AFTERLIFE CONSERVATION PLAN

This document is the deliverable of Action F6

CONTENTS

Contents

INTRODUCTION

Introduction

This report summarizes how the sperm whale detection system of WHALESAFE is going to be implemented in the framework of the KM3NeT-ORCA experiment and in the framework of the new LIFE proposal LIFE20-NAT_IT_001330 FERA'S LIFE

Foreword

The project WHALESAFE came to an abrupt interruption when an exceptional storm hit the Ligurian coasts on 29th October 2018 and destroyed the buoy. However, in the months before this event WHALESAFE detected several Sperm whales, followed them during their diving activities and on 13th July 2018 provided the correct coordinates to a team of UNIGE active in the area with a boat, thus allowing them to visually localize the animal.

The main lesson we learned from this experience is that ALL the detections recorded by WHALESAFE have NOT been anticipated by sightings and the animals have been localized ONLY with the assistance of WHALESAFE, thus meaning that without WHALESAFE the presence of the animals in the area would have been ignored. This is the confirmation of the importance of the project: the risk of collisions with boats can only be reduced informing on the presence of the animals in order to adopt the correct behaviour. Without this information, the risk is maximum!

Therefore, we consider necessary to maintain the monitoring activity even in absence of the WHALESAFE system. To obtain this result we are planning to transfer all the knowhow and the experience gained in WHALESAFE to a long-lasting submarine infrastructure located at the border of Pelagos in French water.

The infrastructure is named KM3NeT-ORCA and is presently under construction close to Toulon. It started the operation in the last years and is operative since 17th May 2019 and it is expected to be completed in 2021. Mauro Taiuti, the coordinator of WHALESAFE is presently also the coordinator of KM3NeT-ORCA and together with Matteo Sanguineti and Carlo Guidi, they are implementing in KM3NeT-ORCA the detection algorithms and the alarm generation system.

Recently three Sicilian MPAs (Isole Pelagie, Plemmirio and Milazzo Cape) invited two beneficiaries of WHALESAFE, namely the University of Genova and Softeco, to participate to the proposal LIFE20-NAT_IT_001330 FERA'S LIFE. The proposal intend to replicate the system developed in WHALESAFE to monitor the cetaceans in the three Marine Protected Areas thus extending the protection actions not only to the sperm whales but also to other cetaceans and in particular to tursiops.

The KM3NeT-ORCA detector

The KM3NeT experiment (https://www.km3net.org/) will open a new window on the study of the Universe using neutrinos as messengers to study the most remote astrophysical objects. The neutrino is a really unique particle: it interacts with matter only through the weak nuclear force, it is neutral and has such a small mass that we haven't yet been able to measure it.

These properties make the neutrino an excellent "messenger" to study the Universe, as it can travel cosmological distances without being absorbed, being neutral it is not deflected by electromagnetic fields and can come from inside astrophysical objects unlike photons that are produced on their surface. Unfortunately, these characteristics that make the neutrino ideal for astrophysics are the same that make it particularly elusive when trying to reveal it.

Large neutrino telescopes exploit the interactions of very high energy neutrinos in seawater or polar ice through which charged particles such as electrons or muons (a particle similar to the electron but 200 times heavier) are produced. Since these particles are very energetic, their passage induces the emission of a light radiation

The detector will be built in the depths of the Mediterranean Sea off Toulon at a depth of 2800m (close to the western border of the Pelagos Sanctuary). The basic unit of the detector is the so-called "optical module", in which 31 photomultiplier tubes, i.e. light radiation meters, are housed. The optical modules, whose diameter is 43 cm, are arranged as in long necklaces (200 m long) called "strings", each of which houses 18 optical modules. In total the KM3NeT-ORCA detector will count 115 strings occupying a volume of about 1 km3 (Figure 1). The strings are powered and data are transmitted to shore by an electro-optic cable and a seafloor network of connecting points.

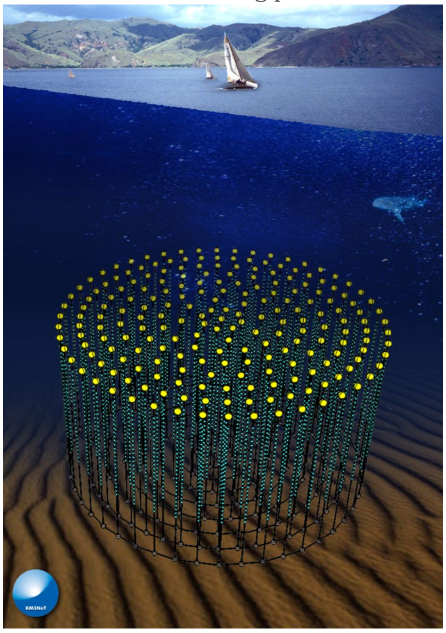

Figure 1 - Layout of the KM3NeT-ARCA detector

THE KM3NET-ORCA DETECTOR

The international collaboration KM3NeT- started in 2016 the construction of what will be the largest underwater telescope in the world. After the deployment of the cable and the seafloor network, on 17th May 2019 the first two strings were put in operation. Presently six strings are operative.

The KM3NeT collaboration counts about 230 scientists from 18 countries, most of them from Europe but also from Australia, South America, Africa and Asia. Globally there are 57 Universities or Research Institutes involved in the project.

The total cost for the realization of the experiment is around 200 million euros to which must be added the operating expenses which are about 2 million per year. The main founding have been obtained through the Regional European Funds for Research and Innovation, the National Operational Programme and the European funds Horizon 2020.

The KM3NeT experiment will not be limited only to research in the field of physics, the opportunity to have a detection system in the depths of the Mediterranean opens up to multiple studies in the fields of biology, oceanography, climatology and geology.

KM3NeT (http://roadmap2018.esfri.eu/projects-and-landmarks/browse-the-catalogue/km3net-20/) is presently in the roadmap of ESFRI (European Strategy Forum on Research Infrastructures - https://www.esfri.eu/) and the definition of its final legal structure has been financed by EU in the frame of Horizon2020 (https://www.km3net.org/km3net-infradev/).

All KM3NeT detection units have an acoustic emitter-receiver system which is normally used to reconstruct the instantaneous shape of each detector component. Close to the detector there are acoustic beacons that emit signals periodically, these signals are detected by the acoustic sensors throughout the detector. The measurement of the delay time between the detection of the various acoustic sensors allows you to reconstruct their instantaneous position so that you can find the configuration of the apparatus that is continuously altered by sea currents.

KM3NeT has two types of acoustic sensors: a hydrophone at the base of each string and a piezoelectric microphone inside each optical module.

