A HOLISTIC APPROACH FOR PROMOTING THE BLUE ECONOMY GROWTH: THE CASE STUDY OF THE PAGURO WRECK

Marco Palma, Ubaldo Pantaleo, Nicola Castelnuovo, Carlo del Grande, Monica Previati, *UBICA srl (Underwater BIo-CArtography)*, **Marco Lezzi, Silvia Pigozzi, Cristina Mazziotti,** *ARPAE Agenzia prevenzione ambiente energia dell'Emilia-Romagna*, **Michela Soldati, Silvia Ulazzi, Matteo Parrinello, Giulia Cillani, Emanuela Medeghini**, *Comune di Ravenna - Servizio Tutela Ambiente e Territorio*, **Enrico Barelli** *OnAir srl,* **Ennio Ottaviani,** *OnAir srl, Università degli Studi di Genova Dipartimento di Matematica*, **Massimiliano Pinat**, *Istituto per le Risorse Biologiche e le Biotecnologie - Consiglio Nazionale delle Ricerche (IRBIM-CNR),* **Francesca Visintin**, *eFrame srl*, **Gianna Fabi***, Istituto Scienze Marine - Consiglio Nazionale delle Ricerche (ISMAR-CNR)*

This paper was presented at the 15th OMC Med Energy Conference and Exhibition in Ravenna, Italy, September 28-30, 2021. It was selected for presentation by OMC 2021 Programme Committee following review of information contained in the abstract submitted by the author(s). The Paper as presented at OMC 2021 has not been reviewed by the Programme Committee.

ABSTRACT

Despite the OSPAR Convention decisions, the Oil&Gas installations placed in the marine environment can have positive impacts on marine ecology, providing hard substrates and habitats to species, increasing the local production and supporting activities based on the blue-economy principles. The Paguro wreck is composed of a jack-up platform sunk in 1965 and several decommissioned structures from other offshore assets relocated on and around the wreck since 1990. Nowadays the site is recognised as a hotspot of biodiversity and, since 2019, protected as a Special Area of Conservation. Recreational scuba diving is the only commercial activity allowed in the area. The wreck and the decommissioned structures act as an artificial reef, supporting a complex trophic net and diverse fauna which represent the pivoting point for the biological, economic and social analysis carried out within the framework of the CBC Programme Interreg V-A Italy-Croatia, Adrireef project.

Under Adrireef project, a complex monitoring plan has been carried out. The holistic approach applied to the Paguro study case empowers its attitudes to scientific research, promotes local tourism and encourages its conservation by also engaging the larger public of non-scuba divers.

Based on the Paguro wreck experience, Adrireef project's results can be the base for further applications of reusing dismissed Oil & Gas structures to improve marine ecosystems and to foster the Blue Economy with new business opportunities.

INTRODUCTION

The new strategy of the European Commission for sustainable blue economy in the green transaction context, highlights the importance of scientific research and innovation for protecting and restoring marine ecosystems to achieve climate-neutrality by 2050.
Protecting biodiversity and enhancing climate resilience are key factors for assessing the sustainability of marine and maritime industries and driving new business strategies.
In this regard the Oil&Gas sector is at a turning point. The use of fossil fuel as primary source of energy is decreasing while the sector of renewable energy is growing fast. In accordance with the Environmental Kuznets Curve (EKC) hypothesis defined by Panayotou [1], economic growth implies

