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REEF HABITATS: NEW FINDINGS IN THE CENTRAL TYRRHENIAN SEA (MEDITERRANEAN SEA)

NUOVE SEGNALAZIONI DI HABITAT CIRCALITORALI ROCCIOSI NEL MAR TIRRENO CENTRALE

Abstract - This study investigated the environmental characteristics of a potential dumping site in the Central Tyrrhenian Sea through geophysical and biological surveys. High-resolution bathymetry and ROV imaging revealed the presence of previously undiscovered lower circalittoral reefs associated to different morphological features. Moreover, Vulnerable Marine Ecosystem taxa indicators and three protected Anthozoan species were identified. Due to the ecological relevance and sensitivity of these habitats, the site was deemed unsuitable for sediment disposal. These findings support the need to improve conservation measures in this area to preserve its sensitive deep-sea reef habitats.

Keywords: Mesophotic assemblages, protected species, Vulnerable Marine Ecosystems, environmental study

Introduction - In recent years, the growing need to identify suitable sites for the disposal of harbour dredged sediments has raised concerns about the potential effects that these activities can have on ecologically relevant habitats and species. Dumping sites are generally located on the continental shelf, beyond 3 nautical miles from the coast and up to 200 m deep, possibly also affecting deep-sea habitats whose distribution is not well-known (Chimienti *et al.*, 2019). Deep habitats, distributed on both hard and soft substrata, are characterized by habitat-forming species able to create complex three-dimensional habitats that support rich biodiversity and resilience of marine ecosystems (Lemieux & Cusson, 2014; Bastari *et al.*, 2018). These habitats and associated species are particularly vulnerable to climate change and to anthropogenic activities such as trawling, oil drilling, sand extraction, and the disposal of dredged sediments (Enrichetti *et al.*, 2019). Within this framework, the present study focuses on the evaluation of the environmental characteristics of a marine site potentially suitable for the disposal of dredged sediments. Geophysical investigation and macrobenthic characterization, carried out to characterize the dumping site, allowed the identification of new lower circalittoral reef habitats and some protected habitat forming species in the Central Tyrrhenian Sea.

Materials and methods - The potential dumping site, located 6.5 nautical miles (NM) off the coasts of Terracina and Gaeta in the Tyrrhenian Sea, was characterized according to the Italian Ministry Decree (M.D.) 173/2016: it was subdivided into 9 square subareas of 1 NM² and 2 control sites of 1 NM². The environmental study, carried out in 2016-2017, included geophysical surveys and the biological characterization of the seabed. Geophysical investigations were performed through Kongsberg EM2040 multibeam echosounder in a depth range of 100-135 m. Multibeam and backscatter data (1 m of resolution) were acquired along 40 transects oriented parallel to the coastline covering an area of about 25.4 NM² (Fig.1a). Macrobenthic samples were acquired using a Van

Veen grab (2 replicates) in 18 sampling stations: 2 per subarea and 3 per control site. Macrofauna was identified to the lowest possible taxon (usually species level) and counted. The geophysical data highlighted the presence of several morphologically elevated structures and circular depressions; a further survey was carried out in 2017 to acquire video images using ROV (Remote Operated Vehicle) on these features to exclude the presence of protected habitats/species. A total of 11 ROV dives in the surroundings of morphologic highs and depressions were performed. For each dive an area of 500 m around the reference point was investigated; videos have been analyzed by extracting frames to classify, to the lowest possible taxonomic level, all megafaunal taxa.

