Work Package 3 – Mapping of Adriatic Reefs from different perspectives

Activity 1 – Reefs' Classification in the cooperation area

DATA COLLECTION
REEF CLASSIFICATION

Deliverable D3.1.2 + D3.1.3

Table of Contents

1. EXECUTIVE SUMMARY

Within the WP3 – Activity 3.1 of the ADRIREEF project, two questionnaires have been designed and shared in order to collect all available information regarding Adriatic wrecks, natural reefs and artificial reefs. Once data have been harmonized, new features to be used as categories for the reefs classification and/or for the webGis application have been created. Finally, all data properly checked and harmonized have been put together to populate the ADRIREEF database (Act.3.1 – Reefs' classification in the cooperation area, D3.1.2 – Data collection).

Moreover, working with the ADRIREEF database, reefs (both natural and artificial) and wrecks have been classified according to different characteristics that can influence the implementation of future economic activities (WP3.1 – Reefs' classification in the cooperation area, D3.1.3 – Reef classification).

The present report gather together the results of D3.1.2 and D3.1.3.

2. DATA COLLECTION

2.1 Introduction

In the Adriatic Sea there is a large number of marine ecosystems which can be used for Blue Economy purposes. In the Blue Innovation concept, the attractiveness of existing marine resources is relevant in order to promote sustainable economic development. Therefore, the recognition of less known and appreciated natural areas and of existing artificial structures (e.g. wrecks, artificial reefs, rig-to-reefs) could be a successful way to pursue Blue Growth. In fact, both natural (NRs) and artificial reefs (ARs) are interesting not only for scientific community but, furthermore, are places where it is possible to practice several activities such as fishing, nautical tourism, diving and aquaculture.

In view of this, the key exercise in Activity 1 of WP3 was to obtain a classification of the reefs (NRs and ARs) occurring in the cooperation area and provide a map of those reefs from different perspectives. WP3 Leader coordinated all PPs involved in this activity to implement the existing database of the Adriatic artificial reefs created by CNR-IRBIM (http://www.habitatartificiali.irbim.cnr.it) by developing two on-line questionnaires that were shared among partners to collect as much information as possible regarding the Adriatic reefs.

The expected result from the data collection process was to obtain a singular database for NRs and ARs which should include both physical and economic aspects of them, so reefs could be later classified according to their characteristics. Given the importance of having a structured and homogenous database it became essential to limit the possibility of free answers. For this reason, in order to collect as much information as possible and do it in a homogenous way, it was decided to use the Google Forms application, where answers can be limited by using the multiple response choice or allowing only short answers.

Moreover, given that also wrecks, that are vessels and airplanes accidentally sunk, may be attractive for some economic activities (e.g., diving and recreational fishing), they have been included as a specific category.

The collected information has been used to create the final ADRIREEF database which has constituted the base of a webGis application allowing the visualization of reefs and wrecks on an interactive map and their selection basing on running queries.

The methodology for the data collection process, thus identification and gathering of Adriatic reefs, was organized in 3 phases as displayed in Figure 1.
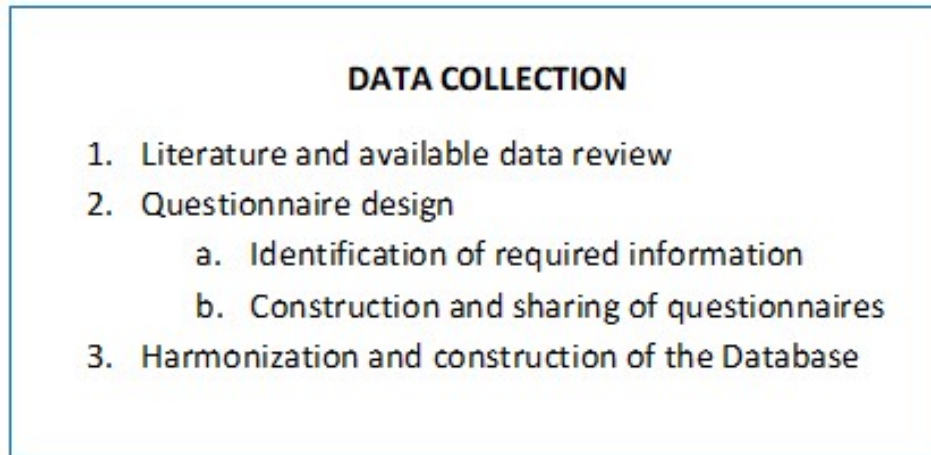
DATA COLLECTION

1. Literature and available data review
2. Questionnaire design
   a. Identification of required information
   b. Construction and sharing of questionnaires
3. Harmonization and construction of the Database

Figure 1. Scheme of the phases and sub-phases of the Adriatic reefs data collection.

2.2   Literature and available data review

In January 2019 WP3 Leader staff collected existing data from European environmental databases such as the European Environment Agency (https://www.eea.europa.eu/data-and-maps) and Natura 2000 sites (https://ec.europa.eu/environment/nature/natura2000/data/index_en.htm) and from other research projects, carried out by CNR-IRBIM, as well as related scientific publications, grey literature and expertise knowledge in order to identify questions that could help to fill the gaps on reefs information.

Main information inputs came from the existing CNR-IRBIM database of artificial habitats in Italy, which was established in 2009 within the Italian Artificial Habitat Group of the Italian Society of Marine Biology (http://www.habitatartificiali.irbim.cnr.it) Thanks to more than 30 years of experience on artificial habitats, the CNR-IRBIM database collected more than 500 bibliographic references and information on 80 Italian artificial habitats. Bibliographic references included scientific publications and grey literature on artificial habitats such as harbours, breakwaters, FADs, offshore platforms and ARs since 1967. By checking this database, it was possible to obtain a list of 150 studies regarding the Adriatic ARs published between 1977 and 2017.

2.3   Questionnaire design

The analysis of the data collected and of CNR-IRBIM database allowed to identify gaps in the information of already known ARs as well as inconsistencies in data harmonization. This, together with the fact that no already existing databases were available for the Adriatic NRs, arose the need to collect new information to complete and include, uniformly, those data that were missing in the previous database. Moreover, as ARs and NRs have completely different characteristics it was decided to develop two distinct questionnaires.

The questionnaires were built in a systematic way, involving two fundamental steps:

1. formulating the appropriate questions for both reef typologies (ARs/NRs) in order to check their suitability for Blue Economy purposes and identify those answers that would help to achieve this target;
2. constructing the questionnaires by ordering the questions into a logical structure which would have made it easier for the experts participating in the investigation.

2.2.1. Identification of required information

Fundamental interrogations about reefs' characteristics that could influence their suitability for economic exploitation purposes were established:

- Which is the reef and where is it located?
- Which are the main characteristics of the area?
- Which are the physical features of the reef?
- Is the reef already managed and/or exploited in any way and/or could be it seat of new activities?

Those fundamental interrogations were used as primary categories to set up more specific questions to be included in the questionnaires and that would help to provide the most exhaustive answers.

1. Which is the reef and where is it located?

   As baseline, data regarding the identification of the reef are needed, therefore data such as location and name were required. In order to answer to this interrogation, the following questions were established:

   - Name of the reef
   - Location of the reef
   - Geographical coordinates (Decimal Degrees)

2. Which are the main characteristics of the area?

   The environmental characteristics of the area where a reef is located may influence the possible exploitation of a reef itself as well as its attractiveness to perform some activities, hence the following factors have been considered:

   - Minimum distance to the coast (km)
   - Typology of surrounding seabed
   - Presence of meadows
   - Important biocenoses, alien and protected species (considered in the case of NRs)
   - Protected area and/or eventual protection level applied to the area (considered for NRs)

3. Which are the physical features of the reef?

The reefs' characteristics themselves may also influence the uses of a reef, especially for ARs which are handmade constructed and designed in some cases for specific scopes. To answer this fundamental interrogation, multiple information are needed and some depend on the typology of the reef:

- Typology of the reef
- Reef bottom depth (m)
- Reef edge (m) (considered for NRs)
- Extension of the reef (m^2)
- Origin of the reef (considered for NRs)
- Material used for the reef construction (considered for ARs)
- Structural design of the reef (considered for ARs where it is necessary to know which and how many are the modules and structures placed as well as how those are arranged)

4. Is the reef already managed and/or exploited in anyway and/or could it be seat of new activities?

The actual use of a reef can limit the development of other activities, therefore knowing the current use or the scope for which it was built (for ARs) is of extremely importance in order to identify possible future uses. At the same time, it could be important to have information about monitoring and surveillance programs, management plans and possible concessions taking place in the area, as those could also limit or benefit future uses. Therefore, the following information have been requested:

- Scope for which an AR was built
- Is the reef managed? If yes, which is the Managing Subject?
- Does a monitoring program exist? If yes, provide information on its lasting on time and the investigations carried out
- Is the reef area subject to concession? (only for ARs)
- Does a surveillance service exist?

Furthermore, questions regarding available data (scientific publications, grey literature, monitoring data) were added to the questionnaires, as this information could help for future research purposes.

