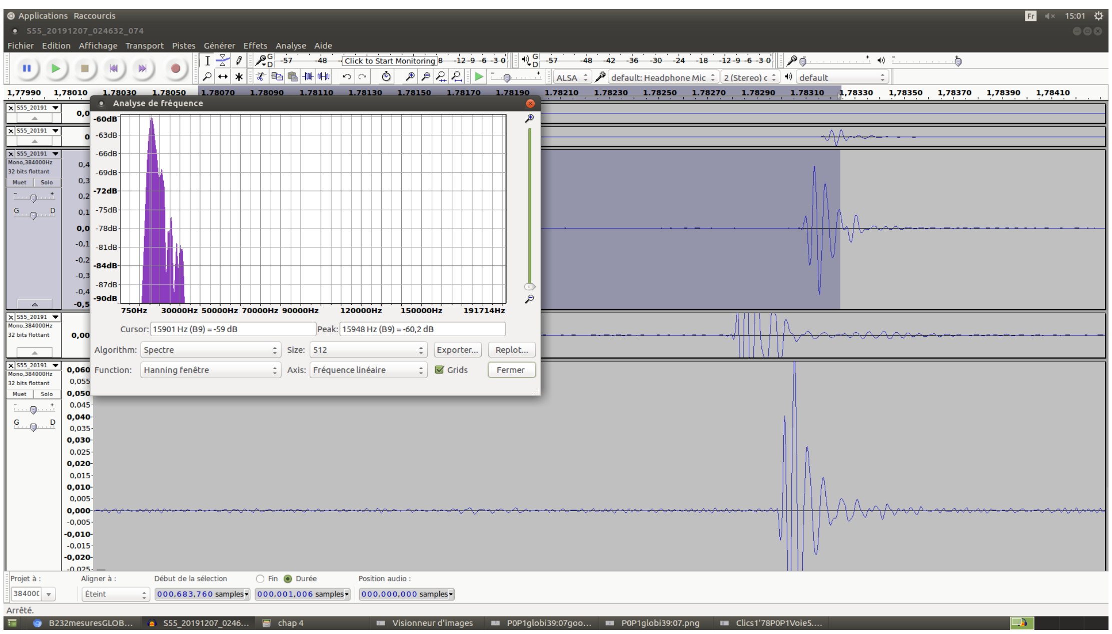

Figure 1.101: The frequency peak of P0 on the channel 3 is about 15948 Hz.

