MONITORING SHIPPING NOISE AND MARINE LIFE USING DAS AT THE PORTOPALO DEEP-SEA SITE

A. Idrissi[1,2], C. De Maria[2,3], D. Diego-Tortosa[1,4], E. Giorgio[1], S. Pulvirenti[1], G. Riccobene[1,3], S. Sanfilippo[1], M. R. Torrisi[1,3], S. Viola[1,3], D. Zito[1]

[1] *Istituto Nazionale di Fisica Nucleare–Laboratori Nazionali del Sud, Via Santa Sofia 62, 95123 Catania, Italy*
[2] *Università degli Studi di Catania–Dipartimento di Fisica e Astronomia, Via Santa Sofia 64, 95123 Catania, Italy*
[3] *Centro Siciliano di Fisica Nucleare e Struttura della Materia, Via Santa Sofia 64, 95123 Catania, Italy*
[4] *Consejo Superior de Investigaciones Científicas–Institut de Ciències del Mar, Passeig Marítim de la Barceloneta 37–49, 08003 Barcelona, Spain*

Abstract

Within the framework of the LOWNOISER project, this work reports Distributed Acoustic Sensing (DAS) observations of shipping noise and fin whale vocalizations along the Portopalo submarine optical fiber. The project aims to investigate underwater radiated noise from shipping and its possible interaction with marine biological signals, with particular attention to fin whales. The system operates continuously at a sampling frequency of 800 Hz, with a gauge length of 10 m and a spatial resolution of 5 m. Vessel passages are observed as coherent low-frequency arrivals extending over several cable sections, while fin whale vocalizations are identified through their characteristic repeated pulse sequences, including type A and type B notes. During one event, fin whale calls and continuous vessel noise overlapped in time and along the same cable region.

Keywords: *distributed acoustic sensing, underwater radiated noise, fin whale, vessel monitoring, environmental monitoring*

1. Introduction

Underwater radiated noise generated by human activities is an important component of the marine acoustic environment. Commercial shipping represents a persistent anthropogenic source, particularly at low frequencies, because propulsion, machinery, and propeller cavitation can generate signals that propagate over large distances underwater [1]. Monitoring the spatial and temporal variability of shipping noise is therefore important for characterizing marine soundscapes and for assessing possible interference with biologically relevant signals [2]. In this context, the LOWNOISER project investigates underwater radiated noise from shipping and its possible interaction with marine biological signals, with particular focus on fin whales.

Baleen whales rely extensively on low-frequency sound for communication. Fin whales (*Balaenoptera physalus*) produce characteristic pulse sequences commonly referred to as 20-Hz calls. These signals are typically short, repeated, and frequency modulated, with a common downsweep from approximately 23 to 18 Hz [3]. Their frequency range overlaps the lower-frequency part of vessel-generated noise, creating the possibility of reduced detectability and acoustic masking during periods of intense shipping activity.

The environmental relevance of continuous underwater-noise monitoring is recognized by the European Marine Strategy Framework Directive (MSFD). Descriptor 11 addresses the introduction of energy, including underwater noise, into the marine environment. For continuous low-frequency anthropogenic sound, European monitoring guidance includes one-third-octave bands centred at 63 and 125 Hz [4], [5]. These standardized bands are particularly relevant to long-term monitoring of shipping-related sound.

Conventional passive acoustic monitoring is generally performed using individual hydrophones or hydrophone arrays. These instruments measure acoustic pressure with high sensitivity but provide observations only at discrete positions. Distributed Acoustic Sensing (DAS), by contrast, uses coherent optical interrogation to transform an optical fiber into a dense

Corresponding author: *abdelghani.idrissi@lns.infn.it.*

array of virtual sensing elements. Existing submarine fibers can therefore provide spatially continuous measurements over tens of kilometres [6], [7]. DAS should be regarded as a complement to traditional acoustic sensors rather than as an alternative to them, since it provides distributed spatial coverage while hydrophones provide direct and calibrated measurements of acoustic pressure. Moreover, DAS measures the axial response of the fiber rather than acoustic pressure directly. Its sensitivity depends on cable orientation, mechanical coupling, gauge length, source direction, and local propagation conditions.

The present work reports preliminary observations obtained with the Portopalo DAS installation, with particular focus on shipping noise and fin whale 20-Hz calls.