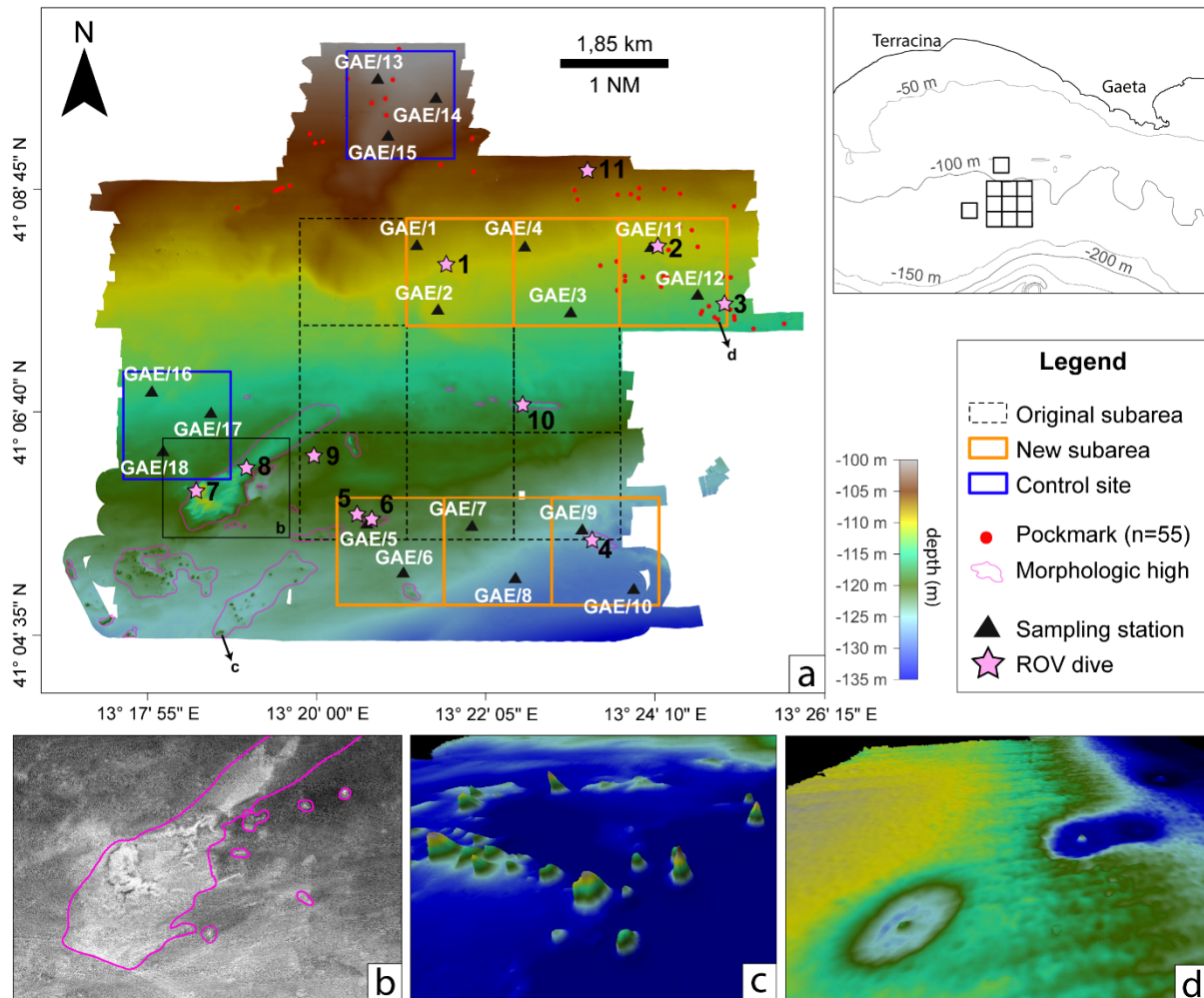


Fig. 1 - (a) Bathymetry of the study area, sampling stations, ROV dives and the morphological findings; (b) Backscatter data of the Secca del Leone; (c) 3D views (10× vertical exaggeration) emphasized seafloor morphology of morphologic highs and (d) pockmarks.

(a) *Batimetria dell'area di studio, stazioni di campionamento, dive ROV e interpretazioni morfologiche;* (b) *Dato backscatter nella Secca del Leone;* (c) *Rappresentazione 3D (esagerazione verticale 10x) che enfatizza il rilievo degli alti morfologici e* (d) *pockmarks.*

Results - High-resolution bathymetry revealed several morphologically elevated structures and circular depressions (Fig. 1). Morphological highs consist of sub-circular features or extended areas with steep flanks (up to 15°) and high backscatter (Fig. 1b) and are therefore interpreted as likely rocky (Fig. 1c). A significant morphologic high, with an area of about 0.46 NM² and a maximum relief of about 8 m above the surrounding seafloor, has been named Secca del Leone (Fig. 1b). 55 circular depressions have been identified, consisting in circular or elongated areas ranging from

0.2 to 1 m in depth and about 100 m in diameter, some with central peaks (Fig. 1d). According to their morphology, these features have been interpreted as pockmarks, among the most distinctive seabed morphologies associated with fluid flow processes and very common in the Italian continental margins (Spatola *et al.*, 2025). Soft bottom benthic assemblages were characterized by the predominance of species typical of coastal terrigenous muds, bathyal muds biocenoses and muddy detritic bottom (Tab. 1).

