WHALESAFE
FINAL REPORT

ANNEX 12

DEEP DIVING FINAL REPORT

This document is the deliverable of Action C.8. It summarizes all the observationof deep diving

Contents

INTRODUCTION

Introduction

This report summarize all detected clicks during the project duration.

A Brief History of the Detection System

A first version of the system consisted of two pair of buoys as shown in Figure 1. The primary buoy powered with photovoltaic panels and instrumented with a GSM data transmission system, hosts the main computer. The acoustic detection system is suspended below the secondary buoy at a depth of 85 meters. The system has been installed in two steps: on April 21st, 2016 the primary buoys have been deployed and on May 18th, 2016 the secondary buoys have been connected. An algorithm recognize the

Figure 1 - System composed of a primary (right) and a secondary (left) buoy

presence of clicks in the sound tracks and reconstructed events are sent via GSM to the **Data Analysis and Alarm Generation Centre** where the data arriving from the two buoys are synchronized and the Sperm whale is localized by triangulation as shown in Figure 2.

The system operated continuously until July 13th, 2016 when a first incident caused the loss of one detection unit and introduced a delay in the time scale of the project of one year.

During this first period of operation, the two buoys regularly transmitted data to shore and a first set of clicks has been recorded. In Figure 3 the summary of 14 days of data taking is shown: each point correspond to a sound recognized as a click and represents the value of the reconstructed azimuthal angle, in particular values larger than 90° represent sounds generated below the buoy and values smaller than 90° sounds arriving from the sea surface. This first set of data still includes true clicks and environmental noise. It has been used to calibrate the system in order to optimize the detection algorithm and to reduce the noise contamination. Nevertheless a true Sperm whale diving has been identified and followed by both buoys as shown in Figure 4 where the reconstructed clicks detected by the two buoys are reported.

