CleanAtlantic

Tackling Marine Litter in the Atlantic Area

DELIVERABLE 5.2. – Overview of the work carried out in CleanAtlantic on improving marine litter monitoring:

- *WP 5.2.1. – Improving methods for marine litter monitoring in the Atlantic Area: seabed, floating and coastal litter*
- *WP 5.2.2. – New tools for the monitoring of marine litter*

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DISCLAIMER

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Introduction

This report collates the main results delivered in the frame of the CleanAtlantic project, Work package 5.2. *Monitoring the presence of marine litter in the marine environment*. With this purpose, an overview of new and improved marine litter monitoring methods for seabed, water surface and coastal compartments in the Atlantic Area is presented. Main findings, gaps on monitoring and research as well as potential improvements and recommendations are highlighted. For some of the topics addressed partners produced fully-dedicated reports. In these cases, links to the original reports are included in the reference section for further information.

Improving current methods for the monitoring of marine litter in the Atlantic Area

Methods for marine litter sampling need to be reliable, feasible, and universal to allow comparison and evaluation of the environmental status and temporal trends. The main objective of this action is the optimization and adaptation of conventional methods used in other marine environmental assessments to be employed in marine debris monitoring.

Seabed, surface and coastal compartments have been considered. Among other methods included scientific observers in fishing vessels as well as in oceanographic campaigns were trained to record marine litter, and protocols and data-recording templates adapted to this purpose.

A citizen science approach and friendly-user Apps were also developed to pinpoint litter accumulation hotspots in seabed and coastal compartments.

1. SEABED LITTER MONITORING

The catchability of two different gears used on ground fish surveys was assessed for seabed litter monitoring. Baka gear is used for demersal trawl surveys carried out by the Spanish Oceanographic Institute (IEO) while GOV (Grand Overture Vertical) gear is employed by IFREMER with the same purpose for sampling campaigns in the ICES area. The trials consisted in 14 paired hauls of 30 minutes carried out in the Bay of Biscay during the Spanish North Coast and French EVHOE surveys (2013-2015).

Additionally, protocols for scientific observers enrolled in fishing vessels were adapted by IEO to record litter catches. The data recorded come from different fishing areas off the coasts of Spain, Portugal and Ireland and different fishing gears, between 2018 and 2019. Fishing grounds comprised in this study were the Gulf of Cadiz, Cantabrian Sea-NW Spain and Sole Bank and fishing gears used included Baka trawl, GOV trawl, Purse seine, Pair trawl, “Rasco” bottom set gillnet and “Volanta” bottom set gillnet.

In Madeira Island, monitoring of seabed litter in coastal areas was assessed by scientific and recreational SCUBA divers, where the detection of conspicuous litter items was included in benthic community surveys by ARDITI/MARE scientific diving team and by requesting recreational SCUBA divers to report remarkable litter items after their dives. Litter reporting was tested during MARE annual benthos surveys in 2018 and 2020. Opportunistic seabed litter characterization was also assessed during organized clean-ups in 2018-19 and through questionnaires and interviews of recreational divers during a test study of the mobile app **Dive Reporter** developed with local stakeholders (i.e., dive operators) and tested in August 2021. The app was first and foremost designed to monitor and report sighting of target species, however, by adding seabed litter categories to the app, divers could also report sightings of litter items. In addition, density and categorization of conspicuous seabed litter items present in harbour and marina facilities in Madeira were assessed by conducting ROV-based underwater video transects, optimizing underwater video analysis protocols for litter monitoring and providing insight to litter contamination inside these facilities.

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1.1. Key findings

In terms of the contrasting analysis between the baka and GOV trawl gears, to allow the comparison the following index was calculated:

Index= (Value BAKA - Value GOV)/ Maximum value (Value BAKA or Value GOV).

Positive values indicate larger capture for the baka gear while negative values indicate major captures for the GOV gear. The index was calculated in items x km^{-2} and kg x km^{-2} for each paired haul. Significant differences were examined with a sample sign test (median equal to cero).

The index calculated with the paired hauls was -0.42 when considering the number of items and 0.08 for weight. This indicates that higher numbers of seabed litter items were collected with the GOV gear, while in terms of weight the yields for both gears were similar although a bit higher with the baka gear. However, one sample sign test did not confirm significant differences (p value >0.05 for items and weight indices).

Figure 1 displays the data per gear and paired haul. Large differences on weight in hauls 6 and 10 are due to heavy items found in these GOV hauls: a big item of 17.1 kg in the haul 6 (classified as Other Miscellaneous) and five items between 1 and 2 kg such a pallet, a tyre, a fishing net and others.

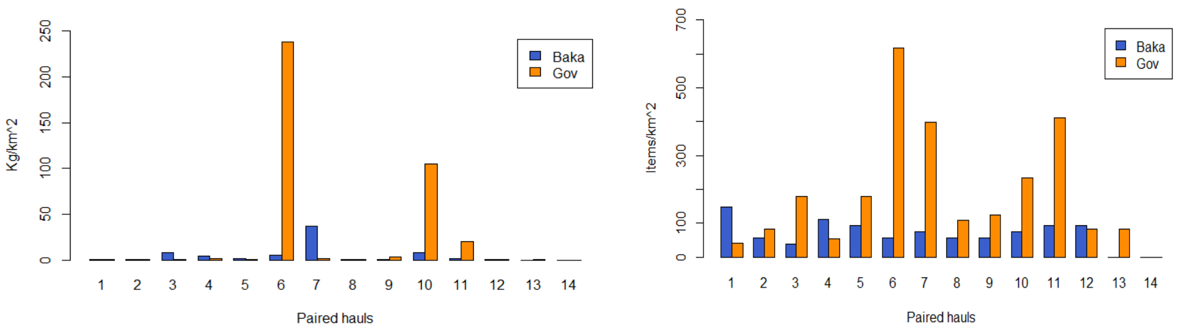

Figure 1. Number of items.km^{-2} (left) and kg.km^{-2} (right) per gear (baka and GOV) and paired haul (figure extracted from the original report).

Plastics were the main litter type collected with either Baka or GOV gears, when considering item abundances (90.2% for Baka and 79.9% for GOV). However, when weight was considered, the main litter type was assigned to Miscellanea category for GOV while plastic still constituted 97.6% in baka gears. Among plastics, plastic bags and synthetic ropes were the most common identified objects.

Considering the data recorded by scientific observers onboard fishing vessels, they showed a higher percentage of hauls with litter with baka gear (11.77%) than with GOV, purse seine, pair trawl, “rasco” and “volanta”. It must be noticed, though, that most of hauls were performed with baka (*i.e.,* 1223 hauls with baka *vs*. 43 hauls with GOV). In this study, after baka, the gear that presented the highest percentage of litter per haul was “rasco” with a percentage of 5.13% (n=39) (**Figure 2**).

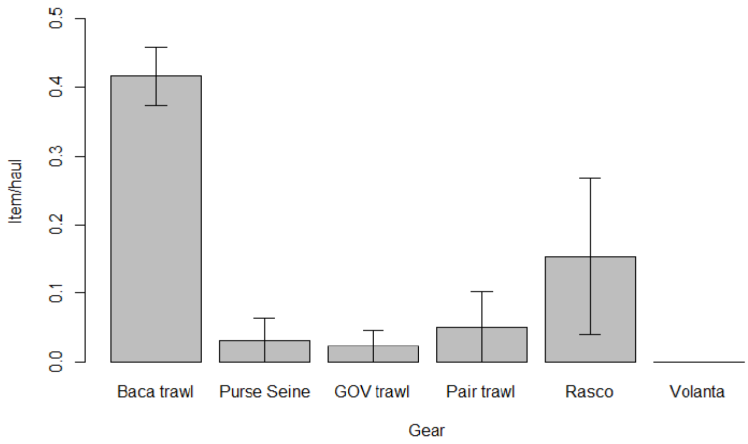

Figure 2. Mean values of marine litter densities estimated per haul and gear (figure extracted from the original report).

Considering the totality of hauls, gear and fishing grounds, marine litter was found in 149 over 1527 hauls included in the study representing 9.8% of the total hauls, with average densities of 0.34 ± 0.034 items per haul (**Figure 3**).

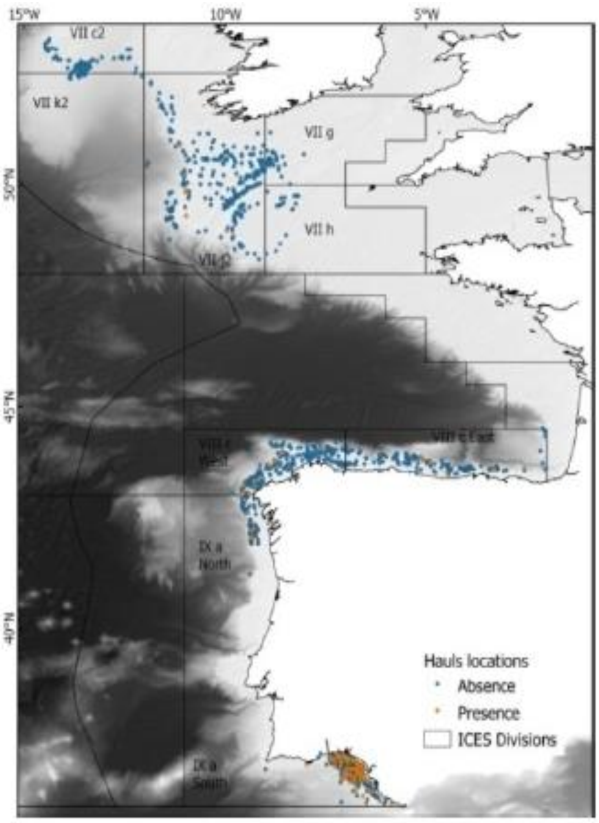

Figure 3. Map of haul locations. Blue spots are represent hauls where marine litter was not recorded, and orange ones those where litter items were found (figure extracted from the original report).

Plastic was the most frequent litter type (41.4%), followed by metals (24.7%) and glass/ceramics (14.6%). Gulf of Cadiz fishing ground was by far the area with the greatest percentage of litter per haul (25.76%), followed by Cantabrian Sea - NW Spain (4.33%) and Sole Bank (1.22%).

In the Madeira island, an analysis of the composition of litter collected during underwater clean-ups and during annual surveys also revealed that plastics (51%) and metals (37%) are the most commonly found materials, with discarded fishing related items being the most commonly found litter (**Figure 4**).

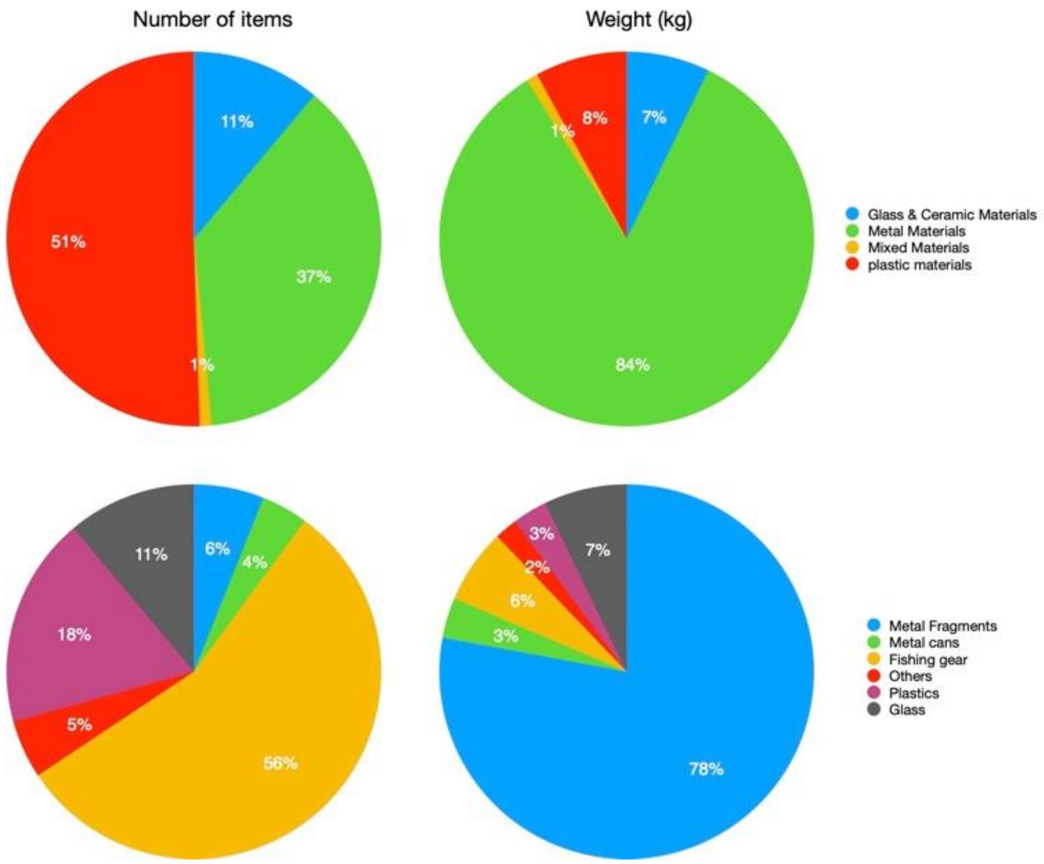

Figure 4. Composition in material type (top) and litter type (bottom) of the number of items (left) and weight (right) detected and collected by SCUBA divers.

During an experimental trial (carried out in August 2021) to test the use and operation of Diver Reporter app to collect information on litter contamination in dive sites without field surveys, 42 interview surveys were conducted, where litter was reported in 60% of the dives. Similarly to other surveys, in these reports, the most frequent litter types were items or fragments of Rubber (56%), and Plastic (40%) followed by Metal (32%) (**Figure 5**), suggesting that this lower effort approach provides comparable data in terms of litter composition assessments.

Artificial polymers (i.e., plastics) and metal items and fragments were also the most common type of litter found inside marinas and harbours in Madeira (**Figure 6**). ROV video transect surveys and analysis enabled to estimate both item density and relative composition of litter contamination on the seafloor. Caniçal harbour was the most contaminated, however, water turbidity greatly hampered surveys conducted in Funchal, where, unsurprisingly detection was much lower.

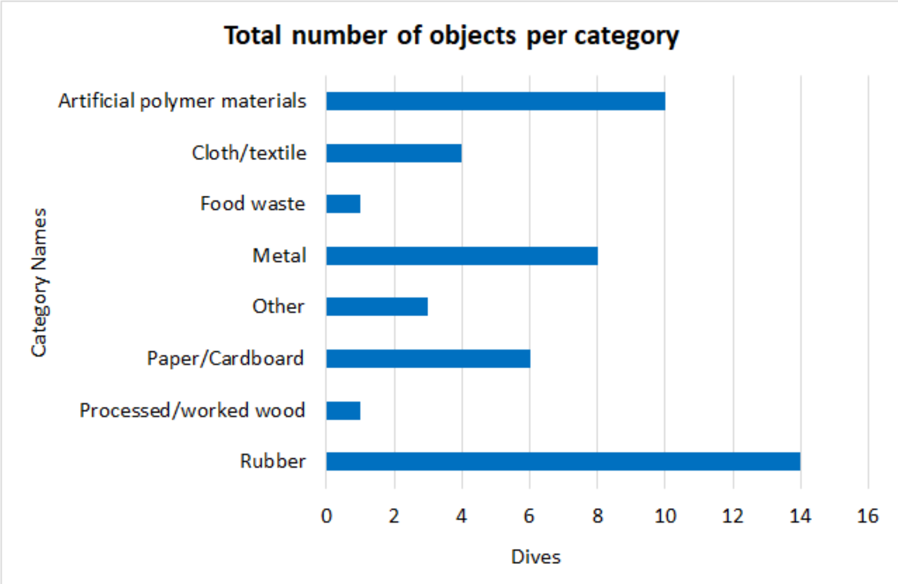

Figure 5. Number of dives where items of each litter category were reported (data collected using Dive Reporter app during August 2021).

