CleanAtlantic

Tackling Marine Litter in the Atlantic Area

DELIVERABLE 7.2

Applicability of a modular basic ROV to detect marine litter in Galician shores: constraints and improvements

WP 7: Tackling Marine Litter

Interreg Atlantic Area
European Regional Development Fund
EUROPEAN UNION
Clean Atlantic

WP	7: TACKLING MARINE LITTER
ACTION	2: FISHING FOR LITTER
LAST UPDATED	
VERSION	
AUTHORS	CETMAR
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1. Background

Although marine litter is present in all the marine environments, it has been estimated that about 70% of marine debris sinks to the seabed with unknown consequences[1]. However, most of the marine litter studies are focused on floating or stranded litter while there is less information available about seafloor litter. This is mainly due to limited access to those areas, especially in deeper waters, and the high cost associated with sampling. The most common approach to evaluate seafloor litter is conducting underwater visual surveys with SCUBA diving in shallow waters or opportunistic bottom trawl surveys mainly aimed at assessing the fish stocks or the state of the benthic and demersal ecosystems. Notwithstanding, high resolution cameras installed on Remoted Operated Vehicles (ROVs), Autonomous Underwater Vehicles (AUVs), towed cameras or benthic sleds are increasingly applied for surveying bottom debris distribution and abundance. Their advantages include, among others, the possibility of being used on all sea bottom types including hard substrates, where trawls are not feasible, the capability to obtain accurate geo-referencing of each litter item and the absence of impact on marine ecosystems. They are specially recommended in sensitive areas or in those protected from fishery activities. Besides, these technologies allow observing and assessing directly the effects of litter in the marine environment and could be used together with trawling surveys to better understand the marine litter pollution on the seafloor.

ROVs have proven useful to detect marine litter and there is a wide range of models commercially available, with advanced designs providing accurate navigational data and high quality information but requiring considerable resources. More basic but modular designs with the potential for being expanded or upgraded, despite exhibiting poorer functionalities, may represent an affordable resource to investigate seafloor litter coupled to other sampling strategies.

In the framework of the CleanAtlantic project, Work Package 7 (WP7) "*prevention and reduction of marine litter*" includes different actions for the removal of marine litter and abandoned, lost or otherwise discarded fishing gear (ALDFG) through different approaches or schemes, some of them in close collaboration with the fishing sector. Framed in this work package, a pilot action was developed in the Ria de Vigo (NW coast of the Iberian Peninsula) to assess the performance of a modified trawling fishing gear to collect and quantify seafloor litter minimizing fish captures (see project report: *Pilot action to investigate the presence of seafloor litter in the Ria of Vigo by using a modified trawling fishing gear coupled with a video recording system)*. Also within WP7 a mini-ROV was acquired and upgrade to identify areas of marine litter accumulation, so-called hotspots, in areas previously studied through trawling surveys carried out in collaboration with Galician Coast Guard Service.

1.1. Objective

The main objective of this task was to assess the applicability of a basic modular ROV to detect marine litter in an area previously surveyed by trawling which presents a moderate concentration of debris. Its performance was tested from different types of boats in a wide range of depths, type of substrates and oceanographic conditions. Different sampling strategies were implemented according to the information that was intended to be obtained (location of marine litter hotspots or estimation of debris abundance along transects).

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[1] UNEP (2005). Marine litter: An analytical overview. Intergovernmental Oceanographic Commission of the United Nations Educational, Scientific and Cultural Organisation. (Nairobi: UNEP), 58.

In this report, we summarize the ROV's main technical aspects (performance, tune-up, and different improvements implemented) as well as the results of the field tests and the methodologies applied in the study area. Moreover, limitations and constraints found are highlighted together with recommendations for future upgrading.

