The underwater wonderland of ancient Puglia

Conference Paper · May 2021

CITATIONS
0

READS
29

2 authors:

Italo Spada
CETMA - Technologies, Design and Materials Research Centre
24 PUBLICATIONS **50** CITATIONS
SEE PROFILE

Nicoletta Spisso
Centro di Progettazione, Design e Tecnologie dei Materiali
4 PUBLICATIONS **0** CITATIONS
SEE PROFILE

The underwater wonderland of ancient Puglia

Rita Auriemma[1], Italo Spada[2], Giuseppe De Prezzo[2], Nicoletta Spisso[2], Andrea Picciolo[3], Cosimo Buccolieri[4], Simone Parizzi[5], Elisa Costa[6]

[1] University of Salento, Department of Cultural Heritage (rita.auriemma@unisalento.it)
[2] CETMA (Technologies Design and Materials European Research Centre), Brindisi, Italy (italo.spada@cetma.it; giuseppe.deprezzo; nicoletta.spisso@cetma.it)
[3] Anton Dohrn, Zoological Station, Napoli (andrea.picciolo@szn.it)
[4] Environmentalist coordination Pro Porto Cesareo Onlus (minobuccolieri@gmail.com)
[5] Indipendent researcher (archeaoengineering@gmail.com)
[6] University of Venice Ca' Foscari, Department of Humanities (elisa.costa@unive.it)

Keywords: Puglia, underwater photogrammetry, underwater 360° video, 3D modeling, wearable VR device

Abstract

The projects Puglia Seascapes - looking at Apulia from an underwater perspective – and UnderwaterMuse, Immersive Underwater Museum Experience for a wider inclusion, both coordinated by Puglia Region, aim to make a significant contribution to better understanding of the underwater cultural heritage; the study cases concern different sites in the Marine Protected Areas of Porto Cesareo and Torre Guaceto: a cargo of columns from Evia island and another cargo of amphoras scattered in the shallow waters of Torre Chianca (Porto Cesareo, Lecce) and the remains of a Late Antique cargo (V-VI century AD) found in the waters of Torre Guaceto (Brindisi). The interpretation of the archaeological and geoarchaeological data about the sites, their formation process and the coastal landscape evolution, as well as the 3D models obtained through photogrammetry techniques based on SfM (Structure from Motion) and underwater 360° and 5K videos, allowed us to develope a methodological and technological protocol based on the use of a software (App), i.e. Puglia Seascapes VR. It provides suggestive scenarios through advanced 3D modeling and animation techniques and results in interactive videos shoot that reconstruct and above all narrate in an emotional way the last journey of the ship in the ancient seascape, deeply different from the current, and the formation of underwater context. Moreover, the application of immersive techniques accessible from a single VR application for wearable devices allows the large public to discover new environments and the scholars to face to a new approach for rewriting the history of ancient Italy.

1. Introduction

Virtual reality applications, which allow the user to visualize and interact with multimedia data of different nature, are still very rare on the market. Most of the applications developed for devices such as Oculus visors are characterized by artificial 3D contents or 360° spherical photos that only capture the current state of an archaeological evidence. This modality of virtual experience does not allow users to understand the history of

the archeological context and the profound evolution of the landscapes, but it represents just a picture of what history has preserved.

The collaboration between CETMA, University of Salento, University of Venice and Marine Protected Area Porto Cesareo in the framework of the project *Puglia Seascapes - looking at Apulia from an underwater perspective* by Regione Puglia, allowed to design and develop a virtual reality application (*Puglia Seascapes app*) aimed at transporting users virtually into the historical events and into the landscapes/seascapes related to two ancient ships and their last seafaring in an immersive way through high-impact multimedia contents and an immersive data fusion. With the application it is possible to go back in the past before the sinking and then explore the shipwrecks at the actual state under the sea. The digital scenes have been realized using advanced 3D modelling techniques for the real time interaction.

2. Materials and Methods

- The activity planning has foreseen this workflow:

- context analysis and survey of the archaeological evidence

- Collection of technical documentation: photogrammetry and 3D model reconstruction

- Archaeological databased interpretation of the historical events: storytelling

- 360° digital scenes set up

- Virtual Reality application

2.1. The first context/case study: the columns shipwreck of Torre Chianca (Porto Cesareo, Lecce)

Between seventeen or eighteen centuries ago, in the sea of Porto Cesareo, between the promontory of Torre Chianca and the islet of Malva, a ship carrying a monumental marble cargo ended its journey that had begun in the Aegean Sea (fig. 1a-b)[1]. The cargo made up of 5 monolithic columns, in a perfectly parallel position, oriented in the N-S direction and about 50 cm apart, encrusted with limestone deposits; little less 9 m long, with a diameter ranging between 85 and 97 cm, they are made of Cipollino marble[2] from Karistos, on the Evia island (samples were taken and analyzed). Between the first and the second monolith (from the east) there is probably a lead artefact, triangular in shape, with numerous grooves, flattened under the columns. The second presents a long transversal gap (which Congedo considers recent). All are presented unfinished or half-worked. A parallelepiped block lies perpendicular to the columns, immediately N of them, while another, uncovered only for a length of 60 cm, is located next to the metal artifact, always below the column, arranged in the N-S direction. In 1964, 14 marble fragments of various sizes and qualities, mainly slabs, were recovered (n. inv. 205177), together with many ceramic sherds. Noteworthy are two amphoras fragments, pertaining the types of Africana II (presumably) and Tripolitana III, both consistent with the presumed chronology to the end of 2nd – 3rd cent. AD. The 1994 survey in the surrounding area, with the use of the water dredge, identified only ceramic material, mostly amphorae and bricks, fragmented and heterogeneous (both "classical" and late antiquity productions were recognized). Marble was noted under the columns. The photogrammetric survey carried out in 2017 by the team from Ca' Foscari university (project '*The routes of the antique marble*' led by

[1] Auriemma 2004, II, 13-14 (SR 6), with references.
[2] So called due the color but especially the layered surface that recalls the onion, that is "cipolla" in Italian.

C. Beltrame) achieved more precise data about dimension, volume and weight of the cargo, and also a reconstructive hypothesis.

Although it was also carried out in the most ancient age, the trade in marble, both raw, simple quarry blocks, and half-worked or finished items (columns, capitals, sarcophagi, slabs, statues, basins, etc.) took on in Roman times, especially Imperial, considerable relevance, with a clear peak in the third century AD: since the 1st century AD there is a state organization for the collection and use of marble, which involved the Imperial property of the quarries and the private contractors. The transport obviously took place by sea: the marbles, embarked on ships of private owners, reached Rome or other metropolises of the Empire, were deposited in warehouses, processed and used in large, monumental works[3].

Although the reconstruction of the routes of these ships is not easy, because of the scarcity of indications available from pottery, it is possible to state that the cargoes, for example of Proconnesian marble, were destined for huge – probably public – monuments[4].

It has already been reported the "marble road" which from the Aegean, after having rounded the fearsome Capo Iapigio, current Capo di Leuca, crossed the Ionian Sea south of Taranto, probably at level of Gallipoli/Porto Cesareo[5]: this is attested by the literary sources[6], but also by the number of the wrecks found both along the Salento coasts in Porto Cesareo, S. Pietro in Bevagna and Torre Sgarrata[7], and, at the same height, along the Calabrian coasts; these are the deposits of Punta Scifo A, the "imperial" marble wreck, probably headed for Porto[8], Punta Scifo D[9], Capo Cimiti, twin - in terms of composition and size of the load - of that of Torre Chianca[10], Cala Cicala[11] and Secche di Capo Bianco[12].

