

# COASTAL CULTURAL LANDSCAPES OF THE TONNARE OF SOUTHEAST SICILY: ANALYSIS AND VISUALIZATION OF DATA

Leopoldo Repola, Justin Leidwanger, Elizabeth Greene, Fabrizio Sgroi, Vincenzo Morra

**Abstract:** The study currently underway along the coasts of south-eastern Sicily, born from the collaboration between the Federico II University, Stanford University, Brock University and the Soprintendenza del Mare della Regione Siciliana, reflects the primary stages of a research methodology focused on the analysis of spaces, both architectural and natural, in relation to the processes of use that have occurred over time. Activities have included an initial phase of 3D digitization using laser scanning, drone Lidar, and terrestrial and underwater photogrammetry of the tonnare of Capo Passero, Marzamemi and Vendicari, as well as the areas of Punta delle Formiche and Morghella in the municipality of Portopalo di Capo Passero. The data were processed to support subsequent geospatial analysis. The georeferenced models can provide an accurate representation of built heritage, settlement traces along the coastline, submerged archaeological features, and geomorphological characteristics of the area, which reflect the dynamics of landscape use and the continuous transformation of these spaces as a result of natural and anthropogenic actions. This integrated work supports new forms of communication of scientific data, both through temporary “pop-up” exhibitions, and through a planned immersive installation project in the Magazzini and in the Tonnara Tower of Vendicari, and through the study of complex spatial interrelations of the integrated data using ArcGIS Modelbuilder.

**Keywords:** Tonnare, digital survey, representation, underwater archaeology, architecture

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## Introduction

Tonnare are complex architectural organisms insofar as they follow their own life over time, having been built and transformed alongside changing fishing techniques and processing of the catch. These structures possess a unique relationship with the coast on which they stand, linking the waters of the sea to the rock on dry land. These architectural spaces connect, almost without limit, the seabed and the land in a continuous transition. Here we understand the intimate relationship between nature and artifice, between function and ritual, between an architecture that stands on the edge of the sea and one that continues into the depths by means of nets and anchors. These complex buildings, crafted of stone on land find their essential counterpart in the sea: the *madraghe*, the net chambers for catching fish [10]. By necessity, tonnare were built close to promontories to better observe the tuna routes; their bays sheltered boats used during fishing periods; their rocky shores offered quarries for blocks necessary to construct buildings and to tie the nets to the seabed and the rope of the *pedale*; their lagoons produced salt for processing the catch; their sandy bottoms prevented damage to the *isula* nets during storm surges. The tonnare on water and land constitute a single building: they have a single name and like an amphibious organism they must respect the laws of sea and stone.

This research project explores the characteristics of these complex architectures, tracing their recurrence and modifications across the layered histories of this corner of Sicily. Along the coastline between Punta delle Formiche in the municipality of Pachino and the Vendicari Reserve in the municipality of Noto, five places follow one another, preserving to different degrees the signs of structures of fishing and tuna processing. Architecture, archaeology, and nature come together in these five landscapes defined by the coexistence of events, histories, persistence and profound transformations. Our explorations include the tonnara of Vendicari (fig. 1) used in



Figure 1 – View of the Vendicari tonnara taken by drone.

the past as a harbor-dockyard and now part of the Nature Reserve; the abandoned tonnara in the center of Marzamemi [3] partly renovated for commercial and tourist uses today; the small promontory of Morghella, which probably housed an ancient tonnara later replaced by that of Capo Passero [1], whose buildings are in a poor state of preservation due to long periods of disuse; and Punta delle Formiche, where signs of the presence of an ancient fish processing plant are clearly visible.

### Technologies and processes for studying tonnare

Our research aims to integrate the spaces of these installations on land and in the sea. This innovative spatial approach begins from three-dimensional digitization of the seabed, considered alongside the technical systems of the *madraghe*, the orographic contexts, and the architectural structures related to tuna fishing. Through the combined use of various systems for the acquisition of 3D data, such as the phase shift laser scanner Faro Focus S70, DJI Phantom 4 Advance drone, GoPro Hero 10, Nikon D70, and the ISU3D prototype system [9], continuous models of portions of the coastline, architectural structures and submerged areas have been produced and georeferenced. These ongoing activities have focused primarily on the area of the ancient port of Vendicari, where 3D digitization procedures have been carried out in tandem with archaeological investigation on an area of approximately 400 square meters. Within this area, a series of ballast piles may reflect the activities of fishing boats and merchant vessels (fig. 2) [6] [7].



Figure 2 – Ballast found in Vendicari.

In 2023, three-dimensional digitization procedures were carried out using photogrammetric and Lidar drone systems of a large area of the Vendicari Reserve (fig. 3) aimed at understanding the long-term transformation of this fragile natural environment: wetlands, riverbed, coastline, bay, and islet.