2.2.2. Construction and sharing of questionnaires

Noting a lack of information in previous databases, to avoid this problem it was considered relevant to identify the person filling in the questionnaire, so to be able to contact him/her in case of missing data.

Questions were ordinated into a logical structure to make it easier for the people participating in the investigation to provide clear answers. Moreover, in order to add collected data directly to the

database avoiding transformations, numerical interrogations (distances, measures, coordinates) were asked in specific measurement units.

On the 11th of March 2019 both questionnaires (annexes I and II) were shared online among all ADRIREEF PPs, other Institutions and researchers dealing with the Adriatic ARs and/or NRs.

Considering the great occurrence of rocky bottoms along the Croatian coast, which made impossible to map each single reef, in that case it was agreed within the ADRIREEF Consortium to identify homogeneous areas each of them reported as a reef.

2.4   Harmonization and construction of the Database

As a first step, all data collected from questionnaires were screened to delete duplicates and identify incomplete entries where important information were lacking, thus making an evaluation of a reef for Blue Economic purposes impossible. For these missing records an integration of data was asked to partners.

In addition, a surface analysis allowed to notice that some accidentally sank wrecks had been submitted as ARs, even if the definition of ARs adopted within the ADRIREEF project included only natural or manmade structures deployed on purpose (Zec *et al.*, 2019). This incongruity was shared with PPs which highlighted the Adriatic reality where many shipwrecks, most of them from the First and Second World Wars, are commonly exploited by divers and recreational fishermen. This fact evidenced the need to consider wrecks as a new category and the requirement for a new data collection. Hence, information on wrecks were requested to all PPs by sharing a specific excel file based on the answers already given in the ARs questionnaire (annex III).

Data collected from questionnaires together with information already present in the CNR-IRBIM database were assembled to construct the ADRIREEF database. The harmonization process required a check of the information collected and transformations to homogenize data, as some answers were not in line with the requirements. Moreover, geolocations of reefs were inspected in a GIS environment and when those were unlikely, PPs were contacted for clarifications.

Basing on the collected information, in November 2019, CNR-IRBIM performed a preliminary analysis and classification of the Adriatic reefs, as well as the identification of filters to be applied in the webGis application, which were shared with the other PPs to get their feedback. Once criteria for reef classification and filters to be applied in the webGis application were definitely established they were adopted in the finalization of the database.

The final database counted for 58 columns, 55 of them containing the information requested in the questionnaires and 3 created by the database manager (Type of reef, Country, Region). From the total, 14 columns were created for being used as filters in the webGis application and/or for the reefs' classification while the remaining 44 as part of technical information sheets (Tab. 1).

Name of parameter	Type of reef including this parameter	Unit of measure	Origin of the data	Filtered and/or classification property
Type of reef	ARs/NRs/wrecks	-	DB manager	Yes
Country	ARs/NRs/wrecks	-	DB manager	Yes
Region	ARs/NRs/wrecks	-	DB manager	No
Location	ARs/NRs/wrecks	-	DB manager	No
Name	ARs/NRs/wrecks	-	Questionnaires	No
Latitude	ARs/NRs/wrecks	Decimal degrees	Questionnaires	Yes
Longitude	ARs/NRs/wrecks	Decimal degrees	Questionnaires	Yes
Year of deployment	ARs/wrecks	-	Questionnaires	No
Year of modification	ARs	-	Questionnaires	No
Depth range	ARs/NRs/wrecks	Meters	Questionnaires	No
Minimum depth	ARs/NRs/wrecks	Meters	manager	Yes
Reef edge	NRs	Meters	Questionnaires	No
Minimum distance from the coast	ARs/NRs/wrecks	Kilometers	Questionnaires	No
Minimum distance from the coast (simplified)	ARs/NRs/wrecks	Kilometers	DB manager	Yes
Surrounding seabed type	ARs/NRs/wrecks	-	Questionnaires	No
Occurrences of meadows	ARs/NRs/wrecks	-	Questionnaires	No
Reef typology	ARs/NRs/wrecks	-	Questionnaires	No
Reef typology (simplified)	ARs/NRs/wrecks	-	DB manager	Yes
Structure of the wreck	wrecks	-	Questionnaires	No
Material (simplified)	ARs	-	DB manager	Yes
Material	ARs	-	Questionnaires	No
Arrangement of modules	ARs	-	Questionnaires	No
Origin of the reef	NRs	-	Questionnaires	No
Total area of the reef	ARs/NRs	Squared meters	Questionnaires	No
Total volume of material deployed	ARs	Cubic meters	Questionnaires	No
Number of oases composing the reef	ARs	-	Questionnaires	No
Distance between oases	ARs	Meters	Questionnaires	No
Oases dimensions	ARs	Squared meters	Questionnaires	No
Type of structures	ARs	-	Questionnaires	No
Number of structures	ARs	-	Questionnaires	No
Dimensions of the structures	ARs	Meters	Questionnaires	No
Distance between structures	ARs	Meters	Questionnaires	No
Modules shape	ARs	-	Questionnaires	No
Number of modules	ARs	-	Questionnaires	No
Distance between modules	ARs	Meters	Questionnaires	No
Length, height and width dimensions of modules	ARs/wrecks	Meters	Questionnaires	No
Weight or displacement	wrecks	Tons	Questionnaires	No
Type of exploitation	ARs	-	Questionnaires	Yes
Scope	ARs	-	Questionnaires	Yes
Exploitation	ARs/NRs/wrecks	-	Questionnaires	Yes

Table 1. Summary of ADRIREEF database

Possible exploitation	ARs/NRs/wrecks	-	Questionnaires	No
Observation	wrecks	-	Questionnaires	No
Biocenosis	NRs	-	Questionnaires	No
Alien species	NRs	-	Questionnaires	No
Alien species (simplified)	NRs	-	DB manager	No
Protected species	NRs	-	Questionnaires	No
Protected species (simplified)	NRs	-	DB manager	No
Protected area	NRs	-	Questionnaires	No
Protected area (simplified)	NRs	-	DB manager	Yes
Management program	ARs/NRs/wrecks	-	Questionnaires	No
Management program (Yes/No)	ARs/NRs/wrecks	-	DB manager	Yes
Concession area (Yes/No)	ARs/wrecks	-	Questionnaires	No
Surveillance service	ARs/NRs/wrecks	-	Questionnaires	No
Surveillance service (Yes/No)	ARs/NRs/wrecks	-	DB manager	No
Monitoring program	ARs/NRs/wrecks	-	Questionnaires	No
Monitoring program (Yes/No)	ARs/NRs/wrecks	-	DB manager	No
Available data	ARs/NRs/wrecks	-	Questionnaires	No
Available literature (Scientific or Grey)	ARs/NRs/wrecks	-	Questionnaires	No

Table 1. Continuation

Table 1 summarizes the structure of the ADRIREEF database specifying the parameters required for each reef typology and its associated unit of measure, the origin of the data (if they come directly from questionnaires or have been created by the database manager) and if the parameter has been used as a filter or as a category for reefs' classification.

The final ADRIREEF database contained information regarding 156 artificial structures (ARs, Rig-To-Reefs, wrecks) and 129 natural reefs, as well as more than 200 related bibliographic references, including scientific reports and grey literature.

3. REEFS' CLASSIFICATION

3.1 Introduction

The present deliverable summarize data collected within the ADRIREEF project and presents a classification of Adriatic reefs and wrecks according to different features that can have an influence in the exploitation of these areas (ARs, NRs, wrecks) for economic purposes.

Data collected has been divided by typology (ARs, NRs and wrecks) and by location, (Tab. 2).

	Croatian waters	Italian waters	International waters	Total
Artificial reefs	-	47		47
Natural reefs	102	27		129
Wrecks	9	87	13	109
Total	111	174		285

Table 2. Classification of the Adriatic reefs and wrecks identified during the project, by typology and country.

Table 2 shows that, in the total, 176 reefs and 109 wrecks have been identified in the Adriatic Sea. The artificial reefs are 47, corresponding to 27% of the reefs and are present only in Italy. All the remaining ones are natural and most of them, representing 79% of the NRs, are located in the Croatian waters in Croatia. In this case, it has to be remembered that, as explained above (Chapter 2.2.2), due to the great occurrence of rocky substrates along the Croatian coast making impossible mapping all of them, during the data collection it was agreed to identify homogenous areas and to map each of them as a single reef.

Finally, a total of 109 wrecks have been counted, 87 in the Italian territorial waters, 9 in the Croatian territorial waters and the remaining ones in international waters.

3.2 Artificial reefs

During the project information regarding 47 Italian ARs deployed in the Adriatic Sea have been collected. These ARs have been classified according to different features, allowing an extended overview on the scopes for which they were constructed, their location and structural arrangement, the actual usage, and the possible activities that could be implemented.

