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Mapping and recycling of marine litter and Ghost nets on the sea-floor

marGnet

DELIVERABLE 3.1.1 ***Planning of the field experiments*** ***and definition of the survey areas***

WP	1
Responsible PP	CNR
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1. INTRODUCTION

Marine Litter (ML) is a global issue threatening marine wildlife, coastal communities and maritime activities. A recent study evaluated globally the amount of litter entering the oceans every year at between 4.8 and 12.7 million tons for plastics alone and this quantity is likely to increase by an order of magnitude by 2025 (Jambeck et al., 2015). Given the seriousness of the problem, several guidelines and recommendations have been prepared for estimating and monitoring ML concentrations on shorelines, in surface waters, on the seafloor as well as on marine biota (e.g. OSPAR, 2010, Lippiatt et al., 2013; UNEP/MAP, 2015 and 2016).
The abundance and distribution of ML on the sea-floor, however, is currently much less well assessed than at the sea surface. The presence of benthic ML is generally investigated by scuba divers in shallow coastal and/or coral reef environments (Donohue et al., 2001; Bauer et al., 2008), submersible dives (Galgani et al., 1996; Watters et al., 2010), remotely operated vehicles (ROVs) in deep waters (Schlining et al., 2013; Angiolillo et al., 2015; Oliveira et al., 2015; Melli et al., 2017) and by trawl sampling by fishing or research vessels (Galil et al.,1995; Galgani et al., 2000; Keller et al., 2010; Galgani et al., 2013; Pham et al., 2014).
Also the EU MSFD TG10 “Guidance on Monitoring of Marine Litter in European Seas” (Galgani et al., 2014) suggests the use of bottom trawling and divers to assess the ML distribution on the sea-floor.
Scattered spatial distribution and variability in litter concentrations on the seafloor, however, make it difficult to track it using these methodologies since they are often cost-prohibitive for the authorities, and often not efficient to map large areas or invasive for benthic habitats.

The ‘marGnet’ project proposes to apply hydroacoustic remote sensing (high resolution acoustic equipment, Multibeam Echosounder System-MBES and High resolution Scanning Sonar -HRSS) and dedicated target identification algorithms in order to map and recognize as many categories of benthic ML as possible.

The use of acoustic methods for waste detection on the seafloor dates back to the early ‘90s: Karl et al. (1994) made use of the side scan sonar and video recording to identify barrels and other containers of low-level radioactive waste dumped on the continental margin offshore of the San Francisco Bay between 1946 and 1970. Chavez and Karl (1995) applied a spatial variability analysis and other digital processing procedures to the sidescan sonar images to automatically detect and map the location of the barrels on the seafloor. Similar nuclear waste and chemical and conventional weapons disposal are reported in the North East Atlantic where between 1949 and 1982 radioactive waste was dumped routinely. However the information concerning the disposal are limited to their location and only estimates of their spatial extent are available (see Benn et al., 2010 and references therein).
A large number of studies are dedicated to underwater target detection using acoustic data and specific dedicated algorithms. High resolution imaging by sonars has proven particulary useful for the detection of proud mines on the seabed (see for example Williams, 2015 for applications of high resolution synthetic aperture sonar and references therein).

The recent development of MBES has made it possible to collect georeferenced co-located bathymetry and backscatter intensity data for the mapping of objects with very high spatial resolution. Already in 1999, Hughes-Clarke et al. (1999) showed the effectiveness of the combined use of side scan sonar imagery and MBES data in the search for aircraft debris after the crash of SwissAir Flight 111, off Nova Scotia, Canada. In 2007, Mayer et al. (2007) conducted specific experiments showing that the resolution of MBES combined with 3D visualization techniques provided realistic looking images of mines and mine-like objects, that were dimensionally correct and enabled unambiguous identification of the mine type on a sandy seafloor.

