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EXPLORATORY STUDY ON THE ACOUSTIC CHARACTERIZATION OF TRANSIT AND TRAWLING NOISE FROM FISHING VESSELS IN THE STRAIT OF SICILY

Sara Ferri[1,2] **Gerardo Sorrentino**[1] **Rosario Grammauta**[3]
Giacomo Milisenda[1] **Francesco Caruso**[1,*]
[1]Stazione Zoologica Anton Dohrn, Naples, Italy
[2]University of Turin, Turin, Italy
[3]University of Palermo, Engineering Department, Palermo, Italy

ABSTRACT

Anthropogenic noise is a serious concern for marine ecosystems, as described in Descriptor 11 of the EU Marine Strategy Framework Directive (MSFD). Among human-made sounds, bottom trawling is a fishing activity that has the potential to impact the underwater environment. The main aim of this study was to analyze the acoustic emission of bottom trawling using a single recorder deployed in offshore waters of western Sicilian coast (Strait of Sicily). Acoustic data were collected from 18 February to 27 April 2022 at 192 kHz sample rate, with 50% duty cycle (5 min every 10 min), for a total of 9,473 5-min recordings (about 1 TB). Additionally, Automatic Identification System (AIS) data were integrated to identify fishing vessel types and activities. A toolbox in MATLAB and custom algorithms were used to determine frequency-domain metrics within 1/3 octave bands, as suggested by MSFD. Preliminary results indicate that fishing activities contribute significantly to ambient noise, with bottom trawling showing a distinctive acoustic signature. This study demonstrates the efficacy of integrating passive acoustic monitoring with vessel tracking data for assessing the impact of anthropogenic activities on marine ecosystems.

Keywords: *Passive acoustic monitoring, Marine ambient noise, Fishing trawling, Human impact*

[*]***Corresponding author***: *francesco.caruso@szn.it*

1. INTRODUCTION

The marine soundscape has changed rapidly in recent decades due to the decrease in sound-producing organisms and the increase in human activities (e.g. commercial shipping, offshore construction, and fishing) [1]. Among these, vessels are the most widespread and persistent source of underwater sound with shipping being the primary source to low-frequency ambient noise in the ocean [2-3-4-5]. The effects of anthropogenic noise from ship transit have been well described in terms of hearing damage and potential stress to marine mammals [5-6-7]. In contrast, trawling activity is a significant but often underestimated source of underwater noise pollution compared to known impacts, and the effects of noise on the marine environment and marine mammals are not fully understood [8].

In this scenario, the 30% of global marine traffic cross the Mediterranean Sea, a semi-enclosed basin, producing high levels of anthropogenic underwater noise [9]. In Europe, this environmental concern is monitored and treated through several international agreements, including the EU Marine Strategy Framework Directive (MSFD; 2008/56/EC), which was the first legislation to directly regulate underwater noise pollution [10].

This study focuses on the characterization of underwater noise generated from different fishing vessels in the central Mediterranean Sea. In particular, the study was conducted in the Sicilian Channel, which is an ideal choice for acoustic analysis due to the high presence of fishing vessels and recent evidence as a potential hotspot for acoustic sensitive marine species such as cetaceans [11-12]. Here, the correlation between AIS (Automatic Identification System) and acoustic data permitted the monitoring and detection of noise pollution associated with fishing vessels during transit and trawling operations.

2. MATERIAL AND METHODS

2.1 Study area

The study area is located in the western part of the Sicilian Channel (or Strait of Sicily, Central Mediterranean), between Sicily and Tunisia. It is characterized by a diverse and complex topography, including seamounts, submarine canyons and plateaus. This region represents an important link between the western and eastern Mediterranean basins and is heavily influenced by anthropogenic activities such as maritime traffic (cargo, tankers) and commercial fishing [14]. Specifically, the Passive Acoustic Monitoring (PAM) site is located in offshore waters, 57 nautical miles off the west coast of Sicily (Fig.1).