2. Methodology

2.1. Study area

The selected area was the intermediate and external part of the Ria de Vigo (Galicia - NW Spain) (Figure 1), formerly investigated using a modified trawling fishing gear specifically developed to collect seafloor litter, avoiding the capture of marine organisms. This ria is an oceanic bay characterised by periodic upwelling events and a high primary productivity which sustains important fishing, shellfish gathering and aquaculture sectors. Approximately 500 small scale vessels and 400 on-foot shellfish gatherers carry out their professional activities in their waters and intertidal banks. Concerning the mussel culture, about 530 floating rafts are distributed in polygons (regulated production zones) along the ria. In addition, this area concentrates an important number of densely populated municipalities and industrial activities (shipyard, canning, freezing and seafood preserving, etc.), with a total population of about 480,000 inhabitants.

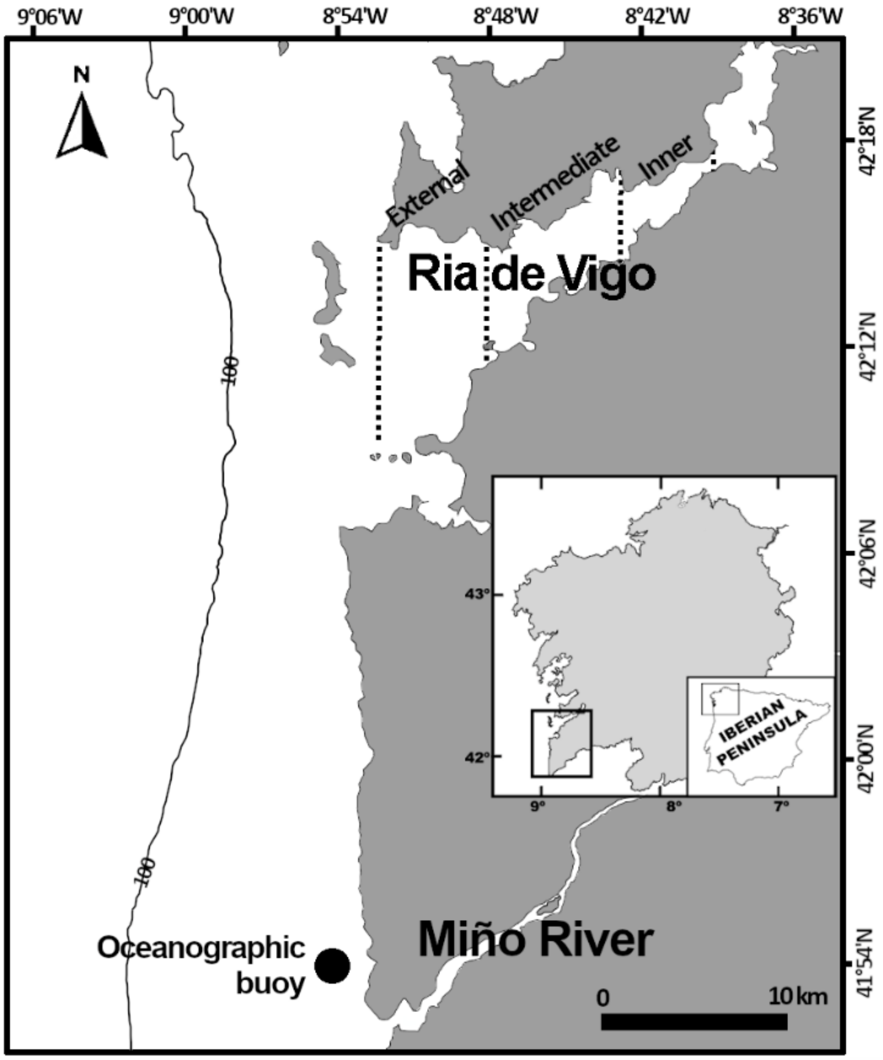

Figure 1. Study area.

The ROV performance was also tested in oceanic conditions outside the Ria de Vigo. On this occasion the survey was carried out in the waters that surround an oceanographic buoy, belonging to the RAIA cross-border Observatory[2]. The buoy is placed at the southwestern tip of Galicia (Figure 1), close to Portugal, an area also affected by the influence of the Miño River, which represents the natural border between both countries.

2.2. Equipment

After considering technical and budgetary aspects, it was decided to acquire the BlueROV2 Heavy Configuration Retrofit Kit[3] (Figure 2). This is a low cost model when compared with more advanced ones. Another key asset of the BlueROV2 is the open-source electronics and software which allows expanding and upgrading their components, configuration and performance (https://bluerobotics.com/).