Montereale Gavazzi et al. (2016) demonstrated that it is possible through high resolution (5 cm) MBES bathymetry and backscatter data to map the spatial distribution of fine scale benthic habitats, even identifying the acoustic signatures of single sponges on the seafloor.

More specifically, Madricardo et al., (2019) used high resolution multibeam data to obtain for the first time a direct assessment of the mean abundance of marine macro-litter (see Figure 1 for an example) in a large area of the Venice Lagoon and to characterize marine litter hotspots.

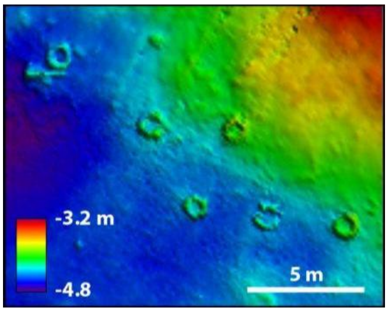


Figure 1 Example of tires on the Venice Lagoon seafloor mapped with a high resolution MBES (modified from Madricardo et al., 2019).

There is much less literature, however, about the acoustic mapping of fishing gear: Corbò and Mollero (2000) demonstrated that underwater acoustics can be used for detecting gillnets. They even proposed to use the small buoys attached to the gillnet for the identification of the lost or abandoned net itself. The buoys would be a scatterer array system attached to the headline arranged to form codes similar to commercial bar codes allowing the net identification.

Moschino et al. (2019) presented the results of acoustic surveys that were carried out during the Life GHOST project using a High-Resolution Scanning Sonar head – HRSS (1171 Series Kongsberg Mesotech Ltd) coupled with Windows(r) based Sonar Processing Software (MS 1000). The HRSS provided very detailed images of the seabed near the sonar head (up to 100 m), highlighting the presence of abandoned, lost or otherwise discarded fishing gears (ADLFG).

Other studies concerned the capability of dolphins to detect gillnets in order to avoid entanglement. Sonar target strength measurements of several types of nets and associated gear were made by Au and Jones (1991) using simulated dolphin echolocation signals.

The 'marGnet' field experiments aim to bridge this knowledge gap by identifying the acoustic signature of different types of ML, mainly ghost nets, both in the water column and on different types of seafloor (acoustic mapping). However, another aim of the experiments is to measure the sinking velocities of different ML types to provide a parameter for the modeling of the sinking ML (sinking velocity).

The first part of the deliverable is dedicated to the definition of the experiments whereas the second part is devoted to the definition of the areas for the surveys to be conducted in Activity 3.3.

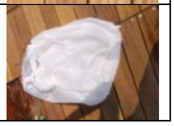
2. PLANNING OF THE FIELD EXPERIMENTS

For the design of the field experiments, the type of ML to be used for the experiments was defined together with the experimental procedures, the experiment location and the equipment needed. All this information was specified while considering the needs of the modeling activity of WP5 (see Table 1).

Based also on the experience gathered during the life GHOST project, different types of waste were identified and collected for the experiments. They are described in table 1, with the purpose of the selection.

Table 1. Different types of ML selected for the experiment, with particular focus on nets

Number	ML type	Property	Indicative dimensions	Acoustic mapping	Sinking velocity	Picture
1	Mussel farming net	clean	1m, 2m	x	x	
2	Mussel farming net	dirty	1 m			
3	Trammel net agglomerate	dirty	1 m x 0.5 m x 0.2 m	x	-	
4	Trawling net piece	clean	1X1 m, 1X2 m	x	x	
5	Trowling net piece type a	clean	1mx1m	x	-	
6	Trowling net piece type b	clean	2m x 1m	x	-	
7	Trap for cuttlefish (*Sepia officinalis*)	clean	1.3mx0.5m	x	-	
8	Trap for *Squilla mantis*	clean	0.3x0.3mx0.1 m	x	-	
9	Plastic rope agglomerate (related to fishing activity)	clean	5 m x 0.05 m	x	x	
10	Plastic rope agglomerate (related to fishing activity)	clean	0.5 m x 0.02 m	x	x	
11	Elastic strap agglomerate (from trawiling nets)	clean	0.3 mx0.4 m x0.03 m	x	x	

