The ADRIREEF database: a comprehensive collection of natural/artificial reefs and wrecks in the Adriatic Sea

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Abstract. The paper presents a database of information on wrecks, natural and artificial reefs located in the Adriatic Sea, collected within the framework of the Interreg Italy-Croatia project ADRIREEF - Innovative exploitation of Adriatic Reefs in order to strengthen Blue Economy. The data collection lasted more than one year and comprehended three surveys and a wide literature review. After being collected, data were harmonized and, where possible, made machine-readable. Moreover, data were widely metadated, published in a webGIS (https://adrireef.github.io/sandbox3/) and shared as Open Data in EMODnet (European Marine Observation Data network) Data Ingestion Portal through the SEANOE repository (Ferrà et al., 2020; http://doi.org/10.17882/74880). The database is composed of 285 three-dimensional records, each one described by 51 attributes. Parameters are clustered in four main groups: identification, reef and site description, management/exploitation information. Available literature (scientific and/or grey) was also included in the database and linked to the corresponding site.

1 Introduction

In the Blue Innovation concept, the attractiveness and possible use of existing marine resources which are not yet properly exploited is relevant to promote sustainable economic development (Vogt, 1998; Orams, 2002; Cater and Cater, 2007; Kiper, 2013; Sakellariadou and Kostopoulou, 2015; Nurhayati et al., 2019) and redefine marine fisheries (Pauly, 2018; Stead, 2018). In this context, the recognition of less known and appreciated natural reefs (NRs), existing artificial structures (e.g. artificial reefs, rig-to-reefs; ARs) and wrecks could also be a successful way to pursue Blue Growth as all these sites might be suitable places for developing or improving sustainable activities such as fishing (both recreational and professional), nautical tourism, diving and aquaculture (Wilhelmsson et al., 1998; Stolk et al., 2007; Uyarra et al., 2009; Needham, 2010; Edney, 2011; Spalding et al., 2017; Alempijević and Kovačić, 2019). Therefore, qualitative and quantitative information about the heritage presence and already existing human activities is fundamental to pursue an ecosystem-based sea use management according to the Maritime Spatial Planning (MSP) Directive (EU Directive 2014/89/EU, 2014; Douvere, 2008; Gilliland and Laffoley, 2008). As MSP is based on the three pillars for sustainable development – social, economic and environmental – its implementation will facilitate in turn the enforcement of the Marine Strategy Framework Directive (MSFD, European Commission, 2008) and the achievement of Good Environmental Status (GES).

This work represents the joint effort of Italian and Croatian partners participating in the Interreg Italy-Croatia project ADRIREEF (Innovative exploitation of Adriatic Reefs in order to strengthen blue economy, https://www.italy-croatia.eu/web/adrireef) aimed at assessing the potentiality of reefs in the Adriatic Sea, in order to strengthen the Blue Economy. Within the framework of the project, natural reefs are defined as either biogenic or geogenic formations protruding from the solid or soft seabed with distinctive living marine resources. An artificial reef is a submerged natural or manmade structure deliberately constructed or placed on the seabed to emulate some functions of a natural reef such as protecting, regenerating, concentrating, and/or enhancing populations of living marine resources, while doing "no harm". Accidentally sunken ships and planes are instead defined as wrecks.

Based on the above considerations, this paper presents a comprehensive collection of 285 natural reefs, artificial reefs and wrecks located in the Adriatic Sea within Italian, Croatian and International waters.

An analogous attempt of inventory was made on intentionally sunk shipwrecks to serve as ARs over six continents (Ilieva et al., 2019). Anyway, no structures of this type were signalled in the Adriatic Sea, whereas available literature (Pivetta and Spazzapan, 2012) and our search highlighted the occurrence of several accidentally sunken ships which, anyway, act as artificial habitats. Similar attempts to geolocalize ARs and wrecks were made along the national coasts and offshore waters of Florida and Alabama (U.S.A.), by querying municipalities about the deployment of the reefs (U.S. Fish and Wildlife Service, Wildlife & Sport Fish Restoration Program, https://www.fws.gov/wsfrprograms/), as well as in the Gulf of Mexico (Alabama Marine Resources Division, https://www.outdooralabama.com/saltwater-fishing/artificial-reefs). The latter dataset reports all the submerged structures (including ARs, rig-to-reefs and wrecks) in the Gulf of Mexico, but only name, type of reef and coordinates are publicly available. Lastly, some efforts were done concerning NRs within the Reefbase project

67 (http://www.reefbase.org/projects_partners/projects.aspx), which helped localize and concisely qualify ~10,000 reefs on a

68 global scale (Oliver et al., 2002).

69 Another attempt made to identify aquaculture zones in the Adriatic Sea, also through a webGIS application

70 (http://www.caps2.eu/caps2/), reports zones of production, harvesting and farms (Tora et al., 2017), but it does not include a

71 few Italian reefs dedicated to this practice.

72 The collection work presented here is thus an ambitious attempt to gather in a single dataset the location, geometries, history

73 and detailed characteristics of natural reefs, artificial reefs and wrecks existing in the Adriatic Sea. It required a deep knowledge

74 on the overall status of the sites, their history, past and ongoing research and monitoring programs carried out to characterize

75 their ecological features, as well as on their current exploitation level. In this perspective, a key exercise in the ADRIREEF

76 project was to obtain a classification of NRs, ARs and wrecks occurring in the cooperation area and to provide a map of these

77 sites from different perspectives: from the environmental to the economic point of view.

78 The result is an interactive map and an Open Access detailed dataset (Ferrà et al, 2020) published on SEANOE whose contents

79 are available for any user and purpose.

80 **2 Data mining**

81 Starting from an existing own database, established in 2009 within the Italian Artificial Habitat Group of the Italian Society of

82 Marine Biology (Fabi et al., 2011; Fabi et al., 2015; http://www.habitatartificiali.irbim.cnr.it/wp) carrying basic information

83 about location and description of the artificial reefs, the National Research Council – Institute of Marine Biological Resources

84 and Biotechnologies (CNR-IRBIM, http://www.irbim.cnr.it/it/index.php) coordinated the data collection activity to improve

85 it by developing and sharing among the ADRIREEF partners three online questionnaires on NRs, ARs and wrecks (Appendix

86 A, B and C, respectively). An initial review of available literature and data was carried out to identify the necessary information

87 on NRs/ARs and wrecks to be required. The questionnaires were structured in such a way to obtain a unique database for the

88 two reef typologies and wrecks, including physical, ecological and economic aspects and allowing to classify elements

89 according to their characteristics. Given the importance of collecting answers quickly and having a structured and

90 homogeneous database, it became essential to use easy online tools and to limit the possibility of free answers by proposing

91 multiple-response questions (e.g. Google Forms application; https://www.google.com/forms/about/).