Tab. 1 – List of macrozoobenthic species identified
Lista delle specie macrobentoniche identificate

Mollusca	<i>Paucibranchia bellii</i> (Audouin & Milne Edwards, 1833)	<i>Apseudopsis acutifrons</i> (Sars, 1882)
<i>Nucula nucleus</i> (Linnaeus, 1758)	<i>Abyssoninoe</i> cfr. <i>abyssorum</i> (McIntosh, 1885)	<i>Fageapseudes retusifrons</i> (Richardson, 1912)
<i>Nucula sulcata</i> Bronn, 1831	<i>Abyssoninoe bidentata</i> D'Alessandro, Cosentino, Giacobbe, Andaloro & Romeo, 2014	<i>Tuberapseudes echinatus</i> (Sars, 1882)
<i>Bathyarca pectunculoides</i> (Scacchi, 1835)	<i>Abyssoninoe hibernica</i> (McIntosh, 1903)	<i>Cyathura carinata</i> (Krøyer, 1847)
<i>Thyasira buplicata</i> (Philippi, 1836)	<i>Gallardoneris natatoi</i> (Ramos, 1976)	<i>Eurydice affinis</i> Hansen, 1905
<i>Varicorbula gibba</i> (Olivi, 1792)	<i>Ninoe armoricana</i> Glémarec, 1968	<i>Ampelisca gibba</i> Sars, 1883
<i>Abra alba</i> (W. Wood, 1802)	<i>Drilonereis</i> cfr. <i>filum</i> (Claparède, 1868)	<i>Ampelisca spinipes</i> Boeck, 1861
<i>Antalis panorma</i> (Chenu, 1843)	<i>Aponuphis bilineata</i> (Baird, 1870)	<i>Ampelisca typica</i> (Bate, 1856)
Polychaeta	<i>Aponuphis brementi</i> (Fauvel, 1916)	<i>Haploops nirae</i> Kaim-Malka, 1976
<i>Heteromastus filiformis</i> (Claparède, 1864)	<i>Nephtys hystricis</i> McIntosh, 1900	<i>Carangoliopsis spinulosa</i> Ledoyer, 1970
<i>Leiocapitella dollfusi</i> (Fauvel, 1936)	<i>Nephtys incisa</i> Malmgren, 1865	<i>Medicorophium rotundirostre</i> (Stephensen, 1915)
<i>Notomastus</i> cfr. <i>latericeus</i> Sars, 1851	<i>Paralacydonia paradoxa</i> Fauvel, 1913	<i>Epimeria (Epimeria) cornigera</i> (Fabricius, 1779)
<i>Chirimia biceps</i> (M. Sars, 1861)	<i>Adercodon pleijeli</i> Mackie, 1994	<i>Eriopisa elongata</i> (Bruzelius, 1859)
<i>Euclymene oerstedii</i> (Claparède, 1863)	<i>Amphiteis gunneri</i> (M. Sars, 1835)	<i>Leucothoe lilljeborgi</i> Boeck, 1861
<i>Leiochone leiopygos</i> (Grube, 1860)	<i>Amphiteis midas</i> (Gosse, 1855)	<i>Othomaera schmidtii</i> (Stephensen, 1915)
<i>Leiochone tenuis</i> Day, 1957	<i>Anobothrus gracilis</i> (Malmgren, 1866)	<i>Pardaliscella boeckii</i> (Malm, 1870)
<i>Lumbriclymene minor</i> Arwidsson, 1906	<i>Melinna palmata</i> Grube, 1870	<i>Harpinia dellavallei</i> Chevreux, 1910
<i>Maldane sarsi</i> Malmgren, 1865	<i>Terebellides gracilis</i> Malm, 1874	<i>Urothoe corsica</i> Bellan-Santini, 1965
<i>Praxillella gracilis</i> (M. Sars, 1861)	<i>Poecilochaetus fauchaldi</i> Pilato & Cantone, 1976	<i>Urothoe elegans</i> (Bate, 1857)
<i>Praxillella praetermissa</i> (Malmgren, 1865)	<i>Poecilochaetus serpens</i> Allen, 1904	<i>Alpheus glaber</i> (Olivi, 1792)
<i>Tachytrypa jeffreysi</i> McIntosh, 1879	<i>Aonides paucibranchiata</i> Southern, 1914	<i>Callianassa subterranea</i> (Montagu, 1808)
<i>Scoloplos armiger</i> (Müller, 1776)	<i>Prionospio</i> cfr. <i>caspersi</i> Laubier, 1962	<i>Chlorotocus crassicornis</i> (A. Costa, 1871)
<i>Scalibregma inflatum</i> Rathke, 1843	<i>Prionospio depauperata</i> Imajima, 1990	<i>Upogebia tipica</i> (Nardo, 1869)
<i>Oxydromus pallidus</i> Claparède, 1864	<i>Prionospio dubia</i> Day, 1961	<i>Ebalia cranchii</i> Leach, 1817
<i>Labioleanira yhleni</i> (Malmgren, 1867)	<i>Prionospio ehlersi</i> Fauvel, 1928	Echinodermata
<i>Eunice pennata</i> (Müller, 1776)	<i>Spiophanes</i> cfr. <i>wigleyi</i> Pettibone, 1962	<i>Oestergrenia digitata</i> (Montagu, 1815)
<i>Lysidice ninetta</i> Audouin & H Milne Edwards, 1833	<i>Spiophanes mediterraneus</i> Meißner, 2005	<i>Amphiura filiformis</i> (O.F. Müller, 1776)
<i>Lysidice unicornis</i> (Grube, 1840)	Crustacea	<i>Astropecten irregularis pentacanthus</i> (Delle Chiaje, 1827)