About 60% of ARs (28) are located at a minimum depth range of 11-20 m, 9 (19%) within the first 10 m and only 2 (4%) between 21 and 30 m (Fig. 2). Most of ARs are located within 6 km from the coast, especially between 5.1 and 6 km (13 ARs) and within 1 km (9).
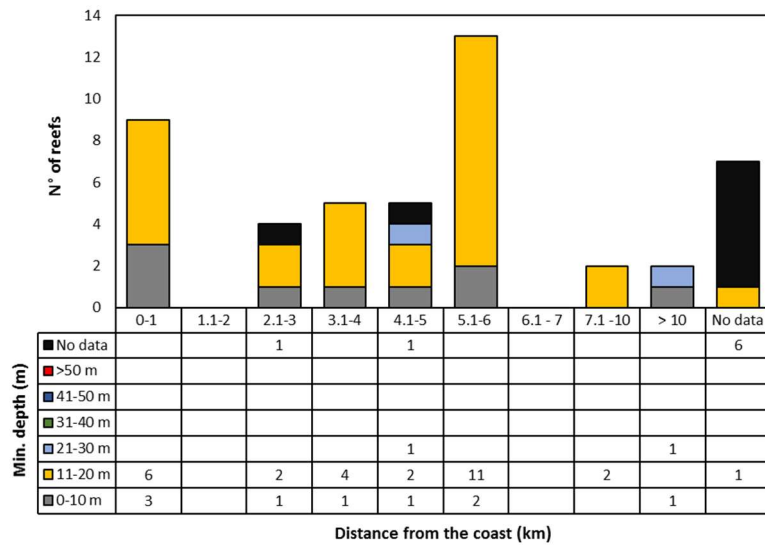
Min. depth (m)	0-1	1.1-2	2.1-3	3.1-4	4.1-5	5.1-6	6.1 - 7	7.1 -10	> 10	No data
■ No data			1		1					6
■ >50 m										
■ 41-50 m										
■ 31-40 m										
■ 21-30 m					1				1	
■ 11-20 m	6		2	4	2	11		2		1
■ 0-10 m	3		1	1	1	2			1	

Distance from the coast (km)

Figure 2. Classification of ARs according to minimum distance from the coast (km) and minimum depth (m).

Forty-four ARs, representing 94% of the total, are made of specifically designed modules, 1 consists of decommissioned structures, and 2 are mixed (Fig. 3).

Most of the ARs formed by specifically designed modules are placed within 1 km or between 5-6 km from the coast, at minimum depths ranging from 11 to 20 m (Figs. 3a and 3b), while information regarding distance and depth are missing for 7 and 8 ARs, respectively.

The AR made of decommissioned structures is the "Paguro" rig located offshore Ravenna, at more than 10 km offshore (Fig. 3a). Although the "Paguro" rig was initially a jack-up drilling platform which accidentally sunk, it can be considered as an ARs instead of a wreck because over the years other decommissioned structures have been added voluntarily to implement the site. The minimum depth specified for this particular reef (0-10 m; Fig. 3b) does not refer to the bottom depth but to the shallowest part of the structure.

The two "mixed" ARs are Porto Recanati AR and Dosso di Santa Croce AR. The first one is installed 4.6 km far from Porto Recanati (Marche Region) at 12-15 m depth and the second one is located 5.5 km offshore Santa Croce (Friuli Venezia Giulia Region) at 11-16 m. Porto Recanati reef is composed by specifically designed modules, rock piles and two sunk vessels, while Dosso di Santa Croce is made of specifically designed modules and two sunk vessels.

Another AR categorization is based on the materials used for their construction (Fig. 4). Concrete is present in 46 ARs and represents the only material in 70% of all reefs. It is associated with polyethylene in 3 ARs, while 4 are formed by concrete, rocks and steel/iron. The only AR made of steel/iron is the "Paguro" rig described above. The category "concrete & other" includes different materials such as wood, coal-ash or clay blocks.

A	0-1	1.1-2	2.1-3	3.1-4	4.1-5	5.1-6	6.1 - 7	7.1 -10	> 10	No data
■ Specifically designed modules & Decommissioned structures					1	1				
■ Specifically designed modules	9		4	5	4	12		2	1	7
□ Decommissioned structures									1	

Distance from the coast (km)

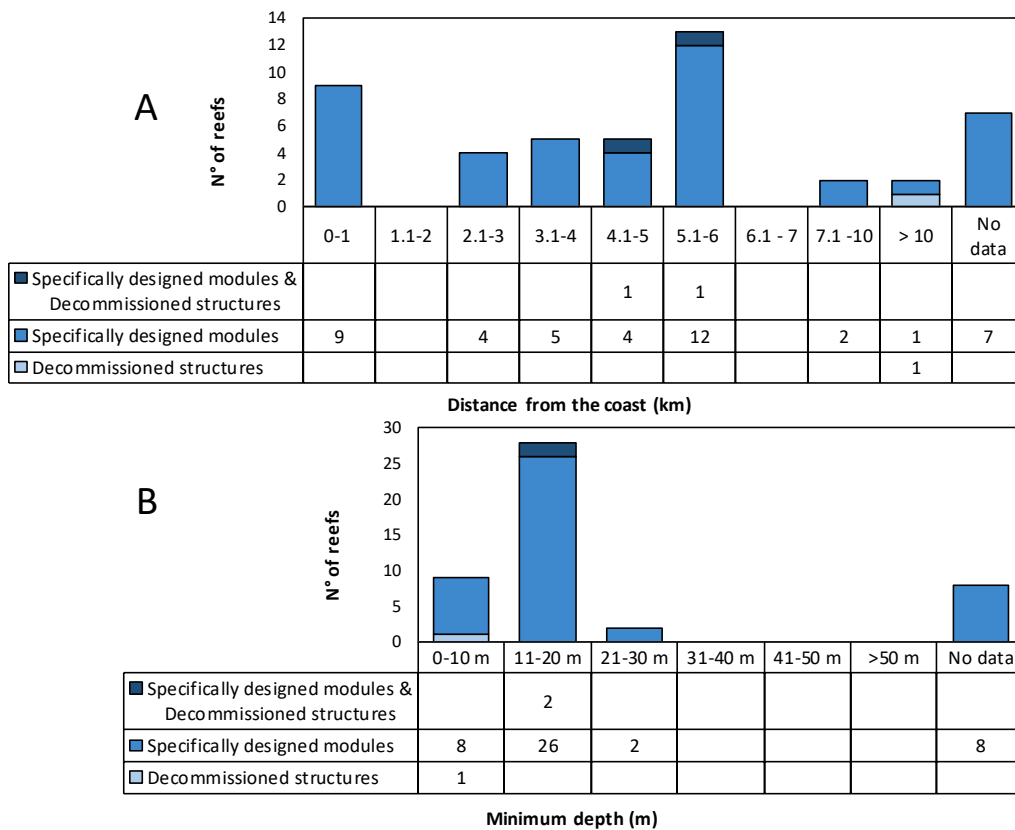| B	0-10 m	11-20 m	21-30 m	31-40 m	41-50 m	>50 m	No data
■ Specifically designed modules & Decommissioned structures		2					
■ Specifically designed modules	8	26	2				8
□ Decommissioned structures	1						

Minimum depth (m)

Figure 3. Classification of ARs by typology according to minimum distance from the coast (km) (A) and minimum depth (m) (B).
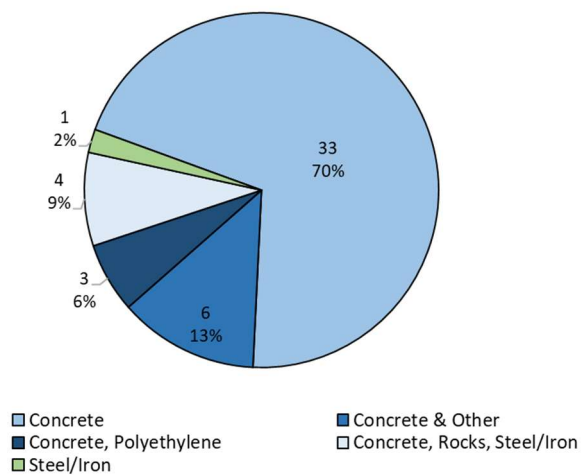

Figure 4. Materials used in ARs' construction.

The choice of material to be used in reefs construction is strictly related to the purposes for which an AR is realized. The main scopes for the deployment of ARs in the Adriatic Sea, as resulted by the questionnaires, are reported in Table 3.

FE	Finfish enhancement	Pol	Polifunctional
HR	Habitat Restoration	D	Diving/Snorkelling
HP	Habitat Protection	FT	Fishing Tourism
Mar	Mariculture	RF	Recreational fishery
Res	Research	PF	Professional fishery

Table 3. Main scopes for the ARs construction in the Adriatic Sea.