A BRIEF HISTORY OF THE DETECTION SYSTEM

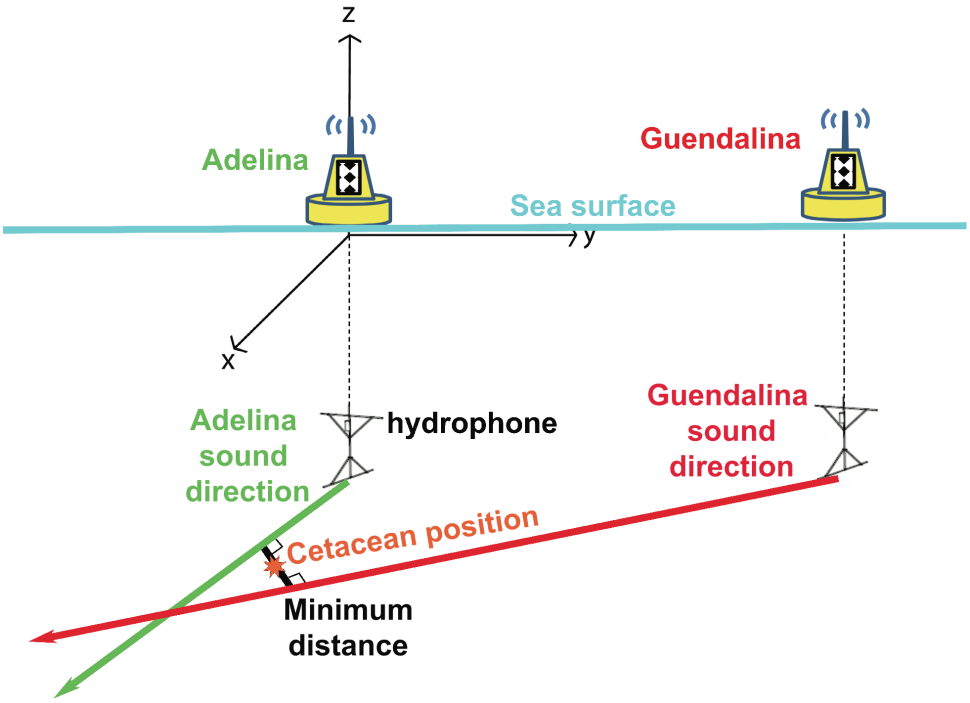

Figure 2 - Detection system principle using two buoys

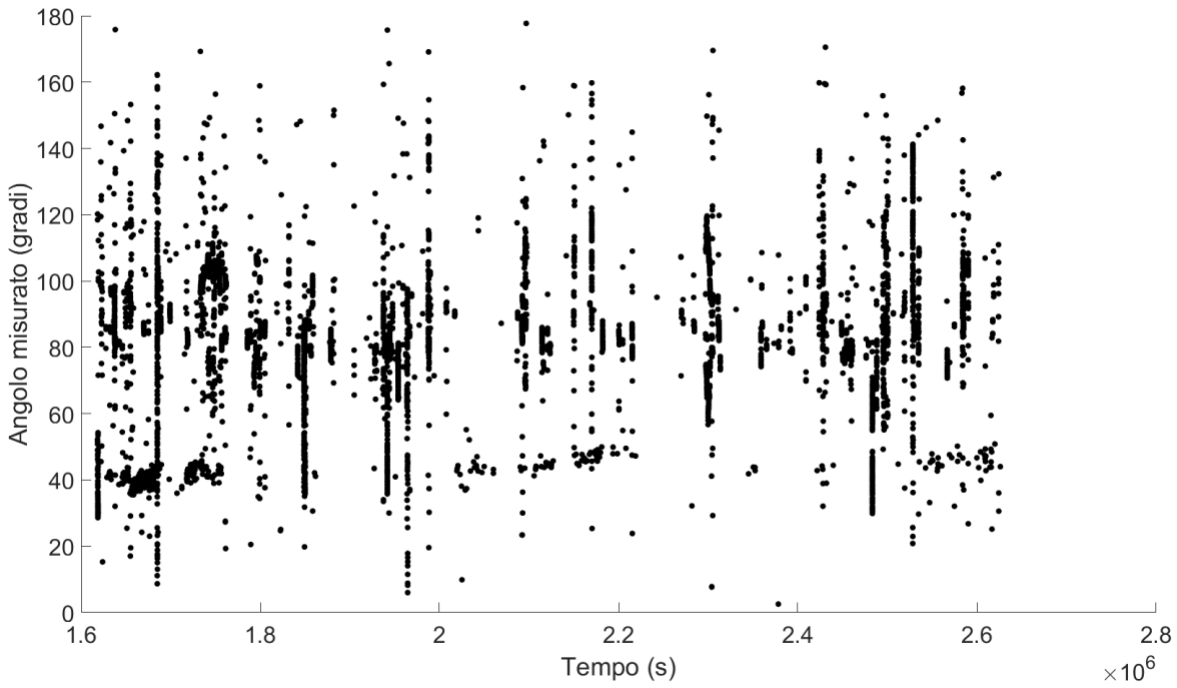

Figure 3 - Summary of detected events in 2016

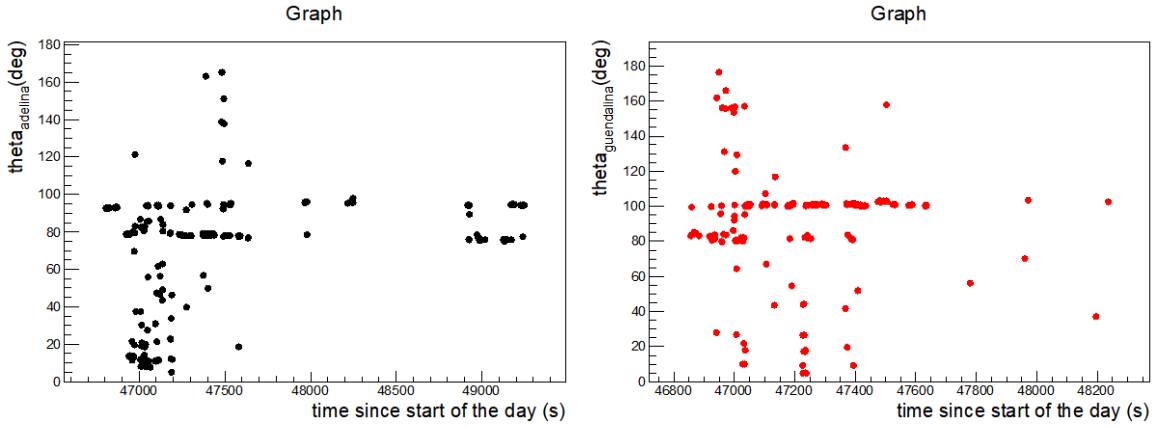

Figure 4 - Zenithal direction of the detected signals for Adelina buoy (left) and Guendalina buoy (right) as a function of the time (s)

Data was analyzed by C.Guidi in his master thesis and a first diving route reconstructed as shown in Figure 5. This analysis has been included in **Progress Report 2**.

The reconstructed data showed also an additional feature that has been used in the second part of the project when due to the loss of one detection unit we were forced to redesign the detection system.

The data taken in the first month of operation showed that each detection unit was able to reconstruct two signal (the direct and the reflected sound) as shown in Figure 6. This means that is possible to localize the Sperm whale with the information arising from a single buoy. A conceptual description of the new algorithm is reported in Figure 7. The comparison between the reconstructed position with two buoys and with a single buoy confirmed that the detection system could be operative also with a single unit. As reported in **Progress Report 3** the results of the two strategies are quite compatible, the difference on the average reconstructed geographical position of the cetacean is 0.0008°= 2,5" which corresponds roughly to 50 m as also shown in Figure 8.