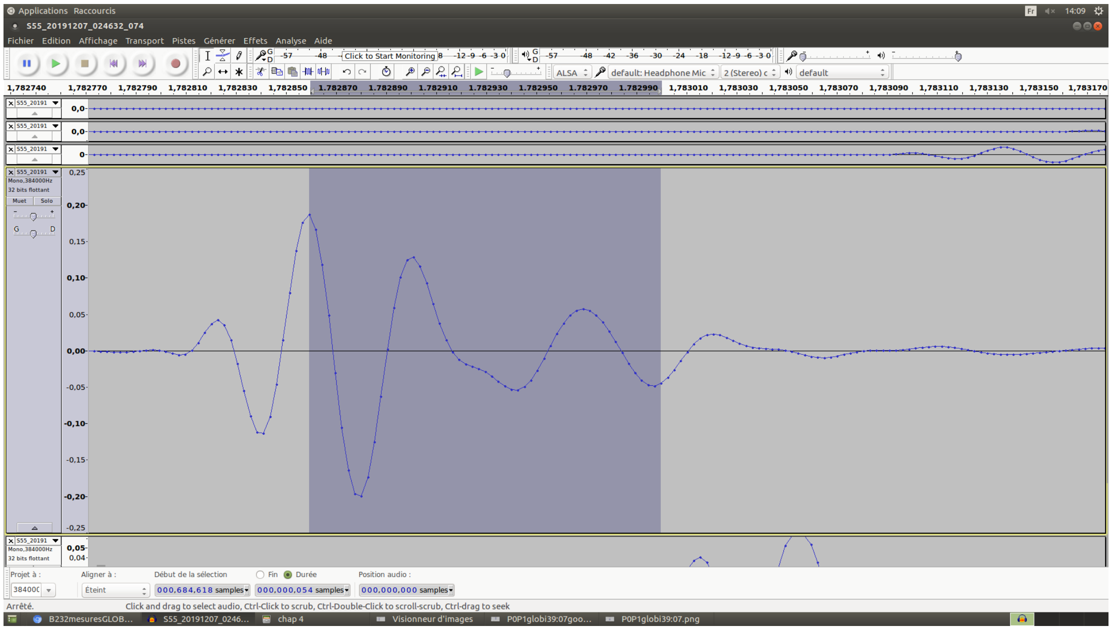

Figure 1.102: The number of samples between P0 and P1 is about 54

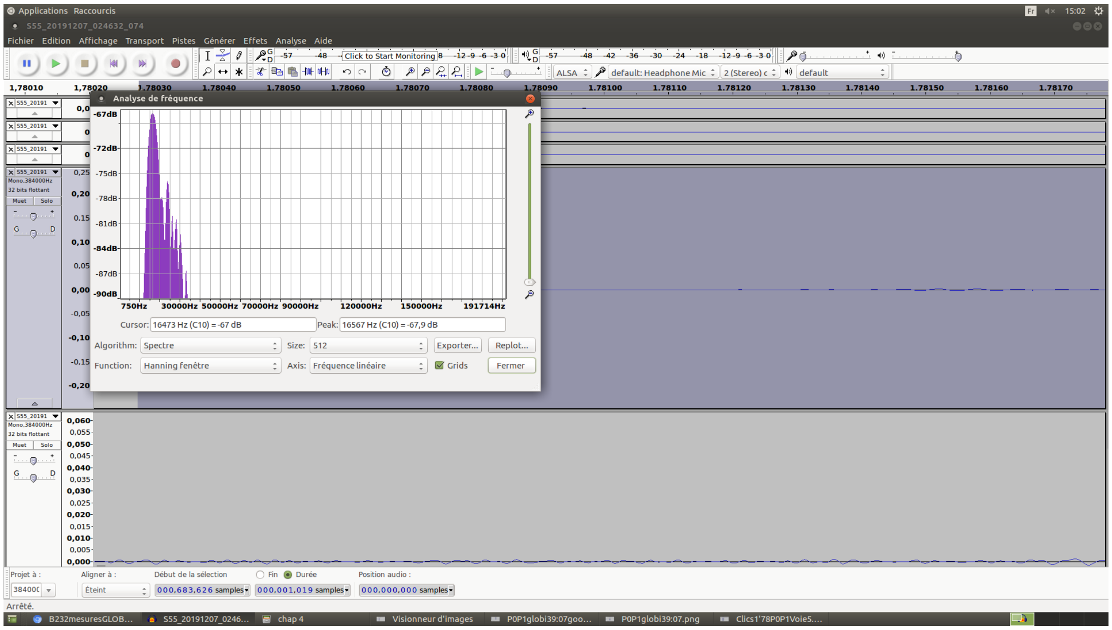

Figure 1.103: The frequency peak of P0 on the channel 4 is about 16567 Hz.