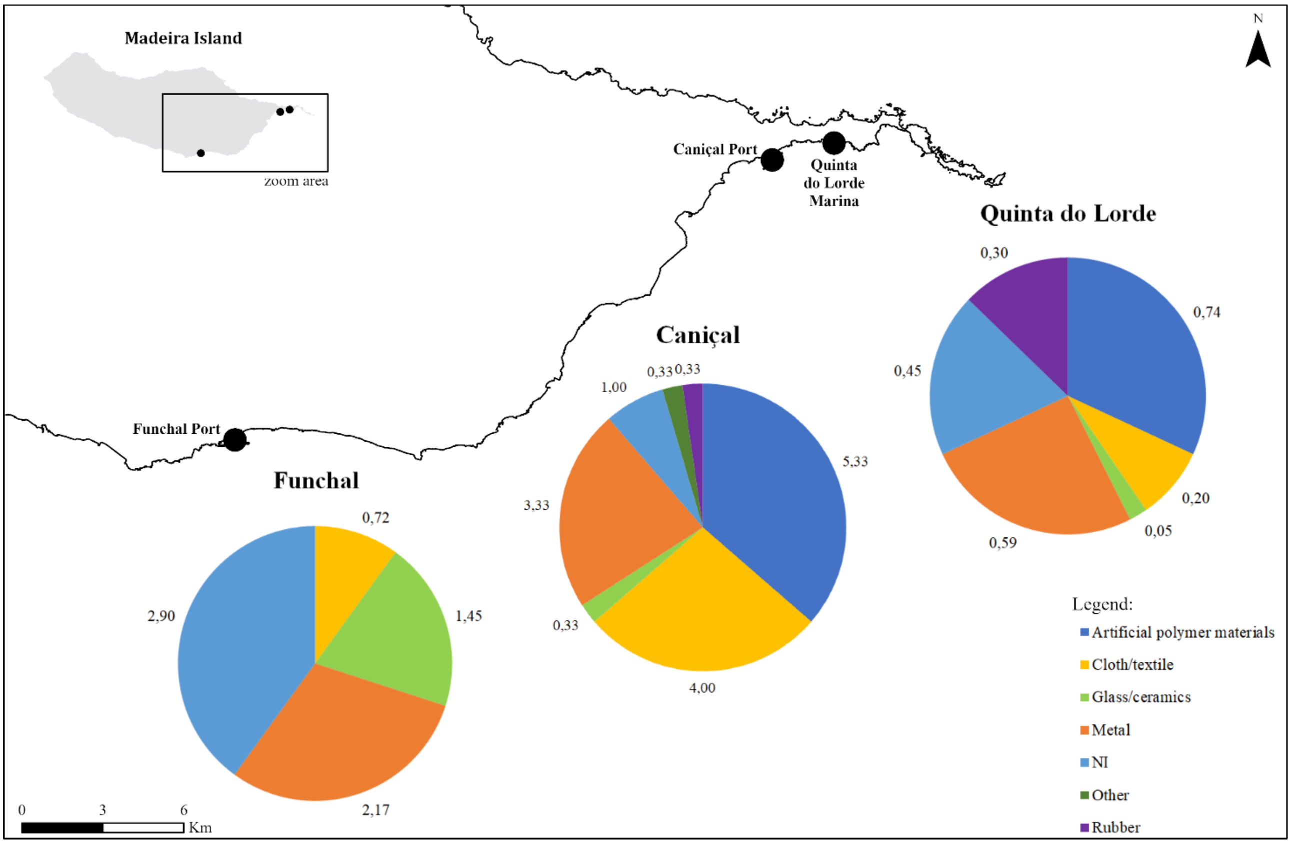

Figure 6. Litter composition and item density (n. of items/100 m^2) of three ports and marinas in the Madeira Island based on ROV underwater video transect analysis.

1.2. Gaps on monitoring and research

The harmonization of methods and protocols for seabed debris assessment is needed. In the case of baka and GOV gears, comparability studies show that even with the same methodology, the two trawl gears tested were not directly comparable for seabed litter surveys. The different behaviour of the gears could hamper data standardization.

Although baka and GOV gears caught a similar quantity of litter in terms of weight km^{-2} in the Bay of Biscay the results differed when expressed in terms of items.km^{-2}. It is recommended to take this fact into account in future surveys. Moreover, despite de data recorded by the scientific observers onboard fishing vessels pointed that baka had a higher percentage of litter in each haul, this result must be taken carefully due to the disparity in methodology and fishing grounds.

The inclusion of litter classification and categorization in SCUBA underwater surveys conducted by scientific diving teams is not always feasible due to task loading of the scientific divers and limited bottom times. When possible, these can be included, however consistent seabed litter monitoring should not rely on SCUBA surveys as these tend to be costly, time consuming and labour intensive. In Madeira, stakeholder engagement and monitoring programs relying on volunteers, interviews and opportunistic reporting can be leveraged by implementing simple questionnaires aided by mobile apps. Interview approaches and stakeholder engagement enable insight into contamination levels and a basic characterization of coastal seabed litter; however, these are not standardised approaches and are typically restricted to where stakeholders develop their activity or direct their actions (e.g., underwater clean-ups). As such, it is crucial to combine these with standardised dedicated monitoring surveys that can be used for comparison and as referential to citizen-based surveys. Underwater video from ROV can be used as a standard method, following the guidelines in Gerigny et al. (2020)[1] or other standardized video transect methods, however, these also have limitations associated with costs, operations restrictions and limitations (i.e., marine traffic, weather) and water turbidity. The use of high resolution side-scanners may complement and enhance litter detection abilities. Also, the further development of artificial intelligence and machine learning may greatly reduce labour and time required for image analysis and data processing.

[1] GERIGNY, O., CLARO, F., LE MOIGNE, M. and GALGANI F. (2020). Strategy and constraints to support monitoring of Marine Litter Harm: Towards a protocol for the observation of marine organisms tangled/strangled/covered by marine litter during ROV operations. Deliverable 5.3. Report, CleanAtlantic, Altantic Area Interreg Project

2. MONITORING OF FLOATING LITTER

2.1. Case studies

2.1.1. Macrolitter

Floating macrolitter can be detected by top-predator observers enrolled on oceanographic campaigns. An adaptation of datasheets used by observers was performed by IEO (Instituto Español de Oceanografía) to be used, as well, for floating marine litter monitoring in the IEO PELACUS campaigns.

2.1.2. Mesolitter and microlitter

In terms of micro and mesolitter, In order to assess the feasibility of manta trawl to detect and sampling small pieces of floating debris, several studies were conducted by IEO and ARDITI.

The seasonal cycle of micro and mesolitter in the Ría de Vigo (NW Spain)

The seasonal cycle of micro and mesolitter in coastal surface waters of the Ría de Vigo (NW Spain) was assessed by IEO in 2017, all year round, being samples collected in a monthly basis. A study was also performed in coastal and offshore waters at several stations of the Galician shelf. Both studies applied a similar methodology using a 333 µm net-hole manta trawl which was towed for 10 minutes at a speed of 3 knots. The retrieved samples were filtered and observed under the stereoscope and then synthetic items were photographed and measured. Plastics below and over the boundary of 5 mm were considered micro and mesoplastics, respectively. Any time organic material hampered direct observation density separation and further digestion were carried out. The nature of suspected plastic pieces was confirmed by spectroscopic techniques.

Monitoring floating microlitter in offshore waters by manta-trawl (collaboration with iFADO project)

In the frame of the CleanAtlantic and in collaboration with iFADO project 10 samples from Galician offshore waters (NW Iberian Peninsula, Figure 7) were collected by means of a manta-trawl net for micro-litter categorization.

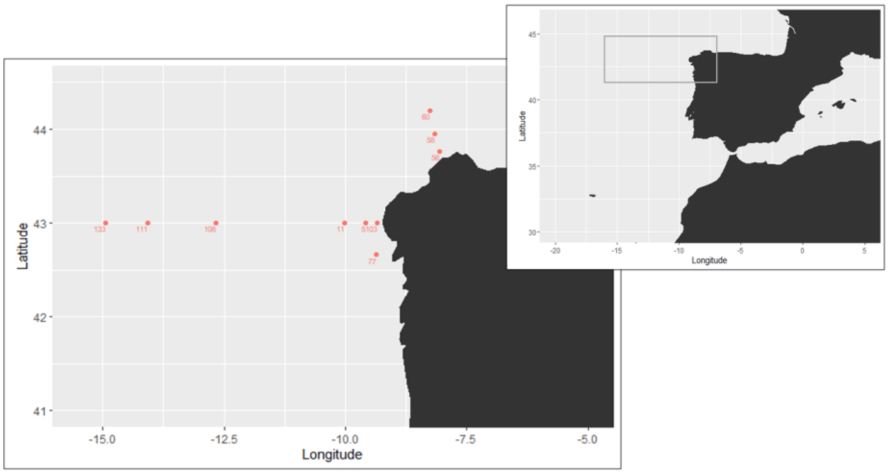

Figure 7. Location of stations where samples were collected.

Assessing floating meso-plastic contamination with Manta Trawl in South Coast of Madeira Island

All samples and data were collected in the south coast of Madeira Island. In 2017 and 2018, eastern and western areas (respectively), were opportunistic sampling campaigns integrated within other projects targeting micro-, meso- and macro- floating litter. Within CleanAtlantic, the opportunity was used to assess if manta-trawl could be used and/or combined with other approaches (e.g., aerial drone surveys) to assess floating litter contamination. Following these campaigns, the methodology was optimised and implemented in 2019 in an area in front of Funchal - the most populated area of the island. The methodology used for sampling consisted in trawling a net with 200 µm and 500 µm mesh during 1 NM at a constant speed of 3 knots. Samples in the collector were stored for later processing in the laboratory following Herrera et al., (2019)[2] and BaseMAN et al., (2019)[3].

Samples from the three years are currently at different stages of processing and analysis:

- 2017 samples (12 transects with 200µm net) have been processed and data has already been published (Herrera et al., 2020);
- 2018 samples (n = 10; 6 transects with 200 µm and 4 transects with 500 µm net) have been processed in lab, not published;
- 2019 samples (n = 23; 12 transects with 200 µm and 11 transects with 500 µm net) have been processed in lab, not published.

2.2. Key findings

2.2.1. Macrolitter

The protocol adapted for observers is the usual for species recording, based on the ‘’distance sampling’’ method. Briefly, this methodology uses perpendicular distances of the sight to obtain an effective bandwidth with the highest probability of detection. Records of floating litter are then classified attending to different characteristics, such as material (*i.e,.* plastic, wood, other), source (*i.e.,* fisheries) and size (small trash / trash) and when possible, the object detected must be identified. The full protocol and templates for data recording are available on a dedicated report (see reference section).

2.2.2. Mesolitter and microlitter

The seasonal cycle of micro and mesolitter in the Ría de Vigo (NW Spain)

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[2] Herrera, A., Ŝtindlová, A., Martínez, I., Rapp, J., Romero-Kutzner, V., Samper, M. D., Montoto, T., Aguiar-González, B., Packard, T., & Gómez, M. (2019). Microplastic ingestion by Atlantic chub mackerel (Scomber colias) in the Canary Islands coast. *Marine Pollution Bulletin*, *139*, 127–135. https://doi.org/10.1016/j.marpolbul.2018.12.022

[3] BaseMAN – Microplastics Analises in Europen Waters. 2019. WP4 Sampling methodologies for microplastics in the marine environment: standardisation, suitability and intercomparison Deliverable 4.1 Standardised protocol for monitoring microplastics in seawater January 2019

After examination of the 32 surface water samples collected in Ría de Vigo during all year round, 886 particles (micro and mesoplastics) were identified. In the case of the 10 samples collected in different sites of Galician offshore and inshore waters, 140 items were visually identified as fibres while 66 were included in the fragment, pellet, filament and film categories, being mostly micro particles (< 5mm). From these results and those from Galician inshore and offshore samples it is inferred that manta trawl is a suitable gear to collect small litter items floating on surface and subsurface water. In both compartments microplastics were more abundant than mesoplastics and no correlation was observed between them. This observation suggests that despite microplastics may be the result of mesoplastic fragmentation the quantity of microplastics in the environment cannot be deduced by mesoplastic estimations and vice-versa.

Furthermore, no significant differences were detected in the different stations between meso and micro plastic (**Figure 8**) and no gradient was observed in the concentration of micro/mesoplastics from the inner zone to the outer zone of the ría.

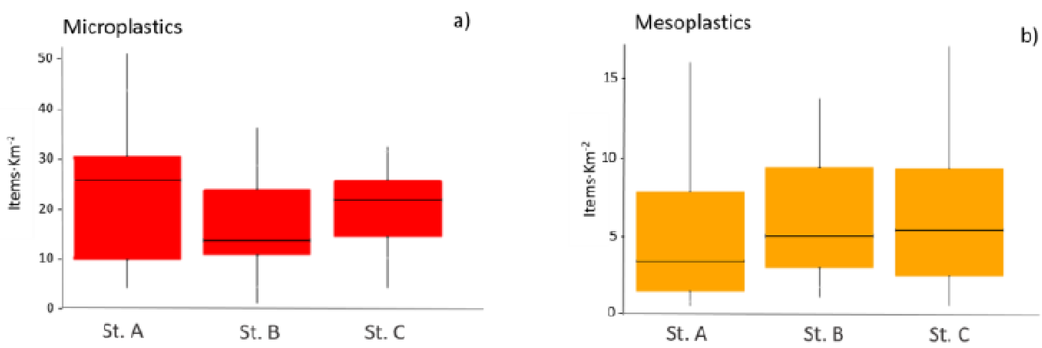

Figure 8. Density of micro and mesoplastics in the three sampled stations in the Ría de Vigo (annual average/10,000) (extracted from the original report).

The study of meso and micro plastic frequency in Ría de Vigo also revealed that their occurrence presents a seasonal pattern which was inversely related to zooplankton variations. In terms of the items characteristics, the two most common item types were fibres and paint sheets displaying mostly dark and green colours, respectively.

Monitoring floating microlitter in offshore waters by manta-trawl (collaboration with iFADO project)

The total number of items for all the sampling sites accounted 140. Over the 140 items, 74 were visually identified as fibres, while 66 were included in the fragment, pellet, filament and film categories, being the former the most numerous. Only one sample (sample 103) was free of synthetic items. This sample was also the one with the highest organic material, which could hampered the identification of small artificial particles. The sample with the highest number of particles was the sample 108 collected approximately 150 miles off the Galician coast (Figure 7). There was a degree of uncertainty about the composition of items identified as fibres, due to their resemblance with vegetal structures and crustacean appendixes. The spectra retrieved from these items by RAMAN spectrometry were also inconclusive. For this reason, fibres were not considered in further analyses.