Figure 3 – Lidar survey phases by Drone Matrice 300.

Survey activities also covered the structures of the tonnara, the warehouse buildings and the ancient tower in order to produce a high-resolution textured model obtained by integrating Lidar data with point clouds generated by terrestrial and aerial photogrammetry. Future integration of local environmental data (e.g. average rainfall indices, wind intensity, wave analysis) will allow the documentation of ongoing silting and erosion phenomena on different types of coastline, to verify the retreat or advancement of wetlands, and to monitor the surface alterations of the blocks and mortar of the architectural structures in relation to their orientation and proximity to the sea. In the same year, a bronze helmet from the early modern age was found on the seabed under investigation, which is currently being restored, adding a further layer to the continued use of the port beyond antiquity (fig. 4).

The area of the discovery was surveyed using photogrammetric procedures to map the wooden elements that were probably brought to the surface by a storm surge (fig. 5). The models revealed a possible shape of the wreck and the presence of numerous ceramic artefacts, probably part of the ship's cargo or ship's furnishings (fig. 6).



Figure 4 – The helmet at the moment of discovery.



Figure 5 – Survey activities of the helmet discovery area.



Figure 6 – 3D model of the seabed with location of wooden parts of the wreck.

Elements of this approach to an integrated study of the tonnara and their landscape have also included survey and recording beyond Vendicari. In 2019, a 3D survey of the tonnara of Marzamemi was carried out alongside initial survey in the associated harbor. Here, a number of large stone blocks (1.20 x 0.70 x 0.50 m) were recorded depth of 9÷16 m; two large anchors discovered nearby would suggest the geometrical layout of a *madruga*. Underwater survey off the Island of Capo Passero in 2020 also yielded the discovery of a large anchor and various stone elements (fig. 7) at a distance of about 3 km from the coast and a depth of 22÷35 m.



Figure 7 – A block and an anchor from the tonnara off the island of Capo Passero.



Figure 8 – Textured point cloud of the Capo Passero tonnara.

The known location of the attachment point of the *pedale* on the east side of the island will facilitate future work to fix the location of the *madruga* and *pedale* and the associated activities of the tonnare in the sea. Surveys of the seabed were followed by 3D digitization activities, through images acquired by drone and processed using Metashape and 3DF Zephyr software, of the entire island of Capo Passero and a limited portion of coastline south of the beach of Scalo Mandrie di Portopalo. The tonnara buildings still present on the island and the historic boats used for the *mattanza*—two *muciare* and one *sciare*—were surveyed with millimeter resolution using a Faro Focus S70 laser scanner. These models were aligned to the island model and imported into the larger georeferenced spatial model. The surveys of the area continued in 2022 with the digitization of the entire tonnara on land using drone photogrammetry for the exterior parts of the buildings and areas in a state of ruin, and Faro laser scanning for the interiors. The processed models were aligned using scalebars and imported into the georeferenced spatial model (fig. 8).

In 2021, photogrammetric drone surveys were carried out of the saltworks, tanks, and quarries in the Morghella area in order to verify the functional relationships between the saltworks and the possible tonnara on the coast.

At the saltworks, a low promontory, about 6 m high, juts out into the sea for about 130 m from the bay of Morghella. Along the southeastern side are evident the entrances of two possible canals (the submerged one to the south may be the more ancient), a *latomia* or quarry area, and rectangular-shaped basins sloping into the water (fig. 9).

In order to confirm the presence in this area of a tonnara predating the eighteenth-century installation at Capo Passero, further detailed recording of shore and adjacent waters using drones, diver reconnaissance, and multibeam survey are planned. Aerial photogrammetric recording of the Punta delle Formiche site, where numerous elements attributable to a Roman fish processing plant are clearly recognizable [4] promise to yield parallels to quarrying, construction, and production processes connected to the structures on land and sea at Morghella. The numerical model was managed and segmented to identify quarry areas, basins, ordered series of holes for different types of bollards (0.20-0.30 m in diameter), docking area for boats, and a tuna sighting post (indicated by two holes connected by a deep cut) (fig. 10).



Figure 9 – Orthophoto with characterization of the areas of the Morghella promontory. Area 1: latomia; point 2: oldest canal; point 3: most recent canal; area 4: recent quarry.