12	Plastic bottle	Empty and full	0.3 m x 0.07 m	x	x	
13	Plastic bag	empty	0.4x0.3 m	x	x	

The experiment will be carried out in three different locations: one in the Arsenale Basin in front of the CNR-ISMAR institute, since it is a protected water basin of known bathymetry which allows us to perform the measurement of sinking velocity without the impact of the currents.

The second location will be in the open sea in proximity to the Malamocco Inlet where the different ML types can be laid over a hard substratum as well, because of the presence of *Tegnùe* (local word for rocky outcrop, see detailed description in the Survey area section) .

The third location will be inside the Venice lagoon, in an area where Madricardo et al. 2019 already documented the presence of a ML hotspot.

In the experiments the following instrumental equipment by CNR-ISMAR will be used:

1) A Kongsberg EM-2040 compact dual-head multi-frequency multibeam system (MBES). The MBES will be pole-mounted on the CNR research vessel Litus, a 10-m-long boat with 1.5-m-deep draft. The MBES has 800 beams (400 per swath) 1° × 1°; the operational frequency can be varied from 200 to 400 kHz. A Seapath 300 system will be used for ship positioning, supplied by Real Time Kinematic (RTK) online corrections based on Veneto region base stations collected with a TRIMBLE GNSS Modular Receiver SPS855. The Kongsberg motion sensor MRU 5 and a Dual Antenna GPS integrated in the Seapath, will correct pitch, roll, heave and yaw movements. A Vale-port mini SVS sensor will be attached close to the transducers to continuously measure the sound velocity for the beamforming. Sound velocity profiles (SVPs) will be collected with an AML oceanographic Smart-X sound velocity profiler). Data will be logged, displayed and checked in realtime by the Kongsberg data acquisition and control software SIS (Seafloor Information System);
2) A 1171 Series Kongsberg Mesotech Ltd High-Resolution Scanning Sonar head (HRSS)), it utilizes a frequency of 675 kHz with a 0.9° horizontal fan beam;
3) Camera Powershot Canon G16 with underwater housing.

2.1 EXPERIMENT PART 1: SINKING VELOCITY AND ACOUSTIC SIGNATURE IN SHALLOW WATER AND SOFT BOTTOM

The first part of the experiment will be done in the Arsenale basin in front of the CNR-ISMAR Insitute in controlled conditions.

To measure the sinking velocity we will use the MBES and divers. In this experiment the acoustic signature of different types of ML will be also investigated collecting MBES and HRSS .

The boat with the pole mounted MBES will be anchored at a floating platform already present in the basin. The targets will be put under a transducer at different ranges and different angles. In order to measure the sinking velocity each target will be left falling under the transducer in order to register its movement in the water column data (WCD) of the multibeam. This procedure will be repeated several times in order to have a statistically significant number of measurements.

At the same time this data will be used to define the acoustic signature of each ML type. The target will be released from the platform and moved along the swath so that the ML acoustic signal will be defined at different angles. The distance from the transducer to the point of the target release will be measured. Moreover, the MBES frequency will be changed in order to define the best frequency for ML identification. Then, the HRSS as well will be deployed on the seafloor to register its acoustic signature for the different ML types. The divers will help to deploy and recollect the ML.

2.2 EXPERIMENT PART 2: ACOUSTIC SIGNATURE IN DEEPER WATERS ON HARD AND SOFT BOTTOM

The second part of the experiment will take place near the *Tegnùe* close to the Malamocco inlet (see description below) with optimal meteorological conditions. Afterwards, data will be collected also inside the Venice lagoon, in a soft bottom area where Madricardo et al. (2019) already documented the presence of a ML hotspot.

