BLUEMED

Activity 3.4
Policy studies, consultation and recommendations

Deliverable 3.4.2
Preservation protocol: methodology and guidelines for designing and implementing restoration and conservation plan of UCH

Greek and Italian Pilot Sites

January 2018

Activity Leader: Ministry of Cultural Heritage and Activities and Tourism - Institute for Conservation and Restoration (MIBACT- ISCR)

Deliverable Team: MIBACT- ISCR, MCS-EUA

ISTITUTO SUPERIORE PER LA CONSERVAZIONE ED IL RESTAURO

HELLENIC REPUBLIC
MINISTRY OF CULTURE AND SPORTS
GENERAL DIRECTORATE OF ANTIQUITIES AND CULTURE HERITAGE
EPHORATE OF UNDERWATER ANTIQUITIES

With support by: UNICAL

UNIVERSITÀ DELLA CALABRIA
DIPARTIMENTO DI
INGEGNERIA MECCANICA, ENERGETICA, E GESTIONALE
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1. Foreword

Before speaking about setting up Underwater Museums and Diving Parks related to the public, recreational use of the UCH Sites, the issue of the correct safeguarding and periodic maintenance of the submerged heritage needs to be addressed.

Being the underwater architectural elements and artifacts subject to a particularly aggressive environment, such as the marine habitat, their state of conservation is to be assessed first, a proper conservation/restoration intervention must then be planned and implemented, and eventually a periodic maintenance plan needs to be set, in order not to lose the achieved results over time.

The key factors to consider for the assessment of the artifacts conditions are related to the site characteristics, the marine species present in the specific habitat, the weather influence (in case of low-depth UCH sites), the polluting elements, the human activities possibly interfering with the UCH site equilibrium. All those parameters need to be carefully measured, monitored and interpolated, in order to recognize the main threats for the safeguarding of each UCH site and intervene with indirect conservation measures aiming to mitigate the adverse factors identified.

Speaking about direct conservation interventions, the basic principle to keep in mind is the ‘minimum intervention policy’, in order to address only the critical factors affecting the future conservation of the archaeological assets, avoiding every excess (e.g. aggressive cleaning procedures, reconstruction of lost parts, arbitrary integration with new elements, etc.).

Another important principle is to avoid the use of chemical compounds while restoring underwater artifacts *in situ*: their use can seriously interfere with the sea environment and harm the marine species.

Chemical compounds must be always avoided while removing the biological growth on the artifact's surfaces: a controlled mechanical action, layer by layer using proper tools, is always the best option.

For the consolidation purposes, natural materials such as hydraulic mortars bear the maximum compatibility with the ancient archaeological remains such as walls or stone elements, while being environment-friendly for the marine habitat.

With respect to the maintenance plan, it is important to carry out the constant monitoring of the environmental parameters and to schedule periodic checks and focused interventions, in order to preserve the artifacts conditions over time, despite the aggressive environmental decay factors.

On the other hand, a very important aspect is the protection of the most fragile underwater surfaces to be maintained *in situ*: this is for instance the case of some ancient mosaic pavements belonging to the Baiae Underwater Park. Their delicate conditions make them particularly subject to bioerosion, and the best way to preserve them is actually to cover their (previously cleaned) surface with geotextile fabrics weighted with sand bags, maybe leaving some 'windows' open for the visitors.

This represents one case of potential conflict between the conservation needs and the enhancement policies of a UCH site. The balance between these two aspects needs to be searched, for instance, trough the 'rotation' of the visits involving several underwater itineraries present in the same area: while one site is closed for maintenance, the other ones can be visited, on a periodic base.

These aspects are linked to an effective and virtuous management policy of the UCH sites at a regional scale, involving several actors taking part to the same synergic maintenance plan and sharing a common enhancement policy.

2. Environmental factors affecting the *in situ* conservation

2.1 'Capo Rizzuto', Calabria, Italy

2.1.1 The climate in Capo Rizzuto area

In the Municipality of Isola Capo Rizzuto and surrounding areas the climate is warm and temperate, with more rains in wintertime. According to Köppen and Geiger, the climate classification of this area is 'Csa' (Mediterranean Climate[1]). Capo Rizzuto area has an average temperature of 17.8 °C, and the average yearly rainfall is 663 mm. The warmest month is August, with an average temperature of 26.4 °C, while January is the coldest month, with an average temperature of 10.5 °C. June is the driest month, with only 8 mm of average rainfall, while October is the most humid, with its average 113 mm.

CROTON	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Average temperature (°C)	10.5	11.0	12.3	14.8	19.1	23.5	26.3	26.4	23.3	19.0	15.1	12.1
Minimum temperature (°C)	7.2	7.4	8.5	10.6	14.3	18.3	20.9	21.4	19.0	15.4	11.8	8.8
Maximum temperature (°C)	13.9	14.6	16.2	19.0	23.9	28.7	31.7	31.5	27.7	22.7	18.5	15.4
Rain (mm)	88	54	71	37	24	8	10	17	44	113	98	99

Figure 1. The average temperatures and rainfalls data inCroton - https://it.climate-data.org/location/1150/

In the Koppen climate system, temperate climates are defined as having an average temperature above -3 C (26.6 F) in their coldest month but below 18 C (64.4 F). The average temperature of -3 C roughly coincides with the equatorward limit of frozen ground and snowcover lasting for a month or more. The second letter indicates the precipitation pattern: **w** indicates dry winters (driest winter month average precipitation less than one-tenth wettest summer month average precipitation; **s** indicates at least three times as much rain in the wettest month of winter as in the driest month of summer; **f** means significant precipitation in all seasons (neither above-mentioned set of conditions fulfilled). The third letter indicates the degree of summer heat: **a** indicates warmest month average temperature above 22 °C (72 °F) while **b** indicates warmest month averaging below 22 °C. https://en.wikipedia.org/wiki/K%C3%B6ppen_climate_classification#Mediterranean_climates

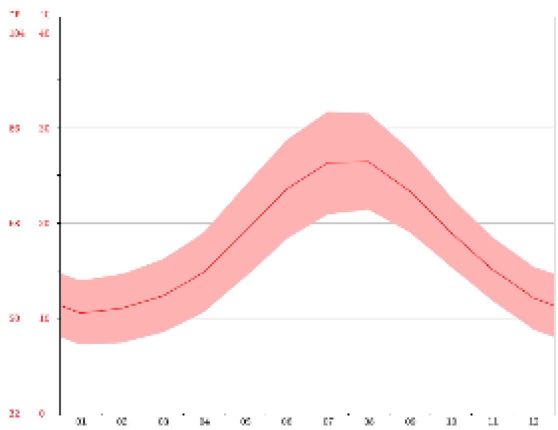


Figure 2. The temperatures chart in Croton over the year (https://it.climate-data.org/location/1150/)

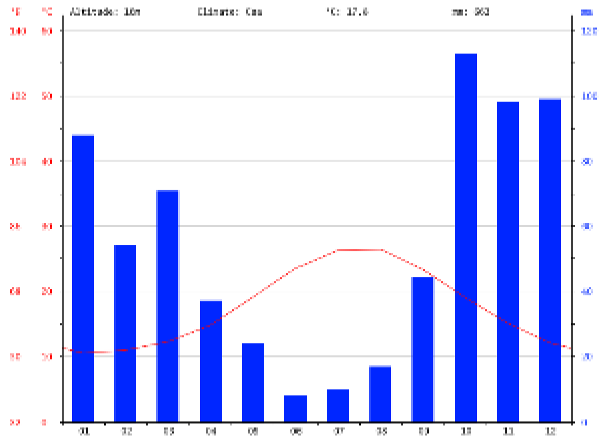


Figure 3. The climate chart in Croton over the year (https://it.climate-data.org/location/1150/)

The prevailing winds in this area are from the Northern quadrant (‘tramontana’) between September and March and in July, from South-west (‘libeccio’) in April and June, from South (‘ostro’) in May, and from North-east (‘grecale’) in August.

Tides and water temperature in the MPA “Capo Rizzuto

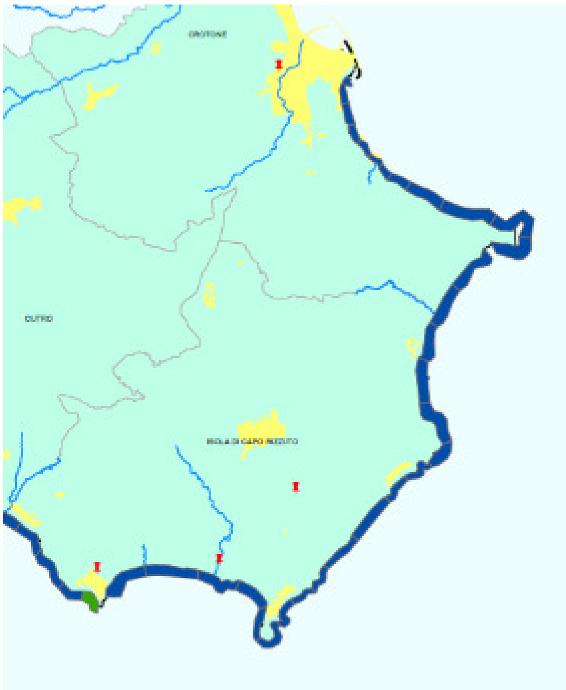
The tide has a prevailing direction East-South-East, but it is influenced by the seabed characteristics and by the coastline shape, forcing it in the same direction of the bathymetric lines. An important factor affecting the tide direction is the water temperature: in Capo Rizzuto, the minimum water temperature is reached in February, when the tide increases its speed and goes rapidly from the coast towards the open sea. A secondary water movement can be detected: water tends to move from the outside towards the MPA internal area.

The water surface temperature, in summer, reaches 25 degrees, and decreases brusquely in the first 50 meters of depth. Then, the temperature slowly stops at 13 °C around 100 meters of depth. The warm superficial water and the fresh deep water don’t mix during this period, blocking the nutrients at the deeper levels.

During the fall season, the lower temperatures allow the mix between deep and superficial water in the higher layers, and a more favorable distribution of the nutrients. In spring, the deep and superficial water layers are completely mixed, and the higher temperatures, together with a more sunny weather, allow the biological organisms to grow faster.

The nutrients concentrations are relatively low along the whole year, with particular respect to the higher water layers, testifying the oligotrophic environmental quality[2].

2.1.2 The seawater quality in the MPA Capo Rizzuto



Figures 4 - 5 Map of the Capo Rizzuto MPA area and related key table. In blue, the 'excellent' water conditions. http://www.arpacal.it/index.php/temi-ambientali/18-tematiche-ambientali/92-acque-di-balneazione

The available data testify the average excellent quality of the water conditions in the MPA Capo Rizzuto, although some pollutants coming from the drainage network of the coastline cities are still present in minimum quantites. Some critical situations are present near the borders of the MPA, close to Crotone city and at the mouth of the Esaro river[3].

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[2] Gioacchino Lena, 'Studio delle condizioni ambientali dell'Area Marina Protetta "Capo Rizzuto" Tuscia University, Viterbo.

[3] Gioacchino Lena, Op. Cit.

2.1.3 The touristic activities in the area

The nearest touristic port is in Le Castella town: a small harbor with two basins, where only boats with a maximum draught of 2 meters are allowed, very crowded in summer time. The environmental pollutants produced in this port have been studied in recent years but the proposals for the mitigation of this issue are still to be traduced into actions[4].