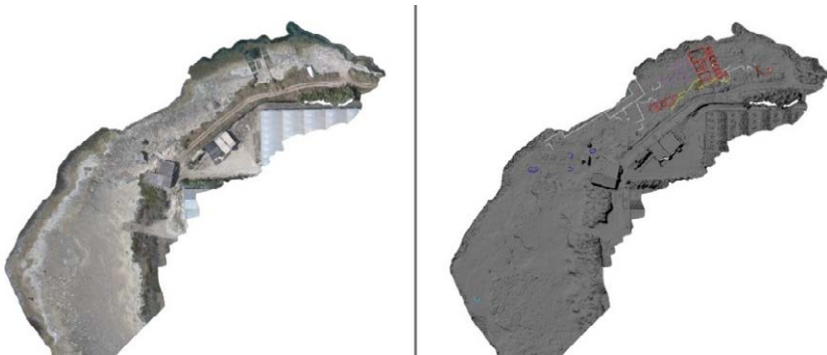


Figure 10 – Two views of the model, textured and in grey tone, of the Punta delle Formiche site showing the traces engraved in the rock. Red: basins; Magenta: holes; Blue: bollards; White: geometries; Light blue: specula; Yellow: rock.

The digital models of these elements and their spatial relationships form a primer of typological elements that will inform spatial analysis of the Morghella models and their application to data from other less well-preserved sites. The models of Morghella and Punta delle Formiche will be integrated with underwater surveys adjacent to the coastline of the two sites, in order to generate continuous models of the visible and submerged parts of the tonnare, including architectural structures, basins, *latomie*, and *madraghe*. These features will enable study of transforming sea levels, coastal erosion, and the associated changes in the local traditions of net fishing.



## Model development visualization and geospatial data management

The current research with its goal of exploring the long connection between past and present of the traditional tuna fishing activities in southeast Sicily, builds on earlier projects undertaken by this team, including archaeological excavation of the famous late antique “church wreck” at Marzamemi and the value of cultural heritage as a means of fostering public understanding of the many connections made possible by the sea [5] [11]. Designed to link archaeological research on the island’s maritime past with modern debates over development, overfishing and the loss of intangible heritage, and migration, the exhibit, *Attraverso il Mediterraneo | Through the Mediterranean* provided a walking itinerary across the local landscape of Portopalo di Capo Passero. In coordination with local officials, we exhibited three boats around the municipality, creating a walking tour for visitors.

Reflecting the sea’s role in economic interaction the Marzamemi “church wreck” offered the starting point along the main street, marked by cafes, restaurants, civic offices, and businesses. A mattanza boat replica offered historical context for three historic tuna fishing vessels already displayed in an adjacent piazza; the exploration boat sat on a point overlooking the sea, offering visitors the chance to imagine themselves navigating by the stars to traverse open waters in search of new shores. The boat geometries were supplemented with imagery, video, sound and a brief informational text panel in Italian and English. To cite just one example of the mattanza boat, the digital content reproduced during the exhibit rendered various moments of the mattanza, the songs, the gestures of the fishermen, the *sciari* and *muciare*, the sea rippled by the tuna caught in the nets, the chimneys and vats of the tonnara, within an ephemeral space extracted from the iconic shapes of boats that recall the cultural landscape of these places, where the sea and the land come together in the tools of work (fig. 11). With its creative staging, this pop-up exhibit of voats engaged local viewers with the long term histories of the sea.



Figure 11 – Exhibition in the Marzamemi square.

This work plan also defined a first step for the production and optimization of multimedia content for the more ambitious project of creating a Museum of the Sea inside the historic Palmento di Rudini in Marzamemi, as imagined together with

Sebastiano Tusa [12]. This building was the subject of an initial valorization hypothesis, in which, through the use of parametric modelling procedures using Grasshopper software, several reconstructive hypotheses were proposed for the architectural elements from the Marzamemi “church wreck” (fig. 12).

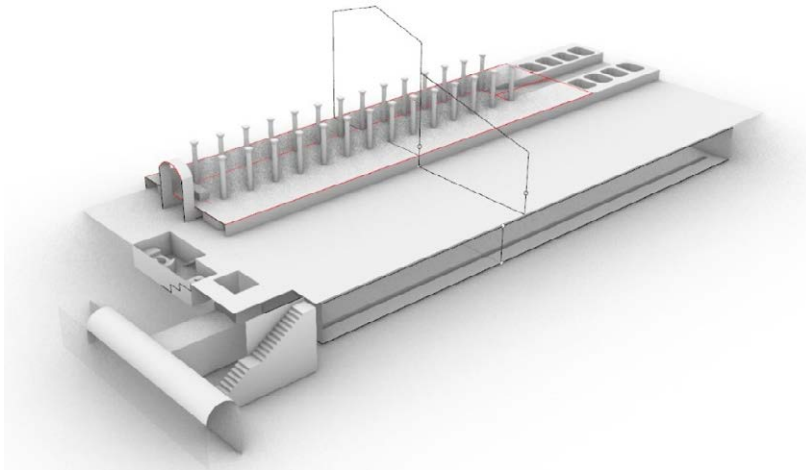


Figure 12 – Study model of the exhibition inside the Palmento.