2. Experimental Site and Instrumentation

2.1. Deep-sea cable infrastructures

The INFN-LNS operates two deep-sea electro-optical cable infrastructures along the eastern and southeastern coasts of Sicily, as shown in Figure 1. The Catania infrastructure extends approximately 25 km into the Gulf of Catania, reaching a water depth of about 2100 m. Previous DAS measurements at this site reported the detection of geophysical events and vessel-generated underwater noise [8].

The Portopalo infrastructure, used in this work, extends from Portopalo di Capo Passero toward the deep Ionian Sea. The 96 km optical fiber reaches a water depth of about 3500 m and was installed primarily for the deployment and operation of the KM3NeT neutrino telescope [9]. Variations in bathymetry, cable geometry, and seabed conditions along the route can influence acoustic propagation and fiber coupling. At the same time, this diversity provides an opportunity to investigate the DAS response and sensitivity under different environmental, geometrical, and coupling conditions.

2.2. DAS acquisition system

Within the framework of the LOWNOISER project, an Alcatel Submarine Networks (ASN) OptoDAS prtotype interrogator was connected to an available optical fiber of the Portopalo infrastructure. The continuous acquisition began in June 2025. The interrogator was configured with a sampling frequency of 800 Hz, allowing signal acquisition up to 400 Hz, according to the Nyquist limit. The original channel spacing is 1.023 m, and the gauge length corresponds to ten original channel intervals, giving a value of approximately 10.23 m. For the analyses presented in the following sections, the channels were decimated by a factor of 5 resulting in an effective spatial sampling interval of approximately 5.12 m. Each DAS measurement represents the fiber response averaged over the 10.23 m gauge length. The measurements are stored in HDF5 files together with the corresponding acquisition metadata.

The Portopalo infrastructure also includes an array of hydrophones installed at the offshore site [10], [11]. In addition, INFN-LNS operates an Automatic Identification System (AIS) receiver for monitoring vessel traffic in the surrounding area. These systems provide complementary acoustic and vessel-position information for the interpretation of the DAS observations.