Video surveys revealed the presence of benthic assemblages typical of low-circalittoral coralligenous biocoenoses (Fig. 2). Epimegabenthic species were observed in 10 out of 11 dives; only dive 4 showed homogeneous muddy bottoms without megafauna. Main taxa contributing to the biodiversity of the area were listed in Tab. 2. Most taxa are classified as habitat-forming, except for echinoderms, whose structural contribution is considered negligible in this hard-bottom habitats. The investigations also revealed the presence of three protected species of Anthozoa: *Callogorgia verticillata* (Pallas, 1766) (Fig. 2a), *Parantipathes larix* (Esper, 1788) (Fig. 2b) and *Funiculina quadrangularis* (Pallas, 1766) (Fig. 2c). *C. verticillata* and *P. larix* are included in Annex II of the SPA/BIO Protocol (UNEP-MAP, 2023); *F. quadrangularis*, typically found on lower circalittoral muddy substrates, are classified as "critically endangered species" in the IUCN Red List. Furthermore, Vulnerable Marine Ecosystems (VMEs) taxa indicators of "Coral Garden" (as *Acanthogorgia hirsuta* Gray, 1857, *C. verticillata*, *Paramuricea macrospina* (von Koch, 1882), *P. larix*, *Paralcyonum spinulosum* (Delle Chiaje, 1822) (Fig. 2d) and "Sea pen fields" (as *F. quadrangularis*) were observed.

Tab. 2 – Main taxa contributing to the biodiversity in the investigated area.
Principali taxa che contribuiscono alla biodiversità dell'area di indagine.

ROV DIVES	TAXA
	PORIFERA
DIVE 11	<i>Mycale</i> sp.
DIVE 7	<i>Poecillastra compressa</i> (Bowerbank, 1866)
	CNIDARIA
DIVE 5, 9	<i>Eudendrium</i> sp.
DIVE 1	<i>Lytocarpia myriophyllum</i> (Linnaeus, 1758)
DIVE 1, 5, 9	<i>Acanthogorgia hirsuta</i> Gray, 1857
DIVE 2, 8, 9	<i>Alcyonium</i> sp.
DIVE 11	<i>Alcyonium palmatum</i> Pallas, 1766
DIVE 5	<i>Callogorgia verticillata</i> (Pallas, 1766)
DIVE 8, 9	<i>Eunicella cavolini</i> (Koch, 1887)
DIVE 1, 3, 6	<i>Funiculina quadrangularis</i> (Pallas, 1766)
DIVE 8	<i>Paralcyonium</i> sp.
DIVE 8	<i>Paralcyonium spinulosum</i> (Delle Chiaje, 1822)
DIVE 5, 9	<i>Paramuricea macrospina</i> (von Koch, 1882)
DIVE 9, 10	<i>Parantipathes larix</i> (Esper, 1788)
	POLYCHAETA
DIVE 5	<i>Filigrana-salmacina</i> complex
	ECHINODERMATA
DIVE 2, 11	<i>Antedon mediterranea</i> (Lamarck, 1816)
DIVE 5	<i>Echinus melo</i> Lamarck, 1816
DIVE 1, 3, 5, 7	Cidaridae