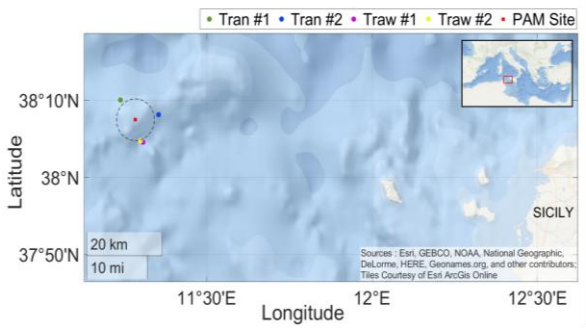

Figure 1. Map showing the location of the PAM site in the Strait of Sicily (central Mediterranean Sea). The PAM site (in red) is surrounded by a circle with a radius of 5 km. The selected vessels are marked as Transit #1 in green, Transit #2 in blue, Trawl #1 in purple and Trawl #2 in yellow.

2.2 Data collection

Acoustic data were collected using seafloor mooring equipped with a static acoustic device (SoundTrap ST600, Ocean Instruments, NZ) deployed at 157 m depth (38° 7.473' N, 11° 17.099' E). The system has four main parts, linked by ropes: two depth buoys, an autonomous recorder, an acoustic release and a ballast for anchoring to the seafloor. The autonomous recorder has a sensitivity of -176 dB re 1V/μPa and operated at 192 kHz sample rate, 16 bits and 50% duty cycle. Acoustic data were collected from February 18 to April 27, 2022, resulting in a total of 9,473 5-minute files in .wav (about 1 TB). Additionally, AIS data were integrated over the study period to identify vessel types and activities (especially the definitions of "transit" and "trawling" fishing vessels). AIS is a coastal tracking system that uses VHF transponders to transmit static (e.g., MMSI, IMO number, ship type), dynamic (e.g., position, speed, course), and voyage-related (e.g., draught, cargo type) details.

2.3 Data analysis

A custom MATLAB [15] algorithm was developed to analyze time and distance between fishing vessels and PAM site. In particular, AIS data were specifically used to identify and select isolated vessels to provide a valid comparison. Based on this, only two vessels for "transit" and "trawling" were found at a minimum distance of about 5 km from the PAM site. These vessels, named Transit 1 & 2 and Trawling 1 & 2 had similar characteristics (Table 1). For each selected vessel, the audio file corresponding to the moment of minimum distance from the recorder was considered for analysis. Additionally, an audio file recorded on a day with no vessel activity was selected to characterize "ambient noise" and distinguish it from vessel-generated sounds. Manual analysis was carried out by expert PAM operators using spectrogram visualization and audio listening in Raven Lite (The Cornell Lab of Ornithology) to identify and confirm characteristic acoustic patterns associated with transit and trawling events.

Finally, noise analysis was conducted across three key categories: "Ambient Noise", "Transit" and "Trawling". Sea state conditions were comparable across categories, remaining mostly < 3 on the Beaufort scale (Copernicus Marine Service, https://data.marine.copernicus.eu). All acoustic recordings were down sampled to 96 kHz to improve computational efficiency while preserving relevant low-frequency information. The acoustic analysis was performed using a toolbox in MATLAB [16]. We measured the Sound Pressure Levels (SPL dB re 1µPa-rms) calculated for one-third-octave bands (TOLs - frequency range 25 Hz – 40 kHz) across the three defined categories: Ambient Noise, Transit and Trawling. Analyses were performed with Hann window, window length 1 second, 50% overlap and 1 second of time-averaged data (average for each individual file).