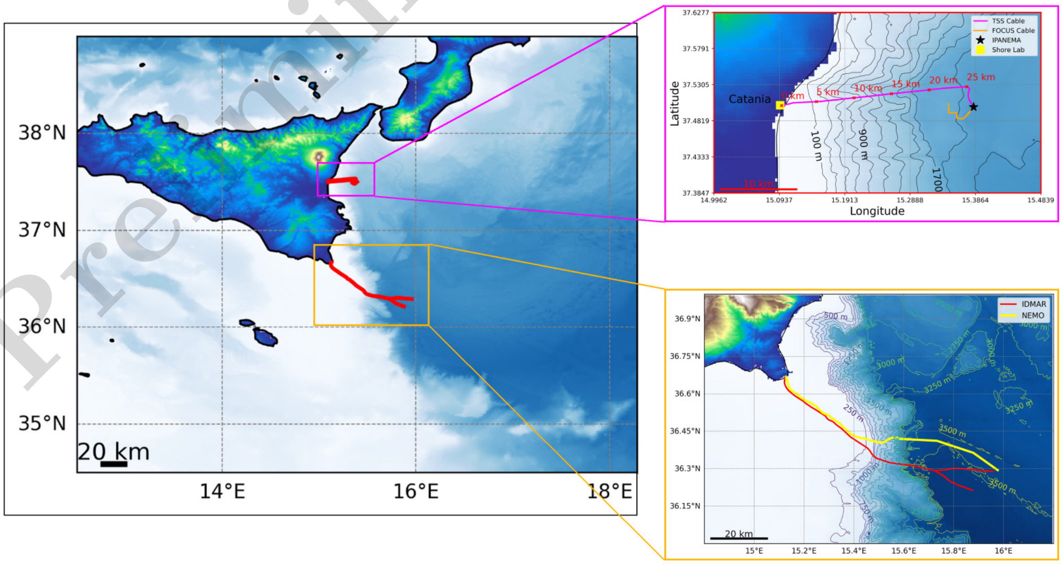
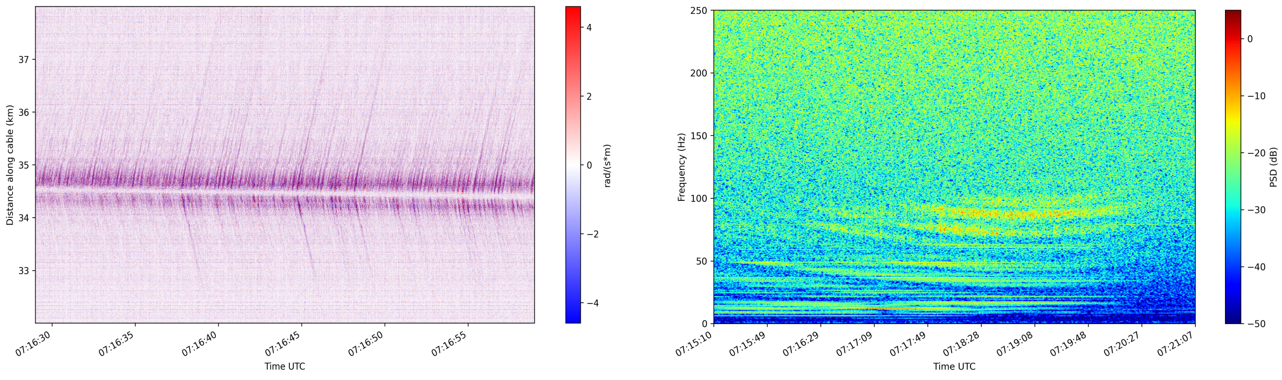
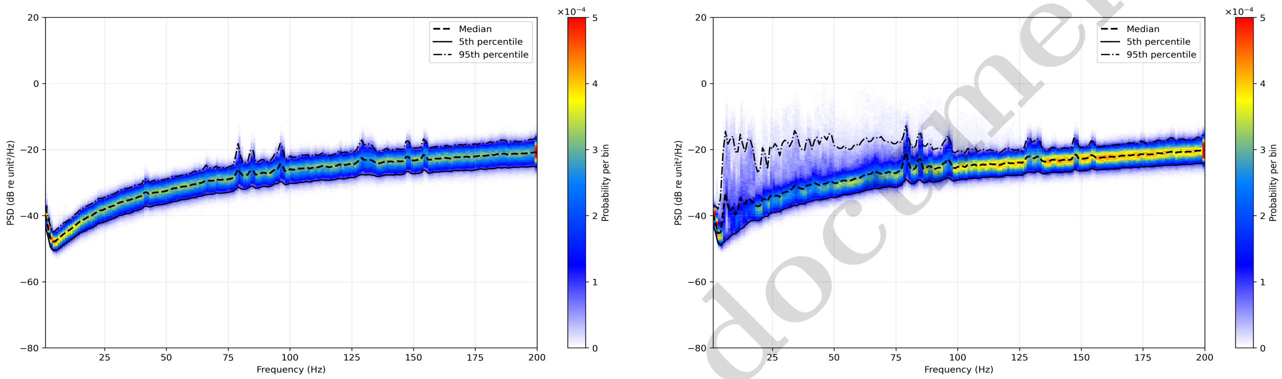


Figure 1: Locations of the two principal deep-sea electro-optical cable infrastructures operated by INFN-LNS: left, location of the two sites along the Sicilian coast; upper right, Catania site; lower right, Portopalo site which is subject of this paper.



(a) **(b)**

Figure 2: Passage of the Suezmax tanker *MONTE ULIA* on 28 June 2026: (a) DAS time–distance representation between 32 and 38 km, filtered between 15 and 150 Hz; and (b) spectrogram at channel 32310, corresponding to 32.998 km.



(a) **(b)**

Figure 3: Empirical probability density distributions computed during the vessel passage: (a) reference cable section between 5 and 25 km; and (b) vessel-affected section between 25 and 45 km.

3. Results

3.1. Target vessel passage

A passage of the *MONTE ULIA* on 28 June 2026 was selected as a target event within the LOWNOISER project to characterize the response of the Portopalo DAS system to shipping noise. The vessel (IMO 9803285) is a Suezmax tanker built in 2019 and sailing under the Portuguese flag, with an overall length of 274 m, a beam of 48 m, and a summer deadweight capacity of 156 424 tonnes.

