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A WAVE GLIDER FOR PASSIVE ACOUSTIC MONITORING OF CETACEANS IN THE MEDITERRANEAN SEA

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ABSTRACT

A Wave Glider is a surface and remotely operable oceanographic platform equipped with multi-parameter sensors, including a towed array hydrophone. Here, we tested the potential use of this autonomous vehicle to acquire high quality acoustic data and provide information on the spatial distribution of different cetacean species in the Mediterranean Sea, including elusive species such as deep-diving whales. This autonomous vehicle was launched from the island of Minorca (Spain) to Apulia (Italy), crossing the southern Tyrrhenian Sea, the Strait of Sicily, the Ionian Sea and the lower Adriatic Sea for about 1,600 nautical miles. Acoustic data were acquired continuously from the 30th September to the 17th December 2022. Data collection was set at a sampling rate of 192 kHz, storing files of 460 sec in the flac format. A total of 10,695 recordings (about 1.3 TB) were acquired. A preliminary data analysis involved spectrogram visualization and audio listening of a subsample of the dataset (3,565 files), both broadband and low-frequency, to identify cetacean vocalizations and anthropogenic noise sources. The acoustic signals of delphinids, sperm whales, fin whales and different anthropogenic noise sources were identified during the route traveled by this autonomous surface vehicle.

Keywords: *autonomous vehicles, large-scale monitoring, vulnerable species, marine conservation.*

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1. INTRODUCTION

The Mediterranean Sea is one of the busiest marine areas in the world. Despite covering only 0.8% of the global ocean surface, marine traffic is extremely high in the basin, with 30% of all the international activity, and resulting in high levels of noise pollution [1]. Currently, eight cetacean species are commonly found in the Mediterranean Sea, where they face other threats besides noise pollution, such as chemical pollution or overfishing [2]. These threats affect the distribution and abundance of Mediterranean cetacean populations, most of which are already classified as threatened on the IUCN Red List [3]. Knowing the spatiotemporal distribution and abundance of a cetacean species in a given area is essential to effectively promote conservation actions and to fill the lack of scientific knowledge about its ecology and biology [4]. In recent years, passive acoustic monitoring (PAM) has been increasingly used to investigate the distribution and abundance of cetaceans and to study the impact of human activities [5]. PAM is a powerful technique for detecting cetaceans, not only because they use sound for their main biological activities, but also because underwater behavior limits traditional visual surveys [6]. This technique offers the possibility of detecting animal information using a non-invasive method, over large areas and for a long time, in remote areas or where data are lacking, and regardless of weather conditions [7]. Therefore, PAM applications are opening up new scientific prospects in ocean exploration [8]. Multiple types of acoustic observatories are deployed around the world and available to the community of international experts [9]. Sound recorders are now built with cost-efficient technologies and installed in fixed configurations (e.g., moorings, cabled stations), drifting devices (e.g., buoy, floats) and autonomous vehicles (e.g., gliders, autonomous underwater vehicles) [5]. Nowadays, ocean gliders equipped with acoustic receivers and signal classification software are able to transmit in near real-time the positions of different species of whales via satellite link [10]. Here, preliminary results of the first deployment of an autonomous surface vehicle (ASV), called Wave Glider, in the central Mediterranean Sea are shown. The glider was deployed to detect cetaceans in order to study their diversity, distribution, abundance and behavior, and to identify the main anthropogenic noise sources.

2. MATERIALS AND METHODS

2.1 Study area

The Wave Glider was deployed on the 13th of September 2022 from the island of Minorca (Spain), crossing several areas of the Mediterranean Sea, such as the southern Tyrrhenian Sea, the Sicily Channel and the northern Ionian Sea until the end of its trip in Italy on the 17th of December 2022. The Wave Glider travelled over 1,600 nautical miles during this deployment at a speed between 1 and 3 knots.

2.2 Data collection

The Wave Glider is an autonomous surface vehicle (ASV), remotely controlled and powered by sun and wave energy. It consists of a floating part on the surface and an underwater part connected by an 8-meter cable. The surface part is equipped with batteries powered by solar panels, a programmable and remotely modifiable navigation system, a satellite communication system, and multi-parameter oceanographic sensors (Fig. 1). In particular, the Wave Glider was equipped with a single-towed hydrophone with a sensitivity of – 193 dB re 1V/μPa with a recording gain of 15 dB. Data acquisition started on the 30th September and recordings were acquired continuously until the 17th December 2022, except for the following days due to technical reasons: from 26th to 30th November, the 10th December and from 13th to 15th December (Fig. 2). Acoustic data were acquired at a sampling rate of 192 kHz and 24 bits, storing a total of 10,695 recordings of 460 sec in flac format (about 1.3 TB).