Figure 2. Images of BlueROV2 taken from different angles.

The BlueROV2 specifications are summarized in ANNEX I.

All the ROV components were received in August 2019 and assembled in the Unit of Marine Technologies of CETMAR (Figure 3). During the project life time, and based on the outcomes of the field tests, different improvements were implemented in order to get a better performance and operational capacity and to reinforce communication systems. The main upgrades carried out are listed below:

- Change of the wiring systems, to make it removable and add new communication and power lines for the sensor module. Revision and adjustment of the wiring systems to ensure tightness.
- Wi-Fi communications installation, allowing the use of a GPS positioning buoy.
- Creation of a visual device to view underwater images without using a PC.
- Integration of two compartments for extra batteries.
- Installation of a gripper clamp.
- Installation of an extra camera.

[2] http://marnaraia.org/en/home-english/
[3] https://bluerobotics.com/store/rov/bluerov2-upgrade-kits/brov2-heavy-retrofit-r1-rp/

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Figure 3. ROV components and assemblage in CETMAR facilities.

3. ROV surveys

3.1. Indoor and from dock tests

Initial tests were carried out in a pool located at the Unit of Marine Technologies premises in CETMAR to check its buoyancy and basic performance (Figure 4).

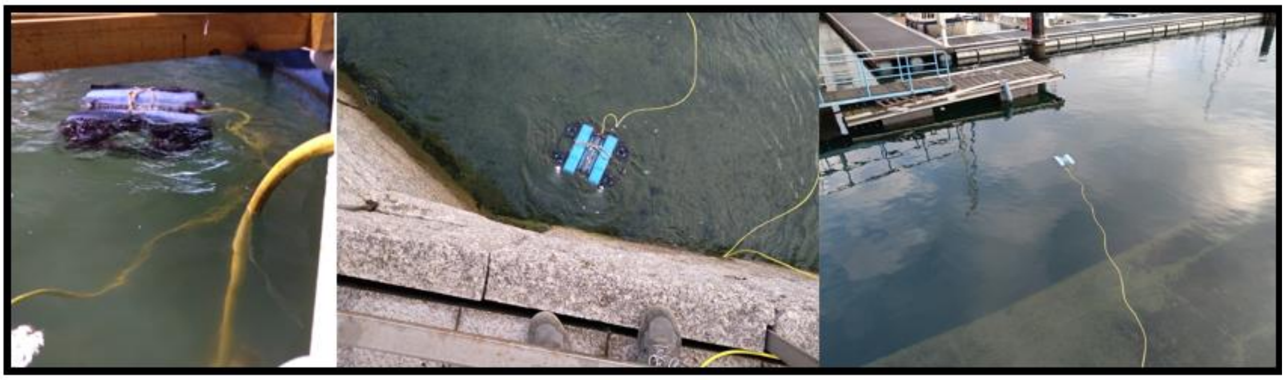

Figure 4. Indoor and from land test carried out in CETMAR facilities.

The following dives were made from the dock, in the shallow waters of a harbour basin located in the vicinity of CETMAR headquarters. They served to train the operator, to control the ROV performance under natural conditions and to find the most suitable joystick configurations. During these first immersions, positioning the ROV under the water was identified as the main issue and challenging task. Technologies like the Global Positioning systems (GPS) or radar, which use radio waves, are not effective in underwater scenarios. Contrariwise, ultrasound waves can be applied and are currently used in this kind of vehicles, but they are expensive systems that are not included in the basic model acquired. Since our ROV model does not incorporate any underwater acoustic positioning system, during the surveys it was not possible to know with precision the location of the vehicle with reference to the operator's one

3.2. Field tests

As previously mentioned, the field dives were conducted from different types of boats in the coastal area of the Ria de Vigo, except for one that took place near the Miño estuary. A template for data collection was designed to gather survey information. For each immersion the date and hour, as well as the coordinates, depth and predominant substrate were noted down. In addition, the most relevant oceanographic parameters (turbidity, bottom-current, wind in surface, etc.) were registered when available. Specific data about the boat characteristics and ROV operational parameters were also recorded to establish the best operational conditions according to the characteristics of the area surveyed and the means employed (ANNEX II). Two main approaches were adopted along the field surveys: i) ROV immersions from a fixed position aimed to confirm marine litter accumulation spots in those particular areas where, according to information from trawl surveys, it was more likely to found higher densities of debris, ii) ROV surveys based on strip transect of different lengths (video transect), intended to estimate the marine litter abundance in different zones in the middle part of the Ria de Vigo.