Piezoelectric microphones, also called crystal microphones, exploit the properties of piezoelectric materials, which react to sound waves by generating an electrical signal. This type of microphone is very simple from a constructive and economic point of view.

Hydrophones are special microphones designed for the underwater environment. They consist of a microphone, usually selective, connected with a diaphragm in contact with the water, capable of receiving and revealing, electromagnetically, electrodynamically or piezoelectrically, the sounds or noises generated by an underwater source which, in water, propagate like pressure waves. The same company that produces the hydrophone used by WHALESAFE provides those adopted in KM3NeT.

This network of hydrophones, beyond its use for the calibration of KM3NeT, records all the sounds of the Mediterranean abysses at depths that have very few precedents for a continuous real-time detection apparatus.

For this reason, they can be used for systematic studies of the behaviour of large marine cetaceans, such as Sperm whales. These animals spend most of their time in the depths of the sea and come up to the surface only periodically to breathe, so a detector in the depths of the sea allows much more accurate studies than common acoustic detectors that are placed near the surface of the sea or at depths less than a few hundred meters.

Sperm whales periodically emit an echolocation signal called a "click" that animals use to recognize obstacles in front of them or for hunting. This signal can be revealed by the KM3NeT hydrophone network, allowing the presence of the animals to be detected, but also reconstructing their movements by triangulation.

This type of measurement allows real-time monitoring of the animals that allows multiple studies of their behaviours such as measuring time spent diving.

Finally, studies of anthropogenic influence on animal behaviour can be carried out by studying the correlation between intense anthropogenic activities and the presence of animals in the vicinity of the detector. The presence of intense marine traffic can be assessed using the AIS tracks of large tonnage ships, which are freely available on the web (https://www.marinetraffic.com/).

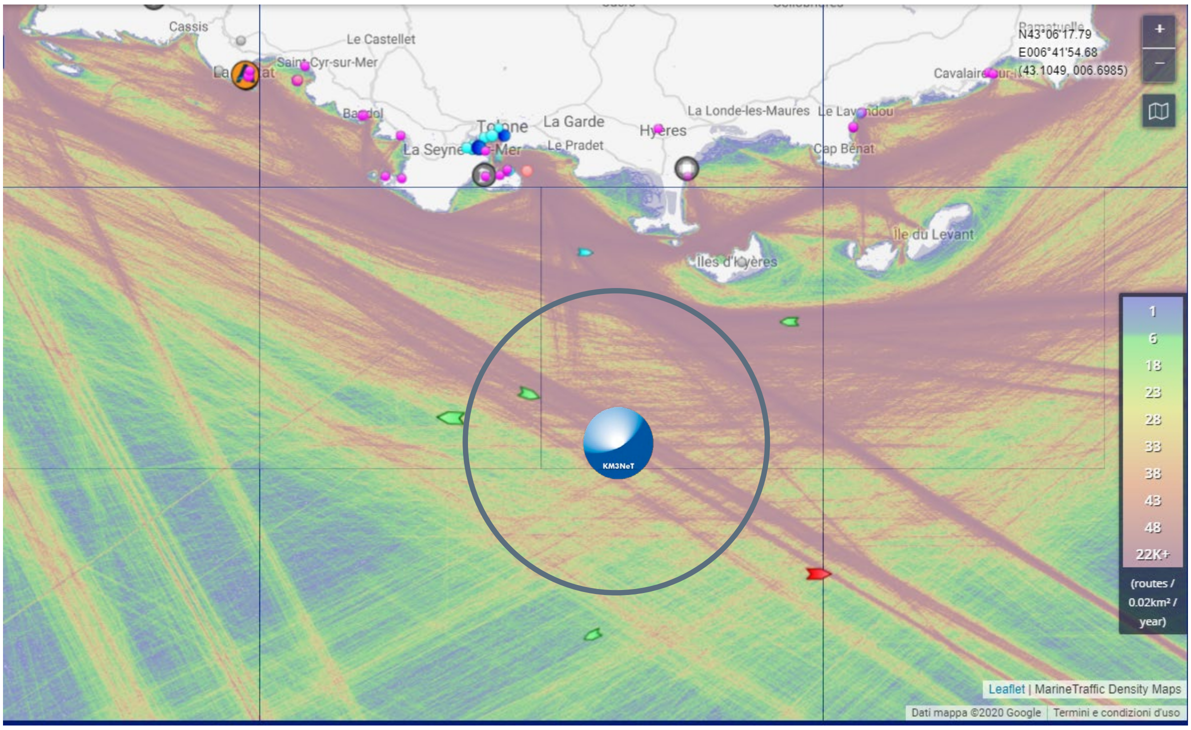

Figure 2 - Location of KM3NeT-ORCA in front of the Toulon harbour and marine traffic activity in the area

The KM3NeT-ORCA architecture, for what the acoustic sensor is concerned, can be considered as an improvement of WHALESAFE:

- the adopted hydrophones are a new version of those used in WHALESAFE, modified to work in deep water;
- the location of the hydrophones in the KM3NeT infrastructure is a reproduction on a larger scale of the 4-hydrohpone system designed for WHALESAFE;

- the disposition of the hydrophone in KM3NeT allows to use the same algorithm developed in WHALESAFE to localize and tracks the Sperm whales;
- in KM3NeT the sound tracks are transferred to shore to allow the full analysis (cetacean detection) in real time, necessary to generate the alarm as proved in WHALESAFE;
- KM3NeT is located at the bottom of the sea, therefore in a safer situation compared to WHALESAFE for what concern the storms and the interaction with fishing activities that caused the anticipated end of WHALESAFE.

The location of KM3NeT-ORCA is strategic for an effective implementation of the WHALESAFE protocol. As shown in Figure 2, KM3NeT-ORCA is located in front of the Toulon harbour and monitors an area heavily interested by commercial activities, being crossed by the routes of ships directed to the Marseille and Toulon harbours. The estimated range of detection is also reported. It is worth noting that the location of KM3NeT-ORCA is close to the reef thus providing good coverage of the area frequented by the sperm whales.

Another advantage of this proposal is that being KM3NeT-ORCA located in France the alarm system could be integrated in REPCET (http://repcet.com/en/). REPCET is active in the Pelagos Sanctuary and consists in a software designed for navigation which aims primarily to limit the risk of collisions between large cetaceans and large vessels. It is easy-to-use and based on the following elements: each cetacean encounter made by watch keeping personnel from a REPCET user vessel, is transmitted in real time by satellite to a shore server. The server centralizes the data and alarms any vessels equipped with REPCET likely to encounter the cetacean on their route. Then, the alerts are mapped on a dedicated screen located on board and are available for 24 hours on the screen.