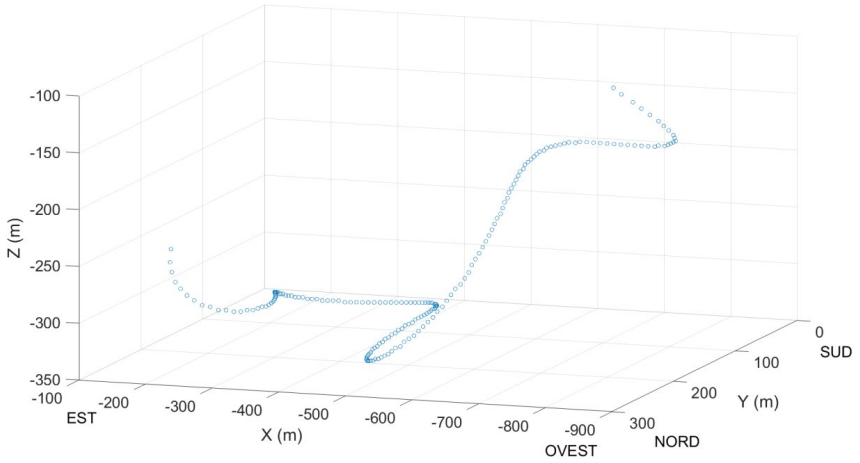

Figure 5 - Reconstructed diving route

A BRIEF HISTORY OF THE DETECTION SYSTEM

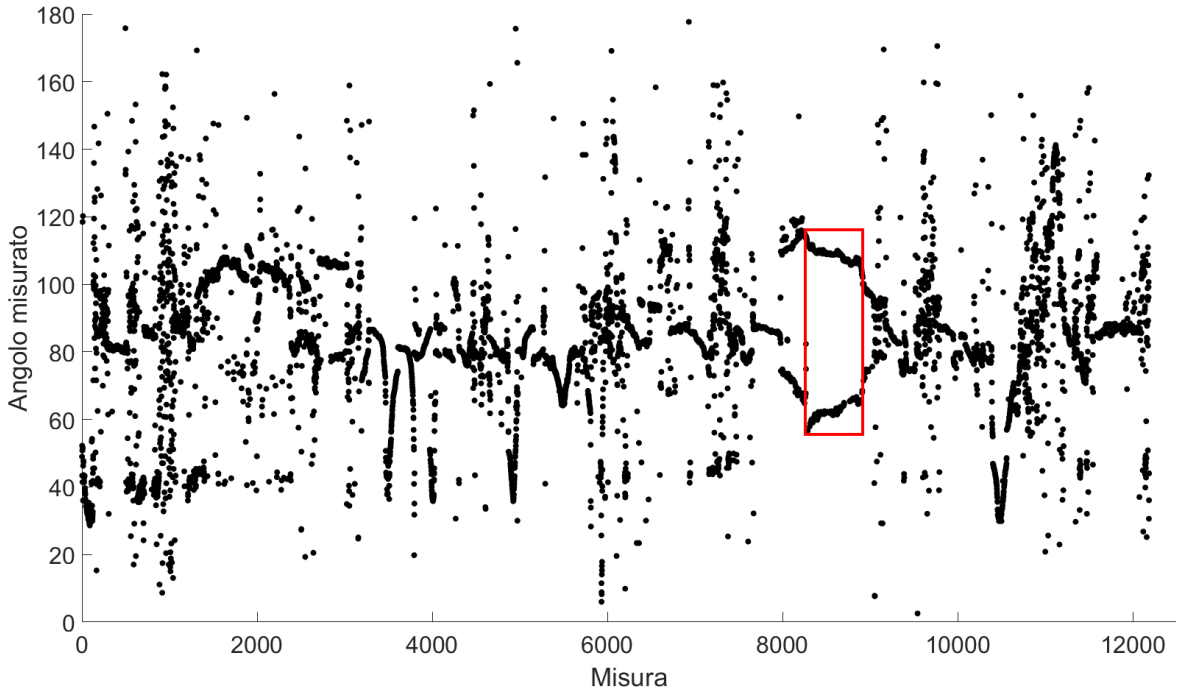

Figure 6 - Measured azimuthal angles

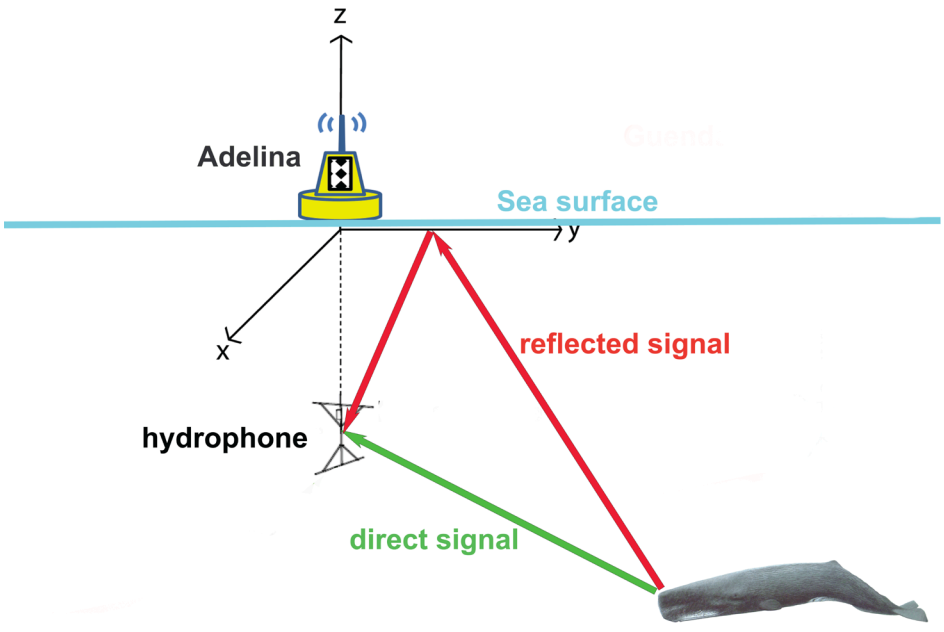

Figure 7 – Path of the sound beams detected by the idrophones

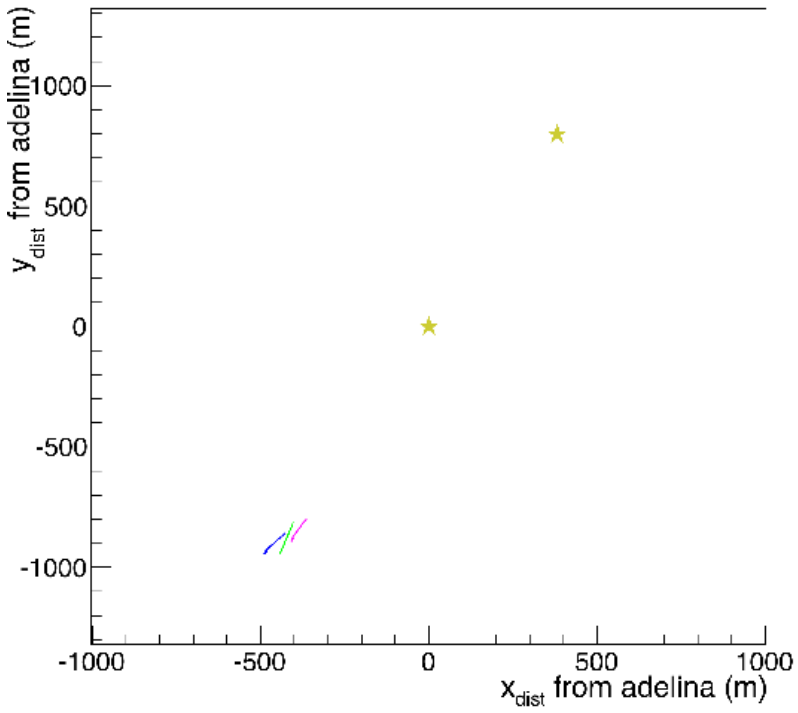

Figure 8 - Reconstructed track of the cetacean according to the "two units algorithm" (green) and according to the "single unit algorithm" using only Adelina unit (blue) or Guendalina unit (magenta), xdist and ydist are the distance of the reconstructed track fr

The new version of the detection system based on a single detection unit still based on a main and a secondary buoy and an improved data transmission system based on a wifi bridge that connects the buoy with the Bergeggi City Hall was installed September 20th-22th, 2017. The WiFi link allows not only the transmission of cetacean data, but also real time vessels monitoring with a webcam mounted on the main buoy. Unfortunately on September 28th, 2017 the data cable connecting secondary and main buoy has been damaged. After Coast Guard investigation it has been discovered that several line with hooks for tuna fishing have torn the data cable. No sperm whale diving have been recorded during the only week of operation of 2017.

This event determined the third change in design and, in order to reduce the risk of collisions, the secondary buoy has been removed and the hydrophone were directly suspended below the main buoy as shown in Figure 9.

This solution was not considered at the beginning of the project because the two buoys configuration has the advantage of the fixed position of hydrophones, while with the one buoy design the position and the heading of the system will change continuously. However, the data recorded during Summer 2017 showed that the position and inclination of the hydrophones can be measured with high precision and the orientation of the detector can be live-time corrected in order to reconstruct properly the cetacean route. In addition, the new configuration allowed increasing the depth of the hydrophone thus improving the accuracy in the position reconstruction.