• **Surveys from fixed position in potential marine litter hotspots**.

Surveys at the intermediate part of the Ria de Vigo

In summer 2020, surveys were carried out during three days in different places located in the middle part of the Ria de Vigo, close to its north bank. Depths ranged between 8 and 16 meters and the predominant substrate was mud with a high algal coverage. Field tests were developed in collaboration with the Galician Coast Guard Service, using one of their surveillance boats (Punta da Guía). Its length and beam are 17 and 5 meters, respectively and the bridge is equipped with an echo sounding, a Global Positioning System (GPS) and a Side Scan Sonar which allows getting an accurate positioning of the boat and depth information. It also has a Platform in its stern, close to the upper layer of the water, which facilitates the ROV operation, and a jet propulsion system that avoids any kind of entanglement of the ROV tether with structures like propellers.

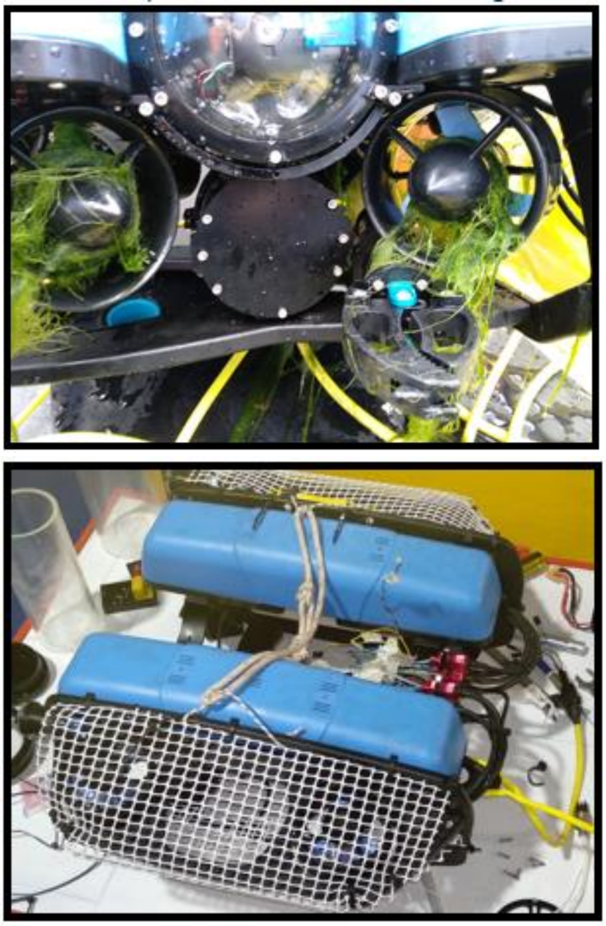

Figure 5. Example of algae entanglement in the ROV thrusters and plastic protection mesh.

Significant turbidity was observed in all dives limiting visibility to approximately 1-1.5 meters ahead of the ROV. Besides, the presence of green and brown macroalgae in the surveyed area demanded extremely well controlled ROV displacements and operating more than one meter above the bottom in order to avoid as much as feasible thrusters' entanglements (Figure 5). These two issues significantly reduced the capability to detect items on the seabed, mainly small size debris or half-buried ones. Algae entanglements caused ROV malfunction, inability to operate it and in some cases required the thruster's subsequent disassembly and cleaning. To sort out this issue, thrusters were covered with a plastic mesh in an attempt to reduce the probability of entanglement.