Figure 5 shows that ARs made of concrete, whether or not associated with other materials, have been deployed for several scopes, manly finfish enhancement, habitat restoration and habitat protection. The unique AR made of steel and/or iron ("Paguro") is devoted to diving, habitat protection and research.
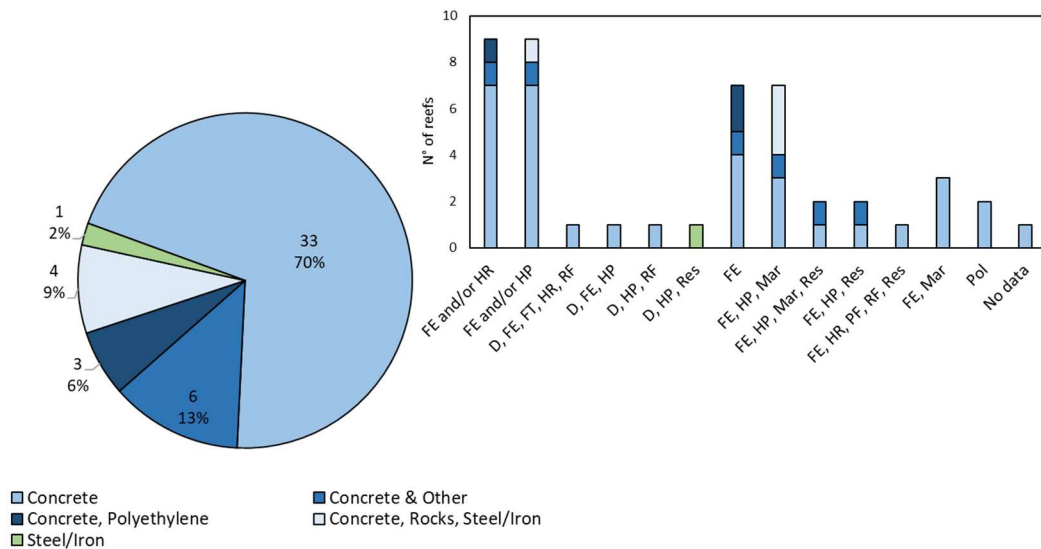

Figure 5. Classification of ARs by scopes according to the materials.

In particular 31 ARs, corresponding to 66% of the total, were experimental, 8 (17%) were exclusively professional and 2 were both; no information were provided for 6 ARs (Fig. 6).
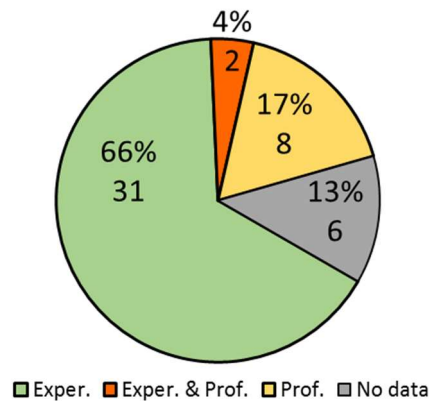
Figure 6. Classification of ARs by purpose.

Despite the original purposes, data collected through the questionnaires allow to note how only 28% of ARs (13) are currently exploited, while 42% (20), all experimental ones, don't seem to be used (Fig. 7a); however, it must be considered that information about the exploitation is missing in 30% of the ARs.

Seven currently exploited ARs are professional, 4 experimental and only 2 fall into both categories (Fig. 7b).

Figure 7. Classification of ARs based on their exploitation (pie graph) and currently uses according to their initial scopes.

A deeper analysis of the current uses of ARs highlights the presence of 5 specific activities, associated with them or not (Fig. 7b). Recreational fishery has resulted the most common activity, being carried out in 54% of ARs, followed by professional fishery (46%), diving and/or snorkelling (31%), mariculture (23%) and research (15%).

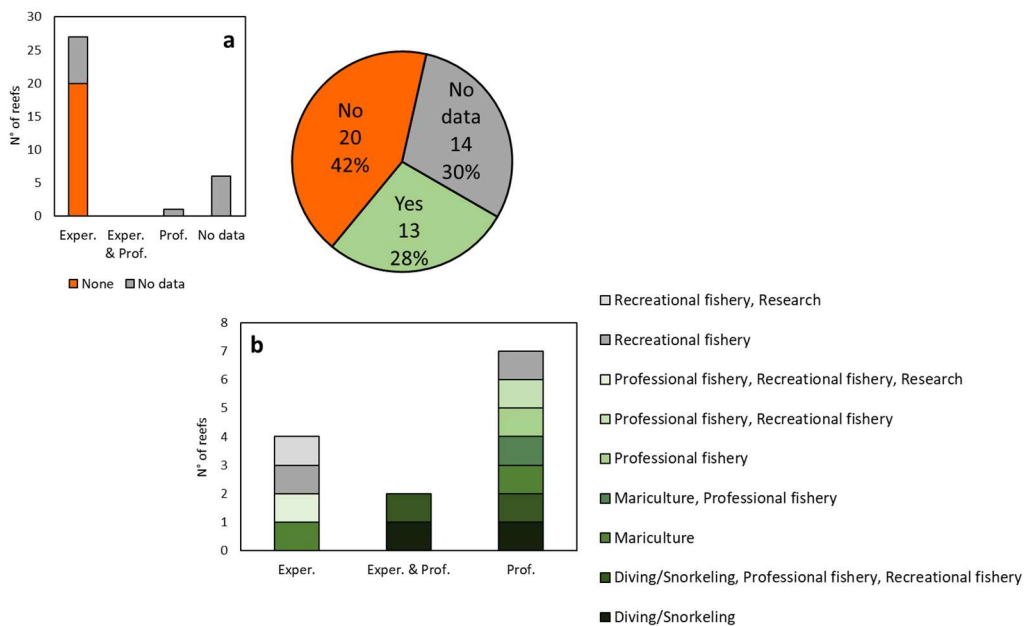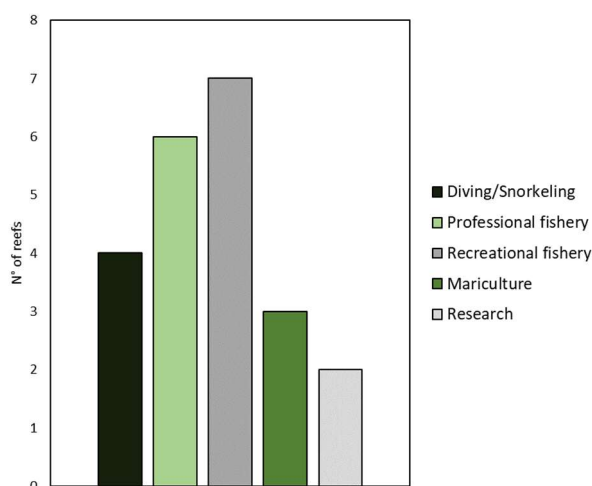*Figure 8. Quantification of current exploitation activities within ARs.*

An interesting aspect regards the possible exploitation of the ARs in the future (Tab. 4). The first evidence is that many possible uses are suggested for the experimental ARs and that most of them include tourism activities such as diving/snorkelling, recreational fishery and fishing tourism, followed by research.

Some professional ARs could also be exploited for tourism and others for mariculture. A multipurpose of the ARs combining some activities is also envisaged.

Possible future uses	Experimental	Experimental and Professional	Professional	No data
Diving/Snorkeling	1		1	
Diving/Snorkeling, Fishing Tourism				1
Diving/Snorkeling, Fishing Tourism, Mariculture, Professional fishery, Recreational fishery, Research	3		4	
Diving/Snorkeling, Fishing Tourism, Recreational fishery, Research	2			
Diving/Snorkeling, Mariculture, Professional fishery, Recreational fishery, Restocking with introduction of juveniles of precious species	4			
Diving/Snorkeling, Professional fishery, Recreational fishery	1			
Diving/Snorkeling, Recreational fishery	4			
Diving/Snorkeling, Recreational fishery, Research	1			
Diving/Snorkeling, Research	2	1		
Mariculture			2	
Recreational fishery, Research	2			
Research	3			
No data	9		1	5

Table 4. Possible future activities to be implemented at the ARs.

3.3 Natural reefs

The definition of NRs adopted in the context of the ADRIREEF project is: "Natural reefs are either biogenic or geogenic formations protruding from the solid or soft seabed with distinctive living marine resources" (Zec *et al.*, 2019).

Following this definition, the 129 NRs have been identified (27 Italian and 102 Croatian) and categorized basing on their origin (biogenic and/or geogenic).

Taking into account that information regarding the reefs' origin was only available for half of the identified reefs (Fig. 9), 35 NRs have a biogenic origin (20 Italian and 15 Croatian), 13 reefs a geogenic origin (7 Italian and 6 Croatian) and 16 (only Croatian reefs) a mixed origin.
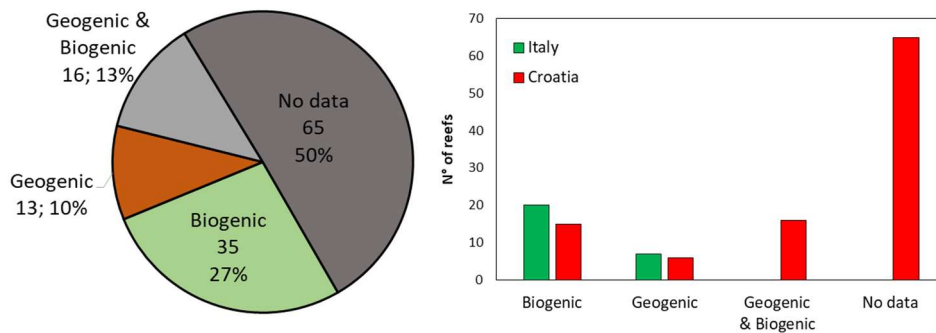

Figure 9. Origin of NRs and subdivision by country.