Differently from REPCET, based on human skills and (working only during the day), KM3NeT/ORCA (inheriting WHALESAFE) will provide an automated procedure based on passive listening to the sound emitted by the animal, therefore it can works autonomously day and night providing a much higher efficiency in detection and localization of whales. The coordination of the two systems will drastically reduce the risk of collisions in the area of the Toulon harbour.

WHALESAFE heritage in KM3NeT-ORCA

The UNIGE group is reimplementing the click detection and route reconstruction algorithms developed during the WHALESAFE project in the framework of the KM3NeT-ORCA experiment.

M. Taiuti, M. Sanguineti and C. Guidi are members of the KM3NeT Collaboration, so they have full access to the detector instrumentation and collected data. The UNIGE group has agreed the following program with the colleagues of the KM3NeT experiment for the implementation of the sperm whale monitoring system.

The program has already received the support of the Italian-French University thanks to the participation of M. Sanguineti to the Galileo 2021 call with the proposal “KM3NeT-Whale”

Italian version: https://www.universite-franco-italienne.org/menu-principal/bandi/programma-galileo/bando-2021/
French version: https://www.universite-franco-italienne.org/menu-principal/appels-a-projets/programme-phc-galilee/appel-a-candidatures-2021/

After the selection of the best proposals, the Italian-French University granted 10 k€ for the support of this activities.

STEP 1: STUDY OF THE ENVIRONMENTAL ACOUSTIC BACKGROUND

In the first phase some preliminary studies will be made on the signals acquired by hydrophones in order to study their background noise, efficiency and sensitivity.

Recording sound samples over a long period of time will make possible to study which are the typical background levels of ambient noise at the depths of the KM3NeT-ORCA detector.

This work will require a synergy with all the KM3NeT collaboration. The length of the acoustic files and the frequency with which they will be collected will have to be agreed: it will be a compromise between the possibility of a sufficient statistics to have an accurate estimate of the background and the bandwidth limit of transmission and collection. The data from the submarine detector reaches the shore via a single electro-optical cable, so the large amount of data recorded by all hydrophones can only be collected for short time intervals.

STEP 2: ALGORITHM DEVELOPMENT FOR SIGNAL RECOGNITION

Once we have estimated the environmental background, we can proceed with the sperm whale click recognition algorithm. The objective is to automatically recognize in the acoustic data flow the segments in which echolocation signals are present, in this way it is possible to carry out a continuous monitoring of the presence of animals by saving only the relevant signal samples (considerably reducing the amount of data saved on disk).

The selection criteria for identifying a sperm whale signal will be directly driven by the experience of the WHALESAFE project: the signal shall be clearly distinguished from the ambient background and have a duration and frequency spectrum compatible with the typical sperm whale echolocation signals. The algorithm will be tested first offline on environmental background samples where sample clicks recorded by WHALESAFE will be artificially inserted and then online on the KM3NeT-ORCA data stream.

STEP 3: TRACKING ALGORITHM DEVELOPMENT

Once the sperm whale click recognition system has been validated, we can proceed with the adaptation of the WHALESAFE route reconstruction algorithm to the new system. Similarly the reconstruction of the path of the animals will be done through triangulation: we learned from the WHALESAFE experience that the cross correlation between the signals detected by the various hydrophones of the system will allow an accurate estimate of the delay time between the various sensors of our detector, this information will be used to triangulate the position of the source of the sound wave (in our case the sperm whale).

During the WHALESAFE experiment we also learned how to take in account the attenuation of sound waves and the thermocline effect, these features will be included also in the KM3NeT-ORCA reconstruction algorithm.

The algorithm will first be tested on simulated data (using “real” WHALESAFE cetacean routes) and then tested on data collected in real time by the KM3NeT-ORCA detector. The results will be compared with results obtained during the WHALESAFE project regarding the duration of sperm whale dives and their movement speed.

STEP 4: DATA COLLECTION

Once the trajectory reconstruction chain for sperm whales has been validated, it will be applied continuously and in real time to the acoustic data stream measured by KM3NeT-ORCA. This is essentially a data collection phase in which only minor interventions are foreseen in case software upgrades or transfer of the collected data to other storage facilities are needed.

STEP 5: DATA ANALYSIS

The data collected on the presence of Sperm whales in the area will be analysed. Several biological studies can be performed, and we can also study the anthropic influence on the presence of sperm whales (correlating their presence with the presence of large vessels in the area).

If the system will work continuously as expected, we could also think to implement a collision avoidance system similar to the one proposed in WHALESAFE project. In the detector area is present a high vessel traffic due to the military and touristic harbour of Toulon and the commercial harbour of Marseille.

WHALESAFE HERITAGE IN KM3NET-ORCA

The protocol of conduct developed in the framework of the WHALESAFE project could be implemented for the prevention of collision in the KM3NeT-ORCA area.

STEP 6: ALARM GENERATION

As soon as the detection system is validated, the same alarm generation system developed for WHALESAFE will be implemented.

FIRST PRELIMINARY ANALYSIS

KM3NeT-ORCA is currently composed of six strings deployed at sea, the base of which is at a depth of approximately 2440 m. Currently three hydrophones, positioned on the basis of the strings, are working and are collecting acoustic data. During the commissioning phase of the detector several short recordings of the hydrophone have been taken; but starting from April 6th, 2020, two hours of raw acoustic data are saved on one of KM3NeT's servers on Monday of each week.

The spectrogram of the data is used for an offline analysis in order to identify the possible presence of sounds emitted by cetaceans, in particular Sperm whales.

Analysing the first set of recordings taken during the commissioning phase, no Sperm whale clicks have been identified, but several whistles of cetaceans, probably Cuvier's beaked whales, have been revealed, as can be seen in Figure 3, which shows the spectrogram, and in Figure 4 that shows the amplitude of the recorded signal as a function of time.

