



D6.2 Scientific Publications

Open Access Scientific articles reporting main results. Report gathering all scientific publications made in the framework of the NETTAG+.



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Summary NETTAG+ Project

NETTAG+ aims to provide a portfolio of three innovative smart and sustainable solutions to address the negative impacts of abandoned, lost or otherwise discarded fishing gear (ALDFG) on marine life and habitats. NETTAG+ will be based on synergistic activities between the fisheries industry, scientists and NGOs to develop three solutions to PREVENT, AVOID and MITIGATE the harmful impacts of ALDFG.

NETTAG+ will PREVENT marine litter derived from fisheries activities, AVOID loss of fishing gears, and MITIGATE harmful impact by removing existing ALDFG. These three solutions will jointly contribute to reduce ALDFG and marine pollution, namely by: reducing the introduction of hazardous chemicals and microplastics originating from ALDFG; reducing ghost fishing, bycatch and entanglements of sensitive or endangered species on ALDFG; and improving mapping, tracking and recovery technologies to retrieve ALDFG.

NETTAG+ aims to upgrade and upscale the integrative preventive approach that started in the previous NetTag project, and aims to replicate it in Mediterranean regions, providing the fisheries industry with three smart and environmentally-friendly solutions to reduce ALDFG and prevent the environmental impacts of fishing gears. The three solutions will be developed to maturity (TRL 7-8) by the end of the project, and will be tested, validated and demonstrated in real conditions in Atlantic and Mediterranean countries, namely Portugal (PT), United Kingdom (UK), Spain (SP), Italy (IT), Croatia (HR) and Malta (MT). NETTAG+'s ambition is to change the paradigm of the fisheries industry, aspiring to transform the societal perspectives about the role of fishers as Guardians and Cleaners of the Ocean. NETTAG+ will empower the sector to take effective actions to address marine pollution, promoting their role as key actors to tackle marine pollution.

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Executive Summary

This deliverable provides an overview of the scientific publications and other scientific outputs produced within the framework of the NETTAG+ project. At the time of reporting, NETTAG+ has produced eleven scientific publications, including ten peer-reviewed journal articles and one conference paper. In addition, one manuscript is currently under revision and at least seven further manuscripts are in preparation. The project has also supported advanced training through the completion of two PhD theses and two MSc theses, as well as the production of one additional non-peer reviewed publication.

1 Introduction

This deliverable gathers the scientific publications and other scientific outputs produced within the framework of the NETTAG+ project.

Scientific publications are an important component of the project dissemination and knowledge-sharing activities. Through peer-reviewed articles, conference papers, PhD and MSc thesis, NETTAG+ contributes to advancing scientific understanding of several topics related with the prevention, avoidance and mitigation of marine litter derived from fisheries, including abandoned, lost, or otherwise discarded fishing gear ALDFG. These outputs also ensure transparency, foster collaboration across research initiatives, and facilitate the uptake of project results by researchers, but also policymakers and practitioners.

The dissemination of NETTAG+ results, including scientific outputs, followed the internal knowledge management framework detailed in the Data Management Plan (DMP) and Plan for Dissemination, Exploitation and Communication (PDEC) of the project. This framework includes a prior notice process and the completion of IP assessment forms to ensure the effective management, protection, and valorisation of knowledge and intellectual property generated within the NETTAG+ project.

At the time of this report, the project has produced eleven scientific publications, including ten peer-reviewed journal articles and one conference paper. One manuscript has been submitted to a peer-reviewed journal and is currently under revision, while seven additional manuscripts are in preparation. In terms of advanced training, two PhD theses and two MSc theses have been completed within the framework of the NETTAG+ project. In addition, one non-peer reviewed publication has been produced.

The following sections provide detailed information on the scientific publications and other scientific outputs within the NETTAG+ project, as well as on the advanced training activities completed.

2 Scientific Publications

Within the framework of the NETTAG+ project, ten scientific publications have been produced to date and are published or in press. These include ten peer-reviewed journal articles and one conference paper. An additional manuscript is currently under revision. Table 1 summarises the publications that are published, in press or under revision. At least seven further manuscripts are currently in preparation, as presented in Table 2. The papers already published are described in greater detail in the following sections.

Table 1. Scientific publications from the NETTAG+ project (published, in press or under revision).

No.	Publication	Lead partner	WP	Open Access	Associated dataset	Status
1	Guedes et al., 2024a. Multibeam Multi-Frequency Characterization of Water Column Litter. OCEANS 2024 - Singapore, pp. 1-6. http://doi.org/10.1109/OCEANS51537.2024.10682168	INESCTEC	WP4	No ¹	No	Published
2	Guedes et al., 2024b. Acoustic Imaging Learning-Based Approaches for Marine Litter Detection and Classification. Journal of Marine Science and Engineering, 12(11). https://doi.org/10.3390/jmse12111984	INESCTEC	WP4	Yes	Yes https://doi.org/10.5281/zenodo.13759505	Published
3	Almeida et al., 2024. Potential of fishing nets for adsorption of inorganic (Cu and Pb) and organic (PAHs) pollutants. Marine Pollution Bulletin 209, 117291. https://doi.org/10.1016/j.marpolbul.2024.117291	CIIMAR	WP4	Yes	Yes https://doi.org/10.5281/zenodo.14047068	Published
4	Ramos et al., 2025. An Integrated Approach to Assessing the Potential of Plastic Fishing Gear to Release Microplastics. Water, 17(10), 1439. https://doi.org/10.3390/w17101439	CIIMAR	WP4	Yes	Yes https://doi.org/10.5281/zenodo.15394706	Published
5	Perdigão et al., 2025. Microbial communities associated with plastic fishing nets: diversity, potentially pathogenic and hydrocarbon degrading bacteria. Scientific Reports, 15(1), 22877. https://doi.org/10.1038/s41598-025-06033-6	CIIMAR	WP4	Yes	Yes https://doi.org/10.5281/zenodo.15585631	Published
6	Guedes et al., 2025, Multibeam Acoustic Image based Detection and Tracking of Marine Litter in the Water Column. OCEANS 2025 Brest, BREST, France, pp. 1-6. https://doi.org/10.1109/OCEANS58557.2025.11104332	INESCTEC	WP4	No ¹	No	Published

No.	Publication	Lead partner	WP	Open Access	Associated dataset	Status
7	Neasham et al., 2025 Low Energy, Real Time Passive Acoustic Detection of Dolphin Clicks and Whistles. 7th Experiment@ International Conference (exp.at'25), Horta, Portugal, pp. 163-167. https://doi.org/10.1109/exp.at2565440.2025.11348486	UNEW	WP3	No ²	No	Published
8	Pita et al, 2026. Challenges and recommendations for marine waste management in European fishing ports. Frontiers in Marine Science 13:1728784. https://doi.org/10.3389/fmars.2026.1728784	UAveiro	WP2	Yes	No	Published
9	Guedes et al., 2026a. Learning-Based Online Tracking Algorithms for Marine Litter in Multibeam Water Column Images. IEEE Access, vol. 14, pp. 47666-47685. https://doi.org/10.1109/ACCESS.2026.3677642	INESCTEC	WP4	Yes	No	Published
10	Guedes et al., 2026b. Descriptor: Forward-Looking Multibeam - Marine Litter Detection and Tracking Dataset (FLM-MLDT). IEEE Data Descriptions. https://doi.org/10.1109/IEEEDATA.2026.3683037	INESCTEC	WP4	Yes	Yes https://doi.org/10.5281/zenodo.18235788	Published
11	Romualdo et al. Autonomous Underwater Vehicle Maneuvering for Precise Localization of Tagged Fishing Gear. IEEE Oceans 2026, Sanya, China	INESCTEC	WP3	No ¹	No	In press
12	Polechońska et al., Effects of time, aging level and water physicochemical properties on copper adsorption by polyethylene microplastics in natural waters	CIIMAR	WP4	-	-	Under revision

¹ Publication in the conference proceedings of IEEE OCEANS, a prestigious international conference dedicated to ocean science and technology, whose proceedings are typically published under restricted access by IEEE

² Publication in the conference proceedings of 7th Experiment@ International Conference (exp.at'25), a prestigious international conference dedicated to online experimentation and distributed sensing, whose proceedings are typically published under restricted access by IEEE.

