

INVESTIGATIONS-BASED RESULTS ON THE HYDROGRAPHIC CONDITIONS WITH SPECIAL REFERENCE TO THE TOURIST BATHING AREAS OF THE PROTECTED ROMANIAN LITTORAL

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ABSTRACT

The aim of the present work is related to the new hydrographic conditions within newly developed coastal areas through coastal protection measures extension. The study also seeks to assess the impact on the touristic bathing areas and its safety. The new bathymetry, induced by the sediment size, together with currents propagation into the bathing areas adjacent to the newly arranged beach areas were subject of Conductivity Temperature and depth profiler (CTD) and Acoustic Doppler Current Profiler (ADCP) measurements in relation to the summer waves regime and sea level variations. Several experiments habitually conducted during the summer period were considered; the experiments are related to the marine hazards associated to the swimming areas, such as seasonal storm-inducing currents and the propagation of the rip currents in the nearshore, but also to the specific marine currents setups around beach protection groins and longitudinal breakwater, the influence of vertical water movements, including up-welling and specific intensifications in the periods with complex stormy waves.

Keywords: hydro-morphological changes, coastal protection works, ADCP measurements, water quality, bathing areas

INTRODUCTION

We are all too familiar with the fact 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. From a geomorphological point of view the shore is a direct result of the interaction between the sea and the land, absorbing the incident wave energy, which is responsible for shaping the shoreline and assuring the sediment mass in the water column for sediment transport (Van Rijn, 1998). Through its characteristics allowing the beach 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). On 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" measures have been established, consisting of large-scale sanding of beaches, a measure meant to solve coastal erosion and create new beach areas. This protection solution consisted of sand nourishments and reconstructed dikes, where the coastal erosion phenomenon

predominates. The sand used in nourishing the eroded beach was obtained from the bottom of the sea (JICA Baseline-study, 2006; Master Plan, 2012).

MATERIALS AND METHODS

The evaluation of coastal hydrodynamic processes was conducted through a comparative analysis of the in-situ measurements on hydrological and physicochemical parameters in tourist bathing areas, during the period from June 2022 to October 2022.

Several field and laboratory research activities were carried out, as follows:

- Measurement campaigns conducted on a network of water quality profiles extended to the shallow water zone, and hydrological/current in-situ measurement campaigns in the shallow coastal areas of southern Romanian coast's tourist sectors.

- Analysis of satellite images taken during the mentioned period, alongside qualitative analysis of terrestrial and aerial (UAV) photos taken during the field campaigns.

- Main features parameters of circulation in shallow water areas corresponding to tourist bathing areas and analysis of its patterns in the field were evaluated, in order to validate the numerical models (Vlasceanu & Buzbuchi, 2019).

Activities such as Acoustic Doppler Current Profiler (ADCP) measurements, bathymetry, WQ multiparameter measurements (water quality/color, sound profiles, CTD measurements – turbidity/transparency), and UAV observations were aimed at studying hydrological and hydro-morphological processes in coastal areas adjacent to bathing areas, especially in the new arranged zones of the Mamaia–Eforie sector.

RESULTS AND DISCUSSION

For tourist zones with bathing areas protected by coastal constructions, such as is Mamaia tourist resort (Fig. 1), it is necessary to consider all the dominant characteristics of the field of currents and waves, determined by the complex configurations of the coastal development (Omer *et al.*, 2015).

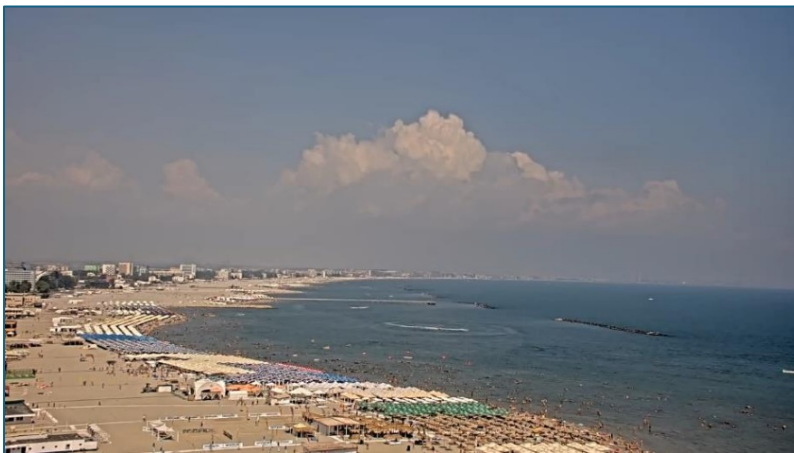


Fig. 1. Bathing area of the Mamaia South Sector

In the dynamics of coastal water bodies, an important role in determining the quality of bathing waters is played by the currents and waves generated by the wind. The variation of the physicochemical parameters that determine the density of coastal water bodies, specifically their temperature and salinity, is related to the flow velocity induced in coastal waters by offshore circulation, as well as by coastal water flows at local scales, produced by areas of shadow/intensification from the complex configurations of the shore protected by hydrotechnical constructions in various coastal management schemes (Caraivan, 1982).