Statistical analyses were run using custom MATLAB scripts to assess differences among the three categories. Since the data were non-parametric, pairwise comparisons (Transit - Ambient Noise, Trawling - Ambient Noise, Trawling – Transit) were performed using the Wilcoxon test. The null hypothesis (H_0) assumed no significant differences between the distributions, while the alternative hypothesis (H_1) indicated a statistically significant difference. A *p-value* < 0.05 determinate the rejection of H_0, that the samples are from different distributions.

Table 1. Table showing characteristics of vessels and their minimum distance from the PAM site.

Vessel	Length/width (m)	Draught (m)	Speed (kn)	Min Distance (m)
Transit #1	29 / 7	3.6	9.3	5,257
Transit #2	32 / 6	4.1	9.2	5,239
Trawling #1	28 / 6	4	3	5,406
Trawling #2	33 / 7	4	2.9	5,262

3. RESULTS

The characterization of third-octave band SPL levels associated with Ambient Noise, Transit, and Trawling at the PAM site is showed in Figure 2. This approach enabled a comparative analysis of how each frequency band contributed to the three distinct categories.

The general trend shows an increase in SPL from low frequencies (~25 Hz) to a peak around 100 Hz, followed by a gradual decrease at higher frequencies.

Ambient Noise consistently shows the lowest SPL values across the spectrum, compared to Transit and Trawling. At frequencies higher than the 63 Hz band, both Transit and Trawling activities contribute to elevated noise levels, with Trawling generally resulting in the highest SPLs, especially in the lower frequency range, where median levels often exceed 100 dB (Fig. 2a). This suggests that while both activities contribute significantly to underwater noise, their impact is more pronounced in certain frequency bands. Trawling also exhibits a greater spread of SPL values, as reflected in the wider interquartile ranges (IQRs) and longer whiskers, indicating greater variability in noise levels. Between the 200 Hz and 2000 Hz bands, Transit shows constantly higher SPLs, above Ambient noise and Trawling, with a relatively narrow interquartile range indicating more stable noise levels (Fig. 2b). At broadband frequencies the trend changes, with Trawling overall exceeding Ambient Noise and Transit in SPL values (Fig. 2c). Trawling exhibits a greater spread of SPL values compared to Transit, with wider interquartile ranges (IQRs) and longer whiskers, indicating greater variability in noise levels. The three categories then merge together, although both Transit and Trawling remain slightly above Ambient Noise levels.

Finally, statistical analysis showed that all one-third octave bands were significantly different between the Transit and Ambient Noise categories (*p-value* < 0.05), except for the 20000 Hz band. Significant differences were also found between the Trawling and Ambient Noise categories for all one-third octave bands. Lastly, all one-third octave bands were significantly different between the Trawling and Transit categories (*p-value* < 0.05), except for the 63 and 80 Hz bands.