Table 2. Scientific publications from the NETTAG+ project in preparation.

No.	Title	Authors	Lead partner	WP
1	Economic evaluations to reduce marine litter in European fisheries	Astudillo-Pascua M., Ainsworth G., Villasante S., Dudouet B., Nahuel N.	USC	WP5
2	Fishers as cleaners of the ocean: feasibility of rewards programs for the collection of marine litter	Ainsworth G., Villasante S., Astudillo-Pascua M., Gatt MP., Bonnici K., Ivanković A., Giampaolletti E., Silva P., Gutierrez A., Pita C.	USC	WP2
3	Does technology help increase empathy and societal awareness regarding marine litter?	Pita P., Ainsworth G., Villasante S., Astudillo-Pascual M., Gatt MP., Brian D., Bonnici K., Ivanković A., Campogianni S., Giampaolletti E.	USC	WP2 & WP6
4	The active role of fishers as Guardians and Cleaners of the Ocean: litter produced onboard versus passive fished waste	Sousa, L., Espincho, F., Rodrigues, S., Campogianni S., Almeida, CMR, Ramos, S.	CIIMAR	WP2
5	Fishing gear as source of microplastics: plastic-based and biodegradable fishing gear	Espincho, F., Rodrigues, S., Sousa, L., Almeida, CMR, Ramos, S.	CIIMAR	WP4
6	Potential of plastic-based and biodegradable fishing gear to absorb contaminants	Espincho, F., Rodrigues, S., Sousa, L., Ramos, S., Almeida, CMR.	CIIMAR	WP4
7	Does microbiofouling varies between plastic and biodegradable fishing nets?	Espincho, F., Rodrigues, S., Sousa, L., Almeida, CMR, Ramos, S.	CIIMAR	WP4

2.1 Peer-review articles

2.1.1 Guedes et al. (2024a)

Title: Multibeam Multi-Frequency Characterization of Water Column Litter

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Published in: OCEANS 2024 - Singapore

Published in: IEEE

Year: 2024

URL: <http://doi.org/10.1109/OCEANS51537.2024.10682168>

Link to repository: <https://zenodo.org/records/19915384>

Abstract:

This paper explores the potential use of acoustic imaging and the use of a multi-frequency multibeam-echosounder (MBES) for monitoring marine litter in the water column. The main goal is to perform a test and validation setup using a simulation and actual experimental setup to determine if the MBES data can detect marine litter in a water column image (WCI) and if using multi-frequency MBES data will allow to better distinguish and characterize marine litter debris in detection applications. Results using simulated HoloOcean Environment and actual marine litter data revealed the successful detection of objects commonly found in ocean litter hotspots at various ranges and frequencies, enabling the pursue of novel means of automatic detection and classification in MBES WCI data while using multi-frequency capabilities.

Keywords:

- Oceans
- Acoustic imaging
- Plastics
- Monitoring

Associated Dataset: N/A

Multibeam Multi-Frequency Characterization of Water Column Litter

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Abstract—This paper explores the potential use of acoustic imaging and the use of a multi-frequency multibeam-echosounder (MBES) for monitoring marine litter in the water column. The main goal is to perform a test and validation setup using a simulation and actual experimental setup to determine if the MBES data can detect marine litter in a water column image (WCI) and if using multi-frequency MBES data will allow to better distinguish and characterize marine litter debris in detection applications. Results using simulated HoloOcean Environment and actual marine litter data revealed the successful detection of objects commonly found in ocean litter hotspots at various ranges and frequencies, enabling the pursue of novel means of automatic detection and classification in MBES WCI data while using multi-frequency capabilities.

Index Terms—*in-situ* monitoring, Underwater Imaging, Marine Litter, Marine Plastic Debris, Multibeam Echosounder, Multi-frequency, Water Column Image, Water Column Litter.

I. INTRODUCTION

Due to population growth in developing and emerging countries, global plastics production and consumption are expected to rise significantly [1]. Addressing the challenge of removing microplastics without harming microscopic ecosystems is complex due to their small size [2]. Therefore, efficient detection and removal of macroplastics and other litter are crucial. The United Nations Sustainable Development Agenda, encompassing 17 goals, includes targets to prevent and substantially reduce marine pollution, particularly goals 14.1 and 14.a related to marine litter [3]. Submerged plastic debris in the water column may result from low-density plastics combined with heavier materials, creating negatively buoyant masses below the water's surface [4], [5].

Marine litter detection primarily relies on remote sensing methods, often utilizing satellite data [6], [7]. Some alternatives use drones, aircraft cameras, or remote hyperspectral imaging to assess the extent of debris covering water surfaces [8]. Recent advancements include applying novel techniques to hyperspectral camera data for improved marine litter detection and classification [9]. Artificial intelligence (AI) has been employed to detect and classify marine litter, using surface imaging data sets (RGB and hyperspectral cameras), bathymetry studies with acoustic sensors, and *in-situ* observations at the seabed, often without sonar imaging [6].

Multibeam Echosounders (MBES) with multi-frequency data acquisition are yet to be fully explored in the context of water column backscattered objects/debris, being mainly applied for the detection and classification of different seabed segments [10]. Multi-frequency echosounding can be done in an Autonomous Underwater Vehicle (AUV) or autonomous vessel, as illustrated in Figure 1.

Using Forward-Looking Sonar (FLS) images, different marine litter types such as plastic bottles, cans, glass bottles, tires, and more were successfully detected at the bottom of a test tank [11], [12]. The acquisition of submerged marine debris was accomplished by FLS, employing an adapted Faster Region-Based Convolutional Neural Networks (R-CNN) algorithm [13]. Transfer learning was applied for feature extraction to address data scarcity, incorporating the Residual Network 50 (ResNet-50) into the algorithm.

An algorithm for automatic detection and segmentation of gas plumes from Water Column Images (WCIs) was proposed by [2]. Haar features were used by this author, combining them with Local Binary Patterns (LBP), which are highly discriminative and invariant to monotonic grey-level images, as are WCIs. A multi-branch shuttle network embedded in You Only Look Once 5 (YOLO5) was proposed to detect fish with an FLS [14].

A Bayesian statistical method for seabed classification with a multi-frequency approach was made with the assumption that the backscatter intensities followed a Gaussian distribution



Fig. 1: Robotic platform for marine debris detection.

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Full article: <http://doi.org/10.1109/OCEANS51537.2024.10682168>

2.1.2 *Guedes et al. (2024b)*

Title: Acoustic Imaging Learning-Based Approaches for Marine Litter Detection and Classification

Authors: Guedes P.A.^a, Silva H.M.^a, Wang S.^b, Martins A.^{a c}, Almeida J.^{a c}, Silva E.^{a c}

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Year: 2024

URL: <https://doi.org/10.3390/jmse12111984>

Link to repository: <https://zenodo.org/records/14393061>

Abstract:

This paper introduces an advanced acoustic imaging system leveraging multibeam water column data at various frequencies to detect and classify marine litter. This study encompasses (i) the acquisition of test tank data for diverse types of marine litter at multiple acoustic frequencies; (ii) the creation of a comprehensive acoustic image dataset with meticulous labelling and formatting; (iii) the implementation of sophisticated classification algorithms, namely support vector machine (SVM) and convolutional neural network (CNN), alongside cutting-edge detection algorithms based on transfer learning, including single-shot multibox detector (SSD) and You Only Look once (YOLO), specifically YOLOv8. The findings reveal discrimination between different classes of marine litter across the implemented algorithms for both detection and classification. Furthermore, cross-frequency studies were conducted to assess model generalisation, evaluating the performance of models trained on one acoustic frequency when tested with acoustic images based on different frequencies. This approach underscores the potential of multibeam data in the detection and classification of marine litter in the water column, paving the way for developing novel research methods in real-life environments.

