Assessment of the Geomorphological and Sedimentological Changes in Mamaia Sector after the Implementation of the Coastal Protection Measures (*Dragoș Marin, Silică Petrișoaia, Alina Spînu, Dănuț Diaconeasa, Răzvan Mateescu, Emil Vespremeanu*†)	"Cercetări Marine" Issue no. 52 Pages 6-16	2022
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ASSESSMENT OF THE GEOMORPHOLOGICAL AND SEDIMENTOLOGICAL CHANGES IN MAMAIA SECTOR AFTER THE IMPLEMENTATION OF THE COASTAL PROTECTION MEASURES

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ABSTRACT

The paper analyses the changes in the beach sector of Mamaia resort from a geomorphological and sedimentological point of view in the context of coastal protection works carried out in 2014-2015 and 2021 (measures to reduce wave energy, beach protection with structures to stabilize the sand and beach nourishment). The Mamaia sector, with a length of about 12 km, is geomorphologically constituted mainly by sandy barrier of Lake Siutghiol representing a transition unit between the northern unit (deltaic and lagoon shore) and the southern unit (small pocket rocks-beaches in front, separated by small coastal sandbars). From an economic point of view, the sector is important for coastal tourism both in terms of the number of tourists and the existing of infrastructure generating significant revenues. Since the 1950s, the sector has been severely affected by the construction of the dikes of the Midia Port in the north, which have affected the longitudinal transport of sediments and accentuated the erosion of the submerged and backshore beach. To counteract the effects of erosion, a longitudinal and transversal coastal protection system was built between 1960 and 1990, which proved to be ineffective in the long term.

The data collected in the field (topographic profiles of the backshore, shoreline, sediment samples) before and after the recent coastal protection works were processed using a dedicated software (ArcGIS 10.x and Gradistat v8) and represented in the form of maps and graphics. The spatial analysis highlighted the modification of the coastal system components, the trends of the beach evolution in longitudinal and transversal profile and the changes in the structure and distribution of sediments determined by the impact of the coastal protection works.

Keywords: geomorphological changes, beach nourishment, coastal protection works, sediment texture

AIMS AND BACKGROUND

Is well known that the beach is a dynamic element of the coast, which can be defined as a strip of land covered with sedimentary material, oriented along the coasts, and descending a gentle slope into the sea. Its main role, from a geomorphological point of view, is to take over and dissipate the incident energy of the waves that are manifested by the action of the waves breaking and induced sediment transport (Van Rijn, 1998). Through its characteristics to adapt its shape to the wave's regime, sea levels and currents, the beach has the most effective role in the natural protection of the coastal area (Spînu, 2015). At the Romanian coast, according to the Strategic Action Plan for the rehabilitation and protection of the Romanian Black Sea coast in the short, medium and long term,"soft" type measures have been established, consisting of large-scale sanding of beaches to solve the costal erosion and create new beach areas. This protection solution consists in taking sand from external borrow sources to a vulnerable beach, where the coastal erosion phenomenon predominates (JICA, 2007), (Master Plan, 2012).

EXPERIMENTAL

The assessment of coastal protection works was done by comparative analysis of associated coastal geomorphological process in the area in which coastal protection measures were implemented, within the period before 2021 and after when the beach sanding/nourishment in Mamaia Centre and North (Fig.1) was done. For this aim, the following activities were realized: shoreline GPS measurement campaigns – four transect of backshore, using landmark network (Diaconeasa, 2014) for the southern littoral monitoring, satellite images, aerial and on-side photo images.

Data acquired from the field, used in the current study were materialized in geomorphological profiles of backshore section, and were realized with GPS Leica Viva GNSS GS08 plus and Leica Zeno 20 (real-time RTK measurements with corrections provided by stations in ROMPOS network). For shoreline monitoring were used GPS Leica VIVA GNSS GS08 plus, Leica Zeno 20, GPS Trimble GeoXH6000 and Trimble GeoXH2005, and also for aerial imaging was used DJI Phantom 3 Advanced quadcopter UAV, equipped with 12MP Sony EXMOR integrated camera, vertical precision +/- 1m (when Vision positioning was active) or +/- 0.5m and horizontal +/- 1.5m. Certain dedicated software for collecting and processing of spatial data were used, including software for aerial imaging processing (DJI Go, Agisoft), as well for beach profile and shoreline changes analysis (ArcGIS 10x, CEDAS, subprogram BMAP) and topographic engineering (TopoSys and MapSys).