In the AMP Capo Rizzuto it is possible to make boat excursions on glass-bottomed boats or mini cruises in motorboats, and the diving activities are subject to special permits released by the MPA Management Authority.

2.1.4 State of conservation of the Cala Cicala wreck

The "Cala Cicala" shipwreck, discovered in the '50th of XX century, lies between the bay of Scifo and Capo Colonna in the Marine Protected Area "Capo Rizzuto" (Crotone, Italy) at a depth of about 5-7 meters.

The ship was a commercial vessel of the Roman Imperial period, which probably sank after crashing against the rocky slopes of the nearby promontory. Nowadays no wooden remains and traces of the vessel exist, and the entire cargo, still poorly investigated, is composed of 36 raw and semi-finished marble artifacts hosted on a rocky seabed with sandy sections and Posidonia meadows. The marbles are relatively steady against the bioerosion caused by the marine organisms; extended colonies of cyanobacteria were detected here over time.

Closer to the coastline, the biocoenosis of *photophylous algae* is present, while going towards the open sea, wide fields of a species considered threatened in the Mediterranean Sea, Posidonia oceanica (L.) Delile 1813, is present in the area. According to the Giraud classification (1977), the Posidonia field of Capo Rizzuto is classified as "very sparse".

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[4] Pierfrancesco Cappa 'Interventi per la raccolta nei porti e negli approdi turistici dei rifiuti prodotti sulle unità da diporto' http://www.parks.it/riserva.marina.capo.rizzuto/gui_dettaglio.php?id_pubb=3855

Caulerpa racemosa and *Padina Pavonica* algae are also present in the area, but in limited colonies. Closer to Capo Rizzuto, coralligenous platforms (Scleractinia Corals) and biocoenosis of coarse sands and fine gravels under the influence of bottom currents (SGCF) are present.[5]

2.2 'Baiae', Campania, Italy

2.2.1 The climate in Baiae area (Municipality of Bacoli)

In the Municipality of Bacoli and surrounding areas the climate is warm and temperate, with more rains in winter time. According to Köppen and Geiger, the climate classification of this area is 'Csa' (Mediterranean Climate). Bacoli has an average temperature of 15.9 °C, and the average yearly rainfall is 821 mm. The warmest month is August, with an average temperature of 23.9 °C, while January is the coldest month, with an average temperature of 9.1 °C.
July is the driest month, with only 19 mm of average rainfall, while November is the most humid, with its average 131 mm.

BACOLI	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Average temperature (°C)	9.1	9.5	11.0	13.5	17.3	21.0	23.5	23.9	21.4	17.5	13.3	10.3
Minimum temperature (°C)	5.5	5.7	7.0	9.2	12.7	16.2	18.4	18.8	16.7	13.2	9.6	6.8
Maximum temperature (°C)	12.7	13.3	15.1	17.8	22.0	25.9	28.7	29.1	26.1	21.8	17.1	13.8
Rain (mm)	94	74	68	60	40	24	19	36	68	104	131	103

Figure 6. The average temperatures and rainfalls data in Bacoli - https://it.climate-data.org/location/14147/

[5] Francesca Riolo, 'Campagna di Monitoraggio 2009 inerente al rilevamento della diversità e stato di salute dei coralli Scleractinia nell'area Marina Protetta Capo Rizzuto.

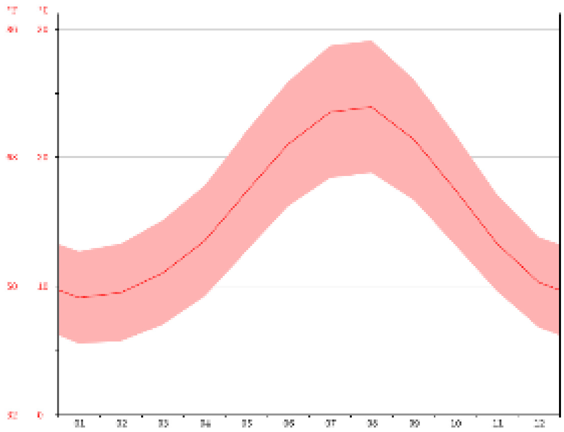


Figure 7. The temperatures chart in Bacoli over the year (https://it.climate-data.org/location/14147/)

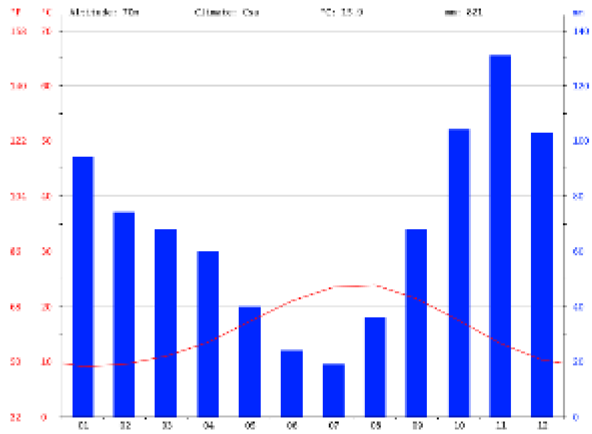


Figure 8. The climate chart in Bacoli over the year (https://it.climate-data.org/location/14147/)

The prevailing wind in this area comes from the Southeastern quadrant (sirocco) and causes a particularly strong wave motion, that in some cases, in the past, seems to have provoked the slow collapse of some walls and architectural elements of the Villa with Vestibule.

2.2.2 The seawater quality in the Baiae MPA

In 2009, the Municipality of Bacoli established an ordinance containing the bathing ban for the majority of the Municipality beaches, including the 10 bathing resorts already created, which provide to their customers with pools and shower facilities.

The whole tirrenian coast of Campania, from Mondragone to Castellammare di Stabia, over 38 km of coastline, was declared off-limits for bathing, due to the high quantity of pollutants detected in the sea water by the Regional Agency for Environmental Protection (ARPAC), that put people’s health at risk. The main cause of this critical situation was due to the malfunctioning of the purification devices related to the sewage system that filled the seawater with urban waste and caused the proliferation of dangerous bacteria.

Ten years after the situation of the seawater of the Neaples coastline happily changed from critical to excellent: the data published by ARPAC in January 2018 testify the excellent status of most of the coastline previously declared as no-bathing zones, and the regular functioning of the related purifying devices.

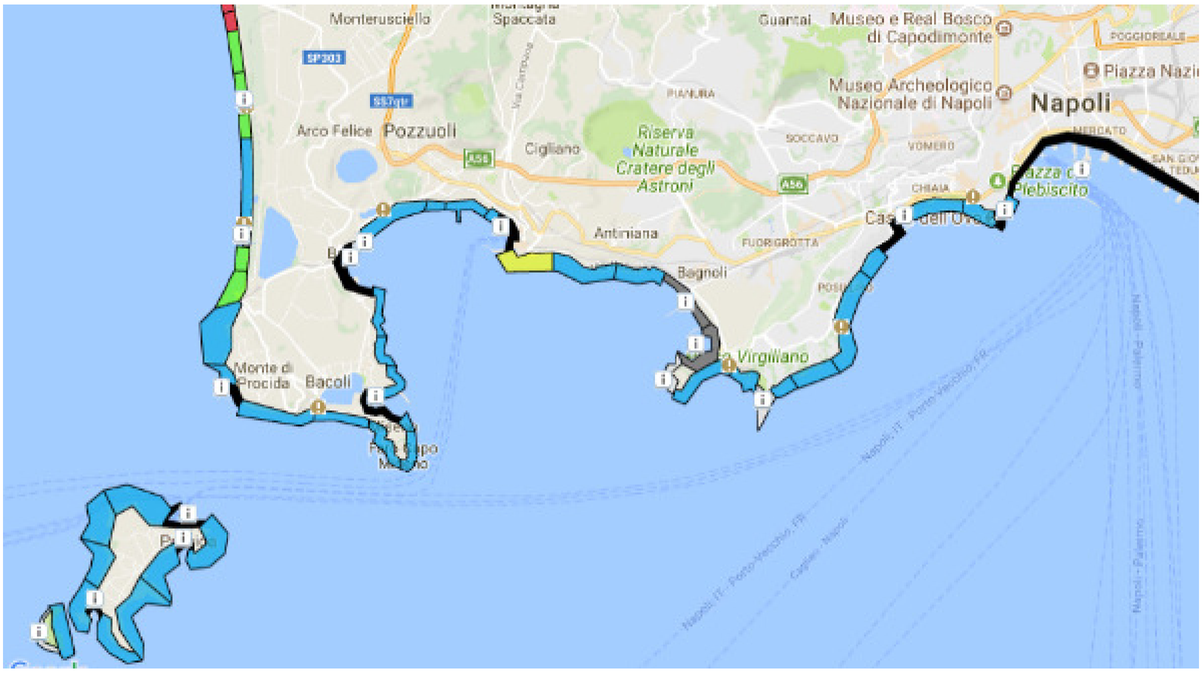


Figure 9. The map of the water quality along the Neaples coastline. In light blue the 'excellent' water quality, in black the harbor areas (see the key table below).
http://balneazione.arpacampania.it/balneazione/monitoraggio_balneazione.asp – © Google Map 2018

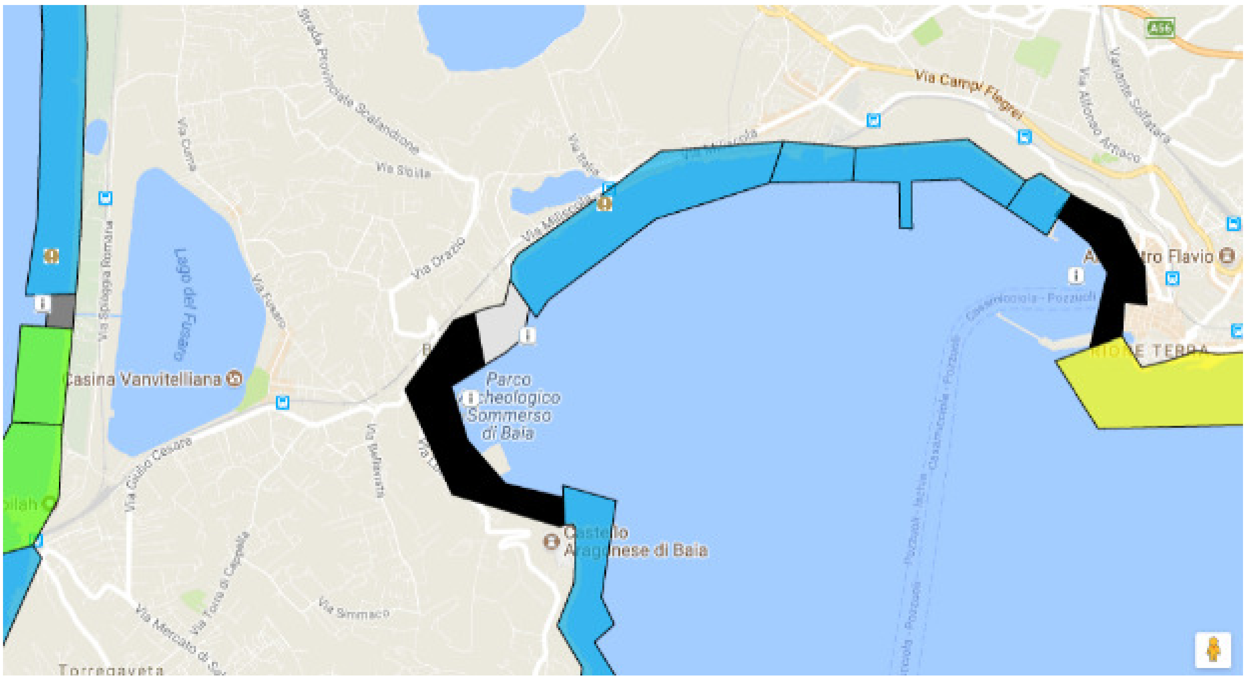
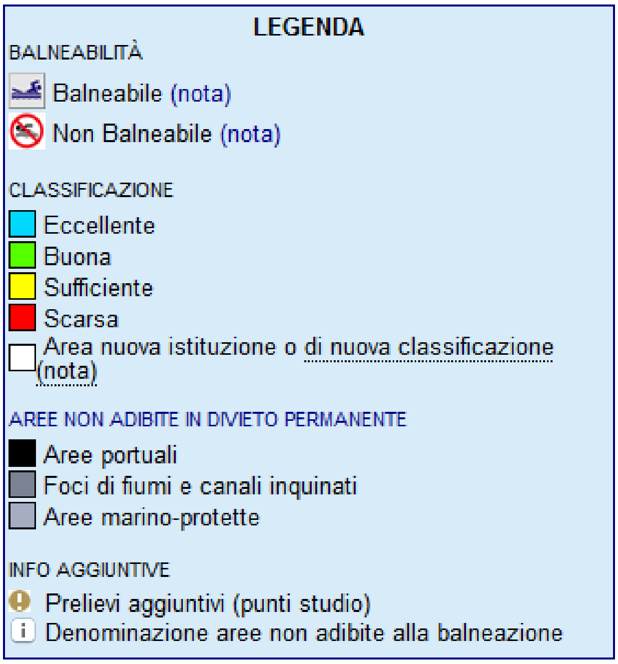


