The Roman fish tanks of the Mediterranean Constraints and interpretations for the definitions of Sea level changes during the last 2000 years

FIELD TRIP GUIDE - ROMAN FISH TANKS OF PUNTA DELLA VIPERA and CASTRUM NOVUM

Marco Anzidei, Flavio Enei and Stefano Giorgi

September 21, 2022

SOPRINTENDENZA ARCHEOLOGIA BELLE ARTI E PAESAGGIO PER LA PROVINCIA DI VITERBO E PER L'ETRURIA MERIDIONALE

CITTÀ DI SANTA MARINELLA POLO MUSEALE CIVICO MUSEO DEL MARE E DELLA NAVIGAZIONE ANTICA MUSEO DEL CASTELLO DI SANTA SEVERA

ISTITUTO NAZIONALE DI GEOFISICA E VULCANOLOGIA

AKTES Society for the Study of Ancient Coastlines

SAVEMEDCOASTS-2 sea level rise scenarios along the mediterranean coasts

CITTÀ DI SANTA MARINELLA

CO OP CUL TU RE

Lazio ETERNA SCOPERTA PARCHI E RISERVE NATURALI parchilazio.it

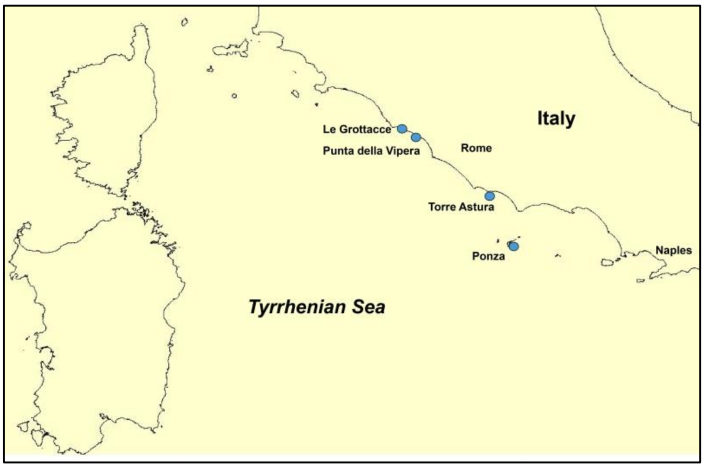
REGIONE LAZIO

Field trip #1 - Punta della Vipera Roman fish tank

Departure from the castle of Santa Severa 09:00 a.m. – Return 5 p.m.
Diving mask and sea shoes required!

1. Location

A few km south of Civitavecchia and about 30 km north of Rome.



Location of Punta della Vipera fish tank

2. Geologic and tectonic environment

Sedimentary and volcanic rocky coast. Bedrock consists of marly-limestones. MIS 5.5 is inland at about 30 m of elevation. Tectonic uplift has been estimated for this area at 0.18±0.05 mm/yr (Lambeck et al., 2004b). Absence of historical and instrumental seismicity or volcanic activity related to the extinct Sabatini volcanic complex.

3. The Fish tanks (piscinae): general description

Roman fish tank were built mainly along rocky coast of Italian peninsula and elsewhere in the Mediterranean beyond the Italian borders. Their age is generally between the end of the second century and early first century BC and were built for fish culture. The best-developed ones were built in a restricted time between 100 B.C. and 100 A.D. and because of high construction and maintenance costs, they were used for a relatively short period only and the building of new tanks ceased during the second century AD.

Most of the known fish tanks in Italy (about 54 sites) occur along the Tyrrhenian coastline near large Roman villas and only a few are known along the Adriatic coast. Remains of piscinae are also found elsewhere along the Mediterranean coasts but these are often lacking in the very features that give the high accuracy for the Tyrrhenian examples and may have served different purposes.

3.1 Fish tank classification

Fish tanks can be classified in two types, based on their realization:

- completely excavated into the bedrock;
- excavated and built. even underwater. using hydraulic concrete (capable to resist to sea water).
- Built using bricks and concrete along the rocky shore

An additional classification concerns their use:

- for fish culture;
- as 'water gardens' to embellish villas of wealthy Romans.

3.2 Constructional elements

They all have constructional elements that bear directly on sea level at the time of construction and well-preserved remains of these features provide a precise measure of sea-level change. Only for a small number of these known sites have precise sea-level markers been preserved or identified, but from Latin publications of Pliny the Elder and Varro as well as from field surveys, the significant sea-level markers have been identified and measured:

- fish tanks were carved into rock to a depth of 2.7 m (9 Roman foot) or less ...*in pedes novem defondiatur piscine…* depending on fish species.

- basins were protected from wave and storm action by exterior tall walls, so the sea in the inner pools was always calm, like a pond: *''Mox praeiaciuntur in gyrum moles, ita ut conplectantur sinu suo et tamen excedant stagni modum''*.

They were often equipped with a water tank or an aqueduct at their back to feed the basins with fresh water. This technique, called *"aquatio",* consists of mixing marine and fresh water to attract some fish species (like seabass). For this reason, the fish tanks were placed near springs or coastal lakes, such in the case of the fish tank of Lucullo, at Circeo, south of Rome. These had constructional features within the complex that controlled the freshwater input and for this reasons some constructional elements, like some of the sluice gates, were at slight higher level.

3.3 Fish Tank key markers of Roman sea level

Foot-walks (crepido)

The foot-walks that border the internal pools and occur at two or three levels. Often the lowest levels of crepido are covered by sand and were not recognized or interpreted in earlier (or even recent) investigations.