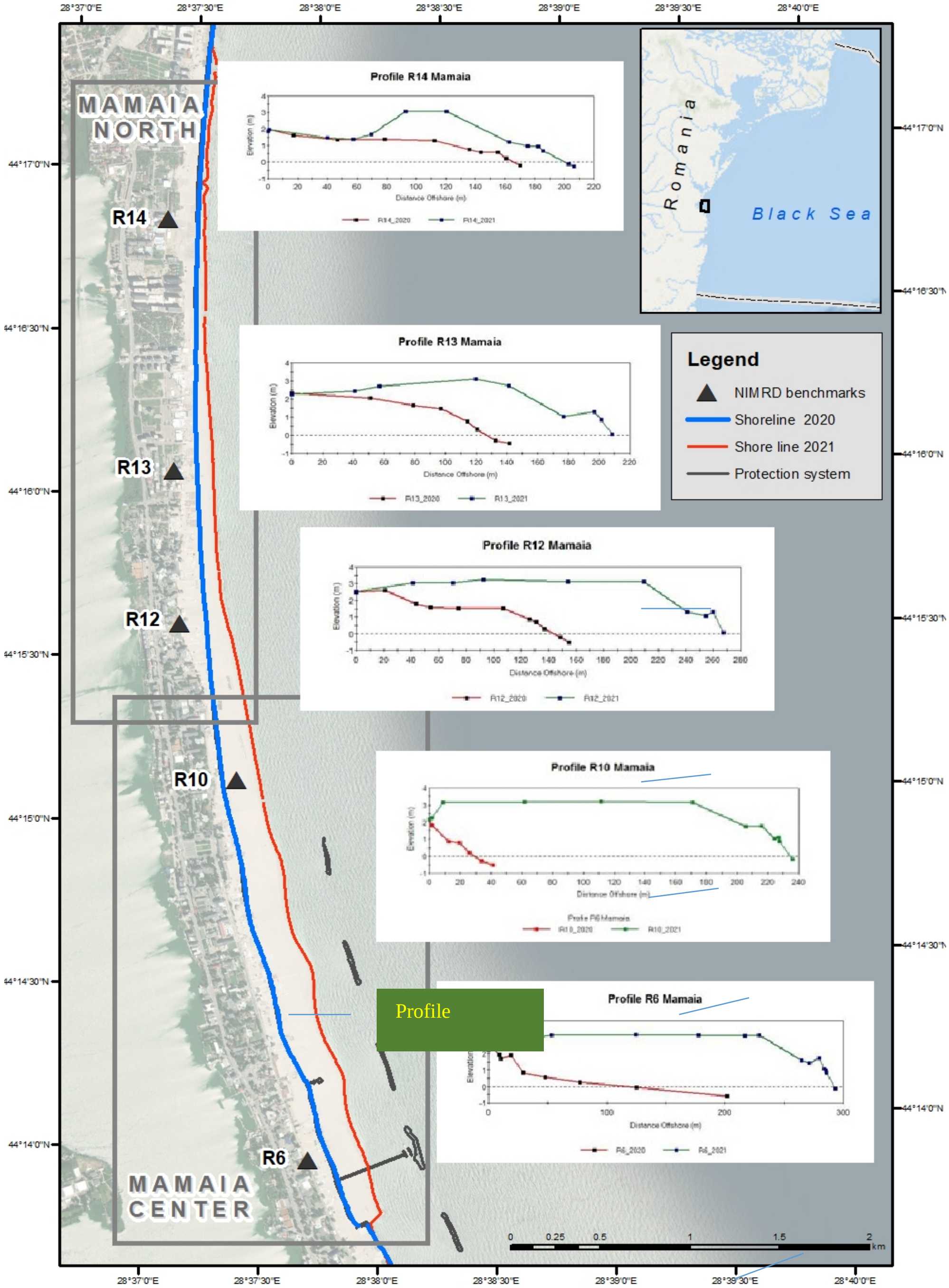

Fig. 1. Shoreline change in the Mamaia shore sector (2020-2021) and cross-shore profiles for Mamaia Centre (R6,10) and Mamaia North (R12,13,14) Sectors