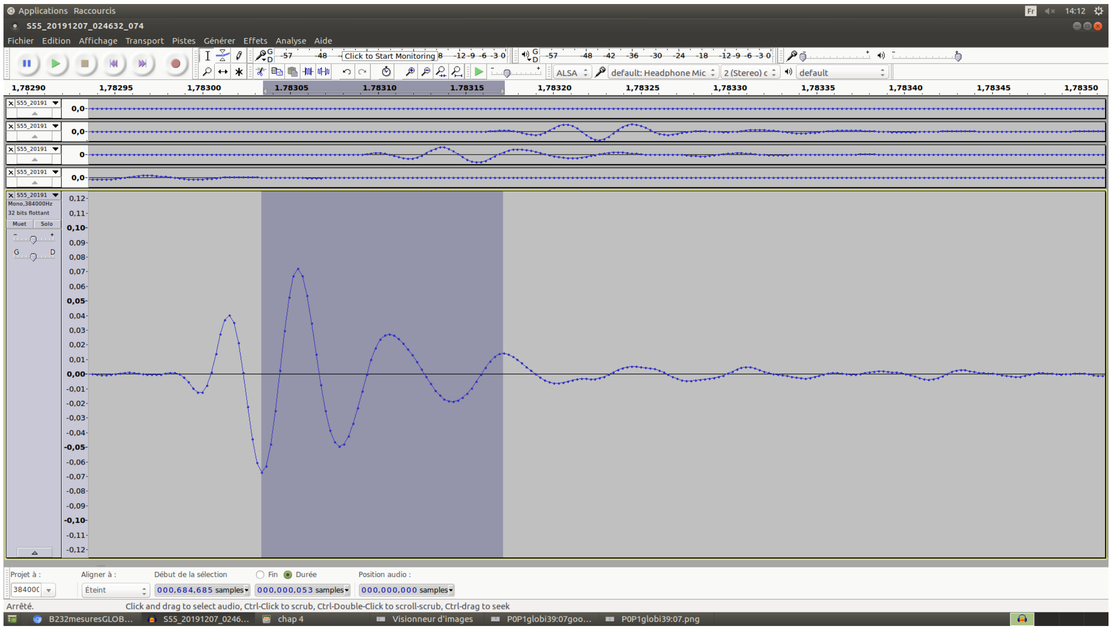

Figure 1.104: The number of samples between P0 and P1 is about 53

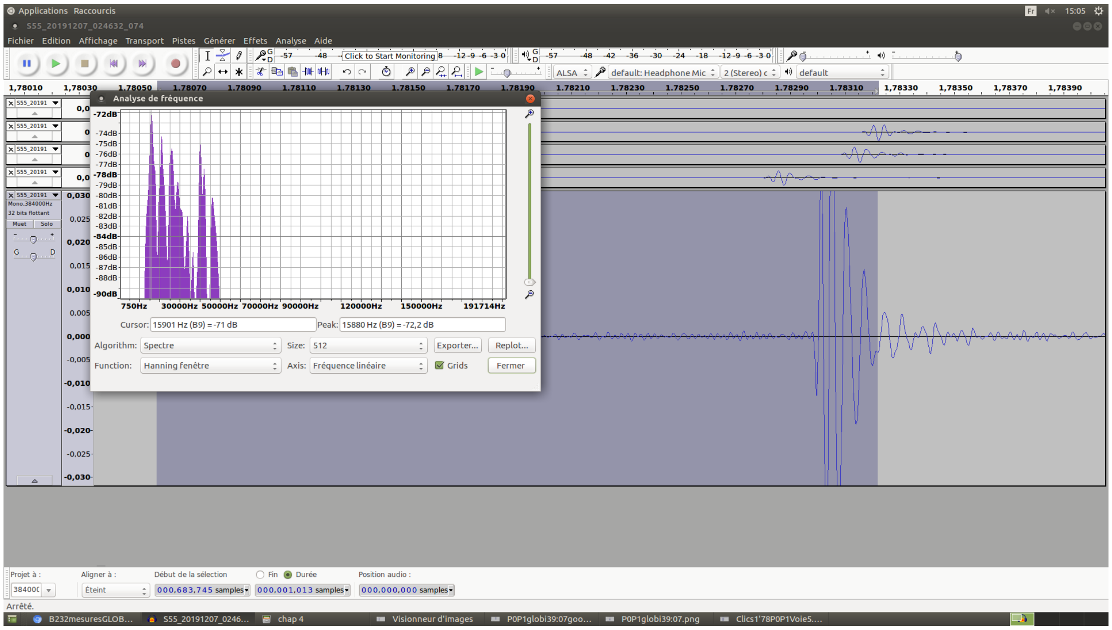

Figure 1.105: The frequency peak of P0 on the channel 4 is about 15880 Hz.

2

Conclusion

This first exploration of IPI hypothesis on Gm would need more time to generate enough numbers and statistical cues. If the position of the individual are not too much nosing an IPI effect, then, according to our results we can suppose that there are 2 individuals. One of them have a head size around 10 cm and the second one have a head size around 15 cm. We used the graph which compared channels 3 and 5 with the channel 2 to see position in function of the time (in green) and the head size (in red).