In Figure 10 the NRs have been subdivided basing on the size and shape of the formation according to the categorization agreed within the ADRIREEF project (Zec *et al.*, 2019).
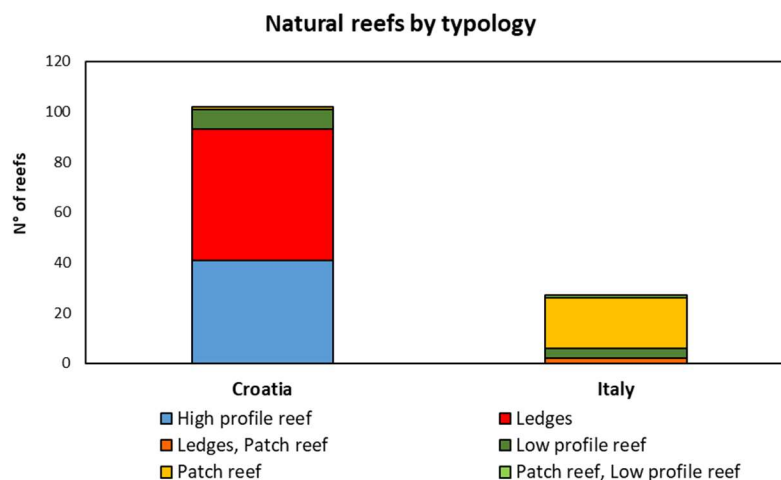
Figure 10. Classification of NRs by size, shape and country.

The Croatian NRs differ from the Italian ones being in most of cases ledges (52; to 51% of the Croatian NRs; Fig. 10) and high profile reefs (41; 40%). Instead, most of Italian NRs are patch reefs (20, 74% of the Italian NRs). The mixed natural reefs (i.e. ledge and patch reef, patch and low profile reef) are only present in Italy.

The Croatian NRs are located at different distances from the coast (Fig. 11), from 0 up to 52 km; the furthest one is the Jabuka reef, a high profile reef located in front of Komiža, Vis Island, which falls however within the Croatian national waters.

Figure 11. Distribution of Croatian NRs by category in terms of minimum distance from the coast and minimum depth.

Only one patch reef is reported in Croatia, located at a minimum distance from the coast of less than 1 km and at a minimum depth of 10 m. High profile reefs and ledges are diffusely distributed being absent only at 6-7 km and 4-6 km from the coast, respectively. Regarding the low profile reefs, their minimum depth appears always to be less than 20 m, even in the case of reefs located at more than 10 km from the coast.

About half of the Italian patch reefs (9) occur within 3 km from the coast and have a minimum depth ranging from 0 to 10 m (Fig. 12). No information regarding the depth has been provided for 3 patched Italian reefs located further than 5 km from the coast. The remaining ones fall within a minimum depth range between 11 and 20 m with the furthest one being located at 19.6 km offshore Venice (Sorse patch reef).

The low profile Italian reefs (4) are located within 5 km and up to 30 m depth. The two mixed ledge and patch reefs are placed at more than 7 km from the coast and at a minimum depth ranging from 15 to 20.2 m, and are part of a particular typology of hard formations called "tegnùe" typical on the seabed of the northern Adriatic Sea. Finally, the unique mixed patch and low profile reef is the "Secca dei due occhi" located off the Apulia Region at 0.5 km from the coast and 17 m depth.

Minimum depth range

0-10 m ▨ 11-20 m ▨ 21-30 m ▨ 31-40 m ■ 41-50 m ■ >50 m ■ No data

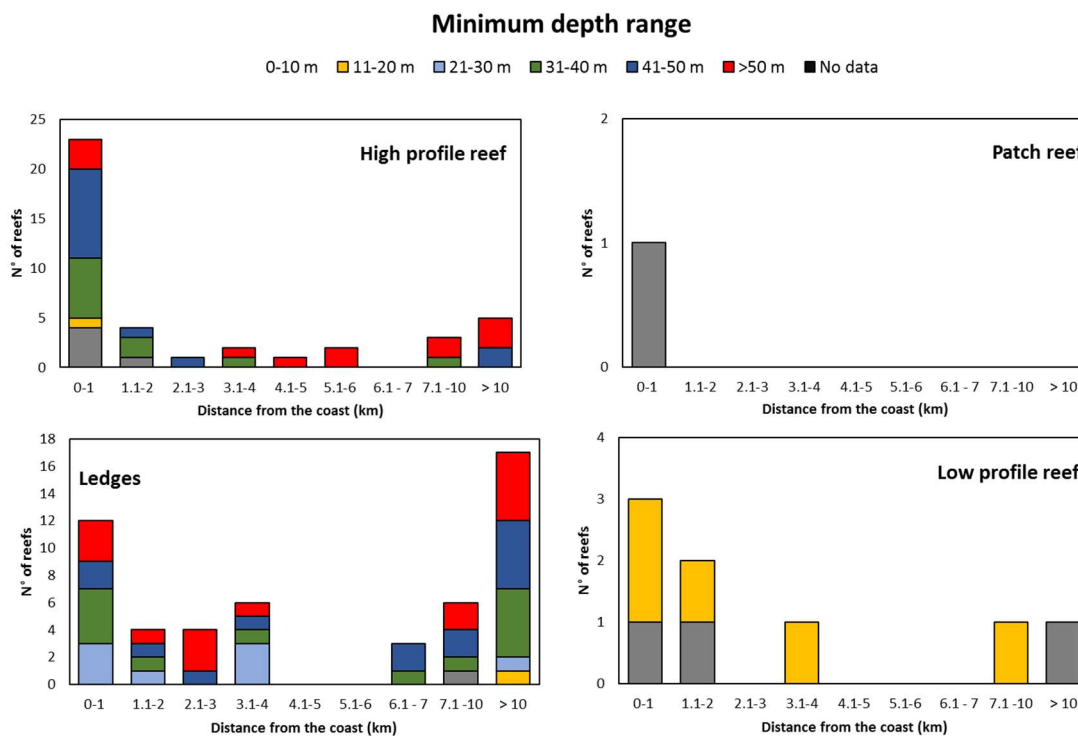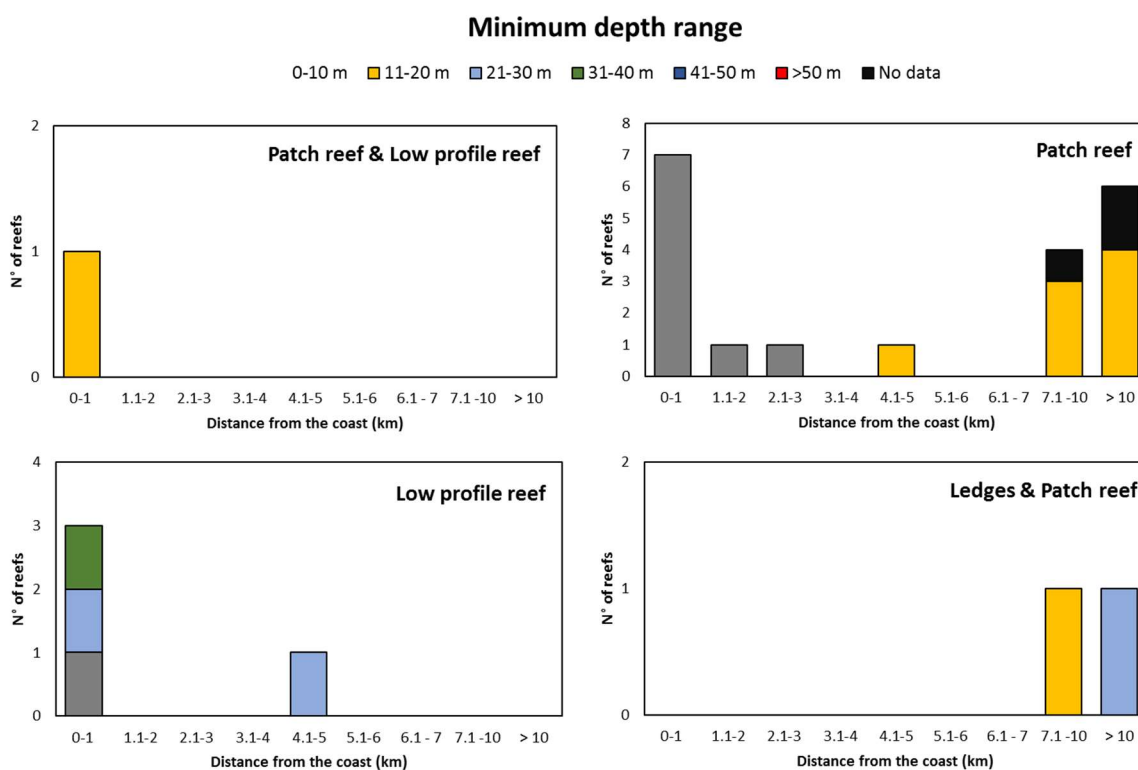*Figure 12. Distribution of Italian NRs by category in terms of minimum distance from the coast and minimum depth.*

Information regarding the eventual inclusion of a NR within a protected area is missing for 12% of the reefs (12 Italian and 4 Croatian) (Fig. 13). However, the available data indicate that more than the half of Croatian NRs (55) are not situated within a protected area, while all the Italian NRs for which the information is available are protected in some way.

