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Continuous monitoring of noise levels in the Gulf of Catania (Ionian Sea). Study of correlation with ship traffic

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ABSTRACT

Acoustic noise levels were measured in the Gulf of Catania (Ionian Sea) from July 2012 to May 2013 by a low frequency (< 1000 Hz) hydrophone, installed on board the NEMO-SN1 multidisciplinary observatory. NEMO-SN1 is a cabled node of EMSO-ERIC, which was deployed at a water depth of 2100 m, 25 km off Catania. The study area is characterized by the proximity of mid-size harbors and shipping lanes. Measured noise levels were correlated with the passage of ships tracked with a dedicated AIS antenna. Noise power was measured in the frequency range between 10 Hz and 1000 Hz. Experimental data were compared with the results of a fast numerical model based on AIS data to evaluate the contribution of shipping noise in six consecutive 1/3 octave frequency bands, including the 1/3 octave frequency bands centered at 63 Hz and 125 Hz, indicated by the Marine Strategy Framework Directive (2008/56/EC).

1. Introduction

Anthropogenic underwater noise has increased substantially over the previous decades and a significant component of noise in marine environment is due to ship traffic. From the 1960s, when the first measures of noise levels were reported (Wenz, 1962), until the 1990s, underwater noise has almost doubled every ten years due to increases in shipping traffic (Andrew et al., 2002; McDonald et al., 2006; Merchant et al., 2012). While some recent studies describe slowly decreasing low-frequency ocean noise levels at different oceanic locations during the early 2000s (Andrew et al., 2011; Miksis-Olds and Nichols, 2016), the typical and long term trends for ship noise are still unknown in many regions of the world.

Exposure to noise can produce a wide range of deleterious effects on marine mammals (Weilgart, 2007), fishes and invertebrates (Buscaino et al., 2010; Celi et al., 2014; Slabbekoorn et al., 2010), from behavioral modifications to physiological and auditory effects.

The European Marine Strategy Framework Directive (MSFD) 2008/56/EC of 17th June, 2008 (European Parliament and Council, 2008) and the Decision 2010/477/EU (European Commission, 2010) intro-

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duced human-induced marine acoustic noise as an important indicator in defining the "Good Environmental Status" of a marine ecosystem. In particular, the Descriptor 11 of the MSFD requires that "the introduction of energy, including underwater noise, is at levels that do not adversely affect the marine environment". Concerning continuous low frequency sounds, the Indicator 11.2 requires year-round measurements of the temporal distribution of noise levels, within the 1/3 octave bands centered at 63 Hz and at 125 Hz. In June 2012, the cabled deep-sea multidisciplinary observatory NEMO-SN1 (NEutrino Mediterranean Observatory – Submarine Network 1) was deployed in the Gulf of Catania (Ionian Sea) (Favali et al., 2013). The acoustic sensors installed on board this observatory gave us the opportunity to monitor environmental and anthropogenic noise sources. High levels of anthropogenic noise from ship traffic were expected in the area due to the proximity of important touristic, commercial and military harbors and shipping lanes.

The main purpose of this study is to report the first long-term measurements of low frequency noise (10 Hz–1000 Hz), recorded during approximately 10 months of continuous acoustic monitoring, in the Ionian Sea. The present work also demonstrates the correlation between background noise measurements and ship traffic. This was achieved through the development of a fast numerical code that calculates the noise induced by ships passing in the area. The code uses information acquired by a ground based AIS proprietary antenna (Automatic Identification System). A comparison between simulated and measured acoustic noise levels was performed.

2. Materials and methods

2.1. The NEMO-SN1 observatory

The NEMO-SN1 seafloor cabled multidisciplinary observatory (Favali et al., 2013) is an operative node of EMSO-ERIC (European Multidisciplinary Seafloor and water-column Observatory - European Research Infrastructure Consortium) (Best et al., 2014, 2016; Favali et al., 2011). The observatory was jointly operated by INGV (Istituto Nazionale di Geofisica e Vulcanologia) and INFN (Istituto Nazionale di Fisica Nucleare) within the activities of EMSO and of the SMO (Submarine Multidisciplinary Observatory) project (SMO, 2016).

The NEMO-SN1 seafloor observatory was installed in the Gulf of Catania (Lat 37.5477° N, Lon 15.3975° E), at a depth of 2100 m (EMSO-ERIC, 2015; Favali et al., 2013) (Fig. 1). The observatory was powered from shore and linked to the acquisition and control station, located in the Port of Catania, through a 28 km long electro-optical cable. Acquired data were sent in real time to the shore station for storage and analysis. The observatory was equipped with several geophysical, oceanographic and acoustic sensors (Favali et al., 2013).