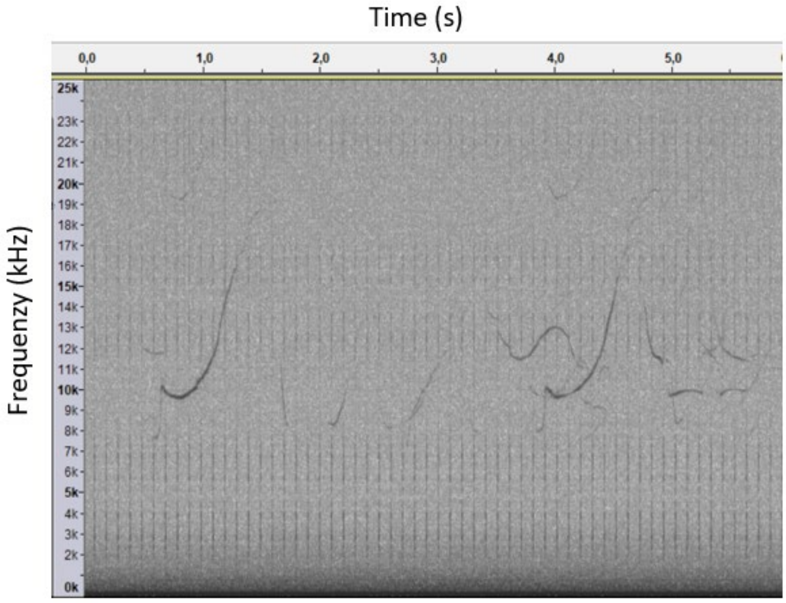

Figure 3 - Spectrogram of cetacean's whistles recorded by KM3NeT hydrophone

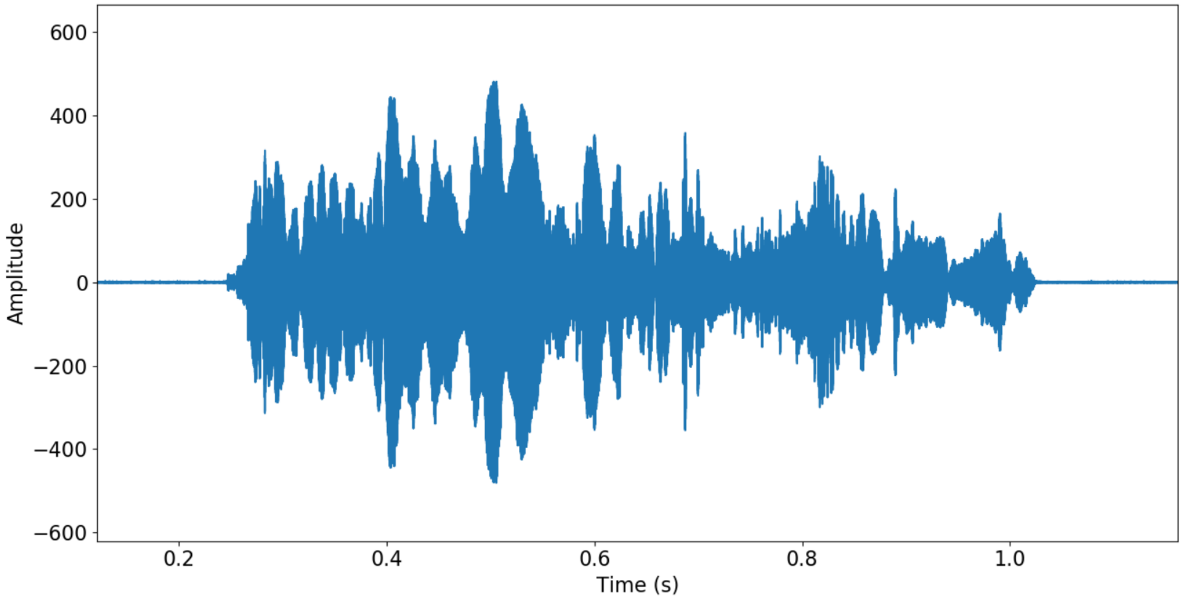

Figure 4 - Amplitude as a function of time of single cetacean's whistle recorded by KM3NeT hydrophone

An analysis of the underwater background noise was carried out, in order to clean the acoustic files and highlight the sounds emitted by passing cetaceans with a better signal to noise ratio.

This preliminary analysis of the raw acoustic data confirms that with this system, that can be considered as an evolution of WHALESAFE, it is possible to detect the presence of marine mammals.

CLICK IDENTIFICATION ALGORITHM

To process the data taken after April 6th we first adapted the WHALESAFE click identification algorithm to the WHALESAFE detector. The algorithm aims to distinguish the vocalization of different animals taking in account the inter click interval, the click shape and the frequency range. From the analysis emerged the presence of several clicks of sperm whales.

In Figure 5, Figure 6 and Figure 7 is reported a comparison between the clicks of striped dolphins and sperm whales showing the different inter click intervals, shapes and frequencies.

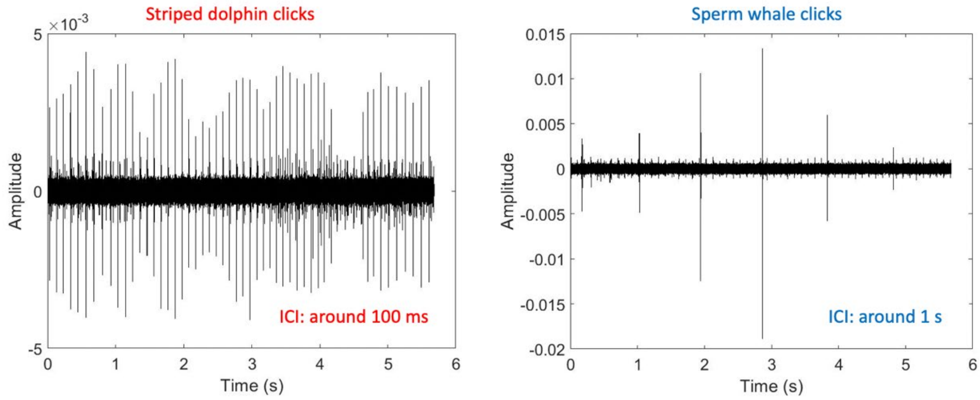

Figure 5: Two cetacean samples detected by KM3NeT that shows clearly different inter click interval for different species

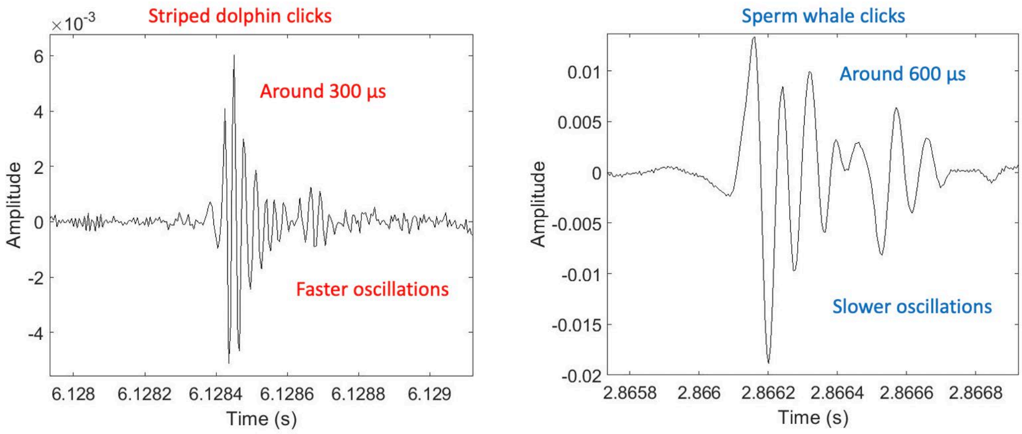

Figure 6 – Recorded clicks of two cetacean samples that show clearly different frequency for different species