The Latin definition of the word crepido is "*Ponitur de mole alta et abrupta, qua maris littus, vel ripa fluminis munitur contra aquarum impetus"*. That means "tall and abrupt basement located on the edge of the sea or rivers where waters have impetus".

Crepido and Latin Authors

Pliny the Elder (23-79 A.D.) «Naturalis Historia»
"marginum eam partem, quae aquas spectat": part of that margin that looks at the water.

Marcus Terentio Varro (116 B.C.-27 A.D.) «De re rustica»
"de lacu, aut stagno, ubi servantur anates": side of the lake or pond where ducks sit.

Juvenale (60-127 A.D.)
"locus editior, vel in ripa fluminis, vel in portu maris, vel rectius ad latera viarum, ubi stare solent mendici stipem petituri": level placed on the bank of the river, or the sea port, or on the roadside, where the beggars are begging.


A


B

The two a) and b) three levels of crepido at Torre Astura and Ponza fish tanks, respectively.

Channel systems

The surrounding walls of the fish tanks and the crepido are cut by channels that permit water exchange between the tanks and the open sea, with the flow being controlled by sluice gates.
Often these channels are covered by sand and were not recognized or interpreted in earlier (or even recent) investigations.

A channel system for water exchange within a fish tank includes:

- channels for water exchange within the basins
- channels for water exchange with open sea
- sluice gates (in stone or lead) with posts, sliding grooves and thresholds placed along the channels

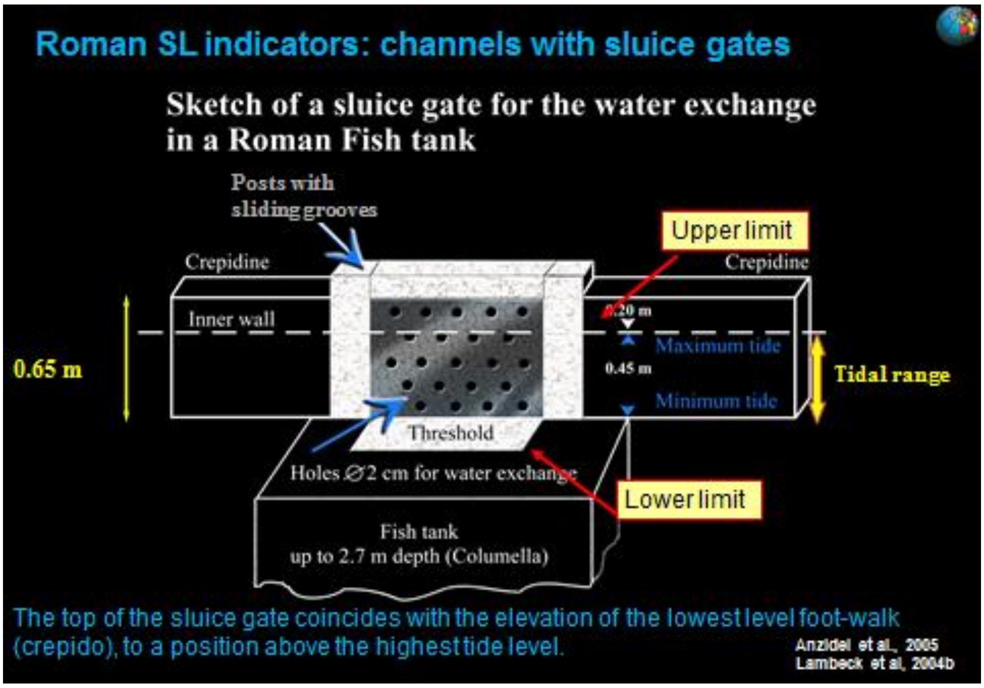
The gates were placed along the channels (mainly at their entrance to the basin) and between the pools. They consist of:

- a horizontal stone surface that defines the threshold and is cut by a groove to receive the gate;
- two vertical posts with grooves to guide the vertical movement of the gate (but some gates are fixed);
- an upper stone slab with horizontal slots (or with a horizontal shot if there is only one) to extract the gate;
- the gate itself with small holes to permit water exchange and prevent the escape of fish.

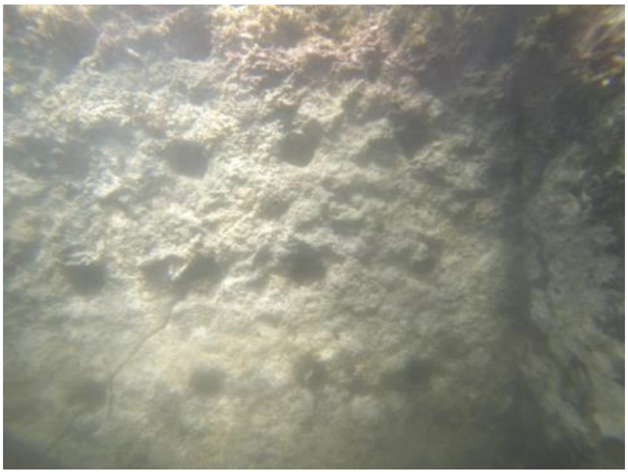
The base of the channels coincides with the position of the threshold slab. The top of the sluice gate coincides with the elevation of the lowest level foot-walk and, to keep a safety margin, corresponds, as reported by Columella to a position above the highest tide level*: "Spissi deinde clatri marginibus infiguntur, qui super aquam semper emineant, etiam cum maris aestus intumuerit".*

From sites with complete preservation of sluice gates, channels and foot-walks, we can verify the height relationship between the various features and we estimate that the level of the lowest crepido occurred at about 20 cm above the highest tide level.