The average of item density for the whole sample collection was 0.0089 ± 0.0091 item/m^2 or 0.0446 ± 0.0455 item/m^3. As expected, the highest densities were obtained for station 108 (0.032 item/m^2 and 0.162 item/m^3) followed by samples 133 and 77, which were located nearer the west coast of Galicia (Figure 9).

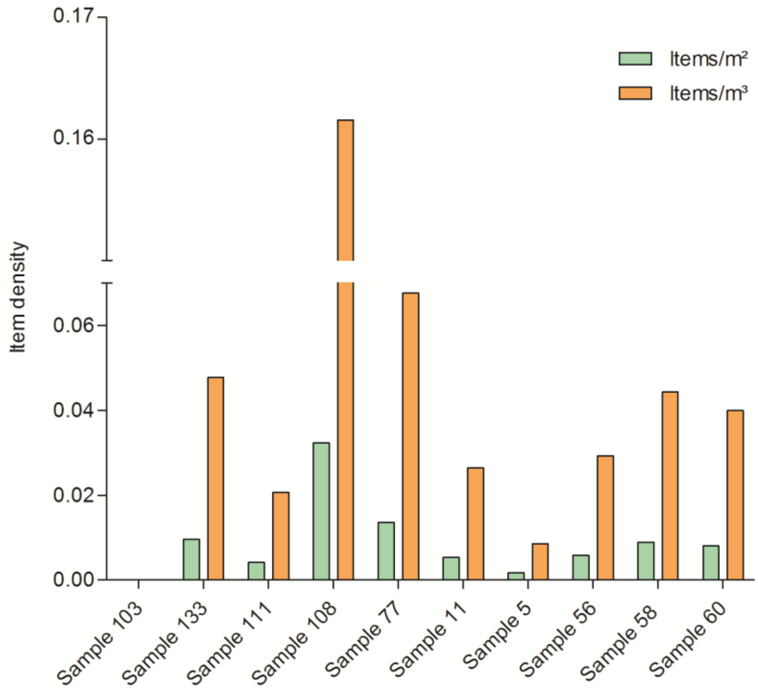

Figure 9. Item density estimations for each sampling site expressed per unit of surface and volume of water filtered.

Only one filament and one film pieces could be categorically identified by RAMAN spectroscopy as polyethylene terephthalate (PET) and polyethylene (PE), in samples 133 and 5 respectively. The percentage of match against the spectra in our RAMAN polymer library was 76.24% for PET and 95.15% for PE.

Assessing floating meso-plastic contamination with Manta Trawl in South Coast of Madeira Island

In the Madeira Island, data analysis for spatial distribution (**Figure 10**) is hindered by the opportunistic nature of 2017 and 2018 collections where target areas were different for each year making it impossible to disentangle time-related from spatial-related variations. However, inspecting the distribution and density data (**Figure 10**) suggests that the eastern side of the South coast of the island may have lower concentration of floating meso-plastics, which could be linked with local oceanographic circulation.

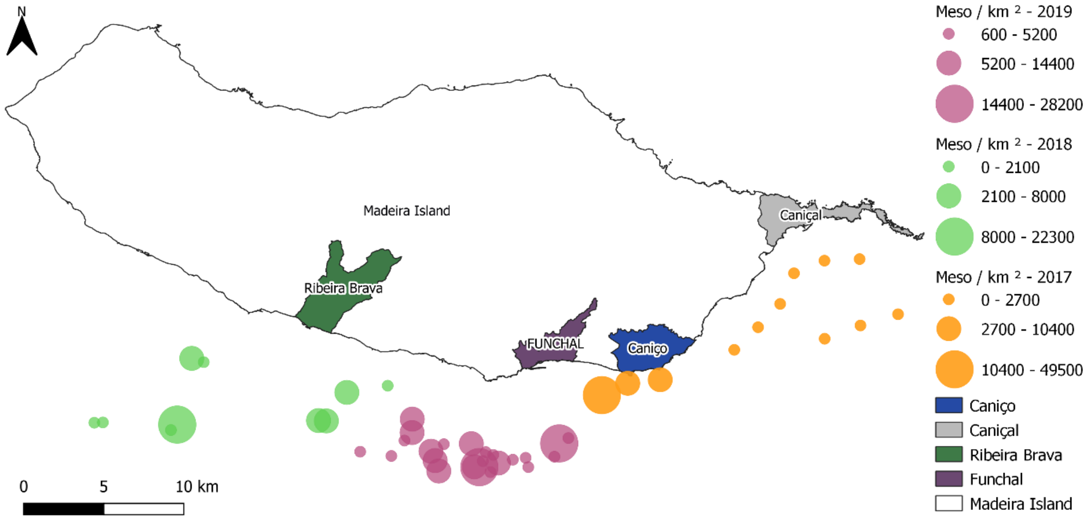

Figure 10. Meso-plastic density (unit/km²) in the south of Madeira Islands (2017, 2018 and 2019 campaigns).

Inspecting meso-plastic concentrations for each year suggests no significant differences between them (**Figure 11**). Protocol and methodological optimization lead to a streamlined protocol and a selection of one area where population density pressure is higher to run monthly monitoring.

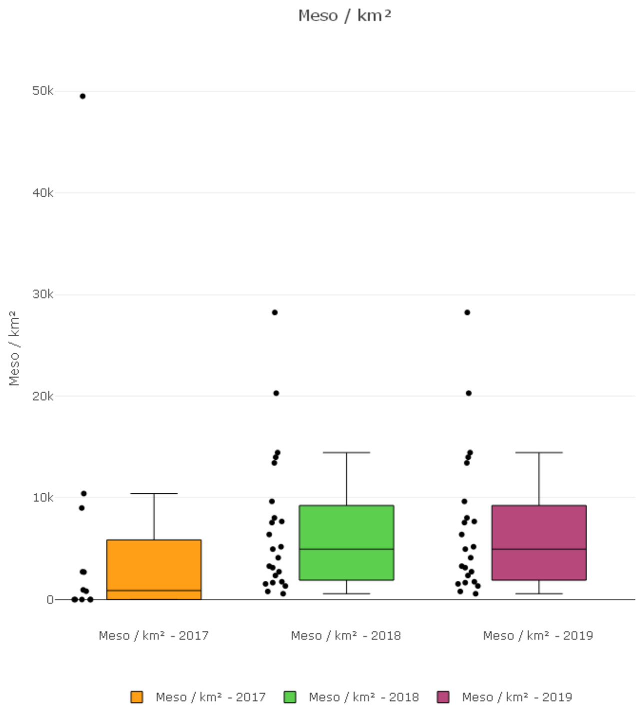

Figure 11. Floating meso-litter density (nº/km²) in the south of Madeira Island in 2017, 2018 and 2019, samples as dots and quartiles and standard deviations as coloured boxplots.

Monthly data in plastic concentration in Funchal (Figure 12) suggests that: i) floating meso-plastic concentrations variations are mostly coinciding, making the 500 µm net useful to produce an indicator of this plastic contamination, but it generally under-estimates density when compared to 200 µm net; ii) meso-plastic density appears to fluctuate with no major discernible pattern.

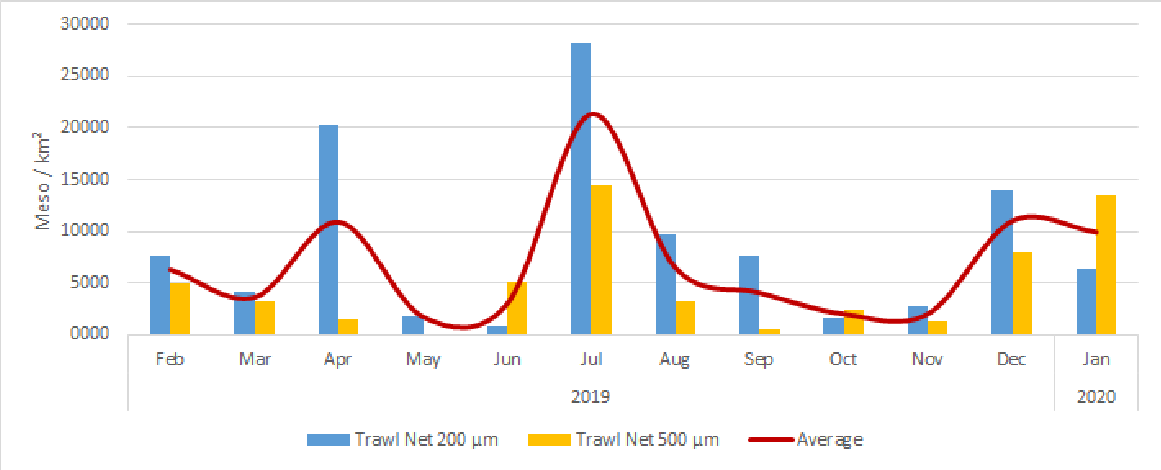

Figure 12. Variability of meso-plastics/km² identified in the 2019 sampling campaign. Blue bar represents number of items/km² sampled with trawl net 200 µm (mesh size), and yellow bar items/km² sampled with trawl net 500 µm (mesh size). The red line represents the average of both nets results.

2.3. Gaps on monitoring and research

These studies contribute to increasing the knowledge of spatial and temporal distribution of meso and microplastic and indicate that their variability is remarkable. Environmental and anthropogenic variables such as up/downwelling events, predominant winds, rainfalls and wastewater discharges may highly influence micro and mesoplastic densities in estuarine and coastal waters. Therefore, the data collected during these campaigns, although valuable, may not be representative of the general state of the whole area. Despite opportunistic samplings shed some light on the trends of small plastic items, the disparity in methodologies and sampling frequency among different studies compels to interpret available data with caution.

Continuous long-term monitoring with standardized approaches is required for better understanding spatial and temporal patterns. Additionally, in order to better understand sources and destiny of micro-, meso- and macro- plastic items, more information is needed on the type of plastic materials most common in several Atlantic regions.

2.4. Potential improvements and recommendations

The great seasonal variability observed for both micro and mesoplastics suggests that the implementation of consolidated monitoring programs is needed.

Taking into consideration that the most numerous items were fibres and paint sheets particular caution is needed to avoid contamination of water samples with researches ´clothing and vessel´s paint scraps, especially during onboard works with manta trawl.

The development and implementation of dedicated long-term programs that include sampling in a broader geographic scope and addressing seasonal variations and identification of polymers will be key to further understand floating plastic pollution in the region. Also, research efforts should be dedicated toward the development of remote sensing techniques leveraging hyper-spectral response of plastic-contaminated sea water, as it would allow broad geographic monitoring based on the specific response of sea-water when contaminated by different micro-plastic materials.

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3. MONITORING OF COASTAL LITTER

In the case of the coastal litter there are areas that, due to their geographical position, are exposed to different ocean-meteorological conditions that lead to a higher accumulation of marine litter than in other areas. The detection of these accumulation zones can be useful to raise awareness and change attitudes among stakeholders and to improve marine litter managing systems.

An exhaustive monitoring of the entire coastline implies a huge effort that is difficult to achieve for administrations. Therefore, improving monitoring protocols for locating these accumulation areas are deemed necessary.

In this line, INTECMAR explored the potential of citizen science using mussel-pegs as indicator, thus 49 students of a high school in Galicia (NW Spain) monitored 39 beaches in Arousa Island. Weekly the students collected the mussel-pegs and recorded data to obtain maps that showed how the marine litter was distributed along the coastline (**Figure 13**).

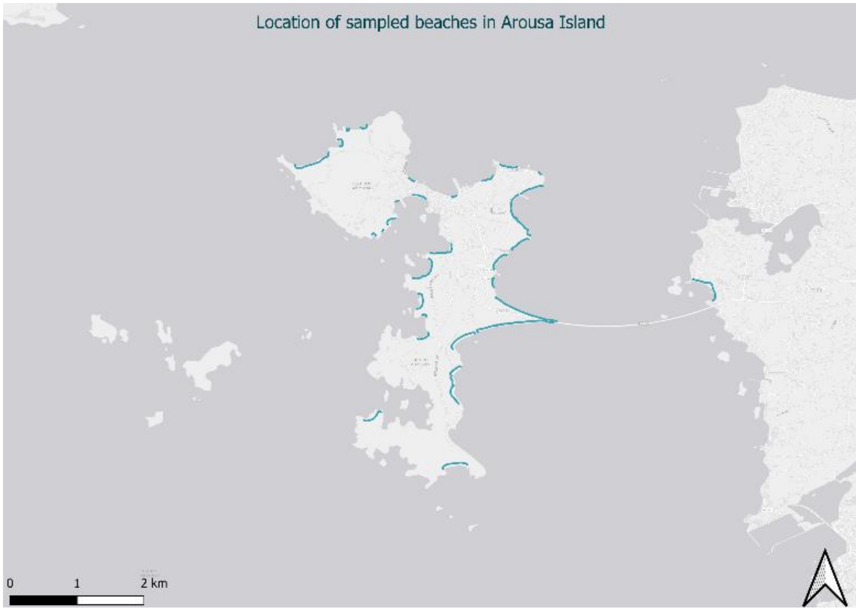


Figure 13. Location of sampled beaches in Arousa Island (Galicia, NW Spain).

The use of the mussel-pegs as tracers was also extended to the Ría de Arousa (i.e., the coastal embayment where the Arousa island is located). In this case, in addition, the SCAT manual (Field guide to documentation and description of oiled shorelines, authored by Owens, E.H. & G.A.Sergy in 1994 and 2009 respectively) was adapted to systematize accumulation area categorization in collaboration with 5 trained samplers (**Figure 14**).

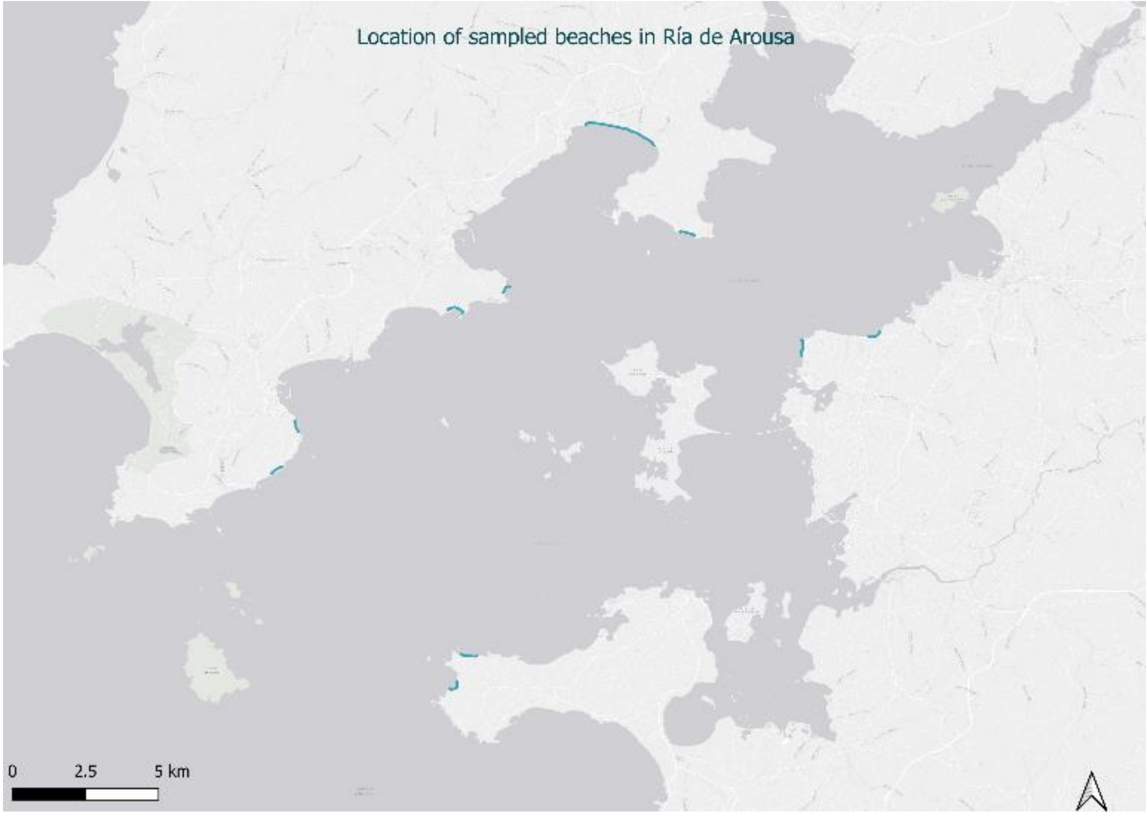


Figure 14. Location of sampled beaches in the Ría de Arousa (Galicia, NW Spain).