a phase of environmental improvement after a period of deterioration. Yao [2] suggests that promoting environmental policies and supporting sustainable energy sources will accelerate EKC to reach its turning point.
From an historical perspective, the Oil&Gas industries started deploying assets at high sea in the mid-twentieth century for depleting new and unreached sources of hydrocarbons. Since then, more than 6000 offshore platforms have been installed around the world and recently the number of decommissioned assets per year have overcome the number of new installations [3]. Most of the platforms at the end of their production life cycle (approximately 50 years) are completely removed following the decommissioning procedures defined by the Protection of the Marine Environment of the North-East Atlantic (OSPAR, 98/3 Decision), which states that disused offshore installations must be considered as dumping sites in accordance with the definition of pollution [4]. However, a large scientific literature has supported the ecological role of disused offshore assets [5]. LGL and SAIC [6] consider platform reefs as a new and distinct habitat rather than an addition to existing reef systems. The structure of offshore platforms favours habitats for the settlement and the growth of invertebrate and fish species [7], supporting complex tropics webs based on local biomass production, and the attraction of other species [8,9]. Benthic communities show to be generally similar to nearby natural reefs but with some variability in species composition, relative abundance and size which is generally larger for mussels, sea stars, and rockfish [3,5,7,10]. The vertical profile of an offshore platform determines a continuum fall of organic material from the top to the bottom of the structure, which in turn support the detritus community colonising the shell beds [5].
In the Mediterranean area, the northern part of the Adriatic Sea has represented an hotspot for natural gas exploitation since the sixties. The jack-up platform Paguro builded in 1963 was drilling new sites when on the 29th of September 1965 it sunk as the consequence of an uncontrolled eruption of underground methane gas. Since then, marine life started colonising the wreck and the site became a natural protected area recognised at the national (DM 21.07.1995 Biological Protection Zone) and the European level Commission (Dec. 2012/14/UE SCI code IT4070026, DM 03.04.2019 Special Area of Conservation). Only scientific and recreational scuba diving are allowed at site.
Thanks to its large bathymetric range, the wreck hosts a complex benthic community. Ponti [11] identified 53 different invertebrate taxa colonizing the wreck by species and photographic sampling. The study showed the community vertical distribution and species dominance. The species *Mytilus galloprovincialis* characterizes the shallower horizon (up to -13 m), and oysters, encrusting sponges, and *Epizoanthus arenaceus* dominated the wreck between -15 and -23 m. While the deeper areas show a less dense community reflecting the water dystrophic conditions near the bottom.
Given the large number of obsolete platforms that will be decommissioned in the next decade, and the European Commission decisions for promoting blue economy growth, the long controversial debate to convert the rigs to reefs is becoming more and more actual, paving the way to consider revising OSPAR Decision (at least partially) [3].
To this end, the Adrireef project (CBC Programme Interreg V-A Italy-Croatia) carried out a complex monitoring plan where biological, oceanographics, socio-economic factors were investigated to identify strengths, weaknesses and opportunities for commercial activities pointing at the blue growth principles. The results underline that the Paguro wreck represents a natural and historical heritage supporting local tourism and public awareness.
For the purpose of the Adrireef project, an artificial reef is defined as ensuring “protection, restoration and regeneration of aquatic habitats, and the promotion of research, recreational opportunities, educational use, sustainable fisheries and aquaculture.” Therefore, within the definition of artificial reefs are included all the accidentally sunk structures and any decommissioned assets intentionally relocated underwater to act as an artificial reef (e.g., rig-to-reefs, sunken ships).

OBJECTIVES

The holistic investigation and monitoring approach tested at the Paguro wreck aimed at:

i) improving marine ecosystems knowledge by monitoring with traditional and innovative methods the water parameters, benthic and fish community at site;

ii) promoting local tourism and the site conservation by engaging scuba divers and the wider public through citizen science based actions and virtual reality immersive experiences;

iii) informing managers on the economic benefits generated by the ecosystem services associated with the alternative use of offshore assets and of decommissioning approaches.

METHODS

The Paguro wreck was studied from July 2019 to July 2021 with a multidisciplinary approach for investigating biotic, abiotic and socio- economic characteristics of the site. A preliminary bathymetric survey with the multibeam echosounder was carried out for planning the underwater sampling of scientific divers. Traditional (i.e. photographic sampling on standard surface, visual census) and new methods (i.e. underwater photogrammetry, stereo videos recording) were applied to characterize the benthic and fish communities. Physical and chemical water parameters were measured regularly as well as the water column currents.

The surveys at the Paguro wreck included the engagement of scuba diver volunteers for mapping the wreck using photogrammetric techniques and to promote the site as touristic attraction.

An in-depth assessment of the legal framework was carried out for identifying the stakeholders to support an ecosystem services analysis (Table 1).

Table 1: **summary of the surveys performed at the Paguro wreck with details on the technology used, the metrics calculated, and the outcomes provided within the Adrireef project**

Study	Technology	Metrics	Output
Bathymetric survey	Multibeam echosounder	georeferenced point cloud	Interactive 3D map available online
Water column chemical and physical parameters	Multiparameter probe and laboratory analysis	Temperature; Salinity; Turbidity; Chlorophyll-a; Oxygen concentration; pH	Long term dataset on water column profile published monthly online
Water column current profile	ACTD probe	water speed and direction every meter depth	Long term dataset on water currents from bottom to surface at 1 meter resolution and recorded with 10 seconds frequency.
Benthos community characterization	Taxonomy identification; Photographic sampling on standard surfaces	Organisms count; Taxa count; Taxa coverage on standard surface; Organisms wet weight and dry weight; Biogenic carbon based shell	Biodiversity indices; Species couverture; Organisms abundance per taxa; Dry weight per taxa; Wet weight per taxa; Shell weight per taxa; Recolonization taxa diversity; Recolonization taxa coverture
Fish census	Stereo videos; Visual census at stationary point	Species diversity; Species abundance; Organisms size	Iconic species selection; Data gathering methods comparison

Photogrammetric survey	Structure from Motion photogrammetry	local referred point cloud	Online Interactive 3D point cloud on scanned wreck; 3D bionomic map; Fouling community volume estimation; Fouling community growth estimation; Volunteer scuba divers training and involvement in scanning activities; Serious Virtual Reality game for simulating a dive at site
Ecosystem services analysis	Survey involving economic operators and literature data analysis	Capacity, flow and benefit indicators related to the selected ecosystem services	Qualitative and quantitative assessment of the socio-economic impact related to the reef exploitation; Swot analysis
Legal framework analysis	Survey involving project partners and legal frameworks analysis	Legal framework in force at local level	Swot analysis; guidelines for reefs' users and recommendations for policy makers and funding agencies