92 The collected information was used to create the final ADRIREEF database which fed, in turn, a webGIS application allowing

93 the visualization of reefs and wrecks on an interactive map and their selection basing on running queries.

94 Projects' partners (PPs) were surveyed and answers were harmonized to obtain a consistent database. New features were

95 defined and used as categories for the elements' classification and/or for the webGIS application. Finally, all data properly

96 checked and harmonized were assembled and used to populate the database.

2.1 Literature and data review

The review of existing literature took into account European environmental databases (https://www.eea.europa.eu/data-and-maps, https://ec.europa.eu/environment/nature/natura2000/data/index_en.htm), research projects carried out by CNR-IRBIM and other entities, scientific publications and grey literature. Based on the results of the review and expert knowledge, existing gaps in the information of already known reef sites and wrecks were identified.

With regard to ARs, a large part of inputs came from the above mentioned CNR-IRBIM database on artificial habitats in Italy, containing more than 500 bibliographic references and information on 80 Italian artificial habitats such as harbours, breakwaters, Fish Aggregating Devices (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. Conversely, a similar literature heritage was not present for NRs and wrecks.

2.2 Questionnaire design

The analysis of the collected information highlighted the need of improving existing data especially on NRs and wrecks. As ARs and NRs have completely different features, it was decided to develop two distinct questionnaires. A third questionnaire was developed for wrecks as they have peculiar characteristics. All questionnaires were built in a systematic way with the aims of (i) investigating the reefs' and wrecks' suitability for Blue Economy purposes and identifying those answers that would help to achieve this target; (ii) facilitating experts' participation in the poll by ordering questions into a logical structure.

The identification of the person/s filling in the questionnaires was considered relevant to collect consistent information and have a contact person in case of missing data. Moreover, numerical information (distances, measures, coordinates) were asked in specific measurement units to add collected data directly to the database avoiding transformations.

2.2.1 Identification of required information

Natural and artificial reefs

Questions about reefs' characteristics that could influence their suitability for sustainable exploitation were divided in four main groups:

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

As a baseline, data regarding the identification of a reef are needed, therefore name and location (in WGS84 Coordinate Reference System and Decimal Degrees) of the reef were required.

2. Which are the main characteristics of the area where the reef is located?

The environmental characteristics of the area where a reef is located may influence its possible exploitation as well as its attractiveness to perform some activities, hence the following features were considered: minimum distance to the coast (km);

typology of the surrounding seabed; presence of meadows; important biocoenoses, alien and protected species (in case of NRs); possible protection level applied to the area (in case of NRs).

3. Which are the physical features of the reef?

The reef's physical features may also influence its potential use, especially for ARs, which are handmade constructed and designed for specific scopes. To answer this fundamental question, multiple information are needed: the typology of the reef; reef bottom depth (m); reef edge (in meters, for NRs); spatial extension of the reef (m²); the origin of the reef (for NRs, if biogenic or geogenic); the material used for the reef construction (for ARs); structural design of the reef (for ARs, where it is necessary to know the type and number of modules/structures put in place and their layout).

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

The actual use of a reef and/or the scope for which it was built, in the case of ARs, can limit the development of further activities, thus such information is crucial to identify possible synergies and conflicts with additional potential users. At the same time, the original purpose of an artificial reef turns out to be a key information for better understanding monitoring and surveillance programs, management plans and possible grants taking place in the area, as those could also limit or benefit future uses. Therefore, the following information were requested: scope/s for which an AR was built; if the reef is managed (for both NRs and ARs) and, if yes, who is the management entity; if a monitoring program is already in place (for both NRs and ARs) and, if yes, its duration and the investigations carried out; if the reef area is subjected to grant or surveillance service (only for ARs). Furthermore, questions regarding available data (scientific publications, grey literature, monitoring data) were added to the questionnaires, as they could help for future research purposes.

Wrecks

The questionnaire related to the category of wrecks required some information shared with reefs and some extra information about the physical features of structure.

Shared information concern (i) wreck identification (location and name), (ii) characterization of the surrounding area (distance from the coast, type of surrounding seabed, presence of meadows), (iii) physical features of the wreck (material, bottom depth and wreck edge), (iv) exploitation and protection of the wreck (exploitation, protection and management of the site, if existing). Extra information asked to the partners were: weight of the wreck (tons), total area of the footprint (m²), total volume of the shipwreck (m³) and known dimensions (length, width, height in meters).

2.3 Harmonisation and construction of the database

Firstly, all data collected from 270 questionnaires were screened to delete duplicates and identify incomplete entries and missing information, in order to make possible an evaluation of a reef/wreck for Blue Economy purposes. For these missing records, a data integration was asked to the contact person.

Data collected from questionnaires were then assembled together with those already contained in the CNR-IRBIM database and harmonized, as some answers were not in line with the requirements. Moreover, geolocations of reefs were inspected in a GIS environment and, when those were inconsistent, clarifications were asked.

160 Once data control and harmonization were completed, a preliminary analysis and classification of the Adriatic reefs/wrecks

161 was performed and query filters of the webGIS application were identified. Once criteria for reef/wreck classification and

162 filters to be applied in the webGIS application were definitely agreed with PPs, the ADRIREEF database was finalized.

163 The final database counted 51 columns, 48 of them derived by the questionnaires and 3 created by the database manager (Type

164 of reef, Country, Region). Of these fields, 10 were used as filters in the webGIS application and/or for the reefs' classification

165 while the remaining 41 as part of technical information sheets.

