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Seafloor integrity of the *Mar Piccolo* Basin (Southern Italy): quantifying anthropogenic impact

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ABSTRACT

The *Mar Piccolo* Basin is a coastal brackish marine ecosystem located along the northern coast of the Gulf of *Taranto* (Southern Italy). Despite the ecological relevance of the area (Site of Community Importance IT9130004, Regional Reserve 'Palude La Vela' EUAP1189), the entire basin is subjected to intensive human usage. The main activities include extensive mussel farming, important industrial activities, a military harbor and densely populated shores. The goal of our study was to spatially quantify human pressure within the basin and its relationship with biocoenoses. A broad set of data was integrated including acoustic remote data (obtained using a multibeam echosounder and side scan sonar devices), direct observations obtained by SCUBA diving and from a trawled camera, an orthophoto and ESRI® Imagery Basemap. At least eight categories of anthropogenic infrastructure and marks of past and present-day human activities were identified within the *Mar Piccolo* Basin water column and on the seafloor. These included line farms, pole farms, breeding frame structures, anchoring scars, excavations, buoys, wrecks and undefined traces. Each category was mapped and described using morphometric characterization. The integration of all available data allowed the production of an original map providing the *Mar Piccolo* seafloor disturbance by anthropogenic impact and an updated distribution of benthic communities, showing their spatial relation. Through the production of a specific thematic map, our work provides the first quantitative assessment of the extent and density of the identified human impact in order to evaluate seafloor integrity.

1. Introduction

The *Mar Piccolo* Basin is a coastal marine ecosystem with lagoonal features located north of the coastal town of *Taranto* (Gulf of Taranto – Southern Italy) (Figure 1(a) and 1(b)). It has a total surface area of 20.72 km^2 (Matarrese, Mastrototaro, D'Onghia, Maiorano, & Tursi, 2004). The basin encompasses two embayments, one to the west and one to the east (Figure 1(c)). The western embayment is the smallest and exhibits an average water depth (wd) of 13 m and a maximum wd of 30 m. The eastern embayment has an average wd of 9 m and reaches a maximum of 18 m wd.

Freshwater inputs originating from small tributary rivers and springs called 'Citri' (at least 31; Cerruti, 1938; Galeandro, Doglioni, & Simeone, 2015; Lisco et al., 2015; Parenzan, 1969; Zuffianò et al., 2015) influence the basin. Due to its peculiar hydrologic characteristics, low hydrodynamic condition, high inputs of freshwater, geographic confinement, eutrophication and the prevalence of uncoherent substrates, the *Mar Piccolo* Basin can be compared to a brackish lake although the salinity value, around 36%, is consistent with average seawater (Annicchiarico et al., 2009;

Caroppo & Cardellicchio, 1995). Human activity also affects salinity values (Parenzan, 1969).

The seafloor is dominated by soft sediment, from mud to mixed sand and is sparsely covered by patches of the seagrass *Cymodocea nodosa* (Ucria; Ascherson, 1870), currently reported to be in regression, and by large beds of pleustophytic macroalgae (Cecere & Petrocelli, 2009). Where algae are absent, large numbers of sabellids, mollusks and ceriantharia have colonized the soft bottom (Gristina et al., 2013). The macrozoobenthic community is unique and characterized by very rich assemblages of filter feeders (mainly consisting of sponges, hydrozoans, polychaetes, bryozoans, mollusks, crinoids and tuinicates) that colonize all types of hard substrates forming pluristratified assemblages (Gristina et al., 2013).

The basin is subjected to urbanization, military harbor activities, industry, aquaculture (Caroppo et al., 2012) and commercial fishing. Since the 1970s, mussel farms have also colonized most of the sea bottom, causing an increase in the availability of hard substrates and mechanical obstacles to fishing activity with towed gears. Hard substrates are abundant and diverse, and largely consist of stones and debris of human origin (ropes and materials abandoned by mussel farmers
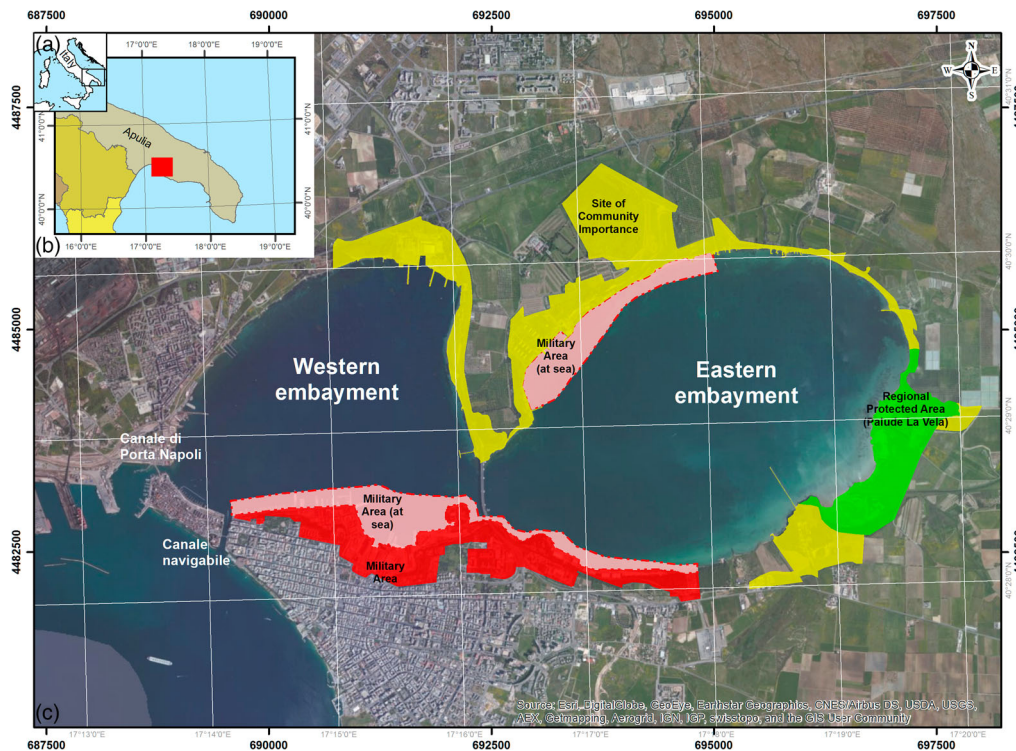
Figure 1. The geographical setting within the *Mar Piccolo* Basin: (a) Italy map with the indication of Southern Italy (black box) reported in (b); (b) a magnification of Southern Italy with the indication of Apulia region and the study area (red box) reported in (c); (c) the two embayments forming Mar Piccolo Basin, the two channels that connect it with the Mar Grande Basin, the SCI, the regional protected area Palude La Vela and military areas with the indication of the prohibited navigation area at sea. Basemap source: Esri, DigitalGlobe, GeoEye, i-cubed, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community.