The coastal area studied supports diverse pressures and uses that are directly related to the marine litter abundance. As described in the report of the pilot action carried out in the same ria, using a modified trawling fishing gear, a relatively high density of items was recorded in the zone where the ROV surveys took place (755.6±76.3 items/km^2). However, due to the issues previously mentioned, it was difficult to identify items on the seabed and as a consequence it was not possible to confirm previous results on seafloor litter by operating the ROV.

During these first dives from boat (Figure 6), it was noticed that controlling the vehicle movement is not an easy task and that joystick controller calibration has to be tested in order to get the best intuitive configuration. In addition, as the ROV lacks acoustic positioning, the operator had to rely on the compass indications which was not always stable, making a frequent recalibration necessary. It is known that this navigation system can be affected by large metal objects or electronic equipment, but in our case the source of this instability could not be assigned to those issues and persisted throughout the subsequent field tests.

Figure 6. Ria de Vigo surveyed areas in summer 2020.

Survey at the external area of the Ria de Vigo. Another test took place in the external area of the Ria de Vigo in collaboration with the Galician Coast Guard Service. The training ship used was "*Valentin Paz Andrade*", which main characteristics are 29 m of length, 6.85 m beam of width, a mean draft of 2.40 m and propulsion by propellers. The chosen area was a shipwreck spot, in a rocky seabed located in the south mouth of the ria at a depth of 16 m. According to the information provided by the ship crew different marine debris, like derelict fishing gears, are sometimes retained in this coastal area.

As in the previous cases, these are coastal waters with a large concentration of suspended particles that reduce visibility to approximately 1 m ahead of the ROV. This field test revealed again the same handling issues aforementioned. In addition it was noticed that in most exposed areas, affected by heavy surge or groundswell, ROV operator can suffer seasickness caused by the mismatch between the motion of the mother ship and the image seen through underwater camera. This may limit its use to sheltered sites or to exposed areas only under good oceanographic conditions. Despite the expectations to detect seafloor litter in the assessed area, this was not confirmed since the visibility was significantly reduced by turbidity and the spatial manoeuvrability was limited by the proximity of the ship wreckage.

The fact that both of the Galician Coast Guard boats had a cabin equipped with additional technology was considered a positive factor, since it provides useful and accurate information (positioning, depth, etc.) and allows working under bad weather conditions, like rain, that could negatively affect electronic devices (computers, monitors, etc.). On the contrary, the boat size difficult the ROV operation when its location has to be corrected regarding the position of the vessel at rest, being more operational and faster in these cases to use smaller vessels.

Survey outside de ría: An additional immersion took place outside the ria, in order to check the ROV performance under oceanic conditions. The selected location was an area close to an oceanographic buoy placed in the vicinity of the River Miño Estuary. Sediment composition is predominantly sandy with an approximate depth of 25 meters. Despite the fact that the dive took place in a deeper area, the low water turbidity made the visibility better than in the previous dives. Seabed close to the anchor point of the buoy was firstly surveyed from a small scale fishing boat (approximately 6 m length) that lack positioning technologies.

Buoy metallic structure was subsequently used as a platform to operate the ROV. In both cases, due the high visibility and the good weather conditions, it was possible to record images with higher quality than in previous surveys and some small pieces of derelict fishing gears were identified. Unfortunately, at the end of this field test, a humidity issue was detected for first time and, although it was not necessary to suspend the survey, it affected the recording quality, fogging up the structure that protect the camera lens. Once in the laboratory, the o-ring that ensure optimum air-tightness of this compartment was checked and lubricated to guarantee a proper functioning.

Figure 7. Galician Coast Guard vessels, small scale fishing vessel and oceanographic buoy used as platforms to operate the ROV.

Although these tests confirmed that small boats enable much easier vehicle handling, the functioning can be more affected by meteorological conditions, like rain or glare caused by sunlight on the computer monitor.

A constraint noticed during this first field test series was the low autonomy of the batteries, which reduced the immersion time to periods of less than 30 minutes. This limitation was fixed by the inclusion of extra compartments in the ROV to install two additional batteries, which were connected between them, thus considerably extending the dive duration.