2.3 Data analysis

In this study, a subset of the entire dataset was selected (every third file, for a total of 3,565 files) and analyzed through spectrogram visualization and audio listening using the software Raven Lite (Bioacoustics Research Program, Cornell Lab of Ornithology). A frequency dowsampling of each acoustic file, set at 1.6 kHz, was also performed with MATLAB (MathWorks, Natick, MA, United States) to detect the "20 Hz calls" emitted by fin whales.

Data analysis consists of detecting the presence/absence of delphinids, sperm whales, fin whales and anthropogenic sound sources (ships, sonars, low frequency pulses). Moreover, sounds emitted by cetaceans have been classified in different categories (e.g., delphinids: echolocation clicks, whistles, pulsed sounds). The dataset was analyzed by three PAM operators to limit the observer bias.

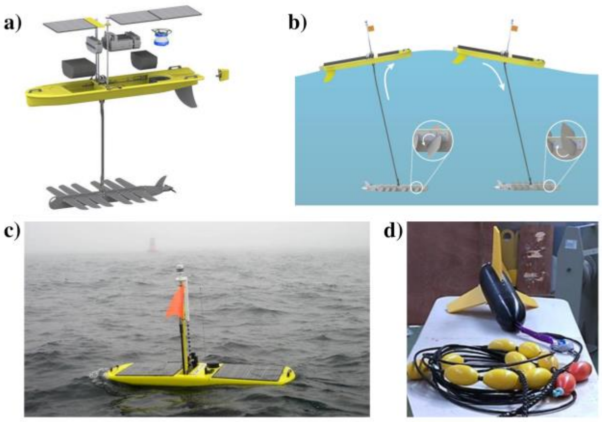

Figure 1. The Wave Glider; **a)** render of the vehicle; **b)** system for energy production and propulsion; **c)** deployment; **d)** the towed hydrophone.

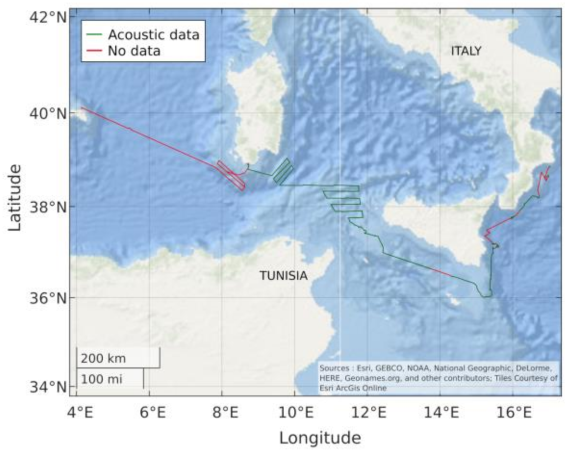

Figure 2. The track traveled by the Wave Glider. The map shows in green when acoustic data has been acquired and in red periods without data.

3. RESULTS

Preliminary results of such large-scale acoustic survey provided information on cetacean species diversity in the study area. Acoustic signals from delphinids, sperm whales and fin whales were identified during the route traveled by the Wave Glider (Fig. 3 and Fig. 4).