Water column parameters, nutrients and currents

Water column parameters were monitored every 14 days during the summer and monthly for the rest of the year. Samples of water were collected with a CTD multiprobe IDRONAUT 316 Plus from surface to bottom for temperature, salinity, turbidity, chlorophyll-a, Oxygen concentration and pH.
Water samples for nutrients were collected at the sea surface (-1 m) and at sea bottom (-26 m) using a Niskin bottle and analysed to measure the nutrients concentration (P, N, NO3, PO_4^{3-}, NH4, HNO_3, Total N).
Water currents were monitored using an Acoustic Doppler Current Profiler Teledyne (ADCP) Marine Sentinel V100 positioned on the seabed at -25 m in proximity to the Paguro wreck from July 2020 to July 2021. The probe was positioned avoiding any direct proximity to the metallic structure to prevent interference in water current recording. The probe recorded current intensity and direction each meter up to the surface every 10 seconds.

Fouling community composition and biomass

Benthic organisms were sampled by scientific scuba divers scraping off the substrate on standard surface quadrat of 20 cm x 20 cm positioned around the wreck at the depth ranges of -10 m to -14 m, -15 m to -18 m, 19 m to -23 m and inside the wreck at the depth of -20 m. All the quadrats were positioned on vertical substrate to avoid the influence of deposition. Photographic samples were collected before and after the scraping. The collected samples were sorted with a siever at 0.5 mm and fixed in 4% formaldehyde solution. At the laboratory, organisms were identified at the lower possible taxonomic level (genus to species) and abundances of solitary organisms was estimated as number of individuals and for colonial ones was calculated the coverage (cm^2) across the standard sampled surface. In order to estimate the biomass (Dry Weight), organisms were dried at 60°C for 24h. The carbonatic part of the organisms (i.e. shells and worm tubes) were weighted separately and accounted for the estimation of the fouling community weight at square meter. Shell

free dry weight (SFDW) Shell free wet weight (SFWW) and whole wet weight (WW) were also reported per square meters.

Fish census

The fish community at site was studied by applying the traditional method of visual census at stationary point. The method is based on the identification, count and size estimation of fish by scientific scuba divers and by recording stereo videos at stationary points. The two cameras were positioned in parallax and at fixed distance from each other. A calibration board was used at the beginning of each survey and the video to calibrate the cameras and to scale the objects identified at the metric system. Stereo videos were processed with object detectors based on deep learning algorithms (RCNN [12], RetinaNet [13], YOLOv3 [14]) and a user web APIs and interfaces to neural nets implementations made public by https://openmmlab.com/ [15]. Annotated datasets to train networks were generated by project partners experts by using a dedicated designed software.

Photogrammetry surveys

Underwater photogrammetry was performed at site aiming to scan the entire submerged structures. The surveys were performed by two scientific scuba divers by using a full frame Sony Alpha 7-mark III camera equipped with a wide lens optic and 15000 lumens video torches over 15 dives. Calibrated dimensional references were designed with aluminium plates and magnetic supports for the easy and stable deployment on the metallic surfaces of the wreck. Because of the large size of the wreck (jack-up leg is 80 meters in length and the remaining part of the deck is approximately 50 m in length), its high morphological complexity (high number of members and decommissioned added structures), and the need of operating over several months, the structure was sectioned in several components and scanned independently. Every component was scanned including at least 3 dimensional references.
Data collected during the photogrammetry surveys were processed in different way and used for different purposes (Figure 1).
The whole scanned area was processed to generate a scaled point cloud and aligned with the three-dimensional bathymetric data collected at site with the multibeam echosounder. Both were converted and loaded into a dedicated online visualization application based on WebGL technology [16].
The photographic dataset recorded during the scanning was analysed for segmenting the benthic communities around the wreck and generating a bionomic map.