Keywords:

- Multibeam echosounder
- Water column data
- Macroplastics
- Classification
- Detection
- Convolutional neural networks
- Machine learning
- Marine litter
- Support vector machines
- YOLOv8

Associated Dataset:

Guedes, P. (2024). MBES M3 KONGSBERG HF MODEL TEST TANK MARINE DEBRIS DATASET.

Zenodo. <https://doi.org/10.5281/zenodo.13759505>

Article

Acoustic Imaging Learning-Based Approaches for Marine Litter Detection and Classification

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Abstract: This paper introduces an advanced acoustic imaging system leveraging multibeam water column data at various frequencies to detect and classify marine litter. This study encompasses (i) the acquisition of test tank data for diverse types of marine litter at multiple acoustic frequencies; (ii) the creation of a comprehensive acoustic image dataset with meticulous labelling and formatting; (iii) the implementation of sophisticated classification algorithms, namely support vector machine (SVM) and convolutional neural network (CNN), alongside cutting-edge detection algorithms based on transfer learning, including single-shot multibox detector (SSD) and You Only Look once (YOLO), specifically YOLOv8. The findings reveal discrimination between different classes of marine litter across the implemented algorithms for both detection and classification. Furthermore, cross-frequency studies were conducted to assess model generalisation, evaluating the performance of models trained on one acoustic frequency when tested with acoustic images based on different frequencies. This approach underscores the potential of multibeam data in the detection and classification of marine litter in the water column, paving the way for developing novel research methods in real-life environments.

Keywords: multibeam echosounder; water column data; macroplastics; classification; detection; convolutional neural networks; machine learning; marine litter; support vector machines; YOLOv8



Citation: Guedes, P.A.; Silva, H.M.; Wang, S.; Martins, A.; Almeida, J.; Silva, E. Acoustic Imaging Learning-Based Approaches for Marine Litter Detection and Classification. *J. Mar. Sci. Eng.* **2024**, *12*, 1984. <https://doi.org/10.3390/jmse12111984>

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1. Introduction

Higher standards and improved living conditions have increased the demand for more materials, leading to greater waste generation [1]. Billions of metric tons are discarded annually, and without proper waste disposal, many environments are being damaged [2]. Recycling policies are failing to adequately address the disposal of plastic products, primarily composed of single-use plastics. Many companies engage in greenwashing, providing misinformation about their environmental actions to enhance their reputations and gain competitive advantages among environmentally conscious consumers [3,4].

The United Nations Environment Programme (UNEP) defines marine litter as any persistent, manufactured, or processed solid material discarded, disposed of, or abandoned in the marine and coastal environment [5–7], with plastic being the most prominent. The accumulation of plastic in the water is rapidly increasing [6]. It is estimated that 60% of all plastics ever made have been discarded in landfills or the natural environment. Positively buoyant plastic objects, commonly called floating plastic debris, illustrated in Figure 1, are influenced by a wide range of physical transport processes [7–10].

Submerged plastic debris can originate from low-density plastics combined with heavier materials, resulting in negatively buoyant masses that sink below the water's surface and biofouling.

2.1.3 Almeida et al. (2024)

Title: Potential of fishing nets for adsorption of inorganic (Cu and Pb) and organic (PAHs) pollutants

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Published in: Marine Pollution Bulletin

Year: 2024

URL: <https://doi.org/10.1016/j.marpolbul.2024.117291>

Link to repository: <https://zenodo.org/records/14197091>

Abstract:

This study aimed to evaluate metals and polycyclic aromatic hydrocarbons (PAHs) adsorption on new plastic fishing nets in both laboratory and quasi-real scenario (nets submersed in marina seawater) experiments as well as in situ monitoring of these contaminants in water and sediments in lost fishing gears hotspots. The latter was inconclusive as environmental contaminants levels were very low. Laboratory experiments showed metals (copper and lead) and PAHs adsorption depended on the thickness and polymeric composition of the net, being lower in thinner nylon nets. Experiments in the marina, also showed significant contaminants adsorption, which increased over time, probably due to biofilm formation on net surface. This work showed the potential role of fishing gears as skins of pollutants, increasing organisms' exposition to contaminants present in the environment. So, initiatives to prevent the loss of

fishing gear and to retrieve them are needed to reduce and/or eliminate their environmental impact.

Highlights:

- Cu and Pb adsorption to fishing net increased with time and varied with polymer and net thickness.
- PAHs adsorption occurred for all nets and adsorption percentages increased with molecular weight.
- Metals and PAHs adsorption influenced by biofilm formation in nets submerged on a seawater marina.
- Metal retention in marina experiment was an order of magnitude higher than in laboratory experiment.
- Fishing nets can adsorb pollutants and act like a pollutant sink.

Associated Dataset:

CIIMAR. (2024). NETTAG+ Data set on adsorption of inorganic (Cu and Pb) and organic (PAHs) pollutants in fishing nets [Data set]. In Marine Pollution Bulletin. Zenodo. <https://doi.org/10.5281/zenodo.14047068>



Potential of fishing nets for adsorption of inorganic (Cu and Pb) and organic (PAHs) pollutants

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ABSTRACT

This study aimed to evaluate metals and polycyclic aromatic hydrocarbons (PAHs) adsorption on new plastic fishing nets in both laboratory and quasi-real scenario (nets submerged in marina seawater) experiments as well as in situ monitoring of these contaminants in water and sediments in lost fishing gears hotspots. The latter was inconclusive as environmental contaminants levels were very low. Laboratory experiments showed metals (copper and lead) and PAHs adsorption depended on the thickness and polymeric composition of the net, being lower in thinner nylon nets. Experiments in the marina, also showed significant contaminants adsorption, which increased over time, probably due to biofilm formation on net surface. This work showed the potential role of fishing gears as sinks of pollutants, increasing organisms' exposition to contaminants present in the environment. So, initiatives to prevent the loss of fishing gear and to retrieve them are needed to reduce and/or eliminate their environmental impact.

1. Introduction

Marine litter derived from fisheries such as abandoned, lost or discarded fishing gear (ALDFG) (e.g., nets, long lines, fish traps) are an important kind of marine litter that can comprise up to 10 % of global marine litter (Giskes et al., 2022). Nowadays, a significant amount of fishing gear is made of plastics or has plastic components. Plastic is an inert material, however, environmental dynamics can induce modifications on its surface, making it suitable for adsorbing pollutants (Rafa et al., 2024). Persistent pollutants, such as polycyclic aromatic hydrocarbons (PAHs) (Tan et al., 2019), polychlorinated biphenyls (PCBs) (Llorca et al., 2020), polybrominated diphenyl ethers (PBDEs) (Xu et al., 2019) and nonylphenol (NP) (Chen et al., 2018) have been detected on floating plastics, raising concern for marine environmental health. These pollutants can be associated with ocean plastics by direct addition during production processes (e.g., flame retardants) or by sorption to plastics from the marine environment through partitioning mechanisms (Chen et al., 2024). Considering that fishing gear is mostly made of plastic, they can have the potential to adsorb contaminants such as

metals or organic pollutants (e.g. PAHs).