Moreover, a smart phone application to collect data on marine litter pilled-up areas along the coast was developed. The mobile application *Marine Litter LOC-app* aimed to facilitate and stardardise data collection of marine litter pilled-up areas along the coast. The app enabled the geolocalisation of the zones of accumulation, the recording of their characteristics, dimensions, pictures and comments, as well as the collection of specific information about the marine litter. *Marine Litter LOC- app* was created with the purpose of being used during predefined monitoring sessions where a coordinator (with the profile of Administrator) must previously choose the sectors that will be monitored and assign each sector to the corresponding operator that will collect data (with the profile of User).

3.1. **Key findings**

During the monitoring campaigns carried out in Arousa Island 9205 mussel-pegs were collected, this meant that about 141,245 kg of plastic were picked up from the coastline(estimated data from an approximate weight of 26 g for each whole mussel-peg).

The total number of mussel-pegs collected on each of the beaches shows great variability, from 1263 mussel-pegs collected in Carcamáns beach to 2 collected in Semuiño beach (**Figure 15**).

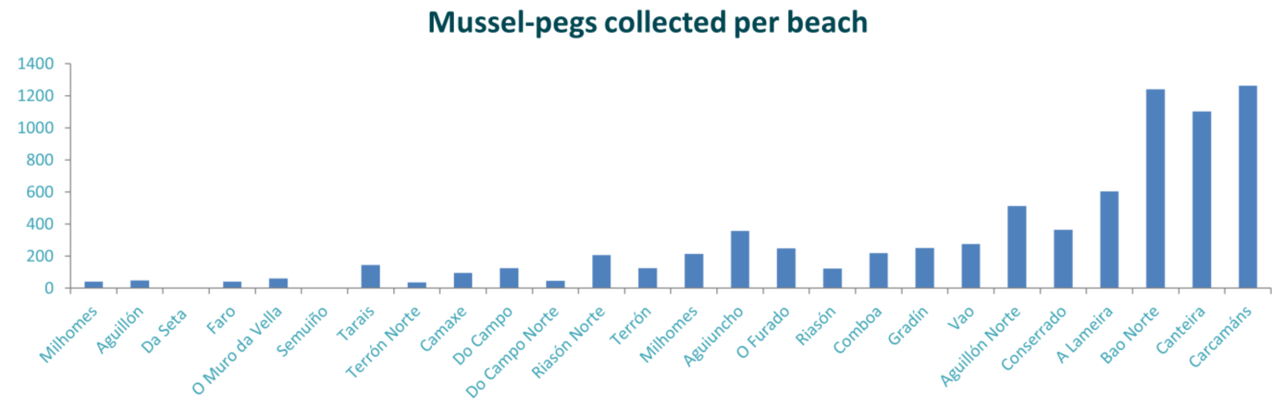


Figure 15. Distribution of mussel-peg collected in every monitored beach in the Arousa Island.

In the other case of study, the Ría de Arousa, 5428 mussel-peg were collected, using the same estimation that in the previous case, 91.182 kg of plastic were picked up. The total number of mussel-pegs collected on the beaches also shows a great variability (**Figure 16**).

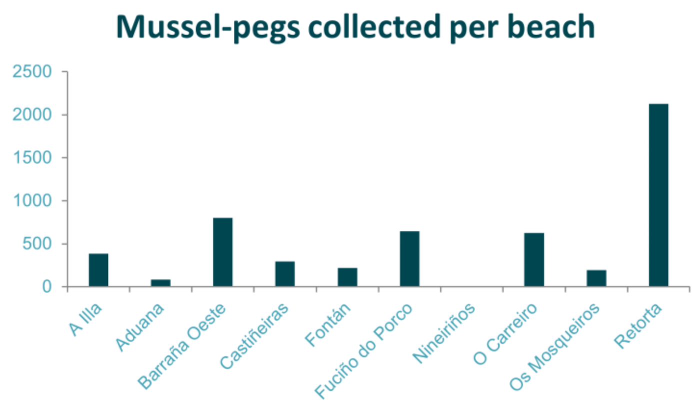


Figure 16. Distribution of mussel-peg collected in each monitored beach of Ría de Arousa.

To find out which beaches are receiving marine litter in a continuous way and not only occasionally, a threshold of the accumulation is mandatory. This threshold was defined through the 80th percentile, calculated for the distribution of the mussel-pegs per week. In this way, every week, those beaches that exceed the threshold are marked as accumulation zones. Analysing how many times each beach is marked, it is possible to decide if a beach is an accumulation zone or not.

This analysis shows that there are several areas where the accumulation rate is higher than in other areas. These areas can be taken into consideration when designing the cleaning strategy for Ría de Arousa (**Figure 17**).

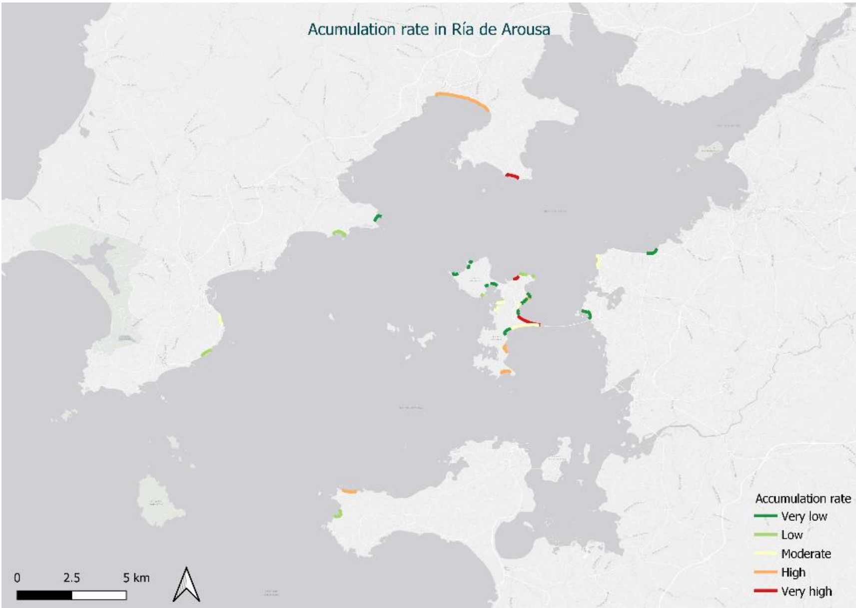


Figure 17. Map of accumulation rate in Arousa Island and in Ría de Arousa

3.2. Gaps on monitoring and research

The restrictions on movement presented by the students caused that some areas of interest within the Arousa Island were left unsampled. Some of these places could be areas with high accumulation rate of marine litter that remain undisclosed.

In the same way, the fact that each student chose the sampling day, within a weekly frequency, caused that between the sampling of one beach and another could be significant differences marked by the ocean-meteorological conditions that occurred between both samplings.

3.3. Potential improvements and recommendations

Ocean-meteorological conditions are key for locating potential marine litter accumulation areas so the establishment of consolidated campaigns that consider these conditions to define the day of the monitoring is highly recommended.

The mussel-pegs are a good indicator to reveal the spatial distribution of marine litter accumulation areas along the Ría de Arousa coastline, because the mussel aquaculture (source of mussel-pegs) is the most relevant economic activity in this area, but it is not certain if in another Rías in this region, with less presence of mussel-pegs, this indicator would work. Thus it is recommended to test this indicator in another rías.

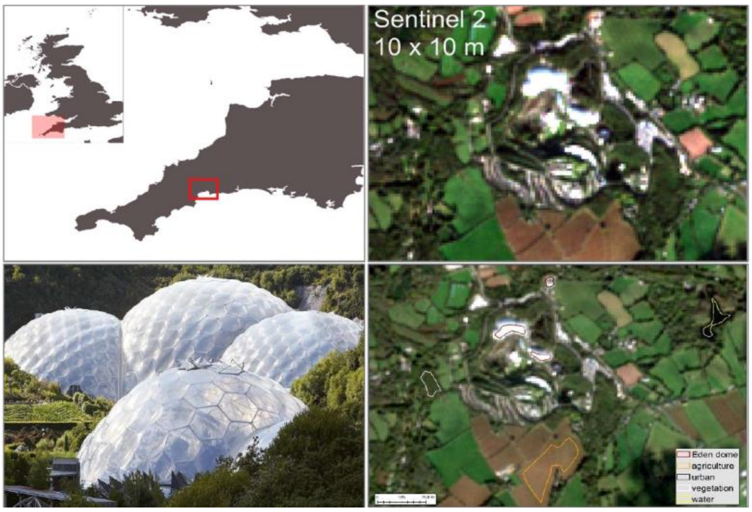
New tools for improving marine litter monitoring in the Atlantic Area

New technologies and applications have been tested for their potential use in marine litter monitoring. Remote sensing satellite data, UAVs (unnamed aerial vehicles) and underwater ROVs (remote operated vehicles) sometimes coupled with imagery-identification and deep learning machines have experienced a great development and are being used in almost all areas of knowledge. The adaptation of these tools for the study of oceanic debris was explored by CEFAS, ARDITI and INTECMAR. The results of these trials are summarised below.

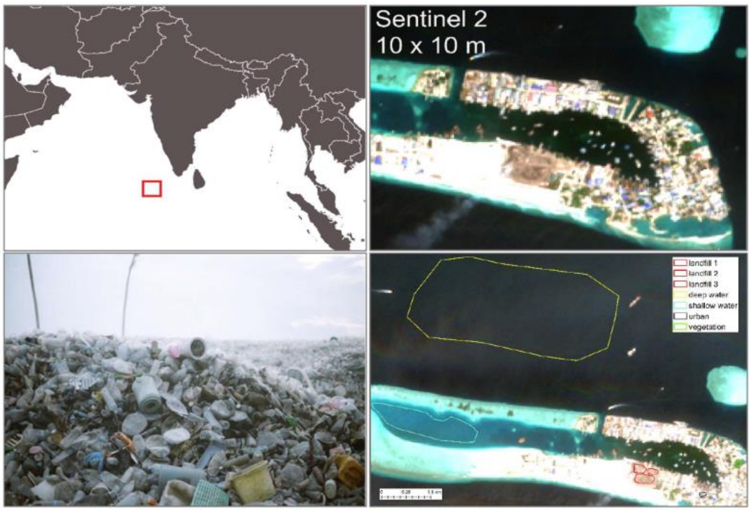
1. REMOTE SENSING TECHNIQUES FOR MARINE LITTER MONITORING: SATELLITES

This study led by CEFAS evaluated the feasibility of remote sensing to detect plastics on the sea. To identify the most suitable spectral signatures, known areas holding plastic structures or plastic items were firstly assessed. The selected case-studies were (**Figure 18**):

- The "Eden Project", which is a land-based assemblage of large domes made of tetrafluoroethylene copolymer (ETFE),
- Thilafushi, an artificial island in Maldives where litter covers most of its surface, and
- The Mytilene Plastic Litter Project, which is a set of 10x10 m floating squares made of determined plastic objects (fishing nets, blue bags and bottles) and was part of a research performed by the University of the Aegean in 2018.



a) Eden project



b) Thilafushi

c) Mytilene

Figure 18. Location and images of the case studies: a) Eden project b) Thilafushi and c) Mytilene (images extracted from the original report).

1.1. Key findings

Freely available Sentinel 2 data from Copernicus could be used for automatic identification of plastic litter hotspots. Specific patterns of spectral signature graphs were identified. Synthetic hydrocarbon objects peaked at 842 nm (B8) with a sharp drop in 945 nm (B9) and the lowest reflectance at 2190 nm (B12). However, this pattern was not shown when litter spots present a mixed composition.

It is possible to use the differences between B8 and B12 to map out areas where the plastics are present on both land and sea, as long as the majority of the pixel is composed of polymers. The higher the difference, the more likely the pixel can be considered to contain plastics. Applying this method on the sea surface classifies plastic bottles, nets and bags. However, there are also false positives (*i.e.*, pixels with high differences which are not plastics but ships or spit of land). These false positives can be ruled out using true colour images.

1.2. Gaps on monitoring and research

In terms of satellites, Sentinel 2 data can be used to detect plastic litter objects in an automatic way, but it fails when the composition of the pixels are not pure plastics. Although plastics account for almost 99.9% of floating debris, there can be other materials. Besides, biofouling can change the spectral reflectance of individual pixels. Consequently, more fieldwork and experiments using remote sensing data with ground-truthing is needed to test large areas with diverse litter and organic material.

The lack of regular monitoring programs and garbage mapping actions and the absence of historical data or updated data with significant spatial coverage, make the assessment of large areas difficult and condition the systematic identification of accumulation zones.

1.3. Potential improvements and recommendations

The recommendations derived from this study are:

- Test different study areas where plastic objects are static or conduct fieldwork and look at the spectral signature graphs of these objects.
- Improve image classification by trying higher spatial resolution.
- Explore other wavebands to successfully identify polymers.

2. DRONES FOR MARINE LITTER MONITORING AND IMAGE MACHINE LEARNING (FLOATING AND STRANDED DEBRIS)

2.1. Case studies

2.1.1. Stranded debris: coastal hotspots

Accumulation zones are not necessarily the places where there is a more significant influx of items and debris, as they may be the result of an accumulation over large periods of time (e.g., years or decades) in which no cleanup interventions have taken place. In contrast, areas where there is greater introduction of debris but cleaned very regularly are not areas of accumulation. Evaluating the distribution and density of marine debris in coastal areas and identifying litter accumulation zones is fundamental for the implementation of effective mitigation measures.

Case study in Portugal

A sampling plan was developed to use remote sensing from aerial images collected with drones or "Unmanned Aircraft Systems" (UAS), which allowed a quick assessment of key zones. The use of this sampling methodology allows the collection of spatially explicit information that enables the identification of zones with greater or lesser density of macro-waste. The collection of aerial images from 15-60 meters of altitude allows the identification of discarded objects and garbage during the inspection of the generated orthophotomosaics. The identified objects are used to estimate contamination levels of the study zone based on density (number of garbage objects per area).