In the last months of 2020 and early 2021, as already detailed in the equipment section, different improvements were implemented in the ROV in order to sort out some of the issues identified, getting a better ROV performance and handling. Due the predominant bad weather, new tests were postponed until February 2021, when a first immersion was carried out in the Port of Vigo from a small vessel without cabin, which allowed us to survey different locations of the docks at a depth that ranged from 3 to 16 meters. The low visibility, around 0.5 m ahead, did not allow us to obtain a high-quality filming, although items like tyres that are normally used like boat fenders were detected (Figure 8).

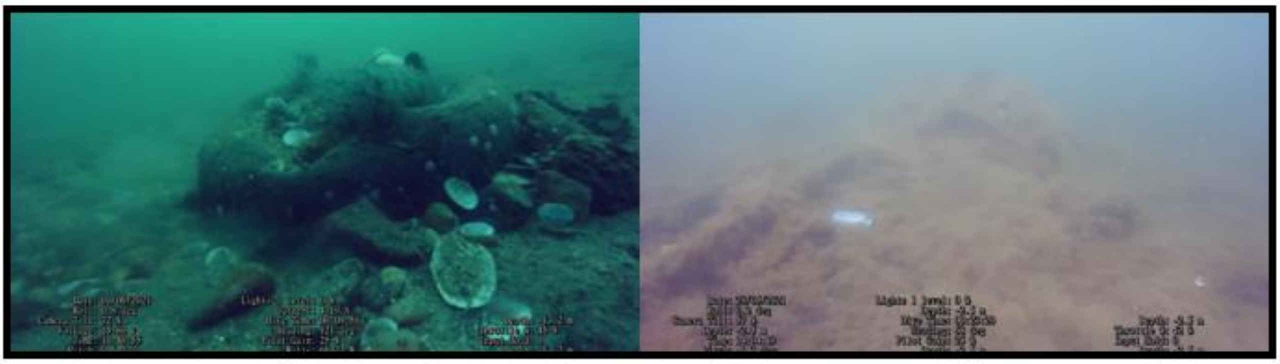

Figure 8. Images recorded in the first test carried out inside the Ria de Vigo and Port of Vigo harbour.

• **ROV surveys based on strip transect**. The ROV is a vehicle that allows multiple modes of operation: on the sea surface or at different depths, towed or thrusted by its propellers to allow yaw, sway and surge movement. In this second round of surveys, carried out in summer 2021, the vehicle was operated in a live-boat mode, implying that the ROV and the support vessel are moving simultaneously. Two different approaches were tested; i) towing the ROV behind a boat along a straight transect and navigating at low speed and ii) thrusted ahead the boat, also describing transects.

Taking into account the previous trials, it was decided to use a small-scale boat (approximately 6 m long), allowing us to minimize some of the handling issues identified during the first immersions and easily correct drifts in the position. In addition, a visual device, connected by a HDMI cable to a computer, was implemented, allowing the view of images without using a PC and reducing the screen glare caused by the sunlight (Figure 9). Moreover, a Go-Pro© camera was also installed in the ROV structure, enabling to obtain videos from different angles, thus providing additional information.

Figure 9. ROV operator using the visual device and the boat employed during this second round of dives.

Three different areas located in the middle part of the Ria de Vigo were chosen to carry out the dives (Figure 10). They are characterised by different depths, types of substrates, visibility and anthropogenic uses.

Surveys in Rande Straight

First surveys took place in the vicinity of the Rande Straight, which is the eastern limit of the inner part of the Ria de Vigo (figure 1). Transects were carried out at a depth that ranged between 15 and 25 metres, with mud being the predominant substrate. Since the ROV is not equipped with a calibrated laser system needed to estimate the transect width, only qualitative information of marine litter could be gathered. As visibility in this area was low, less than 0.5 m, the total surface covered in each transect was quite reduced. This may have influenced the low amount of marine litter items detected, despite the fact that the linear distance of each of the ROV surveys on the seafloor was longer than 500 m. The seabed surveyed is dominated by high macrofaunal abundance, with organisms like sea pens (*Veretillum cynomorium*) and Mollusca bivalves (scallops, queen scallops, clams). In all the transects, large marine litter items were not found and only small pieces of plastics among the species previously mentioned were recorded. These results are in agreement with those registered in the trawling surveys carried out in this area with the "*Valentin Paz Andrade*" vessel, in which plastic bag fragments or bottles were among the five most abundant typologies of marine litter. The net installed to protect the ROV from algal entanglement did not prevent the entanglement of other benthonic species, like sea pens or sea stars, in the thrusters, when the ROV was moved displaced near the sea floor, making it impossible to continue the dive.