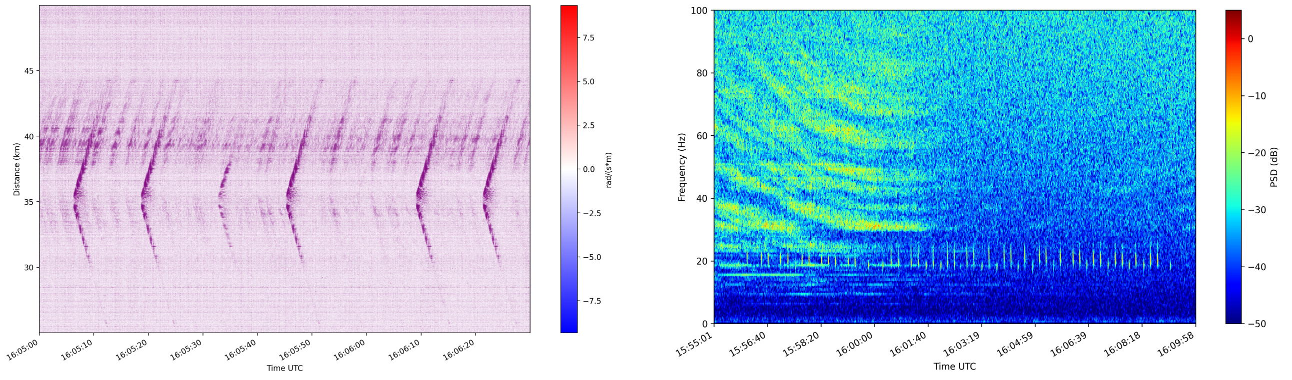
During the passage, the strongest DAS response was observed between 34 and 35 km along the cable. In this region, the water depth is approximately 150–200 m. Figure 2(a) shows the time–distance representation between 32 and 38 km, after band-pass filtering between 15 and 150 Hz.

The vessel-generated signal forms a series of V-shaped or approximately hyperbolic arrivals centred near 34.5 km. The V-shaped or hyperbolic pattern results from differences in acoustic travel time between the vessel and the DAS channels. The signal arrives first at the cable section closest to the vessel and progressively later at channels located farther away.

A reduction in amplitude is visible close to 34.5 km, where the vessel was approximately above the cable. This localized gap is consistent with the directional sensitivity of DAS. The system is primarily sensitive to strain projected along the fiber axis, whereas an acoustic wave arriving nearly perpendicular to the cable produces a weaker axial-strain component. Consequently, the reduced response at the closest point of approach should not be interpreted as a reduction in the acoustic energy radiated by the vessel.

Figure 2(b) presents the spectrogram calculated at channel 32310, corresponding to a distance of 32.998 km. The vessel signal is clearly observed from a few hertz up to approximately 100 Hz. It contains low-frequency tonal components together with a broader contribution extending over several tens of hertz.

The spectrogram also shows a frequency-dependent interference pattern that is interpreted as the Lloyd's mirror effect. This effect results from the superposition of two propagation paths: the direct signal travelling from the vessel to the receiver and a second signal reflected by the sea surface. The difference in path length produces alternating constructive and destructive interference, visible in the spectrogram as curved or regularly spaced regions of enhanced and



(a) **(b)**

Figure 4: Candidate fin whale pulse sequence recorded on 6 February 2026: (a) DAS time–distance representation between 25 and 50 km, band-pass filtered between 15 and 35 Hz and displayed using every fourth spatial channel; and (b) spectrogram calculated at channel 36230, corresponding to a distance of 37.002 km. A vessel-related contribution is also present during the analysed interval.

reduced spectral amplitude.

To quantify the spectral changes associated with the vessel passage, empirical probability density (EPD) distributions were calculated for two cable sections over the same time interval. The section between 5 and 25 km was selected as a reference region dominated by background signals, whereas the section between 25 and 45 km includes the region affected by the vessel.

Figure 3(a) shows the distribution in the reference section. The median, 5th percentile, and 95th percentile remain relatively close over most of the analysed frequency range, indicating comparatively limited temporal and spatial variability.

In the vessel-affected section, shown in Figure 3(b), the distribution becomes substantially broader. At selected frequencies, the upper spectral levels increase by approximately 20 dB relative to the background section. The largest differences are observed mainly below approximately 100 Hz, in agreement with the frequency range identified in the vessel spectrogram.

The increase is more pronounced in the 95th percentile than in the median because the vessel signal is not distributed uniformly over the entire 25–45 km section. Instead, the strongest response is concentrated near the vessel trajectory, while other channels retain levels closer to the background distribution. Spectral peaks occurring in both cable sections are not attributed uniquely to the vessel and may originate from persistent environmental, instrumental, or infrastructure-related sources.