The study areas for drone survey and monitoring protocol development were selected based on several factors, including the existence of restrictions on drone flight operations, the topography of the surrounding terrain, accessibility to the site, population density in surrounding areas and bathing use. The study areas were: two beaches in Lisboa, Portugal – Cova do Vapor beach and Caixas beach - and eight beaches in Porto Santo island, Arquipelago of Madeira Island, Portugal – Calheta beach, Ilhéu da Cal beach, Hotel Vila Baleira beach, Fontinha beach, Docas beach, Ponta da Galé, Porto dos Frades and Calhau da Serra de Fora beach.

The use of Object Based Imagery Analysis and Artificial Intelligence was too laborious and time consuming (due to long processing requirements) and not fully tested as the main purpose of UAS based remote sensing to detect beached marine litter was to assess overall contamination and map areas with high-density of litter items. As such, the collected images from UAS were used to generate georeferenced orthophoto mosaics with a resolution greater than 6 cm^2/pixel. Each mosaic of the selected areas was then visually inspected using Pix4D Cloud interface (**Figure 19**) to detect and tag conspicuous debris items in order to determine density and distribution of debris. This approach allows remote collaboration in detecting and tagging items and to use multiple surveyors for statistical purposes. With tagged georeferenced items can easily be exported as shapefiles and to generate heatmaps on any GIS software.

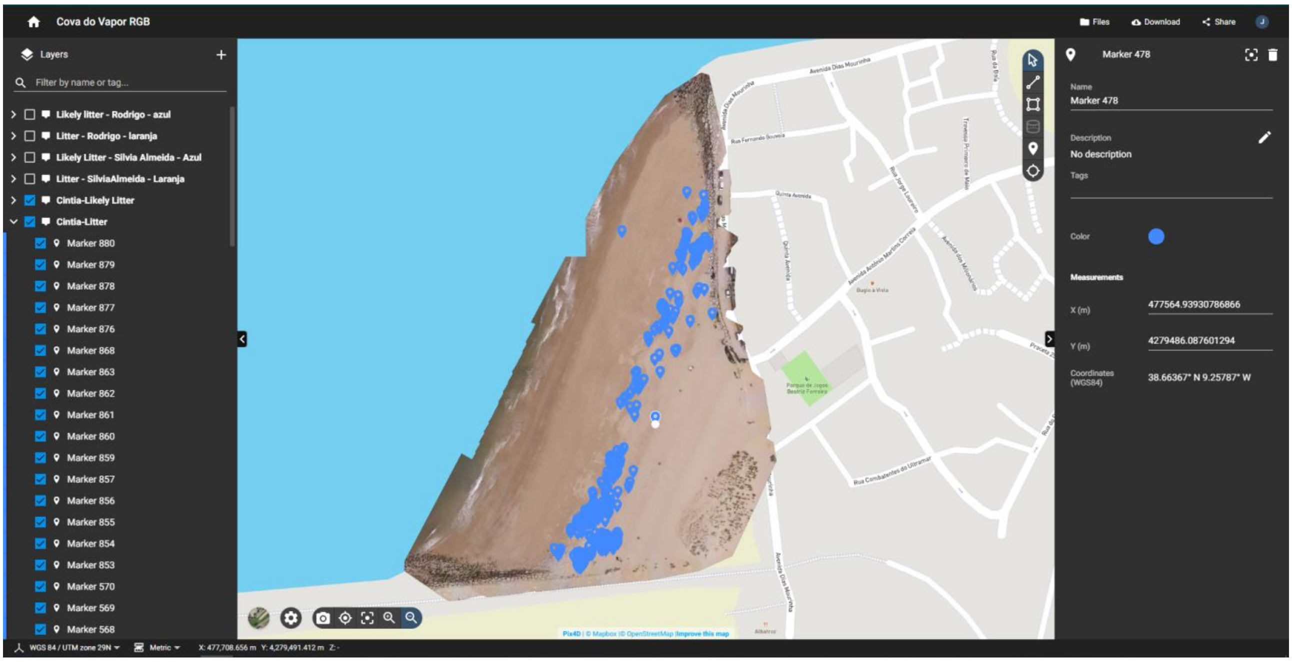


Figure 19. Example of one case of study, Cova do Vapor in Lisbon. Interface Pix4D Could.

<u>Case study in Spain</u>

A study was carried out on the effectiveness of drones for the location of areas of accumulation of marine litter (ML) on the coast related to specific ocean weather patterns. This study was developed on the Island of Sálvora located at the mouth of the Ría de Arousa. This uninhabited Island, which belongs to the Maritime-Terrestrial National Park of The Atlantic Islands of Galicia, has an area of 1.9 km^2 and divides the ria into an entrance to the south, the main and deepest, with a width of 4.6 km and a depth of 50 m, and another to the north, 5 m deep, and 3.7 km wide (**Figure 20**).

Figure 20. Location of the Sálvora Island in the Ría de Arousa (NW Spain)

The drone flights were carried out in the period between November 2018 and October 2020, planning their execution based on the meteorological predictions of Meteogalicia, (Regional meteorological service). As, in general, each ocean-meteorological situation can be associated with a specific ML distribution pattern, the flights were planned taking into account the 8 Galician typical weather situations.

The drone used was a DJI Mavic 2 Pro. A protocol that allows capturing images of the entire perimeter of Sálvora in a semi-automated way was established, generating fixed transects that are repeated in each flight session. For that, the perimeter of the island of Sálvora was divided into 13 transects, each transect being a polygon of 1000 m long by 100 m wide. The number of transects was chosen in collaboration with the CleanAtlantic model group, in order to use the results of this study to validate the model results. In this line, the dimension of the transect has been set to ensure the best reproduction of the coastline, since a lower resolution cannot ensure the correct definition along the coast.

The collection of aerial images from 37-49 meters of altitude allowed the identification of ML items of length greater than 10 cm. For the processing of the images, the *Precision Mapper* Software was used, generating the orthomosaics for each of the transects that served as the basis for automatically calculating the accumulation zones. For that, Photoshop has been used to turn to red 255-0-0 all the pixels with ML accumulations. The % of red pixels was used to estimate the accumulation level of each transect.

2.1.2. Floating debris

Fluxes of litter and contamination levels in the sea vary depending on the proximity to urban activities, coastal uses, and on wind and ocean currents. These factors may cause the accumulation of marine litter in oceanic convergence zones, but they often are in low densities making them hard to be detected from vessel-based observers, sampling devices or from remote sensing platforms.

The recent development of inexpensive commercial off-the-shelf (COTS) drones and other advanced Unmanned Aerial Systems (UAS) has made high-tech aerial imagery platforms easily and widely accessible. Automated flight ability at low altitudes enables UAS to produce aerial imagery with higher resolution than that achieved by current satellites or by manned aerial platforms. UAS based remote sensing has already demonstrated a variety of applications in the marine realm, including assessment of intertidal areas, shallow coral reefs and estuarine algal cover, bathymetry, habitat and biotope mapping and detection of beached litter. Operation flexibility and simplicity make Unmanned Aerial Systems promising platforms to develop remote sensing protocols and monitor floating litter using systematic approaches.

Here, we report a case study designed to use low-cost COTS quadcopter equipped with a high-resolution RGB camera and compare different processing workflows. The goal of this case study is to compare different imagery analysis approaches and develop guidelines for the implementation of floating litter monitoring protocols with UAS-based remote sensing.

Follow up experimental trials were conducted where floating litter objects were deployed from a boat while a UAS flying between 10-30 meters was used to collect multiple pictures of the sea surface area where the items had been deployed. The UAS was initially positioned over the vessel and image capture was setup to collect individual images at each 10 seconds. Items were launched to the water and the vessel was repositioned to be outside of the image frame (**Figure 21**).

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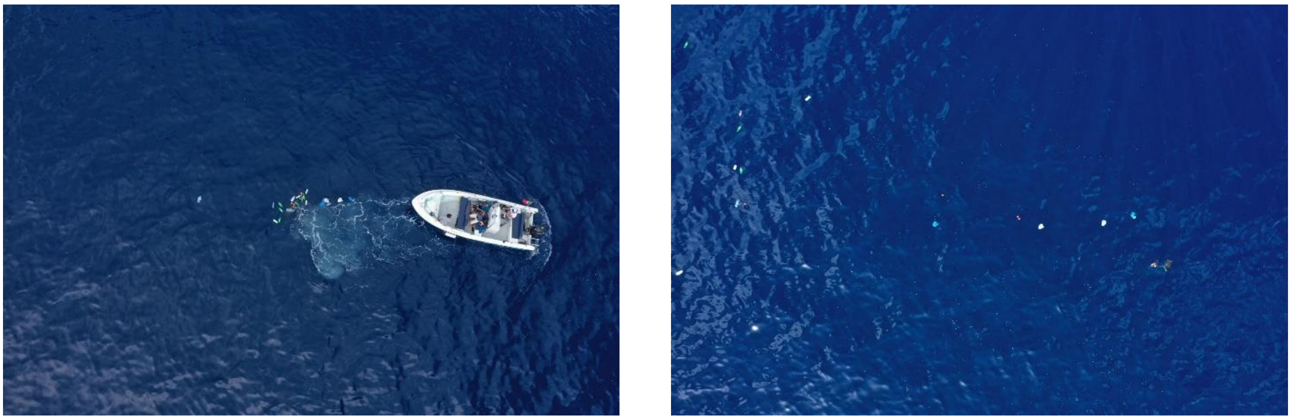

Figure 21. Example of an aerial image of the experimental trial where floating litter objects were deployed from the boat to collect aerial imagery.

Deployed objects naturally drifted at different speeds and directions, for which after some hovering time collecting imagery 5-10 mins, the UAS was recovered and all items collected. Deployment was repeated to collect additional data and compare processing of imagery with different exposure settings (i.e., normal exposure and low exposure; **Figure 22**) to collect aerial imagery for the development and streamlining the processing and analysis workflow.

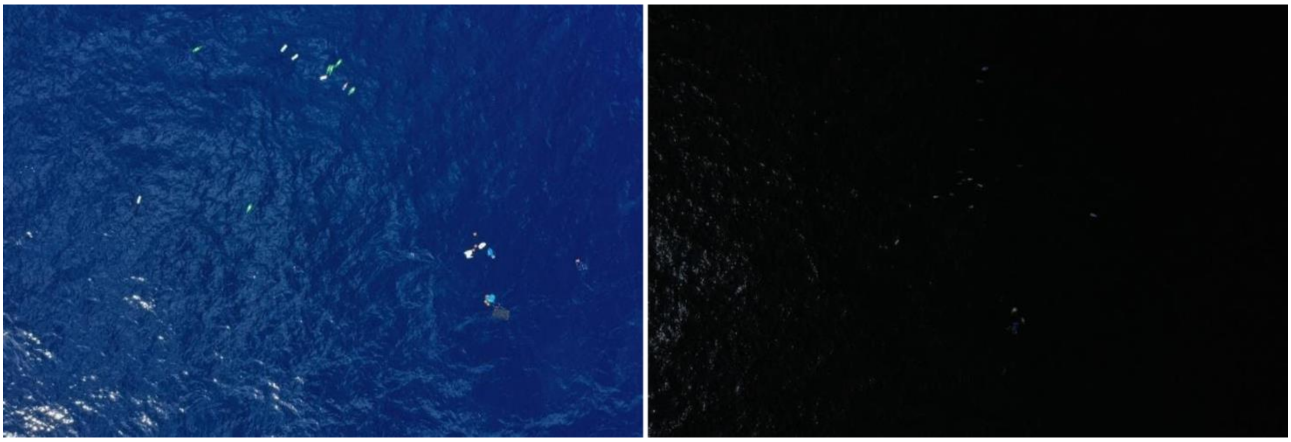

Figure 22. Example of two types of aerial images collected; left is normal exposure (Blue) and right is exposure for low EV (Dark).

The collection of low exposure imagery was included to enable a major reduction in light and colour variations of the background (i.e., sea surface) while maintaining the ability to detect floating objects. A total of 148 valid images (with objects and no vessel in frame) were collected to use on the analysis workflow development, 74 images with normal exposure (blue background) and 74 images under-exposed (dark background).

The experimental trials enabled collecting imagery with discrete floating litter items that could be used to assess and compare different strategies and analytical procedures for monitoring floating litter with UAS-based remote sensing. In this experimental trial, we selected three different strategies for analysing collected imagery and compare how they can be used in assessing contamination levels or detecting floating litter items:

I. a visual inspection with manual annotation;
II. a colour and pixel-based analysis, and;
III. the use machine learning (ML) for automated object identification and classification.

2.2. Key findings

2.2.1. Stranded debris: coastal hotspots

<u>Case study in Portugal</u>

Focussing on UAS platforms, the use of RGB cameras and other remote sensors are more flexible and can repeatedly survey target areas of interest, with 6 cm² resolutions being easily achieved in areas greater than 27000 m². The use of web-based services and visual inspection for tagging items of interest is a cost effective fashion of assessing contamination as it takes ≈ 30 mins to analyse each mosaic, enables collaborative approaches and allows the analysis to be paused and continued. The ability to export information on tagged items to GIS allows to generate heatmaps and assess contamination areas and density over time and within the surveyed area (**Figure 23**). As expected an inspection and analysis of the orthophotomaps where items of litter are identified reveal a higher occurrence of items and clusters of objects in the upper areas of the beaches and in the dunes. In addition to the natural accumulation in the upper part of the beaches due to the swell, this higher occurrence may also result from the fact that they are less frequented areas, in some cases, less accessible and probably subject to fewer cleaning actions, making them conducive to the accumulation and greater persistence of garbage.

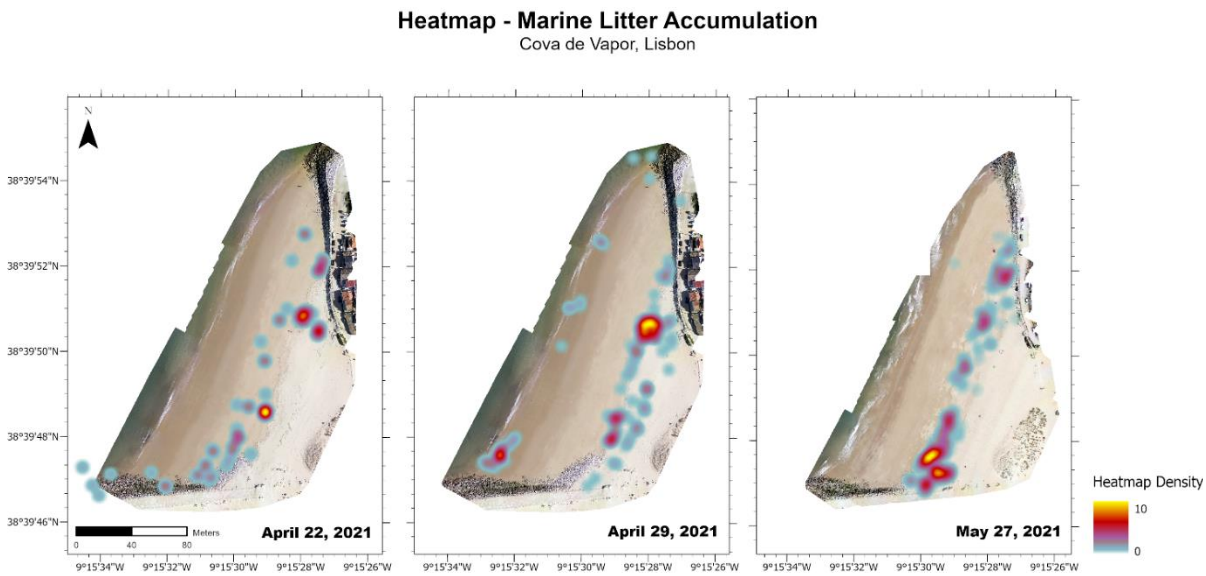

Figure 23. Marine debris accumulation represented by Heatmap for Cava de Vapor beach. The Heatmap is a representation of the relative density of points distribution.