and fishermen). Furthermore, several kilometers of stone walls exist along the coastline. In 1991, the Italian Ministry of Environment declared this area a 'High Environmental Risk' zone. Several studies have focused on the high level of air pollution and its tragic consequences for *Taranto* inhabitants (Bianco et al., 2013; Pirastu et al., 2013). Others have focused on the accumulation of dangerous compounds in the *Mar Piccolo* Basin waters and sediments (Buccolieri et al., 2006; Calace et al., 2005; Cardellicchio et al., 2007; Petronio et al., 2012). Nevertheless, the area hosts several species protected by the Barcelona convention (Cardone, Corriero, & Gaino, 2010; Cerruti, 1938; Gristina et al., 2013; Parenzan, 1969; Matarrese et al., 2004) and received several conservation designations: Site of Community Importance (SCI; IT9130004 – EU Habitats Directive 92/43/CEE) and a Regional Reserve ('Palude La Vela' EUAP1189) along the eastern coast (Figure 1).

Over the past 50 years, several studies have been undertaken in order to study the benthic community of the *Mar Piccolo* Basin (Cecere, Cormaci, & Furnari, 1991; Cecere, Cormaci, Furnari, Tursi, & Caciorgna, 1989; Cecere, Saracino, Fanelli, & Petrocelli, 1992; Mastrototaro et al., 2008; Matarrese et al., 2004; Panetta, Mastrototaro, Matarrese, Tanzarella, & D'alessandro, 2004; Parenzan, 1969, 1983; Scardi et al., 1997; Tursi, Pastore, & Panetta, 1974). However,

only Parenzan (1969, 1983) and Matarrese et al. (2004) mapped the biocoenoses, with the latter reporting that benthic communities were severely affected by anthropogenic impacts. For this reason, preliminary studies, aimed at possible recovery strategies, have been performed by the Apulian Regional Agency for Environmental Protection (ARPA PUGLIA; 'Attività tecnico scientifiche mirate all'approfondimento sulle interazioni tra il sistema ambientale del mar piccolo di taranto ed i flussi di contaminanti da fonti primarie e secondarie') and financially supported under national framework (D.L. 7/8/2012, n.129 and L. 4/10/2012). Updated geological and geomorphological maps of the coastal area of the *Mar Piccolo* Basin were presented by Lisco et al. (2015).

Maintaining the integrity of the seafloor is an important component to preserve marine biodiversity and living resources (see Marine Strategy Framework Directive [MSFD]; EC, 2008). Thematic maps illustrating the distribution of human pressures on the maritime space provide a quantitative basis for (i) assessing the coverage and scale of landscape transformations due to human activity and (ii) evaluating the persistence of anthropogenic landforms within natural environments (Latocha, 2009). In the current work, the seafloor of the *Mar Piccolo* Basin was investigated using remote-sensing techniques, diving observations and underwater trawled video camera

inspections. Our goals were (i) to map all anthropogenic traces of past and contemporary human activity within the entire *Mar Piccolo* Basin, using modern cartographic tools (i.e. Geographic Information Systems – GIS), (ii) to determine and quantify the distribution of detected anthropogenic impacts and biotic features and (iii) to investigate the spatial relationship between the latter two. The main result is an original map for the *Mar Piccolo* Basin that illustrates the distribution of present anthropogenic impacts produced by a variety of human activities, both in the water column and on the seafloor, and their spatial relationship with present benthic communities. Such indicators are instrumental to assess seafloor integrity as defined by MSFD Descriptor 6 of Good Environmental Status (EC, 2010).

2. Methods

The work is based on a dataset obtained from a ship-based research survey conducted in July 2013 on board the vessel 'Issel', the property of CoNISMa (Consorzio Nazionale Interuniversitario per le Scienze del Mare).