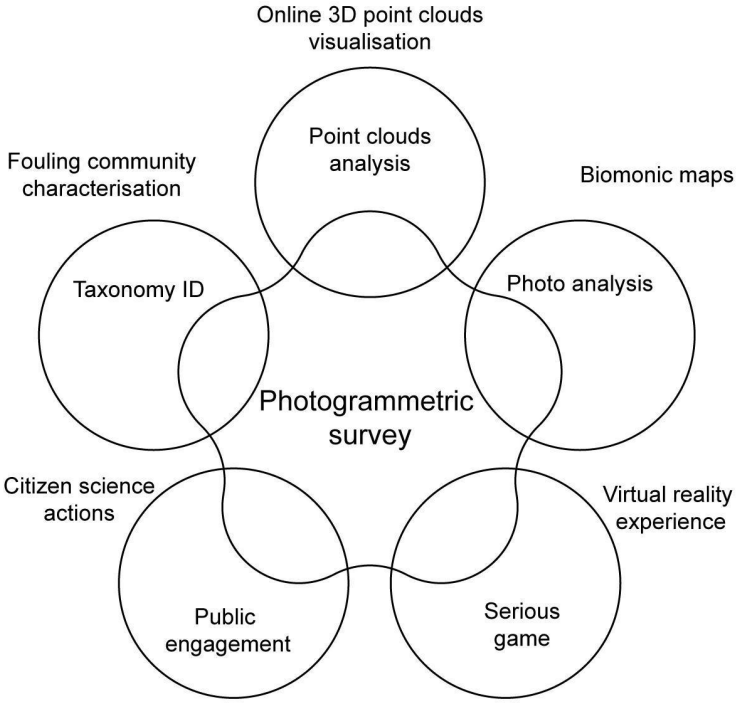

Figure 1: the underwater photogrammetric surveys performed at Paguro wreck were used for supporting several project outcomes demonstrating the high flexibility of the technology and the possibility to use the same original dataset for several different analyses.

The high resolution 3D textured model of the scanned areas was optimised to a low number of polygon models preserving roughness detail by using UV maps (i.e. normals, occlusion, displacements). The resulting object was embedded in a 3D seascape scene for producing a virtual reality experience simulating a scuba diving around the wreck.
The experience gained during operations was used to perform two training events on underwater photogrammetry at Paguro wreck for the involvement of volunteer scuba divers. A practical session of underwater scanning at the Paguro wreck followed the training events.
Benthos community analysis was integrated with a photogrammetric dataset collected on small areas (approximately 3 m^2) at the same depth ranges where samples were collected for taxonomic identification and biomass estimation. High resolution 3D models were processed and the primitive geometries of the original metallic substratum (i.e. a pipe, a plane) were calculated to calculate the volume of the ongrowing fouling community.

Ecosystem services analysis

The economic benefits provided to human activities by ecosystem services at natural and artificial reefs were analysed. Fisheries, aquaculture and shellfish farming, and coastal tourism (recreational scuba diving and boat excursions) were identified as blue economy activities considered in the project. To such activities, it was added scientific research and its application as a further domain to be investigated for assessing the overall benefits provided by ecosystems services also in terms of knowledge development and knowledge-based economy.

For promoting the attitudes of the site, both legal and economic feasibility were assessed. The legal framework for a sustainable exploitation of the reefs was studied with the involvement of the project partners and the criteria for the economic sustainable use of the site were designed.

Stakeholders were identified and their potential benefits in the Paguro wreck exploitation were assessed according to the assessed capacities of the identified ecosystem services following the CICES classification [17]. The capacity indicator based on ecological data should provide the extent and condition of the ecosystem in a way that sustainability threshold could be established and

allow the calculation of the potential flow or sustainable flow as defined by La Notte [18]. If the actual flow of the service is equal or below the potential flow, then the capacity to provide the same or enhanced amount of ecosystem service is guaranteed, otherwise the exploitation leads to degradation.

RESULTS

Water column parameters, nutrients and currents

Data collected at the Paguro wreck contributed to implementing the information available at offshore sites in the Adriatic Sea. The Temperature, Salinity, Turbidity, Chlorophyll -a and Oxygen concentration data, along the water column were near real time after each survey and published and interactive plots on the social media project profile. The communication intended to provide accurate punctual information on the water conditions at site for recreational scuba divers and diving centres.
The data recorded with the ADCP were processed to identify the extreme environmental conditions at site which may have caused structural changes on the wreck; water current velocity reached 70 cm/ second the 27th of December 2020 and 50 cm/second the 14th February 2021 and from 200° of direction. After the winter period, in March 2021, some parts of the wreck were observed to have fallen apart and probably because of these winter extreme environmental conditions (Figure 2).

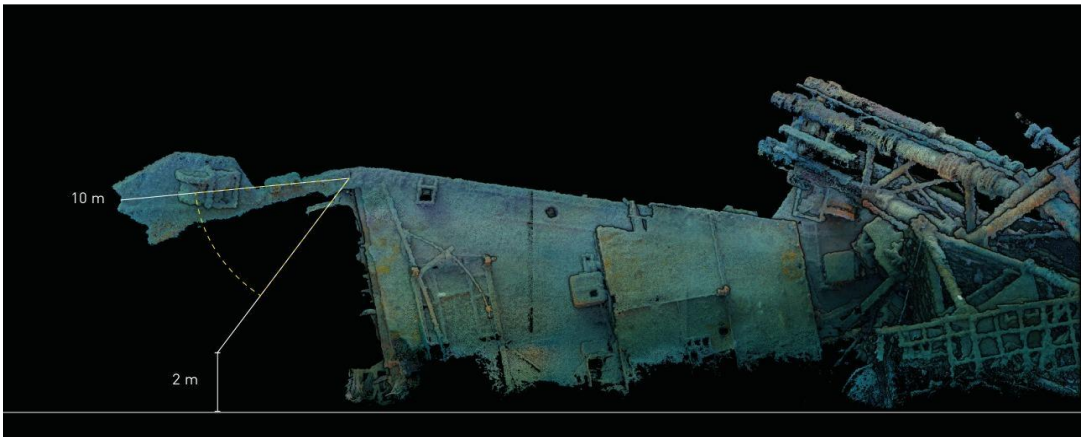

Figure 2: part of the Paguro wreck that was fallen apart during the 2021 winter period.