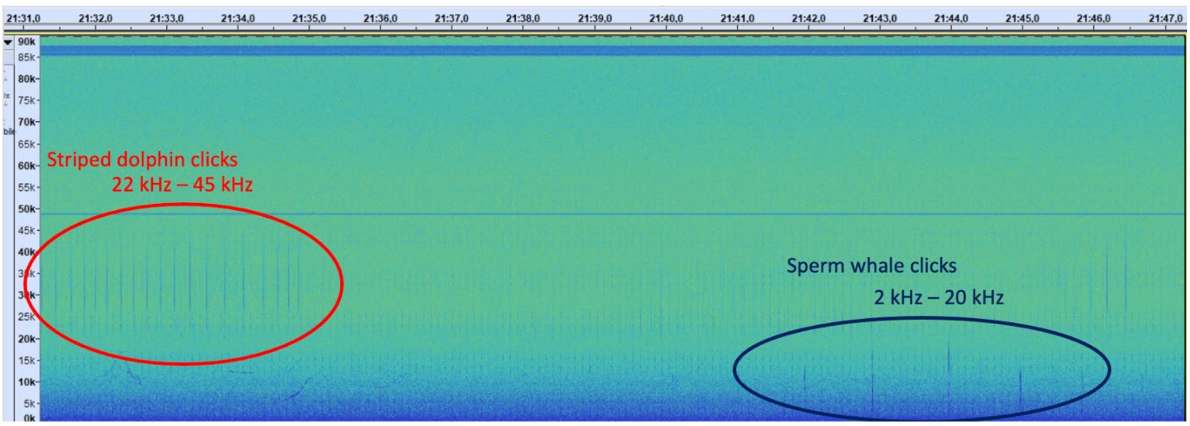

Figure 7 – Spectrogram of two cetacean samples that show clearly different frequency for different species

Here below the steps of the click identification algorithm are reported:

- Application of a high pass filter (2 kHz or 5 kHz) to mitigate the low frequency noise
- Subdivision of the audio file into time windows of a certain duration (0.15 s) with an overlap of 50% in order to avoid click signal splitting in different time windows (Figure 8).
- For each time window, calculation of the Signal to Noise Ratio (SNR) as a function of time, taking as reference noise the median of the absolute value of the envelope (Hilbert function) of the data stream.
- In each time window a click is identified if the SNR is greater than 10 times the median of SNR of the background (SNR threshold) (Figure 9). The value of the threshold is empirical.

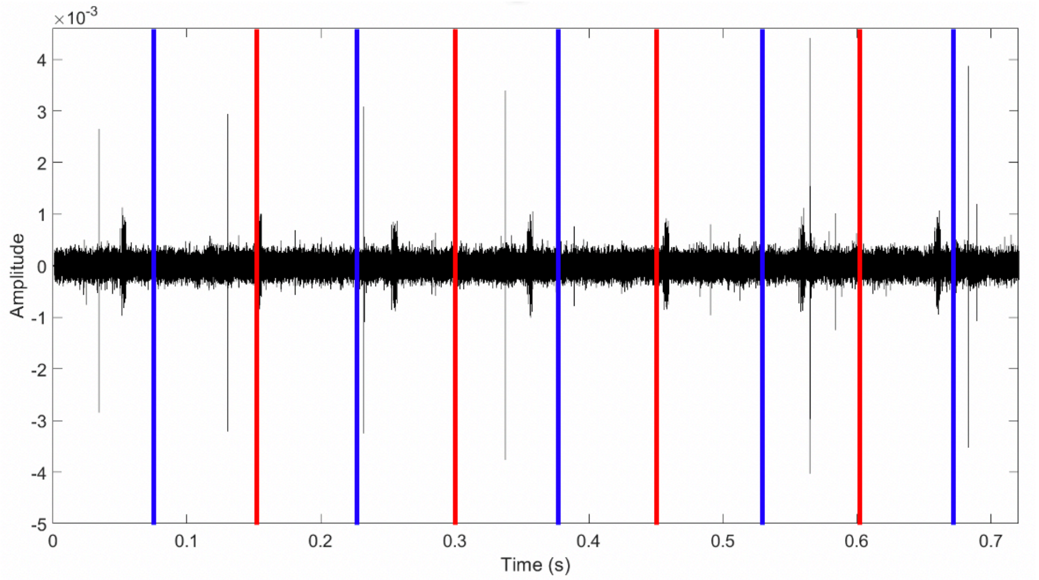

Figure 8 – Example of subdivision of the data stream in different time windows (red and blue vertical lines)

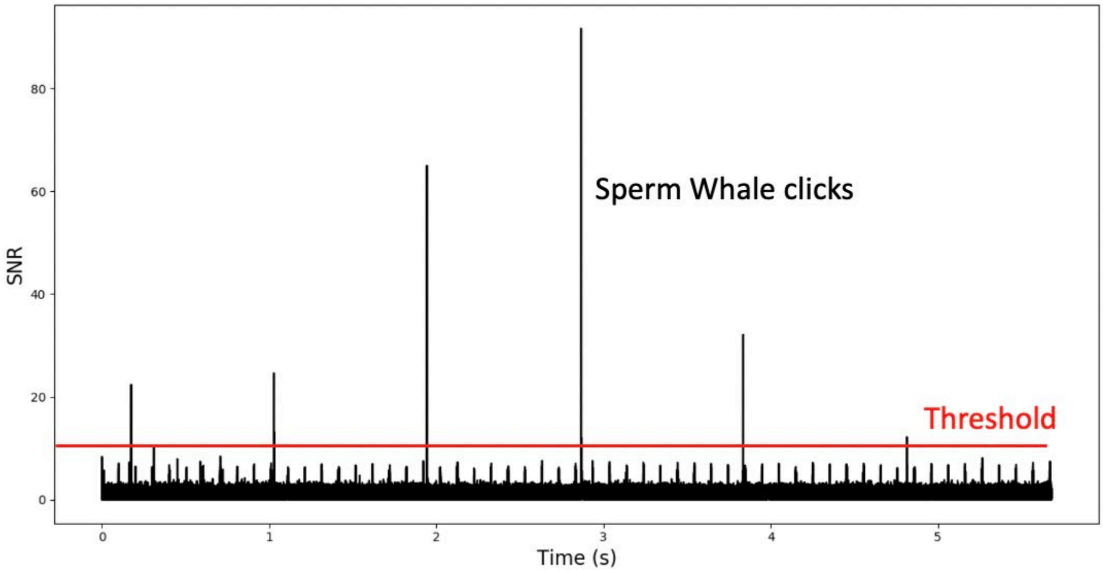

Figure 9 – Comparison of the SNR of sperm whale clicks with the identification threshold.

