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LONG-TERM CHANGES IN SPECIES AND HABITAT OCCURRENCE IN THE MARINE PROTECTED AREA OF BAIA (GULF OF POZZUOLI, NAPLES)

CAMBIAMENTI A LUNGO TERMINE NELLA PRESENZA DI HABITAT E SPECIE NELL'AREA MARINA PROTETTA DI BAIA (GOLFO DI POZZOULI, NAPOLI)

Abstract - *The MPA of Baia (Gulf of Pozzuoli, Naples) is a unique area designed to protect both the natural habitat and the submerged archaeological structures represented by ancient Roman ruins. Long-term changes in benthic species and habitat occurrence in the MPA of Baia are here discussed based on an ecological survey conducted in July 2023 in the frame of the FEAMP project. We registered the loss in the whole MPA of the seagrass* Cymodocea nodosa *and of the two green algae* Caulerpa prolifera *and* C. cylindracea*, mixed with* Cymodocea*, which in 2004 were covering the 36% of the soft bottoms of the area. On the other hand, a* Posidonia oceanica *bed of ~2 ha extension was recorded between 6 and 7.5 m depth. While a few cryptogenic and alien species were recorded, in particular the cryptogenic alga* Acetabularia caliculus*, represents the second record of this thermophilous species for the Italian coasts.*

Keywords*: Marine Protected Area, long-term changes, benthic habitat distribution,* Posidonia oceanica*, Gulf of Pozzuoli, Tyrrhenian Sea.*

Introduction – The Marine Protected Area of Baia (Gulf of Pozzuoli, Naples), established in 2002, is a unique area designed to protect both the natural habitat and the submerged archaeological structures represented by ancient Roman ruins (harbour remains of *Portus Julius*, mosaics, villas and a ninfeo). Some informations on the area and its hystorical biodiversity were summarized in Gaglioti *et al.* (2020) for benthic animal organisms and *Posidonia oceanica* distribution, and in Porzio *et al.* (2020) for the macrophyte distribution, while large scale habitat distribution, surveyed in 2004, are reported in Russo *et al.* (2008). Long-term changes in benthic species and habitat occurrence in the MPA of Baia are here discussed based on a recent ecological survey conducted in July 2023 in the frame of the FEAMP project (Gambi *et al.,* 2024). The benthic surveys was designed to check transects and areas where previous information was available, based on a general benthic survey conducted in 2004 (Russo *et al.,* 2005; 2008), in order to make comparisons on species and habitat occurrence after 19 years.

Material and Methods - The MPA area surveyed is reported in Fig. 1. The benthic survey was conducted by SCUBA diving from 9 to 15 July 2023, in various transects perpendicular to the coast where previous data were available due to a survey conducted in July 2004 by Russo *et al.* (2005) (Fig. 1), as well as in most of the archaeological remains (*e.g., Portus Julius*, the pilae, the ninfeo and Villa dei Pisoni). Visual census of both benthic and fish fauna was conducted along the transects, using also the support of video and photos. In a *Posidonia oceanica* L. Delile meadow, discovered in the area (Fig. 2), shoot density measures, on 40x40 cm quadrats, were done in 4 plots (approx. 10 m^2 each) at a distance of 20 m from each other (4 replicates per plot = 16 density counts), while 15 orthotropous (vertical) shoots were collected for evaluation of the morphological parameters of the plant (Tab.1).