In the Tyrrhenian Sea the maximum tidal excursion is about 40–45 cm (see fig.11), in agreement with the observed depths of the channels, and this indicates that the flow of water into the holding tanks was tidally controlled.



Sketch of the channel sluice gate with sliding posts, threshold and lowest level crepidinae as viewed from within the fish tank. The top of the sluice gates coincides with the elevation of the lowest level footwalks and corresponds to a position above the highest tide. In this example, the lowest foot-walk is now 0.72 m below the sea surface at the time of measurement and the threshold is 1.37 m below present sea level (Lambeck et al. 2004b / Earth and Planetary Science Letters 224 (2004) 563–575).

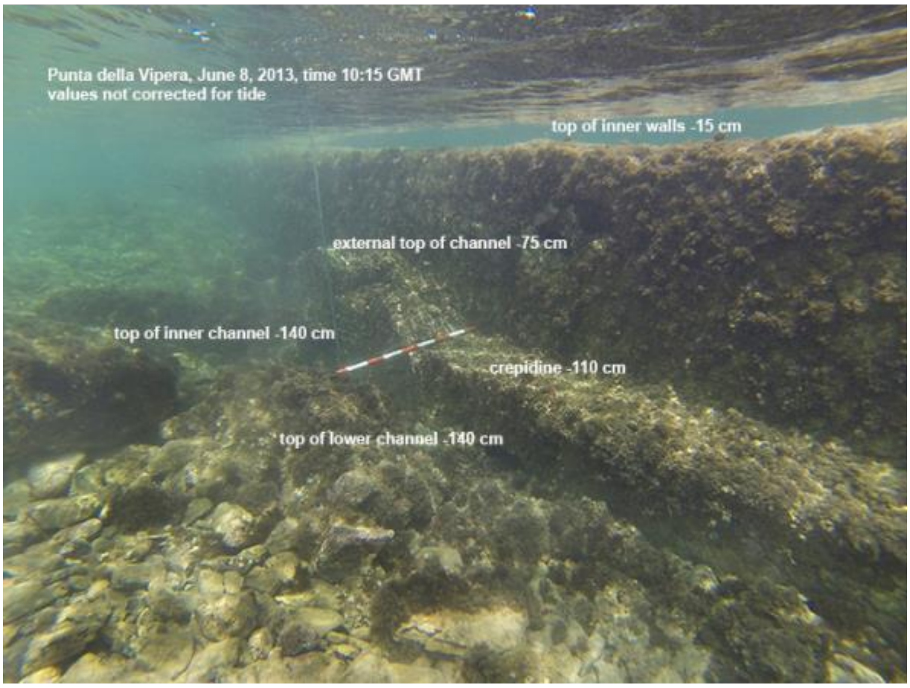


Left) Torre Astura: the channel for water exchange equipped with sluice gate and posts; right) the holes in the same sluice gate that allow for water exchange but prevent the escape of fish.