Some studies have reported the adsorption of both inorganic (e.g., metals) and organic pollutants by microplastics of different composition, including by microplastics of polymers used in fishing net manufacturing, e.g., polyamine and polyethylene (e.g., Llorca et al., 2018; Ahechti et al., 2020; Yu et al., 2019). Adsorption of metals and PAHs by microplastics in brackish and saline waters has already been observed (Almeida et al., 2020 and unpublished results). In addition, metals such as Cd, Cu, Cr, Ni, Pb and Zn were detected in fragments of fishing nets collected from beaches on SW English coast (Turner, 2017), and ALDFG in Palk Bay, India (Pasumpon and Vasudevan, 2022). So, one can assume that ALDFG made of plastic can adsorb pollutants from the surrounding water, and become itself a hotspot for those pollutants. By floating around from one place to the other, ALDFG can carry contaminants from one place to the other also. Besides, adsorbed organic contaminants can degrade with time and their metabolites can even be more toxic. In addition, by adsorbing and desorbing contaminants ALDFG can increase contaminants concentrations in sites where they are located, comparatively to sites with no ALDFG. Therefore, hotspots of ALDFG can

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Full article: <https://doi.org/10.1016/j.marpolbul.2024.117291>

2.1.4 Ramos et al. (2025)

Title: An Integrated Approach to Assessing the Potential of Plastic Fishing Gear to Release Microplastics

Authors: Ramos S.^{a b}, Espincho F.^a, Rodrigues S.M.^{a c}, Pereira R.^{a c}, Silva D.^{a c}, Rivoira L.^d, Perdigão R.^{a c}, Almeida C.M.R.^{a e}

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Published in: Water

Year: 2025

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Link to repository: <https://zenodo.org/records/15394457>

Abstract:

Abandoned, lost, or discarded fishing gear (ALDFG) poses significant environmental threats, namely contributing to microplastic (MP) pollution. However, the release of MPs from ALDFG remains poorly studied, despite its crucial role in understanding plastic pollution in marine ecosystems. This study is, to the best of our knowledge, the first to assess the environmental impact of ALDFG as a source of MPs, using an integrated approach combining laboratory experiments, in situ field trials, and environmental surveys. Laboratory tests showed that in the presence of light and sediment, braided polyethylene net released 1 fibre after incubation, demonstrating that the studied plastic fishing nets had the potential to release MPs. In situ

experiments in a semi-enclosed marine environment did not show a clear influence of submerged fishing nets on water MPs, due to the high MP contamination in the selected location ($5322 \pm 4936 \text{ MP m}^{-3}$). Nonetheless, at ALDFG hotspots off northwest Portugal, an increased presence of MPs in water samples compared to locations without ALDFG suggested potential MP release. These findings demonstrate the potential of ALDFG to act as a source of MPs and showcase the need for further studies, in order to comprehensively investigate the degradation of different plastic fishing nets in the field. Reducing ALDFG pollution is critical to mitigating its environmental impact and preserving marine ecosystems.

Keywords:

- Microplastics
- Fishing nets
- ALDFG

Associated Dataset:

Ramos, S., Espincho, F., Rodrigues Magalhães, S., Pereira, R., Silva, D., Rivoira, L., Perdigão Mendes, R., & Almeida, C. M. (2025). NETTAG+ data set on microplastics released by ALDFG [Data set]. Zenodo. <https://doi.org/10.5281/zenodo.15394706>



Article

An Integrated Approach to Assessing the Potential of Plastic Fishing Gear to Release Microplastics

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Luca Rivoira ⁴, Rafaela Perdigão ^{1,3} and C. Marisa R. Almeida ^{1,5}

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Abstract: Abandoned, lost, or discarded fishing gear (ALDFG) poses significant environmental threats, namely contributing to microplastic (MP) pollution. However, the release of MPs from ALDFG remains poorly studied, despite its crucial role in understanding plastic pollution in marine ecosystems. This study is, to the best of our knowledge, the first to assess the environmental impact of ALDFG as a source of MPs, using an integrated approach combining laboratory experiments, in situ field trials, and environmental surveys. Laboratory tests showed that in the presence of light and sediment, braided polyethylene net released 1 fibre after incubation, demonstrating that the studied plastic fishing nets had the potential to release MPs. In situ experiments in a semi-enclosed marine environment did not show a clear influence of submerged fishing nets on water MPs, due to the high MP contamination in the selected location ($5322 \pm 4936 \text{ MP m}^{-3}$). Nonetheless, at ALDFG hotspots off northwest Portugal, an increased presence of MPs in water samples compared to locations without ALDFG suggested potential MP release. These findings demonstrate the potential of ALDFG to act as a source of MPs and showcase the need for further studies, in order to comprehensively investigate the degradation of different plastic fishing nets in the field. Reducing ALDFG pollution is critical to mitigating its environmental impact and preserving marine ecosystems.

Keywords: microplastics; fishing nets; ALDFG

1. Introduction

Abandoned, lost, or otherwise discarded fishing gear (ALDFG), such as buoys, lines, nets, traps, and other related fishing gear, is an important source of marine litter. ALDFG has been present in the marine environment for as long as fishing activities have taken place and has been identified as a major problem since the 1980s [1,2]. Before the large-scale production of plastic began in the 1950s, fishing gear was produced using non-synthetic resources such as cotton, flax, or hemp fibres [3]. However, due to rapid evolution and industrialization, the exploitation of synthetic fibres increased substantially, leading to their

2.1.5 *Perdigão et al. (2025)*

Title: Microbial communities associated with plastic fishing nets: diversity, potentially pathogenic and hydrocarbon degrading bacteria

Authors: Perdigão R.^{a b}, Tavares A.S.^{a b c}, Carvalho M.F.^{a b}, Magalhães C.^{a c}, Ramos S.^{a c}, Almeida C.M.R.^{a c}, Mucha A.P.^{a c}

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Published in: Scientific Reports

Year: 2025

URL: <https://doi.org/10.1038/s41598-025-06033-6>

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Abstract:

Abandoned, lost or otherwise discarded fishing gear (ALDFG) represent a major source of marine plastic litter pollution. Similar to other plastic litter, these items can provide a new surface for the growth of biofilms harboring distinct microbial communities, containing potential opportunistic pathogens or pollutant-degrading microorganisms. While knowledge is increasing for marine plastic litter and microplastic-associated biofilms, there is a gap on the plastisphere research for fishing gear. This study aimed to comprehend the structure and dynamics of the microbial communities attached to plastic fishing nets, mimicking a scenario when lost at sea, but also to assess if polymer type can influence these communities. For that, a one-year in situ experiment was employed inside a recreational marina (port of Leixões, Portugal), using 3 types of plastic fishing nets (Braided Polyethylene (PE), Braided Nylon and Thin Nylon) submersed in the seawater. Seasonal samplings of nets and surrounding seawater were performed for microbial community analysis by 16 S rRNA metabarcoding. One month-old-nets samples were additionally collected for cultivation of bacterial strains in the laboratory. In general, microbial

communities found in the biofilms attached to fishing nets were taxonomically distinct and more diverse, when compared to the surrounding seawater. Biofilm communities were not shaped by the polymer type, instead, they displayed a succession pattern over time. Biofilm communities were predominantly composed of the phyla Proteobacteria, Bacteroidetes and Verrucomicrobiota. Additionally, the families *Sphingomonadaceae*, *Rubritaleaceae*, *Rhizobiaceae* and *Saprospiraceae* were specifically associated with fishing net biofilms. From the 3 nets, a total of 123 bacterial strains from 46 bacterial genera were recovered. The genera *Acinetobacter*, *Bacillus*, *Rhodococcus*, *Shewanella*, *Streptomyces* and *Vibrio* were common to all nets. Commonly associated hydrocarbon and plastic - degrading taxa were highly abundant in the biofilm communities (> 2% abundance) and some were even possible to cultivate in laboratory. In addition, biofilm communities presented as well, potentially pathogenic genera, such as *Clostridium* and *Mycobacterium*, but in low abundances (< 1%). With this work, a deeper knowledge on the plastisphere associated with different plastic fishing gear was obtained, along with the isolation of bacterial strains with potential for future exploration of plastic biodegradation.