Figure 10. A detail of the map of the water quality in the Baiae bay. In light blue the 'excellent' water quality, in black the harbor areas (see the key table below). The Baiae AMP is the light grey area close to the harbor area.
http://balneazione.arpacampania.it/balneazione/monitoraggio_balneazione.asp – © Google Map 2018



WATER QUALITY

Light blue: excellent

Green: good

Yellow: average

Red: poor

White: not yet detected

Black: harbor area

Dark grey: polluted river mouth

Light grey: marine protected areas

2.2.3 The touristic harbor

Baiae AMP is adjacent to the touristic port: a facility hosting until 200 private boats maximum 12 meters long, with a maximum draught of 4,5 meters.

Previously, the area hosted the commercial port of Baiae that operated until 2000.

Figure 11. A view of the touristic port of Baiae. https://www.inautia.it/porto-turistico-porto-di-baia-1200.html

In 1987 the whole Phlegrean area is submitted to archaeological restriction within the 500 mt maritime belt; this restriction aims to conserve the area without manipulations. Between 1994 and 1998, specific ordinances rule the activities of the commercial ships, and in 1998 the Soprintendenza of Napoli and Caserta obtains the Northern coastline sea straight.

In 1999, the first underwater itinerary was created, and in 2000 the commercial port activities eventually stop after a ferry boat accident, that caused the ship sinking on the seabed and provoking heavy damages to the archaeological remains. In 2002 the MPA 'Baiae' was created, and its management charged on the 'Soprintendenza of Napoli and Caserta', now 'Parco Archeologico dei Campi Flegrei'. The touristic harbor is still operating.

http://parcoarcheologicosommersodibaia.it/parco_text.php%3Fid%3DSTOR

2.2.4 The Baiae underwater site state of conservation

General situation in AMP Baiae

The presence of archaeological remains and of modern human artefacts (harbour structures) leads to an environment rich of ecological niches.

Eight biocoenosis are present: *photophylous algae* (AP), coralligenous platforms (AP-C), biocoenosis of superficial muddy sands in sheltered waters (SVMC), biocoenosis of coarse sands and fine gravels under the influence of bottom currents (SGCF), biocoenosis of well sorted fine sands (SFBC), association with *Caulerpa prolifera* and *Caulerpa racemosa* (HCp-HCr), association with *Cymodocea nodosa* on superficial muddy sands in sheltered waters (HCn, HHCn). The AP biocoenosis consists of hard bottom photophylous species, mainly vegetal. It can be found on the dock of Lido Augusto. The AP-C is the typical biocoenosis of underwater artefacts present in shallow waters. It is made of photophylous and sciaphilous species that settle respectively on exposed surfaces and inside cavities or in shadowed areas of the roman structures. The biocoenosis SVMC is the most widespread in the MPA. It consists of soft bottom species that live in calm waters, delimited by natural or artificial reefs. The

presence of this biocoenosis in the MPA up to 15 m in depth is attributable to the shape of the bay of Puteoli. In facts, it is an inlet of the bigger Gulf of Naples, protected from waves.
Next to archaeological structures the seabed is rich in fragments of disintegrated lapideous material and of encrusting organisms' calcareous exoskeletons. This ecological niche is typical of the SGCF biocoenosis that is made of species living between the grains of coarse sands and fine gravels consisting mainly of organogenic elements (calcareous exoskeletons and shells) carried by bottom waves. The soft bottom vegetation cover is mainly made of meadows of *Caulerpa prolifera* (Forsskål) J.V.Lamouroux 1809 and *Caulerpa racemosa* J. Agardh 1873. In some areas of the MPA (e.g. the port of Baiae) these species grow on the top of roman walls together with photophylous filamentous algae. Three main meadows of different extension are present in the MPA.
Meadows of *Cymodocea nodosa* (Ucria) Ascherson 1870 (HCn, HHCn) and associations of the biocoenosis SVMC and SFBC are present in areas with high level of hydrodynamism.
None of the threatened species listed in the Red List of Threatened Species compiled by the International Union for the Conservation of Nature and Natural Resources (IUCN) is present in the MPA of Baiae. Two species of bivalve molluscs (*Lithophaga lithophaga* L. 1758 and Pinna nobilis L. 1758) included in the annex IV – List of protected species of the Habitat Directive (Council Directive 92/43/EEC of 21 May 1992) are present in the MPA. The first one, *Lithophaga lithophaga*, is an endolithic species living inside calcareous substrates. In the MPA it can be found inside archaeological remains made of limestone or marble. *Pinna nobilis* lives on sandy bottoms, attached to the substrate by byssum. Furthermore, a species considered threatened in the Mediterranean Sea, Posidonia oceanica (L.) Delile 1813, is present in the area. Usually this species forms dense and large meadows but in the MPA of Baiae there are only few tufts displaced near Punta Epitaffio and off lake Lucrino.[6]

[6] Sandra Ricci, 'La colonizzazione biologica di strutture archeologiche sommerse. I casi di Torre Astura e Baia' in 'Archaeologia Maritima Mediterranea. An International Journal on Underwater Archaeology', n. 1 – 2004. Pisa-Roma, Istituti Editoriali e Poligrafici Internazionali.

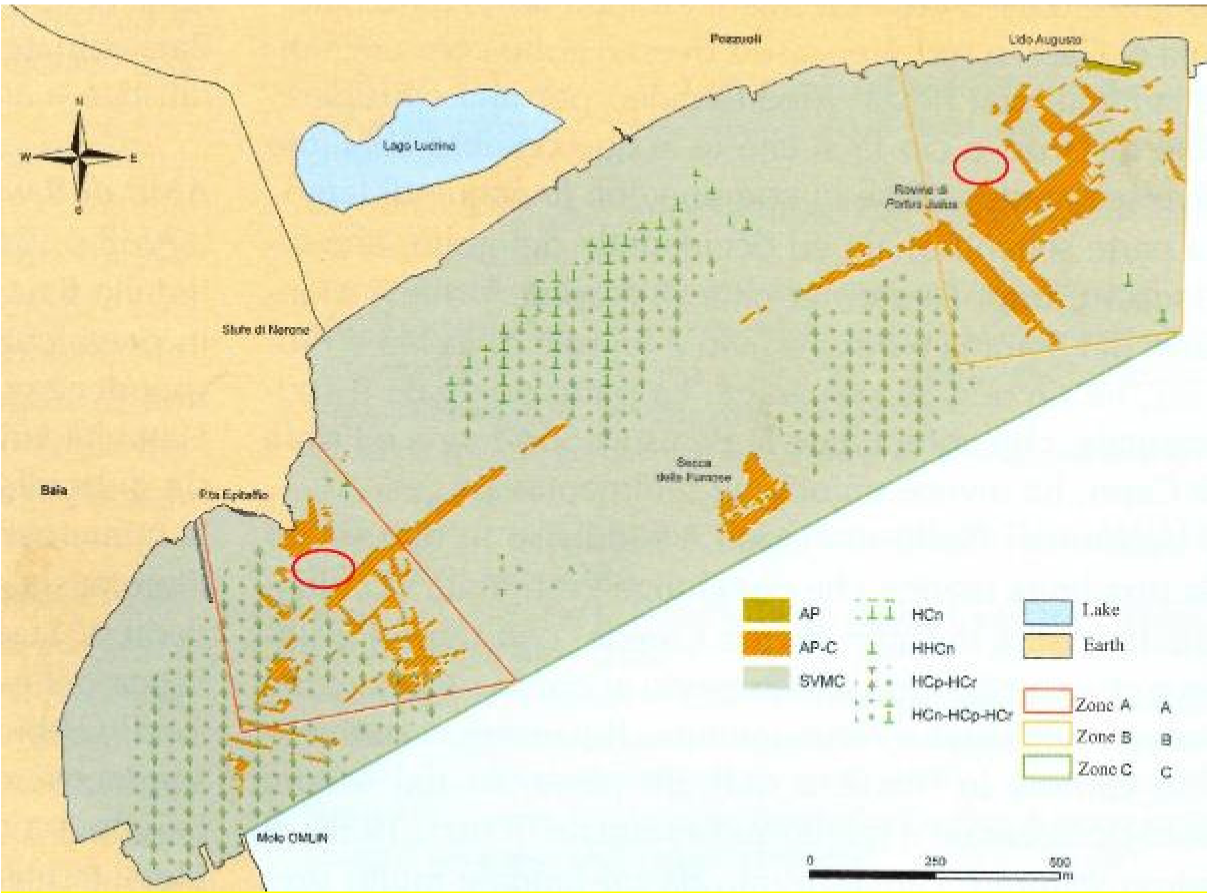


Figure 12. Map of the distribution of biocoenosis in the Marine Protected Area - Underwater Archaeological Park of Baiae (from: Russo, G.F., Di Donato, R., Di Stefano, F., 2008. Gli habitat sottomarini delle coste della Campania. Biologi Italiani, 6, 36-40).

Focus on the Villa with Vestibule

A thorough byological growth survey was carried out in this area in 2003, when a first restoration campaign took place in the “Villa with Vestibule” of Baiae. Below, the results of this survey show how the biological attack was affecting the architectural structures, with particular respect to the mosaic pavements. “Diverse species of green algae were present on the structures as well as coralline and bivalvular organisms firmly anchored to the surface.