3 Database structure and geographical coverage

167 The database counts 285 three-dimensional elements (Latitude/Longitude coordinate and bottom depth), described by 51

168 parameters and divided into 129 natural reefs, 47 artificial reefs and 109 wrecks located in the Adriatic Sea falling into Italian,

169 Croatian and International waters (Table 1).

170 All artificial reefs and most of wrecks fell within the Italian territorial waters, while the majority (79%) of natural reefs was

171 located within the Croatian ones. The presence of almost all the natural reefs on the eastern side of the studied area is mainly

172 due to the geological morphology of the Adriatic basin (Stefanon, 1972), while the complete absence of artificial reefs on the

173 same side is currently due to Croatian legal constraints. It is worth noting that the number of wrecks reported in the Croatian

174 waters is somewhat underestimated. This fact is due to the lack of basic information about several wrecks (e.g. lack of exact

175 position of the shipwreck, which did not allow to place it in the map), so it was decided to keep into the database only those

176 with adequately detailed information. It is also worthy to note that, given the great occurrence of rocky substrates along the

177 Croatian coast, it was agreed within the ADRIREEF Consortium to identify homogeneous areas and map each of them as a

178 single natural reef (Zec et al., 2019).

179

	Croatian waters	Italian waters	International waters	Total
Artificial Reefs	-	47	-	47
Natural Reefs	102	27	-	129
Wrecks	9	87	13	109
Total	111	161	13	285

180 **Table 1: Adriatic reefs and wrecks by typology and country**.

181

182 Location of reefs and wrecks is expressed in decimal degrees and Coordinates Reference System WGS84. The database is

183 available as a unique Comma Separated Values (CSV) file.

184 Table 2 summarizes the structure of the ADRIREEF database specifying the parameters required for each new element:

185 parameter name, description, unit of measure, origin of the data (if they come directly from questionnaires or have been created

186 by the database manager) and possible applicability restrictions. Table 2 also reports, for each parameter, the group it belongs

187 to. As mentioned in paragraph 2.2.1, Group no. 1 corresponds to reef identification and geolocation information, Group no. 2

188 contains parameters summarizing the characteristics of the area hosting the reef or wreck, Group no. 3 concerns aspects of the

189 reef/wreck that may also have an effect on its usage, Group no. 4 includes parameters about the present and/or possible future

190 reef or wreck exploitation.

191

Column name	Description	Group	Unit of measure	Origin of the data	Applicability
type	type of reef/wreck	1		DB manager	NRs, ARs, Wrecks
country		1		DB manager	NRs, ARs, Wrecks
region		1		DB manager	NRs, ARs, Wrecks
location	reference city or zone for the reef/wreck	1		DB manager	NRs, ARs, Wrecks
name	common name of the reef/wreck	1		Questionnaires	NRs, ARs, Wrecks
latitude		1	[decimal degrees]	Questionnaires	NRs, ARs, Wrecks
longitude		1	[decimal degrees]	Questionnaires	NRs, ARs, Wrecks
year_deployment	year of reef deployment/wreck sink	1		Questionnaires	ARs, Wrecks
year_modification	year of eventual modification	1		Questionnaires	ARs
min_depth_m	bottom depth altitude	2	[m]	DB manager	NRs, ARs, Wrecks
depth_m	depth range covered by the structure	2	[m]	Questionnaires	NRs, ARs, Wrecks
reef_edge_m	height of the structure	2	[m]	Questionnaires	NRs
min_dist_km	minimum distance from the coastline	2	[km]	Questionnaires	NRs, ARs, Wrecks
surrounding_seabed	surrounding seabed	2		Questionnaires	NRs, ARs,

	sedimentary composition				Wrecks
meadows	presence of meadows	2		Questionnaires	NRs, ARs, Wrecks
reef_typology	reef typology	3		Questionnaires	NRs
structure_wreck	type of wreck	3		Questionnaires	Wrecks
material	material composing the reef	3		Questionnaires	ARs
arrangement_modules	global arrangement of modules composing the reef	3		Questionnaires	ARs
origin_reef	origin of the reef	3		Questionnaires	NRs
total_area_sqm	total footprint area of the reef	3	[sqm]	Questionnaires	NRs, ARs
total_volume_cubm	total volume of the reef	3	[cubm]	Questionnaires	ARs
n_oases	number of oases, composed by structures	3		Questionnaires	ARs
dist_between_oases_m	linear distance between oases	3	[m]	Questionnaires	ARs
dimens_oases_sqm	footprint area of the oases	3	[sqm]	Questionnaires	ARs
type_structures	type of structures present in the reef, composed of modules	3		Questionnaires	ARs
n_structures	number of structures present in the reef	3		Questionnaires	ARs
dim_structures_m	relevant dimensions of the structures of the reef	3	[m]	Questionnaires	ARs
dist_between_structures_m	linear distance between structures of the reef	3	[m]	Questionnaires	ARs
modules_shape	shape of the modules composing the structures of the reef	3		Questionnaires	ARs
n_modules	number of modules composing the structures of the reef	3		Questionnaires	ARs
dist_between_modules_m	linear distance between modules composing the	3	[m]	Questionnaires	ARs

	structures of the reef				
dimension_leng_width_heigh_m	dimensions L H W of the reef/wreck	3	[m, m, m]	Questionnaires	ARs, Wrecks
weight_or_displacement_tons	weight or displacement of the wreck	3	[tons]	Questionnaires	Wrecks
experimental_professional	describes the type of exploitation, if professional or experimental, of the reef	4		Questionnaires	ARs
scope	describes original conception scopes of the reef	4		Questionnaires	ARs
exploitation	current exploitation of the reef/wreck	4		Questionnaires	NRs, ARs, Wrecks
possible_exploitation	potential exploitation of the reef/wreck	4		Questionnaires	NRs, ARs, Wrecks
observations	additional observations	3		Questionnaires	Wrecks
biocoenosis	presence (and types, if available) of biocoenosis	2		Questionnaires	NRs
alien_species	presence (and names, if available) of alien species	2		Questionnaires	NRs
protected_species	presence (and names, if available) of protected species	2		Questionnaires	NRs
protected_area	presence of a protected area where the reef is placed	2		Questionnaires	NRs
management_prog_Y_N	existing of a management program insisting on the reef/wreck	2		Questionnaires	NRs, ARs, Wrecks
management_body	name of the management body of the reef/wreck (if applicable)	2		DB manager	NRs, ARs, Wrecks
concession_area_Y_N	presence of a concession area insisting on the reef/wreck	2		Questionnaires	ARs, Wrecks
surveillance_service	presence (and name, if available) of a surveillance service on reef/wreck	2		Questionnaires	NRs, ARs, Wrecks

current_monitoring_ program_Y_N	presence of a current monitoring program on reef/wreck	2		Questionnaires	NRs, ARs, Wrecks
monitoring_program s	present or past monitoring program insisting on the reef/wreck	2		Questionnaires	NRs, ARs, Wrecks
available_data	eventually available data related to the reef/wreck	-		Questionnaires	NRs, ARs, Wrecks
available_literature	available literature, scientific or grey	-		Questionnaires	NRs, ARs, Wrecks

Table 2: Column name, the current name of the parameter, type of parameter, unit of measure, origin of the information and eventual applicability restrictions.