The NRs subjected to protection measures (43 Croatian and 15 Italian) have been further categorized according to the typology of protection and the eventual application of a management plan. Figure 14 shows that a variety of measures are established, some of them being specific of the country (e.g., ZTB "*Zona di Tutela Biologica*" is exclusively an Italian protected area). However, most of the NRs subjected to protection measures are located within Natura 2000 areas.
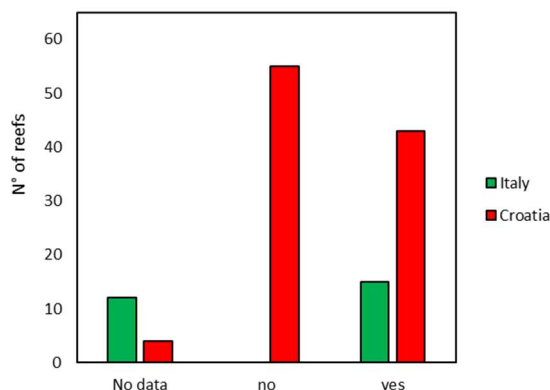
Figure 13. Categorization of NRs according to the application of a protected area by country.

Independently from the applied protection measure, 67% of the overall Italian NRs have not a management plan in force, while for the Croatian NRs this percentage decreases to 37%.
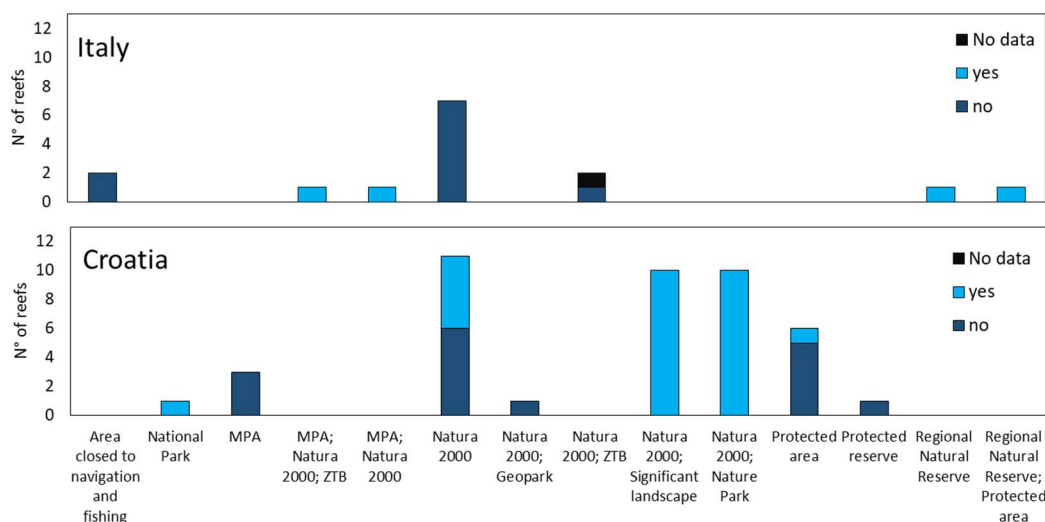
Figure 14. Italian and Croatian NRs within a protected area according to its management state (Yes = active management plan; No = without a management plan). (ZTB= "Zona Tutela Biologica; MPA: Marine Protected Area)

In terms of exploitation, the data collection has evidenced that, in the overall, 89% of NRs are currently exploited by 3 main activities - diving and/or snorkelling, professional fishery and recreational fishery (Tab. 5), 4% are devoted to research, while the remaining 7% includes those reefs not subjected to any activity or for which data were not provided. Currently, research and fishery (both recreational and professional) are more common in Italy (being carried out in 70% of the Italian NRs) than in Croatia (7% of the Croatian NRs), while diving and/or snorkelling are more common in Croatia (89% of Croatian NRs) rather than in Italy (52% of the Italian NRs).

Current uses	Croatia	Italy
Archaeological site - research	1	
Diving/Snorkelling	89	4
Diving/Snorkelling, Professional fishery, Recreational fishery		6
Diving/Snorkelling, Recreational fishery	2	4
Professional fishery	2	
Professional fishery, Recreational fishery	3	5
Research		4
None	3	2
No data	2	2

Table 5. Current uses of NRs by country.

Regarding the possible future uses of the NRs (Tab. 6), two new potential tourism usages have been proposed (fishing tourism and cultural tourism) within 4% of the Adriatic NRs. Professional fishery, which currently occurs in 12% of the Adriatic NRs (Tab. 5) could almost disappear if the possible future uses were applied, which could enhance the development of other more sustainable economic activities such as fishing tourism. Table 6 highlights how diving and/or snorkelling activities could become in the future the most practiced activities, being suggested for 98% of the Croatian NRs and 56% of the Italian ones.

It is also possible to observe a possible implementation of research activities within the NRs, which could increase from the actual 15% of presence in the Italian NRs up to 22%.

Possible future uses	Croatia	Italy
Diving/Snorkelling	95	10
Diving/Snorkelling, Cultural tourism	1	
Diving/Snorkelling, Professional fishery	1	
Diving/Snorkelling, Recreational fishery	1	4
Diving/Snorkelling, Recreational fishery, Fishing Tourism	1	
Diving/Snorkelling, Research		1
Diving/Snorkelling, Research, Fishing Tourism	1	
Recreational fishery		5
Recreational fishery, Fishing Tourism		2
Research		5
No data	2	

Table 6. Possible future uses of NRs by country.

3.4 Wrecks

The 109 identified wrecks have been categorized according to their minimum distance from the coast and their minimum depth, in order to identify the most suitable ones for an economic exploitation.

Seventy-two percent of Italian wrecks with distance information are located within 10 km from the coast and the remaining 28% farther away. In addition, more than half of Italian wrecks (70%) have their minimum depth within 20 m, with 33% of them situated farther than 6 km from the coast (Fig. 15).

Min. depth (m)	0-1	1.1-2	2.1-3	3.1-4	4.1-5	5.1-6	6.1 - 7	7.1 -10	> 10	No data
>50 m	1		2		1		2	2	5	
41-50 m									2	
31-40 m		1			1				2	
21-30 m					1			1	5	1
11-20 m	2	2	5	1	5	3	4	6	8	3
0-10 m	15	1	1		2		1		1	

Distance from the coast (km)
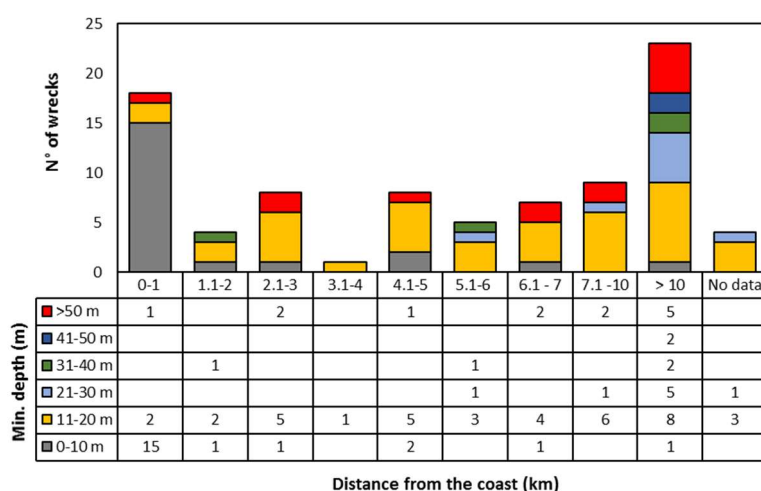
Figure 15. Classification of Italian wrecks according to minimum distance from the coast (km) and minimum depth (m).

Regarding the Croatian wrecks, 78% of them are located within the first km from the coast in a wide range of minimum depths, varying from 11 to more than 50 m (Fig. 16). The remaining two wrecks are placed respectively at 1.5 km (8 m depth) and 14.8 km (45 m depth) from the coast.