In the sea, we will deploy the ML on the seafloor and we will pass over it at different angles and directions to identify the acoustic response to the ML with respect to different seafloor types. Particularly, given the experimental challenge of recognizing the nets on the seafloor, expecially on a hard substrate, divers will deploy floaters to identify unequivocally the net. Successively they will remove it from the seafloor. The boat will then pass several times on the same route: first over the net without floaters, then over the net with floaters and finally over the bare seafloor. In this way, we will test the acoustic instruments capability of identifying the nets on the seafloor. The HRSS will be deployed on the targets and divers will collect pictures of them, if the underwater visibility is sufficient.

3. DEFINITION OF SURVEY AREAS

The survey areas for the ML monitoring were identified on the basis of the previous project outcomes, mainly the Life 'GHOST' project (http://www.life-ghost.eu/index.php/en/) and the IPA Adriatic 'DeFishGear' (http://www.defishgear.net/), choosing different types of sea bottom (coherent and incoherent) in the Northern Adriatic Sea. The Adriatic Sea is an elongated water body in the central Mediterranean Sea separating the Italian Peninsula from the Balkan Peninsula (Figure 1). The countries surrounding the Northern Adriatic Sea are Italy, Slovenia and Croatia.

The pilot areas for the survey are located in the Gulf of Venice in proximity to the Venice Lagoon in Italian waters and close to the Island of Losinj in Croatian waters (Figure 1)

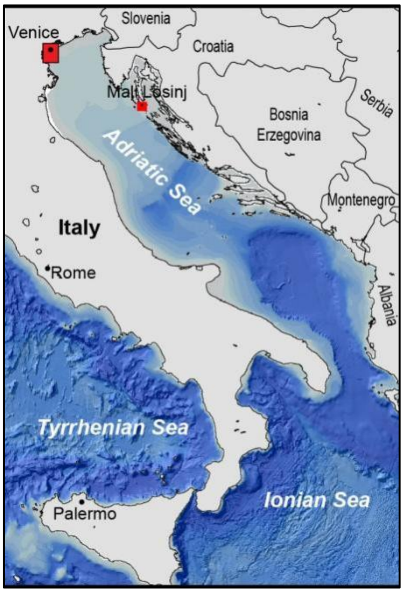


Figure 2: Location of the survey areas in Italy and Croatia

The sites were selected so that they:

1) comprise areas with different substrate (coherent and uncoherent);
2) are likely to be areas that accumulate litter;
3) avoid areas of risk (presence of munitions or other hazardous waste);
4) avoid areas with strong currents or waves;

In Italian waters we will focus more on sites where it is likely to find ML related to the fishery and maricultural activities. In Croatian waters we will focus instead on sites where it is likely to find ML generated by touristic activities.

3.1 THE SURVEY AREAS IN ITALY

In Italian waters, we decided to survey three areas characterized by the presence of rocky outcrops (locally named '*tegnùe*', a dialectical term meaning "holding back" used by fishermen since their nets remained often entangled and lost on these rocks) that were previously investigated during the GHOST project. This choice allows us to not only capitalize on the knowledge collected by the Life GHOST project, but also allows us to compare the efficacy of different methods of acoustic mapping.

These submerged rocky outcrops of partial biogenic origin are located along the coastal area stretching from the mouth of the river Brenta to the Grado lagoon. They extent varies from a few m^2 to some km^2, with a height ranging from a few decimetres up to a few meters (Stefanon and Boldrin, 1979; Mizzan, 1995, Moschino et al. 2019) from the seafloor. The presence of these rocky outcrops promotes the growth and expansion of animal and plant assemblages rich in species and biomass in these eutrophic and shallow waters. The richness in biodiversity is related also to the vertical gradient in elevation from the sandy bottom, and to the abundance of suspended organic matter and sediments as food sources (ARPAV, 2010). These environments are unique and extraordinary in terms of ecological, aesthetic and economic value. They provide a number of ecosystemic services, from fisheries to recreational (e.g. Martin et al. 2014; Moschino et al. 2019), offering shelter, reproduction and nursery grounds to fish and invertebrate species (Tosi et al. ,2017). At the same time they are threatened by human activities (Tonin, 2018), being under stress due to severe fishing pressure (e.g. Falace et al., 2015). The richness in species of these areas attracts a large number of professional and recreational fishermen, as well as divers who are particularly interested in the rich local biodiversity.