4 Data interrogation and visualization

With the purpose of easily exploiting, representing and filtering data, a webGIS was created enabling the contemporary filtering (where applicable) of more than one of the following selected attributes:

- Type of element;
- Country;
- Minimum depth of the reef/wreck;
- Distance from the coastline;
- Usage of the reef/wreck;
- Reef typology (for natural reefs);
- Reef material (for artificial reefs)

The webGIS main page is reachable at the following URL: https://adrireef.github.io/sandbox3/ and it is composed of two user-friendly windows (Fig. 1), one reporting all available data filters (left side) and the other one (right side) showing the map where points, identifying elements, are divided by colour in NRs (green), ARs (blue) and Wrecks (red). Hovering on an element with the mouse, its Name and Location appear in the left bottom corner of the map.

208

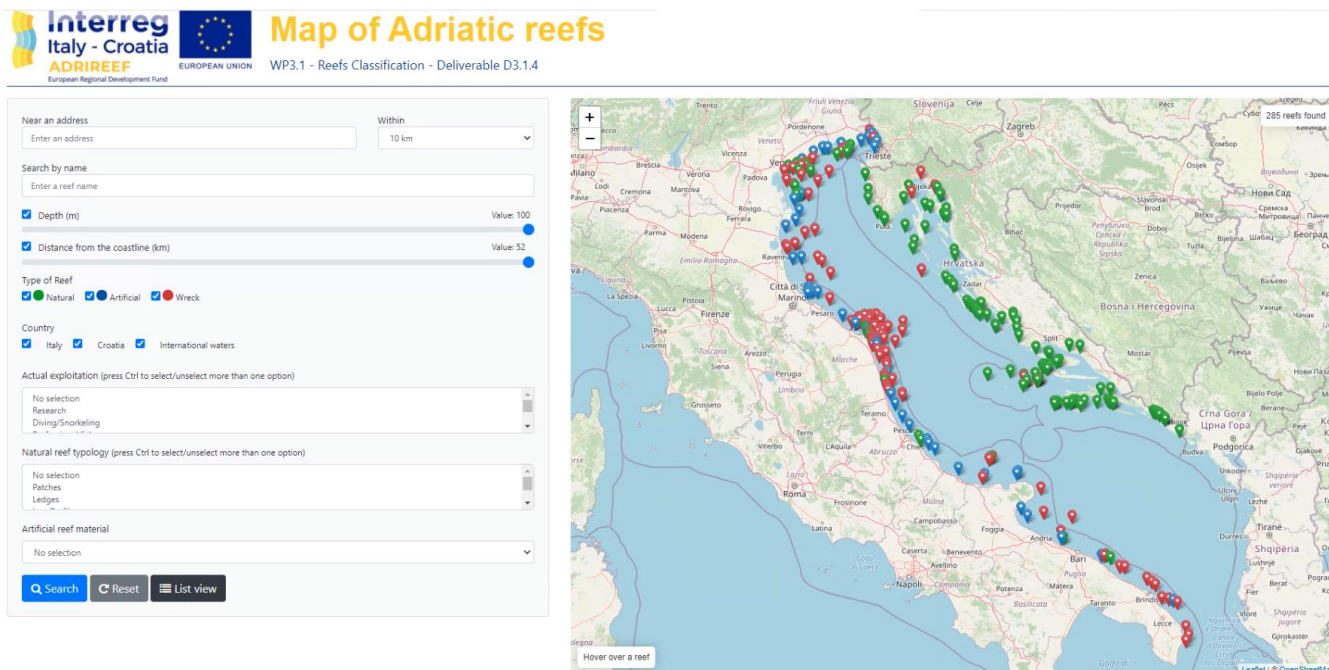
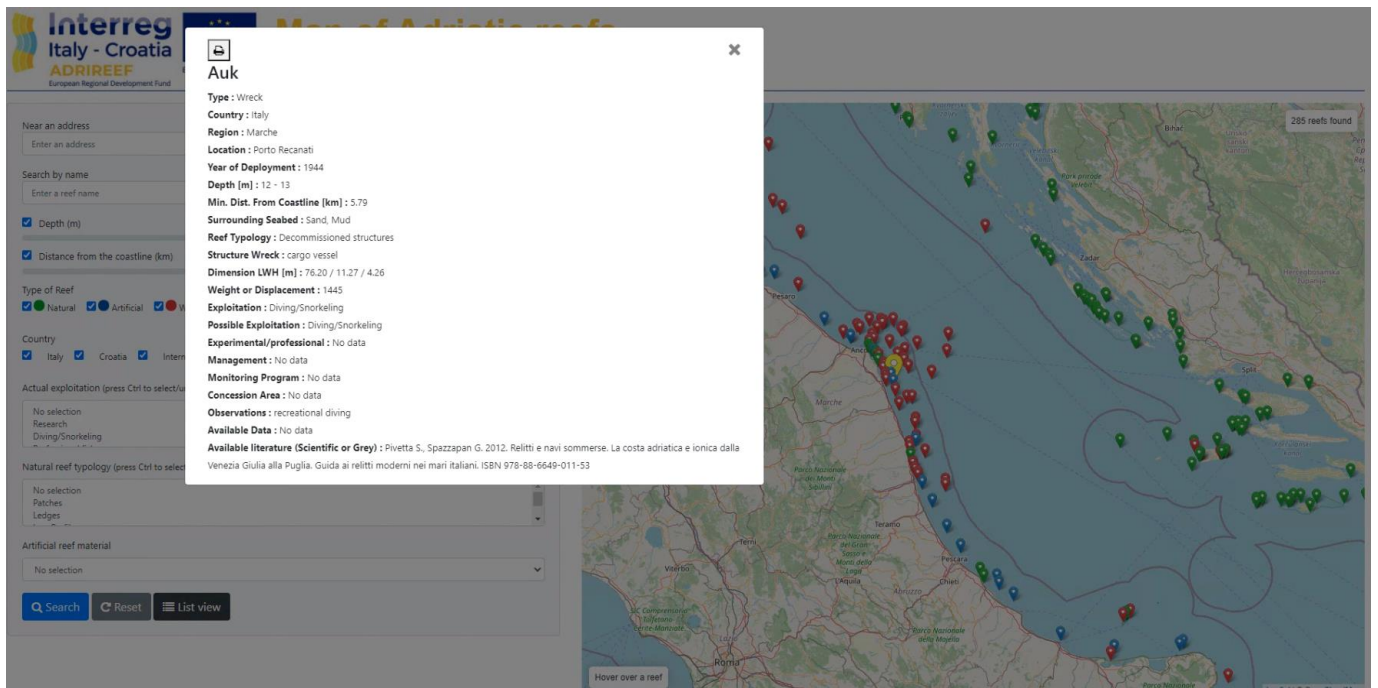