RESULTS AND DISCUSSION

The shore sectors of Mamaia, from the 19th century until the 90's was protected, over a couple of stages, with several coastal protection systems, encompassing both ”soft” and ”hard” type of coastal protection solutions.

The coastal protection Plan (developed under the Coastal Master Plan from 2005 to 2013) which is supposed to run for more than 30 years (until 2020 and beyond), includes short-, medium- and long-term coastal rehabilitation, in the context of the integrated managements of coastal areas and of the Framework Directive on Strategy for the Marine Environment. These works mainly include measures to reduce the energy of the waves (which reach the shore), sanding and sand stability piers (measures to retain sand on the beach) by making new piers, repairing existing parallel breakwaters and construction of perpendicular groins. In the framework of coastal protection measures planned on the short term, for five locations (Mamaia South, Tomis North, Tomis Center, Tomis South and Eforie North), were made nine dams transverse of shore (groins), seven dams longitudinal of shore (nearshore breakwaters) and beach-fill sanding. Based on geomorphological measurements (25 sections) performed by NIMRD before and after beach nourishment, it result that the width of the backshore increased as follows: 86.4 m in the Mamaia South; 117.7 m in Tomis North; 105 m in the Tomis Centre; 108,5m in the Tomis South and; 122.4 m in the Eforie North (Diaconeasa, 2016).

So, as a result of the short - term coastal protection measures implemented in the southern part of the Romanian coast by artificial sanding with sand brought from Mamaia Bay-Constanta North (cca. 3.5millions m^3) the beach was extended by more than 40 ha on approx. 7 km.

The solution has the advantage of restoring the ”natural” aspect of the beach, and is the most effective form of marine protection, as it has the ability to adapt naturally to changes in wave conditions and to dissipate the energy of waves. There are certain disadvantages related to the changing hydrographic condition determined by the equilibrium profile change in submerse area, respectively a different sediment texture from the borrowed material.

Geomorphological changes of the Centre and North Mamaia Beach between 2020 and 2021, time interval (medium term of coastal rehabilitation, first phase). Coastal geomorphological process assessment was realized based on 5 geomorphological profiles: R6, R10, R12, R13, R14 (Diaconeasa, 2014), executed in the area of Mamaia Centre and Mamaia North, and respectively shoreline GPS measurements before and after the end of the nourishment, in April 2021.

In some parts (near profile 10), the beach has diminished a lot due to coastal erosion so, during severe storms, the tourist beach was almost completely flooded and the tourist infrastructure was in danger of destruction (Fig. 2 and Fig. 3).

Fig. 2. Profile 10 before nourishment (2013)

Fig. 3. Profile 10 after nourishment (2022)

Beginning of the second stage (medium term) of rehabilitation of the Romanian beaches, in 2021, Mamaia beach (Centre and North), was extended with a width ranging from 80 m to 210 m, thus it was determining an increase of surface of 74.9 ha of the sand barrier, separating the lake (Siutghiol) from the sea, along 7.9 km of its total length.

The shoreline emphasizes the conditions for a sharped slope for the beach-face in the area of the cuspate features (Fig. 4) induced by the parallel breakwater protection system within five months. The beach profile observed from a lateral image reveal a sharp slope of the submerged beach as well, due to the new equilibrium profile determined by a coarser type of sediment of the borrowed material of the nourishment.