The areas investigated during the GHOST project (Figure 3) were identified thanks to the information collected mainly from the scientific literature and websites, the routes of fishing vessels longer than 15 m extracted by their Blue Boxes transmitting to the local Coast Guard and on the basis of questionnaires distributed to fishermen and local divers.

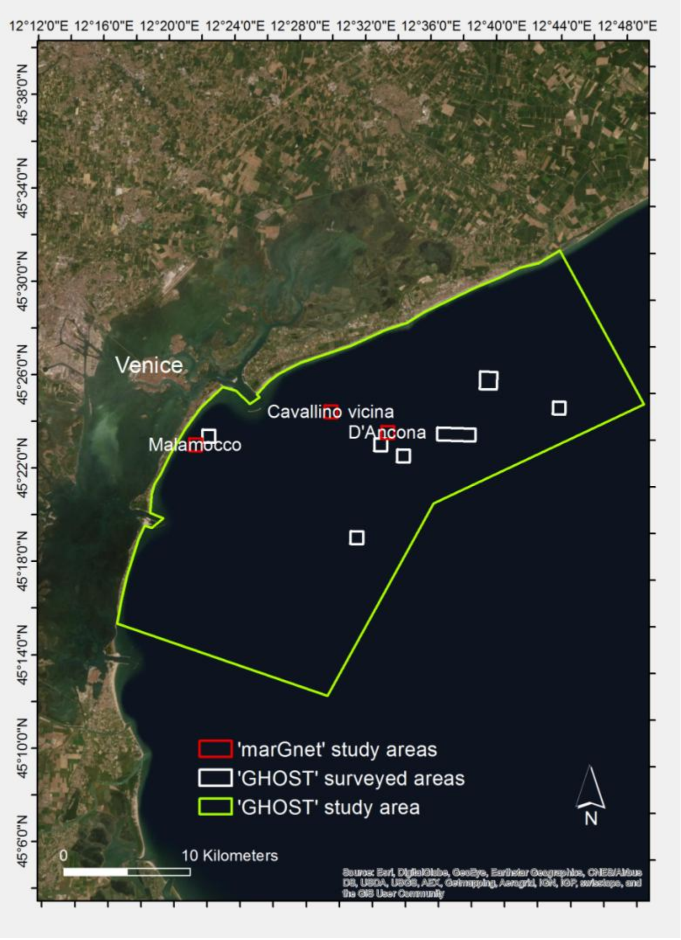


Figure 3 Map of the 'marGnet' survey areas in the Italian waters overlapped to the map of the 'GHOST' survey areas in the Gulf of Venice (adapted from Fiorin et al., 2014a).

During the GHOST project 15 areas were investigated which had a high probability of finding the presence of abandoned, lost and discarded fishing gear (ALDFG). In these areas acoustic investigations were carried out to obtain high resolution maps thanks to the High-Resolution Scanning Sonar series 1171, Kongsberg Maritime. The instrument dropped on the seafloor provided circular images with a radius of 100 m, like the one in Figure 4.