Figure 1: The webGIS interface. On the left side: the filter window. On the right side: the map window with hover function (bottom left) and the total number of identified elements (top right). Basemap credits: © OpenStreetMap contributors 2020. Distributed under a Creative Commons BY-SA License

The total number of currently visualized elements is reported at the top right of the map. Moreover, when an element is clicked, a pop-up window appears showing the associated relevant information (Fig. 2). From this pop-up, it is possible to print out information regarding the selected element in PDF format. From the main page, it is also possible to access to the "List view" that shows, for the visualized elements, some common information throughout natural, artificial reefs and wrecks (Fig. 3). The number of visualized elements, in the top right corner of the map view, is updated accordingly to the output of data filtering operations.

218

219 **Figure 2: Example of the pop up that appears once an element is clicked. Basemap credits: © OpenStreetMap contributors 2020.**

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221

222

223 **Figure 3: List view. Once elements are selected, it is possible to obtain some common information by clicking the "List view" button**

224 **(that turns into "Map view" when the list is visualized, evidenced in red).**

225

226 From a technical point of view, data were entered in .csv format, then transformed in JSON objects as "Collection of Features"

227 class, with prototype (generic) and object (specific) capabilities. For each element, an integer and consecutive identification

228 number was assigned by default. The interactive map has been published using the GitHub Pages extension

229 (https://pages.github.com/), which represents an easy and rapid way to make information quickly available online. The base

230 map coming from the open-source cooperative geographical project OpenStreetMap (https://www.openstreetmap.org/) and the

231 Nominatim package for geocoding operations (https://nominatim.openstreetmap.org/) were used. The whole infrastructure is

232 based on Searchable Map Template – CSV project (https://github.com/datamade/searchable-map-template-csv).

233 **5 Data analysis**

234 Data contained in the database can be analysed in many different ways and for different purposes. For example, Figure 4,

235 representing the wrecks' sink and the artificial reefs' deployment on time (excluding missing information elements), shows

236 that until the end of 1990s the majority of artificial structures occurring on the seabed of the Adriatic Sea were represented by

wrecks, most of which accidentally sunken. Afterwards, almost all the manmade structures deployed on the seabed were purposely-constructed artificial reefs.

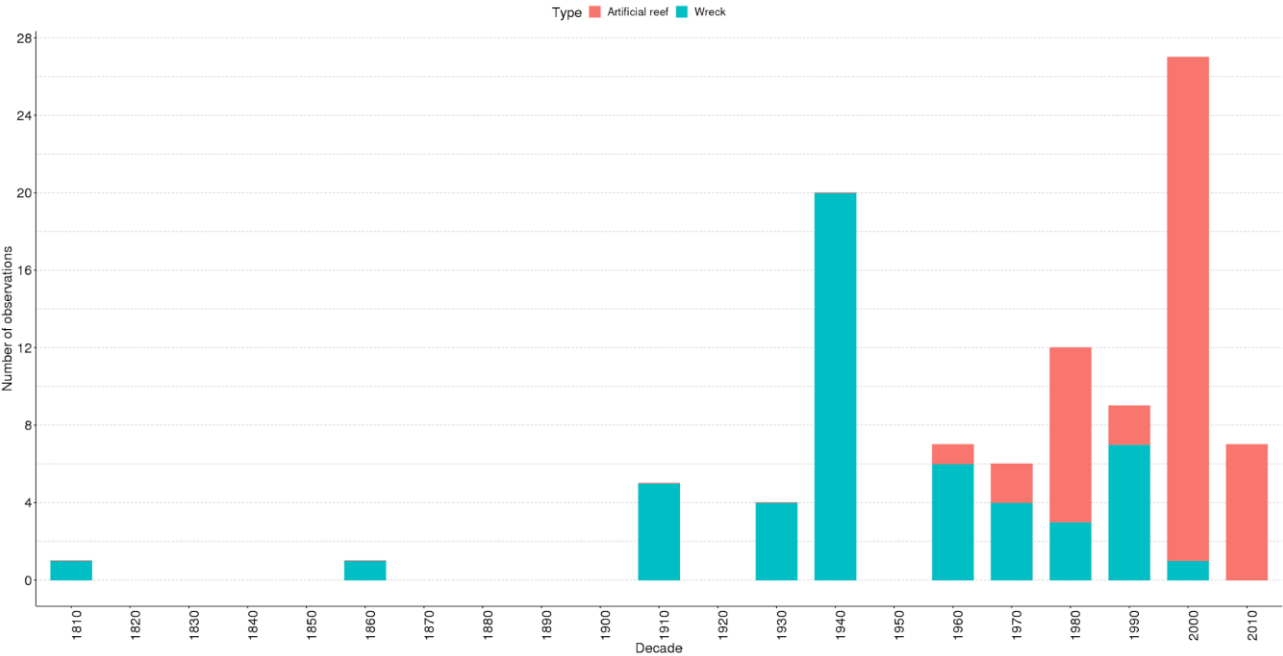
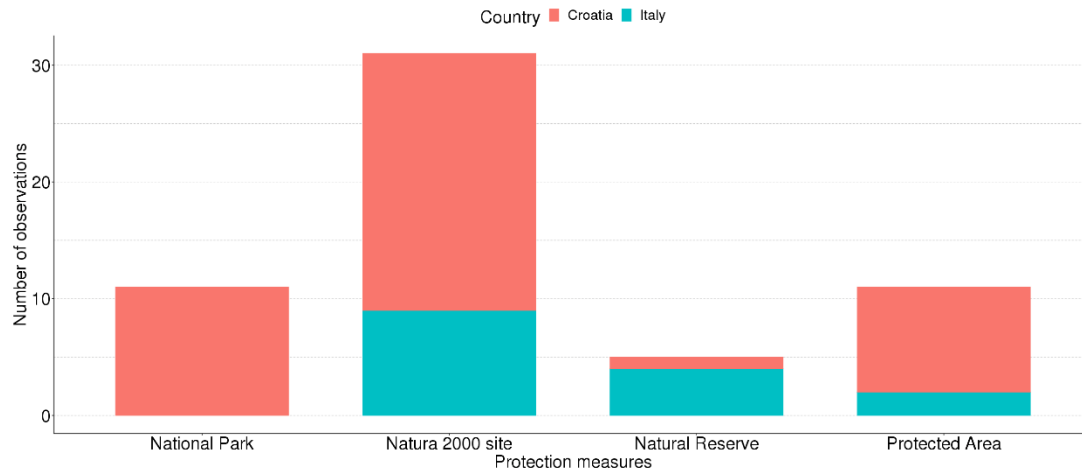