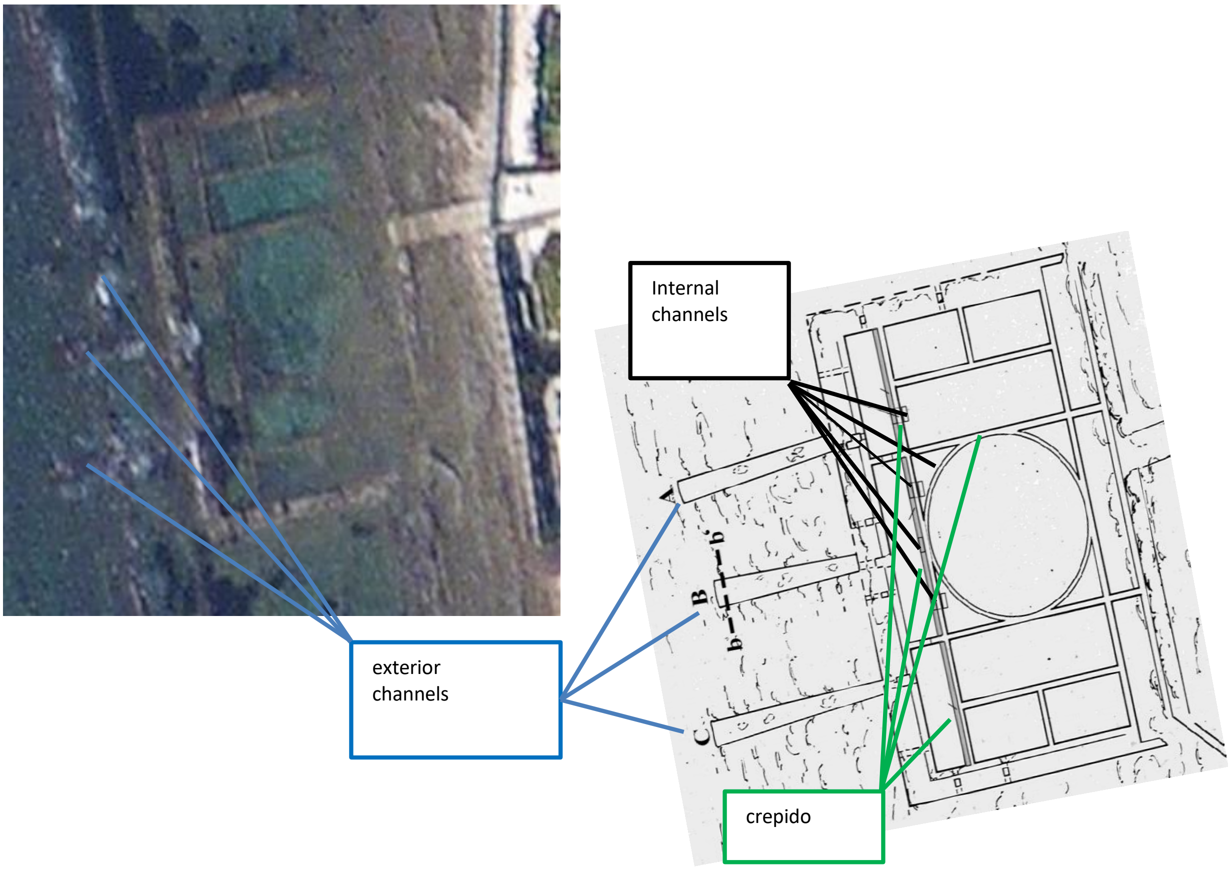
4. Punta della Vipera fish tank

This fish tank was constructed between 0-100 AD. Its constructional elements show several inner channels and three 15 m long covered channels connected with the open sea. This is one of the best preserved fish tanks in the Mediterranean, still showing many original constructional parts, like vaulted channels and *crepido* with pavements.

The fish tank of Punta della Vipera with the separation walls between the pools and the channel.



The fish tank of Punta della Vipera and some sea level markers consisting in the crepido and the channel (data not corrected for tide).



The fish tank of Punta della Vipera and some sea level markers consisting in crepido, exterior and internal channels for water exchange.

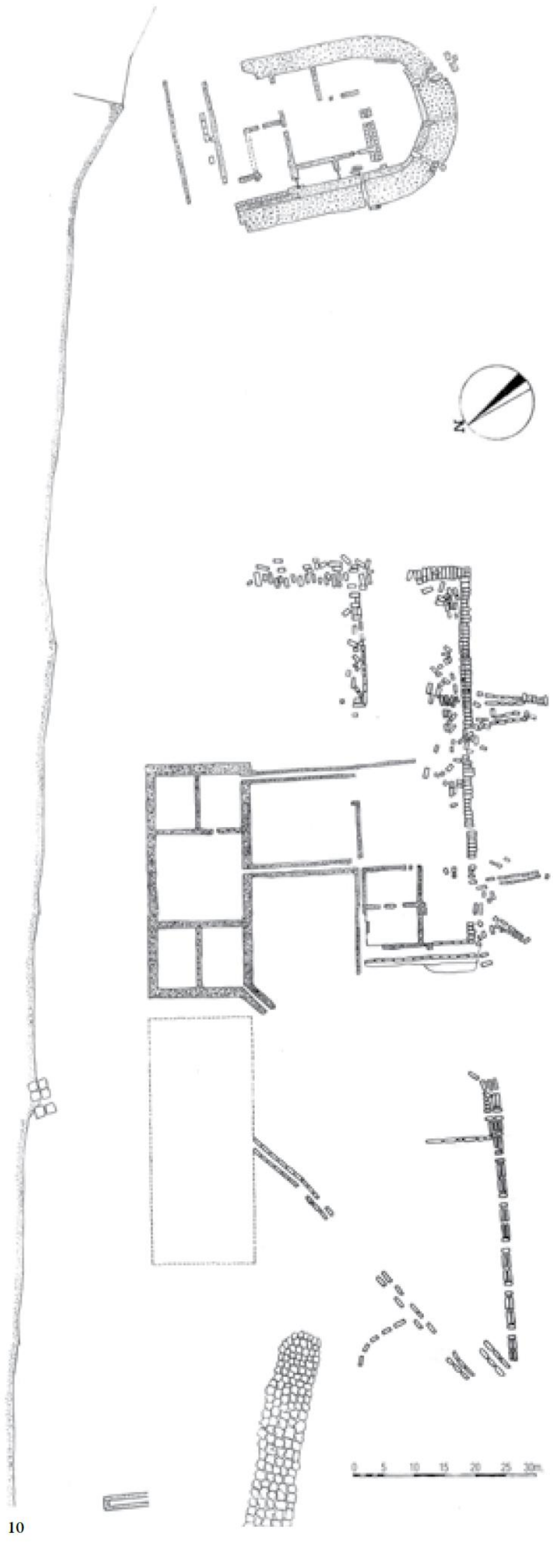
5. The Roman fish tanks of Castrum Novum