Some of these ships carrying marble were very large vessels which had a particularly strong structure (such as a double layer of mortise and tenons joining the planking), comparable only with the large *onerariae* of the Late Republican period, such as the Madrague de Giens (France) (320-350 tons of cargo) and the Albenga (Italy) (about 500 tons) wrecks[13], but others – such as the one of Torre Chianca, show standard “medium” size, around 80-100 tons.

Nevertheless, the dimension of the five columns suggest they were destined to important and probably public buildings, as it is suggested by C. Beltrame[14] for the column from Marzamemi I shipwreck, however shorter even if wider (6.4 long and m 1.85 wide) of the Torre Chianca ones.

[3] Russell 2011, 2013a, 2013b.
[4] Beltrame 2021.
[5] Gianfrotta, Pomey 1981, 215 ff.; Gianfrotta 1988, 122.
[6] *Liv*. XXVI, 42.
[7] Auriemma 2004, II, 18-9 (SR 7, S. Pietro in Bevagna); 41-42 (SR 48 – Torre Sgarrata), in both cases with references. Further data related to T. Sgarrata wreck in Gabellone at al. 2009; Calia et al. 2009; for S. Pietro. Petriaggi, Davidde 2010 (intervention of Central Institute for Restoration aimed at the site enhancement).
[8] Pensabene 1978; Pensabene 2002, 36-37, 45; Medaglia 2010, 290-293..
[9] Medaglia, Beltrame, Lazzarini 2014.
[10] The cargo consists in 6 column shafts of green cipollino marble: Pensabene 2002, p. 40, n. 9.
[11] It is a cargo of marble in the form of just-hewn blocks from the Greek island of Thasos, in the northern Aegean Sea, very similar to that of Torre Sgarrata near Taranto: Antonelli et al. 2020.
[12] The marble cargo dates back to modern age, between 18th and 19th cent.: Beltrame, Medaglia 2012; Beltrame, Lazzarini, Medaglia 2012.
[13] Gianfrotta 2016; Beltrame, Lazzarini, Parizzi 2016; Parizzi, Beltrame 2020; Beltrame 2021.
[14] Beltrame 2021, 455.

In the case of the Torre Chianca shipwreck we can easily postulate that the ship, like the others that mainly transported columns – Capo Taormina (Taormina I), Giardini Naxos[15] and Capo Cimiti - could be directed to Rome, to the warehouses of Ostia and Porto, or to other Italian ports, to supply public, "imperial" monumental building programs, along a direct route but could also respond to private clients, as cipollino marble was frequently used in "civil" building[16].

As far as the distribution and storage are concerned, two hypotheses have been proposed: Russell[17] suggests, following a “modernist” model, that blocks and raw columns were destined to specific architectural programmes, they were never stocked and that the items visible at Portus (Fiumicino) and Rome were discarded and abandoned in the harbour. Pensabene, on the other side, considers those items what remains of stocks required by a prevision of use[18].

2.1. The photogrammetry and 3D model

Specifically, the mission of Ca’ Foscari University was aimed at conducting the following operations:

1. measurement of lithics;
2. free photographic documentation;
3. positioning and measuring of targets;
4. 3D photogrammetry;
6. testing an underwater miniRov.

Following the best practice conducted in different underwater marble context[19], the field has been set to carry out the survey by trilateration and with digital photogrammetry, placing numbered targets on the columns (fig. 2a). These were detected with the DSM (Direct Survey Method) technique, measuring the direct length between the points and the depths by underwater computer. The data were then managed with Site Recorder software which made it possible to check any errors of the trilateration and to create a net of points with 3D coordinates, that have been used to insert the 3D model in a metric reference system and to define the correct scale of it (fig. 2b).

The photogrammetry consisted of a photographic documentation performed with a Nikon D610 reflex camera with a fixed 20 mm lens with streaks conducted both from above, in a nadiral position with respect to the columns, and at 45° along the sides of the various marble elements and the images were processed with Agisoft's Photoscan software (fig. 3).

The 3D reconstruction makes it possible to better appreciate the position of the cargo of the ship compared with a two-dimensional survey. In fact, from the textured three-dimensional model it is possible to obtain perspective views of the entire cargo or of some individual elements depending on the needs of study and visualization of the site (fig. 4a). In addition, an orthophotography of the column cargo plan was created (fig. 4b).

[15] Capo Taormina I: 37 columns (max lenght 6.65 m) of Marmor Scyreticum and 2 blocks of green marble; 2nd cent. AD (Kapitän 1971, 304); Giardini Naxos: 14 blocks of Cipollino marble and 24 columns of white marble; 3rd cent. AD (Basile 1988, 138); see also Tusa 2016, 196-197.

[16] Pensabene 2002, 45; a cargo like that of Camarina, with two shafts, even if monumental, associated in the same ship with another one of amphorae, would indicate "a single private buyer".

[17] Russel 2013a DA VD.

[18] Pensabene 2015. DA VD.

[19] Balletti et al 2016, Beltrame, Costa 2018.

Furthermore, the site has been the subject of experiment in the use of an underwater MiniRov for photographic and video shooting, using innovative instrumentation for the application of the photogrammetric technique that had given excellent results in previous archaeological missions. Video and photo shooting were carried out with the mini OpenROV. Photogrammetric strips were carried out in the same way carried out by the diver in order to compare the potential of this instrument and of the GoPro cameras mounted on the ROV for the realization of photogrammetric surveys (fig. 5)[20].

The 3D model obtained by photogrammetric survey was finally used to calculate the volume and the precise weight of each single column and has been compared with the manual measurement of the columns, as referred to in the following table.

The calculation and the model of the columns has been employed by the engineer to reconstruct the size of the carrying ship.

The final elaboration of the shape of the boat starts from the 3D model of a boat processed for the shipwreck of Capo Taormina[21] that carried a cargo of marble block that has a weight similar to Torre Chianca (fig. 6). Then, thanks to engineering calculation, the shape the boat has been modified for this particular cargo of columns.

COLUMN	LENGHT m	DIAMETER m		VOLUME m^3	WEIGHT t
1	8,55	0,97		6,32	17,21
2	8,7	0,97		6,43	17,52
3	8,6	0,85		4,88	13,30
4	8,77	0,87		5,21	14,20
5	8,6	0,92		5,71	15,58
6				0,135	0,37
			TOTAL	**28,68**	**78,18**

2.3. The reconstruction of the Columns' shipwreck of Torre Chianca

The reconstruction of ship starting from the shipwreck's evidence available at the end of archaeological investigation relevant both cargo and ship structure (if available). This process is divided in the next two stages, one preparatory for the follow one:

- *stage 1 cargo reconstruction*
- *stage 2 definition of ship's*

In the stage 1 the stone blocks laying on the seabed (blocks could show a different level of scattering based on the number of blocks itself, the sinking *scenario* and the seabed morphology) are assessed taking into consideration:

[20] Costa et al. 2018

[21] See above, note 15. According to the reconstruction by Beltrame, Parizzi 2020 (figs. 5-6): length overall 30.54, max width / main section 9.26; depth (fully loaded, below the waterline): 3.03; draft 2.14; total weight of the load: 81 t (max 85); cargo area, without deck (with gangway): length about 12 x 7.5 width.