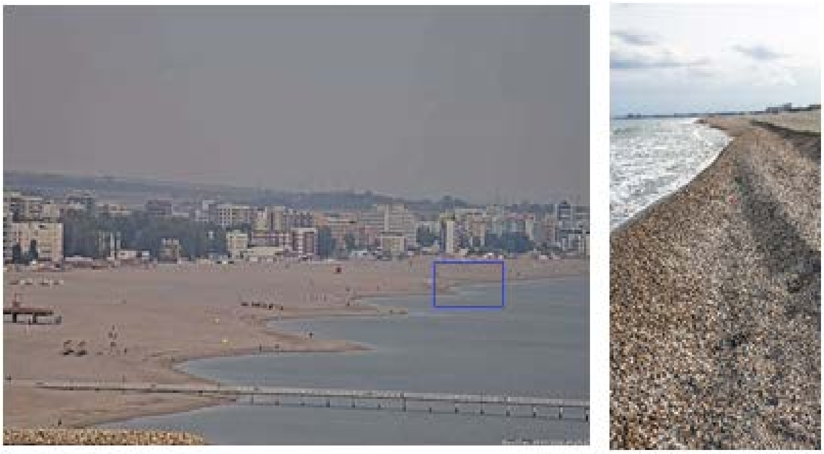

Fig. 4. Shoreline shape under the influence of wave action

The beach profile variation on the Central and Northern Mamaia Beach sector. At the time of its execution, the nourishment solution for the beach protection was extended by hydraulic mechanization (pumping) (Fig.5), it was considered the decompensation action of the wind that transfers the fine sand outside the beach, thus made certain stabilized dune around the vegetation limit, but the lifetime period of the extended beach was 50 years.

Fig.5. Artificial sanding, Mamaia center sector

The massive beach extensions encompass widening between 36.5 m and 194.74 m, and a volume increase ranging from 167.81 to 633 m^3/m of shoreline (Table 1 and Fig. 1).

Table 1. Determination of the variation domain in Centre and Northern sectors of Mamaia Beach (2020-2021)

Profile	2020		2021		Difference	
	Backshore width (m)	Volume (m^3/m)	Backshore width (m)	Volume (m^3/m)	Backshore width (m)	Volume (m^3/m)
R6	201.86	81.579	293.61	817.745	91.75	736.16
R10	41.24	26.755	235.98	659.76	194.74	633.00
R12	155.07	233.438	267.27	741.761	112.2	508.32
R13	141.79	215.029	208.56	481.095	66.77	266.06
R14	170.11	202.255	206.61	370.07	36.5	167.81

The new cross-shore profiles designed for a period of 50 years, shows a steep slope at the beach-water interface, which relate the sediment size of the new equilibrium profile, in a period of sediment redistribution and sortation on the active part of the profile.

Sediment grain size. A number of 32 samples were collected in 2017 (16 samples) and 2021 (16 samples), on 4 beach profiles (R6, R10, R13 and R14) from Mamaia (center and north): on the backshore 16 samples (upper-Bsh up and medium-Bsh-c position of beach), on the swash zone 8 samples (medium position Sw-c) and on the surf zone 8 samples (depth of 1m). Organogenus sediment with dimension larger the 6.3mm, frequently used during the nourishment, it was not the object of the dry sieving granulometric analysis. Sediment analyses were carried out to analyse the grain size of the sediments using the standard of dry sieving techniques (Anastasiu, 1983, Jipa, 1987). Data were statistically analysed according to Folk and Ward formulae (1957), in terms of mean grain size (mean), standard deviation (sorting), skewness and kurtosis (Blott, 2001). The classification between coarser and finer particles was based on Wentworth's scale (1922).

The beach, which develops in Mamaia Bay is a geological formation that was formed recently (Caraivan, 1982), primarily from the contribution of terrigenous longshore sediments, with mainly north – south direction and secondary organogenous sediments, which are transported to the backshore, mainly by transversal conveying on land (onshore-offshore)

It is well known that in the nearshore area the wave regime is influenced by local geomorphological configuration of the beach shoreline, marine relief, and the coastal and marine hydraulic structures. In this context, there are several medium wave actions in the offshore area (the transformation of waves, surf, swash, and backshore). The boundaries of these sectors are highly mobile and determined by the sea state. After the nourishment, the geo-morphology and sand quality of the beach suffered modification.