Water current data provided information for the better understanding of the benthic community diversity, distribution, and recruitment processes at site. Major current direction is North- South oriented according to the general Adriatic Sea water circulation and impact the wreck on the helideck and living modules side.

Fouling community composition and biomass

In total, 60 taxa were identified. Phylum Annelida is the most represented with 19 species identified, followed by Mollusca (15 species), Arthropoda (12 species), Porifera (5 species), Cnidaria (4 species), Bryozoa (2 species), Echinodermata (2 species) and one species for phylum Nemertea and Sipuncula (Table 2).
In the depth range from -10 m to -14 m, the community are dominated by filter feeders as the mollusc *Mytilus galloprovincialis,* the sponge *Halicona mediterranea* and encrusting sponges (eg. *Crambe crambe*) together with detritivorous vagile species (*Chorophium sextone* and *Ophiotrix*

fragilis and *Amphipolis squamata*). It is worth noting in these areas the presence of *Epizoanthus arenaceus*. The calculated biomass reaches about 320g/m^2 (SFDW) and 2.5 kg /m^2 (SFWW) , and 8.5 kg/m^2 (WW) when the weight of carbonatic parts were included. From -15 m to -18 m depth the most abundant taxa were the Mediterranean zoanthid *E. arenaceus* together with encrusting sponges, the bryozoan *Scrupocellaria scruposa* hte amphipod *C. sextone* and the ophiuroid *O. fragilis*. In this depth range the biomass reaches about 170 gr/m^2 (SFDW) and 0.9 kg/m^2 (SFWW), and 4.5 kg m^2 (WW). In the deepest bathymetry range (-20 m) the most abundant taxa were *C. sextone E.* arenaceus and encrusting sponges that includes *Crambe crambe*, *Dysidea* spp. and *Spirastella* spp. There are also other species such as the isopod *Uromunna petiti,* the serpulid *Pomatoceros triqueter* and *O. fragilis*. Moreover, the biomass reaches about 160 gr/m^2 (SFDW) and 0.9 kg/m^2 (SFWW), and 4.6 kg m^2 (WW). In the internal part of the wreck, at -20 meterher depth, the most abundant species were *E. arenaceus* and *Dysidea* spp. and other numerous encrusting sponges. Here the biomass reaches about 60gr/m^2 (SFDW) and 0.45 kg/m^2 (SFWW), and 1.3 kg/m^2 (WW).

Table 2: check list of identified species

Class	Species		
Annelida	*Aphelochaeta sp.*	*Polydora hoplura*	*Glycera tesselata*
	Caulleriella viridis	*Prionospio sp.*	*Harmothoe spinifera*
	Dodecaceria concharum	*Protocirrineris sp.*	*Sphaerosyllis hystrix*
	Exogone naidina	*Protula sp.*	*Spirobranchus triqueter*
	Filograna implexa	*Serpula vermicularis*	*Lumbrineris coccinea*
	Marphysa sanguinea	*Timarete sp.*	*Syllis gracilis*
	Platynereis dumerilii	*Pilumnus hirtellus*	
Arthropoda	*Alpheus macrocheles*	*Plumulojassa ocia*	*Janira maculosa*
	Cerapopsis longipes	*Stenothoe monoculoides*	*Monocorophium sextonae*
	Elasmopus rapax	*Uromunna petiti*	*Balanus trigonus*
	Ericthonius brasiliensis	*Trygaeus communis*	
Bryozoa	*Schizoporella errata*	*Scrupocellaria scruposa*	
Cnidaria	*Actinaraea ind.*	*Epizoanthus arenaceus*	*Corynactis viridis*
	Idrozoa indet.		
Echinodermata	*Amphipholis squamata*	*Ophiothrix fragilis*	
Mollusca	*Anomia ephippium*	*Musculus subpictus*	*Hiatella arctica*
	Arca noae	*Mytilus galloprovincialis*	*Mimachlamys varia*

	Arca tetragona	*Ostrea edulis*	*Modiolus barbatus*
	Arcidae sp.	*Rocellaria dubia*	*Striarca lactea*
	Bittium scabrum		
Nemertea	*Nemertea ind.*		
Porifera	*Sycon sp.*	*Spirastrella* spp.	*Haliclona (Reniera) mediterranea*
	Dysidea spp.	Encrusting sponge sp. 1	
Sipuncula	*Phascolosoma (Phascolosoma) granulatum*		

Fish census

Fish community at the sampling stations is mainly represented by pelagic and demersal fish species. *Boobs boobs* and *Chromis chromis* are the most abundant species living the wreck over the whole year (Figure 3). *Diplodus annularis, D. vulgaris, Oblada melanura, Serranus scriba, Spicara maena, Sciaena umbra, Scorpaena scrofa, Sparus aurata* are the most iconic species that were observed during the summer period in addition to *B. boobs* and *C. Chromis*. Changes in dimensional class ranges were observed for *C. chromis* over the year; summer period showed high frequency of small size individuals (0 to 2 cm in length) demonstrating that the species completes its living cycle at site.
Not frequent species were also observed during operation at site and reported; *Thunnus thynnus, Seriola dumerili*, *Sarda sarda* are attracted to the wreck for hunting local reef fishes and were observed especially during the summer period when water horizontal visibility reaches 10 metres.