The use of UAS-based remote sensing for litter contamination assessments and monitoring can also be integrated into spatial analysis and normalized for comparison with other sources of data and methodologies. In Porto Santo, the use of drones in remote areas and where no *in situ* monitoring was conducted was used to generate heatmaps. Data was then normalised for direct comparison with densities estimated from *in situ* sampling following OSPAR protocols and standards (**Figure 24**).

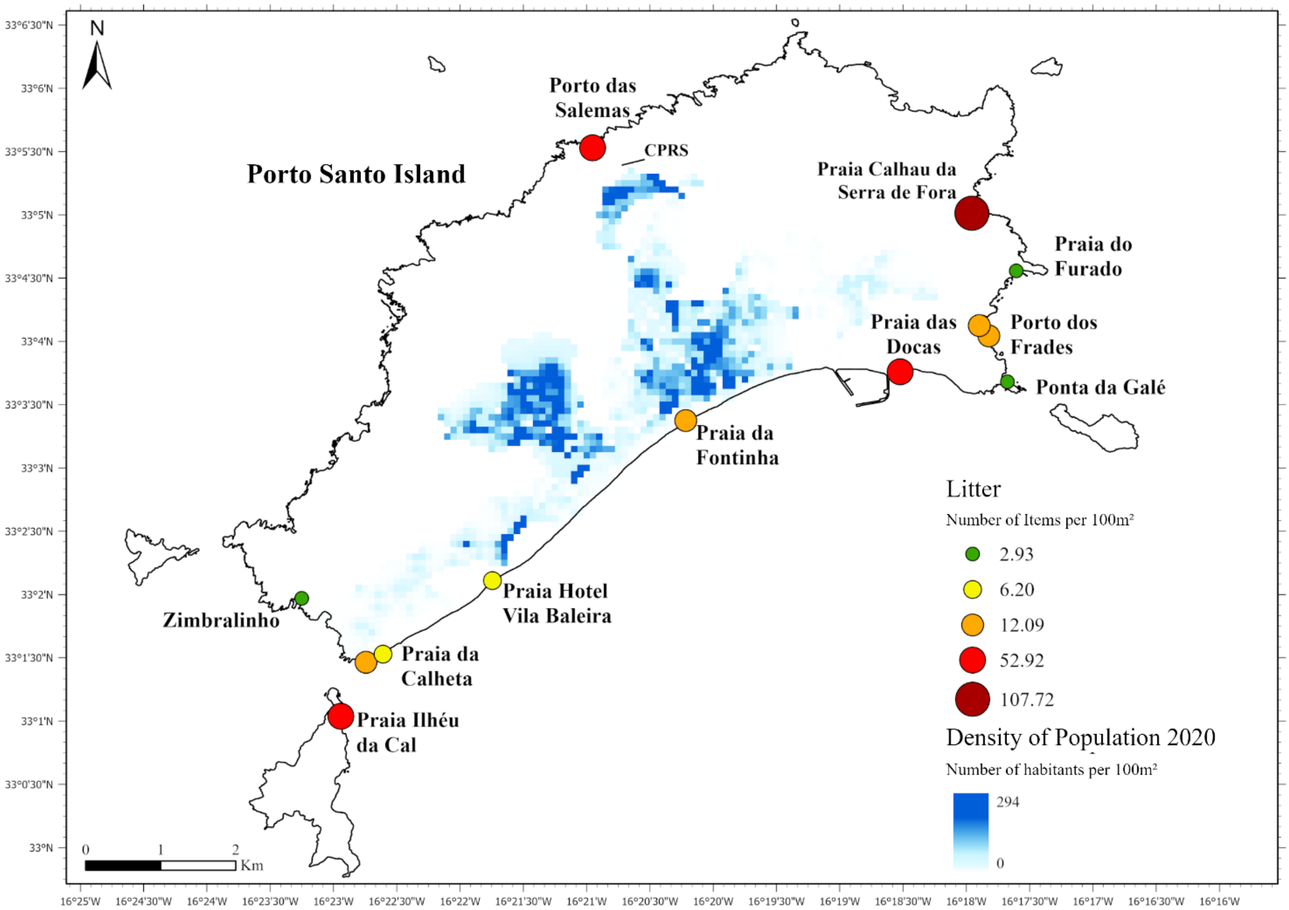

Figure 24. Estimated population density (WordPop, blue gradient) and ranking of sampling zones based on estimated garbage densities for each area (circles) and minimum values (green), Q1 (yellow), median (orange), Q3 (red) and maximum (dark red) as reference values. Red areas (with higher than average density) are considered as garbage accumulation zones.

<u>Case study in Spain</u>

The use of drones has made it possible to sample Sálvora Island, that is, 6500 meters of coastline, inaccessible in some cases to people, in a short period of time. High-resolution images (10 cm in object identification) have been used in this study and may be used in the future with other digital image processing techniques.

The generation of orthomosaics of each transect is rapid, it can be obtained in approximately 24 hours. The technique used to calculate the surface covered by the accumulations in each transect can be performed in about 40 hours for the entire perimeter of the island.

The ability to export information on % of pixels with accumulation of ML to GIS allows to generate hotspots maps and assess the accumulation rate over time in each transect (**Figure 25**).

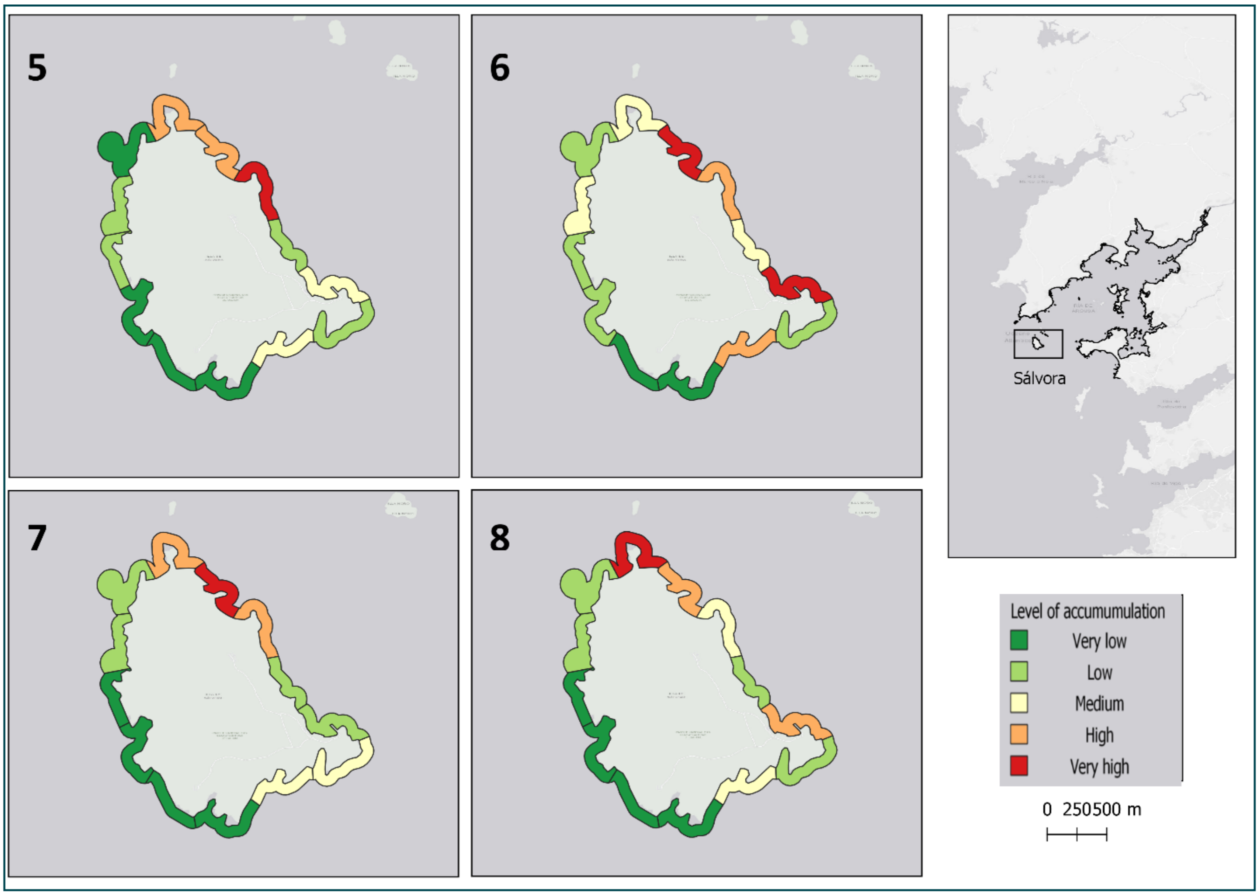

Figure 25. Level of accumulation of the Island of Sálvora in flights 5-8.

However, despite being fast, the protocol developed is prone to errors when the composition of the background is not pure (see more detail in sections "Gaps on monitoring and research" and "Potential improvements and recommendations").

2.2.2. Floating debris

For the purposes of this case study, three major aspects were considered in comparing methods:

I. average time required to inspect and process each image;
II. ability to adequately assess floating litter contamination, and;
III. skills and logistical requirements for implementing a monitoring program using each method.

The concept for this comparison rationale is to assess overall advantages and disadvantage of different analytical and classification approaches in order to design floating litter monitoring programs with UAS-based remote sensing that fit different conditions, training, and available resources.

Average time required for each image processing was considered an essential indicator for determining most adequate methods and analytical approaches, as some require a user to inspect and make annotation on each single image, whereas automated methods may process large number of images automatically.

When comparing the time required for a user to visually inspect an image and label floating items to the time required in automated processes, the human labelling performs within comparable ranges to those of colour-based selection of debris pixels and considerably better than those of automated floating object detection (**Figure 26**).

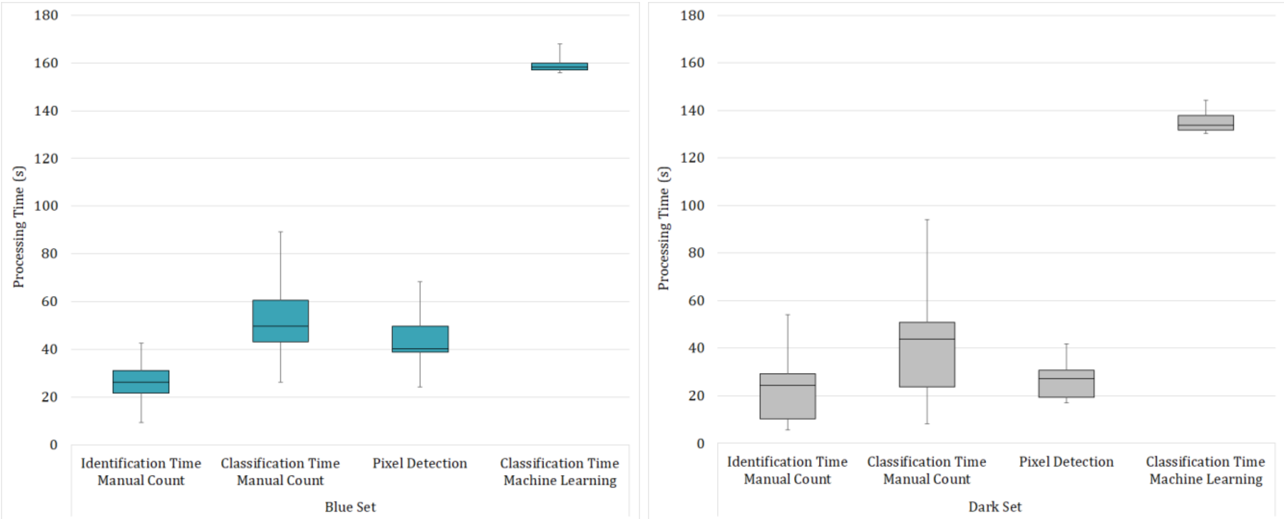

Figure 26. Timing comparison between identification and classification over the three methods tested.

Colour based pixel detection process is more consistent in terms of the time required (i.e., lower variance) and performs slightly better than human classification of objects, even though differences were not significant. Automated classification of floating objects in this study took significantly more time per image than any other analytical approach. Despite some differences in variance, processing times did not differ much when using the normally exposed Blue image set or the underexposed Dark image set, except for Machine Learning automated classification, which had lower processing times with underexposed images.

For the purposes of this case study, data from visual inspections and classification was considered as ground truth data for assessing how automated approaches performed. Linear regressions (**Figure 27**) were used to assess if both colour-based pixel detection and ML automated floating items detection were adequately assessing contamination. The use of linear regressions is a simplistic method to assess performance under the assumption that the number of floating items visually detected is proportional to the proportion of pixels detected using colour difference and proportional to the number of floating items detecting with ML.