The observed enhancement is also relevant to continuous underwater-noise monitoring under MSFD Descriptor 11. In particular, the vessel produces a clear increase around and below the one-third-octave band centred at 63 Hz, while the difference near 125 Hz is less pronounced. Since the DAS response has not been calibrated to acoustic pressure, these measurements are interpreted as relative DAS spectral levels and not as absolute underwater sound-pressure levels.

3.2. Candidate fin whale pulse sequence

A sequence of low-frequency pulses was recorded on 6 February 2026. This event represents the first fin whale call sequence identified by a DAS at the Portopalo site. No additional sequences with comparable clarity were identified in the data examined up to mid-July 2026. This absence should not be interpreted as evidence that fin whales were not present during this period, since call detectability depends on animal vocal activity, source distance, and background noise. The event was analysed using a time–distance representation covering the cable interval between 25 and 50 km and a spectrogram calculated at a sensing channel located approximately 37 km from shore. The time–distance measurements were band-pass filtered between 15 and 35 Hz.

Figure 4(a) shows the time–distance representation between approximately 16:05:00 and 16:06:30 UTC. Repeated coherent pulses are visible, with the strongest response close to 35 km and detectable arrivals extending approximately from 30 to 42 km.

The arrivals display pronounced moveout on both sides of the region near 35 km. The signals arrive first at the cable section closest to the acoustic source and progressively later at channels located farther away. The resulting curved or approximately V-shaped patterns depend on the source–cable geometry, acoustic propagation conditions, and local cable layout. The apex of the moveout cannot be interpreted directly as the position of the animal without a dedicated localization analysis.

A vessel-related signal is also visible during the same observation interval and over the same portion of the cable where the fin whale arrivals are strongest. The time–distance representation therefore shows a clear overlap in time and along-cable position between the candidate fin whale calls and the continuous underwater radiated noise from the vessel. The vessel position can be reconstructed from AIS data, whereas no independent position information is available for the fin whale. Also, because the analysed cable section is approximately straight, the DAS measurements are subject to a left–right ambiguity: sources located on opposite sides of the cable can produce similar arrival-time patterns. The observations can therefore constrain the fin whale source position along the cable, but they cannot determine uniquely on which side of the cable the whale was located or its exact distance from the vessel.

Figure 4(b) presents a longer observation interval at channel 36230, located at about 37 km from shore. fin whale calls are clearly visible whenever they occur throughout the spectrogram. In particular, between approximately 16:00:00 and 16:09:00 UTC, both type A and type B notes can be distinguished. Type A, or classic, notes appear as downward-frequency sweeps within the 20-Hz band, whereas type B, or backbeat, notes have a shorter and more nearly constant-frequency structure around 18–20 Hz [12].

The temporal occurrence of the calls corresponds to the coherent arrivals observed in the time–distance representation. The Inter-Note Interval (INI) is approximately 10–15 s, although the repetition interval is not completely uniform. Vessel-related spectral energy is also present during part of the same interval. The two signal types therefore overlap in time and along the same cable region.

Previous passive acoustic observations have documented fin whale presence offshore eastern Sicily throughout the year, with seasonal variations [13]. In the broader central Mediterranean, feeding activity has been reported near Lampedusa from late winter to early spring, while the Strait of Messina has been described as a seasonal feeding and transit area [14]. The February observation at Portopalo is therefore consistent with the documented seasonal use of the central Mediterranean by fin whales, although the present measurements do not demonstrate that feeding occurred at the Portopalo site.

4. Conclusions

The Portopalo DAS system successfully recorded both shipping noise and fin whale 20-Hz calls over extended sections of the submarine cable. The vessel passage produced strong low-frequency signals and spectral levels up to about 20 dB above the background, while type A and type B fin whale calls were clearly identified around 20 Hz. A temporal and along-cable overlap between the whale calls and vessel noise was also observed. Further analyses will exploit the complementary hydrophone and AIS measurements to support the interpretation of the DAS observations and to extend the study over longer periods.

5. Acknowledgments

The authors thank the *MONTE ULIA* team for providing the vessel information used in this study. This work was supported by the LOWNOISER project, GA 101192302, CUP I63C23000540006.