In spite of these drawbacks, it became clear in this second round of dives that the ROV's operator handling had significantly improved, as a result of the acquired experience and the upgrades implemented.

Regarding the survey modality (ROV operations in transects in a live-boat mode), transects can provide us a valuable picture with information on abundance, typology and distribution of marine litter on larger areas. Since our ROV did not include navigational data, like USLB (ultra-short baseline positioning system), transects tracks were obtained from the boat position. In order to increase the track precision, ROV displacement was followed by means a surface buoy tied to the tether, on which a GPS system was placed. This system provided better information on the ROV position but requires further tests to determine how the tether tension could affect the ROV operation.

Survey of maerl seabeds

Other areas inside the ria, with very different conditions, were also assessed using the live-boat mode. A test was focused on shallow (5 – 15 m deep) coralline red algae (maerl) seabeds, where living coloured maerl beds are on top of a thick deposit of dead maerl, forming ripples. In contrast to previous dive areas, these seabed zones normally present a visibility of several metres and lack benthic fauna and flora that could damage or misfunction the ROV by entanglement. Vehicle control was easier than in previous immersions and navigation errors (position and orientation) were quickly fixed, maintaining it on the desired path without any remarkable constraint. Despite the proximity of mussel raft polygons and other potential source of residues, low marine litter abundance was registered in all transects carried out. This could be explained by the fact that thick maerl beds, like those surveyed, usually occur in areas of intense water movement (waves or currents), that could prevent that debris like plastics sinks and finally settles on the seafloor.

Surveys in sheltered locations

The final surveys took place in two sheltered locations, placed in the vicinity of the city of Vigo, along the south bank of the ria. Both areas are affected by anthropogenic pressures like shipyard industries or a sewage treatment plant. In both cases, transects of ~ 250 m were covered with the ROV thrusted ahead the boat at a very low speed (approximately 1 knot). Despite the negligible current effects, other factors like high water turbidity, algal coverage, close distance to the seabed (0.5 metres average) and high risk of entanglements imposed constraints that seriously limited the ROV control actions. Operating under these conditions was a challenging task, to cope with the low visibility. In addition, compass problems were registered again, confirming that recalibration is required before each field survey. Marine litter items were not recorded in any transect.

Previous marine litter clean-ups carried out in this area by the Vigo fishermen's guild members in the framework of other initiatives showed a high abundance of marine litter, including tyres or fishing and aquaculture related items. However, the dive constraints previously described together with the dense algal coverage, could have made that debris present, if heavily colonized by algae had become incorporated into seafloor and could currently be underestimated.

Figure 10. Ria de Vigo surveyed areas in summer 2021.

A selection of pictures that illustrate the different surveys carried out during the project life are included in ANNEX III. Besides, a short video gathering images filmed during the field test carried out during the summer of 2021 was edited and is accessible through the following link:
https://www.youtube.com/watch?v=GH0uBmO_LRE

4. Conclusions and recommendations for further improvements

The technical difficulties experienced during most field tests described in this report did not allow us to properly complete the information obtained from the pilot action carried out with the "*Valentin Paz Andrade*" vessel regarding the presence of seafloor litter in the Ria de Vigo (Project report:*Pilot action to investigate the presence of seafloor litter in the Ria of Vigo by using a modified trawling fishing gear coupled with of a video recording system*[4]). However, the surveys provided us with valuable experience and information that will be used to improve the ROV technical characteristics and performance as well as to facilitate its handling and increase operator skills.
As main conclusions and opportunities for improvements, we could highlight the following ones:

- The ROV performs better from small size boats enabling much easier vehicle handling and faster track corrections.