1. The actual level of scattering
2. The actual position on the seabed
3. The best practices for proper stowage of cargo on board in term of stability and ergonomic aspect to ease and speed up the loading and unloading operations

Based on the above points, the original arrangement of the cargo onboard is hypothetically reconstructed, following the steps shown in fig. 7.

Following the completion of the cargo reconstruction and its stowage on board, it is possible to start the stage 2 of the process. This second stage used as input data the hypothetical reconstruction of the cargo on board, defined in the stage 1, and estimates the main ship's dimensions ensuring the arrangement of the cargo does not interfere with the ship's structures, and allowing enough space for handling the cargo during loading and unloading. This preliminary definition of the main ship's dimension based only on geometric and ergonomic criteria provide a rough approximation which could underestimate/overestimate the dimensions of the vessel. In order to obtain the correct dimension of the vessel, ensuring the suitable space for cargo handling as well as the buoyancy of the vessel according to Archimedean principle, a further process to refine and adjust the dimension to be carry out. The further step based on hydrostatic calculation, verifies that:

1. the equilibrium draught, ensure the hull's buoyancy necessary to support both the weight of the hull structure and cargo, according to the Archimedean principle;

2. the freeboard associated to the equilibrium draught, ensuring it is sufficient to guarantee safety margins during sailing.

In addition to the calculation of the above-mentioned parameters also the displacement and other parameter such as metacentric position and geometrical coefficients are calculated. These additional parameters provide information about the nautical behaviour of the vessel and allow us to better understand the suitability of the vessel for assigned purpose. The above-mentioned process is summarized in fig. 8.

On completion of the above-mentioned process, the ship main dimensions are properly defined, and the hull shape completely defined.

2.4 The second context/case study: the ghost boat of Torre Guaceto (Carovigno, Brindisi)

In the MPA the Underwater Archaeology group of the University of Salento, supported by the same MPA, has launched since the beginning of 2000 an intensive research programme aimed at the reading and understanding of the dynamics of the coast changes. The archaeological contexts and finds showed a relevant frequentation form Protohistorical age to the Mediaeval[22].
This site has been well known as a safe harbour ever since ancient times supplying abundant freshwater from springs fed by large marshes and two main streams (Canale Apani and Canale Reale) (Scarano et al., 2008). Currently, archaeological remains dated back to the Bronze Age are the most important testimonies identified in this area, such as protohistoric evidence of a stretch of coast about 3.5 km long, including five islets (namely, Torre Guaceto and Scogli di Apani) as well as large sea bottom areas (fig. 9).

As regards the Late Antique phase, on the S side of the third islet (marked by a small but evident inlet), the remains of a structure with large squared blocks are preserved (30 blocks have been found; max dimensions 150x40x50 cm) inside which we recognized the collapsed layer of the tiled roof and the floor with ceramic

[22] Scarano et al. 2008; Scarano et al. 2017; Mastronuzzi et al. 2017.

materials (Late Roman 1 and 2 oriental amphorae, African Red Slip ware D, small *spathia*) dated back to the 5th-6th cent. AD. These foundations - given the monumentality of the blocks and the position - have been hypotetically referred to a tower-lighthouse, being in use during the centuries of Late Antiquity (fig. 10).

Significant is the discovery, on the seabed immediately in front of the spur on which the structure stands, of an archaeological deposit (at depth between -2.8 and -3.5 m) consisting of the remains of ballast and sporadic materials: sherds of presumably Late Antique amphorae, roof tiles and a millstone, probably belonging to the onboard equipment (fig. 11). Unlike the previous wreck, we don't know much about the original cargo of this phantom vessel; the few fragments of amphorae found suggest that the goods were transported in other containers, which have not been preserved - sacks, skins, barrels, for example - or traveled loose in the hold, as happened with cereals. However, in spite of some inconsistencies with the previous reports, this context could be identified with the wreck Torre Guaceto 1 or Torre Guaceto 2[23] but, in the light of the survey campaign, would be considered coeval with the presumed tower-lighthouse[24] and would indicate that in the Late Antiquity the islet, once coincident with a tip, a promontory of the coast high on the sea, was separated from the land by an arm of sea (a sort of strait), due to the relative sea level rise and consequent marine ingression that had caused the detachment of this protruding part of the coast.

2.5. Archaeological data-based interpretation of the historical events: storytelling

CETMA production team and the University of Salento led by Rita Auriemma focused on the contents to be narrated; such activity was very important because it has permitted to define the production phases of digital contents for the realization of the app.

At the same time, part of the team worked on the construction of the storyboards, that are important elements for the 3D production (fig. 12).

In this creative phase designers, archaeologists and 3D animators work together on the technical data as surveys, photos, archaeological documents, in order to build up the storytelling of the digital scenes.

The scenes were conceived as frames of a movie sequence that tells the final act of the last journey of the ships, the passage from the tranquillity of navigation to the explosion of the storm and again to the silence of the sea bottom. The first scene is the appearance of the ship in navigation, the second one the crescendo of the sea and the stranding in the water shallows or crushing against the reef, the third one the formation of the underwater deposit, that is transformation of the ship into the shipwreck and, the last scene, the current underwater real situation, as we can see it.

The first scene of the two app shows the waterscape, very characterized, of the two contexts, reconstructed since the geoarchaeological data. In the case of Torre Chianca Columns' shipwreck of Porto Cesareo MPA the setting includes on background the coastline and, also, the close Malva islet, meanwhile the ones of Torre Guaceto app focus the presence of the presumed lighthouse standing on on what has now become an islet. Furthermore, the scenes of the stranding or destruction against the reef hidden by the storm are very realistic, with an accurate rendering of the rough and then stormy sea and the scattering of the objects through the leak.

[23] Auriemma 2004, II, 28 (SR 21); 45 (SR 57, presumed), with references; probably the first discoveries and reports caused some errors and duplications.
[24] On the same islet a quarry (about 1000 m2) seems compatible, at least in the most ancient phase, with the blocks just described.

2.6. Virtual Reality application

The VR application allows users to interact with the following different types of digital contents:
- Photogrammetric models of the current state of the archaeological evidence
- 4K 360° video of the two submerged sites.
- 3D reconstruction of the scenes of the two shipwrecks of Torre Guaceto and Porto Cesareo;

After collecting the data, the production team worked on the definition of the optimization processes to apply on the photogrammetric data realized by Ca' Foscari University in previous survey campaigns. For each site the 3D models have been optimized in terms of geometry, reduced numbers of polygons, surfaces cleanup and tangents alignment. Finally, the optimized 3D models have been translated in a real-time format and uploaded into the application framework.

After the optimization of the photogrammetric data has been completed, CETMA focused on the realization of the video shooting campaigns in collaboration with the University of Salento and the AMPs of Porto Cesareo and Torre Guaceto. With the objective to obtain high resolution 360° video a GoPro Hero 4 Camera and a Go Pro Hero 5 360° fixed on ballasted tripod have been used. Thanks to the collaboration with the AMP'S professional photographers, CETMA has achieved 4K video footages of the archeological evidence and a stock of 360° frames to post-product (fig. 13).

After the conclusion of the underwater campaigns, the team worked on the production of the scenes of the sinking through advanced 3D modelling and animation techniques.