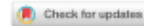
Keywords:

- Fishing nets
- Microbial communities
- Plastic
- Polyethylene
- Nylon
- Pathogens
- Hydrocarbon degraders
- Maritime port

Associated Dataset:

Perdigão Mendes, R. (2025). NETTAG+ data set on microbial communities and bacterial strains from an in situ experiment [Data set]. Zenodo. <https://doi.org/10.5281/zenodo.15585631>

scientific reports



OPEN

Microbial communities associated with plastic fishing nets: diversity, potentially pathogenic and hydrocarbon degrading bacteria

Rafaela Perdigão^{1,2✉}, Ana Sofia Tavares^{1,2,3}, Maria F. Carvalho^{1,2}, Catarina Magalhães^{1,3}, Sandra Ramos^{1,3}, C. Marisa R. Almeida^{1,3} & Ana P. Mucha^{1,3}

Abandoned, lost or otherwise discarded fishing gear (ALDFG) represent a major source of marine plastic litter pollution. Similar to other plastic litter, these items can provide a new surface for the growth of biofilms harboring distinct microbial communities, containing potential opportunistic pathogens or pollutant-degrading microorganisms. While knowledge is increasing for marine plastic litter and microplastic-associated biofilms, there is a gap on the plastisphere research for fishing gear. This study aimed to comprehend the structure and dynamics of the microbial communities attached to plastic fishing nets, mimicking a scenario when lost at sea, but also to assess if polymer type can influence these communities. For that, a one-year in situ experiment was employed inside a recreational marina (port of Leixões, Portugal), using 3 types of plastic fishing nets (Braided Polyethylene (PE), Braided Nylon and Thin Nylon) submersed in the seawater. Seasonal samplings of nets and surrounding seawater were performed for microbial community analysis by 16 S rRNA metabarcoding. One month-old-nets samples were additionally collected for cultivation of bacterial strains in the laboratory. In general, microbial communities found in the biofilms attached to fishing nets were taxonomically distinct and more diverse, when compared to the surrounding seawater. Biofilm communities were not shaped by the polymer type, instead, they displayed a succession pattern over time. Biofilm communities were predominantly composed of the phyla Proteobacteria, Bacteroidetes and Verrucomicrobiota. Additionally, the families *Sphingomonadaceae*, *Rubritaleaceae*, *Rhizobiaceae* and *Saprospiraceae* were specifically associated with fishing net biofilms. From the 3 nets, a total of 123 bacterial strains from 46 bacterial genera were recovered. The genera *Acinetobacter*, *Bacillus*, *Rhodococcus*, *Shewanella*, *Streptomyces* and *Vibrio* were common to all nets. Commonly associated hydrocarbon and plastic-degrading taxa were highly abundant in the biofilm communities (> 2% abundance) and some were even possible to cultivate in laboratory. In addition, biofilm communities presented as well, potentially pathogenic genera, such as *Clostridium* and *Mycobacterium*, but in low abundances (< 1%). With this work, a deeper knowledge on the plastisphere associated with different plastic fishing gear was obtained, along with the isolation of bacterial strains with potential for future exploration of plastic biodegradation.

Keywords Fishing Nets, Microbial communities, Plastic, Polyethylene, Nylon, Pathogens, Hydrocarbon degraders, Maritime Port

Abandoned, lost, or otherwise discarded fishing gear (ALDFG), contributes heavily to the marine litter problematic in our ocean. Although it is extremely difficult, to quantify the amount of ALDFG entering the ocean¹, Kuczenski et al.² estimated a global loss of about 48.4 kt of fishing gear, for industrial fisheries alone (trawl, purse-seine and pelagic longline fisheries), in 2018. By collecting trawl samples across the Great Pacific

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Full article: <https://doi.org/10.1038/s41598-025-06033-6>

2.1.6 *Guedes et al. (2025)*

Title: Multibeam Acoustic Image based Detection and Tracking of Marine Litter in the Water Column

Authors: Guedes P.A.^a, Silva H.^a, Wang S.^b, Martins A.^{a c}, Almeida J.M.^{a c}

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Published in: OCEANS 2025 Brest

Published in: IEEE

Year: 2025

URL: <https://doi.org/10.1109/OCEANS58557.2025.11104332>

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Abstract:

This paper presents the development and implementation of learning-based detection and tracking methods using multibeam data to detect marine litter in the water column. The presented work encompasses (i) the creation of acoustic videos and the application of multiple post-processing techniques; (ii) the training of multiple You Only Look Once (YOLO) detection models, specifically YOLOv8, across different variants, acoustic frequencies, and input types (both raw and post-processed); (iii) and the development of a marine litter tracking system based on DeepSORT. The results include a multibeam multi-frequency data study demonstrating the potential of acoustic image sensing for detecting and tracking marine litter materials in the water column.

Keywords:

- YOLO
- Training
- Echo sounders
- Oceans
- Acoustic imaging

- Acoustics
- Data models
- Sensors
- Object tracking
- Videos

Associated Dataset: N/A

Multibeam Acoustic Image based Detection and Tracking of Marine Litter in the Water Column

Pedro Alves Guedes^{*,†}, Hugo Silva^{*,†}, Sen Wang^{*,†}, Alfredo Martins^{*,†} and
José Miguel Almeida^{*,†}

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Abstract—This paper presents the development and implementation of learning-based detection and tracking methods using multibeam data to detect marine litter in the water column. The presented work encompasses (i) the creation of acoustic videos and the application of multiple post-processing techniques; (ii) the training of multiple You Only Look Once (YOLO) detection models, specifically YOLOv8, across different variants, acoustic frequencies, and input types (both raw and post-processed); (iii) and the development of a marine litter tracking system based on DeepSORT.

The results include a multibeam multi-frequency data study demonstrating the potential of acoustic image sensing for detection and tracking marine litter materials in the water column.

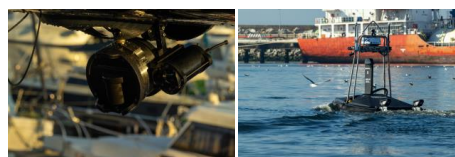
Index Terms—Acoustic Imaging, Multibeam echosounder (MBES), Marine Litter Detection, Underwater object tracking.

I. INTRODUCTION

Marine litter is a major threat to the ocean environment and marine life. Fifty-three million tonnes of plastic are estimated to enter the oceans annually by 2030 [1]. Until now, most of the marine litter detected has been found at the water surface level, with data collected mainly by satellites, drones, and aircraft. This led to the development of novel techniques applied to data extracted by optical sensors, such as hyperspectral cameras, to detect and classify marine litter [2].

In our previous work [3], multibeam acoustic data was utilized to detect different materials of marine litter in the water column at different acoustic frequencies. During this study, we observed that acoustic images captured at different ranges within a test tank could distinguish between different materials in the water column. This finding motivated the development and implementation of learning-based approaches for image classification and multi-label target detection using an updated dataset within a test tank, yielding positive results. Acoustic data collected at different frequencies was shown to effectively differentiate various objects in the water column under these conditions [4].

A recent study successfully developed a three-dimensional (3D) detection and tracking solution for sonar images acquired in a test tank. This approach combined the You Only Look Once (YOLO) detector [5] with a particle filter to estimate the position of detected targets [6]. That study also highlighted



(a) Kongsberg M3 High-frequency model and camera setup. (b) PORTUS surface vessel.

Fig. 1: Multibeam data acquisition mounted on PORTUS ASV during field trials in Leixões harbour.

the potential application of tracking algorithms such as DeepSORT [7], [8].

In another controlled test tank experiment, targets were detected and tracked using Otsu segmentation, a classic computer vision-based automatic threshold method, followed by a particle filter to estimate target positions [9]. The state of the art in acoustic imaging object tracking predominantly employs hybrid solutions, where traditional estimation algorithms such as Kalman and Particle filters [10], [11] are often integrated with learning-based approaches. This has led to the advancement of multi-object tracking (MOT) algorithms based on deep learning techniques. Particularly focusing on the development of MOT algorithms to track the trajectories of foreground targets across a sequence of frames, ensuring the correct association of identical objects over time [12]. A widely used paradigm for MOT is Tracking-by-Detection (TBD), where individual objects are first identified in each frame during the detection phase. These detections are then linked through data association, forming continuous tracks for each target [12].