The pavement was covered with a thin layer of algae, sponges, incoherent deposits, sediment and sand. Algal colonization seems to prefer the bedding mortar of the cubilia (bricks), probably due to the lesser difficulty encountered in root penetration, while benthic organisms, in equal density, were found indiscriminately on all the stone surfaces and mortars.

The algae present, in particular, included green algae (*udotea*), red algae (encrusting and otherwise) and brown algae that encrust themselves to the surface.

The microscopic algae recorded include diatoms (planktonic, epiphytic or epilitic), brown algae (epiphytic), red algae (epilitic), and green algae (epiphytic and epilitic). Moreover, cyanobacteria and perforating sponges (demosponges) of minute dimensions were active on the tesserae. The sponges present were of considerable dimensions, and of a verrucose nature with tubers. Serpulids (*polychaete* worms), briozoans (colonising calcareous or corneous organisms of minuscule dimensions: 1-2 mm) and ascidians were widespread on all surfaces.

The decay action of these living organisms was apparent everywhere: on the reticulated perimeter walls, where the impoverishment of the bedding mortars had resulted in stone elements becoming detached, as has occurred on the surface of the mosaic pavement.

On the mosaic tesserae, in particular, the action of the demosponges showed extensive thickly perforated areas. Subsequent colonizations, in numerous cases, caused marked alveolization of the tesserae. Next to the longitudinal crack that marks the outer limit of the pavement on the east-southeast side, fragments of mosaic and of its underlying preparatory layers of varying dimensions, which have become detached from main body of the pavement, are littered on the seabed. This structural collapse revealed an extensive cavity below the preparatory layers, partially filled with mud. The wave motion, in fact, is particularly strong in this area, on account of the prevailing winds from the southeast quadrant (sirocco), which has caused the progressive collapse of the structure over time, as a result of the continuous erosive action of the waves.[7]"

[7] Roberto Petriaggi, Riccardo Mancinelli "An experimental conservation treatment on the mosaic floor and perimeter walls of room n. 1 of the so-called «Villa con Ingresso a Protiro» in the Underwater Archaeological Park of Baia (Naples)" in Archaeologia Maritima Mediterranea. An International Journal on Underwater Archaeology 1-2004, pp.110-112.

2.3 'Western Pagasetic/Northern Sporades', Greece

In the framework of the good preservation of the ancient shipwrecks and in order to make them accessible to the public, the Ephorate of Underwater Antiquities will implement the following activities:

1) Orthophotomosaic of high resolution of the shipwrecks and their surrounding at a distance of thirty meters at least from its main deposition.

2) Lateral orthophotomosaics of the shipwrecks.

3) Photogrammertic survey of the current state of the shipwrecks using modern techniques.

4) Filming of the shipwrecks.

5) Locating and marking all the underwater findings, which lie off the main deposition of the cargos.

6) Cleaning the shipwrecks and their surrounding from disposals and fishing tools, piled up over the last years.

7) Dismantling and removing roaps from Peristera shipwreck, during the researches of the years nineteen ninety-two and nineteen ninety-three.

8) Conduct of study/documentation on the present state of the shipwrecks.

9) Establishing educational programs on «The Underwater Archaeological Wealth of Greece».

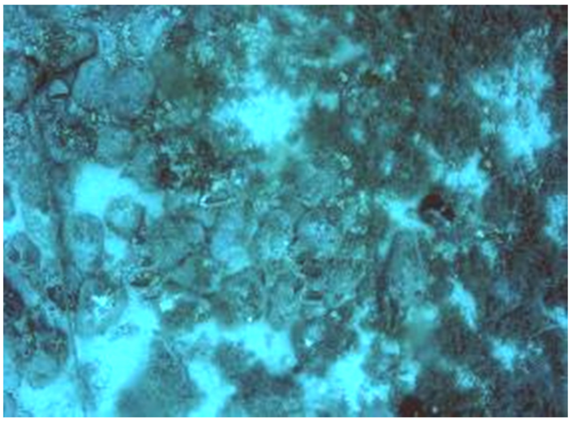
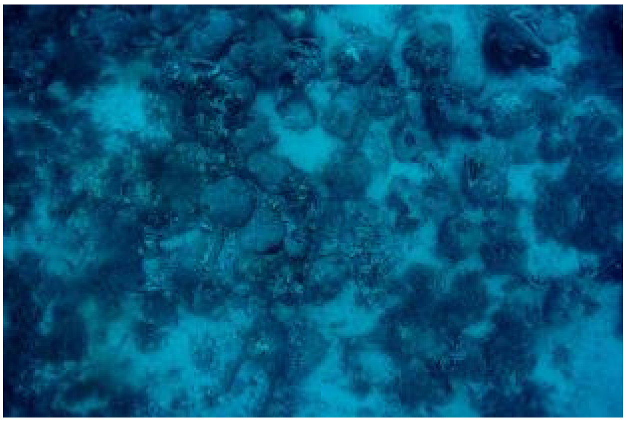
Furthermore, in the framework of the BLUEMED project, the Ephorate of Underwater Antiquities has suggested to expand the accessible underwater archaeological sites in North Sporades, Western Pagasetic and in Skopelos, which is a second island of North Sporades.

2.3.1 Northern Sporades

SHIPWRECK IN THE AREA OF "AGIOS PETROS" COVE

A large Byzantine shipwreck dated in the middle of the 12th century AD, is located near "Agios Petros" cove in Kyra-Panagia island, about 100 meters Ssouth of the coast of the homonymous islet, in a muddy and rocky bottom, in a depth of 29-34 meters. A large part of its load was refloated (Kritzas, 1971 and Throckmorton, 1971).

Its remaining dimensions are 25x8 meters and its capacity more than 100 tons. The ship was carrying 6th type magaric amphorae and a significant variety of other archaeological findings. Except its load, a big part of the ship's rack was also detected.

Figures 13 & 14. Byzantine shipwreck in Agios Petros Cove@MCS-EUA

SHIPWRECK IN "SKANTZOURA" ISLAND

The classical shipwreck was discovered in 2008 by Mrs. K. Tagonidou, during an underwater research of the Ephorate of Underwater Antiquities. During the research, indicative types of amphorae and other characteristic finds were refloated. The shipwreck is located in a distance of 110 meters from the southwestern shores of the island and it is dated in the post-classic era. The load of the ship lies in a depth of 29 to 40 meters and its ending is hidden under the sandy bottom. Various types of amphorae are spread in a surface of 27x12.50 meters.


Figures 15 & 16. Shipwreck in Skantzoura Island@MCS-EUA

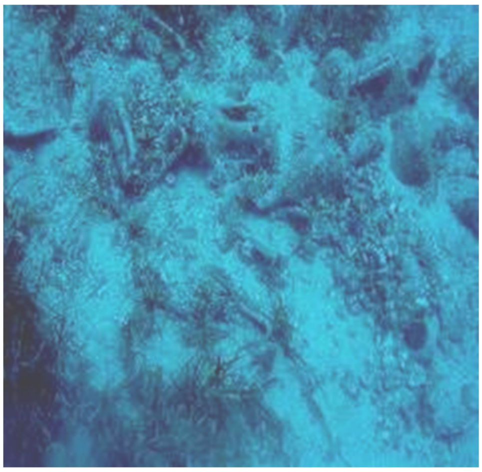
SHIPWRECK IN “FAGROU” ISLET

This shipwreck is located in the eastern side of Fagrou, in about 100 meters from the East coast and in a depth of 28 to 37 meters. It is a merchant ship of the classic period, dated in 476 BC, with remaining dimensions 18x11 meters, while a large part remains buried in the sandy bottom. The ship was carrying mainly wine amphorae from the city of Mendi. During the excavations, important archaeological items were discovered. (Chaniotis, 1994). A great finding was the revelation of a wooden part with dimensions 70x17 cm. (Kazianis, 1996), deriving from the ship’s rack, amplifying the possibility of future discovery of more of the rack’s parts.

Figures 17 & 18. Classical shipwreck in Fagrou Islet@MCS-EUA

SHIPWRECK IN CAPE «TSELIOS»

A large merchant ship of the Hellenistic era sunk 50 meters distance from the coast of “Tselios” cove in Peristera Island. It lies in a slope of an impressive sea bottom, in a depth of 32-36 meters. The visible part of its load consists of about 30 Hellenistic era amphorae.



Figures 19 & 20. Shipwreck in Cape Tselios@MCS-EUA

2.3.2 Skopelos

BYZANTINE SHIPWRECK AT DASIA ISLAND

The area can be seen from the Neo Klima of Skopelos. The shipwreck is composed by concentrated concrete amphorae at a depth 17 to 20 meters. Moreover, smaller concentration of amphorae is found at a depth up to 30 meters. The underwater archaeological site has not been declared; however the site can become an accessible underwater archaeological site.

Figures 21 & 22. Shipwreck at Dasia Island@MCS-EUA

SHIPWRECK OF CHRISTOFOROS

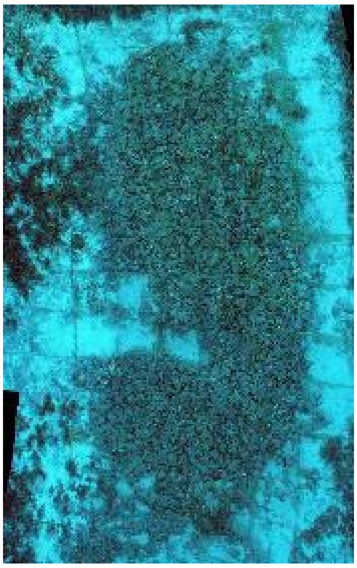
At Panormos bay a modern cargo ship, Christoforos, is sunk, registered at Piraeus 5864, 1586 gt, 855 net registered tonnages, capacity 2.774 tones and length 82 meters, owned by the company CHRISTIN COAST COMPANIA NAVIER. The ship carrying 2.600 tones of cement sailed from Volos on the 2nd of October 1983. It was heading for Piraeus and then to Algeria. The journey began but due to bad weather conditions the ship sunk the next day.

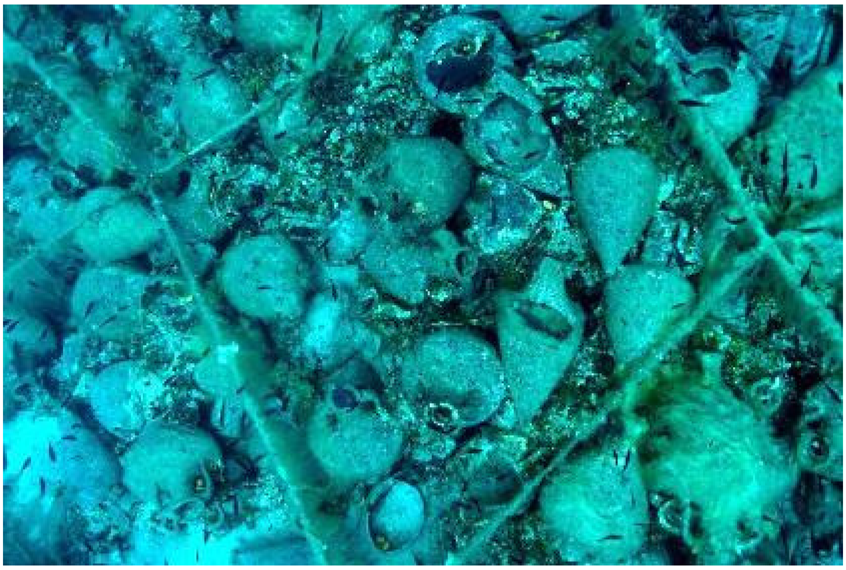
 

Figures 23 & 24. Shipwreck Christoforos@MCS-EUA.