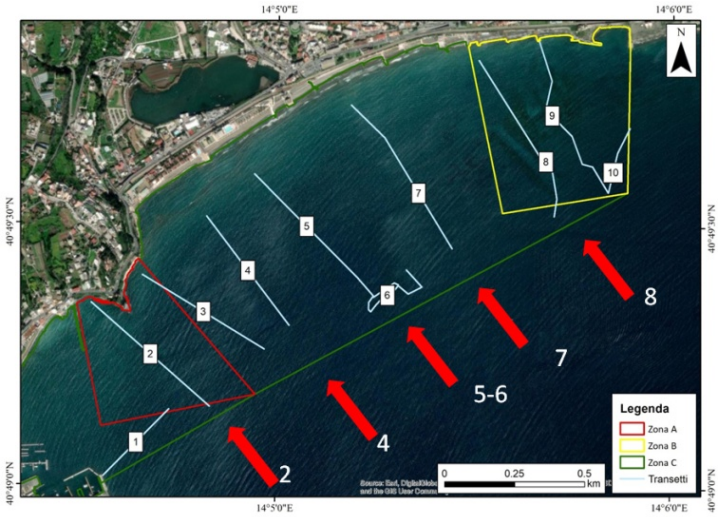

Fig. 1 – Map of the MPA of Baia with indication of its zonation and of the transects of the 2004 survey (from Russo *et al*., 2005) and with the transecst repeated in July 2023, indicated with red arrows.
Mappa dell'AMP di Baia con indicata la zonizzazione ed i transetti effettuati nel 2004 (da Russo et al*., 2005) e ripetuti nel survey del luglio 2023 (indicati con le frecce rosse).*

Tab.1 - Parameters of the *Posidonia oceanica* plants in the meadow of Baia. N= 15 shoots; distance between shoot density Plots: 20 m (4 replicates per plot). The values are % or mean with s.d. in paretheses.
Parametri dei fasci di Posidonia oceanica nella prateria di Baia. N= 15 fasci; distanza tra i Plot di densità 20 m (4 repliche per plot). I valori sono % o medie con d.s. tra parentesi.

# leaves/shoot	4.5 (0.6)
% adult leaves	61
% intermediate leaves	32
% juvenile leaves	3.4
Leaf base length (cm)	3.7 (0.9)
Leaf length (cm)	63.0 (29.5)
Longest leaf length (cm)	95.5 (21.2)
Brown tissue (cm)	7.17 (9.0)
Width (mm)	9.4 (0.8)
% entire apex	35.6
% mechanic erored apex	37.3
% biological eroded apex	27
Coefficient A	64.3
Shoot density (#shoots/m^2)	
Plot 1	342.1 (42.6)
Plot 2	328.1 (87.8)
Plot 3	428 (102.1)
Plot 4	341 (31.4)
Mean shoot density	359.8 (66)

Results - The most relevant change between the two surveys is the loss in the whole MPA of the seagrass *Cymodocea nodosa* (Ucria) Ascherson and of the two green algae *Caulerpa prolifera* (Forsskål) J.V.Lamouroux and the alien *C. cylindracea* Sonder, mixed with *Cymodocea*, which in 2004 occurred in the majority of the soft bottoms, covering 36% of the whole area (Carannante *et al*., 2015) (Fig. 2). On the other hand, a *Posidonia oceanica* bed was recorded between 6 and 7.5 m depth. The meadow shows a rather continuous trend, and a coverage estimated from 100% to 80%, as there are sparse clearings and channels. The side closer to the coast that delimits the upper limit (at about 6 m depth) has a slightly arched shape. Overall, an area of 2.18 hectares of seabed colonized by the plant was estimated. The average shoot density and the values of the morphometric parameters measured on the plants (15 shoots) taken at 7 m are shown in Tab. 1