- In each time window where a click has been identified Fast Fourier Transform (FFT) is applied and amplitude between 5 kHz and 50 kHz are selected.
- The FFT of the selected window is compared with the FFT of a background only sample. If at least 20% of the values in frequency range 5-50 kHz are greater than the reference noise, the time window is saved (possible click), otherwise it is discarded
- The FFT in the range 5-22 kHz and 20-50 kHz are compared to recognize the cetacean
- Further empirical filters.

The number of cetacean clicks identified in April 2020 are reported in Figure 10.

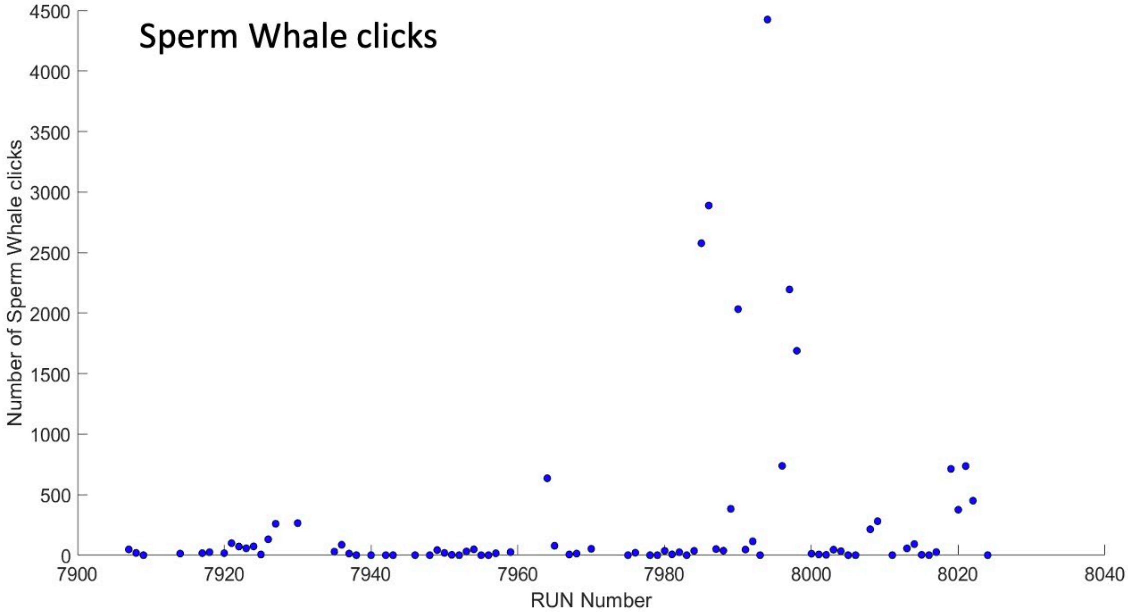

Figure 10 – Number of sperm whale clicks identified in April 2020

The number of identified clicks (around 20000) is very comforting and testifies to the likely intense sound activity of marine mammals in that area and therefore the possibility to reproduce and implement the Protocol of Conduct developed in the WHALESAFE project.

CETACEAN POSITION RECONSTRUCTION ALGORITHM

The steps of the cetacean reconstruction algorithm, which is derived by the WHALESAFE experience, is reported below:

- Collect all acoustic files of a selected time interval
- Select a reference hydrophone
- Apply the click identification algorithm to the reference hydrophone
- Select the time window containing a click for the reference hydrophone and the corresponding time interval for all the other receivers (Figure 11)
- Perform cross-correlation between the time window of the different receivers (Figure 12)
- Derive the time delay between the receivers using the maximum value of the quality factor of the cross-correlation (Figure 13)

- An empirical threshold is applied on the maximum quality factor in order to determine if a particular receiver has detected the click or not in that particular time window.
- Apply the position reconstruction algorithm to the clicks that have a sufficient number of receivers

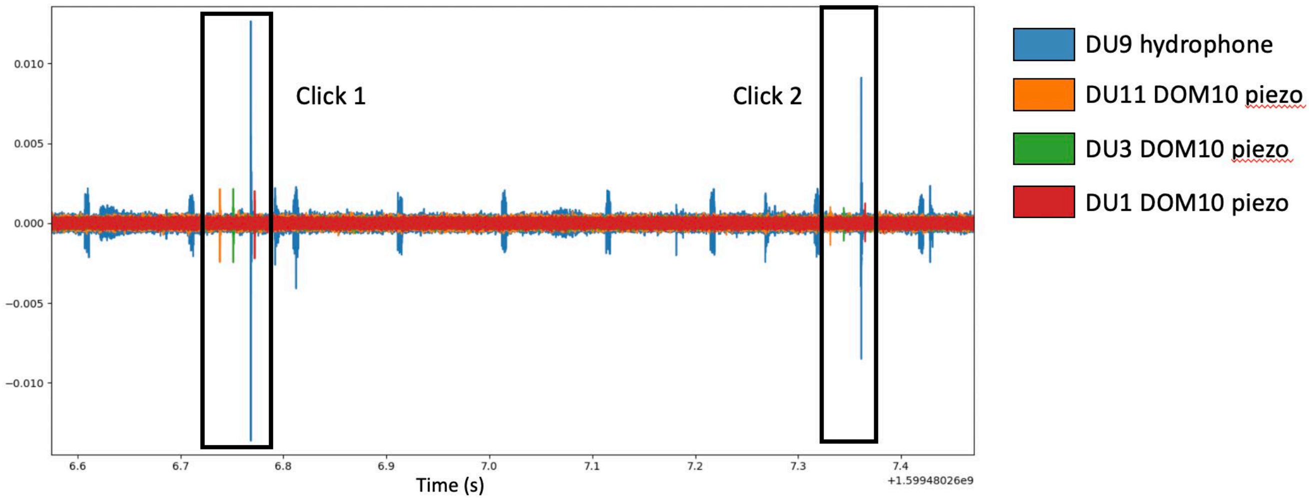

Figure 11 – Comparison between the signal detected by and hydrophone and several piezo-electric microphones. The black box represents a time window.