2.3.3 Western Pagasetic

In the future there is provision to declare the prehistoric settlement at Nies an accessible underwater archaeological site, which is currently being excavated. This May a priority will be given to the classical shipwreck of Peristera in Alonnisos, where the following activities will take place: the removal of excavation roaps, the cleaning of the shipwrecks from the modern materials and the removal of fauna, which covers the cargo of the shipwreck. Furthermore, the Oceanography Centre - University of Cyprus, under the direction of Dr. Yianna Samuel, will study the biodiversity of the shipwreck as well as the climate and environmental impact.





Figures 25 & 26. The classical shipwreck of Peristera Island@MCS-EUA.

2.4 'Epidaurus', Peloponnese, Greece

2.4.1 The climate in Epidaurus

Epidaurus' climate is warm and temperate, with more rains in wintertime. According to Köppen and Geiger, the climate classification of this area is 'Csa' (Mediterranean Climate).

The warmest month is August, with a maximum temperature of 31.8 °C, while January is the coldest month, with a minimum temperature of 7.2 °C. June is the driest month, with only 6 mm of average rainfall, while December is the most humid, with its average 68 mm.
The sunniest month is July, with average 360 sun hours, while December has 130.

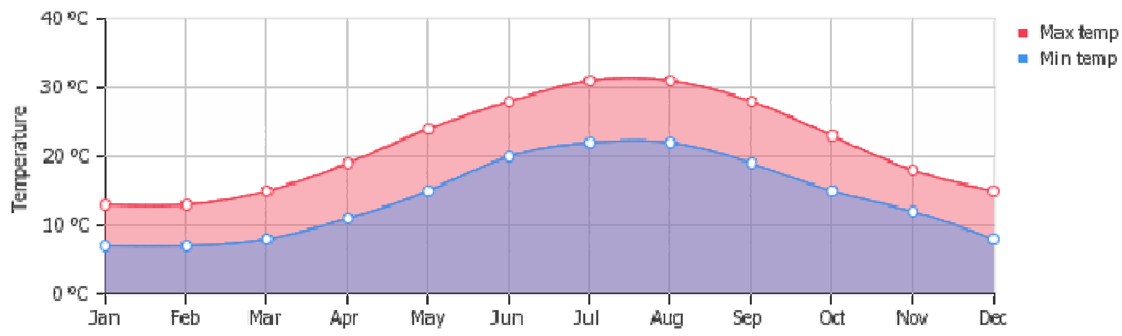


Figure 27. Temperature chart in Epidauros

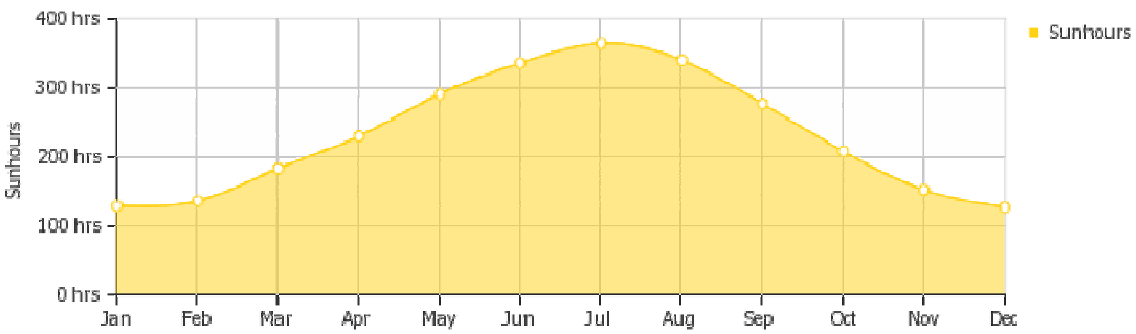


Figure 28. Sunhours chart in Epidauros

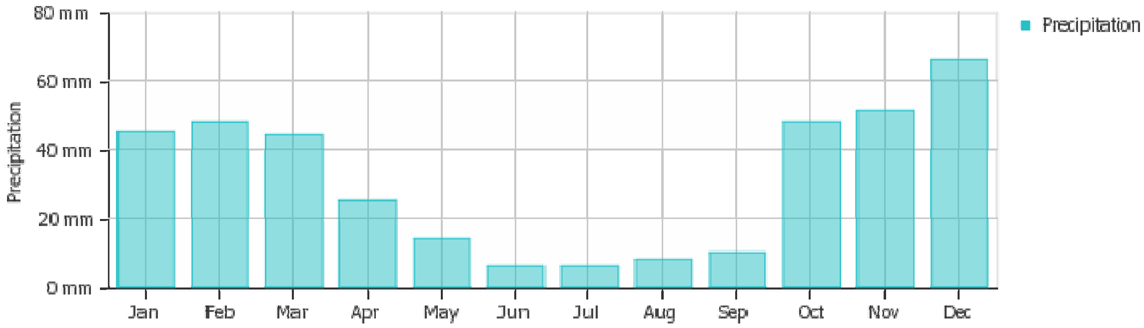


Figure 29. Rainfall chart in Epidauros

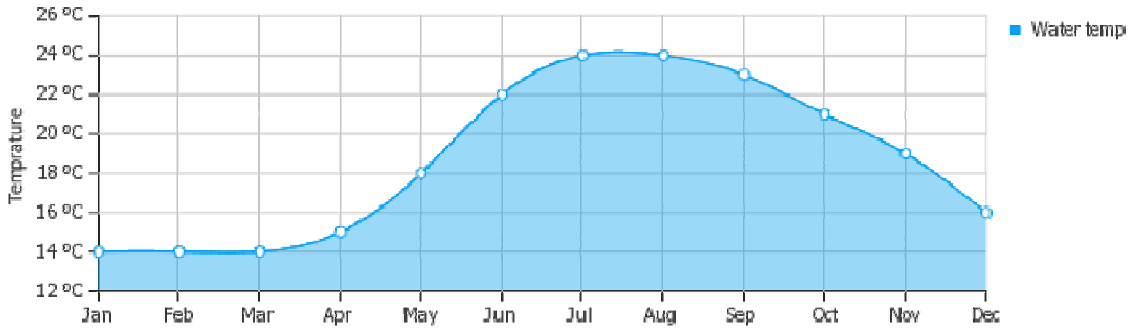


Figure 30. Water temperature chart in Epidauros

The water temperature reaches its maximum values in July and August, at 24 °C, while is around 14°C between January and March.

The weather data related to Epidaurus are provided by the weather station of Athens. https://weather-and-climate.com/average-monthly-Rainfall-Temperature-Sunshine,ancient-epidavros-peloponnese-gr,Greece

2.4.2 The seawater quality in the Epidaurus Bay

According to the 'Bathing Water in Greece, reference year 2010' released by the Greek Ministry of Environment, Energy & Climate Change, Secretariat for Water, the water quality for bathing purposes on the Epidauros coast was classified as 'excellent'.

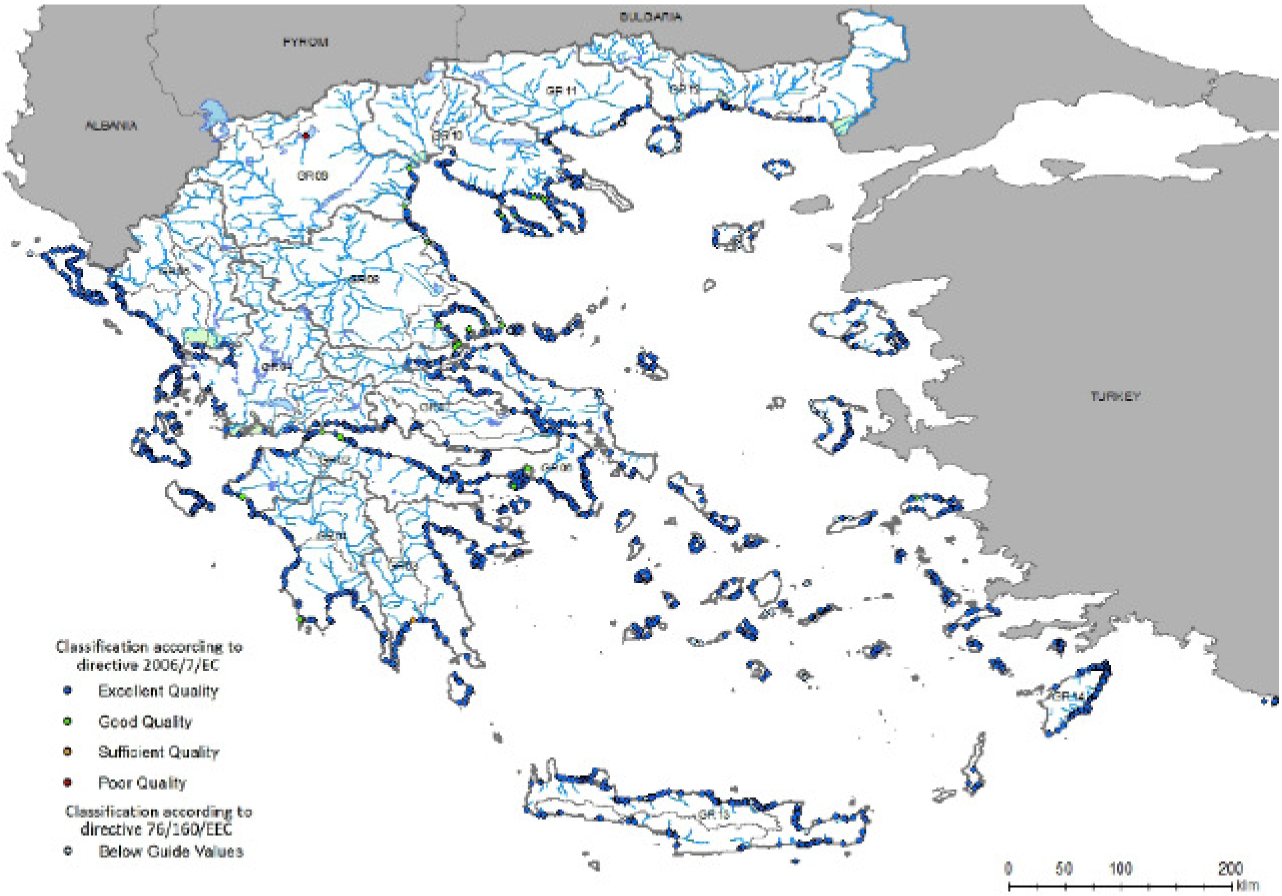


Figure 31. Water temperature chart in Epidauros. Source: 'Bathing Water in Greece. Reference year 2010.' Ministry of Environment, Energy & Climate Change, Secretariat for Water.
http://cdr.eionet.europa.eu/gr/eu/nbwd/envte3h_g/BATHING_REPORT_2010_EN.pdf/manage_document

No further information is available with respect of Epidauros water quality. Further information will be gathered during the BLUEMED on-site campaign.