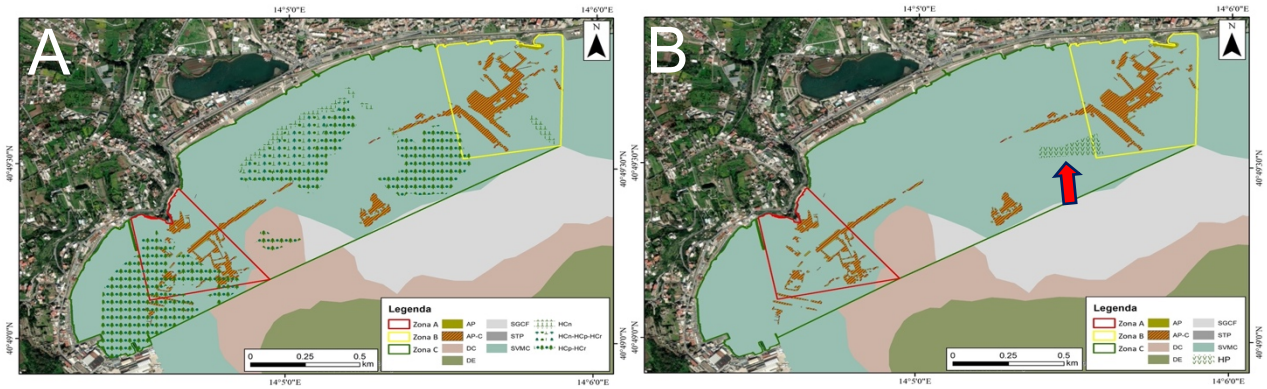

Fig. 2 – A) Map of the benthic habitat and biocoenoses of the MPA of Baia based on the survey in 2004 (from Russo *et al.,* 2008, modified); B) map of the benthic habitat and biocoenoses of MPA of Baia based on the 2023 survey. The red arrow indicates the *Posidonia oceanica* meadow. Legend of the biocoenoses in the figure: AP= photophilous algae; AP-C= photophilous algae- with coralligenous *in enclave*; DC= coastal detritic sediment; DE= coastal mud detritic sediment; SGCF= sand and gravel under current conditions, STP= highly polluted sediment; SVMC= fine sands under sheltered conditions; HCn= *Cymodocea nodosa* meadows; HCn-HCp-HCr= *C. nodosa*, *Caulerpa prolifera* and *Caulerpa racemosa* mixed meadows; HCp-HCr= *C. prolifera* and *C. racemosa* mixed meadows; HP= *Posidonia oceanica* meadow.
A) Mappa delle biocenosi ed habitat bentonici dell'AMP di Baia sulla base del survey del 2004 (da Russo et al., 2008, modificato); B) mappa degli habitat e biocenosi bentoniche dell'AMP di Baia basata sul survey del 2023. La freccia rossa indica la prateria di Posidonia oceanica. Legenda delle biocenosi in figura: AP= alghe fotofile; AP-C= alghe fotofile con coralligeno in enclave*; DC= detritico costiero; DE= detritico costiero infangato; SGCF= sabbie grossolane e ghiaie fini soggette a correnti di fondo; STP= sedimenti molto inquinati; SVMC= sabbie fini di moda calma; HCn= prateria di* Cymodocea nodosa*; HCn-HCp-HCr= prateria mista di* C. nodosa, Caulerpa prolifera *e* Caulerpa racemosa*; HCp-HCr= prateria mista di* C. prolifera *e* C. racemosa*; HP= prateria di* Posidonia oceanica*.*

(see also Gambi *et al*., 2024). The overall average density is 359.8 ±66 shoots/m^2, which according to Pergent-Martini and Pergent (1995) results in a density value slight below (abnormal) the range considered normal for the average depth of the surveys at 7 m. This probably due to limitation of light rather than the general conditions of the habitat. The plant present relatively low values of the average number of leaves per shoot (4.5), but a rather large average leaf length (63 cm), with the highest values between 95.5 cm and 120 cm, consistently with the summer period which represents the maximum development stage of the *Posidonia* canopy. However it is hard to establish the medow presence before 2004, since it is located in the area between transects 7 and 8 (see Fig. 1).

A few ecological relevant species were missing (e.g., the sponge *Geodia cydonium* (Jameson, 1811), previously reported for the Secca delle Fumose), others were confirmed (e.g., the browm habitat-forming alga *Cystoseira compressa* (Esper) Gerloff & Nizamuddin, occurring only in the intertidal at Punta Epitaffio; Porzio *et al.,* 2020), or first recorded, such as *Pinna rudis* L., 1758 (5 specimens recorded in the whole area associated to Roman remains*)*, as well as a few cryptogenic and alien species (the red alga *Asparagopsis armata* Harvey, the polychaete *Branchiomma luctuosum* (Grube, 1870), the bivalve *Pinctada radiata* (Leach, 1814)). In particular, the cryptogenic alga *Acetabularia caliculus* J.V. Lamouroux, recorded at 2-4 m depth in the soft bottoms around Punta Epitaffio, represents the second record of this termophilous species for the Italian coasts (Ravera *et al.,* 2023).

Conclusions - Relevant changes in the area after 19 years are mainly due to loss of several hectares of vegetated habitat (*Cymodocea* and *Caulerpa* spp.) in the soft bottoms, probably due to several recreational boat mooring camps developed within the area. On the other hand, the complex mosaic of photophilous algal assemblages and sciophilous/coralligenous ones, associated to the hard bottoms of the Roman ruins was still present and highly diversified (Gambi *et al.,* 2024).
About the *Posidonia* meadow recorded, it would be important to understand how long it has been present and to clarify this further studies are needed.

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