Just in front of the *castrum*, at a short distance from the current beach, the remains of buildings belonging to the city coexist with an Etruscan port from the 5th century BC (with subsequent reuse as a fish pond) and a large fish tank, datable between the late Republican and the imperial era. There are various structures which due to their characteristics, chronology and functions, show different life stages, with different uses over the centuries. In particular, the piers that delimit the southern side of the complex, built in large blocks of square work, already identified by Frau as port structures from the Etruscan period. These constructions were founded on a rock embankment and kept in elevation even up to three rows of large blocks, for a total length of about 150 meters. These may not be in phase with the fish tank complex, built between the late Republican era and the early imperial era. The latest studies concerning the ancient sea level and the technical characteristics of the works do not exclude the possibility that the piers can be identified with the remains of the quays of a port, built to serve the Roman maritime colony in the first half of the third century BC. At the southern outer corner of the longest pier, there are still about two meters of water today, compatible with a port use in the Middle Republican era. Only at a later time, also likely due to the sea level rise, the fish tank was built reusing the oldest quays as protections of the complex. In particular, the water supply channels were put in place and some parts of the piers rebuilt by reusing at least two mooring stones from the oldest systems in the masonry. In light of what is known to date, it is possible to hypothesize that in the first settlement phase of the colony a special port structure was also set up. Only in the late Republican phase, the piers were restructured and readapted.
In the late Republican period, between the 2nd and 1st centuries BC, the large fish tank was extending for more than a hundred meters and was repeatedly reorganized perhaps. It remained operational for several centuries until the imperial era. The structure was likely built by reusing and re-adapting the oldest port structures of the Republican-era, built in the third century BC. The fish tank is divided into several rectangular basins, in cement work with hydraulic mortar and traces of *opus signinum* coatings. The water supply channels are north-west oriented and mark the progressive retreat of the coastline and the consequent need to readjust the hydraulic systems for feeding and cleaning the tanks. In addition to the ancient piers of the port, built in square work, the large fish tank was originally supplied with fresh water from the Guardiole creek. The discovery of numerous oyster shells in the area suggests that this type of farming (*ostriaria*) was also present in the fish tank.

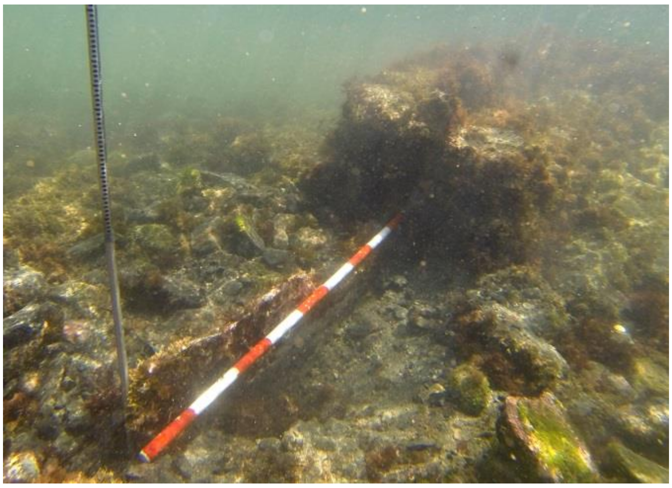
A different story concerns the fish tank with an apse facing the sea, built entirely of concrete with brick facings. It is also today semi-submerged and placed at short distance from the beach, a few hundred meters northwest of the castrum walls. The researches have traced internal subdivisions in more rectangular basins connected each other with some sluice gates (*cataractae)*, still found in place in the appropriate posts (*gargami)*. It was likely pertaining to one of the maritime residences located along the coast, certainly built in the imperial era, between the 1st and 2nd centuries AD. The discovery of a small marble statue, suggests that the fish tank was embellished with decorative objects such as statues and marble coatings (Fig. 70). The surveys and the aerial photos also confirm the presence of a large pre-existing breakwater, now submerged, which protected the structure from storms.

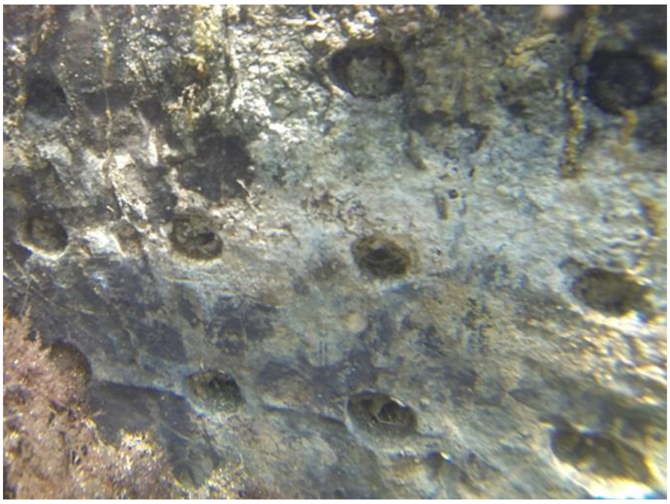
The large semi-submerged fish tanks which with their considerable extension, occupy a wide strip of the coast. Research activities focused on the fish tanks of Castrum Novum, creating a new detailed documentation of the complexes, useful for the knowledge of their chronology, the ancient functioning as well as the sea level in Roman times. The construction took place in several phases starting from the Republican era and the presence of a long defensive barrier of the structures that shields the main fishpond from the Libeccio wind, creating a sort of protected dock functional to the plants. There is no doubt that it is one of the oldest and largest fish tank complexes in the Mediterranean. The investigations have led to the discovery of other interesting chronological and structural elements also in the fish tank with apse which is in turn protected by a considerable mass of stones to protect it from storm surges. Also interesting is the identification of a long semicircular pier that from the mainland, with a width of about 8-10 meters, extends towards the open sea with an oblique course for at least 100 meters. The structure could be relevant to the port infrastructure of the ancient castrum landing.