Backshore zone. In 2017, the categories of fine sand and very fine sand are prevalent in backshore sediments participating on average by 69.3% with variations between 49.9% (in R13 – Bsh-c profile) to 95.5% (R14 – Bsh-c profile). Fine sand class represents 53.5% on average, with variations between 40.5% and 68%. The percentages of the very fine sand class of 15.8%, ranges between 6.9% (R10 profile) and 28.5 (R14 profile).

The mean has a range of variation from 0.13 mm to 0.35 mm. The degree of sorting is poor to very well across the 4 beach profiles. Sedimentary deposits have generally a statistical distribution of very coarse skewness, with kurtosis frequently mesokurtic on the 2 southern beach profiles, and leptokurtic, mesokurtic and platykurtic on the 2 northern beach profiles (Table 2).

Table 2. Sediment texture in the backshore area before nourishment (2017)

Profile		**Sand**	**Mean (mm)**	**Sorting**	**Skewness**	**Kurtosis**
R14	Bsh-up	Fine	0.26	Poorly	Very coarse	Mesokurtic
	Bsh-c	Fine	0.13	Very well	Symmetrical	Leptokurtic
R13	Bsh-up	Fine	0.18	Moderately	Very coarse	Very leptokurtic
	Bsh-c	Medium	0.35	Poorly	Very coarse	Platykurtic
R10	Bsh-up	Fine	0.22	Poorly	Very coarse	Leptokurtic
	Bsh-c	Medium	0.26	Poorly	Very coarse	Mesokurtic
R6	Bsh-up	Fine	0.20	Moderately	Very coarse	Mesokurtic
	Bsh-c	Medium	0.24	Poorly	Very coarse	Mesokurtic

After the beach nourishment, in 2021, fine and very fine sand category had an average of 44.7% of total sand, which varied from 31.8% (R10) to 65.5% (R14). Fine sand represents on average 38.95%, with variations between 27.9% and 52%. The percentage of the very fine sand class of 5.82% varies between 1.8% (R6) and 13.5% (R14).

The mean has a wide range of variation from 0.6 mm to 1.02 mm. The degree of sorting is poor across the 4 beach profiles. Sedimentary deposits have generally a statistical distribution of very coarse (R14, R13, R6) and coarse (R10) skewness with kurtosis frequently mesokurtic and Platykurtic (Table 3).

Swash zone. Swash zone overlaps the area of foreshore and shoreline with two components: uprush and backwash (advancing and withdrawing of the water on the backshore), which is consuming the final wave energy by throwing the jet upward on the shore.

A total number of 8 samples have been collected from the swash zone of the 4 beach profiles (4 samples in 2017 and 4 samples in 2021).

Table 3. Sediment texture in the backshore area after nourishment (2021)

Profile		Sand	Mean (mm)	Sorting	Skewness	Kurtosis
R14	Bsh-up	Medium	0.6	Poorly	Very coarse	Mesokurtic
	Bsh-c	Coarse	0.92	Poorly	Very coarse	Platykurtic
R13	Bsh-up	Coarse	0.7	Poorly	Very coarse	Mesokurtic
	Bsh-c	Coarse	0.84	Poorly	Very coarse	Platykurtic
R10	Bsh-up	Medium	0.98	Poorly	coarse	Platykurtic
	Bsh-c	Medium	1.02	Poorly	coarse	Platykurtic
R6	Bsh-up	Medium	0.81	Poorly	Very coarse	Platykurtic
	Bsh-c	Medium	0.89	Poorly	Very coarse	Platykurtic

Accumulated sedimentary deposits had a medium sand composition in 2017, and medium and coarse in 2021 post nourishment. The average diameter ranged from 0.31 mm to 0.39 mm in 2017, while after the nourishment it increased and varied from 0.67 mm to 1.24 mm. The degree of sorting is mostly poor for both before and after the nourishment, with only one modification on R14 profile which went from poor to very poor sorting. The skewness varies in both period from very course to symmetrical and kurtosis is mostly very platykurtic for the samples from 2017 and platykurtic for the samples acquired post nourishment (Table 4).