The CETMA production team developed the underwater digital scenarios for the two archeological areas using dedicated 3D tools as Autodesk Maya. At the same time, part of the production team concentrated on the creation of wrecks 3D models. This activity was very difficult but the collaboration between CETMA, University of Salento and Ca' Foscari University has resulted in a very detailed integral models of the wrecks (fig. 14).

Subsequently, the models were adapted to the virtual scenarios and modified in relation with the different scenes of the sinking to be represented.

3. Results and discussion

In a couple of months, the project team has been able to:

- Optimize and re-utilize previous photogrammetric data and translate them in a real-time model for virtual reality applications;
- Obtain video and photo in 4K resolution and 360° of the two archeological sites at the actual state;
- Reproduce through advanced 3D modelling techniques two virtual scenarios and two digital wrecks (integral models and damaged models).

The produced materials were uploaded in the application framework. The application has been developed with Unity 3D framework and it is available for Oculus Devices, Go and Quest model:
- *The ship of the columns of Porto Cesareo (Lecce, Italy): the unfinished journey*
- *The ghost boat of Torre Guaceto (Carovigno, Brindisi, Italy)*

The control interfaces designed for the VR application are user friendly and accessible. A recorded voice support users in the correct interaction with the digital contents, menus and buttons. The user is completely immersed in a virtual scenario mixed with 360° video of the real environment. That is an easy way to understand the history and interact with the past (fig. 15).

Obviously, only the strict synergy between various competences and an exhaustive archaeological investigation and interpretation made it possible to create a plausible storytelling, that doesn't manipulate and distort the evidence, sometimes scarce and little eloquent, at our disposal.

In the case of Columns shipwreck, after the stranding/getting stranded, the decomposition and transformation of the hull on the seabed took place, mainly due to the wave motion. In addition, the strong water absorption caused the sides to decompose, and the wood was attacked by fungi, bacteria and a mollusc, the teredo navalis, which feeds on it. In the end, only those parts of the hull survive "sealed" by the cargo (when this is composed of non-perishable material: for example, ceramic, metals or, as in our ship, marble or stone). This makes us understand why we no longer see the remains of the ship of the columns: what remains of the wood is hidden by the gigantic marble shafts.

In the second case the ship was shipwrecked in the strait between the coast and the islet, probably during a strong storm, perhaps running aground against the rocks due to the lower sea level at the time, by about one and a half meters. A large leak probably caused the objects that were on board to escape. The hull, already broken up and without the protection of a load, gradually decomposed, mainly due to the wave motion, the water imbibing and the attack of marine organisms. We can think that some remains are still under the stones, which was the ballast present at the bottom of the hold.

In the case of the Columns shipwreck the app implementation represented an added value, because the reconstruction and simulation of the dynamics which caused the formation of the archaeological site make us understand that the ship probably didn't sink but was thrown towards the shore by a storm and ran aground there, also due to the heavy load and perhaps to the broken hull. Today it is 4.5 m deep but at the time there was only 3 meters of water at this point, as much as its draft, that is the height of the submerged part of the hull. In fact, we know that the sea level has risen by a few meters since the second millennium BC, due to various geological phenomena that have affected both the sea and the land. The beached wrecks are, like other archaeological sites, valuable clues to reconstruct the ancient coastline and the evolution of maritime landscapes.

4. Conclusions

The close connection between scientific research and enhancement, the synergy between different skills and the narrative and communicative use of virtual reality and augmented reality have made it possible to satisfy the series of ambitious objectives that the Puglia Seascapes project aimed at:

- identify submerged paths in the MPAs that are emblematic of the cultural and natural values that water landscapes/seascapes can offer;

- make the data of systematic surveys carried out with the holistic, contextual, diachronic, multi and transdisciplinary approach typical of landscape archaeology, in this case coastal and underwater landscapes, therefore characterized by a particular dynamism, available to the community;

- enrich the experience of submerged landscape through the use of multimedia technologies and the production of audio-visual information material in Italian and English, accessible free of charge via the Internet;

- contribute to a more aware and informed visit by tourists who intend to know the peculiarities and assets of the territory that hosts them;

- inform and sensitize the various social actors to the natural and cultural landscape heritage of the area in which the AMP falls, its conservation, management and enhancement;

- to make the actors themselves responsible for forms of co-management of heritage, which once again becomes a common good, capable of increasing the cultural, moral, social and economic well-being of the community and individuals.

The process involved the preliminary collection, analysis and study of the scientific, graphic and photographic documentation available for both the sites, the revision and possible completion of the same, by the Department of Cultural Heritage of the University of Salento.

As regards, in particular, the wreck of the columns of Torre Chianca, the photogrammetric survey and the 3D model of the original ship have been reviewed by the Ca 'Foscari University of Venice and, on the basis of this, it has been proposed a hypothetical reconstructive model of the navis marmorum based on the calculation of tonnage and engineering analysis.

A fundamental step was the drafting of the subject and the script and the creation of the storyboard of the app, by the Department of Cultural Heritage, which saw the creation of the different interactive scenarios: navigation, storm, sinking or stranding, creation of a new body at the bottom of the sea, and, at the end, the current situation.

The CETMA creative modeling experts optimized the 3D model of the Imperial age ship with the load of cipollino marble columns from Evia island and fine-tuned that of the boat shipwrecked close to the islet of Torre Guaceto on the basis of archaeological and iconographic data available; they also took care of the development of both models in a navigable and interactive sense also through the design of 10 POIs (Points of interest) that animate the application in virtual reality, allowing the user to interactively deepen some details of the boat and the load in virtual reality usable through immersive viewers. The user is also able to switch from the digitally reconstructed scenario (the past) to the real underwater environment (today), thanks to the interaction with 4K/3D/360° videos of the sites.

The productions lend themselves to a vast dissemination intervention, first of all through direct use with viewers in the centers of the Marine Protected Areas, home to a permanent archaeological exhibition and a section of environmental education, true access gate to the MPAS. The project also envisaged the publication of the app on the websites of the two Marine Protected Areas involved and the dissemination to all stakeholders of the same content, downloadable from the website, through a communication and awareness campaign on the network.

Link to the video of two apps:
1. The ship of the columns of Porto Cesareo (Lecce, Italy): the unfinished journey
https://www.youtube.com/watch?v=HSGKBKnAcqY
2. The ghost boat of Torre Guaceto (Carovigno, Brindisi, Italy)

https://studio.youtube.com/video/CwZHXxzO93g/edit

Acknowledgements
This paper has been realised within the framework of the project *Destinazione Puglia - macroazione 3 Archeologia Subacquea – intervento "Puglia Seascapes"*, carried out by Regione Puglia – Dipartimento

Turismo, Economia della Cultura, Valorizzazione del Territorio, through Teatro Pubblico Pugliese – Consorzio per le Arti e la Cultura.
The authors would like to thank the Porto Cesareo and Torre Guaceto MPA direction and staff, as well as theCoordination of Environmentalists Pro Porto Cesareo onlus for the generous support to the operations.