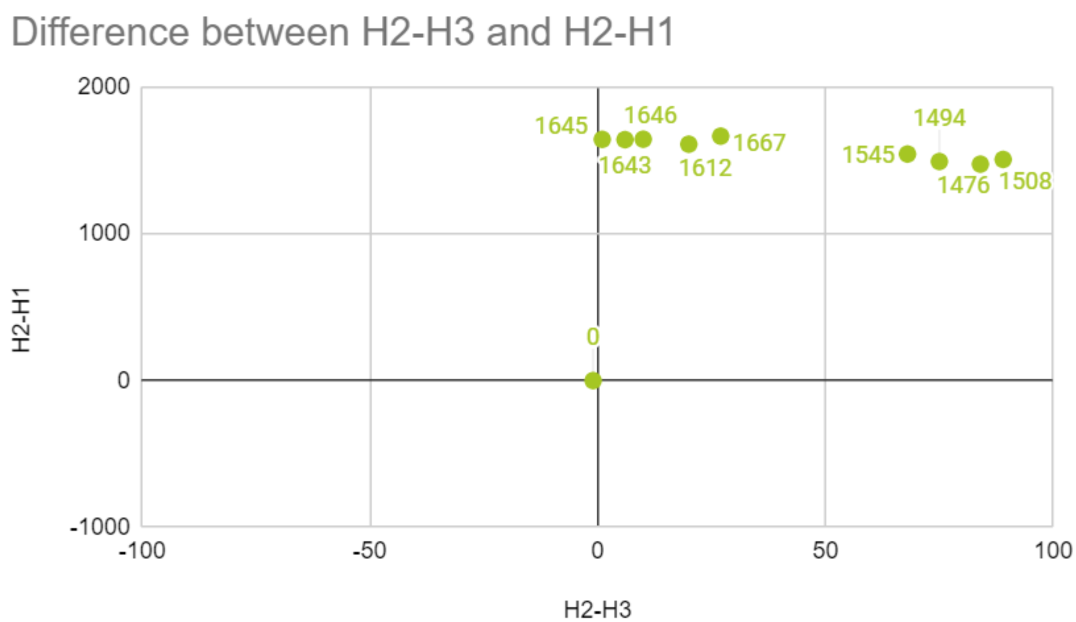

Figure 2.1: Graph showing the positions of the individuals analyzed by comparing the channels 3 and 1 with the second channel