Table 4. Sediment texture in the swash zone before and after nourishment

Profile			Sand	Mean (mm)	Sorting	Skewness	Kurtosis
R14	2017	Sw-c	Medium	0.32	Poorly	Very coarse	Very platykurtic
	2021	Sw-c	Medium	1.24	Very poorly	Symmetrical	Very platykurtic
R13	2017	Sw-c	Medium	0.39	Poorly	Symmetrical	Very leptokurtic
	2021	Sw-c	Medium	0.83	Poorly	Coarse	Platykurtic
R10	2017	Sw-c	Medium	0.39	Poorly	Symmetrical	Very platykurtic
	2021	Sw-c	Coarse	0.78	Poorly	Very coarse	Platykurtic
R6	2017	Sw-c	Medium	0.31	Poorly	Coarse	Mesokurtic
	2021	Sw-c	Coarse	0.67	Poorly	Very coarse	Platykurtic

Surf zone. This area is the result of wave dissipation by generating turbulence in the water and sediment transport driven by the bottom. In this area, sediments become more homogenous, as an effect of the environmental conditions (wave, currents). In 2017 (before nourishment), the median sand samples had a fine and very fine sand composition of more than 76% on R10 profile and over 90% on the other 3 profiles (R14 – 93.2%; R13 – 91.6%; R6 – 91.8%). The average diameter has a smaller range of variation between 0.14mm and 0.23 mm, with well and poorly sorting and a very coarse skewness (Table 5).

After the nourishments (in 2021), sand structure suffered a modification. Fine and very fine sand has an average of 56.6%, with the lowest percentage being on R13 (35.6%) and the highest being on R14 (74.7%). The mean diameter increased as well, with a variation from 0.4 mm to 1.22 mm., with sorting being poor and a very coarse skewness.

Table 5. Sediment texture in the surf zone (1m) before and after nourishment

Profile			Sand	Mean (mm)	Sorting	Skewness	Kurtosis
R14	2017	h-1m	Fine	0.15	Well	Very coarse	Very Leptokurtic
R14	2021	h-1m	Medium	0.54	Poorly	Very coarse	Very Leptokurtic
R13	2017	h-1m	Fine	0.14	Moderately well	Very coarse	Very Leptokurtic
R13	2021	h-1m	Coarse	1.22	Poorly	Very coarse	Platykurtic
R10	2017	h-1m	Fine	0.23	Poorly	Very coarse	Very Leptokurtic
R10	2021	h-1m	Medium	0.47	Poorly	Very coarse	Leptokurtic
R6	2017	h-1m	Fine	0.14	Well	Very coarse	Very Leptokurtic
R6	2021	h-1m	Medium	0.4	poorly	Very coarse	Very Leptokurtic

CONCLUSIONS

The analysis-based results for the time interval before and after sand nourishment period for the Mamaia shore sector (centre and north), it determined significant modifications of the touristic beaches, but, also, on the land-sea interface, in relation with coastal protections measures.

Despite the 50 years designed lifetime and a maximum of the beach extension of 197.7m in the alignment of landmark R10, the comparative beach width measurement reveals that the maximum value of erosion of -8.4m was determined in a season on the R13 profile, associated with a coarsening of the beach sediments.

Certain significant post construction changes were determined on the submerged beach, which required specific investigations for the new equilibrium hydro-morphologic conditions, in relation with definite inquiries in the domain of beach user perceptions, as well.

The average width of the backshore has increased by about 100m. Before medium term of coastal rehabilitation, the categories of fine sand and very fine sand are prevalent in backshore sediments participating on average by 69% after beach nourishment fine and very fine sand category decreases to an average of 45%.

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