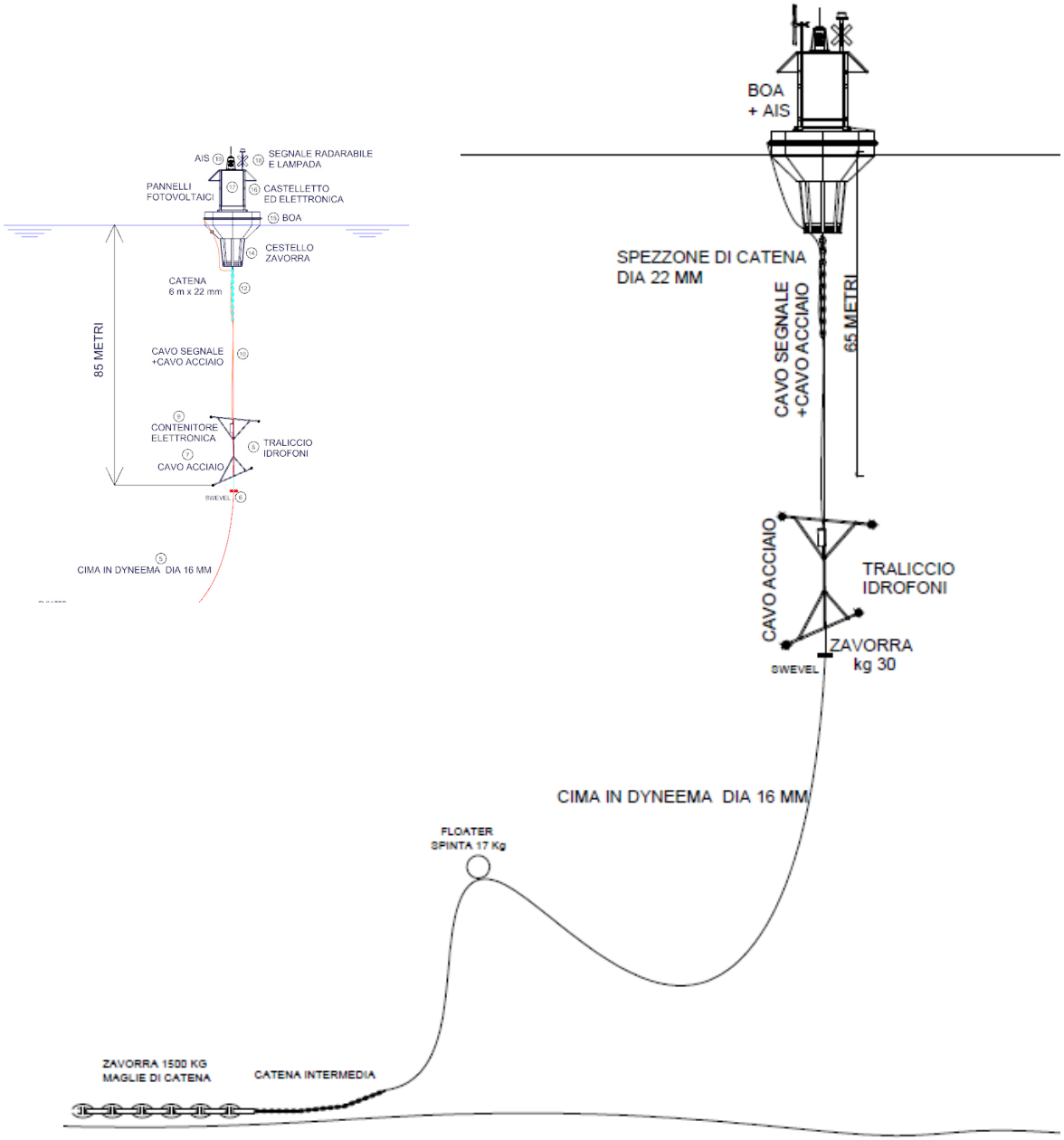

Figure 9 – Acoustic system and mooring

A BRIEF HISTORY OF THE DETECTION SYSTEM

The deployment of the buoy with the new proposed design and all the Wifi communication systems has been completed on June 6th, 2018.