Acoustic images attained in the underwater environment are associated with a dynamic scenario. This variability introduces challenges such as occlusion, overlapping detections, and changes in acoustic footprints. MOT algorithms, such as DeepSORT and ByteTrack, can address these challenges. DeepSORT is a deep learning-based approach that incorpo-

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2.1.7 Pita et al. (2026)

Title: Challenges and recommendations for marine waste management in European fishing ports

Authors: Pita C.^{a, b}, Ainsworth G.B.^c, Astudillo-Pascual M.^c, Silva P.M.^b, Gutierrez A.^b, Villasante S.^c

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Abstract:

The fishing sector plays a crucial role in the effective management of marine litter, emphasising the importance of facilitating waste collection for fishers and ensuring its subsequent management in port reception facilities (PRFs). EU Directive 2019/883/EU provides a unified sector-specific legal framework for managing ship-generated waste within EU ports, but harmonising PRFs and waste management remains challenging across Member States. Key areas for improving waste management include streamlining the regulatory framework (policies and processes), enhancing economic viability, fostering partnerships, promoting knowledge sharing, improving infrastructure, and increasing stakeholder awareness. The measures taken should consider the context, including port characteristics and the country in which it operates.

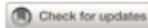
Keywords:

- Croatia
- Italy
- Malta
- Marine litter

- Port reception facilities
- Portugal
- Spain

Associated Dataset:

N/A



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Challenges and recommendations for marine waste management in European fishing ports

Cristina Pita^{1,2*}, Gillian B. Ainsworth³, Marina Astudillo-Pascual³,
Priscila M. Silva², Angel Gutierrez² and Sebastian Villasante³

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Coruña, Spain

The fishing sector plays a crucial role in the effective management of marine litter, emphasising the importance of facilitating waste collection for fishers and ensuring its subsequent management in port reception facilities (PRFs). EU Directive 2019/883/EU provides a unified sector-specific legal framework for managing ship-generated waste within EU ports, but harmonising PRFs and waste management remains challenging across Member States. Key areas for improving waste management include streamlining the regulatory framework (policies and processes), enhancing economic viability, fostering partnerships, promoting knowledge sharing, improving infrastructure, and increasing stakeholder awareness. The measures taken should consider the context, including port characteristics and the country in which it operates.

KEYWORDS

Croatia, Italy, Malta, marine litter, port reception facilities, Portugal, Spain

1 Introduction

Marine pollution is one of the most pressing environmental crises of our day (Chang and Saqib, 2025). The proliferation of marine waste over the last half-century is closely tied to the dramatic rise in plastic production, maritime transport, and extractive activities at sea (OECD, 2022). Plastics constitute up to 80% of all marine waste (Morales-Caselles et al., 2021), and cumulatively between 86 and 150 million tonnes of plastic are estimated to be present in the oceans (Jang et al., 2015), with most ending up on the seafloor (Madriscardo et al., 2020; Morales-Caselles et al., 2021).

At least 22% of all marine litter is estimated to originate from sea-based activities, including fishing, aquaculture, and shipping (Morales-Caselles et al., 2021). The fishing activity is especially important, as it is estimated that more than half (61%) of the plastic items found in the open ocean consist of synthetic ropes, strings, threads, buoys, and nets from lost or discarded fishing gear (Morales-Caselles et al., 2021). Although quantifying the precise contribution of fishing vessels to marine litter is challenging - due to methodological limitations, underreporting, and a lack of empirical data from at-sea operations (Delft, 2017; Deshpande et al., 2023; IMO, 2021) - the fishing sector is identified as playing a critical role in effectively managing marine plastics globally (Morales-Caselles et al., 2021).

Full article: <https://doi.org/10.3389/fmars.2026.1728784>

2.1.8 Guedes et al. (2026a)

Title: Learning-Based Online Tracking Algorithms for Marine Litter in Multibeam Water Column Images

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Link to repository: <https://zenodo.org/records/19825905>

Abstract:

Marine litter is a growing environmental threat, with severe ecological and socio-economic impacts. Most monitoring strategies rely on optical sensors to detect surface pollution, however these approaches fail to capture submerged plastics dispersed throughout the water column. Multibeam acoustic imaging offers a complementary solution, but the scarcity of annotated sonar datasets and the high noise levels of acoustic imagery make automated detection and tracking particularly challenging. This study presents a comparative evaluation of deep learning based multi-object tracking (MOT) algorithms applied to water column acoustic data. Pre-trained YOLOv8 detectors were integrated with tracking-by-detection frameworks including BoT-SORT, OC-SORT, ByteTrack, and DeepOC-SORT. Performance was assessed across acoustic frequencies and preprocessing strategies using standard MOT metrics. Results show that adaptive Gaussian thresholding and opening morphology improved robustness at lower frequencies (950 kHz and 1200 kHz), while unprocessed inputs proved more resilient to severe clutter at 1400 kHz . BoostTrack and ByteTrack achieved the most consistent tracking, effectively managing intermittent detections to maximise MOTA and IDF1. In contrast, OC-SORT underperformed, struggling with fragmented sonar trajectories. Furthermore, while efficient Nano models dominated at lower frequencies, Medium models were required under higher

noise. These findings demonstrate the feasibility of applying MOT methods to sonar-based litter monitoring. Future work will explore unsupervised learning approaches to leverage intrinsic sonar data structure, reduce annotation needs, and enable scalable marine litter tracking.

Associated Dataset:

N/A

RESEARCH ARTICLE

Learning-Based Online Tracking Algorithms for Marine Litter in Multibeam Water Column Images

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ABSTRACT Marine litter is a growing environmental threat, with severe ecological and socio-economic impacts. Most monitoring strategies rely on optical sensors to detect surface pollution, however these approaches fail to capture submerged plastics dispersed throughout the water column. Multibeam acoustic imaging offers a complementary solution, but the scarcity of annotated sonar datasets and the high noise levels of acoustic imagery make automated detection and tracking particularly challenging. This study presents a comparative evaluation of deep learning based multi-object tracking (MOT) algorithms applied to water column acoustic data. Pre-trained YOLOv8 detectors were integrated with tracking-by-detection frameworks including BoT-SORT, OC-SORT, ByteTrack, and DeepOC-SORT. Performance was assessed across acoustic frequencies and preprocessing strategies using standard MOT metrics. Results show that adaptive Gaussian thresholding and opening morphology improved robustness at lower frequencies (950 kHz and 1200 kHz), while unprocessed inputs proved more resilient to severe clutter at 1400 kHz. BoostTrack and ByteTrack achieved the most consistent tracking, effectively managing intermittent detections to maximise MOTA and IDF1. In contrast, OC-SORT underperformed, struggling with fragmented sonar trajectories. Furthermore, while efficient Nano models dominated at lower frequencies, Medium models were required under higher noise. These findings demonstrate the feasibility of applying MOT methods to sonar-based litter monitoring. Future work will explore unsupervised learning approaches to leverage intrinsic sonar data structure, reduce annotation needs, and enable scalable marine litter tracking.

INDEX TERMS Acoustic imaging, acoustic frequencies, autonomous surface vehicle, detection algorithms, marine litter, multibeam echosounder, multi-object tracking, ocean sensing, sonar.

I. INTRODUCTION

Marine litter is a growing threat to marine ecosystems and to global sustainability, it is estimated that 73 million tons of plastic will enter the oceans annually by 2030 [1]. New technologies are being introduced for more efficient and sustainable plastic degradation, namely enzyme engineering, however, this type of solution will be useful after the marine litter is detected [2]. As global attention to sustainability grows, industries are increasingly making environmental

claims that are not always substantiated. A large number of these claims constitute greenwashing, where vague or misleading language is used to promote a false image of sustainability [3]. In this context, the development of transparent, sensor-based monitoring systems becomes even more critical.