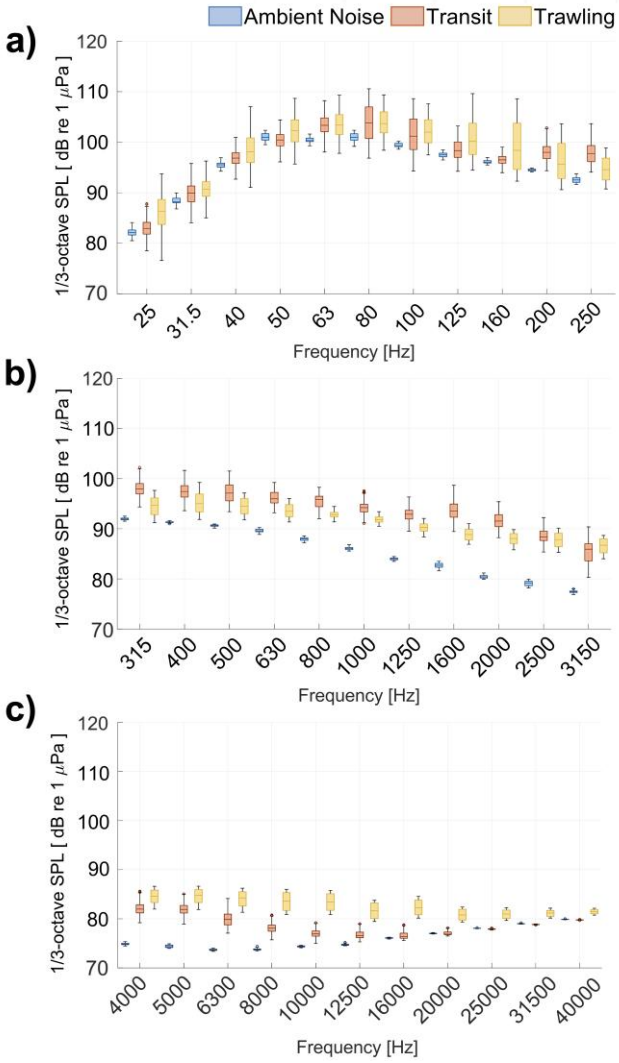

Figure 2. Boxplot showing results of 1/3-octave SPL for the three categories: Ambient Noise, Transit and Trawling. On each box, the central mark indicates the median, the bottom and top edges of the box indicate the 25th and 75th percentiles, respectively. a) the one-third octave bands from 25 to 250 Hz; b) the one-third octave bands from 315 to 3150 Hz; c) the one-third octave bands from 4000 to 40000 Hz. In the legend: Ambient Noise (in blue), Transit (in red), and Trawling (in yellow).

4. DISCUSSION

The preliminary data here showed the underwater noise levels in the study area, with a specific focus on the contributions of Trawling and Transit. As the study area has the highest regional bottom trawling impact in the world [17], it was expected that the noise produced by the trawling activity would significantly influence the soundscape of the area. Instead, our results show that both Trawling and Transit play a significant role in shaping the acoustic environment, with different contributions in the frequency bands. The percentile distributions show significant variability within and between noise categories. Trawling has the greatest variation in SPL values, mainly at lower and higher frequencies, indicating that its acoustic signature is more irregular and depending on the operational conditions. Transit similarly does not follow a uniform distribution but still shows less variability than trawling in some frequency bands. Ambient noise stays constantly lower and has a more regular distribution over all frequencies.

These preliminary results are consistent with previous studies, which identified trawling as the dominant low-frequency noise source in the Celtic Sea [18]. In this study, however, Transit activity emerges as an important contributor to mid-frequency noise, likely due to differences in the amount of vessel traffic, fishing techniques, or environmental conditions. The variability of Trawling noise suggests that its impact may be context-dependent, influenced by several factors such as vessel speed, gear deployment, and distance from the recording site.

Despite this, there are limitations to this study that should be considered. The relatively small number of selected vessels (only two for each category) may limit the applicability of these findings. In addition, the distance from the PAM site was not as close as in the referenced paper, but it was the closest choice available. These considerations may lead to some degree of variability in the results, and future studies with bigger data samples and closer recordings may help to improve the discussions.

These results highlight, in fact, the need of further research to better characterize the acoustic emissions of trawling and transit activities. Although the contribution of vessel transit has been much discussed in the literature, this work highlights the need to characterize trawling noise, which remains an area with limited information available [19-20]. Future insights could focus on the effects of vessel characteristics (size, engine type), fishing equipment (net type, deployment methods), including different environmental conditions and time periods.

In addition, in line with the objectives of the Marine Strategy Framework Directive (MSFD, Descriptor 11), noise analysis (e.g. SPL on 1/3 octave bands) to monitor underwater noise, particularly in the 63 Hz and 125 Hz bands, is essential as key indicators of anthropogenic pollution.

The use of Passive Acoustic Monitoring (PAM) combined with AIS data has proven to be a valid approach to identify noise sources and assess their impact. Therefore, increased research on the acoustic impact of different maritime activities is essential to provide a better knowledge of underwater noise sources and its impact on marine ecosystems.

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