Vessel positioning was provided by a Hemisphere Crescent R100 differential global positioning system. The project's datum was WGS84 and the projection chosen for navigation and display was UTM zone 33N. A total of ∼160 nm of dual frequency side scan sonar (SSS, Klein 3000) and multibeam echosounder system (MBES, Teledyne RESON° Seabat 8125) data were collected. Sound velocity calibration within the water column was obtained using SeaBird profiling. SSS data were acquired using a swath width of 100 m (50% of overlap between adjacent lines) and attain a 50-cm resolution. SSS data processing, performed using the Triton Elics Information (TEI) suite software packages, produced geo-referenced, gray-tone acoustic images of the seafloor. MBES data were processed using Teledyne PDS2000° to produce a digital terrain model (DTM) that was mapped and described using morphometric characterization. The seafloor mapping procedure considered all positive or negative bathymetric anomalies. The DTM was also used for final georectification of the processed SSS mosaic. The acoustic dataset (i.e. MBES and SSS data) was overlapped with the orthophoto (2008 version, DATUM WGS84, projection UTM33N, resolution 50 cm) available from Apulia region's cartographic database and the ESRI° Imagery Basemap (the July 2014 version) in order to obtain complete coverage of anthropogenic structures visible on the sea surface (i.e. mussel farming structures and buoys) that were accurately mapped.

Different categories of anthropogenic traces were established on the basis of current knowledge of human activities within the *Mar Piccolo* Basin (breeding), and interpretation of all of the anomalies observed in the sonar datasets (Table 1). All of the data were

mapped, integrated and analyzed using Esri ArcGIS™. To quantify and analyze the spatial distribution of the identified categories of anthropogenic impacts, we considered wrecks, dredged areas and pole farms as polygons in order to obtain their precise coverage area on the seafloor. Buoys were first mapped as points then their spatial impact on the seafloor was determined on the SSS and MBES data, and polygons were drawn. Line farms, breeding frame structures and anchoring scars were first mapped as lines. In the basin, line farms are formed using two parallel rows of buoys that are spaced at 1–2 m, each buoy has a 1-m diameter and buoys are connected using a rope. Under each buoy, the rope is pulled toward the seafloor and provides support for mussel cultivation. Frame structures typically consist of a rope that is pulled between two buoys and anchored to the seafloor but more complex structure has been reported. Anchoring scars are signs left by vessel anchors and appear as negative linear anomalies on SSS and MBES data. The effects of all of these identified categories are well defined on the seafloor and cover a wider area than a thin line. In order to obtain the areal distribution of all of these categories and to calculate the associated coverage, buffers of 2 m for line farms, 8 m for frame structures and 3 m for anchoring scars were created.

An updated map of the biocoenoses was created on the basis of results from direct observations. In particular, 74 video transects (totaling 14 hours) were obtained using a trawled camera (Quasi Stellar) in areas of the basin accessible to navigation. Furthermore, 15 SCUBA diving surveys were performed at the most interesting points such as the freshwater springs and areas characterized by mussel farms and other anthropogenic structures representing the principal hard substrates of the basin. Each visual transect was annotated for predominant substrate type (e.g. sand, mud, mussel poles and concrete anchors), presence of algae/seagrass coverage and conspicuous zoobenthos. New data on the biocoenoses of the *Mar Piccolo* Basin were integrated with the biocoenoses map of Matarrese et al. (2004).

The spatial overlap of anthropogenic impact traces with benthic associations in the GIS environment enabled the production of an original map (named 'Seafloor integrity of the *Mar Piccolo* Basin: anthropogenic impact categories and benthic associations'). This result was used to quantify the coverage of each category *per* benthic communities and to evaluate which types of benthic associations were the most impacted by detected human activities (Table 2).

The spatial distribution of anthropogenic impact categories was converted to density rate using the kernel density tool (KDT) of Esri ArcGIS™. The tool is based on the kernel density estimator (Silverman, Jones, Fix, & Hodges, 1951) and the quadratic kernel function (Silverman, 1986) and is one of the most

Table 1. List of identified anthropogenic impact category with a short general description, its appearance on orthophoto/ESRI Basemap, SSS mosaic, DTM and the value of areal coverage (ha).