References

1. Antonelli F., Bloise A., Bruno F., De Luca R., Allegretta I., Medaglia S., Taliano Grasso A., Terzano R., Miriello D. 2020, *Archaeometric approach to identifying the provenance of white marbles from the shipwreck of Cala Cicala (Crotone, Calabria, Italy)*, Journal of Archaeological Science: Reports 30, 102204.
2. Auriemma R. 2004, *Salentum a salo. I. Porti, approdi, merci e scambi lungo la costa adriatica del Salento. II. Forma Maris,* Università di Lecce, Dipartimento di Beni Culturali, 9-10, Lecce.
3. Balletti C., Beltrame C., Costa E., Guerra F., Vernier P. 2016, *3D Reconstruction of Marble Cargos Shipwreck Based on Underwater Multi-Image Photogrammetry,* Digital Applications in Archaeology and Cultural Heritage, 3, 1-8.
4. Basile B. 1988, *A roman wreck with a cargo of marble in the bay of Giardini Naxos (Sicily)*, IntJNautA 17, 2, 33-142.
5. Beltrame C. 2021, *The contribution of four shipwrecks to the reconstruction of the trade dynamics of proconnesian marble in the Roman period*, Archeologia Classica LXXII - n.s. II, 11, 437-462.
6. Beltrame C., Costa E. 2018, *3D survey and modelling of shipwrecks in different underwater environments,* Journal of Cultural Heritage, 29, 82-88.
7. Beltrame C., Medaglia S. 2012, *Il relitto di Capo Bianco (Isola di Capo Rizzuto, Crotone): un caso di trasporto transmarino di marmo tra '700 e '800,* in Archeologia e Memoria storica, Atti delle Giornate di studio (Viterbo 25-26 marzo 2009), "Daidalos" 13, Viterbo, pp. 371-388.
8. Beltrame C., Lazzarini L., Medaglia S. 2012, *Underwater Investigation on a Marble Cargo Wreck at Capo Bianco near Isola di Capo Rizzuto, Crotone, Italy,* in IJNA, 41, 1, pp. 3-16.
9. Beltrame C., Lazzarini L., Parizzi S. 2016, *The Roman Ship 'Punta Scifo D' and its Marble Cargo (Crotone, Italy)*, Oxford Journal of Archaeology 35, 295-326.
10. Calia, A., Giannotta, M.T., Lazzarini, L., Quarta, G., 2009, *The Torre Sgarrata wreck: Characterization and provenance of white marble artefacts in the cargo*, in Y. Maniatis (ed.), Asmosia VII. Actes du VIIe Colloque International de l'Asmosia (Thasos, 15–20 Septembre 2003) BCH Suppl. 51, Athène, 333-342.
11. E.Costa, F. Guerra, P. Vernier, 2018, *Self-assembled ROV and photogrammetric surveys with low cost techniques*, The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, Volume XLII-2.
12. Gabellone, F., Giannotta M.T., Alessio A. 2009, *The Torre Sgarrata wreck (South Italy): Marble artefacts in the cargo*, in Y. Maniatis (ed.), Asmosia VII. Actes du VIIe Colloque International de l'Asmosia (Thasos, 15–20 September 2003). BCH Suppl. 51, Athène, 319–331.
13. Gianfrotta P. A. 1988, *Archeologia sottomarina in Puglia*, in C. Marangio (ed.), *La Puglia in età repubblicana*. Atti del I Convegno di Studi sulla Puglia romana (Mesagne 20-22 marzo 1986), Galatina, 119-125.
14. Gianfrotta, P.A., Pomey, P., 1981. *Archeologia subacquea. Storia, tecniche, scoperte, relitti*, Arnoldo Mondadori editore, Milano.
15. Gianfrotta P.A. 2016, *Relitti con marmi (naves lapidariae?): trasporti di stato, maestranze itineranti e coincidenze ostiensi*», Archeologia Classica LXVII, 341-359.
16. Kapitän G. 1971, *Esplorazioni su alcuni carichi di marmo e pezzi architettonici davanti alle coste della Sicilia orienta*le, in *Atti del III Congresso Internazionale di Archeologia Sottomarina* (Barcellona 1961), Bordighera, 296-309.
17. Mastronuzzi G., Antonioli F., Anzidei M., Auriemma R., Alfonso C., Scarano T. 2017, *Evidence of relative sea level rise along the coasts of central Apulia (Italy) during the late Holocene via maritime archaeological indicators,* Quaternary International 439, 65-78 http://www.sciencedirect.com/science/article/pii/S1040618216301550;
18. Medaglia S. 2010, *Carta archeologica della provincia di Crotone. Paesaggi storici e insediamenti nella Calabria centro-settentrionale dalla Preistoria all'Altomedioevo*, Cosenza.

19. Medaglia S., Beltrame C., Lazzarini L. 2014, *La* navis marmorum *di età romana "Punta Scifo D" (Crotone). Risultati preliminari della prima campagna di indagini subacquee*, Rivista di Archeologia 37, 137-165.
20. Parizzi S., Beltrame C. 2020, *Calculating the Tonnage and the Dimension of the Cargos of Marble of Roman Period*, Digital Applications in Archaeology and Cultural Heritage 18, online.
21. Pensabene P. 1978, *A Cargo of Marble Shipwreck at Punta Scifo near Crotone (Italy)*, International Journal of Nautical Archaeology 7.2, 105-118.
22. Pensabene P. 2002, *Il fenomeno del marmo nel mondo romano*, in M. De Nuccio, L. Ungaro (eds.), I Marmi colorati della Roma imperiale, Venezia, 3-67.
23. Pensabene P. 2015, *Marmi pubblici e marmi privati. Note in margine ad un recente volume di Ben Russell*, ArchCl LXVI, 2015, 575-593.
24. Petriaggi R., Davidde B. 2010, *The sarcophagi from the wreck of San Pietro in Bevagna (Taranto): the subject of new works by the Istituto Superiore per la Conservazione ed il Restauro*, Archaeologia Maritima Mediterranea, 7, 131-137.
25. Russell B. 2011, *Lapis transmarinus: stone-carrying ships and the maritime distribution of stone in the Roman empire*, in D. Robinson, A. Wilson (eds.), *Maritime Archaeology and Ancient Trade in the Mediterranean*, Oxford, 139-155.
26. Russell B. 2013a, *The Economics of the Roman Stone Trad*e, Oxford.
27. Russel B. 2013b, *Roman and late-antique shipwrecks with stone cargoes: a new inventory*», Journal of Roman Archaeology 26, 331-361.
28. Scarano T., Auriemma R., Mastronuzzi G., Sansò P. 2008, *L'archeologia del paesaggio costiero e la ricostruzione delle trasformazioni ambientali: gli insediamenti di Torre Santa Sabina e Torre Guaceto (Carovigno, Br)*, in *Atti del Secondo Simposio Internazionale "Il monitoraggio costiero mediterraneo: problematiche e tecniche di misura"* (Napoli 4-6 giugno 2008), CNR-IBIMET, Firenze, 391-402.
29. Scarano T., Auriemma R., Alfonso C. 2017, *Approccio geoarcheologico per la ricostruzione dei paesaggi costieri e delle dinamiche insediative nel Salento del II millennio a.C.*, in F. Radina (a cura di), *Preistoria e Protostoria della Puglia.* Atti XLVII Riunione Scientifica dell'Istituto Italiano di Preistoria e Protostoria (Ostuni, 9-13 ottobre 2012), Studi di Preistoria e Protostoria 4, Istituto Italiano di Preistoria e Protostoria, Firenze, 977-982.
30. Tusa S. 2016, *Le navi lapidarie in Sicilia*, in F. Agneto, A. Fresina, F. Oliveri, F. Sgroi, S. Tusa, *Mirabilia maris. Tesori dai mari di Sicilia*, Palermo, 195-204.