Min. depth (m)	0-1	1.1-2	2.1-3	3.1-4	4.1-5	5.1-6	6.1 - 7	7.1 -10	> 10	No data
>50 m	1									
41-50 m									1	
31-40 m	2									
21-30 m	1									
11-20 m	3									
0-10 m		1								

Distance from the coast (km)
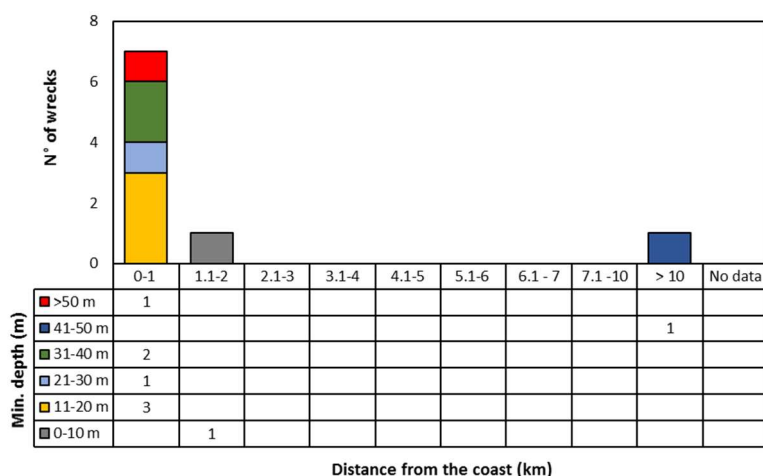
Figure 16. Classification of Croatian wrecks according to minimum distance from the coast (km) and minimum depth (m).

All wrecks in International waters are placed at more than 10 km far from the coast or no information have been provided. The wreck with the minimum depth is located at 19 m, while the deepest one is at 85 m (Fig. 17).
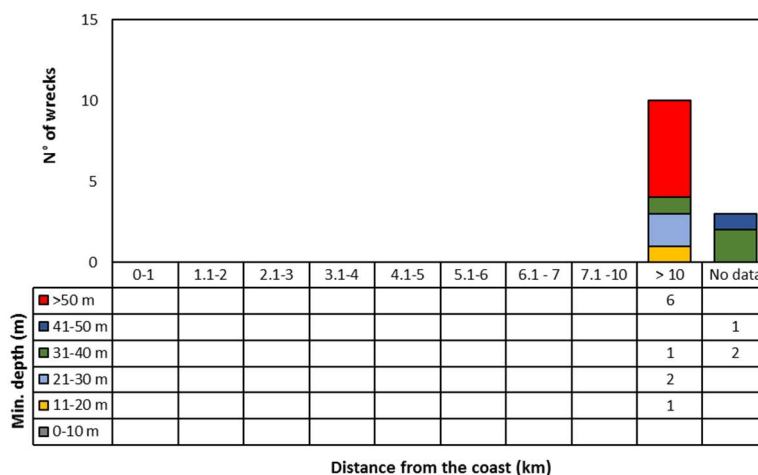
Figure 17. Classification of wrecks in International water according to minimum distance from the coast (km) and minimum depth (m).

Diving and/or snorkelling (D) have resulted the most common activities taking place on wrecks in both countries and in international waters, being present in the 100% of Croatian wrecks, in the 49% of Italian ones (as for 44 wrecks this information was not available) and in the 69% of wrecks located in international waters (Fig. 18). Recreational fishing (RF) has been reported at 3 wrecks, 2 in the Italian waters and 1 in international waters, but it is very likely that much many wrecks are exploited by this activity.
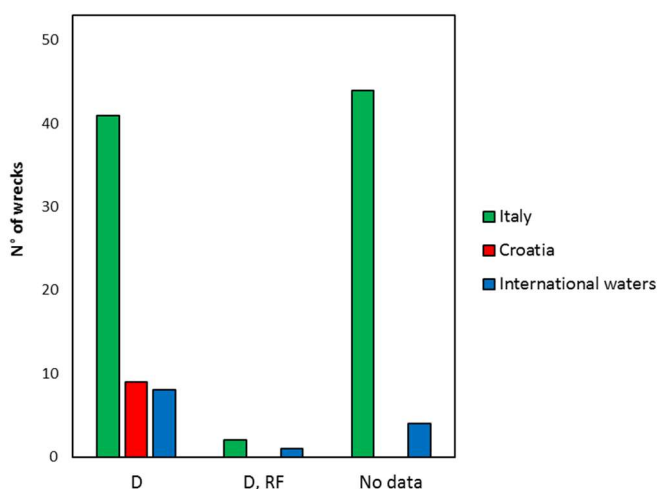
Figure 18. Current exploitation of wrecks.

Concerning the future (Fig. 19), for the Croatian wrecks it has been proposed the implementation of new uses such as fishing tourism (FT), mariculture (Mar), recreational fishery (RF) and research (Res), as well as new activities to be carried out in the context of diving and/or snorkelling, such as underwater exhibitions and competitions (Und). Instead, for wrecks located in Italian and International waters only the expansion of diving and/or snorkelling activities has been proposed to those wrecks where no activities currently take place.
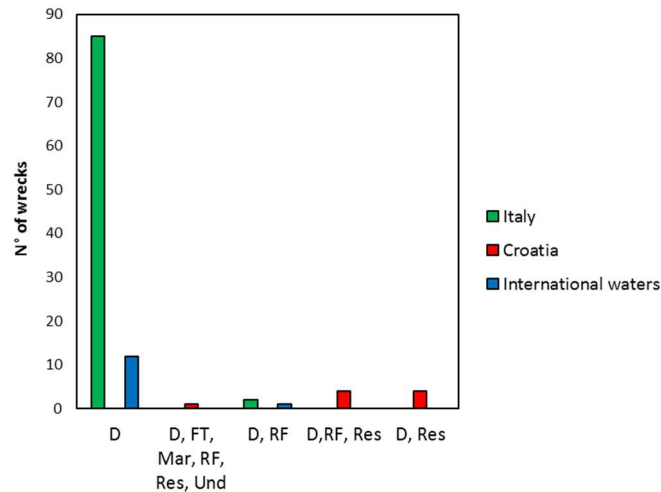
Figure 19. Possible future uses of wrecks by country.

3.5 Conclusions

The investigation carried out has evidenced the presence of a large number of both natural and artificial reefs, (176) as well as of submerged wrecks (109) in the Adriatic Sea.

It has also highlighted that, although 68% of such reefs and wrecks are currently exploited (Tab. 7), this percentage could increase to almost 100% in the next future, through a further implementation of activities with low environmental impact according with the Blue Economy.

The most probable activities could be diving and snorkelling which, according to this study, could be performed in at least 87% of the Adriatic reefs and wrecks as evidenced in Table 8 which reports a summary of the possible future usages of the three typologies of reef/structure considered in this project.

Current uses	ARs	NRs	Wrecks
Archaeological site - research		1	
Diving/Snorkeling	2	93	58
Diving/snorkeling, Professional fishery, Recreational fishery	2	6	
Diving/Snorkeling, Recreational fishery		6	3
Mariculture	1		
Mariculture, Professional fishery	1		
Professional fishery	1	2	
Professional fishery, Recreational fishery	1	8	
Recreational fishery	2		
Research		4	
Research, Professional fishery, Recreational fishery	1		
Research, Recreational fishery	1		
Shellfish farmers associations	1		
None	20	5	
No data	14	4	48

Table 7. Activities currently taking place in Adriatic ARs, NRs and wrecks.

Possible future uses	ARs	NRs	Wrecks
Diving/Snorkeling	2	105	97
Diving/Snorkeling, Cultural tourism		1	
Diving/Snorkeling, Fishing Tourism	1		
Diving/Snorkeling, Fishing Tourism, Mariculture, Professional fishery, Recreational fishery, Research	7		
Diving/Snorkeling, Fishing Tourism, Mariculture, Recreational fishery, Research, Underwater photo exhibitions and competitions			1
Diving/Snorkeling, Fishing Tourism, Recreational fishery, Research	2		
Diving/Snorkeling, Mariculture, Professional fishery, Recreational fishery, Restocking with introduction of juveniles of precious species	4		
Diving/Snorkeling, Professional fishery		1	
Diving/Snorkeling, Professional fishery, Recreational fishery	1		
Diving/Snorkeling, Recreational fishery	4	5	3
Diving/Snorkeling, Recreational fishery, Fishing Tourism		1	
Diving/Snorkeling, Recreational fishery, Research	1		4
Diving/Snorkeling, Research	3	1	4
Diving/Snorkeling, Research, Fishing Tourism		1	
Mariculture	2		
Recreational fishery		5	
Recreational fishery, Fishing Tourism		2	
Recreational fishery, Research	2		
Research	3	5	
Recreational fishery, Research	2		
No data	15	2	

Table 8. Possible activities to be performed in the Adriatic ARs, NRs and wrecks in the future.