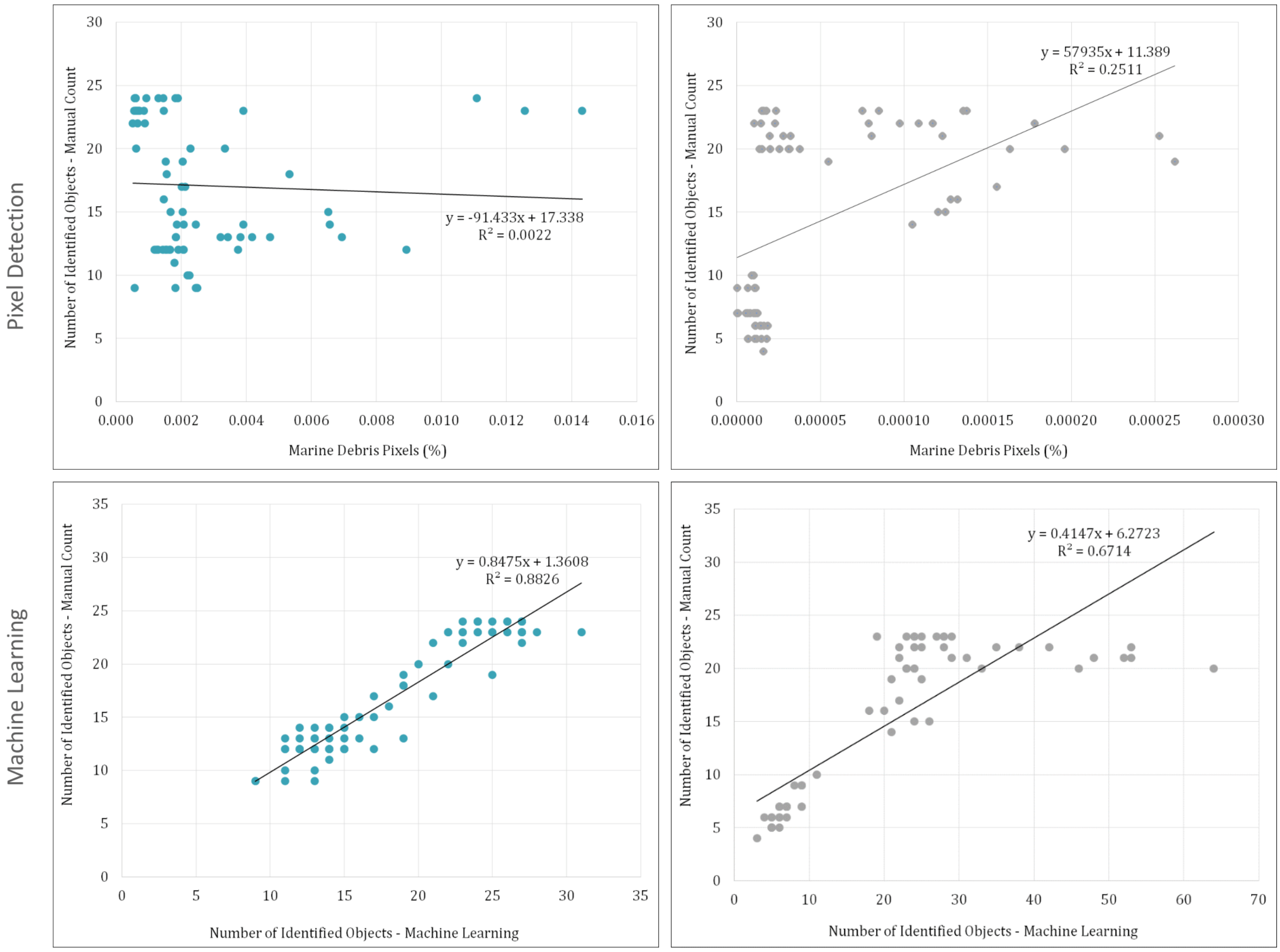

Figure 27. Linear analyses between Pixel Detection and Machine Learning. Time request to identified objects per method.

A comparison of both methods illustrates that:

i) ML object detection matches better with human visual detection, especially with normally exposed imagery;
ii) Colour difference selection of pixels from normally exposed imagery is inadequate for floating litter contamination assessments, and;
iii) Colour difference selection of pixels from underexposed imagery performs better than with underexposed imagery, but still lacks strong linear relation with number of floating items.

Despite this general advantage for automated image annotation processes, these generally have errors associated to the critical discrimination of objects, leading to the need of evaluating how good the approach is in assessing floating debris contamination or in classifying floating objects.

To carry out the process of deep learning classification of floating objects, it was created nine different categories: Cleaner Bottles – Containers; Drink Bottles – Green; Drink Bottles – Transparent; Drink Bottles – Large (>5L); Tetra Pak; Plastic Bags; Other Containers; Floating Fishing Gear and Other Floating Debris.

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In normally exposed imagery, green drinking bottles and tetra packs were greatly under estimated (not detected on the latter one), whereas transparent drinking bottles, other containers and other debris was over estimated (**Figure 28**). This over estimation of these categories is likely due to backscattering light being mistakenly identified as items from these classes. The under estimation of green bottles may be related to spectral similarity between blue background and the bottle's colour, for which the inclusion of additional multispectral data can contribute improve object recognition.

In underexposed imagery, tetra packs were also not recognised, making this category completely undetected by the deep learning classification approach. Floating items on the category Other Containers were significantly overestimated, likely due to the variability of shapes and spectral response of training set generating automated miss-detection of sun glint and backscatter as items from this category.

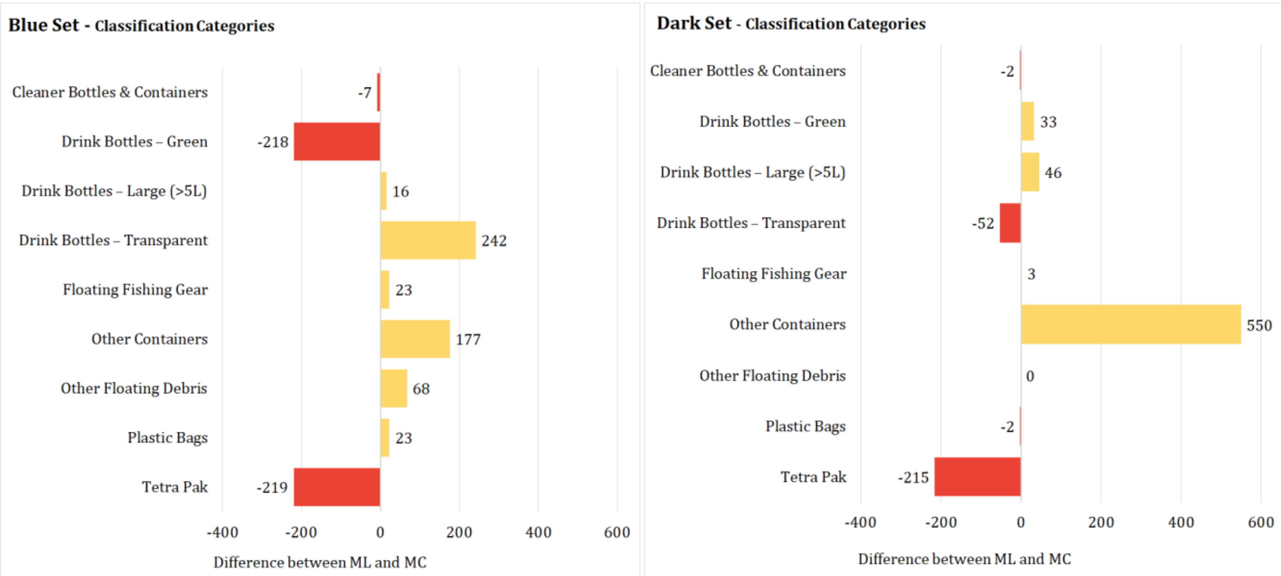

Figure 28. Differences per category on the number of classified objects between Manual Count (MC) and Machine Learning (ML). The negative values on red represent the number of missing classified objects on method Machine Learning. The positive values in yellow represent the number of over classified objects on method Machine Learning.

2.3. Gaps on monitoring and research

2.3.1. Stranded debris: coastal hotspots

Case study in Portugal

Considering UAS, the analysis of aerial images only allows the identification with exposed objects and with dimensions and characteristics visible in the images. The use of UAS for litter monitoring is recent (Bennett-

Martin et al., (2016)[4]; Deidun et al., (2018)[5]) and allows to identify the accumulation zones and assess the contamination levels with reduced sampling effort but without the ability to detect inconspicuous or smaller objects. Similarly, it is still not feasible to fully categorise litter items from aerial images and mosaics, making in situ samplings required to identify and classify litter composition.

Case study in Spain

The protocol developed for digital image processing can be used to detect objects in an automatic way but, despite being fast, it is error prone when the composition of the background is not pure. For example, artifacts such as shadows or darker areas on cliffs were marked as accumulation areas when in fact they are not. Consequently, a better training of the digital image processing is needed.

2.3.2. Floating debris

Initial monitoring efforts with UAV image collected in 2018 demonstrated that the low abundance of floating litter in Madeira was conditioning the ability to access and customise an imagery analysis workflow (i.e., with 10 transects of 1 km and over 700 images, only a very low number of images had floating debris and at very low abundance).

As the approaches differ on the output, simple descriptive statistics were applied to compare outputs whereas standard metrics were used to assess deep learning classification models. Finally, an evaluation of requisites such as computational infrastructures and skills for each analytical approach must be considered, as to determine feasibility of monitoring program that relies on imagery analysis.

Overall, the lack of strong collinearity with number of floating items renders the colour-difference detection of debris pixels from RGB imagery as a less reliable method for estimating contamination by floating debris. Despite this limitation in reliability, colour difference can be used to estimate debris contamination in underexposed imagery, if imagery is systematically collected with similar light, weather and sea conditions. One other option is to use Near-Infrared and Infrared sensors to detect floating objects and debris, as these spectra are quickly absorbed by water.

2.4. **Potential improvements and recommendations**

2.4.1. Stranded debris: coastal hotspots

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[4] Bennett-Martin, P., Visaggi, C. C., & Hawthorne, T. L. (2016). Mapping marine debris across coastal communities in Belize: Developing a baseline for understanding the distribution of litter on beaches using geographic information systems. *Environmental Monitoring and Assessment*, *188*(10), 81. https://doi.org/10.1007/s10661-016-5544-4

[5] Deidun, A., Gauci, A., Lagorio, S., & Galgani, F. (2018). Optimising beached litter monitoring protocols through aerial imagery. *Marine Pollution Bulletin*, *131*, 212–217. https://doi.org/10.1016/j.marpolbul.2018.04.033

Case study in Portugal

Considering remote sensing from UAS, the studies carried out in this project proved that their use in monitoring and sampling of litter on beaches allows not only to establish comparable levels of contamination but also to characterize in detail the typology of litter found. However, this type of monitoring is time-consuming, requires considerable effort, and relies on trained teams to do it if comparable baseline data is to be obtained. In contrast, the use of drones equipped with cameras and subsequent image analysis offers less detail in the information produced but requires less effort and present the easy systematization of the survey of larger areas. Thus, it is recommended the integration of this type of survey and beach monitoring, ensuring:

a) The performance of monitoring and sampling flights of reference beaches in a synchronized way to ensure calibration between methodologies, and

b) the regular performance of flights over larger areas and in different locations (for example, quarterly sampling of two reference beaches with in situ samplings and, at least, other areas of the coastline).

The implementation of this type of methodology allows the use of two reference indicators for marine debris contamination levels: density of items per 100 m^2 and georeferenced identification of debris accumulation and deposition areas.

Case study in Spain

The results derived from the study carried out in Spain indicates the need to explore other image processing techniques to successfully identify marine litter debris.

2.4.2. Floating debris

Overall, trial data suggests that UAS remote sensing can be effectively used for floating litter monitoring in two main fashions:

i) by visually inspecting each image and identify or classify images, or
ii) by using deep learning to detect floating items without classifying them.

The use of colour difference debris pixel detection requires additional test and development to reduce error, namely by integrating additional multispectral data and/or hyperspectral data and conducting spectral profiling of sampled litter items.

3. ROVS FOR SEABED LITTER MONITORING

Seabed litter has typically been assessed by trawling and opportunistic sampling. Gerigny et al., 2020[6], provide guidelines for the use of video analysis collected with ROVs to assess interactions between biota and litter. Here, we tested its application in assessing litter contamination of harbours and marinas in Madeira island. For that purpose, a custom built BlueROV 2.0 equipped with sonar and two independent video systems (onboard camera and PARALENZ Dive Camera+) were used to conduct video transects and assess seabed litter density inside these infrastructures.

Pilot and support team (3-4 persons) deployed the ROV from land and made annotations of objects and items detected on the live feed. Videos were later georeferenced and inspected for mapping, density estimations and comparison with data collected during dive operations.

3.1. Key findings

Within this case study in Madeira island, 12 video transects were conducted to assess litter items density and composition inside harbours and marinas (**Figure 29**). Overall, the guidelines of Gerigny et al. (2020) provide a core protocol to map and assess seabed contamination by conspicuous litter items. Interestingly, a comparison of density estimates from video inspections with those from live feed annotations were comparable in Funchal harbour and Quinta do Lorde marina, but more than 20% lower in Caniçal (**Figure 29**).

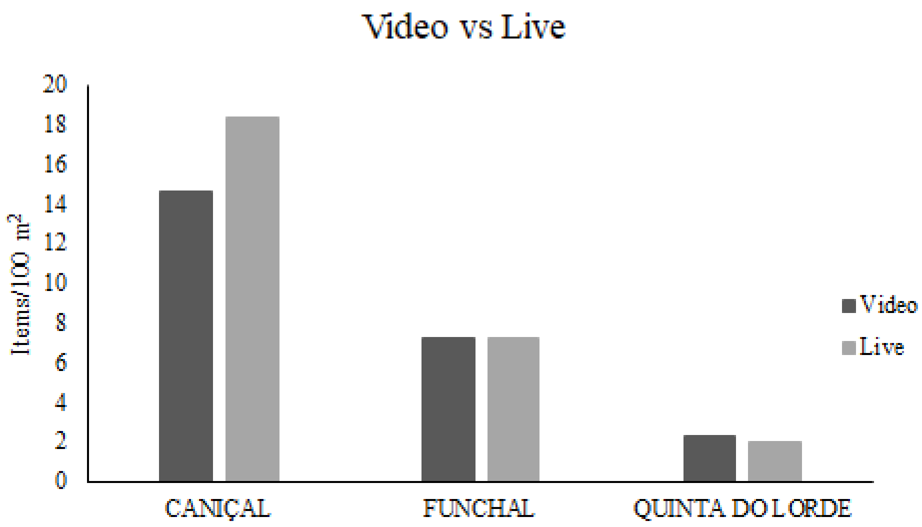

Figure 29. Comparison between live and video regarding the number of identified objects.

[6] GERIGNY, O., CLARO, F., LE MOIGNE, M. and GALGANI F. (2020). Strategy and constraints to support monitoring of Marine Litter Harm: Towards a protocol for the observation of marine organisms tangled/strangled/covered by marine litter during ROV operations. Deliverable 5.3. Report, CleanAtlantic, Altantic Area Interreg Project.

Such differences may result from the depth of field perception and fixed angle of the 4k external camera used to collect the video footage for inspection. On the other hand, live annotation can be extremely difficult under sunny conditions, where backscatter in screens hamper the ability for correctly detect and identify items. Similarly, harbours and other locations, where visibility is < 3-5 meters, are extremely difficult to assess using ROVs and video due to difficulties in piloting and in discriminating objects.

3.2. Gaps on monitoring and research

Overall, the use of small ROVs from land, piers or small vessels seems adequate for coastal waters, harbours and marinas where visibility is > 5 meters. However, there are multiple operational limitations ranging from tether/umbilical management and length, boat traffic restricting operations on the surface, wind, waves and currents to limitations in visual or image detection range.

3.3. Potential improvements and recommendations

Despite the great advances in marine technology over the last decades, further advances in wireless underwater communications, marine robotics and sonar imaging could greatly improve the ability for autonomous vehicles or wireless ROVs to operate and detect objects beyond “line of sight”. Wireless communications and autonomous vehicles could reduce issues related to marine traffic at the surface and tether management, making safer to operate on a broader set of conditions. Long range Autonomous Underwater Vehicles equipped for litter detection could also enable more cost-efficient and long-term monitoring of seabed litter contamination over broad geographic ranges. One other avenue for improvement is the development of imaging sonars and machine learning to detect seafloor items that are beyond the detectability of optical sensors.

Interreg Atlantic Area
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4. AUTOMATIC DETECTION OF MICROPLASTICS WITH FLUORESCENCE DETECTION

Micro and meso plastic items and fragments are amongst the most pervasive litter pollutants in the marine environment. Their small size and different densities make them present as floating litter, in the water column, on the seabed, and into food chains. Sampling and monitoring these litter items have relied on surface sampling with manta trawls or other nets and by collecting sediment samples from beaches or the seafloor. In any case, samples typically require inspection, triage and visually count and characterize plastic items, which is a laborious process that typically hampers timely reporting and monitoring.