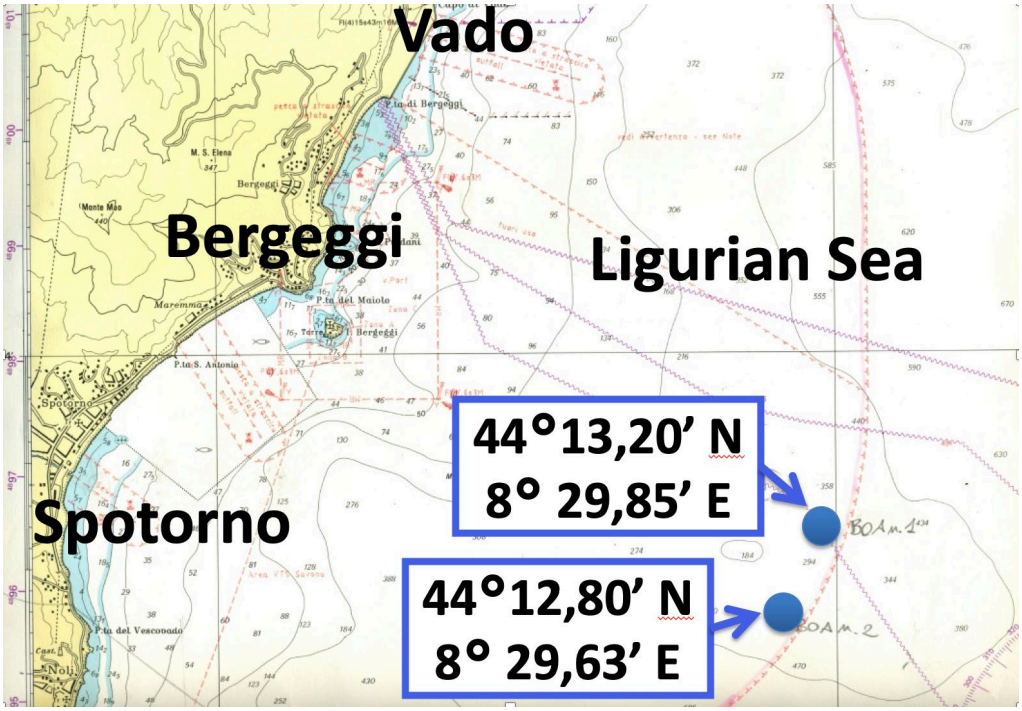

Figure 10 - Location of the WHALESAFE Detection Units

In Figure 10 the location of the two detection unit is reported. When in the second part of the project only one buoy was in operation it was located in the lower point.

The first presence of a Sperm whale has been recorded June 29th, 2018. In Figure 11 are reported the reconstructed angles while in Figure 12 it is reported a typical sound track shown for each hydrophone the direct and the reflected click.

During the 2018 summer campaign, we had a consistent presence of sperm whales in the project area between 12th and 13th July 2018. After the detection of the first clear cetacean signals on 12th July, a sea campaign has been scheduled for the next day allowing the visual identification of the sperm whales and the validation of the estimated emersion location with on-site verification. Details of the analysis of the 12th-13th July data sample are provided in the next chapter.

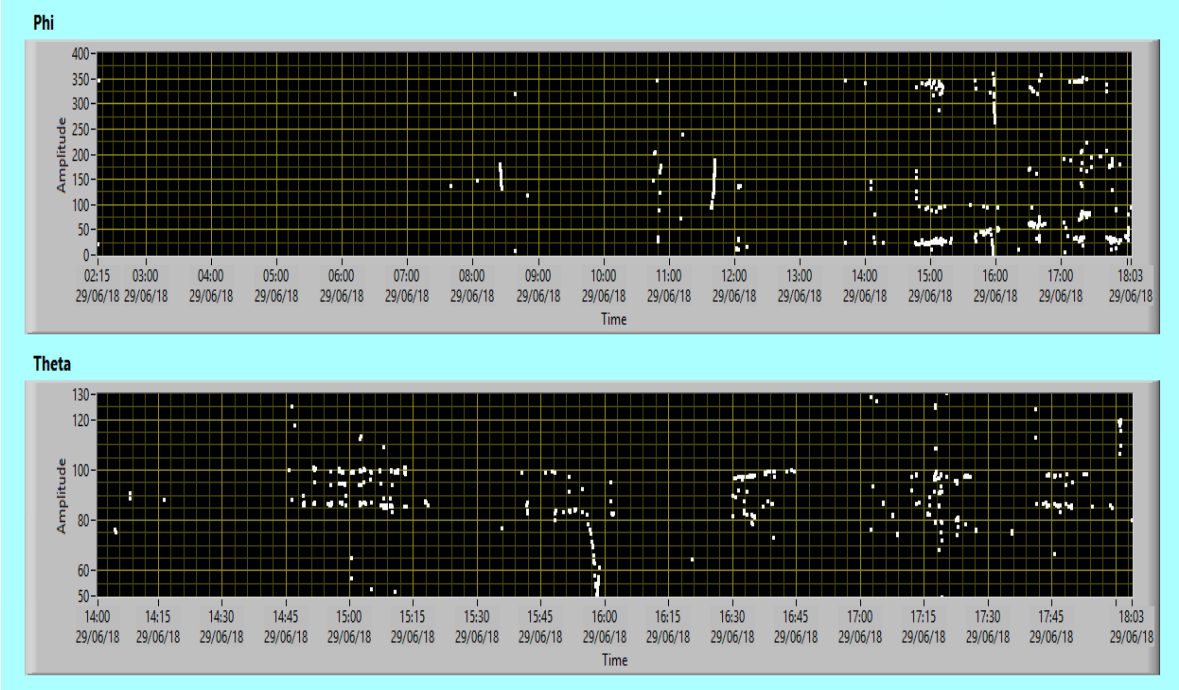

Figure 11 - Azimuthal (phi) and zenith (theta) of the detected sounds. In particular, in the zenith angle plot, the two series of "direct" and "reflected" signals are clearly visible.