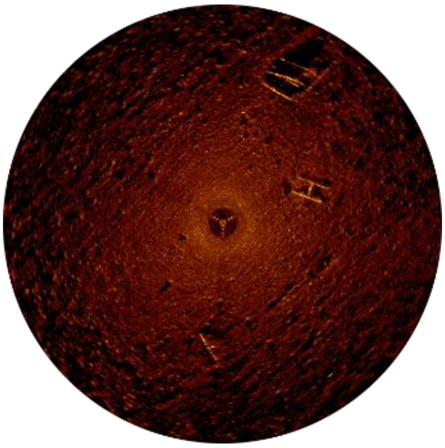


Figure 4 Tegnùa Cavallino Vicina. Example of a seafloor image obtained with the HRSS -MS 1000 that shows the presence of metallic structures of ghost nets (from Fiorin et al. 2014b).

More specifically, we will focus on the following three *tegnùe* that were demostrated to be highly impacted by the presence of ADLFG: 1) the Tegnùa Malamocco;2) Tegnùa Cavallino Vicina and Tegnùa D'ancona taking into account as well their proximity to the coast and their different depths.

3.1.1 TEGNÙA MALAMOCCO

In the area of the Tegnùa Malamocco single rocks or small groups of rocks are distributed over a surface of 3000 m^2 within a sandy seafloor at a depth of about 7 m. The flora and fauna monitoring with the grattage technique (over a surface of 100*100 cm^2), the photographic survey and the scientific fishing carried out in this area showed the presence of over 170 different taxa (157 invertebrates; 13 vertebrates) (ARPAV, 2006; ARPAV, 2010).

Within the GHOST project, in the area of the *tegnùa* Malamocco, 117 ALDFG were collected over three days of cleaining activity. Most of the collected objects were mussel farming nets (see table 3-7 pg 29 of the GHOST report about ADLFG removal activities, Riccato et al., 2014).

3.1.2 TEGNÙA CAVALLINO VICINA

The rocky outcrop surface extends for about 4800 m^2 at a depth of about 16 m. The Tegnùa has a length of about 100m in the NNO-ESE direction and a maximum width of about 40 m. On the northern side of the Tegnùa, the surveys carried out during the GHOST project highlighted the presence of a large number of ALDFG (see Fig. 6 of Moschino et al. 2019 and table 3-1 pg 22 of the GHOST report about ALDFG removal activities, Riccato et al., 2014).

The flora and fauna monitoring with the grattage technique (over a surface of 100*100 cm^2), the photographic survey and the scientific fishing carried out in this area showed the presence of 88 different taxa (87 invertebrates; 1 vertebrate) (ARPAV, 2006; ARPAV, 2010).

3.1.3 TEGNÙA D'ANCONA

The Tegnùa Ancona is the largest rocky outcrop investigated during the GHOST project with a surface area of about 12,000 m^2 and an average depth of about 19 m.

The flora and fauna monitoring with the grattage technique (over a surface of 100*100 cm^2), the photographic survey and the scientific fishing carried out in this area showed the presence of 386 different taxa (379 invertebrates; 7 vertebrate) (Mizzan 2000; Cenci & Mazzoldi, 2005; ARPAV, 2006; ARPAV, 2010).

Within the GHOST project , in the area of the *tegnùa* D'Ancona 117 ALDFG were collected over 13 days of cleaining activity. Most of the collected objects were elastic straps from trawling nets (see table 3-3 pg 25 of the GHOST report about ADLFG removal activities, Riccato et al., 2014a).

3.2. THE SURVEY AREA IN CROATIA

The Cres-Lošinj archipelago is situated in the northern part of the Croatian Adriatic coast, in the Kvarner Bay. The island of Cres is the largest island in the Adriatic, with a total of 36 islands, islets, mounds and reefs associated with the municipality. The island of Lošinj is separated from Cres by an 11 meter wide artificial channel in Osor, over which is a drawbridge.

The coast of the island of Lošinj is 117.95 km long, 1.4 km of which is a very steep and inaccessible rocky coast, 114.5 km of the coast is accessible and rocky, while 2.1 km of the coast is covered by sandy to pebbly beaches (City of Mali Lošinj Development Plan 2013-2020, Regional development agency Porin d.o.o., Rijeka, 2013).