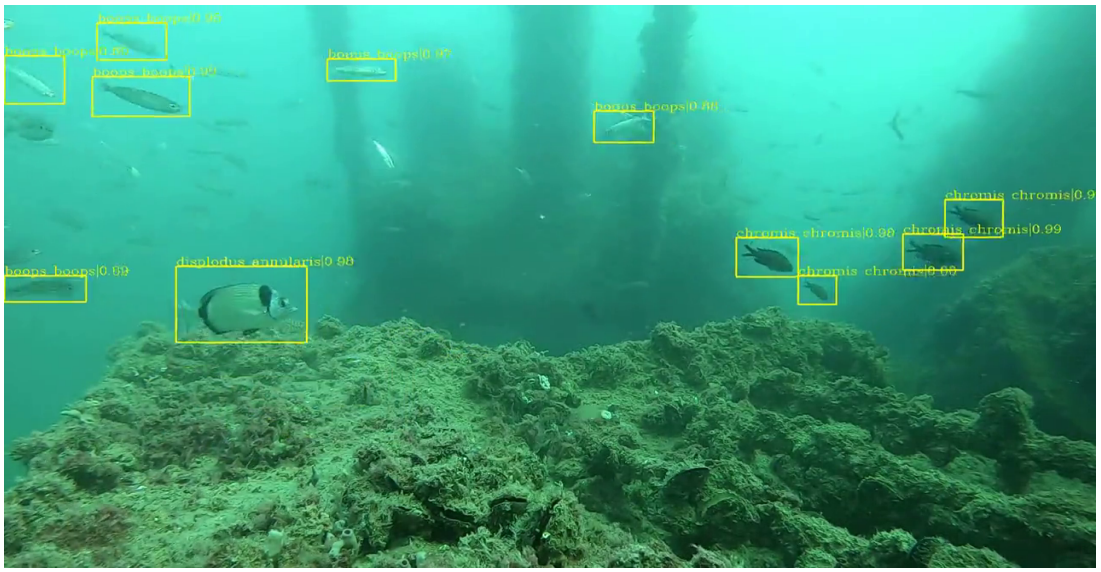

Figure 3: example of a stereo video frame processed to identify fishes' species and the calculating individual length.

Photogrammetry surveys

The dataset resulting from underwater photogrammetry surveys, including those collected with the participation of scuba diver volunteers, was processed to generate a 3D scaled and optimised model for mobile devices of the sunk jack-up rig and of the decommissioned structures. A Virtual Reality based app was developed using the generated 3D model within a virtual seascape environment (Figure 4). The App was developed for standalone virtual reality headset Oculus Quest 2 and is populated with schools of animated models of the most iconic fish species described at site.

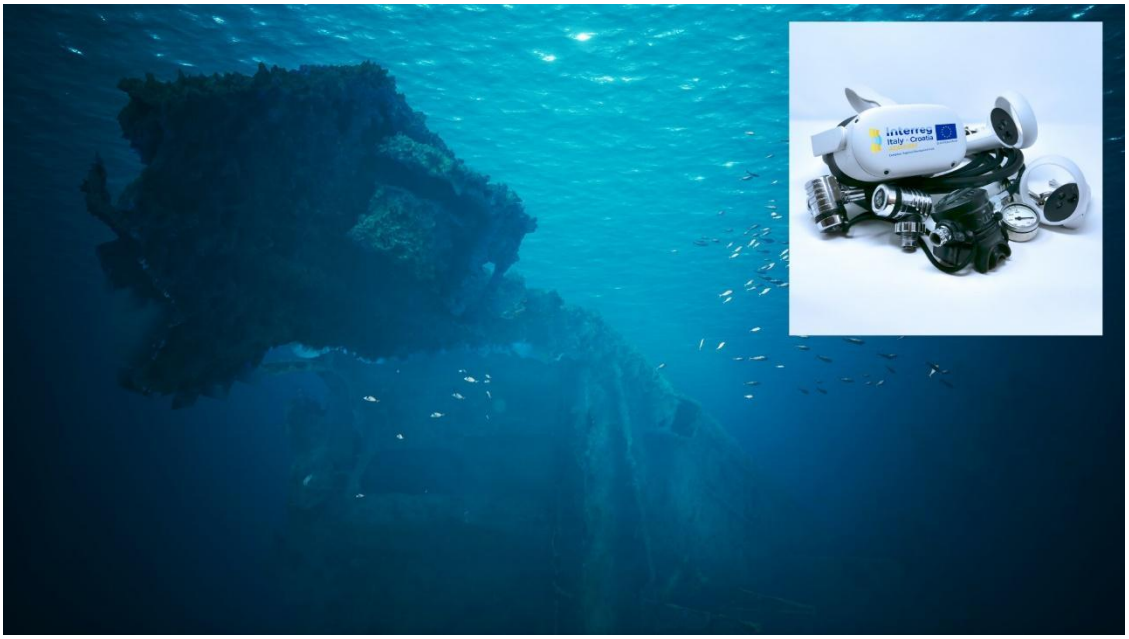

Figure 4: View of the virtual reality app during the exploration of the Paguro wreck with the Oculus Quest 2 headset.