4. REFERENCES

Zec D., Fabi G., Soldati M. 2019. Deliverable 3.1.1. Definition of reefs' category. Work Package 3 – Mapping of Adriatic Reefs from different perspectives. Activity 1 – Reefs' classification in the cooperation area. ADRIREEF project

http://www.habitatartificiali.irbim.cnr.it Access date: 31/01/2019

https://ec.europa.eu/environment/nature/natura2000/data/index_en.htm Access date: 01/02/2019

https://www.eea.europa.eu/data-and-maps Access date: 05/02/2019

NATURAL REEFS QUESTIONNAIRE

1. Name and Surname: ....

2. Occupational qualification and workplace: ....

3. Name of the reef: ....

4. Location of the reef: ....

5. Geographical coordinates LATITUDE (WGS84 DD.DD. e.g. 43.023N): ....

6. Geographical coordinates LONGITUDE (WGS84 DD.DD. e.g. 13.123N): ....

7. Reef bottom depth (m) (If it is in a range please specify the max and min): ....

8. Reef edge (m): ....

9. Minimum distance from the coast (km): ....

10. Total area occupied by the Natural Reef (m^2): ....

11. Typology of the reef:
    - ☐ High profile reef (the reef protrudes more than 20 meters from the base substratum)
    - ☐ Low profile reef (the reef protrudes less than 20 meters from the base substratum)
    - ☐ Ledges (vertical reef face characterized by visible crevices)
    - ☐ Boulder reef (structure elevating from the flat seabed)
    - ☐ Patch reef (sand bottom with small reef structures protruding from the sediment)
    - ☐ I don't know

12. Origin of the reef:
    - ☐ Biogenic
    - ☐ Geogenic

13. Type of surrounding seabed:
    - ☐ Rocks
    - ☐ Sand
    - ☐ Mud
    - ☐ Detritic
    - ☐ Gravel
    - ☐ Other

14. Occurrence of meadows?
    - ☐ Yes, phanerogams
    - ☐ Yes, algae
    - ☐ no

15. Which are the most important biocenoses? ....

16. Any alien species?
   ☐ Yes
   ☐ No
   ☐ Maybe

17. If "Yes", which alien species? ....

18. Any protected species? (e.g. IUCN Red List of Threatened Species, ASPIM Protocol, Berna Convention, etc.)
   ☐ Yes
   ☐ No
   ☐ Maybe
   ☐ If "Yes", which species?

19. Is the natural reef within a protected area?
   ☐ Yes, MPA
   ☐ Yes, Natura 2000 site
   ☐ Yes, National park
   ☐ Yes, Natural park
   ☐ Yes, Marine reserve
   ☐ No

20. Is the reef managed?
   ☐ Yes
   ☐ No
   ☐ I don't know

21. If yes, which is the Managing Subject? (Please give a short summary of the management measures adopted)

22. Does exist a monitoring program?

   ☐ Yes
   ☐ No

23. If "Yes" please give a short summary of the program ....

24. Surveillance service?
   ☐ Yes
   ☐ No

25. Current use of the Reef:
   ☐ Diving
   ☐ Mariculture
   ☐ Research
   ☐ Professional fishery
   ☐ Recreation fishery
   ☐ Fishing tourism
   ☐ Nothing

☐ Other (please, specify) ....

26. Development perspectives of the Natural Reef:
☐ Diving
☐ Mariculture
☐ Research
☐ Professional fishery
☐ Recreation fishery
☐ Fishing tourism
☐ Nothing
☐ Other (please, specify) ....

27. Please list the available data (If "Other" please specify):
☐ Geophysical map
☐ Water column
☐ Sediments
☐ Benthic community
☐ Fish community
☐ Other (please, specify) ....

28. Available literature (Scientific or Grey):

(Please add as many papers/works you know about the reef using the scheme:
1 Title/ 2 Authors / 3 Year of publication / 4 Journal or project / 5 Pages / 6 Abstract / 7 Keywords)

ARTIFICIAL REEF QUESTIONNAIRE

1. Name and Surname: ....
2. Occupational qualification and workplace: ....
3. Name of the reef: ....
4. Location of the reef: ....
5. Geographical coordinates LATITUDE (WGS84 DD.DD. e.g. 43.023N): ....
6. Geographical coordinates LONGITUDE (WGS84 DD.DD. e.g. 13.123N): ....
7. Year of deployment of the AR: ....
8. Bottom depth (m) (If it is in a range please specify the max and min): ....
9. Minimum distance from the coast (km): ....
10. Type of surrounding seabed:
    ☐ Rocks
    ☐ Sand
    ☐ Mud
    ☐ Detritic
    ☐ Gravel
    ☐ Other (please, specify) ....
11. Occurrence of meadows?
    ☐ Yes, phanerogams
    ☐ Yes, algae
    ☐ No

ARTIFICIAL REEF STRUCTURE

1. Reef typology:
   ☐ Specifically designed modules (basic module)
   ☐ Decommissioned structures
   ☐ Other (please, specify) ....

Specifically designed modules (basic module)

1. Material:
   ☐ Concrete
   ☐ Sea-friendly concrete (e.g., Tecnoreef)
   ☐ Coal Ash

□ Rocks

□ Fiberglass

□ Other (please specify) ....

2. Shape of the single module:

□ Cube

□ Pole

□ Plinth

□ Other (please, specify) ....

3. Dimension of the single module (m): ....

4. Total volume of deployed material (m^3): ....

5. Arrangement of the modules:

□ Geometrically assembled to form structures

□ Scattered

□ Other (please, specify) ....

Artificial Reef geometrically assembled to form structures

1. Typology (e.g., pyramid): ....

2. Number of deployed structures: ....

3. Height of the structures (m): ....

4. Distance among structures (m): ....

Scattered Artificial Reef

1. Number of deployed structures: ....

2. Distance between structures (m): ....

If the Artificial Reef is composed by areas or oases, please indicate:

1. Number of the oases: ....

2. Distance among oases: ....

3. Dimension of each oasis (m^2): ....

4. Total area occupied by the Artificial Reef (including the area covered by the bodies, the distance between the bodies and the area of respect) (m^2): ....

Decommissioned structures

Please specify the nature of the structure:

□ Offshore extraction platform

□ Sunk vessel/ship

☐ Other (please, specify) ....

Offshore extraction platform:

1. Type of the platform (e.g., one-leg platform): ....
2. Part of the platform used to realize the AR (e.g., jacket, deck): ....
3. Total area occupied by the Artificial Reef (m^2): ....

Sunk vessel/ship:

1. Number of sunk vessels: ....
2. Vessel material:
   ☐ Wood
   ☐ Iron
   ☐ Fiberglass
   ☐ Other (please, specify) ....
3. Dimension of the sunk vessel/ship - LFT (m) and Weight (ton): ....

Other Artificial Reefs:

1. Number of bodies: ....
2. Material of bodies:
   ☐ Wood
   ☐ Iron
   ☐ Fiberglass
   ☐ Concrete
   ☐ Other (please, specify) ....
3. Dimension of each body - length (m) and Weight (ton): ....

ARTIFICIAL REEF UTILIZATION

1. Scope:
   ☐ Habitat protection
   ☐ Habitat restoration
   ☐ Finfish enhancement
   ☐ Diving
   ☐ Mariculture
   ☐ Research
   ☐ Professional fishery
   ☐ Recreational fishery
   ☐ Fishing tourism

☐ Other (please, specify) ....

2. Type of Artificial Reef:

    ☐ Experimental

    ☐ Professional

3. Is the Reef exploited at present?

    ☐ Yes

    ☐ No

    ☐ Maybe

    If "Yes", by whom? ....

4. Does exist a management program?

    ☐ Yes

    ☐ No

    ☐ Maybe

    If "Yes", please specify the Managing Subject and give a short summary of the adopted management measures ....

5. Concession area?

    ☐ Yes

    ☐ No

6. Surveillance service?

    ☐ Yes

    ☐ No

7. Does exist a monitoring program?

    ☐ Yes

    ☐ No

    ☐ Maybe

    If "Yes", please give a short summary (Duration / Monitored aspects / Involved Institute or Agency /address, e-mail address) ....

8. Possible exploitation of the Artificial Reef:

    ☐ Diving

    ☐ Mariculture

    ☐ Research

    ☐ Professional fishery

    ☐ Recreational fishery

    ☐ Fishing tourism

    ☐ Nothing

    ☐ Other (please, specify) ....

9. Please list the available data:

☐ Geophysical map

☐ Water column

☐ Sediments

☐ Benthic community

☐ Fish community

☐ Other (please, specify) ....

10. **Available literature (Scientific or Grey):**

(Please add as many papers/works you know about the reef using the scheme: 1 Title/ 2 Authors / 3 Year of publication / 4 Journal or project / 5 Pages / 6 Abstract / 7 Keywords)

ANNEX III

WRECK QUESTIONNAIRE

1. Country
2. Region
3. Location
4. Name
5. Latitude (Decimal Degrees)
6. Longitude (Decimal Degrees)
7. Year of deployment (Year of sank)
8. Bottom depth (m)
9. Minimum distance from the coast (km)
10. Type of surrounding seabed
11. Occurrence of meadows
12. Reef typology: Decommissioned structures
13. Material
14. Total area occupied by the wreck (m^2)
15. Total volume of the wreck (m^3)
16. Structures
17. Dimension (m)
18. Weight (Tones)
19. Exploitation
20. Possible exploitation of the wreck
21. Management program
22. Concession area
23. Surveillance service
24. Monitoring program
25. Available data
26. Available literature (Scientific or Grey)