Figure 12 – Amplitude and time correlation of the acoustic signal

The deep diving

A consistent presence of cetacean has been found on 12th and 13th July 2018, when 1308 sperm whale clicks has been recognized. A summary is reported in a table at the end of the documereconstructed direction of the direct and recflected signal are reported in Figure 13. The data shows five periods that

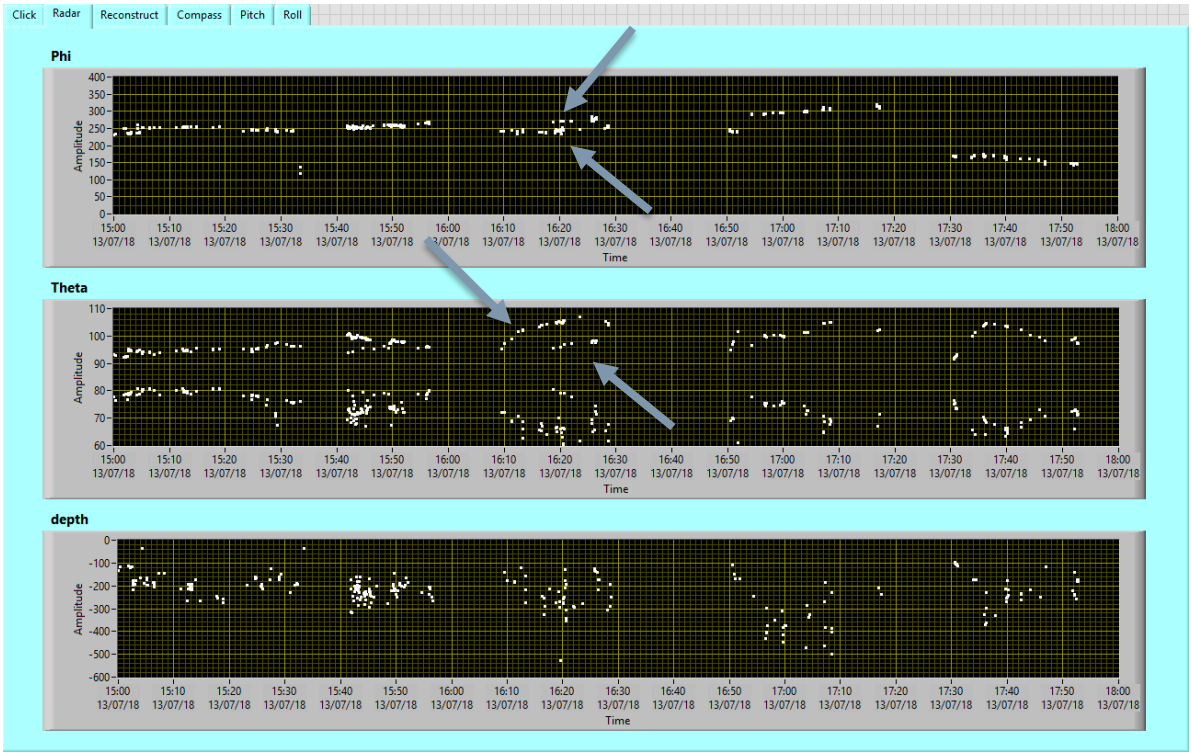

Figure 13 - Azimuthal (phi) and zenith (theta) of the detected clicks

corresponds to five different diving activities and the arrows indicate the presence of two animals. Also the shape of the signals confirms that the two series of clicks can be attributed to different Sperm whales.

The reconstructed tracks of the sperm whales was compared with the visual identification of the cetacean made by the DISTAV team on a boat in the area. The DIFI team was following in real time the predicted track of the cetaceans according to the reconstruction performed by the WHALESAFE system and communicated by M.Brunoldi at UNIGE. The position of the sperm whales was notified by mobile phone to the crew on the boat, which tried to follow the path of the animal in order to verify the predicted emersion location.

Figure 14 shows the GPS route of the boat and the three location of visual identification of the sperm whales. The two orange dots correspond to a first observation on surface of the whale and his immersion, the green dot corresponds to the immersion of a second whale. In Figure 15 are shown two frames of a short movie taken during this activity. The silos of the Savona port are clearly visible.