The georeferenced point cloud generated with the multibeam echosounder covering an area of 7.1 He, was aligned with the point cloud of the areas of the wreck mapped through underwater photogrammetry and uploaded to a dedicated online platform where users can view and interact with the scaled dataset (Figure 5).

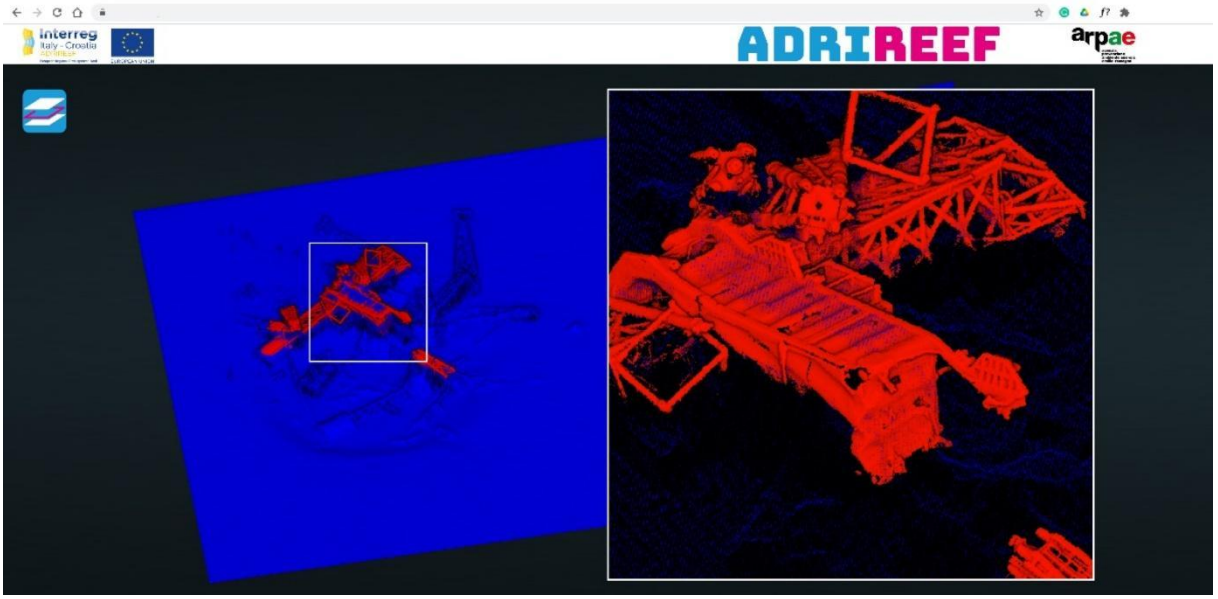

Figure 5: the online platform to interact and view the 3D point clouds of the mapped areas of the Paguro and surrounding structures. In blue the bathymetric survey performed with multibeam echosounder; in red the areas mapped through underwater photogrammetry.

The point cloud of the mapped area of the wreck was classified according to the biocenosis and the composition of the benthic community. The twilight community and the infralittoral community were identified; the first mainly represented by the presence of the filter feeder *Ostrea edulis* and detritivorous species (i.e. *O. fragilis*) that populated the deeper areas and the sheltered part of the wreck. Inside structures where low light condition and low water circulation are key factors, the presence of *O. fragilis* is generally substituted with a continuous pattern of *E. arenaceus.* The infralittoral community is dominated by *M. galloprovincialis,* and several species of sponges (i.e. *H. mediterranea*).
The reference areas mapped with photogrammetric techniques and processed to estimate the volume occupied by the fouling community showed that the higher volumes were associated to the shallower community where *M. galloprovincialis* is dominant (74.5k cm^3) (Figure 6). Deeper communities showed a lower level of biogenic contribution to the three dimensionality of the structure; between 15 m to -18 m the estimated volume reached 52.4k cm^3, and from 19 m to -23 m the estimated volume was 32.7k cm^3 where the biomass associated is lower and the shellfish sparser.