2.2. Study area

The study area is characterized by steep slopes and high depths are reached at a very short distance from the shore. The deep-sea location of the platform and the proximity of the Port of Catania make the area a privileged observation point to monitor the acoustic noise produced by ship traffic. The characterization of background noise levels from fixed deep-sea recording sites has several advantages due to the low temporal variability in acoustic propagation features and in the sound velocity profile (Merchant et al., 2012). The location of the acoustic sensor and the inter-seasonal homogeneity of the sound velocity profile, in the deep sea, allow reliable estimates of the typical noise trends in the area. In the Western Ionian Sea the time variations of the sound velocity profile are significant only in the upper layers of the water column (depending on the depth of the seasonal thermocline). This avoids notable changes in the propagation of low frequency sounds from a source close to the surface, to a receiver, installed at high depth in an almost flat sea bottom.

2.3. Acoustic data acquisition and analysis

The acoustic noise was continuously (24/7) monitored, in the Gulf of Catania, for over 10 months, from 2nd July, 2012 to 10th May, 2013. The acoustic data used in this study were acquired by the SMID DT405D (V)1 seismic hydrophone. The hydrophone has an almost flat frequency response in the range from 50 mHz to 1000 Hz and an average sensitivity of 197 ± 1 dB re 1 V/μPa (Embriaco, 2012). Data were digitized offshore at a sampling rate of 2 kHz and they were sent to the shore station through the 28 km long electro-optical cable. A GPS signal was sent from the shore station to the observatory, to tag the digital acoustic data, providing time synchronization with millisecond accuracy. On shore, the acquired data were stored in 10-minute-long files for off-line processing. Further information about the data acquisition system, that was designed and operated under the SMO (Submarine Multidisciplinary Observatory) project (Simeone and Viola, 2011; SMO, 2016; Viola et al., 2013), is available from other studies (Embriaco, 2012; Giovanetti et al., 2016; Sciacca et al., 2015). The average values and percentile distribution of noise Power Spectral Density (PSD) were measured up to 1000 Hz. These values are useful indicators of the typical background noise trends in the area (Klinck et al., 2012; Merchant et al., 2015). The PSD of each file was computed using Welch's overlapped segment averaging estimator (2048 FFT points, Hamming window: 2048 samples, overlap 50%).

2.4. AIS data acquisition

The AIS is a vessel-tracking system that operates on VHF radio frequency bands. The transmission of VHF-AIS data is mandatory for all passenger ships, for cargo ships heavier than 500 tons and for every ship heavier than 300 tons and traveling in international waters, according to the International Convention for the Safety of Life at Sea (SOLAS) (IMO, 2004). The data transmitted carry all the information useful for the identification and location of the vessels. From this information, the position of the vessels, the MMSI (Maritime Mobile Service Identity), route, speed and heading can be derived. An AIS receiver is installed at the INFN-LNS laboratory, located in Catania, at approximately 160 m above sea level. The receiver allows the decoding of the input signal, decrypted through the standard NMEA 0183 Protocol (National Marine Electronics Association, www.nmea.org). Received data are then parsed and stored on a dedicated server for analysis. The receiver continuously provides information on ship traffic in a large area around the NEMO-SN1 location. The area of interest for this study lays between 36.8°–37.8° N and 15.0°–16.0° E. For this work AIS data were available almost continuously from 1st October, 2012 and 28th February, 2013 and allowed the determination of shipping noise impact on measured acoustic data (see Section 3.2).

Fig. 2 shows the cumulative minutes of ship traffic in the study area, calculated with a grid size of 100 m × 100 m, over the studied time interval. Vessels coordinates were recovered by the AIS receiver installed at the INFN-LNS. In this period the AIS receiver installed at the LNS collected 6,198,123 NMEA entries from 1937 vessels.

2.5. Modelling acoustic noise from AIS data

A fast custom MATLAB code was developed to calculate the acoustic noise induced by ship traffic in the Gulf of Catania (between 36.8° N to 37.8° N and 15.0° E to 16.0° E) from the data collected by the AIS receiver. The shipping source spectral density was calculated according to the Research Ambient Noise Directionality model RANDI 3.1 (Breeding et al., 1994) where ship source levels are estimated using a modified version of the empirical Ross formula (Ross, 1987). A simple geometric spreading model was used to take into account spherical spreading to the maximum water depth along the transect from the ship location and cylindrical spreading for the remainder of the transect (Erbe et al., 2012). These simplifications were implemented to run fast