References

[1] C. Erbe, S. A. Marley, R. P. Schoeman, J. N. Smith, L. E. Trigg, and C. B. Embling, "The effects of ship noise on marine mammals—a review," *Frontiers in Marine Science*, vol. 6, p. 606, 2019. DOI: 10.3389/fmars.2019.00606.

[2] S. Viola et al., "Continuous monitoring of noise levels in the gulf of catania (ionian sea). study of correlation with ship traffic," *Marine Pollution Bulletin*, vol. 121, no. 1, pp. 97–103, 2017, ISSN: 0025-326X. DOI: https://doi.org/10.1016/j.marpolbul.2017.05.040.

[3] W. A. Watkins, P. Tyack, K. E. Moore, and J. E. Bird, "The 20-hz signals of finback whales (*Balaenoptera physalus*)," *The Journal of the Acoustical Society of America*, vol. 82, no. 6, pp. 1901–1912, 1987. DOI: 10.1121/1.395685.

[4] European Commission, *Commission decision (eu) 2017/848 of 17 may 2017 laying down criteria and methodological standards on good environmental status of marine waters and specifications and standardised methods for monitoring and assessment*, 2017.

[5] R. P. A. Dekeling, M. L. Tasker, S. Van der Graaf, M. A. Ainslie, M. H. Andersson, M. André, et al., "Monitoring guidance for underwater noise in european seas, part ii: Monitoring guidance specifications," Publications Office of the European Union, Luxembourg, EUR 26555 EN, 2014. DOI: 10.2788/27158.

[6] N. J. Lindsey, T. C. Dawe, and J. B. Ajo-Franklin, "Illuminating seafloor faults and ocean dynamics with dark fiber distributed acoustic sensing," *Science*, vol. 366, no. 6469, pp. 1103–1107, 2019. DOI: 10.1126/science.aay5881.

[7] E. F. Williams et al., "Distributed sensing of microseisms and teleseisms with submarine dark fibers," *Nature Communications*, vol. 10, p. 5778, 2019. DOI: 10.1038/s41467-019-13262-7.

[8] A. Idrissi et al., "Detection of seismic and acoustic sources using distributed acoustic sensing technology in the gulf of catania," *Journal of Marine Science and Engineering*, vol. 13, no. 4, 2025, ISSN: 2077-1312. DOI: 10.3390/jmse13040658.

[9] S. Adrián-Martínez et al., "Letter of intent for km3net 2.0," *Journal of Physics G: Nuclear and Particle Physics*, vol. 43, no. 8, p. 084 001, Jun. 2016. DOI: 10.1088/0954-3899/43/8/084001. [Online]. Available: https://doi.org/10.1088/0954-3899/43/8/084001.

[10] D. Diego-Tortosa et al., "Effective strategies for automatic analysis of acoustic signals in long-term monitoring," *Journal of Marine Science and Engineering*, vol. 13, no. 3, 2025, ISSN: 2077-1312. DOI: 10.3390/jmse13030454.

[11] D. Bonanno et al., "The italian ocean sound monitoring subsystem for the "italian integrated environmental research infrastructures system (itineris)" project," in *The Effects of Noise on Aquatic Life IV*, A. N. Popper, J. A. Sisneros, P. A. Lepper, and K. J. Vigness-Raposa, Eds. Cham: Springer Nature Switzerland, 2026, pp. 1–9, ISBN: 978-3-031-94229-7. DOI: 10.1007/978-3-031-94229-7_11-1.

[12] V. Sciacca et al., "Song notes and patterns of the mediterranean fin whale (*Balaenoptera physalus*) in the ionian sea," *Journal of Marine Science and Engineering*, vol. 11, no. 11, p. 2057, 2023. DOI: 10.3390/jmse11112057.

[13] V. Sciacca et al., "Annual acoustic presence of fin whale (*Balaenoptera physalus*) offshore eastern sicily, central mediterranean sea," *PLOS ONE*, vol. 10, no. 11, e0141838, 2015. DOI: 10.1371/journal.pone.0141838.

[14] M. Aïssi, A. Celona, G. Comparetto, R. Mangano, M. Würtz, and A. Moulins, "Large-scale seasonal distribution of fin whales (*Balaenoptera physalus*) in the central mediterranean sea," *Journal of the Marine Biological Association of the United Kingdom*, vol. 88, no. 6, pp. 1253–1261, 2008. DOI: 10.1017/S0025315408000891.