Most detection methods focus on surface-level litter, relying on satellites, drones, and aircraft remote sensing. Examples of said solutions use hyperspectral imaging for the detection of marine litter and its classification [4]. Regions such as the North Pacific Garbage Patch, are not only hotspots for plastic accumulation, but also critical

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Full article: <https://doi.org/10.1109/ACCESS.2026.3677642>

2.1.9 Guedes et al. (2026b)

Title: Descriptor: Forward-Looking Multibeam - Marine Litter Detection and Tracking Dataset (FLM-MLDT)

Authors: Guedes P.A.^a, Lysak M.^a, Amaral G.^a, Martins P.^a, Almeida C.^a, Silva H.M.^a, Martins A.^{a,b}, Wand S.^c, Almeida J.M.^{a,b},

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Published in: IEEE Data Descriptions

Year: 2026

URL: <https://doi.org/10.1109/IEEEDATA.2026.3683037>

Link to repository: The paper will be made available on the NETTAG+ Zenodo community once it is fully published, as it is currently available only in early access.

Abstract:

Institute for Systems and Computer Engineering, Technology and Science (INESC TEC) aims to make a significant contribution to the advancement of marine robotics and environmental monitoring by providing a novel dataset: the Forward-Looking Multibeam - Marine Litter Detection and Tracking Dataset (FLM-MLDT). Addressing the critical scarcity of labelled underwater data, this work presents 8,156 acoustic images acquired using the Kongsberg M3 High-Frequency Multibeam Echosounder with a forward-looking configuration installed in the PORTUS Unmanned Surface Vehicle (USV). Collected in the manoeuvring basin of Leixões harbour, this dataset offers information on 10 distinct types of marine debris. It provides input for developing deep learning algorithms, refining sonar signal processing, and enhancing the perception capabilities of different platforms for data extraction and environmental interaction. To ensure immediate utility and reliability, the dataset provides baseline metrics established using the You Only Look Once version 8 (YOLOv8) detector. By making this dataset publicly

available, INESC TEC seeks to drive further innovation in underwater computer vision and automated clean-up solutions, fostering a cleaner and more sustainable ocean environment.

Keywords:

- Acoustic imaging
- Marine litter
- Multibeam echosounder
- Perception
- Sonar
- Sustainability
- Underwater
- Unmanned surface vehicle (USV)
- Water column data

Associated Dataset:

Guedes, P. (2026). Forward-Looking Multibeam - Marine Litter Detection and Tracking Dataset (FLM-MLDT) [Data set]. Zenodo. <https://doi.org/10.5281/zenodo.18235788>

Descriptor: *Forward-Looking Multibeam - Marine Litter Detection and Tracking Dataset (FLM-MLDT)*

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ABSTRACT Institute for Systems and Computer Engineering, Technology and Science (INESC TEC) aims to make a significant contribution to the advancement of marine robotics and environmental monitoring by providing a novel dataset: the Forward-Looking Multibeam - Marine Litter Detection and Tracking Dataset (FLM-MLDT). Addressing the critical scarcity of labelled underwater data, this work presents 8,156 acoustic images acquired using the Kongsberg M3 High-Frequency Multibeam Echosounder with a forward-looking configuration installed in the PORTUS Unmanned Surface Vehicle (USV). Collected in the manoeuvring basin of Leixões harbour, this dataset offers information on 10 distinct types of marine debris. It provides input for developing deep learning algorithms, refining sonar signal processing, and enhancing the perception capabilities of different platforms for data extraction and environmental interaction. To ensure immediate utility and reliability, the dataset provides baseline metrics established using the You Only Look Once version 8 (YOLOv8) detector. By making this dataset publicly available, INESC TEC seeks to drive further innovation in underwater computer vision and automated clean-up solutions, fostering a cleaner and more sustainable ocean environment.

IEEE SOCIETY/COUNCIL IEEE Oceanic Engineering Society (OES)

DATA DOI/PID 10.5281/zenodo.18235788

DATA TYPE/LOCATION Multibeam echosounder acoustic images; Manoeuvring basin of Leixões harbour, Porto, Portugal

INDEX TERMS Acoustic imaging, marine litter, multibeam echosounder, perception, sonar, sustainability, underwater, unmanned surface vehicle (USV), water column data.

BACKGROUND

Public datasets on marine litter detection can be extremely useful for various reasons related to ecosystem preservation and robotic intervention, including environmental monitoring, automated clean-up and integration of autonomous systems. The United Nations Environment Programme (UNEP) defines marine litter as any persistent, manufactured, or processed solid material discarded in the marine environment [1]–[3]. With an estimated 53 million tonnes of plastic projected to enter the oceans annually by 2030 [4], having comprehensive and reliable datasets on underwater debris could significantly improve our ability to manage and mit-

igate this threat. This could lead to more efficient and sustainable robotic clean-up systems that can effectively handle submerged litter before it fragments into microplastics [2], reducing potential global damage.

The continued development of autonomous monitoring has prompted further inspection into the capabilities of underwater sensors to detect debris in the water column. This is most prevalent in turbid coastal areas, ports, or high-traffic routes where optical sensors fail. Although data from surface observations (satellites, drones) are available [4], very few if any have compiled extensive underwater acoustic data into a comprehensive dataset. Most existing research relies on

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Full article: <https://doi.org/10.1109/IEEEDATA.2026.3683037>

2.2 Conference proceeding articles

2.2.1 Neasham et al. (2025)

Title: Low Energy, Real Time Passive Acoustic Detection of Dolphin Clicks and Whistles

Authors: Neasham J.^a, Burnett R.^a, Lowes G.^a, Sherlock B.^a, Berggren P.^b, Dickson S.^b

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Published in: 7th Experiment@ International Conference (exp.at'25)

Year: 2025

URL: <https://doi.org/10.1109/exp.at2565440.2025.11348486>

Link to repository: <https://zenodo.org/records/19894493>

Abstract:

This paper describes the development of software algorithms and hardware for real time passive acoustic detection of dolphin clicks and whistles, with strong emphasis on low power implementation to allow long term deployment with a small alkaline battery pack. The objective is to produce an affordable and practical technology for live reporting of dolphin presence, via underwater acoustic communication or terrestrial/satellite radio link, to support mitigation of impact of offshore construction and fishing activity, as well as data for marine science. Highly computationally efficient algorithms were developed and validated by offline processing of acoustic recordings from the UK waters, annotated by expert bioacousticians. Accuracy of 98.3% and 99.7% was achieved for click and whistle detection respectively, with zero false positives. These algorithms have been successfully ported onto a proven ARM Cortex M4 based embedded processor platform, with a mean power consumption of only 12 mW, and tested by playback of the above recorded data. This has proven the feasibility of this approach and a full prototype system is being prepared for deployment in the sea trials at the time of writing.

Keywords:

- Passive acoustic detection
- Underwater acoustics
- Bioacoustics

- Wireless sensor networks
- Cetaceans
- Low-power

Associated Dataset:

N/A

2025 7th Experiment@ International Conference (expat'25)
September 3-5, 2025, University of the Azores, Faial, Azores, Portugal

Low Energy, Real Time Passive Acoustic Detection of Dolphin Clicks and Whistles

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Abstract—This paper describes the development of software algorithms and hardware for real time passive acoustic detection of dolphin clicks and whistles, with strong emphasis on low power implementation to allow long term deployment with a small alkaline battery pack. The objective is to produce an affordable and practical technology for live reporting of dolphin presence, via underwater acoustic communication or terrestrial/satellite radio link, to support mitigation of impact of offshore construction and fishing activity, as well as data for marine science. Highly computationally efficient algorithms were developed and validated by offline processing of acoustic recordings from the UK waters, annotated by expert bioacousticians. Accuracy of 98.3 % and 99.7% was achieved for click and whistle detection respectively, with zero false positives. These algorithms have been successfully ported onto a proven ARM Cortex M4 based embedded processor platform, with a mean power consumption of only 12 mW, and tested by playback of the above recorded data. This has proven the feasibility of this approach and a full prototype system is being prepared for deployment in the sea trials at the time of writing.

Keywords—passive acoustic detection, underwater acoustics, bioacoustics, wireless sensor networks, cetaceans, low-power

I. INTRODUCTION

There is an ever increasing requirement to monitor the occurrence and distribution of marine mammals, both for ecology studies and the mitigation of human impacts. There are concerns around the impact of offshore construction activities on marine mammals, such as the acoustic emissions from pile-driving for the installation of offshore wind turbines [1]. There are increasing requirements for marine mammal surveys, both for pre and post installation and also to try to mitigate impacts e.g. suspending operations if animals are detected in the vicinity. Similar requirements are also becoming more common for sonar and seismic survey activities and even fishing activity in sensitive areas.