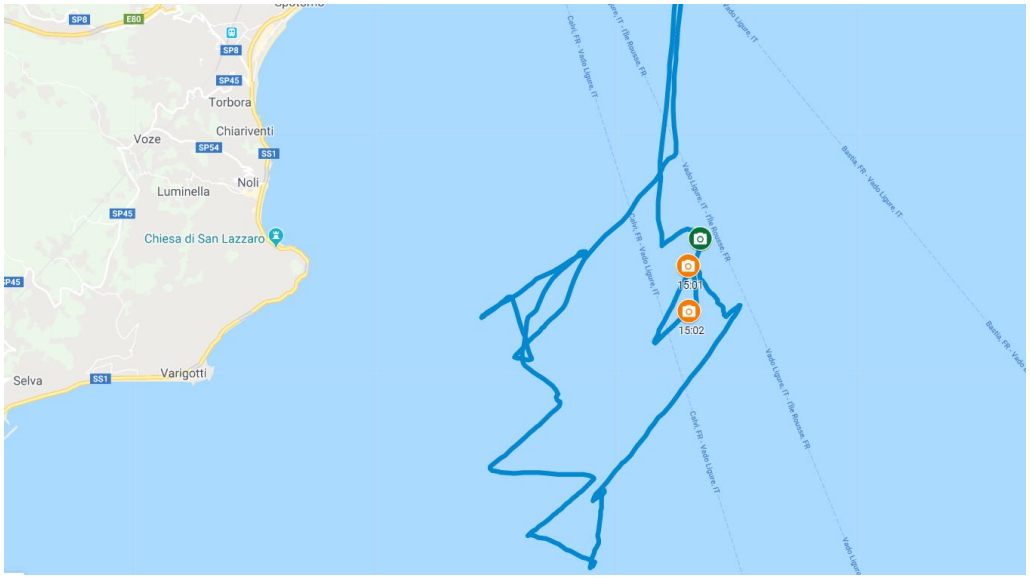

Figure 15 - DISTAV route and sightings

Figure 14 - two moments of the presence of the sperm whale observed by DISTAV

These sigthing where also used to fix the compass calibration by adding a constant value to all azimuthal angle in order to make the click detection compatible with the sightings. The effect is reported in Figure 16. It is evident that we obtain now a clear spatial correlation between the sighting and the reconstructed sperm whale routes, which confirms the previous hypotheses about immersion and emersion of the animals.

Finally the reconstructed routes have been superimposed to the batimetry of the area (Figure 14) and the comparison shows that the Sperm whale follows the profile of the canyon according to its normal behaviour as reported in literature.

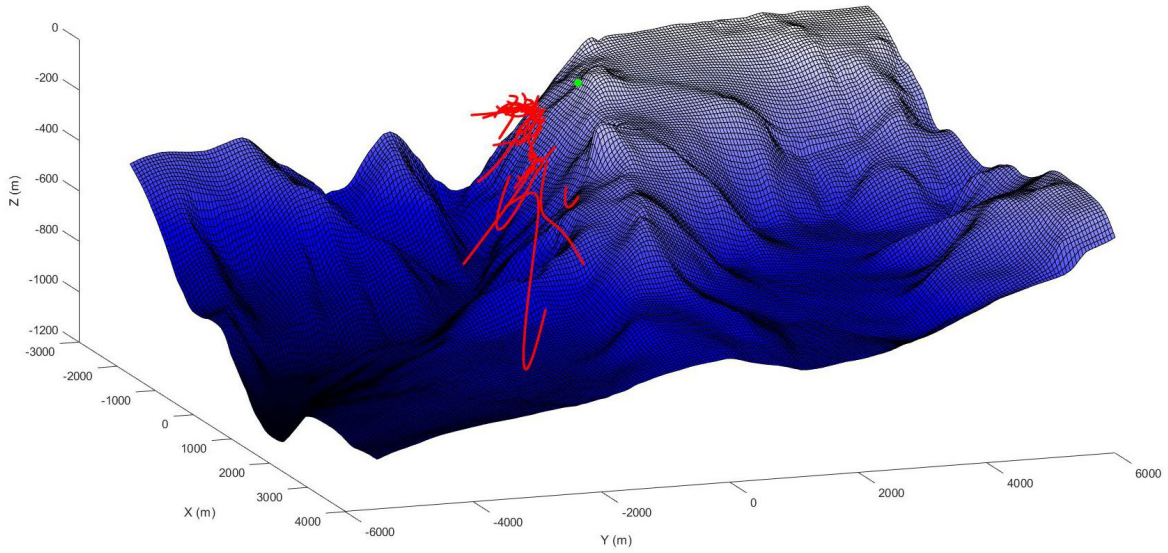

Figure 17 - All the reconstructed sperm whale routes recorded in the 12th'-13th July data sample compared with the batimetry of the area where the orientation calibration has been applied. The location of the buoy is indicated with a green dot

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