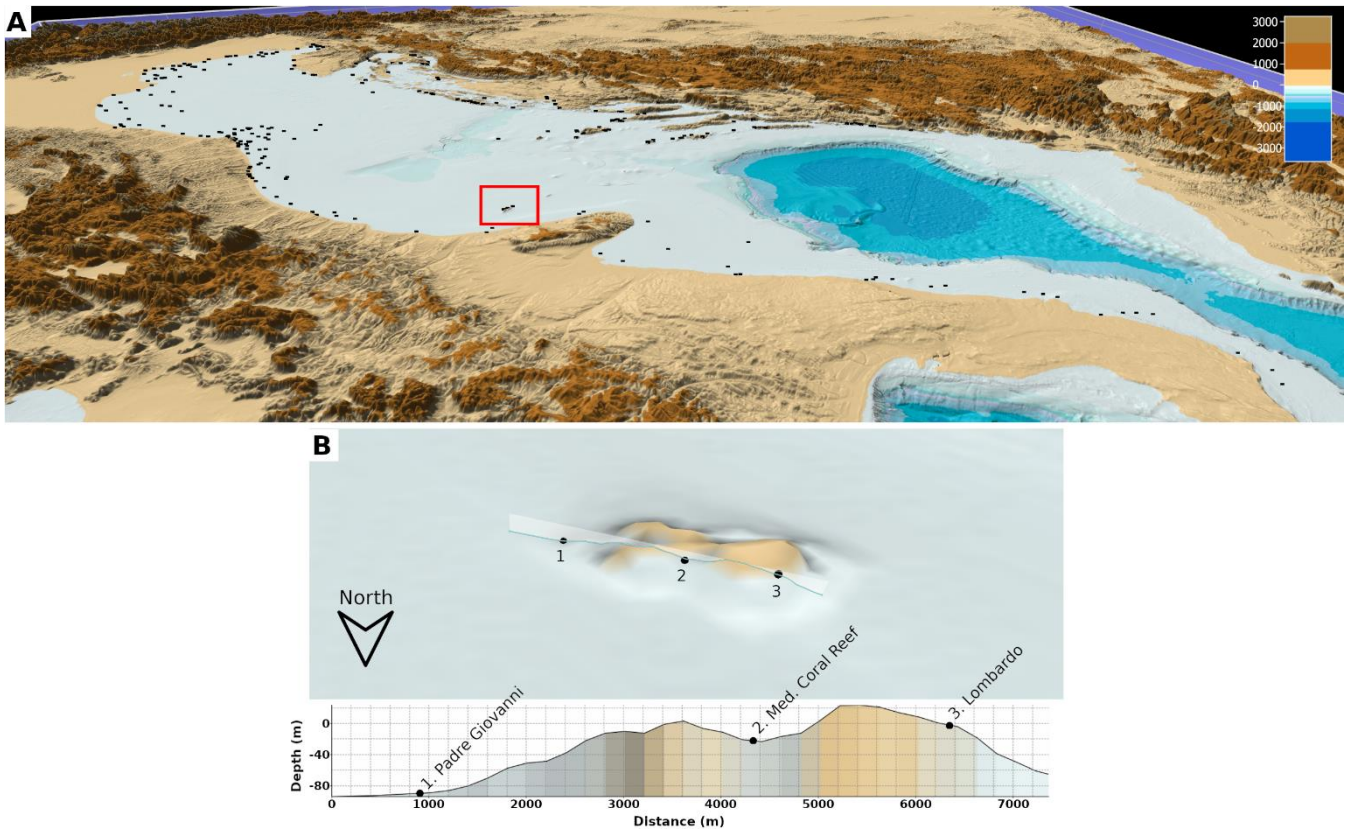
Figure 4. Artificial reefs and wrecks by year of deployment at decadal scale.

Another interesting example of analysis that can be performed on the data is the evaluation of the number of natural reefs subjected to any form of protection. Again, after deduction of "No data", it is possible to identify 31 Natura 2000 sites, 12 Protected areas, 4 Natural reserves and 11 National parks (Fig. 5) with an overlapping at some sites. Figure 5 also shows how NRs are distributed in these categories through Italian and Croatian waters. Coupling this graph with the information contained in Table 1, it results that almost the totality of the Italian natural reefs is subjected to some form of protection, while only half of the Croatian ones are under preservation constraints.

Also, the 3D representation of the sites can be useful for dissemination purposes. For example, in Figure 6 (A) all reefs and wrecks are reported over a bathymetric map of the Adriatic Sea. A section of the Tremiti Islands (Apulia, Italy), connecting three observations of the database is reported in the zoom (B).