Visual surveys for marine mammals are very expensive, in terms of personnel and vessel time, and can also yield very poor results in high sea states and low visibility conditions, becoming impossible in darkness. Hence automated detection based on passive acoustic monitoring (PAM) of cetacean echolocation signals or calls is increasingly used. Several commercially available technologies have been employed to detect echolocation 'clicks' [2], from dolphins, porpoises or other toothed whales, or less commonly communication calls (whistles). These technologies fall into two broad categories:

- Recording hydrophones which capture continuous broad spectrum acoustic data. These devices are

retrieved after the recording period and data is downloaded and analysed offline, typically with the aid of semi-automated detection software such as PAMGUARD [3].

- Click detector devices such as C-POD [4] which perform detection of individual clicks, logging time-stamps and information about amplitude and frequency content of each click. Logged data is again downloaded after the instrument is retrieved and proprietary software processes the data to report occurrence of dolphin and porpoise click trains.

Both of these categories can be described as *archival* devices, since data can only be processed after the instrument is retrieved. Hence, neither is able to deliver real-time (live) updates of marine mammal occurrence and so they have limited use in mitigation measures described earlier. Furthermore, even as a data gathering tool for longer term studies there is a high risk of data loss if the instrument is not recovered, along with potentially months of valuable data. Hence there is a genuine need for fully automated, real time detection technology with immediate communication of animal detections. Ideally this technology should be easily installed, have a long deployment life and communicate data wirelessly back to the operators.

II. SYSTEM DESIGN

A. Hardware Platform

Previous work by the authors demonstrated the feasibility of low-power, real time PAM for vessel propulsion noise [7]. This employed a hydrophone listening to signals in the 5-40 kHz frequency band, acquired and processed by a low power ARM microprocessor which applied the Detection of Envelope Modulation Of Noise (DEMON) principle to detect noise generated by propeller cavitation. Live vessel detection data was sent back to shore via either:

- LoRa radio communication in the 868 MHz ISM band, using a lightweight surface buoy developed by the authors [8]. This has a range of up to 20 km.
- Underwater acoustic communication from the PAM device(s) to the surface buoy using low cost/power acoustic modems developed by the authors [9].

Fig. 1 shows images of the surface buoy system which can act as either a vessel detection node with PAM transducer or a communication gateway for collecting data via acoustic modem from subsea PAM units and transmitting back to shore. Vessel detection systems based on this technology have

3 Advanced Training

Within the framework of the NETTAG+ project, two PhD theses and two MSc theses have been completed (Table 3), as detailed in following sections.

Table 3. PhD and MSc theses associated with the NETTAG+ project.

No.	Publication	Lead partner	WP	Repository
1	Oliveira R., 2024. Acoustic Characterization and Detection of lost fishing gear. Universidade do Porto.	INESCTEC	WP4	http://hdl.handle.net/10400.22/26844
2	Silva C., 2024. AUV navigation simulation for detecting ghost nets through deep learning. Universidade do Porto.	INESCTEC	WP4	http://hdl.handle.net/10400.22/26489
3	Magalhães S., 2025. Bioavailability and effects of microplastics in estuarine and coastal larval fish assemblages. Universidade do Porto.	CIIMAR	WP4	https://hdl.handle.net/10216/167824 Embargoed Access (end date: 25-06-2026)
4	Perdigão R., 2026. Exploring native microorganisms for bioremediation of oils and other pollutants inside ports. Universidade do Porto.	CIIMAR	WP4	https://hdl.handle.net/10216/173719 Embargoed Access (end date: 24-02-2027)

1.1. PhD thesis

1.1.1. Sabrina Magalhães (2025)

Title: Bioavailability and effects of microplastics in estuarine and coastal larval fish assemblages

Name: Sabrina Rodrigues Magalhães

Institution: Universidade do Porto

Supervisors: Sandra Ramos, Marisa Almeida, Michael Elliott

Year: 2025

URI: <https://hdl.handle.net/10216/167824>

Access type: Embargoed Access (end date: 25-06-2026)

1.1.2. *Rafaela Mendes (2026)*

Title: Exploring native microorganisms for bioremediation of oils and other pollutants inside ports

Name: Rafaela Alexandra Perdigão Mendes

Institution: Universidade do Porto

Supervisors: Ana Paula Mucha, Marisa Almeida, Maria de Fátima Carvalho, Catarina Magalhães

Year: 2026

URI: <https://hdl.handle.net/10216/173719>

Access type: Embargoed Access (end date: 24-02-2027)

1.2. MSc thesis

1.2.1. *Rui Oliveira (2024)*

Title: Acoustic Characterization and Detection of lost fishing gear

Name: Rui Filipe Martins de Oliveira

Institution: Universidade do Porto

Supervisors: Eduardo Silva, Alfredo Martins

Year: 2024

URI: <http://hdl.handle.net/10400.22/26844>

Access type: Open Access

1.2.2. *Carlos Silva (2024)*

Title: AUV navigation simulation for detecting ghost nets through deep learning

Name: Carlos Miguel Mendonça e Silva

Institution: Universidade do Porto

Supervisors: Eduardo Silva, Alfredo Martins

Year: 2024

URI: <http://hdl.handle.net/10400.22/26489>

Access type: Open Access



4 Other Scientific Outputs

4.1 Ramos et al. (2026)

Title: Smart acoustic tagging and robotic recovery systems for ghost gear pollution

Authors: Ramos S.^a, Almeida M.^a, Sousa L.^a, Neasham J.^b, Martins A.^c, NETTAG+ consortium

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Published in: Open Access Government

Year: 2026

URL: <https://doi.org/10.56367/OAG-050-12543>

Abstract:

N/A

Keywords:

N/A

Associated Dataset:

N/A



Abandoned, Lost or otherwise Discarded Fishing Gear (ALDFG) is recognised as one of the most harmful and persistent forms of marine litter, estimated to account for 10% of all plastic in the Ocean.⁽¹⁾ Predominantly composed of plastic, ALDFG can persist for long periods, posing several adverse environmental and socio-economic impacts. In 2018, the European Union (EU)⁽²⁾ reported that at least 20% of EU fishing gear is lost or discarded at sea, totalling up to 11,000 tonnes.

Although fisheries are a source of sea-based marine litter, they are also among the activities most affected. Marine debris can damage catches, fishing gear, and vessels, and compromise navigational safety. It is estimated that marine litter costs the EU fishing fleet approximately €61.7 million

per year.⁽³⁾ Impacts extend beyond fisheries, also affecting other key coastal economic activities, namely tourism, as polluted beaches discourage visitors and contribute to job losses. Therefore, innovative strategies to tackle ALDFG and marine litter are needed.

NETTAG+ project

The NETTAG+ project addresses these challenges by developing and implementing three complementary and innovative solutions to PREVENT, AVOID and MITIGATE the harmful impacts of fishing gear and marine litter derived from fisheries.

The PREVENT solution focuses on preventing marine litter derived from fisheries activities by empowering professional fishers as 'Guardians and Cleaners of the Ocean'. Through

awareness actions (from fishers to fishers) and NETTAG+ solutions demonstration events, the project promotes the adoption/refinement of best practices for litter management and supports behavioural changes within fishing communities. These actions are reinforced by co-designed reward programs that recognise fishers for their voluntary efforts to help clean up the Ocean by retrieving marine litter passively collected by their gear during routine fishing operations, along with policy recommendations for waste management in European fishing ports.

The AVOID solution addresses the unintentional loss of fishing gear by developing and testing innovative, low-cost technologies that enable fishers to rapidly locate and recover gear before it becomes ALDFG, directly reducing

Full article: <https://doi.org/10.1109/IEEEDATA.2026.3683037>