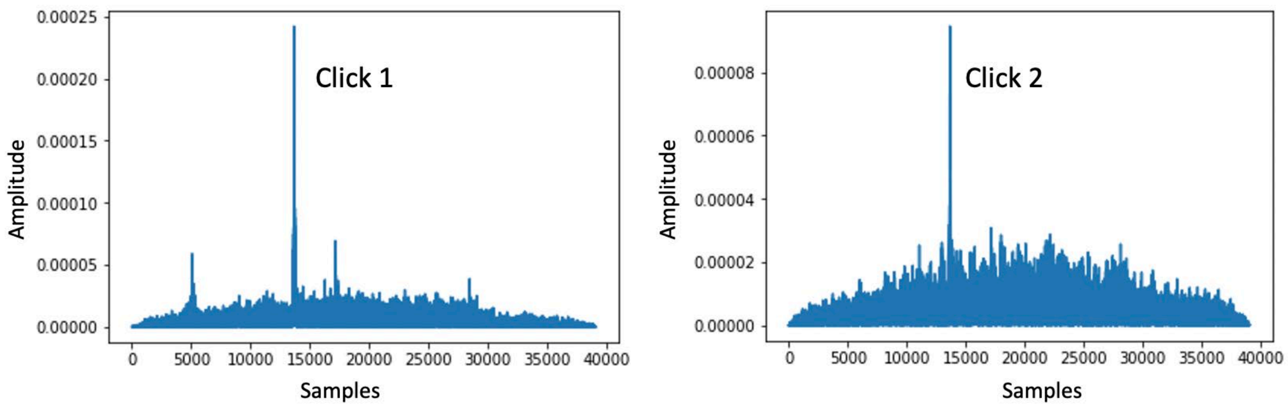

Figure 12 – Cross correlation quality factor between two consecutive clicks. The sample at which the maximum value of the quality factor is obtained, represent the delay time between the two receivers considered.

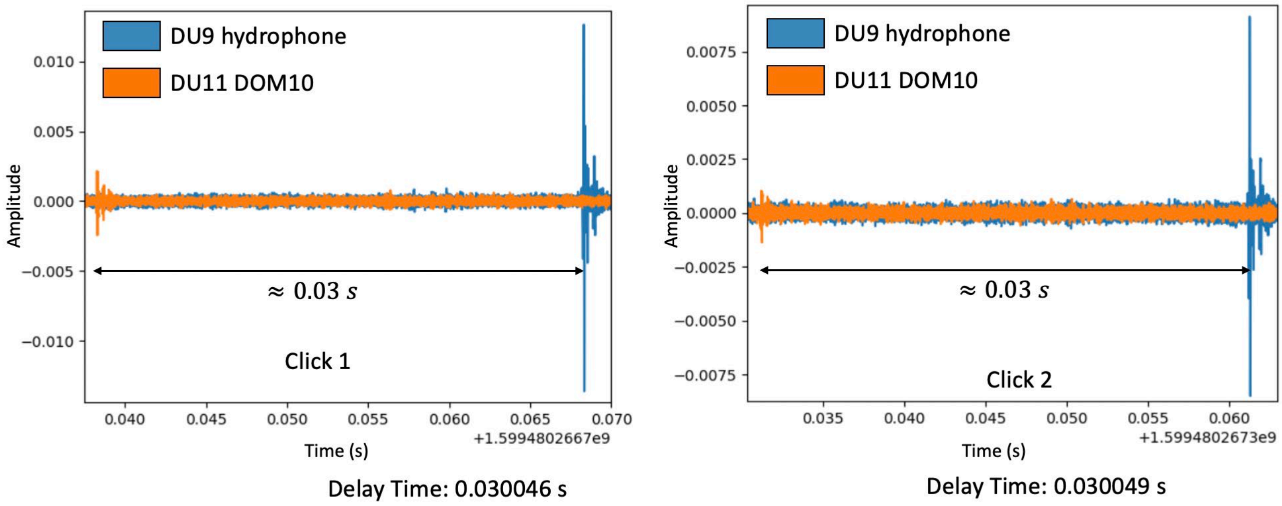

Figure 13 – Comparison between two consecutive clicks detected by two different receivers. The delay time is computed through the cross correlation

Once the time delay between the different receiver has been computed, the position of the cetacean is computed minimizing the time difference between the theoretical arrival time and the measured one (assuming a position of the sound emitter). The position which minimizes this quantity is the most likely position of the cetacean.

At the moment the detector counts only two working hydrophones, but it has multiple piezo-electric sensors, even if their accuracy is much lower with respect to hydrophones.

In Figure 14, the delay time between two hydrophones is shown for a series of sperm whale clicks.

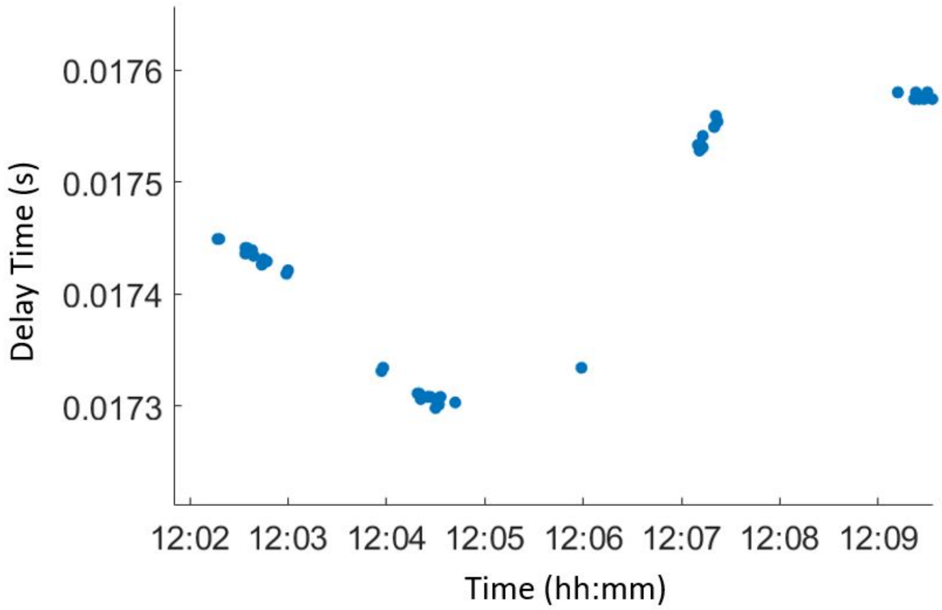

Figure 14 – Delay time between two hydrophones for a series of sperm whale clicks.