253

254   **Figure 5. Protection measures applied to Natural Reefs in Croatia and in Italy.**

255

256

257   **Figure 6. A 3D visualization of the spatial distribution of natural reefs, artificial reefs and wrecks in the Adriatic Sea (A). In the red**
258   **square, the area concerning the zoom reported below. A view of Tremiti Islands and the vertical terrain section from left to right**

259 **side crossing three elements (B): Padre Giovanni and Lombardo wrecks (points no. 1 and 3) and Mediterranean Mesophotic Coral**
260 **Reef (point no. 2).**

6 Data availability

262 The database (Ferrà et al., 2020) is currently available for download through the SEANOE (https://www.seanoe.org/)
263 repository and it is reachable at the following URL: https://doi.org/10.17882/74880. The dataset is also published in the
264 EMODnet (European Marine Observation Data network, Novellino et al., 2015) Data Ingestion Portal and it is currently
265 undergoing the required procedure to be published into the EMODnet catalogues. EMODnet was chosen for two main reasons:
266 it ensures long-term data availability and has increasingly become a reference point for all available European maritime data
267 (Martín Míguez et al., 2019). In fact, the platform was financed in the framework of EU's Integrated Maritime Policy definition
268 (Commission of the European Community, 2007) to unlock existing but fragmented and hidden marine data and make them
269 freely accessible for a wide range of users (Calewaert et al., 2016), while respecting FAIR data management principles
270 (Findable, Accessible, Interoperable, Reusable; Wilkinson et al., 2016). In this way, an invaluable heritage of marine data was
271 collected and all data uploaded in EMODnet are indexed in Web Of Science. The database was released under Creative
272 Commons Attribution license (CC-BY, v. 4.0, https://creativecommons.org/licenses/by/4.0/deed.it)

7 Conclusions

274 The data collection work and publication represent an unprecedented, consistent and robust recognition of the reefs and wrecks
275 in the Adriatic Sea. The database represents a comprehensive collection providing a well-detailed state of the art and some
276 hints on possible/future exploitation of reefs and wrecks in this geographical zone and a tool to implement the EUSAIR strategy
277 (European Commission, 2014), aimed at promoting economic and social prosperity and growth in the Adriatic-Ionian region
278 by creating synergies and fostering coordination in some thematic pillars: sustainable tourism, environmental quality,
279 connecting the region and, in wider terms, the Blue Growth (European Commission, 2017).
280 Indeed, the collected information can be useful for different purposes, from spatial management, to the strengthening of some
281 economic activities and/or development of new ones taking into account the local environmental features
282 Knowing the environmental status and current exploitation level of reefs/wrecks located in a specific geographical area is in
283 fact fundamental to identify potential additional ecosystem services they can provide and, consequently, develop sustainable
284 economic activities with subsequent positive impacts on the local communities (Costanza et al., 2014). In addition, from the
285 research point of view, a comprehensive database like the one presented here could be a starting point for the implementation
286 of ecological studies where the information is still scarce or lacking as well as of monitoring programmes aimed at evaluating
287 the impact of some economic activities (e.g., tourism, small-scale fisheries) on sensitive habitats.
288 Lastly, the interactive map represents a tool that allows, through the simultaneous usage of different filters, to highlight and
289 quantify particularly interesting situations in a user-friendly and quick manner, so to be also easily handled by the wide public.

It could be, for example, used by tourists to identify suitable and less known sites for recreational activities such as snorkelling, diving and sailing.

Overall, the provided collection can be helpful to increase visibility and attractiveness of reefs and wrecks existing in the Adriatic Sea while increasing awareness of both policy makers and citizens towards the need of managing and exploiting these sites in a sustainable way in order to assure their preservation over time.

The general perception derived from an overall evaluation of the collected data is that, in the Adriatic context, reefs and wrecks still represent an underestimated environmental heritage that, if adequately preserved and promoted, could provide in the near future new opportunities for developing activities in line with the Blue Economy.

Appendix A: Natural Reefs Questionnaire

301   1.   Name and Surname: ....

302   2.   Occupational qualification and workplace: ....

303   3.   Name of the reef: ....

304   4.   Location of the reef: ....

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

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

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

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

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

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

311   11. Typology of the reef:

312   ☐ High profile reef (the reef protrudes more than 20 meters from the base substratum)

313   ☐ Low profile reef (the reef protrudes less than 20 meters from the base substratum)

314   ☐ Ledges (vertical reef face characterized by visible crevices)

315   ☐ Boulder reef (structure elevating from the flat seabed)

316   ☐ Patch reef (sand bottom with small reef structures protruding from the sediment)

317   ☐ I don't know

318   12. Origin of the reef:

319   ☐ Biogenic

320   ☐ Geogenic

321   13. Type of surrounding seabed:

322   ☐ Rocks

323   ☐ Sand

324   ☐ Mud

325   ☐ Detritic

326   ☐ Gravel

327   ☐ Other

328   14. Occurrence of meadows?

329   ☐ Yes, phanerogams

330   ☐ Yes, algae

331   ☐ no

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

333   16. Any alien species?

334   ☐ Yes

335   ☐ No

336   ☐ Maybe

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

338   18. Any protected species? (e.g. IUCN Red List of Threatened Species, ASPIM Protocol, Berna Convention, etc.)

339   ☐ Yes

340   ☐ No

341   ☐ Maybe

342   ☐ If "Yes", which species?

343   19. Is the natural reef within a protected area?
344   ☐ Yes, MPA
345   ☐ Yes, Natura 2000 site
346   ☐ Yes, National park
347   ☐ Yes, Natural park
348   ☐ Yes, Marine reserve
349   ☐ No
350   20. Is the reef managed?
351   ☐ Yes
352   ☐ No
353   ☐ I don't know
354   21. If yes, which is the Managing Subject? (Please give a short summary of the management measures adopted)
355   22. Does exist a monitoring program?
356   ☐ Yes
357   ☐ No
358   23. If "Yes" please give a short summary of the program ....
359   24. Surveillance service?
360   ☐ Yes
361   ☐ No
362   25. Current use of the Reef:
363   ☐ Diving
364   ☐ Mariculture
365   ☐ Research
366   ☐ Professional fishery
367   ☐ Recreation fishery
368   ☐ Fishing tourism
369   ☐ Nothing
370   ☐ Other (please, specify) ....
371   26. Development perspectives of the Natural Reef:
372   ☐ Diving
373   ☐ Mariculture
374   ☐ Research
375   ☐ Professional fishery
376   ☐ Recreation fishery
377   ☐ Fishing tourism
378   ☐ Nothing
379   ☐ Other (please, specify) ....
380   27. Please list the available data (If "Other" please specify):
381   ☐ Geophysical map
382   ☐ Water column
383   ☐ Sediments
384   ☐ Benthic community
385   ☐ Fish community
386   ☐ Other (please, specify) ....
387   28. Available literature (Scientific or Grey):
388   (Please add as many papers/works you know about the reef using the scheme:
389   1 Title/ 2 Authors / 3 Year of publication / 4 Journal or project / 5 Pages / 6 Abstract / 7 Keywords)
390

Appendix B: Artificial 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. Year of deployment of the AR: ....
8. Year of modification of the AR: ....
9. Bottom depth (m) (If it is in a range, please specify the max and min): ....
10. Minimum distance from the coast (km): ....
11. Type of surrounding seabed:
    ☐ Rocks
    ☐ Sand
    ☐ Mud
    ☐ Detritic
    ☐ Gravel
    ☐ Other (please, specify) ....
12. 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

436   ☐ Other (please, specify) ....