	Short description	Orthophoto/ESRI basemap	SSS	DTM	Coverage (ha)
Line farm	Two parallel rows of buoys connected by ropes spaced at 1–2 m. Each buoy has a diameter of 50 cm roughly. Widespread between 3 and 15 m of wd within the two inlets. Lines are often grouped, with tens of structures, and aligned (Figure 2(a1))	White lines (ropes) interrupted by circular white structures (buoys) (Figure 2(a2))	High backscattering singular line or two very close thin lines, spaced by 1–2 m (Figure 2(a3))	Elongated thin topographic anomalies forming one or two parallel lines spaced at a distance of 1–2 m (Figure 2 (a4))	44.10
Pole farm	Three wooden or iron poles, placed vertically on the seafloor, that act as a support for mussels while at the same time supporting one another. Groups of poles are placed very close to each other and form the field of a breeding framework, structured as a square or rectangle. In most cases, they are abandoned structures and only remnants are identifiable on the seafloor (Figure 2(b1))	White lines forming a squared or sub-rectangular polygon with a crosstree design within them (Figure 2(b2))	High backscattering lines corresponding to poles within a lower backscattering associated with surrounding muddy–sandy bottom. The crosstree design within the pole farm is still identifiable and associated with high backscatter signal (Figure 2 (b3))	A complex morphology characterized by a group of square or rectangular structures that rise from 0.5 to 1 m from the bottom (Figure 2(b4))	42.45
Frame structure	Iron poles and ropes used as stands for pots by fishermen (Figure 2(c1))	Continuous white lines (Figure 2(c2))	A very dark jagged line wiht high backscatter (Figure 2 (c3))	Rectangular morphology that rise from 0.5 to 1 m from the bottom (Figure 2(c4))	10.69
Buoys	Metallic buoys used to delimit an interdict the navigation area and to defend infrastructures such as the bridge shafts located between the two inlets (Figure 2(d1))	White circle, a total of 54 buoys have been counted at the sea surface (Figure 2(d2))	Circular high backscatter where buoy are anchored to the seafloor (Figure 2(d3))	A central depression a few centimeters deep and a few meters wide surrounded by radial anchoring traces (Figure 2(d4))	0.36
Dredged areas	Hydraulic engineering remnants appearing as soft surficial sediment clearly moved or re-arranged, located within the central portion of the first inlet. The largest one crosses it completely from the north-west to the south-east	Not visible at the surface	Positive seafloor irregularities that form shadows and locally high backscatter on a generally flat low backscatter bottom characterized by soft surficial sediment (Figure 2 (e1))	Sub-rectangular depressions from a few to 10 m in depth with respect to the surrounding seafloor characterized by vertical flanks with high slopes sometimes interrupted by steps. Removed sediment into the depression forms an irregular topography (e.g. hummocky dunes) (Figure 2 (e2))	27.25
Wrecks	Eight small or remnants of breeding-related boats principally localized within the western portion of the first inlet, in front of the fishing port	Not visible at the surface	High backscatter and shadows forming a typical boat shape (Figure 2(f1))	Positive irregular morphology with a typical boat shape, from 3 to 8 m long and placed at a few meters of wd (Figure 2(f2))	0.06
Anchoring scars	Signs associated with tourist, mussel farming-related boat or military anchoring activity. Mapped within the two inlets but the highest concentration in front of the Military Navy Area	Not visible at the surface	High backscattering lines associate to a linear shadow on one side (Figure 2(g1))	A linear trench for the deepest end, with a length up to 1 m that becoming less pronounced on the other end (by only a few centimeters). With a length from few to hundreds meters, and from 1 to 5 m wide (Figure 2(g2))	24.87
Undefined traces	Anomalous shape not related to one of the other seven categories	Not visible at the surface	High backscatter spots/zones	Topographic anomalies	1.32

popular methods used in geostatistical analyses. The KDT calculates the density of the represented features and creates a smoothly curved grid surface in neighborhood. Cell values depend on the distance from those features decreasing away from the features. The density map was created using a 1-m grid resolution and a 50-m search radius with no population value.

3. Results and description of the map

An analysis of backscatter intensity identified peculiar landforms on the seafloor associated with anthropogenic impacts. Acquired MBES data did not achieve a 100% coverage along the coast and where mussel farming infrastructure was too dense to permit safe

Table 2. Results on the coverage of anthropogenic impact and benthic communities: singular anthropogenic impact category coverage per benthic association (m²); the total of human impact coverage per benthic association (ha); the coverage of benthic association of present *Mar Piccolo* seafloor (ha) and the coverage expressed in percentage of impacted area per benthic association (%).

	Sandy mud	Sandy mud with low algal cover and grazers	Macroalgae associations	Pleustophytic algae association	C. nodosa meadow	Shell debris	Macroalgae association with facies of Pectinidae	Caulerpa sp. turf	SVMC	Muddy sand
Line farms (m²)	80,959.56	21,134.63	47,664.30	26,293.86	292.85	0.00	5382.73	19,441.87	0.00	2797.22
Pole farms (m²)	845.21	7.05	2510.57	106.74	0.00	0.00	105.68	14.09	0.00	14.09
Frame structures (m²)	34,685.76	51,426.39	70,841.96	302.63	0.00	14,242.28	34,605.70	536.49	0.00	8508.92
Excavation (m²)	12,216.22	0.00	8818.75	39,082.82	6187.30	0.00	3149.00	4844.99	655.27	6593.78
Buoys (m²)	80,977.17	286.74	83,498.21	16,3771.70	1418.00	0.00	15,713.53	24,865.54	1589.12	19,694.26
Wrecks (m²)	50,007.83	468.98	44,634.67	196,289.56	4122.35	0.00	14,796.12	12,496.27	11,548.82	25,589.00
Anchoring (m²)	102.70	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	194.88
Undefined traces (m²)	3130.28	0.00	1043.87	1500.88	0.00	0.00	2066.91	34.34	0.00	0.00
Total of anthropogenic impact covered area (ha)	26.29	7.33	25.90	42.73	1.20	1.42	7.58	6.22	1.38	6.34
Covered area of benthic communities (ha)	290.24	95.25	232.25	592.87	15.42	1.87	61.60	122.32	141.65	154.61
% of impacted area	9	8	11	7	8	76	12	5	1	4

navigation. Nevertheless, very high-resolution bathymetry was obtained for the surveyed seafloor (i.e. 1-m cell size). Since surface structures have direct anchoring on the seafloor (that in rare cases is not detectable on remote data) and since the orthophoto and the Basemap have complete cover over the *Mar Piccolo* Basin area, the proposed data integration (MBES, SSS, orthophoto and ESRI Basemap) allowed us to map all of the anthropogenic structures, even where an acoustic survey was not possible. Nevertheless, some restricted areas with no data persist (Main map).