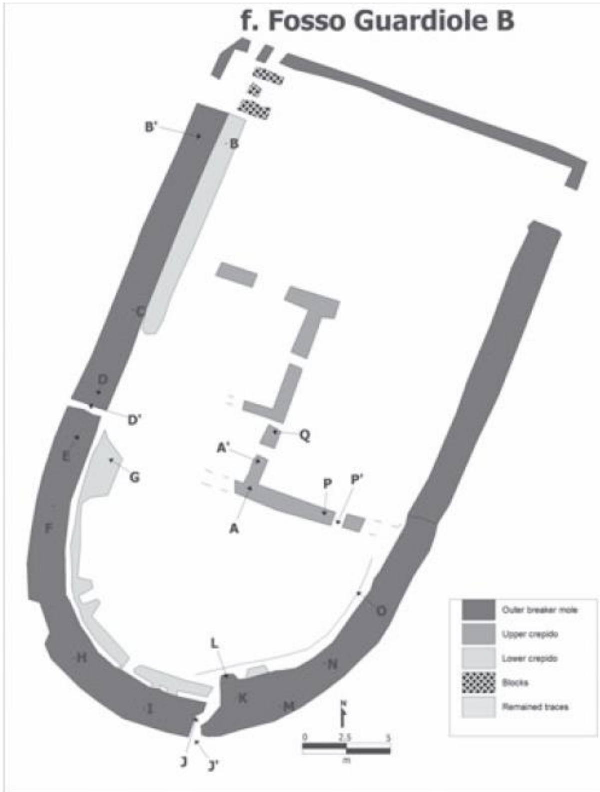
Castrum Novum: the Guardiole fish tank. Aerial view of the southern part of the fish tank with the channels for water supply.



Plan of the Castrum Novum fish tanks (from Stefano Giorgi of the GATC Maritime Studies Center)



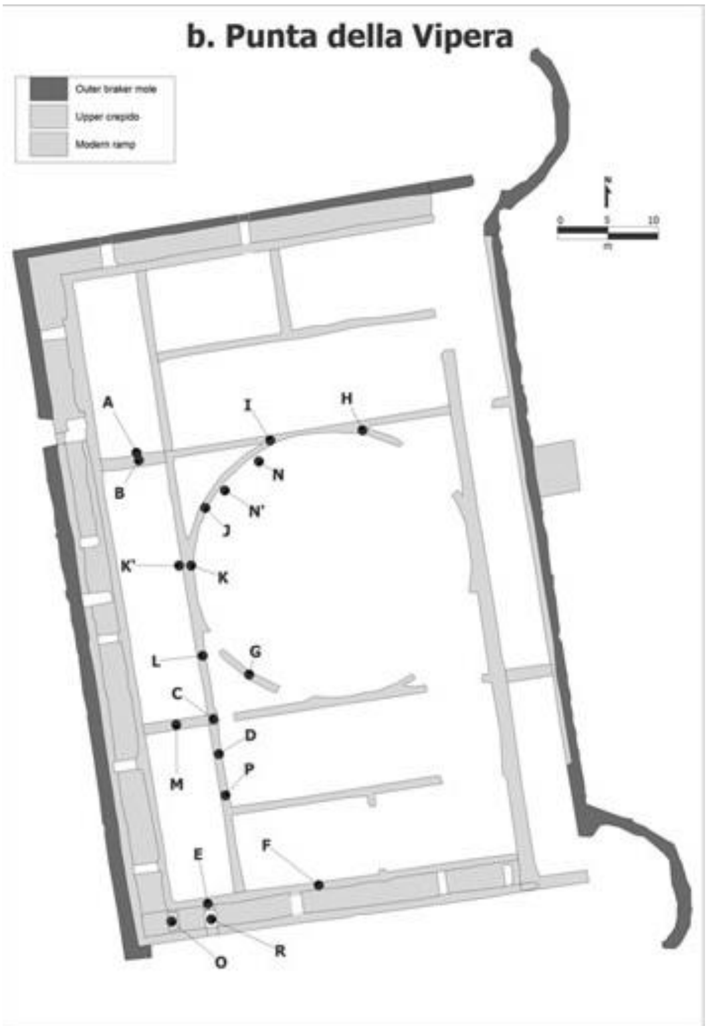




Top left: The sluice gate made of lead with holes of 3 cm of section for the water exchange**.**

Bottom right: the fish tank of Fosso Guardiole

6. Interpretations of roman sea level. Evelpidiou et al., 2012 vs Lambeck et al., 2004B



		(a)	
A	– 69.0	—	Top (internal) of the arch connecting two basins
B	– 24.0	—	Top of the *crepidine* above arch connecting two basins
C	– 19.5	—	Upper *crepidine*
D	– 24.0	—	Upper *crepidine*
F	– 20.0	—	Upper *crepidine*
E	– 28.0	—	Upper *crepidine*/top of the covered channel
G	– 14.0	—	Upper *crepidine*
H	– 21.0	—	Upper *crepidine*
I	– 18.0	—	Upper *crepidine*
J	– 12.0	—	Upper *crepidine*
K	– 29.0	—	Upper *crepidine*
K′	– 79.0	—	Upper *crepidine*
L	– 19.0	—	Upper *crepidine*
M	– 19.5	—	Top of the *crepidine* above arch connecting two basins
N	– 40.0	—	Arch-producing shadow to fishes
N′	– 40.0	—	Arch-producing shadow to fishes
P	– 37.0	—	Upper *crepidine*
O	– 21.0	—	Bottom of small basin at the outer breaker (?)
R	6.5	– 53.50	Bottom of small basin at the outer breaker

Fig.8 with Table. Measured points in Evelpidiou et al., 2012. Failure to identify the relevant features?

- ✓ **Failure to identify all relevant features?**

Evelpidiou et al., 2012 did not recognize the channels, such as inner channels and the three~15 m long exterior channels (features of in Fig.8 with table above) used to exchange water with open sea. These provide a rslc of 132±20 m.