[4] http://www.cleanatlantic.eu/wp-content/uploads/2021/10/Report-Marine-litter-retrieval-7.2_DEF.pdf

- Operating the ROV in live boat mode allows obtaining approximate information about the seabed litter abundance of extensive areas sampled by straight transects.

- In order to have adequate visibility, environmental conditions leading to high turbidity should be avoided when selecting survey dates.

- Its use may be limited to sheltered sites or to exposed areas only under mild metocean conditions.

- Seafloor with high algal coverage and/or colonized by species like sea pens should be avoided to prevent entanglement.

- Accuracy of transect length measurements affect directly the quality of data collected and alternative low-cost solutions like using the ship's position or a buoy in surface connected to vehicle tether only provide an imprecise information and can also affect negatively its performance. An underwater GPS system have to be coupled to the ROV to get a precise navigation positioning.

- The ROV compass should be recalibrated before each field test since its performance is easily altered by the presence of large metallic object or other magnetic forces

- The assembly of a specific box to place hardware and peripherals, facilitated the ROV control. It was designed with additional space for accommodating hardware components that may be coupled in the future.

- A waterproof high brightness (1000 nits) monitor should be included to avoid rain or glare effects.

- A crucial issue is to avoid potential entanglements in seafloor colonized by some species like sea pens or high algal coverage. Navigation in these conditions, very common inside the rias, needs to be done far from the bottom, a position that could affect the location and identification of marine debris. In soft substrates a potential solution to be implemented is the use of a drag sled under the ROV. Such sled is already available in CETMAR's headquarter and it will be tested in future field tests (Figure 11).

- The ROV could be used as a platform for integrating extra instrumentation. Additional technologies like conductivity, temperature and depth (CTD) sensors, turbidimeters, extra cameras placed in different ROV positions, a side scan sonar and/or an altimeter could be installed.

- To obtain quantitative estimations of seafloor litter abundance, laser systems should be installed to obtain information about transect width. This technology also can provide information about size and shape of items that pass between the lasers and are accurately measured.

- The template for data collection can be further improved. Additional sections should be included to register information that facilitates the location of items in subsequent review of the videos recorded during the ROV dives.

Figure 11. ROV drag sled prototype.

5. ANNEXES

ANNEX I

ROV Technical characteristics

Technical characteristics		
Physical	Length	457 mm
	Width	338 mm
	Height	254 mm
	Weight in Air (with Ballast)	10-11 kg
	Weight in Air (without Ballast)	9-10 kg
	Net Buoyancy (with Ballast)	0.2 kg
	Net Buoyancy (without Ballast)	1.4 kg
Performance	Maximum Rated Depth	100 m
	Maximum Tested Depth (so far)	130 m
	Temperature Range	0-30°C
	Maximum Forward Speed	1.5 m/s
Tether	Diameter	7.6 mm
	Length	25-300 m
Camera	Tilt Range	+/- 90-degree camera tilt (180 total range)
	Field of View (Underwater)	110 degrees (horizontal)
	Light Sensitivity	0.01 lux
	Resolution	1080p

ANNEX II

Remotely Operated Vehicle (ROV). Underwater surveys

Test Number

Location: ____

VESSEL PICTURE

- Immersion number-	
Date	_ _/_ _/_ _ _ _
Type of dive	*Hotspot survey □ – Transect □*
START POINT	
Hour	
Latitude coordinate	
Longitude coordinate	
Depth (metres):	
Predominant substrate	
END POINT	
Hour	
Latitude coordinate	
Longitude coordinate	
Depth (metres):	
Predominant substrate	
OCEANOGRAPHIC PARAMETERS	
Visibility (turbidity)	
Bottom currents	
Wind in surface	
Other relevant information	
VESSEL CHARACTERISTICS	
Type of vessel	
Approximate dimensions	
Include cabin	*Yes □ – No □*
Describe if the vessel include means to facilitate the dive operation	
Other relevant information	
ROV PARAMETERS	
Describe if the ROV include any additional technology	
Indicate any data or information in relation ROV operation or handling in this dive.	
OTHER INFORMATION	
Indicate any other information that may be useful to improve the operation of the ROV	

ANNEX III