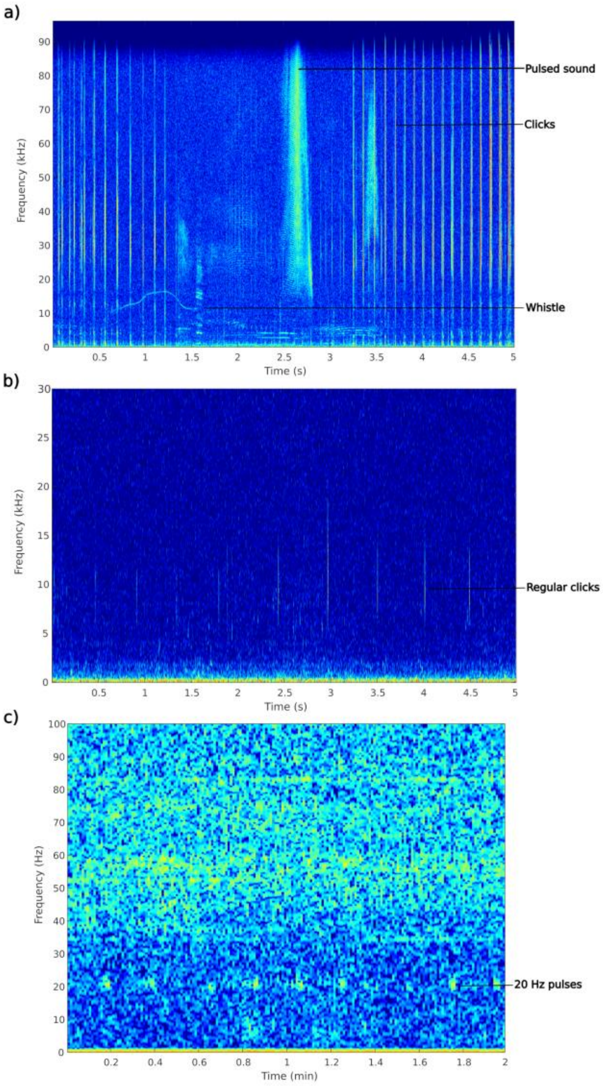

Figure 3. Spectrograms of short sound clips with acoustic signals from different cetacean species; **a)** delphinids; **b)** sperm whale; **c)** fin whale.

In total, 1,594 files with detections (i.e., presence of at least one signal from the specific sound source) of delphinids have been reported (44.7% of the analyzed dataset), 104 files with detections of sperm whales (2.9%) and 13 files with detections of fin whales (0.4%) (Fig. 4a). Whistles were the most-common type of sound emitted by delphinids (78.3% of files with detections), followed by clicks (57.4%) and pulsed sounds (17.2%). Among the files with sperm whale detections, regular clicks were found in all the recordings (100%), while codas and creaks were accounted for 4.8% and 3.8%, respectively.

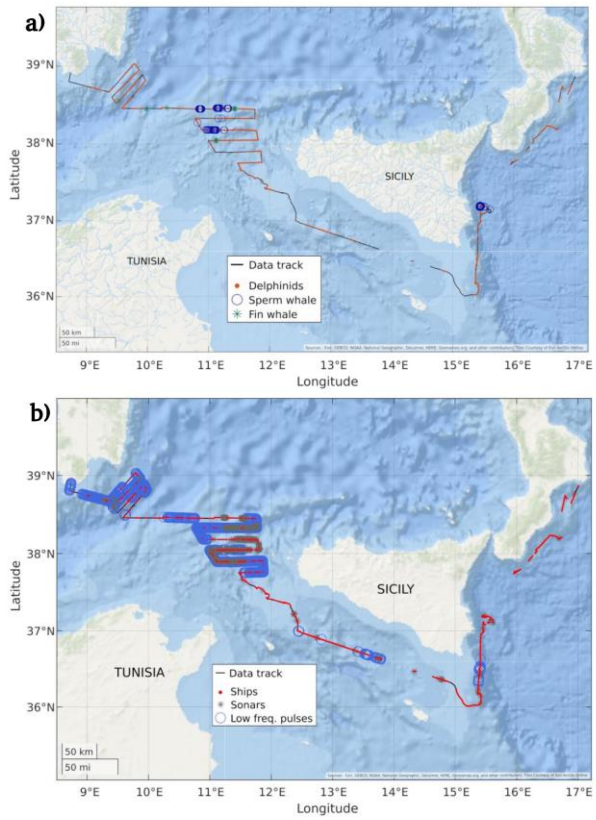

Figure 4. Spatial distribution of sound sources. **a)** cetaceans (delphinids, sperm whale, fin whale); **b)** human activities (ships, sonars, low freq. pulses).

Regarding the anthropogenic sounds, ship noise was the most common source with 2,414 detections (67.7%). Sonars were detected in 389 files (10.9%) and low-frequency pulses (uncertain sources, possible airguns) were found in 699 files (19.6%).

4. DISCUSSION

Traditionally, long-term PAM surveys are based on the installation of hydrophones on mooring platforms or underwater cabled stations [11]. More recently, autonomous observation systems (AOS) have been used for passive acoustic monitoring [5]. In particular, gliders can stay at sea for several months and are equipped with sensors to measure both environmental parameters and ambient noise [12-14]. Within this type of platforms, there are two main categories based on their buoyancy and locomotion system: ocean gliders and wave gliders. In the Mediterranean Sea, ocean gliders have been shown to be effective in detecting the presence of cetaceans and to be able to characterize their habitats [13]. Preliminary results presented in this study showed that also wave gliders can provide essential information about cetaceans in the Mediterranean Sea, especially in remote and offshore areas. Further analysis and deployments are ongoing to obtain more insights on species abundance, behavior, habitat use and impact of human activities.

5. CONCLUSIONS

Marine mammals play a key ecological role in maintaining the integrity of marine ecosystems as apex predators. Mediterranean populations are currently under severe pressure due to the negative effects of human activities and climate change. Actions to protect these vulnerable species require reliable data through scientific expeditions that are difficult and expensive to carry out. Autonomous platforms are now the largest *in situ* ocean observation tool and provide an enormous amount of significant information.

6. ACKNOWLEDGMENTS

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