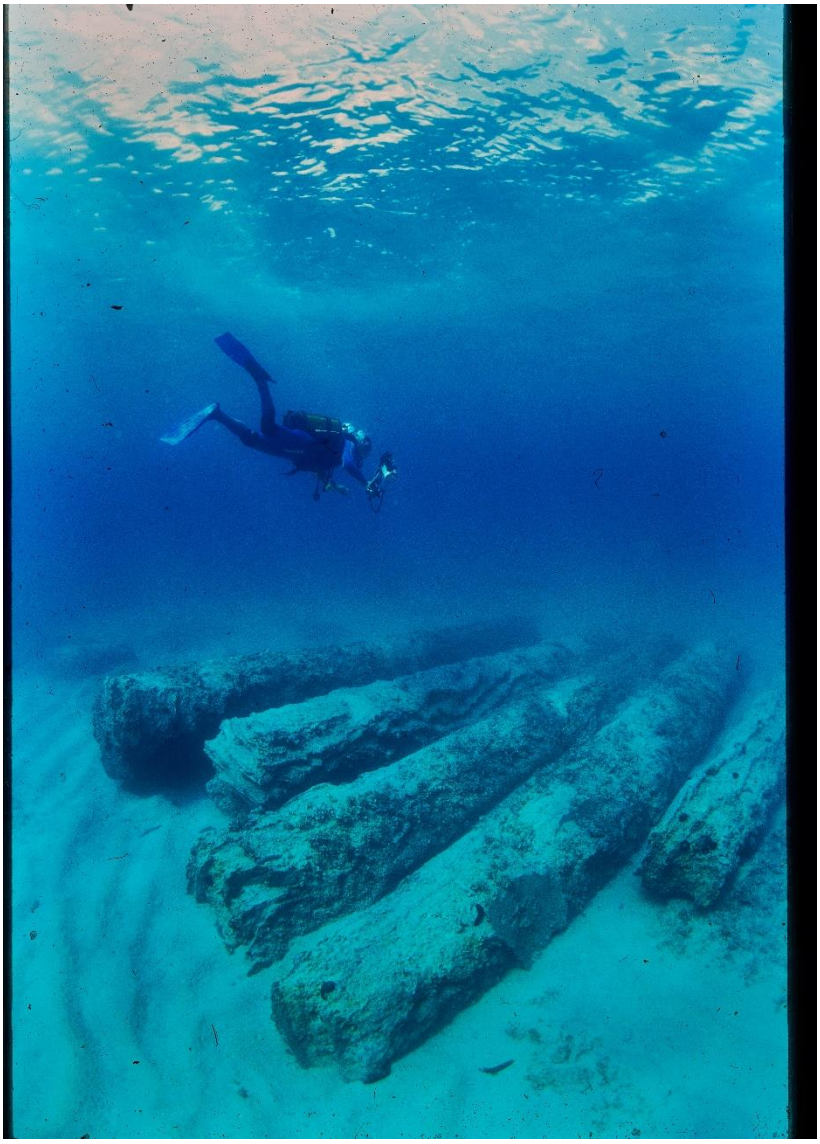

Figure 1a-b. Torre Chianca di Porto Cesareo. Column shipwreck (photo:).

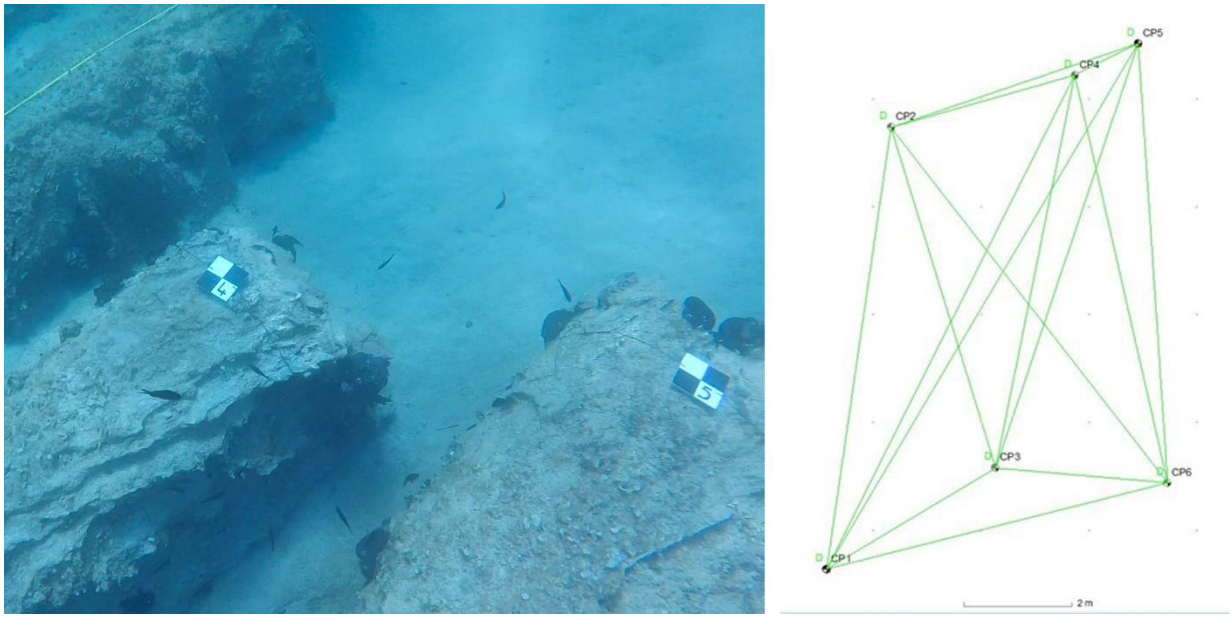

Figure 2a. Detail of the targets positioned on the columns; b. Plan of the survey of the targets with the linear measurements (photo and elaboration E. Costa).