3D models of the Palmento’s architecture allow for proposed exhibits in both the main floor’s basilica-like plan, and the spaces of the underground cisterns in which immersive installations might represent the events of the ancient shipwreck. This hypothesized path offers a framework in which real and virtual data define narrative scenarios for public storytelling [2] [13].

With the same objective of enhancing and communicating the knowledge obtained through field research activities, a musealization project was launched in 2023 in agreement with the Vendicari Nature Reserve, the Superintendency of the Sea, and the Superintendency for Cultural and Environmental Heritage of Syracuse, to transform the Vendicari storehouses and tower as spaces for storytelling. With light and reversible interventions in these important structures, along with digital technologies, the exhibit aims to include 3D models of the heritage surveyed, and narrative videos of maritime life and coastal change on land and underwater. The valorization plan includes two primary goals:

- To install, in the warehouse building next to the Ecomuseum Library, a multimedia installation by means of video documentaries and animations concerning underwater research, tonnare, ancient Mediterranean routes, and marine biodiversity. The installations will include immersive video- and audioscapes for viewers that draw from archaeological, historical, geological, natural, and ecological investigations at Vendicari. The exhibition plan includes a graphic design to which illustrative and didactic panels will be connected on the southern walls of the two rooms.

- As a second phase, we aim to install in the tower an exhibit aimed at representing the historical sequences of Vendicari Bay and the stratigraphic complexity of its seabed and coastline. The project intends to create a visitor route from the steps at the side of the entrance to the terrace. Infographics on glass and multimedia content, which can be visualized using augmented reality apps, will represent the points in the sea where wrecks and artifacts have been found, as well as the geological transformations of the area from prehistoric era to recent times. Going down the steps inside the tower, it will be possible to experience immersive video mapping and soundscapes that will narrate the research on the tonnara at sea, the wrecks, the anchorages, and other signs of historical use of the bay and the extended area surrounding Vendicari. The narration will be linked to an exhibition of archaeological finds from these waters.

The second management strategy is aimed at harnessing digital data in the development of an advanced data management system in a three-dimensional simulation environment where multi-level data and interoperable numerical models converge. The aim is to devise a tool for interpolating data from multiple scientific disciplines, in order to graph and execute complex interrelations in the progressive development and long-term transformation of the maritime landscape of the tonnara. The architecture of this GIS platform will allow the use of exchange diagrams between textual data, images and models, towards SIM (Spatial Information Modeling) visualization environments [8] to support the segmentation and analysis of geo-spatial data (fig. 13).

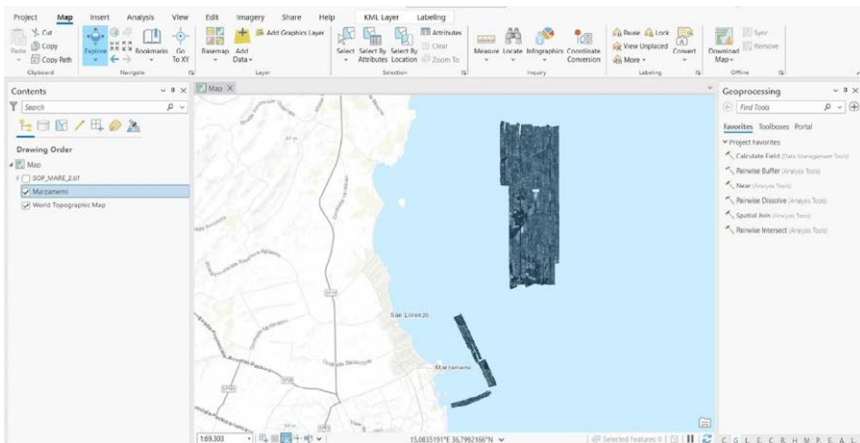


Figure 13 – GIS platform interface.

## Conclusion

The survey of the buildings and traces of ancient installations on the rocks near the sea, the 3D digitization of the sequences of blocks and anchors still lying on the seabed, their origins and dating by means of petrographic and biological

investigations, the study of the geological transformations of the coast (also due to calamitous events like earthquakes), the variation of the sea level with the relative transformation of the seabed, and the evolution of fishing and fish preservation techniques (including the shifting socio-economic relationships within communities), composed interrelated information layers using tools such as ArcGIS Pro's ModelBuilder. These visual programming tools for the construction of geoprocessing workflows will allow for the automation of spatial analysis and data management processes. Through the integration of diverse data collected from archaeological recording, historical research, ethnographic interviews with local fishermen, aerial and LIDAR data, and records of coastal erosion and transformation, we seek to build a more complete understanding of the coincidence of contextual, historical-cultural and technological conditions which have influenced the shapes, sizes and location of the tonnare over time.

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