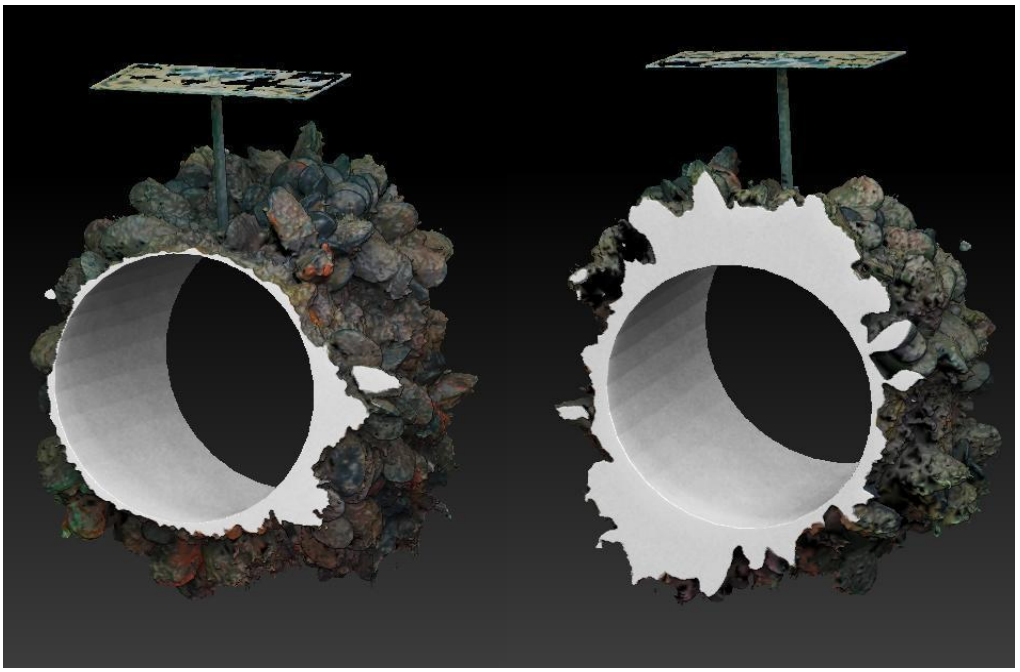

Figure 6: the volumetric estimation of the fouling community at the depth range of -10 m to -14 m has been calculated by fitting a cylinder within the scanned area for extruding the volume occupied by a standard dimensioned pipe of 55 cm in diameter. The highly dense point cloud has been interpolated to generate e high number of polygon mesh for the calculation of the internal volume.

Ecosystem services analysis

The following ecosystem services were identified by adopting the CICES classification: “Wild animals and their outputs", “Experiential use of plants, animals and land-/seascapes in different environmental settings". Both ecosystem services are analysed from the socio-economic point of view by assessing the related capacity of providing a service, the flow (actual use of that service) and benefit indicators in terms of socio-economic value as perceived by the community [19,20] (Table 3).

Table 3: selected indicators following the CISES classification.

CAPACITY INDICATOR	Percentage or extent of marine protected areas
	Presence and list of iconic species
	Educational and scientific facilities
	Fish and shellfish abundance
FLOW INDICATOR	Number of economic operators operating at site
	Recreational and educational activity flows
	Number of research projects and publications related
	Fish and shellfish caught/landed from site
	Number of facilities nearby the site
BENEFIT INDICATOR	Employment rates
	Revenue of diving centers
	Fish and shellfish market value
	Excursions' prices
	Research projects' budget

A questionnaire for investigating the selected indicators was designed and filled by four identified economic activities (fisheries, aquacultures and shellfish farming, boat excursions and diving centres). The questionnaire with 36 open questions, 7 multiple choice questions, is divided in two sections for investigation of the actual and the potential business development at site.
From the gathered data it is possible to estimate the interest related to the reef exploitation and the impact in terms of both revenue and human resources involved.
A second questionnaire for collecting data and investing the local legal frameworks was designed and filled by project partners and local stakeholders (local authorities responsible for the legal framework): it is composed of 39 multiple choice questions, divided in 5 sections (1 on general characteristics of the legal framework; 4 on the specific characteristics of the legal framework related to the investigated economic activities), with open fields for integrating the choices with specific information and data. From the gathered data it is possible to assess if and how the targeted economic activities are regulated (both permitted and prohibited activity), how the legal framework is impacting on the valorisation of the ecosystems services as well as to provide some recommendations about how to redesign the legal framework to support blue growth development at site with guidelines for reefs' users and recommendations for policy makers and funding agencies.

CONCLUSIONS

The Interreg Italy-Croatia Adrireef project represented the unique opportunity to develop a multidisciplinary framework to characterize, monitor and promote the sustainable use the Paguro rig wreck as natural and cultural heritage.

The presented methods included traditional approaches integrated with innovative technologies, such as deep learning for fish tracking and census and underwater photogrammetry for estimating i) the volume of the fouling community, ii) developing tools for interactive data visualization, iii) creating 3D bionomic maps, iv) producing virtual reality immersive experience and v) engaging scuba diver volunteers to scan the wreck.

The study insight on the opportunity of promoting the ecological and cultural value of the existing offshore assets to support blue growth economy-based activities as suitable alternative to the complete removal at the end of the production life.

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