The detector is currently under construction, so the number of hydrophones and piezo-electric sensors will increase in the following years. We performed already a study of the detector accuracy with a larger number of sensor assuming 17 hydrophones (the full detector will count around 100 hydrophones).

In figure 15 the percentage error on x and y coordinate of the reconstructed position is shown as a function of the cetacean distance.

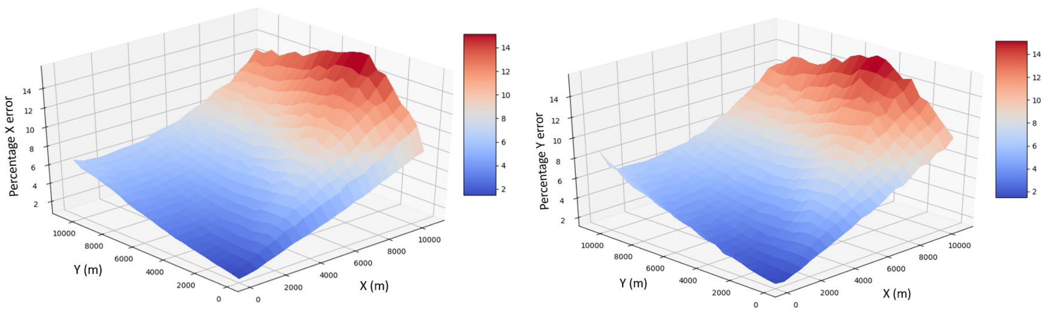

Figure 15 – Estimated percentage error on x and y coordinate of the reconstructed position is shown as a function of the cetacean distance (simulation)

The figure clearly shows that even at very large distances the percentage error is below 15%.

WHALESAFE and FERA'S LIFE

The UNIGE and SOFTECO groups are beneficiaries of the recently submitted LIFE proposal LIFE20-NAT_IT_001330 FERA'S LIFE.

The main purpose of FERA'S LIFE is the reduction of the impacts between marine traffic and bottlenose dolphins in particular to reduce:

The risk of collision,

The alteration of dolphins behavior;

The masking of dolphin's communication and echolocation sounds;

The dolphins area avoidance.

These will be achieved through a reduction of negative interactions between dolphin and boating in 3 Italian MPAs, by means of a new real-time passive acoustic monitoring (PAM) system aimed at the detection of dolphins, other occasional cetaceans species and boats transiting in the monitored areas, and by diffusing a code of conduct to be applied in presence of dolphins. The PAM system will be an evolution of the acoustic system implemented by the ARION (LIFE09 NAT/IT/000190 ARION) and WHALESAFE Projects.

The Coordinating Beneficiary is the MPA of Pelagie Islands founded in 2002 by Ministry of Environment to establishing in 2003 Municipality of Lampedusa and Linosa as managing authority. The MPA is composed by 3 small islands sited in the Strait of Sicily covering 4136 ha and encompassing three different protection zones where the keys species under protection rules are Cetaceans and Marine Turtle. The MPA is managing authority of the marine site of Natura2000 (ITA040014) which includes conservation measures on marine biodiversity to leading to sustainable management of the area.

In the MPA Pelagie islands exists a resident sub-population of bottlenose dolphins, that is one of the most densest community inside the Mediterranean Sea. The most recent estimates count 176 dolphins. At the same time Lampedusa is one of the most touristic island in the Mediterranean Sea with an average of 200.000 tourists each year (municipality data) and its inhabitants (6,200 municipality data) rely on boat tourism as one of their main economic resources counting more than 2,000 boats. Each year MPA releases about 600 authorization of small boat for tourism. This waters are also used by many fishing boats, resulting in a very intense boat traffic, 94 professional fishing boat are authorized among trawl and artisanal activities. Has been proved that dolphins living in the waters around Lampedusa Island, are impacted by boat disturbance, in particular has been observed that powered engine boats disrupt dolphins feeding, social and resting activities, for this reason enforcement of conservation measures are strongly recommended. In the other MPAs, Plemmirio (Siracuse) and Capo Milazzo (Messina), situated near important harbor with high maritime traffic, Bottlenose dolphins are represented by several individuals and conservation measures are included in MPA's rules. In these area is needed an improvement of dolphins population knowledge in front of high maritime traffic and disturbance.

FERA'S LIFE concrete actions are largely inspired by WHALESAFE

C1 Eavesdrop system for dolphin. The acoustic detection systems able to reveal dolphins in realtime in the monitored areas will be designed and realized by implementing and adapting the WHALESAFE system. The new system will be able to detect both communication (whistles as in ARION) and echolocation (clicks as in WHALESAFE) sounds produced by dolphins and other cetacean species, to incrementing greatly the cetacean's detection success. The system will be installed in 3 MPAs to reduce direct and indirect impacts of marine traffic on dolphins. The system will be designed and put in operation by the WHALESAFE members of UNIGE. The lower depth of the seafloor in the three MPAs will permit to easily remove the system during the winter season when storm could damage the infrastructure as happened in WHALESAFE.

C2 Local management plan to reduce disturbance of dolphins in the MPAs. Specific rules for the protection of bottlenose dolphins and other cetacean will be adopted in the MPA's rules to ensuring the conservation of dolphins population as a concrete tool to protect local populations.

C3 Surveillance plan for Coast Guard and risk mitigation. A surveillance plan for the conservation of dolphin will be implemented by the maritime authority. The Coast Guard will act specific periodical control of the MPAs to verify navigation behavior in order to ensure the respect of the Eco-sustainable dolphin encounter protocol (C5) through real time notification to guarantee the mitigation of the impacts.

C4 Application of alert system. A real time alert system will be developed to inform users about the presence of dolphins in the MPAs to reduce interaction between the dolphins and the anthropic activity. Notifications will be transmitted through multiple support (VHF, mobile app, hub, social networks, WhatsApp, telegram). The WHALESAFE members of SOFTECO will implement the same communication tools developed for WHALESAFE.

C5 Eco-sustainable protocol for dolphin encounter. A protocol of conduct to be applied in the presence of dolphins or other cetacean species will be defined and diffused. It is a concrete tool to define the rules in the MPAs to make the encounters eco-sustainable, to regulate the anthropic activities and to reduce disturb.

C6 Training courses and best practices. Training courses on eco-sustainable dolphin watching will be organized for each stakeholders group: fishermen, diving centers, boat rentals, guided visits, commercial navigation.

CONTACTS

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