2.4.3 The Epidaurus port

The port of Palaia Epidaurus (Ancient Epidaurus) is bigger and better known than the Nea Epidaurus's one. It is enough congested during the summer season, being the boat one of the fastest ways to get here from Athens, in order to attend the famous Epidauros Festival, held every year in June and July at the Ancient Theatre of Epidauros. Very close to the submerged roman villa, its polluting factors need to be thoroughly investigated.

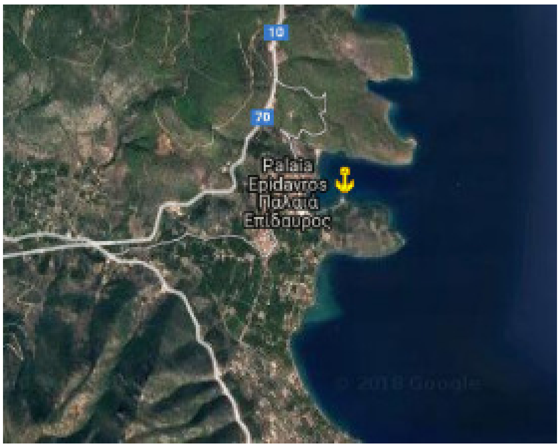


Figure 32. The touristic harbour location in Epidauros. Source: Google Maps © 2018.

Figure 33. The port entrance, Epidauros. http://www.mythicalpeloponnese.gr/tourist-guide/en/epidaurus-port

Figure 34. View of the Epidauros port. Source:

http://www.marinetraffic.com/en/ais/details/ports/17265/Greece_port:EPIDAVROS

2.4.4 State of conservation of the Roman Villa

The submerged remains of the Roman Villa, at an average depth of -2 meters, are subject to biological grouth and bio erosion. The walls, mainly built in opus testaceum (brick walls), are colonized by coral algae, bryozoans, sponges, sea squirts, polychaeta. The major decay factor, observed along the mortar joints, is the perforation by bivalve shellfishes L. Litopghaga, able to solubilize the calcium carbonate and to drill the material, and the colonization by endolithic sponges Cliona celata.

No algal turf or algal plants are present, due to the grazing action of the sea urchins; black sponges are homogeneously spread allover the wall stones and bricks. The major damage produced by the biological growth on the ancient walls of the Villa is the complete loss of joint mortars, that provoked the fall of several bricks and stones. Many walls already collapsed or are close to break apart. The wall core is also subject to the same bio erosion affecting the mortar joints.

2.4.5 Former conservation interventions at the Roman Villa

In 2017, through a pilot collaboration program organized by the Ephorate of Underwater Antiquities and the Italian Ministry of Cultural Heritage and Activities and of the Tourism – Institute for Conservation and Restoration (ISCR), the conservation at a roman villa in Palaia (Ancient) Epidaurus in Argolic Gulf began. The clay floors of the villa were cleaned and the hydraulic mortar damaged by the sea was restored. This was the material that connected the building with the clay bricks of the villa. The program is expected to continue in 2018.

Figure 35. Roman villa in Palaia (Ancient) Epidaurus@MCS-EUA

3. General overview of the conservation intervention methodology

3.1 The major decay factors to be considered in the assessment phase

"The state of the underwater environment and sediment are crucial factors in determining the preservation status of the archaeological remains. By understanding the nature of the environment and the processes in the environment that can affect the preservation / deterioration of the site's archaeological materials, it is possible to assess how conducive the site's environment is to preservation. Effectively, an underwater archaeological site and its component parts are exposed to two very differing environments – the open sea water and the sediments of the seabed.[8]"

In the underwater sea environment, two are the major decay factors affecting the conservation of the underwater artifacts:

The physical process of scour, and the biological attack by organisms living in the water environment. Their action will be examined with respect of the stone artifacts and submerged architectural elements present in the BLUEMED pilot sites.

SCOUR

"Important factors controlling scour are the presence and strength of water currents and the type of seabed sediments (clay, silt, sand and gravel). Effectively, these two parameters - along with the nature of any solidly standing structures on the seabed - will determine both the likelihood of scour occurring and its nature. Often, remote sensing techniques, such as side-scan and multi-beam sonars can be used to assess sediment transport and scour by examining the form of the seabed: sand waves and ripples are caused by sediment transport, and thus indicate that the area is dynamically active. Other parameters can also be studied to better understand the processes of sediment transport. In determining the likelihood of sediment transport, it is useful to take samples of the sediment in order to classify the sediment types

[8] EU Project 'SASMAP', Guideline Manual 2, page 52.

present and their degree of sorting, along with measurements of the water currents (velocity).[9]"

BIOLOGICAL GROWTH

Apart from the physical process of scour, biological organisms in the open water environment are the main threat for the conservation of underwater artifacts.

"The Sea is a natural ecosystem hosting several communities of flora and fauna species, classified as 'planctonic', nectonic' and 'benthic' according to their habits and behaviors.

Benthic organisms, in particular, settle on rigid substrata from where they can move and swim nearby, or inside which they can dig tunnels. They are pioneer organisms that create on the colonized surfaces a biofilm made out of their own cells, their methabolic by-products and some inorganic compounds coming from the marine environment. The biofilm itself is home for further settler species like macro-algae and animals.

These micro and macro organisms are potentially dangerous for the conservation of underwater artifacts and their distribution is heavily influenced by factors like: kind of substratum, light conditions, temperature, water murkiness, oxygen availability, pH value.

For the benthic organisms light is a particularly important parameter: it influences their kind, quantity and distribution, and their populations vary according to the water depth.

Cyanobacteria and shellfishes mainly colonize the water edge and tide areas; going down in the steady underwater environment, eukaryote algae follow, until 150-200 meters of depth, where the light penetration limit allows the colonization of rhodophyceae algae, able to absorb the green-blue light rays.

Seawater algae are considered one of the biological communities more active in the biodeterioration processes related to both natural and artificial substrata. The algal fouling mainly grows on substrata nearby the water surface or periodically exposed to the dry environment (riptide).

[9] EU Project 'SASMAP', Guideline Manual 2, page 53.

With respect of the benthic organisms settling on the underwater stone artifacts, the Sponges and the Serpulides (worms with a calcareous skin) play a significant role against the conservation of the surfaces. Other encrusting species are represented by Bryozoa, Anthozoa and shellfishes, in particular the bivalves.[10]"

3.2 The 'Restoring Underwater Project': new perspectives for the underwater restoration

'The project 'Restoring Underwater', launched and conducted by the Underwater Archaeology Operations Unit of the Istituto Superiore per la Conservazione ed il Restauro (MiBACT-ISCR) is aimed at the study and the experimentation of instruments, materials, methodologies, and techniques for the restoration, conservation, and in situ display of ancient submerged artefacts. The project started in 2001 with the restoration of the *vivaria* of the Roman villa of Torre Astura (Nettuno, Rome).

Since 2003 the main subject of the project researches has been the submerged archaeological site of Baiae (Naples, Italy), where, over the years, the restoration of sectors of some buildings in the protected marine area has been carried out: the Villa con ingresso a Protiro, the Villa dei Pisoni, the Via Herculanea, and the Building with porticoed courtyard near Portus Iulius.

In 2007, 2009, and 2010 three new archaeological targets have been added to the research: a group of nine cast iron cannons discovered offshore the coast of the Marettimo Island (Sicily, Italy), the Roman wreck carrying a load of sarcophagi discovered off the coast of San Pietro in Bevagna (Taranto, Italy), and the traditional fishing boat recently discovered off the cost of Martana Island (Bolsena Lake, Italy)[11]'.

[10] Sandra Ricci, 'La colonizzazione biologica di strutture archeologiche sommerse: i casi di Torre Astura e Baia', in Archaeologia Maritima Mediterranea. An International Journal on Underwater Archaeology 1-2004, pp. 127-128.

[11] R. Petriaggi, B. Davidde, The ISCR Project "Restoring Underwater": an evaluation of the results after ten years from the beginning, 4th Conference on Preserving Archaeological Remains in Situ PARIS4, «Conservation and Management of Archaeological Sites», vol.14, 2012,pp. 192-199.

This Project, still ongoing, was a unique opportunity for testing conservation methodologies and products and for exploring the new technological opportunities now available. The long-term activities of this project gave the scientists the possibility to monitor their results over several years, in order to better understand strength and weaknesses of the applied methodologies, learning by doing campaign after campaign.

The most highly valuable results of such effort, together with the project UCH sites safeguarding, are the following restoration and conservation methodologies.

3.4 Preliminary interventions: partial excavation and debris removal

Underwater sites already excavated in the past are, very often, periodically subject to partial or total cover by the seabed sediments and sand, caused by the sea tides. In these cases, a partial excavation or a simple debris removal needs to be carried out in order to assess the site conditions and the state of conservation of the surfaces.

"Using a water dredge or airlift, it is possible to remove excess sediment from a site to expose the archaeological remains. The water dredge and airlift not only clear sites, but can also be a valuable asset in excavation, provided it is possible to regulate the suction power.

However, these powerful tools need to be handled carefully onsite. The water dredge and airlift will suck up loose sediment and transport it to the desired location. This can be done by dispersing the sediment a few meters from the site, or by transporting the sediment to the surface to be filtered and investigated for any artefacts it contains. Airlifts are used in deep(er) water because the pipes need to stand upright and to be long enough to enable the passage of air required to create a significant vacuum.

Pipes not connected to the surface may dispose the sediment in the water column; from there, the current can take it away from the site. Water dredges can be used in shallow water since the sediments suspended in water can be transported (almost) horizontally to either the surface or to some place outside of the archaeological site[12]".

Figures 36 & 37.Clearing a submerged archaeological site with water dredges to remove the sand.©MiBACT-ISCR

When a site is cleared of any excess of sediment, all the archaeological remains can be documented and their state of conservation correctly assessed and compared with the information gathered in previous *in situ* conservation campaigns.

3.5 Mechanical cleaning of architectural surfaces and stone elements

An excessive growth of algae, covering the archaeological surfaces, makes them hard to recognize and definitely subject to biological damage. First of all, it is necessary to remove the infesting vegetal organisms and the incrusting biofilm in order to assess the conservative conditions of the surfaces.

The mechanical removal of biodeteriogens can be carried out using the same instruments normally employed in the dry environment, such as drills, mills, hammers, chisels and spatulas.

[12] EU Project 'SASMAP', Guideline Manual 2, page 85-88.

Thanks to the innovative battery-powered mechanical tools provided by UNICAL, the use of those tools has become easier and faster, allowing underwater restorers to shorten their dives while performing more work.

Figures 38 & 39. Removal of the thick encrusting layers and refining phase with chisels. ©UNICAL

After removing the thick encrusting layer, a refined cleaning can be carried out with scalpels, hammers and small hardtipped chisels. The calcareous sessile valves of certain bivalvular organisms should be mechanically eliminated with hammers and hard-tipped chisels.

3.6 In-depth consolidation of submerged walls and mosaic pavements

The filling of cracks and lacunae (grouting) must be carried out using mortars for injections carefully designed for the purpose, ensuring the maximum compatibility with the wall or the pavement surface under both the physical and chemical point of view, and of course granting a complete hydraulic grip, necessary in the underwater environment.

The viscosity of the mortar must avoid its dispersion in the water (not too liquid) and at the same time allow a constant supply and a regular flow rate (not too dry), without blocking the grouting channel too early.

The grouting operations can be performed manually, through waterproof supply pockets (very low pressure or sole gravity), or through pneumatic antiwashout mortar distributors, working with compressed air at controlled pressure.