The most common cause of coastal sea pollution is the inadequate sewerage and drainage systems. But with regards to tourism, all major cities on the islands have central sewage systems. In addition, the most significant source of pollution of the marine environment, besides sanitary wastewater, is a small shipyard in the harbor of Mali Lošinj, which is the only industrial facility on the island (City of Mali Lošinj Development Plan 2013-2020, Regional development agency Porin d.o.o., Rijeka, 2013).

The proposed survey location is the Bay of Artatore situated at the western side of the island of Lošinj, 5 km away from the city of Mali Lošinj (Figure 5). In the bay there is a small village with a highly accentuated seasonal character, meaning that most of the houses are used as summer holiday houses. The bay is well shelterd from northern, eastern and western winds, therfore it's very attractive for nautical tourists. During the summer months, numerous ships anchor at this bay.

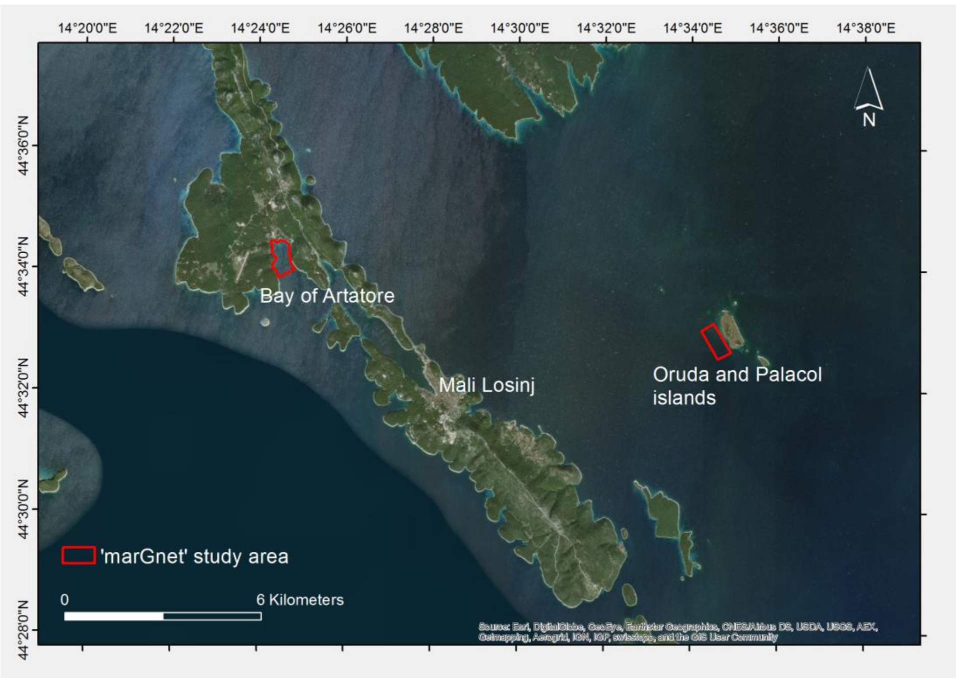


Figure 5: Possible study areas for the survey in Croatian waters: Bay of Artatore situated at the western side of the island of Lošinj and the area close to the uninhabitated islets of Oruda and Palacol

The sea-floor is covered with a mix of rocks, pebbles, sand and posidonia meadows which make it a good survey area to test this method. The depths range from 20 m at the entrance of the bay. Total surface of the bay is approximately 1.3 km^2.

The second possible survey area is situated on the eastern side of the Lošinj archipelago, at the rocky reefs of the two small uninhabitated islets of Oruda and Palacol (Figure 5). This area is under the strong influence of the east-northern winds and sea currents. The sea-floor is a combination of rocks, posidonia meadows and sand.

Although no scientific data are available about the presence of ML in these areas, they are likely to be ML hotspots because they are highly impacted by tourism activities during the summer. Discussions with the local port authority and expert fisherman of the island confirmed this hypothesis.

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