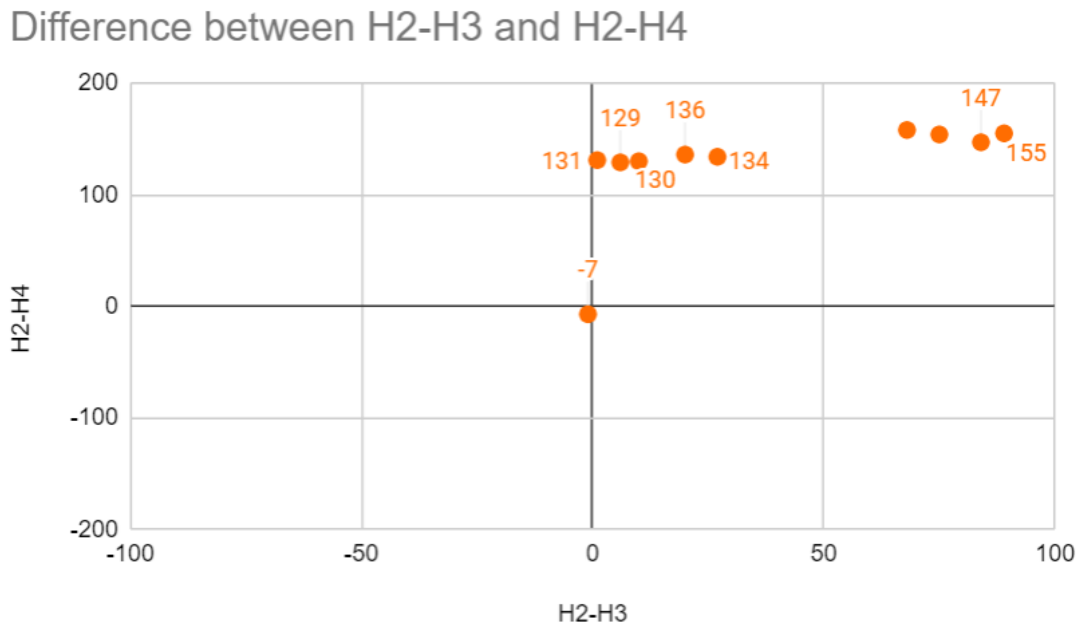

Figure 2.2: Graph showing the positions of the individuals analyzed by comparing the channels 3 and 4 with the second channel

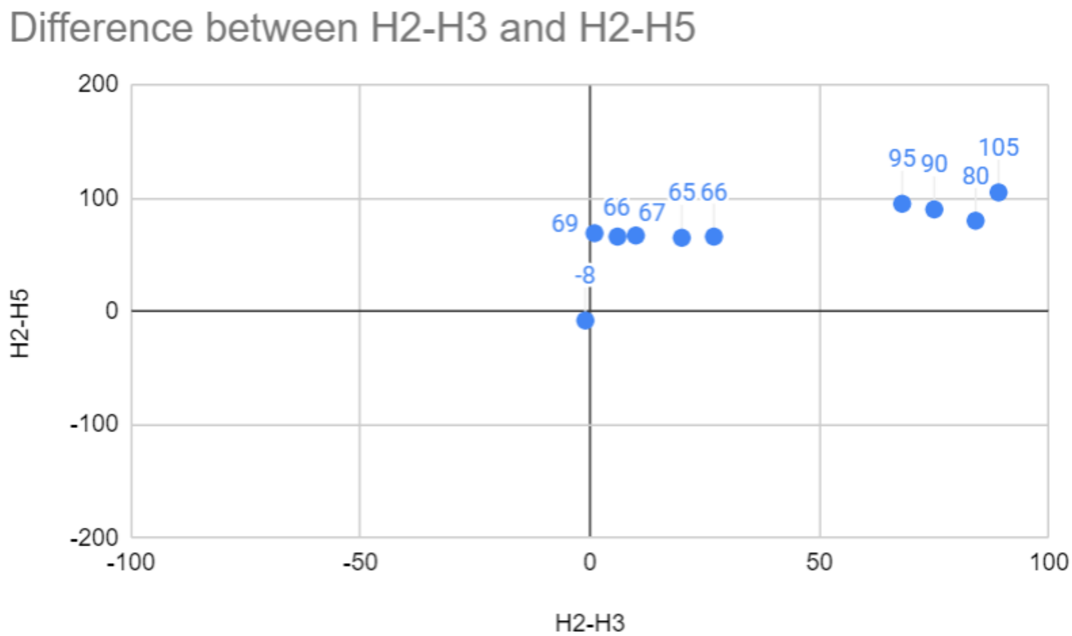

Figure 2.3: Graph showing the positions of the individuals analyzed by comparing the channels 3 and 5 with the second channel