- ✓ **Misinterpretation of architectural features?**

The *"…the best preserved crepido at about -20cm"* in Evelpidiou et al., 2012, corresponds to the top of the eroded wall that separated the inner pools of the FT (points G, P, D, etc., Fig. 8).

- ✓ **Discrepancies in elevation measurements of some markers?**

In Evelpidiou et al., 2012 the lower crepido is given at -79 cm (point K') whereas we find -114 cm (diff. 35 cm).

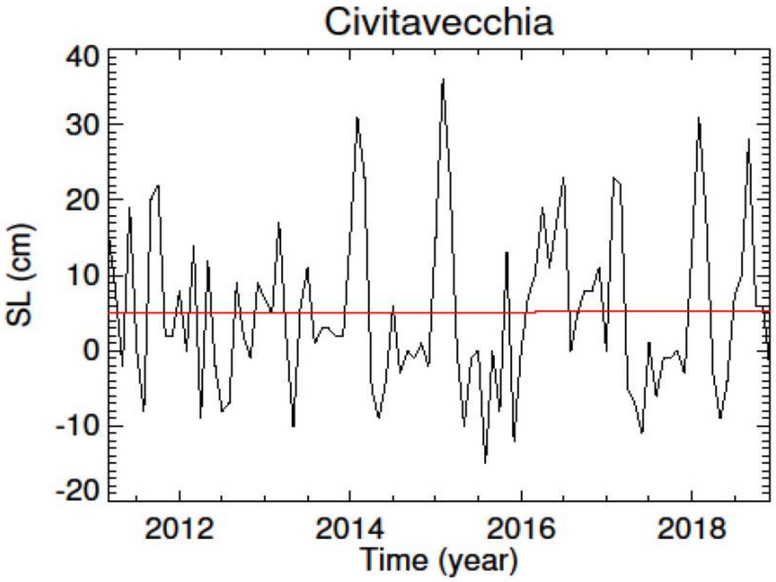
- ✓ **Consistency with Latin authors?**

The *crepido* were used to walk around the inner basins without getting wet. Therefore, the valid sl marker is the lowest level of *crepido*, especially when in conjunction with channels. At Punta della Vipera the lower *crepido* is at -114 cm (while top of channels are at -139 cm and their bottom at -335 cm) (e.g. Fig. 7?).

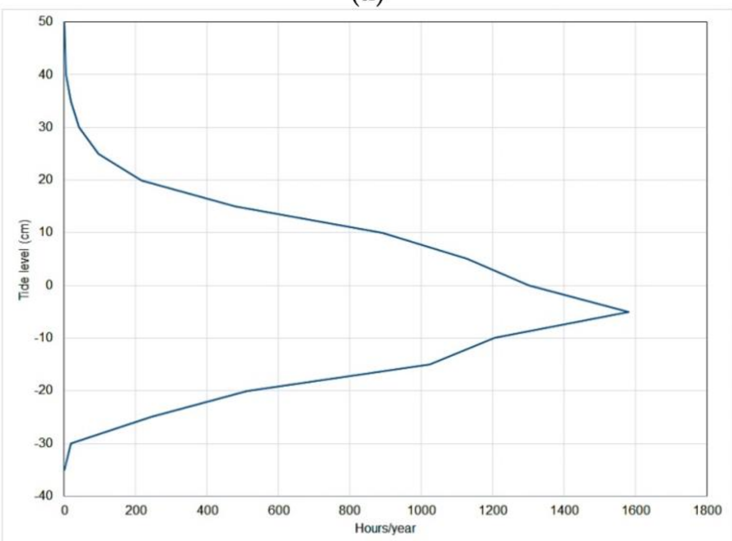
6.1 What makes the difference

- ✓ Cleaning sites to to identify significant buried sea level markers so as to avoid errors of mis-interpretations.
- ✓ Distinguish between different type of fish tanks (industrial use or to embellish villas).
- ✓ The water level in some fish tanks was often controlled by fresh water from springs, aqueducts or coastal lakes, and used to make the "aquatio".
- ✓ The cross check observation between many different fish tanks reinforce interpretations

7. Tide, sea level trend and vertical land movements along the coast of Santa Severa

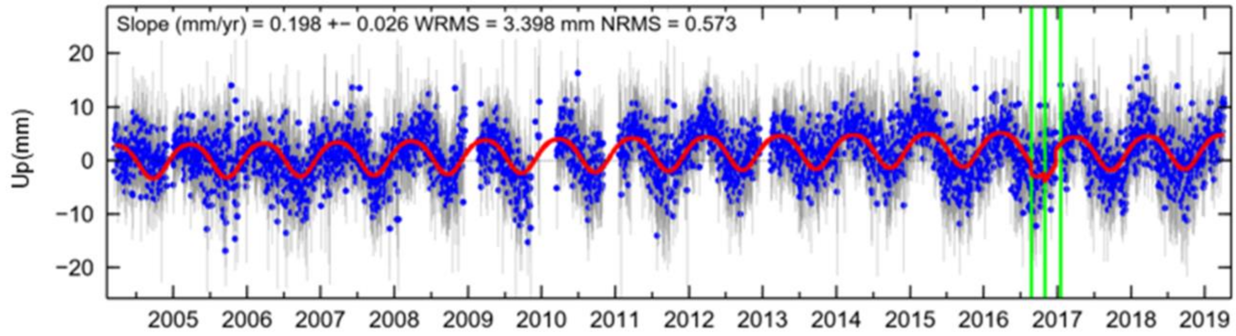


(**a**)