Figures 40 & 41. Manual joint and cracks filling (left) and with the use of an air compressed distributor (right). ©MiBACT-ISCR

3.7 Joints and cracks filling in submerged walls and mosaic pavements

The repair of wall joints, where loss of the original mortar had occurred, and the filling on the upper masonry surfaces, can be carried out using the above-mentioned supply pockets made of a waterproof fabric. The mortar must be applied by exerting gentle pressure on the sack, and must ensure perfect adherence at the edges of the lacunae and excellent hardening properties. Some additives can be mixed into the mortar recipe: antiwashout compounds in order to reduce the loss of binder in water, a small biocide product percentage in order to slow down the further colonization by biodeteriogenic organisms, inorganic pigments in order to obtain a colour compatible with the original surface.

3.8 In situ protection

The in situ protection of the pavements and of the most delicate archaeological layers must be carried out using sandbag-weighted geotextile mats, as previously experimented near the Pisoni Villa in Baiae. Some limited parts of the pavements can be left without protection in order to allow the recreational diving visits.

Figures 42 & 43. Manual joint and cracks filling (left) and with the use of an air compressed distributor (right). ©MiBACT-ISCR

4 Specific recommendations for the maintenance of the Pilot Sites

4.5 'Capo Rizzuto'

4.3.1 Stone blocks and slabs

Removal of bio-incrustations

The removal of marine organisms encrusting and damaging the archaeological surfaces is preliminary to the consolidation interventions and possible finishing operations. The living organisms not interfering with the operations and not damaging the artifacts must be left in place, while the dangerous organisms must be carefully removed through progressive mechanical actions aiming to make the encrusting material thinner layer after layer, in a controlled manner.

The macro organisms and their carbonatic by-products adhering on the archaeological surfaces should be mechanically detached through drills, mills, hammers, chisels, scalpels and spatulas. The complete removal of the adhering deposits will be achieved only if the original archaeological surfaces can be fully preserved from the mechanical damage.

4.6 'Baiae' and 'Epidaurus'

4.4.1 Mosaic pavements

Edge cleaning and in-depth consolidation

Cleaning of the mosaic edges in order to evaluate the adhesion of the perimeter tesserae to the groundwork layer. In case the mosaic edges are detached, hydraulic mortar grouting is necessary. The mortar injections need to be performed through small drills in the mosaic pavement, or removal of some tesserae in the detached areas, using waterproof supply pockets.

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Joint mortar filling

The joint mortar, where lacking, will be applied along the joint using waterproof supply pockets filled with hydraulic premixed mortar. Exceeding mortar quantities can be removed through spatulas, and the perfect adhesion of the new mortar joints to the ancient surfaces must be ensured through sponges, exerting a gentle pressure. Small lacunae can be filled using the original tesserae found close to the mosaic pavements, using the same hydraulic premixed mortar.

In situ *protection*

The in situ protection of the pavements and of the most delicate archaeological layers must be carried out using sandbag-weighted geotextile mats, as previously experimented near the Pisoni Villa in Baiae. Some limited parts of the pavements can be left without protection in order to allow the recreational diving visits.

4.4.2 Brick walls

Removal of bio-incrustations

The removal of marine organisms encrusting and damaging the archaeological surfaces is preliminary to the consolidation interventions and possible finishing operations.

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In-depth consolidation

The filling of cracks and lacunae (grouting) must be carried out using mortars for injections carefully designed for the purpose, ensuring the maximum compatibility with the wall or the pavement surface under both the physical and chemical point of view, and of course granting a complete hydraulic grip, necessary in the underwater environment.

The viscosity of the mortar must avoid its dispersion in the water (not too liquid) and at the same time allow a constant supply and a regular flow rate (not too dry), without blocking the grouting channel too early.

The grouting operations can be performed manually, through waterproof supply pockets (very low pressure or sole gravity), or through pneumatic antiwashout mortar distributors, working with compressed air at controlled pressure.

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4.7 'Western Pagasitikos/Sporades'

4.7.1 Amphorae deposits

Being the terracotta artifacts very fragile and subject to mechanical damage, the only recommended intervention for sites hosting this kind of artifacts is the periodic, careful debris removal, in order to avoid the self reburial of the archaeological underwater site.

The mechanical removal of encrusted biofilms could be only possible under exceptional circumstances, having previously tested the material thickness and resistance.

5 The role of new technologies applied to the conservation interventions

The removal of biodeteriogens from walls and floors is generally performed by means normally employed above ground, such as scalpels, axes, hammers, chisels and metal spatulas. In the last years, the set of underwater restorers' instruments has been enriched by the introduction of a pneumatic microgrinder (**Errore. L'origine riferimento non è stata trovata.**9) that allows to faster the practice of reducing large-sized calcareous or carbon-based residues from the surface of the submerged artefacts. The tool was developed by making appropriate modifications to a stainless steel drill, normally used in orthopedic surgery, and it is supplied by an air compressor with a reserve tank that allows adapting the provision of air to the high consumption rate of the work.

Figure 44. Pneumatic microgrinder tested in the Underwater Archaeological Park of Baiae.

Speaking about the filling of cracks and lacunae, a pneumatic mortar distributor has been specifically manufactured by ISCR with the support of the Fluimac S.r.l.. It consists of a stainless steel tank, with a PVC tank inside that contains the mortar, with pressure gauges and safety valves placed on its lid. The air passes from a diving cylinder to the tank and compresses a piston over the mass of mortar from the top downwards determining the flow of it. The microgrinder and the pneumatic mortar distributor were tested for the first time in the Underwater Archaeological Park of Baiae with positive results.

The collaboration and cooperation between the University of Calabria and the ISCR during the CoMAS project gave a strong boost to the design, development and test of new tools able to make more efficient the work carried out by the underwater restorers and, furthermore, to overcome the limitations of the hand and pneumatic instruments.

These tools have been designed to meet the different restorers' needs that occur during the subsequent phases of the cleaning work performed, during the in-situ restoration process, on the submerged artefacts. With these needs in mind, the new devices have been developed to remove the loosely adhering deposits and proceed with the removal of tightly adhering deposits, thus achieving a complete removal of all the materials that cover the artefacts without damaging their surfaces. In particular, as detailed in the following sections, three electromechanical tools have been developed in order to satisfy specific needs:

- a cleaning brush that is useful to remove the loosely deposit and the marine organisms that reside on the surface of the artefacts;
- a small electrical chisel that helps the restorers to remove carbonatic incrustations and to demolish calcareous shells of bivalves in the sub-fossil state firmly adherent to the surface;
- an electrical hand-held grinding tool that allows restorers to reduce the carbonatic incrustations thickness too hard to be removed by the small electrical chisel.

These devices can be easily used by underwater restorers who, thanks to the electric motors, can operate with better results in terms of speed and freedom, where pneumatic or hydraulic tools require a pipe for connecting the tools to the compressor placed on a support vessel. Moreover, the pneumatic and hydraulic tools used in professional diving are heavy-duty equipment designed for the off-shore and marine construction sectors. Such kind of equipment does not meet the requirements of the underwater restorers, who usually adopt manual tools like chisels, metal spatulas, scalpels and brushes, in order to have a precise control of the cleaning operations and prevent any damage of the surfaces.

5.1 Electric Cleaning Brush

The first device is an electric tool (**Errore. L'origine riferimento non è stata trovata.** 22), that allows restores to perform a first rough cleaning of the submerged archaeological artefacts. Indeed this device can be equipped with brushes and abrasive wheels of different shapes and materials (Fig. 23) that can be easily loaded by the operator. In particular, using this cleaning brush tool, the restores remove in few minutes all kind of epilithic organisms, such as algae, sponges and mollusks that cover the underwater artefacts. The Fig. 24 shows the results of the adoption of the cleaning brush on a delimited area where all the living organisms have been removed and a dense and thick encrustation is unveiled.

In particular the electric tool can perform its work thanks to a 1200 W brushed motor, housed in an aluminum case, that gives a maximum torque of 30 Nm and a maximum no-load speed of 1800 rpm, allowing restorers to use the device also for drilling holes (with a maximum diameter of 20 mm in masonry) and to collect samples by coring. The device is also featured by keyless chuck that allows a quick and simple tool switching - an important feature in underwater environment. The electric device is powered by a 36V, 4Ah Lithium-ion battery pack, mounted inside an aluminum case for an optimal cooling.

Also, the handle design has been performed in accordance to the restorers' suggestions and needs. Different designs have been developed and tested prior to the final version showed in Fig. 20. The cleaning brush tool have two large handles, if compared to the aluminum case, to assure a power grip and then make the tool use safe and risk-free. The first U-shaped handle is form fitting and ergonomic due to its curved shape manufactured by means of 3D printing technologies. This design provides a comfortable control on the switch handle placed on it. The second handle has a locking knob that allows to customize its angle in accordance to the direction's force the user want to exert. For instance, when the tasks require a perpendicular force the handle will be set straight otherwise it can be angled.

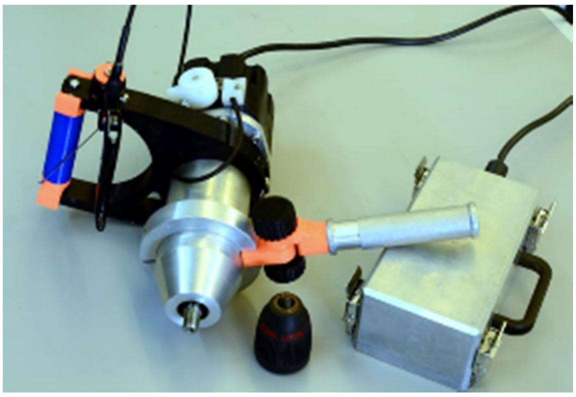


Figure 45. *Set of brushes with nylon bristles.*

Figure 46. Electomechanical multipurpose tool.

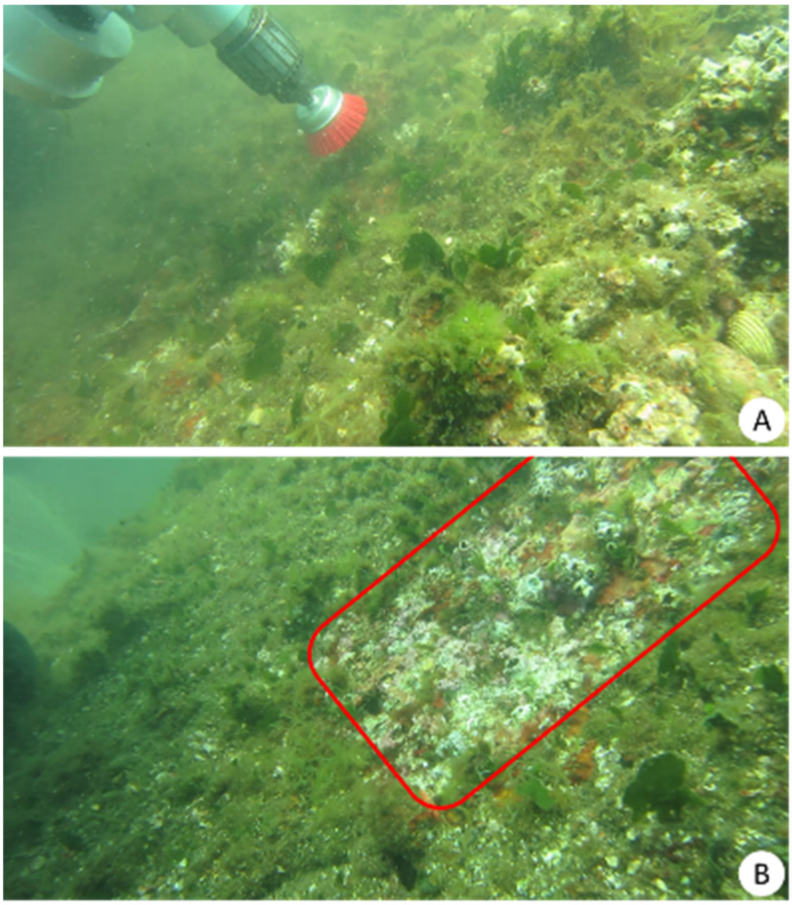


Figure 47. Living organism before (a) and after (b) the adoption of the multipurpose tool inside the area delimited by the red frame.