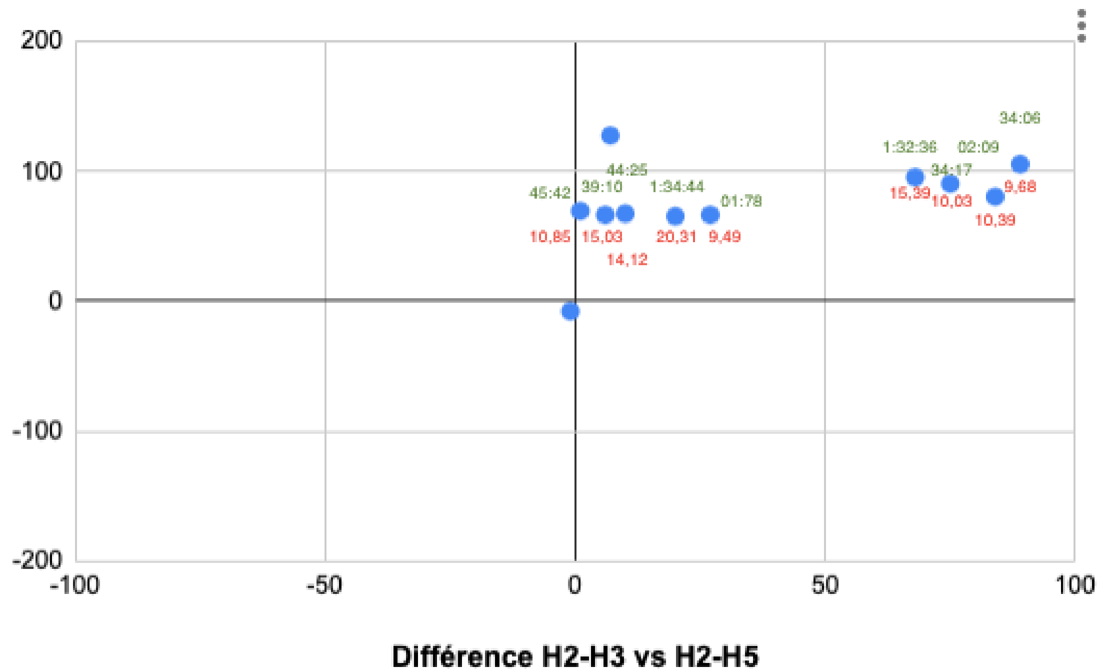

Figure 2.4: Graph showing the positions of the individuals with their head size (red) and the time analyzed (in green) by comparing the channels 3 and 5 with the second channel

Overall we can see 2 groups of points which, depending on the standard deviations, which correspond to a relatively similar head size average.

Indeed, thanks to this graph we can see one group of elements close to x= 10/y= 60 which can correspond to an individual with head size of almost 15cm. A second individual with a head size almost 10 cm can be detected close to x= 80/ y= 90. We analyzed an other element close to x=0/y=-5, which can perhaps reflect the presence of a third individual however in view of the lack of values we cannot affirm this.

Our results unfortunately do not allow us to detect a significant direction of these two individuals. It might be better to analyze other clicks to find, perhaps, their way.

Finding their way allows us to increase our knowledge of pilot whales and thus be able to give statistics on their populations.

Figura 6. Dorsal and ventral of skull, and lateral view of skull and mandible of *Globicephala melas* MLP 3.X.00.28. Scale 10 cm.

Figure 2.5: Picture of a Pilot Whale head squeleton from Catalogue of marine mammals of the Mammalogical collection of the Museo de La Plata, Argentina

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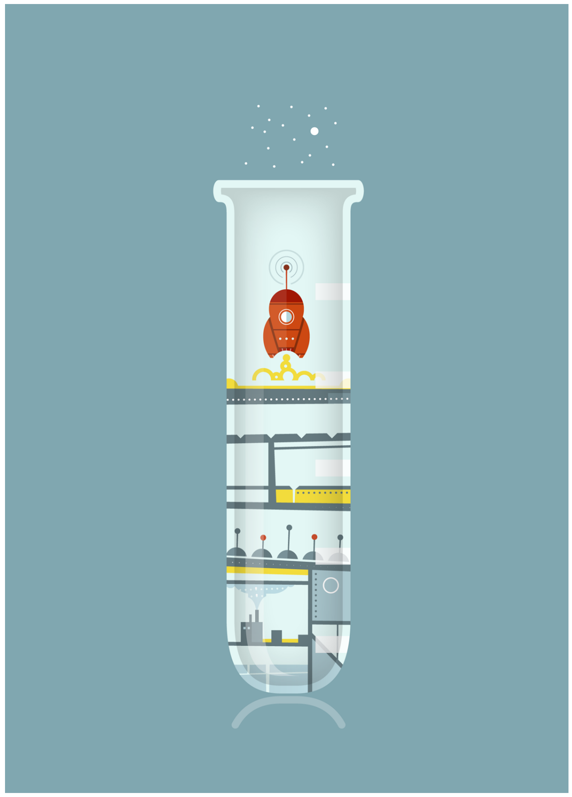

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