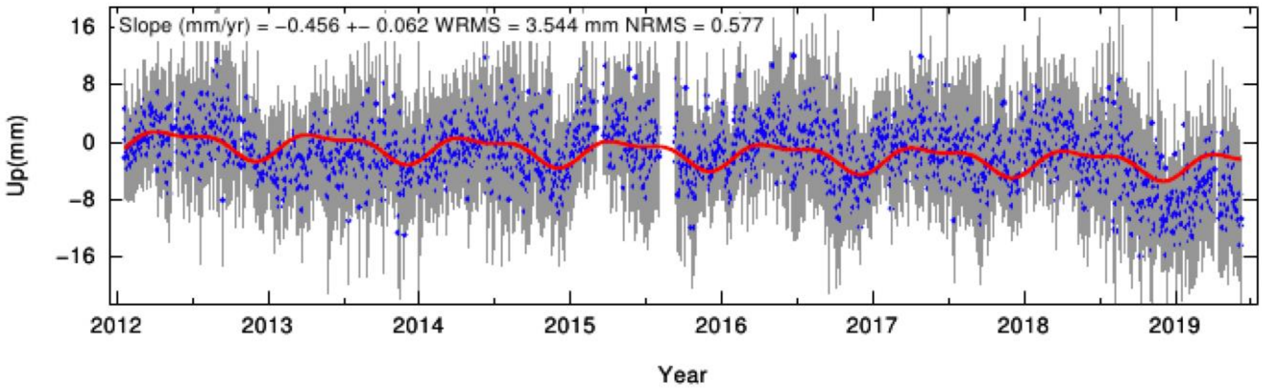


(**b**)

Sea level data analysis for the tide gauge of Civitavecchia, which is located a few km North of Santa Severa. (**a**) Monthly data of sea level recordings collected in the time span 2011–2019 (about nine years). The red line is the linear fit of the sea level trend at 0.25 ± 0.1 mm/yr. (**b**) Statistical diagram of sea level heights (cm) versus time (hours/year). The values of sea level height frequency are reported during one year, including maximum sea level heights of about 45 cm that may exceed the tide amplitudes. These can be related to storm surge events that occur only a few hours in a year, when water is pushed from the sea onto the land due to a temporary decrease in atmospheric pressure and wind. Sea level data from www.mareografico.it



(**a**)



(**b**)

The vertical components (UP) of the time series of the GNSS station for (**a**) TOLF (time span 2004–2019, about 15 years) and (**b**) MAR8 (time span 2012–2019), both located near Santa Severa. Both sites are relatively stable in the IGb08 reference frame with a vertical velocity of −0.061±0.135 mm/year for TOLF and −0.456±0.344 mm/year for MAR8. We remark that uncertainties associated on the vertical velocities are about ±0.5 mm/year and are barely significant in view of unresolved questions about the GPS reference frame stability and additional factors. The tectonic stability of this region is also inferred from the low level of seismicity deduced from historical data and instrumental recordings of earthquakes (**www.ingv.it**), which do not report the occurrence of significant events for the last 3000 years BP.

References

Evelpidou, N., P. Pirazzoli, A. Vassilopoulos,G. Spada, G. Ruggieri, and A. Tomasin. Late Holocene Sea Level Reconstructions Based on Observations of Roman Fish Tanks, Tyrrhenian Coast of Italy. Geoarchaeology, 27 (2012), 259–277.

Lambeck, K., Anzidei, M., Antonioli, F., Benini, A., Esposito, E., 2004b. Sea level in Roman time in the Central Mediterranean and implications for modern sea level rise. Earth and Planetary Science Letters 224, 563-575.

Lambeck, K., Anzidei, M., Antonioli, F. *et al.* Tyrrhenian sea level at 2000 BP: evidence from Roman age fish tanks and their geological calibration. *Rend. Fis. Acc. Lincei* **29** (Suppl 1), 69–80 (2018). https://doi.org/10.1007/s12210-018-0715-6

F. Marra, M. Anzidei, A. Benini, E. D'Ambrosio, M. Gaeta, G. Ventura, A. Cavallo, Petro-chemical features and source areas of volcanic aggregates used in ancient Roman maritime concretes, Journal of Volcanology and Geothermal Research, Volume 328, 2016, Pages 59-69, ISSN 0377-0273, https://doi.org/10.1016/j.jvolgeores.2016.10.005.

Flavio Enei, Klára Preusz, Michal Preusz. CASTRUM NOVUM. STORIA E ARCHEOLOGIA DI UNA COLONIA ROMANA NEL TERRITORIO DI SANTA MARINELLA. QUADERNO 4, 2020.
https://www.academia.edu/43800674/CASTRUM_NOVUM_STORIA_E_ARCHEOLOGIA_DI_UNA_COLONIA_ROMANA_NEL_TERRITORIO_DI_SANTA_MARINELLA_QUADERNO_4

Anzidei, M.; Doumaz, F.; Vecchio, A.; Serpelloni, E.; Pizzimenti, L.; Civico, R.; Greco, M.; Martino, G.; Enei, F. Sea Level Rise Scenario for 2100 A.D. in the Heritage Site of Pyrgi (Santa Severa, Italy). *J. Mar. Sci. Eng.* **2020**, *8*, 64. https://doi.org/10.3390/jmse8020064

Anzidei, M.; Lambeck, K.; Antonioli, F.; Furlani, S.; Mastronuzzi, G.; Serpelloni, E.; Vannucci, G. Coastal structure, sea-level changes and vertical motion of the land in the Mediterranean. *Geol. Soc. Lond. Spec. Publ.* **2014**, *388*, 453–479