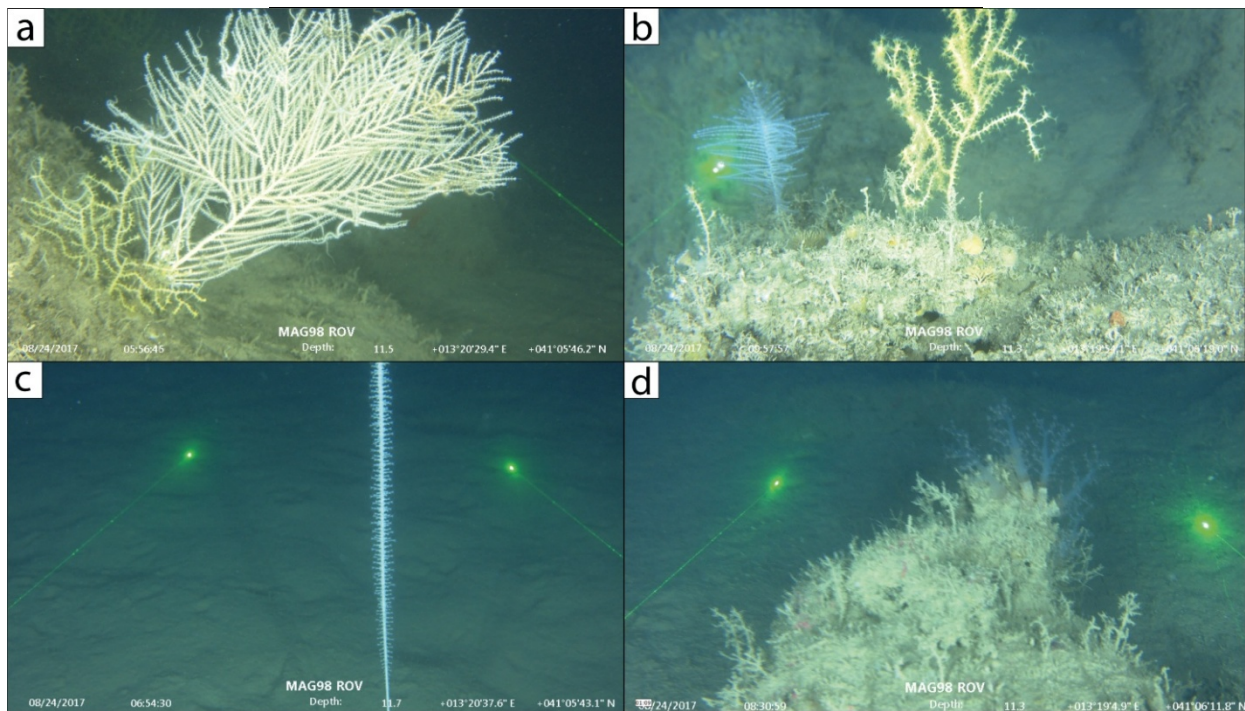


Fig. 2 – (a) *Callogorgia verticillata* imaged by dive 5; (b) *Parantipathes larix* imaged by dive 9; (c) *Funiculina quadrangularis* imaged by dive 6; (d) *Paralcyonium spinulosum* imaged by dive 8.
 (a) *Callogorgia verticillata* rilevata in corrispondenza del dive 5; (b) *Parantipathes larix* rilevata in corrispondenza del dive 9; (c) *Funiculina quadrangularis* rilevata in corrispondenza del dive 6; (d) *Paralcyonium spinulosum* rilevata in corrispondenza del dive 8.

Discussion and Conclusions – Geophysical investigations performed to characterize a potential marine site for sediment dumping allowed us to identify several morphologic highs and circular depressions interpreted as pockmarks. ROV data highlighted the presence of lower circalittoral reef habitats with key habitat-forming species, which have never been reported in this area. Moreover, VMEs taxa indicators revealed habitats

vulnerable to fishing, with structurally complex species supporting essential ecological functions (FAO, 2009; 2011). Based on these ecological findings, the site was not authorized for the disposal of dredged sediments. This characterization study, planned for sediment management purposes, led to the discovery of previously unknown lower circalittoral reef habitats of the Tyrrhenian Sea, which are considered hotspots of biodiversity and ecosystem functioning in the deep sea. Habitat-forming species have positive impacts on species richness and abundance, playing a key role in organizing community structure (Lemieux & Cusson, 2014). VMEs are also characterized by high vulnerability to mechanical disturbance and low recovery ability due to the fragility, uniqueness, structural complexity, and life-history traits. Implementing appropriate conservation measures, such as the designation of a Site of Community Importance (towards a Special Area of Conservation) or the establishment of an offshore Marine Protected Area, is crucial to guarantee the long-term preservation of these deep-water habitats and their vulnerable communities.

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Acknowledgments

The Authors thank the Northern Central Tyrrhenian Sea Port Authority for the financial support.