437 Artificial Reef geometrically assembled to form structures

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

    439   2. Number of deployed structures: ....

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

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

442 Scattered Artificial Reef

    443   1. Number of deployed structures: ....

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

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

    446   1. Number of the oases: ....

    447   2. Distance among oases: ....

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

    449   4. Total area occupied by the Artificial Reef (including the area covered by the bodies, the distance between the bodies

    450   and the area of respect) (m^2): ....

451 **Decommissioned structures**

452 Please specify the nature of the structure:

453 ☐ Offshore extraction platform

454 ☐ Purposely sunk vessel/ship

455 ☐ Other (please, specify) ....

456 Offshore extraction platform:

    457   1. Type of the platform (e.g., one-leg platform): ....

    458   2. Part of the platform used to realize the AR (e.g., jacket, deck): ....

    459   3. Total area occupied by the Artificial Reef (m^2): ....

460 Purposely sunk vessel/ship:

    461   1. Number of sunk vessels: ....

    462   2. Vessel material:

    463   ☐ Wood

    464   ☐ Iron

    465   ☐ Fiberglass

    466   ☐ Other (please, specify) ....

    467   3. Dimension of the sunk vessel/ship - LFT (m) and Weight (ton): ....

468 Other Artificial Reefs:

    469   1. Number of bodies: ....

    470   2. Material of bodies:

    471   ☐ Wood

    472   ☐ Iron

    473   ☐ Fiberglass

    474   ☐ Concrete

    475   ☐ Other (please, specify) ....

    476   3. Dimension of each body - length (m) and Weight (ton): ....

477 **ARTIFICIAL REEF UTILIZATION**

    478   1. Scope:

    479   ☐ Habitat protection

    480   ☐ Habitat restoration

    481   ☐ Finfish enhancement

482		☐ Diving
483		☐ Mariculture
484		☐ Research
485		☐ Professional fishery
486		☐ Recreational fishery
487		☐ Fishing tourism
488		☐ Other (please, specify) ....
489	2.	Type of Artificial Reef:
490		☐ Experimental
491		☐ Professional
492	3.	Is the Reef exploited at present?
493		☐ Yes
494		☐ No
495		☐ Maybe
496		If "Yes", by whom? ....
497	4.	Does exist a management program?
498		☐ Yes
499		☐ No
500		☐ Maybe
501		If "Yes", please specify the Managing Subject and give a short summary of the adopted management measures
502		....
503	5.	Concession area?
504		☐ Yes
505		☐ No
506	6.	Surveillance service?
507		☐ Yes
508		☐ No
509	7.	Does exist a monitoring program?
510		☐ Yes
511		☐ No
512		☐ Maybe
513		If "Yes", please give a short summary (Duration / Monitored aspects / Involved Institute or Agency /address, e-mail
514		address) ....
515	8.	Possible exploitation of the Artificial Reef:
516		☐ Diving
517		☐ Mariculture
518		☐ Research
519		☐ Professional fishery
520		☐ Recreational fishery
521		☐ Fishing tourism
522		☐ Nothing
523		☐ Other (please, specify) ....
524	9.	Please list the available data:
525		☐ Geophysical map
526		☐ Water column
527		☐ Sediments
528		☐ Benthic community
529		☐ Fish community
530		☐ Other (please, specify) ....

531 10. Available literature (Scientific or Grey):
532   (Please add as many papers/works you know about the reef using the scheme: 1 Title/ 2 Authors / 3 Year of
533   publication / 4 Journal or project / 5 Pages / 6 Abstract / 7 Keywords)
534

Appendix C: Wreck Questionnaire

1. Name and Surname: ....
2. Occupational qualification and workplace: ....
3. Name of the Wreck: ....
4. Location of the Wreck: ....
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 accidental sinking of the Wreck: ....
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
12. Vessel material:
    ☐ Wood
    ☐ Iron
    ☐ Fiberglass
    ☐ Other (please, specify) ....
13. Total area occupied by the Wreck (m^2): ....
14. Total volume of the Wreck (m^3): ....
15. Eventual fragments of the Wreck and their spatial configuration:...
16. Dimension of the sunk vessel/ship - LFT (m) and Weight (ton): ....
17. Is the Wreck exploited at present?
    ☐ Yes
    ☐ No
    ☐ Maybe
    If "Yes", by whom? ....
18. 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
    ....
19. Concession area?
    ☐ Yes
    ☐ No
20. Surveillance service?

580	☐ Yes
581	☐ No
582	21. Does exist a monitoring program?
583	☐ Yes
584	☐ No
585	☐ Maybe
586	If "Yes", please give a short summary (Duration / Monitored aspects / Involved Institute or Agency /address, e-mail
587	address) ....
588	22. Possible exploitation of the Wreck:
589	☐ Diving
590	☐ Mariculture
591	☐ Research
592	☐ Professional fishery
593	☐ Recreational fishery
594	☐ Fishing tourism
595	☐ Nothing
596	☐ Other (please, specify) ....
597	23. Please list the available data:
598	☐ Geophysical map
599	☐ Water column
600	☐ Sediments
601	☐ Benthic community
602	☐ Fish community
603	☐ Other (please, specify) ....
604	24. Available literature (Scientific or Grey):
605	(Please add as many papers/works you know about the reef using the scheme: 1 Title/ 2 Authors / 3 Year of
606	publication / 4 Journal or project / 5 Pages / 6 Abstract / 7 Keywords)
607	

Author contribution

AM, CF, GF and ANT worked to the conceptualization of the paper; AM and CF analysed the data and wrote the original draft; AM, ANT, GF, AS, MSc, MSo, DB reviewed and edited the manuscript; CF, AS, MSc, ANT, GF, CRF, CM, SP, ZJ, TŠ, MŠ, CK, DP, EB, MDG, DB, EG, RA, IB, ĐVS, SO, VF, DZ, IOK, MSo, SU contributed to the collection and curation of data descripted in this paper; AM worked at data visualization; GF supervised the whole work.

Competing interests

Authors declare that they have no conflict of interest.

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