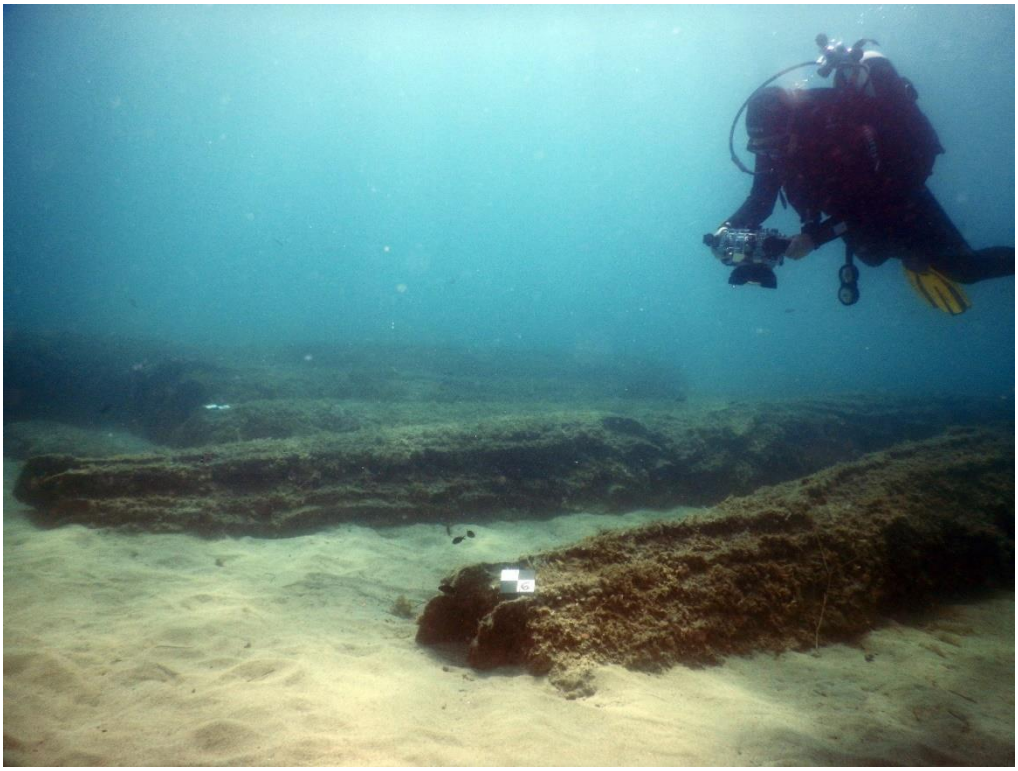

Figure 3. A moment of the photogrammetric survey with the reflex camera Nikon D610 (photo. M. Secci).

Figure 4a. Perspective view of the 3d model. Plan ortophoto of the 3d model (elaboration: E. Costa)

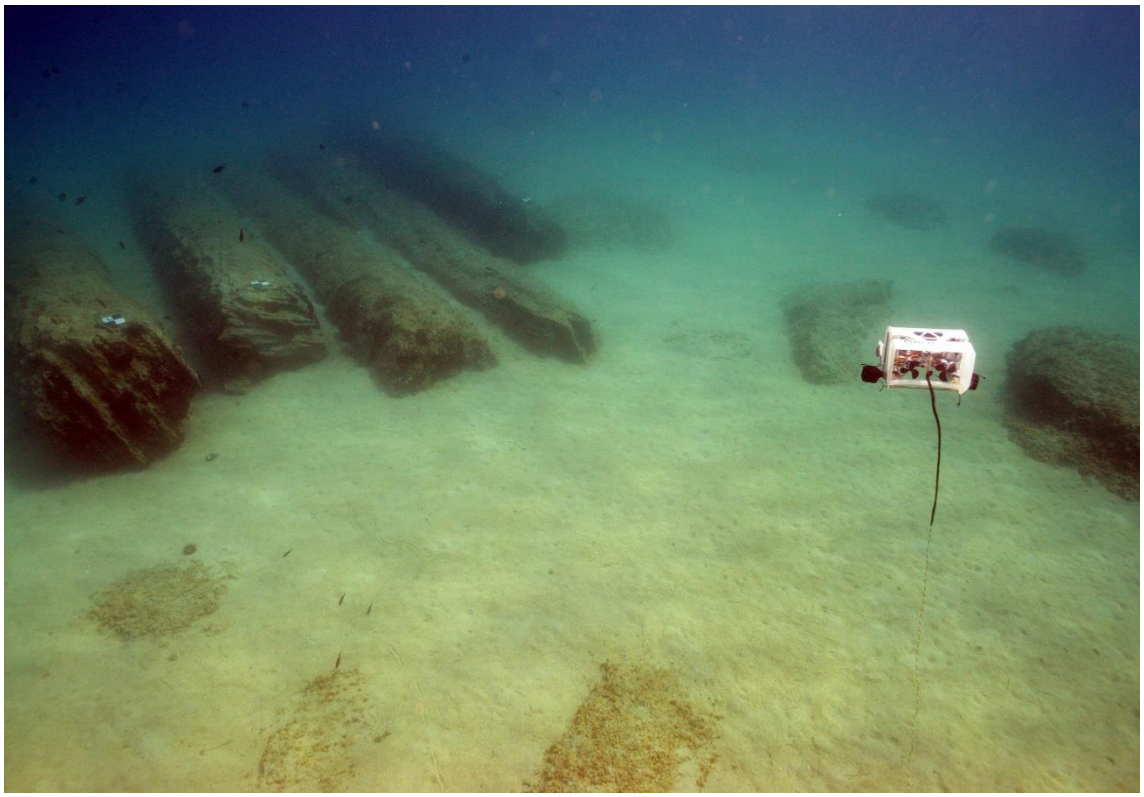

Figure 5. The photogrammetric survey realized with the go pro mounted under the OpenROV. (photo M. Secci).

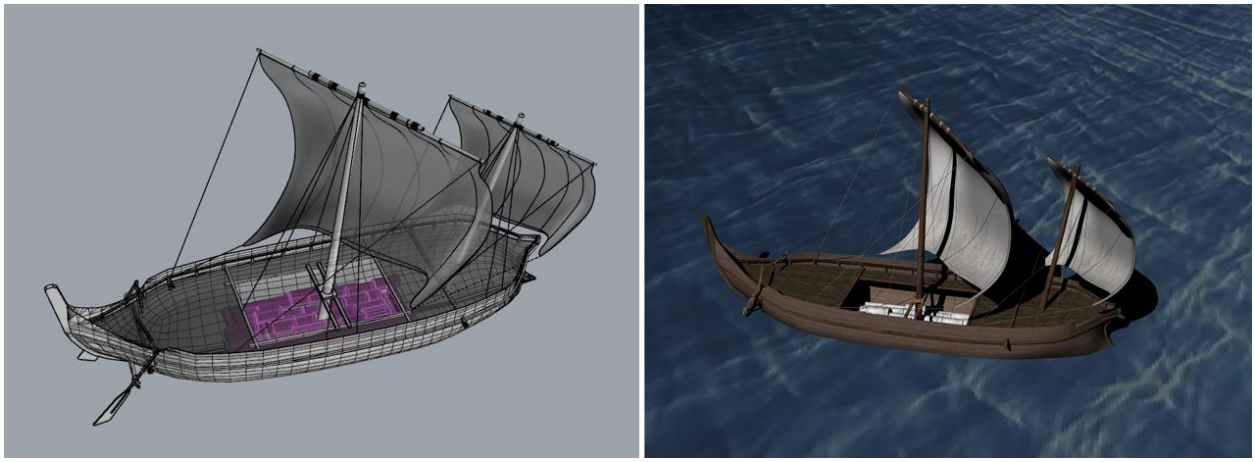

Figure 6. The reconstruction of the shipwreck of Capo Taormina: a. wireframe model, b. rendered model (elaboration: E. Costa).