At least eight categories of anthropogenic infrastructure and marks were recognized on the *Mar Piccolo* Basin seafloor (Figure 2(a)–(h)) (Main map). Details on the identification and morphometric features of each category on the orthophoto, ESRI Basemap, SSS and DTM, with the indication of areal coverage, are reported in Table 1. They include mussel farming activities (line farms, pole farms and frame structures, respectively, in Figure 2(a), 2(f) and 2(b), Table 1), hydraulic engineering (dredged areas and buoys, respectively, in Figure 2(c) and 2(e), Table 1) and navigation (wrecks and anchoring scars, respectively, in Figure 2(g) and 2(h), Table 1). An additional category, named unidentified traces (Figure 2(d), Table 1), was established for signs and objects with anomalous shapes and unknown origin. All of the categories cover ≈151 ha in total area and represent 7.3% of the *Mar Piccolo* Basin seafloor (Main map). The farming structures represent the most widespread category of all of the anthropogenic impacts (97.24 ha) reported for the two embayments. Wrecks represent the least extensive category (0.06 ha; Figure 2(g), Table 1) and occur only within the western sector of the western embayment, corresponding to a small harbor used by mussel farmers.

On the main map 10 benthic associations have been identified on the *Mar Piccolo* seafloor (Figure 3): (1) sandy mud (290.24 ha, Figure 3(a)); (2) sandy mud with low algal cover and grazers (95.25 ha); (3) macroalgae associations (232.25 ha, Figure 3(b)); (4) pleustophytic algae association (592.87 ha, Figure 3(c)); (5) *C. nodosa* meadow (15.42 ha, Figure 3(d)); (6) shell debris (1.87 ha, Figure 3(e)); (7) macroalgal association with facies of Pectinidae (61.60 ha, Figure 3(f)); (8) *Caulerpa* sp. turf (122.31 ha, Figure 3(g) and 3(h)); (9) SVMC (muddy sands in sheltered areas) from Matarrese et al. (2004) (141.65 ha); and (10) muddy sand from Matarrese et al. (2004) (154.61 ha).

Many of the benthic communities detected are typical of impacted basins and their presence is due to anthropogenic activities. Their distribution can be addressed through massive breeding activities, which are de facto influencing the sedimentary environment including the production and accumulation of mud. In particular, mussel breeding represents an anthropogenic impact that has an important role in structuring the benthic community

of the *Mar Piccolo* Basin. Indeed, by providing hard substrates and organic matter, mussel farms support and feed the bio-diverse fouling community and create the best possible trophic conditions for nitrophylous algal communities such as the pleustophytic algae *Chaetomorfa linum* (O.F.Müller) (Kützing, 1845). For this reason, the pleustophytic algae association is largely interested in breeding activities which enhance the development of these algal associations (Cecere et al., 1992). Nevertheless, as reported by several authors (Balduzzi, Boero, Cattaneo-Vietti, Pansini, & Pronzato, 1986; Pierri, Longo, & Giangrande, 2010), anthropogenic structures often provide coherent substrates for the development of benthic associations on the hard bottom (Figure 4 (a)–(d)) promoting the development of typical *fouling* flora and fauna (Pierri et al., 2010) that colonize hard substrates of human origin.
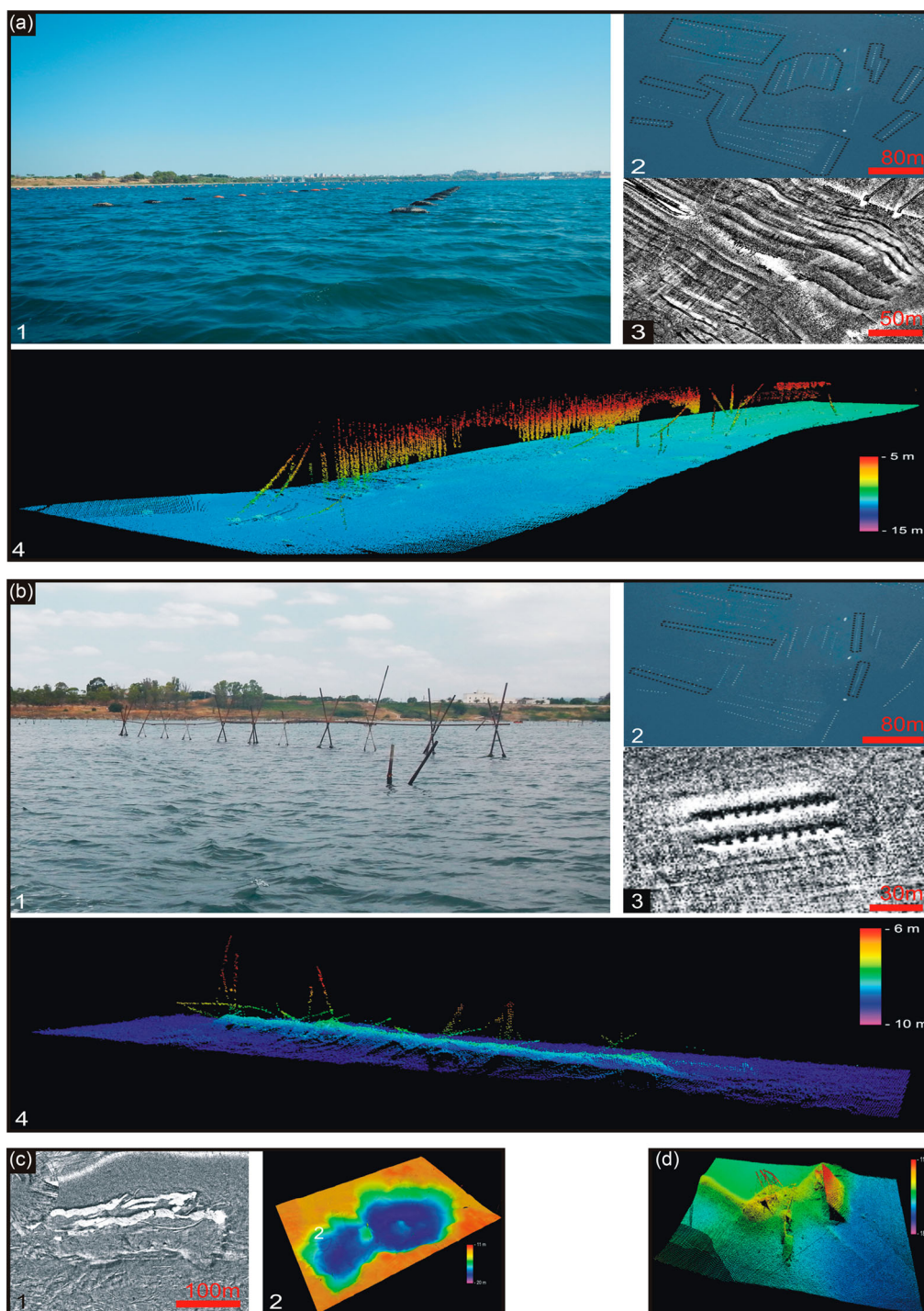
Figure 2. Details of anthropogenic impact categories: (a) Line farms: 1. picture; 2. orthophoto, indicated by dotted black lines; 3. SSS mosaic; 4. MBES; (b) Frame structures: 1. picture; 2. orthophoto, indicated by dotted black lines; 3. SSS mosaic; 4. MBES; (c) Dredged areas: 1. SSS mosaic; 2. MBES; (d) Undefined traces: 1. MBES; (e) Buoy: 1. picture; 2. orthophoto; 3. SSS mosaic; 4. MBES; (f) Pole farms: 1. picture; 2. orthophoto, indicated by dotted black lines; 3. SSS mosaic; 4. MBES; (g) Wrecks: 1. SSS mosaic; 2. MBES; (h) Anchoring traces: 1. SSS mosaic; 2. MBES.