5.2 Small Electrical Chisel

Mechanical cleaning is the only feasible alternative for removing the encrustation. To accomplish this task, usually restorers use a variety of hammers and chisels that are indispensable especially on the very large pieces. By hammering and chiseling along cleavage lines, the encrustation can be detached from the objects with little or no damage to the artefacts. In accordance to these needs a small electrical chisel (**Errore. L'origine riferimento non è stata trovata.** 25) has been designed to support restorers in the removal of the strong encrusting organisms placed on underwater structures. The device is powered by an 18V, 4Ah Li-ion battery pack, placed in a separate case for a better handling of the tool. The chisel is actuated by a pneumatic system with an impact rate of 4950 bpm (maximum) and a maximum impact energy of 1 Joule. These values meet the requirements of underwater restorers. The device allows the removal of large amounts of encrustation, especially in the presence of the massive compact crust that usually makes the conservation procedures time consuming and laborious.

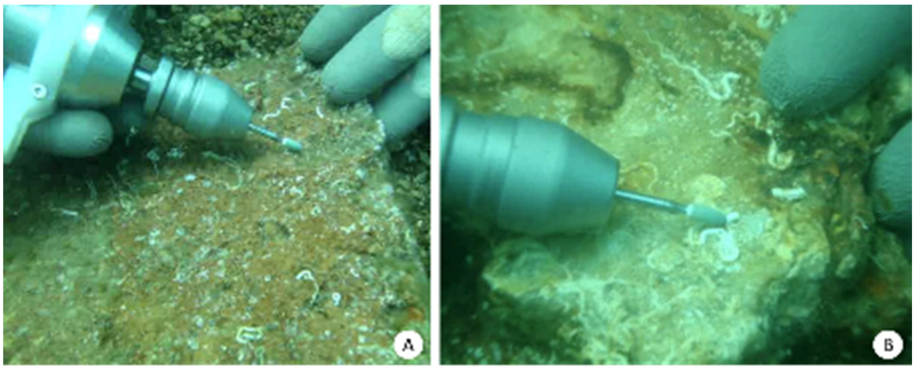
Figure 48. Small electrical chisel.

Figure 49. Removal of carbonate incrustations, electrical chisel.

5.3 Handle-held grinding tool

After that restores removed as much as possible of the encrustation, they needs smaller, more precisely controlled tools for removing the encrustation from small and fragile pieces and for getting into restricted places. In order to accomplish these needs a third electromechanical device has been developed. This is an electrical hand-held grinding tool (**Errore. L'origine riferimento non è stata trovata.** 27) designed to perform a precise cleaning of small areas and surface finishing operations. The device consists in a hand-held tool containing the micro-motor and an external case for batteries and electronics. In particular, the external case contains a 24V, 5.3Ah Li-poly battery pack that powers a very small 200W sensored brushless motor. The speed of the tool can be continuously adjusted from 0 to 16700 rpm through the knob housed on the lid of the battery pack, according to the specific needs of the underwater restorer. The actuation is performed by means of a pressure-sensitive electronic switch handle placed on the handle-held tool.

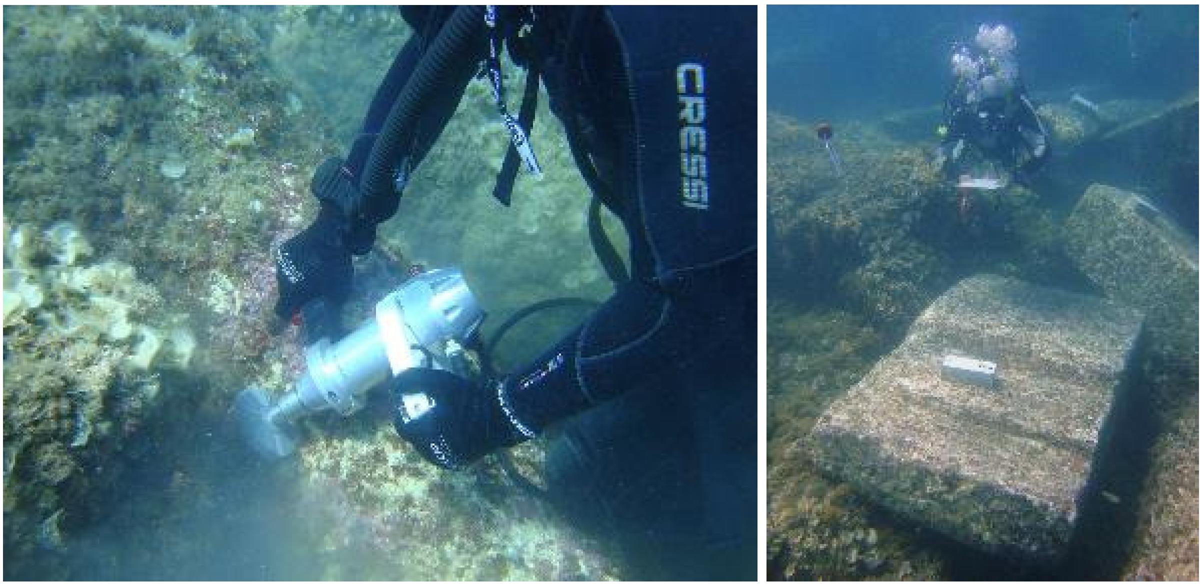
Figure *50.* Handel-held grinding tool.



Figures *51* a & b: Testing of the grinding tool on a marble plane (a) and removal of sepolidae canals from a lapideous fragments (b).

The testing campaigns above mentioned have been performed during the “CoMAS” Project (Ref.: PON01_02140 – CUP: B11C11000600005), financed by the MIUR under the PON ’R&C’ 2007/2013 (D.D. Prot. n. 01/Ric. 18.1.2010).

Furthermore, within the activities of the BLUEMED project, a preliminary surveys campaign at the underwater Roman wreck of "Cala Cicala" (Crotone) it has already been undertaken with the aim of testing the methodology described above, concerning the cleaning procedures with new tools implemented during the “CoMAS” Project (Figure 29). The real survey campaign, expected among the activities of BLUEMED project, will be carried out next summer in the same pilot site.



Figures *52 & 53.* Optical survey and cleaning activities in the Cala Cicala pilot Site.

Source: F. BRUNO, M. MUZZUPAPPA, A. GALLO, L. BARBIERI, D. GALATI, F. SPADAFORA, B. DAVIDDE PETRIAGGI, R. PETRIAGGI, Electromechanical devices for supporting the restoration of underwater archaeological artefacts, in OCEANS 2015 - Genova , vol., no., pp.1-5, 18-21 May 2015.

6. Future developments and new possibilities

Although cleaning activities could be sometimes in contrast between the safeguarding of the cultural heritage and the respect of the organisms, they are sometimes necessary in order to promote the enjoyment of on-site cultural heritage. In addition, after the cleaning procedures, site maintenance activities can be undertaken in order to further protect archaeological assets.

The application of innovative products (low environmental impact) for the conservation of materials against biofouling could be taken into account, to be applied directly *in situ* and always respecting the environment. Science applied to conservation of UCH has an increasing interest toward nanotechnology.

In particular, photocatalytic materials have a great potential due to theirantimicrobial and photocatalytic features. For example, ZnO and TiO_2 are photocatalytic materials, characterized by high chemical stability, non-toxicity, high photo-eactivity, broad-spectrumactivation, antibiosis and cheapness; they have been used as biocide against various microorganisms: bacteria, fungi and viruses, etc.

By using such products, a significant slowdown of the marine community's growth covering the underwater archaeological surfaces may have a positive outcome on the site management costs, reducing the need of maintenance activities.

UNICAL, throught DiBEST department, within The Italian National Project COMAS (Planned COnservation, *in situ*, of Underwater Archaeological Artefacts), has tested metal oxide nanoparticles on stone surfaces for preventing the biological growth directly *in situ*, by using materials with antifouling property and an acceptable environmental impacts[13].

The experimentation was set-up in the underwater archaeological park of Baiae, giving important results related to the preservation of submerged Cultural Heritage, by proposing novel methodological approach based on the use of nanotechnology[14]. Based on the achieved results, this technical solution against biofouling has been patented[15]. It represents a milestone for the development of innovative antifouling solutions for underwater restoration.

[13] L.D. Chambers, K.R. Stokes, F.C. Walsh, R.J.K. Wood, Modern approaches tomarine antifouling coatings, Surf. Coat Technol. 201 (2006) 3642–3652.

[14] S.A. Ruffolo, M. Ricca, A. Macchia, M.F. La Russa. Antifouling coatings for underwater archaeological stone materials. Progress in Organic Coatings. 2017, 104, 64–71.

[15] Italian Patent Composizione antifouling per la protezione delle strutture sommerse BI4897R, 2015.

7. Conclusions

In recent years, during the last underwater conservation campaigns, the restoration perspectives of the submerged heritage have been dramatically enlarged by the usage of new technological tools making the underwater restorers' work easier and faster, providing at the same time complete safety for the user and remarkable results for the artifacts to be preserved. Together with a sane restoration policy, which sticks to the 'minimum intervention' principle and the usage of natural materials only, respecting both the compatibility with the ancient artifacts and the safeguarding of the marine environment, the underwater conservation challenge is not frightening any longer. A desirable advancement in this field would be the formation of specific figures of 'underwater restorers', starting from the traditional professionals trained for the on land interventions. Such kind of specific formation, or upgrade, would ensure that the public authorities in charge of the conservation and maintenance tasks could count on specifically trained professionals, able to work together with the already existing figure of the 'underwater archaeologist' and to establish a fruitful cooperation. The technological and conceptual progress in the field of the underwater restoration and conservation interventions makes our tasks eventually feasible, but it is not enough. The future of the UCH sites actually depends also on our capabilities to set up efficient conservation - monitoring - maintenance - enhancement plans at a large scale, and to provide organizational resources to achieve the expected results. If wide sites like the 'Baiae Underwater Park' can be considered self-sufficient for these purposes, other smaller sites, like the 'Capo Rizzuto' wrecks, would need to be considered as a multi-site network in order to reach a sustainable equilibrium between resources needed and activities performed, in economies of scale. The conservation, monitoring and maintenance plan should be ideally released at network scale, with all the foreseen activities planned accordingly and following a rotational site-by-site timetable; also, the enhancement and recreational activities could reach the maximum benefits if performed on a multi-site platform, similarly to what already happens in many monuments and archaeological sites on land.