In this case study, we explored the fluorescence properties of plastic fragments in water and sand samples using blue lighting and red filters, without recurring to dyes. The aim is to assess the feasibility to use image processing techniques and fluorescence to speed processing times in simplified micro and meso-plastic contamination assessments of sand, sediments, or water samples.

4.1. Key findings

Many of the meso and micro plastic items found in sand samples are translucid white and have a strong fluorescence response when exposed to a blue light and inspected through a red/orange filter using a Blue Light Transiluminator (**Figure 30**). This enables a fast contamination assessment by using imagery analysis software. Freeware software suites such as ImageJ have color-based selection and item counting tools that can be used to quickly process an image and assess plastic density and fragment sizes.

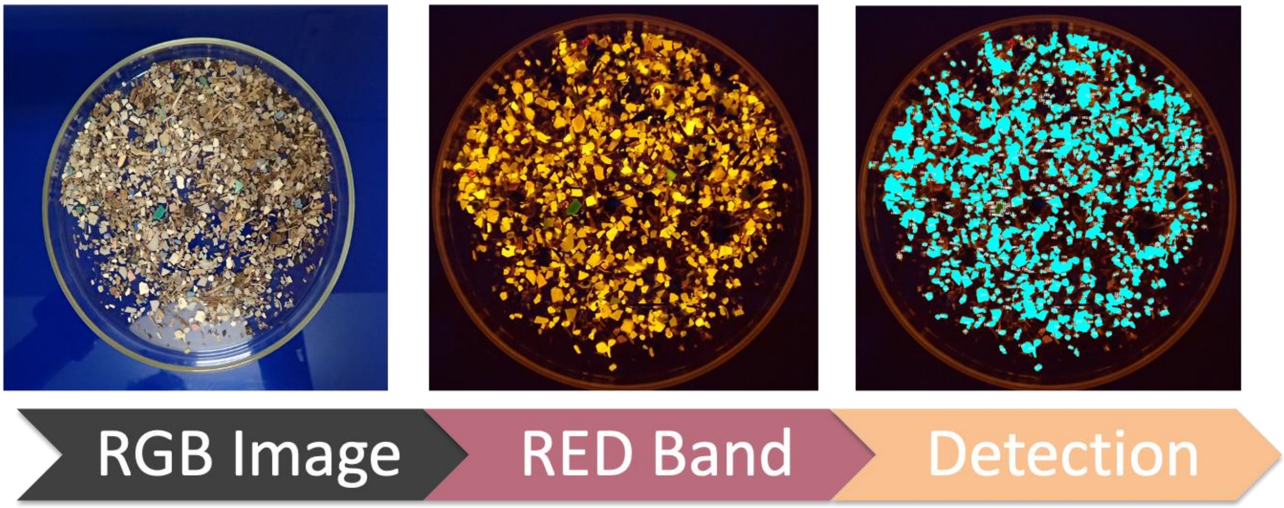

Figure 30. Imagery of sand sample (after density separation), RGB under ambient light (left), under blue light and red filter system (middle) and with area auto-selection of red-band high saturation using ImageJ (right).

Micro- and meso plastic contamination of sediment samples using this approach generally underestimates micro-plastics and appears to be more “accurate” in detecting fragments above 0,5 cm (meso-plastics), but still generates false-negatives and false-positives (**Figure 31**). Additional limitations arise when dealing with samples from sea water collected with manta trawl or other nets, namely the occurrence of translucid zooplanktonic creatures that have a similar response to the blue light transiluminators and the presence of non-translucid plastic fragments that are not detected using this approach (**Figure 32**).

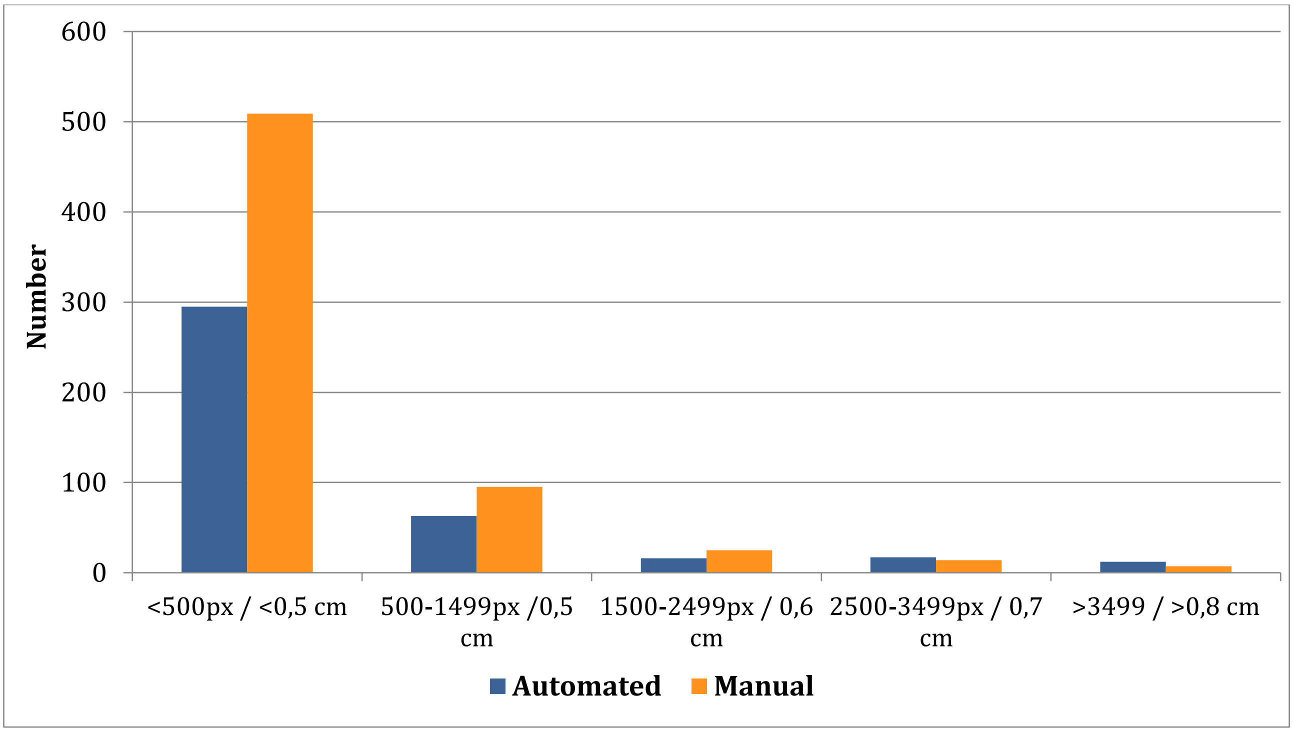

Figure 31: Automated fragment detection and manual count of different sized fragments.

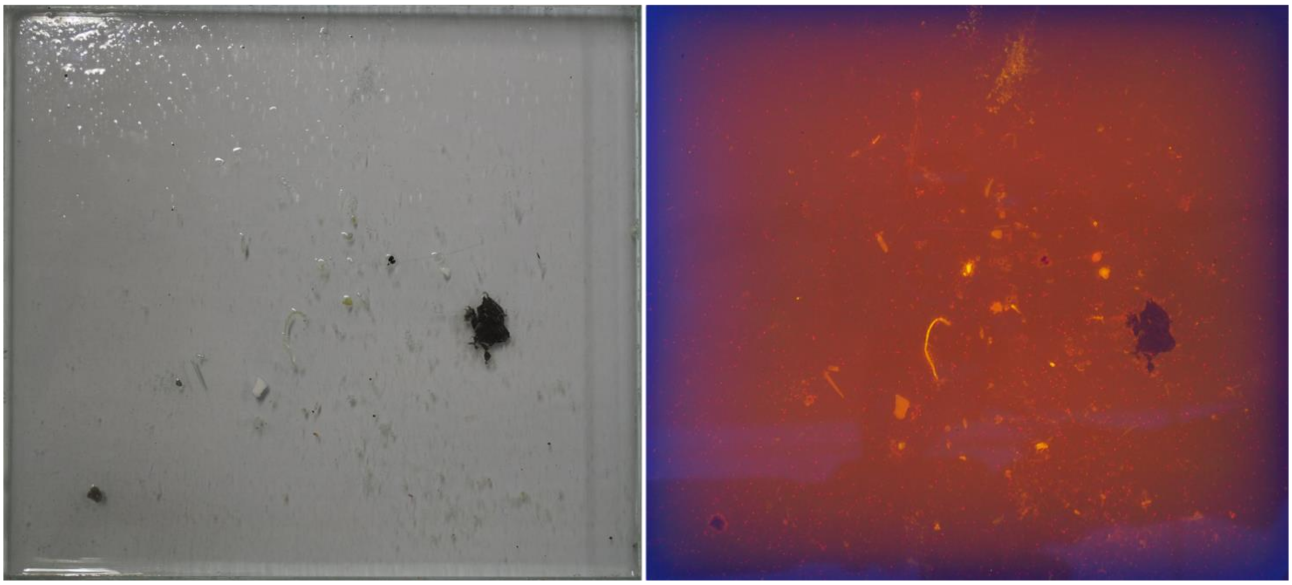

Figure 32: Example of a sample collected with manta trawl (300 µm) under normal light (left) and under Blue Light Transiluminator (right).

4.2. Gaps on monitoring and research

The use of automated detection and imagery analysis can greatly speed the processing times of samples collected to estimate micro and meso plastic contamination, however, there is still multiple issues in consistency and accuracy when using fluorescence with no dyes. Major concerns are related to misidentification of translucid zooplankton as plastic and the non-detection of translucid plastic items and fragments. In addition, samples with overlapping layers of sediment and/or fragments will hamper the accuracy of items detections and discrimination when using automated imagery analysis.

4.3. Potential improvements and recommendations

One obvious solution, already explored and routinely used when processing samples for microplastic assessments, is to dye samples in order to improve plastic item detection. However, this process implies the access to laboratories and additional time for processing samples. The use of an approach that leverages fluorescence and response of plastic items and fragments under blue light and using red/orange filters should be further explored as it could potentially be implemented in recreational sail boats and vessels for opportunistic sampling and quick processing to estimate contamination of surface waters or in beach monitoring programs dealing with large number of samples. The development of a custom-built set up that allows standardization of camera positioning or an imaging scanner with multiple lighting and filters will likely improve the standardization and reproducibility of this approach when assessing micro and meso plastic contaminations.

5. HF-RADAR

The High Frequency Radar or HF Radar technology allows remote real-time monitoring of currents and waves in an area between hundreds and thousands of square kilometres based on compact stations that are located on land. By placing two or more radar stations facing the same area of the sea, maps of surface currents for that area can be obtained. The current data obtained is representative of the upper layer of the sea to a depth of approximately two meters. In addition to measuring surface current maps, HF radar technology facilitates significant height, direction, and an estimator of the wave period.

INTECMAR and USC conducted a bibliographic review to define the state of art on the usability of HF Radar to monitoring the presence of ML in the marine environment. The main conclusion of the review is that HF Radar is not able to detect directly marine litter, but it can follow its drift through numerical models.

5.1. Key findings

The integration of current data obtained from HF radar has shown to be promising for tracking and forecasting floating marine litter. Radar HF provides maps of surface currents, which can be processed to be used as forcing fields for litter lagrangian or FTLE models.

5.2. Gaps on monitoring and research

HF Radars provide measurements to calculate the Lagrangian particle tracks and therefore, to extract the barriers and alleyways to Lagrangian transport in a fluid flow. Nevertheless, these data cannot be used directly, since there are spatial gaps in these fields (Paduan and Cook, 1997[7]). There exist some techniques to interpolate, extrapolate and filter these data to get a smoothed velocity field, for example, the Variational Analysis (Yaremchuk and Sentchev, 2011[8]). Nowadays, one of the most popular is the Open-Boundary Modal Analysis - OMA (Lekien et al., 2004[9], Kaplan and Lekien, 2007[10]). It provides a complete functional basis over a domain that can be used to project the flow on modes which depend only on the geometry. This allows a fast and robust nowcast field without gaps, projecting the data on the modes. Once this surface current field is obtained, it can be used as a forcement for a lagrangian model simulating the marine litter debris.

5.3. Potential improvements and recommendations

Field exercises using marine litter debris could help to explore the use of this technology.

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[10] Kaplan, D.M. and Lekien, F. 2007. Spatial interpolation and filtering of surface current data based on open-boundary modal analysis. Journal of Geophysical Research, Volume 112, Issue C12. https://doi.org/10.1029/2006JC003984

References: links to fully dedicated reports

Topic		Full report	Link
IMPROVING METHODS	Seabed litter	Assessment between trawl gears baka and GOV for the study of seabed litter. 2020. IEO.	http://www.cleanatlantic.eu/wp-content/uploads/2021/05/5.2.2_Assessment-Baka-and-Gov.pdf
		Assessment of seabed litter data recorded by scientific observers onboard fishing vessels. 2020. IEO.	http://www.cleanatlantic.eu/wp-content/uploads/2021/05/CleanAtlantic_datos_observadores_2018.pdf
	Floating litter	Optimized protocol and template for monitoring floating macrolitter by scientific observers onboard research vessels. 2021. IEO	http://www.cleanatlantic.eu/wp-content/uploads/2021/10/CleanAtlanticWP5-2-Template_APEX_observers_210907.pdf
		Monitoring floating microlitter in offshore waters by manta-trawl (collaboration with iFADO project). 2021. IEO	http://www.cleanatlantic.eu/wp-content/uploads/2021/10/CleanAtlantic_Microlitter_ifado_210907.pdf
		The seasonal cycle of micro and meso-plastics in surface waters in a coastal environment (Ría de Vigo, NW Spain). Carretero, O., Gago, J., Filgueiras, A.V., Viñas, L. 2021. Science of The Total Environment: 803.	https://doi.org/10.1016/j.scitotenv.2021.150021.
	Coastal litter	Analysis of strategies for the monitoring and evaluation of accumulations of marine litter on the coast. 2021. INTECMAR	http://www.cleanatlantic.eu/monitoring-and-data-management/
NEW TOOLS	Satellites	Monitoring the presence of marine litter in the marine environment: potential of remote sensing. 2019. CEFAS	http://www.cleanatlantic.eu/wp-content/uploads/2020/05/Cefas_5.2-Final_-Monitoring-the-presence-of-marine-litter.pdf
	Drones	Analysis of strategies for the monitoring and evaluation of accumulations of marine litter on the coast. 2021. INTECMAR	http://www.cleanatlantic.eu/monitoring-and-data-management/
		Monitoring floating litter from UAS-based remote sensing. 2021. ARDITI.	http://www.cleanatlantic.eu/monitoring-and-data-management/
	ROVs	Seabed litter assessments in marinas and harbours using ROV and video transects. 2021. ARDITI.	http://www.cleanatlantic.eu/monitoring-and-data-management/
	HF-Radar	Analysis of strategies for the monitoring and evaluation of accumulations of marine litter on the coast. 2021. INTECMAR	http://www.cleanatlantic.eu/monitoring-and-data-management/