In terms of absolute coverage (ha), anthropogenic impacts are much extended on the 'pleustophytic algae association' (42.73 ha), followed by 'sandy mud' (26.29 ha) and the 'macroalgae association' (26.29 ha). Less is covered by 'shell debris' (1.42 ha), likely due to the very restricted distribution of this association. On the other hand, if we consider the percentage of impacted seafloor per benthic community area, the highest is shell debris (76%), followed by macroalgae association with facies of Pectinidae (12%), with the lowest SVMC (1%) (Table 2).

Finally, we calculate the cumulative density of all of the identified categories (Figure 5) based on the intensity of human impact *per* identified category. In general, the western embayment shows a higher density than the eastern one. This is partly due to its smaller dimension, but largely due to the highest concentration of human traces on the seafloor. Pole farms are more concentrated within the western embayment, and even if such structures are light, they are characterized by a wider impacted area on the seafloor. In addition, line farms are much closer and concentrated in the
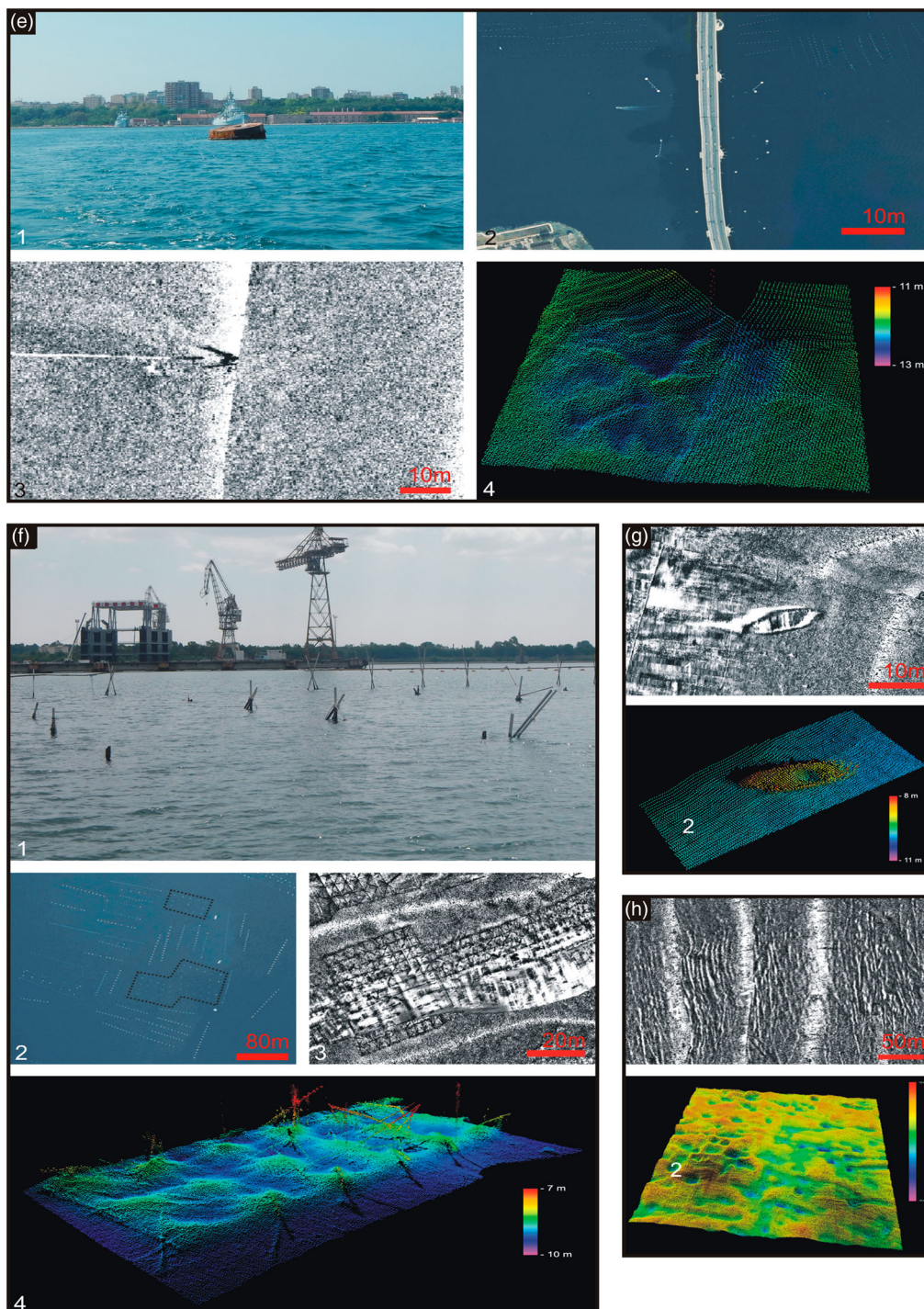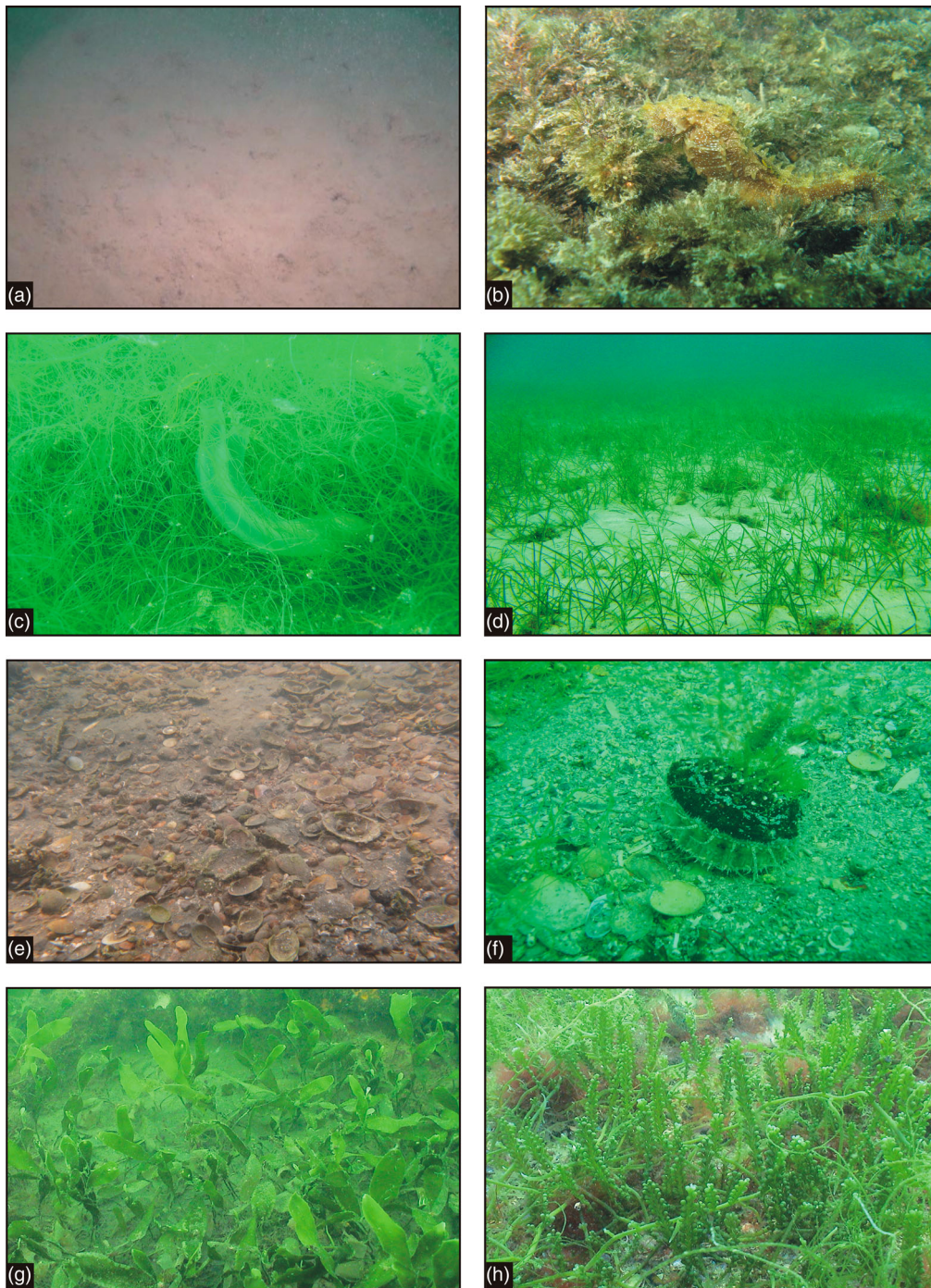