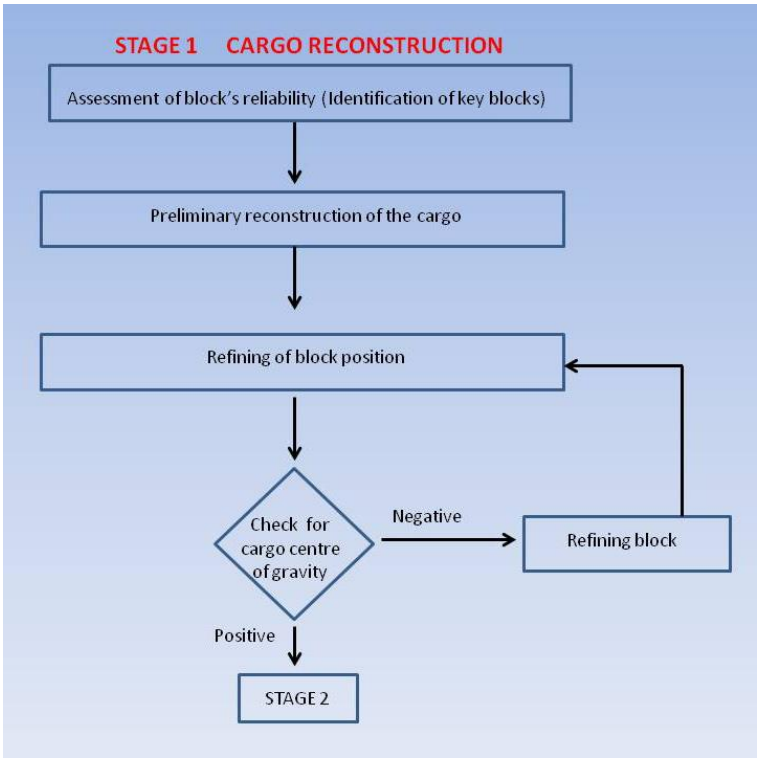

Figure 7. Stage 1. Cargo reconstruction (elaboration: S. Parizzi).

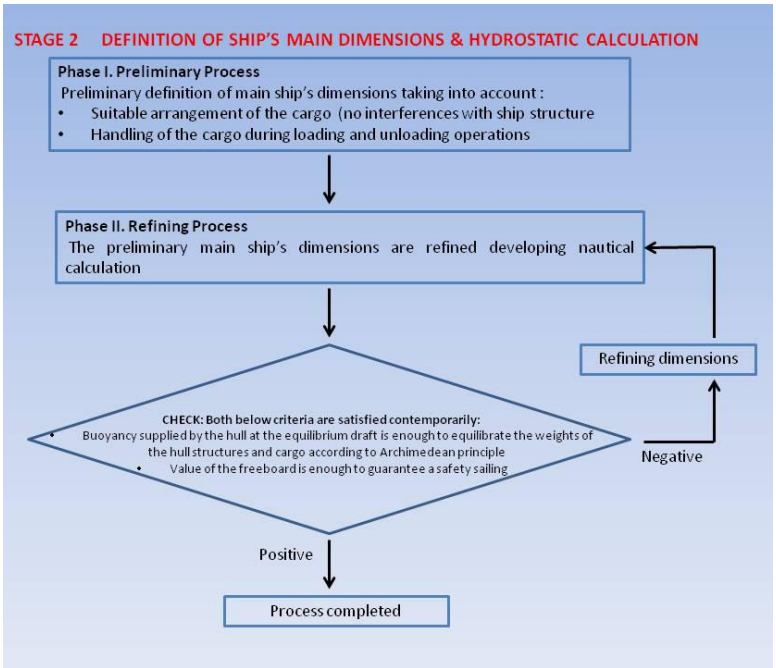

Figure 8. Stage 2. Definition of ship's main dimensions and hydrostatic calculation (elaboration: S. Parizzi).

Figure 9. Torre Guaceto (Carovigno, Brindisi): the promontory and the islets; in the foreground the third islet (photo: courtesy Poli Bibliomuseali Regione Puglia).

Figure 10. Torre Guaceto, third islet. Foudations of the presumed tower-lighthouse (photo: Dipartimento Beni culturali, Università del Salento).

Figure 11. Torre Guaceto. Remains of the ghost shipwreck: millstone and ballast (photo: Dipartimento Beni culturali, Università del Salento).

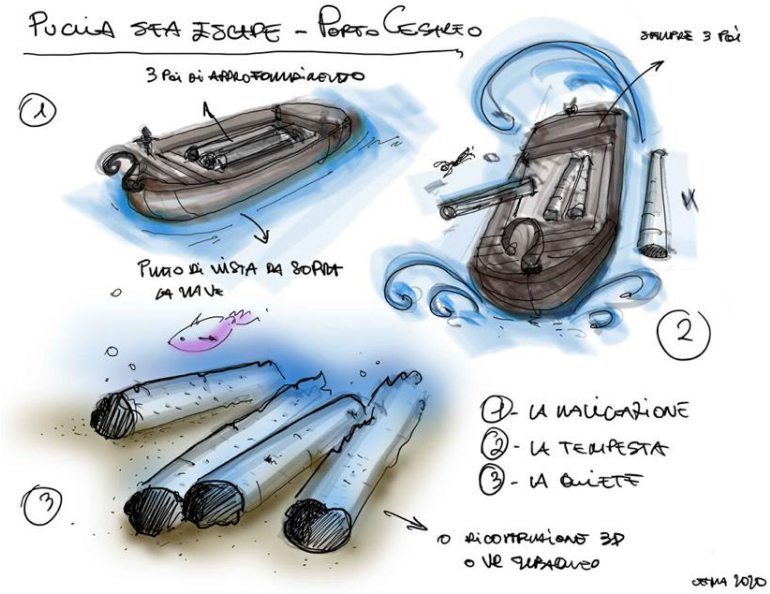

Figure 12. - Storyboard realized for the site of Torre Chianca - Porto Cesareo (drawing: CETMA)

Figure 13 - Briefing and video campaigns realized by CETMA in collaboration with AMP Porto Cesareo and Torre Guaceto, Coordination of Environmentalists Pro Porto Cesareo onlus and University of Salento (photo: CETMA)

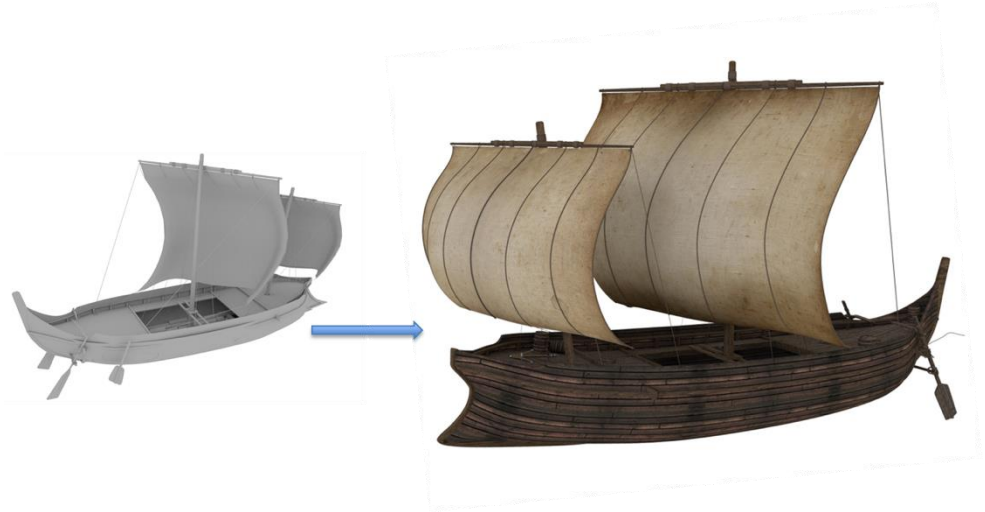

Figure 14 *- Off-line 3D and optimized 3D models of the Torre Chianca Wreck (elaboration: CETMA)*

Figure 15 *– Images of the Puglia Seascapes application virtual scenarios (elaboration: CETMA)*