Figure 2. Continued

Figure 3. Examples of some of the benthic associations within the *Mar Piccolo* Basin: (a) sandy mud; (b) macroalgae associations; (c) pleustophytic algae association; (d) *C. nodosa* meadow; (e) shelly detritus; (f) macroalgae association with facies of Pectinidae; (g) *Caulerpa prolifera* (Forsskål) J.V.Lamouroux (1809) and (h) *Caulerpa racemose* J. Agardh (1873).

western embayment than in the eastern one, as well as frame structures. Finally, most of the dredged areas are located in the western embayment while its southern sector, in front of the Military Navy Area, is completely impacted by the anchoring activity of military vessels.

Other seafloor areas show a high density, for instance, the area between the western and eastern embayments, and are linked to the occurrence of large buoys (to protect a bridge and indicate navigation routes), or undefined traces (in particular, garbage such as wood boxes and tires on the seafloor).

4. Conclusions

This study defines spatially and quantitatively the distribution of present anthropogenic impacts on the *Mar Piccolo* Basin seafloor (Main map). This is achieved through the integration of a broad collection of datasets collected by remote-sensing technologies as well as direct observation. Eight categories of anthropogenic impact were identified, associated with mussel farming activity (pole and line farming), hydraulic engineering (dredging and buoys), navigation (wrecks and anchoring scars) and undefined traces.

Figure 4. Underwater pictures as example of anthropogenic structures providing coherent substrates: (a) polichaeta on metallic structures abandoned as rubbish on the seafloor; (b) a submerged buoy, completely encrusted by benthic fauna; (c) submerged chain completely encrusted by benthic fauna and (d) wooden poles completely encrusted by benthic fauna.

Anthropogenic areas cover a total area of about 151 ha (Main map). Farming structures (lines, poles and frame structures) represent the most widespread categories, occupying 97.24 ha and generally displaying a high density within the western embayment.

In terms of absolute coverage, the benthic association most affected is the 'pleustophytic algae association' although in terms of percentage the most affected is 'shell debris' (76%). Our results present the first useful map for the present-day distribution of anthropogenic landforms within the *Mar Piccolo* Basin.

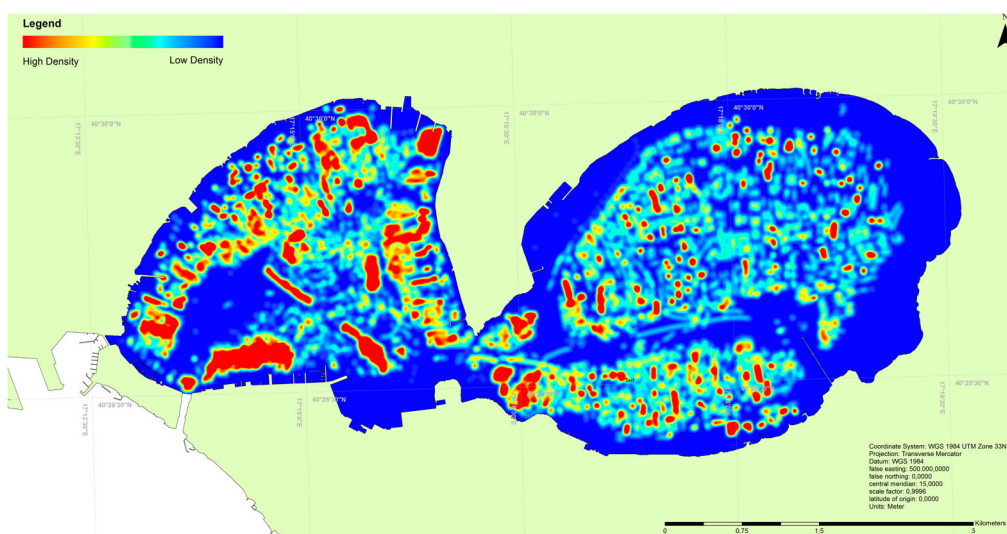Detailed and accurate bathymorphological mapping together with focused analyses performed in a GIS

Figure 5. Density map of the anthropogenic impact of the *Mar Piccolo* Basin seafloor for the sum of all anthropogenic traces mapped. This is a raster image with a stretched color ramp: red indicates high-density value, whereas blue indicates low-density value.

environment provide a useful synthesis for spatial data on the distribution and intensity of human activities and on the overlap of their impacts on the benthic habitat mapped on the seafloor. Therefore, our results allow the evaluation of seafloor integrity as explicitly requested by MSFD (EC, 2008), thus providing a valuable tool for basin management and for the identification of restoration measures.

Software

SSS data have been processed using the TEI software package. MBES data were processed using Teledyne PDS2000®.

All of the data were mapped, integrated and analyzed using Esri ArcGIS™.

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