The chosen study interval, corresponding to the summer season of 2022, from June to September 2022, corresponded with a significant change in the climatic regime. According to the studies and analyses conducted so far, the year 2022 was a drought year, with frequent periods of intensified wind, corresponding to the trend of rising global temperatures - one of the most important indicators of climate change, viewed as an impact of human activities, related to the cumulative increase in the atmosphere of greenhouse gas emissions.

The most influential direction during the summer season was for waves from the ENE direction (Fig. 2), according to data recorded by the wave meter at Mamaia/Cap Singol at a depth of 12 meters, approximately one nautical mile from the shore - sensor SPOT1622 (44.235333, 28.662667), (Fig. 3).

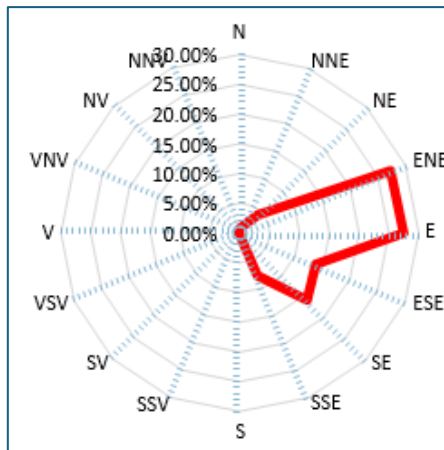


Fig.2. Wave rose for the values recorded during the summer season of 2022 at the INCDM wave meter, GPS/Spot_1622 buoy type, located in the southern of Mamaia area, at a depth of 12 m (approx. 1 nautical mile from the shore) (<https://spotters.sofarocan.com/?spotter-filter=SPOT-1622>)

A comparative analysis of coastal current characteristics was developed based on currents measured in the field, for a typical situation of current formation in Mamaia Bay. In-situ measurements: current profiles from the shore to offshore, performed with the Acoustic Doppler Current Profiler (ADCP RDI Teledyne HWS 1200KHz), in the main circulation cells associated with the tourist beaches of Mamaia Bay.

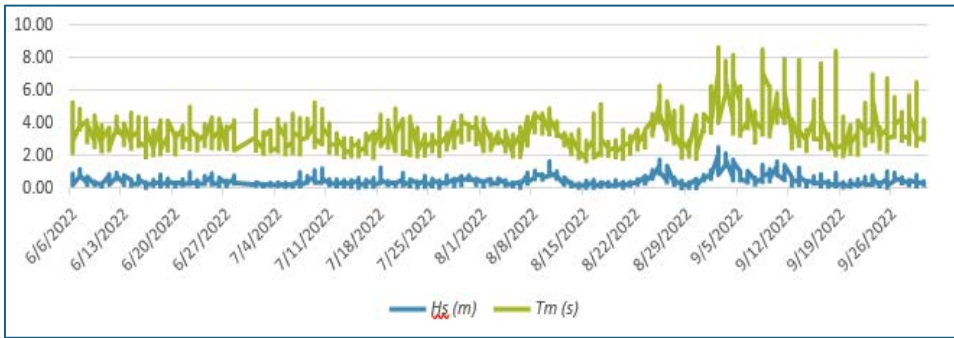


Fig.3. Characteristic parameters (H_s and TP) recorded during the warm season of 2022 at the INCDM wave meter, GPS/Spot_1622 wave rider type, located in the Pescarie Mamaia area, at a depth of 12m (traverse at 1 nautical mile from the shoreline)

The measurements results highlight the fact that, for the southern area of Mamaia Bay, a complex current pattern develops around the breakwater jetties (Fig. 4), as the longshore current pattern is influenced by the irregular radiation stress field generated by the characteristics of diffracted waves in the openings/gaps between the jetties, which influence the displacement of the boat carrying lateral the ACDP at the water surface.

The current profiles were made perpendicular to the shoreline in 17th of August 2022, in certain summer sea state conditions, at 1 - 2 degree in the Beaufort scale, as well as in conditions of the optimal use of the bathing areas – shows typical sea condition, considered the main sections of the circulation characteristics in the most vulnerable and first protected perimeter of Mamaia beach sector (Fig. 5).

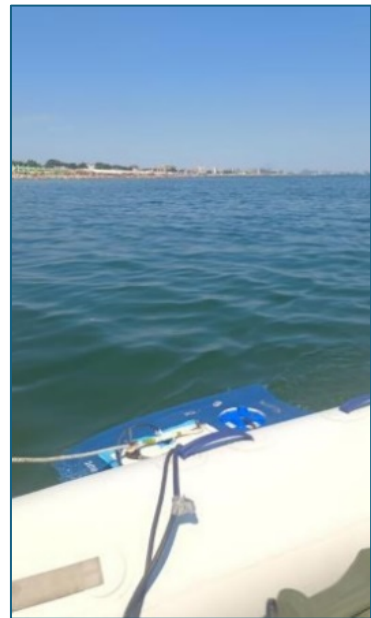


Fig. 4. Floating assembly towed laterally by the boat for measuring currents in dynamic mode, on cross-shore profiles

Also, it was considered the maximum speed of coastal currents in the Mamaia’s southern protected area is generally determined by oblique waves direction, but also the normal direction to the shore, which force a continuous circulation of currents in the sheltered zone, directed primarily southward (very accentuated during storms from the NE and ENE sectors) and northward during summer seasons, with waves predominance from the E and/or SE sectors.

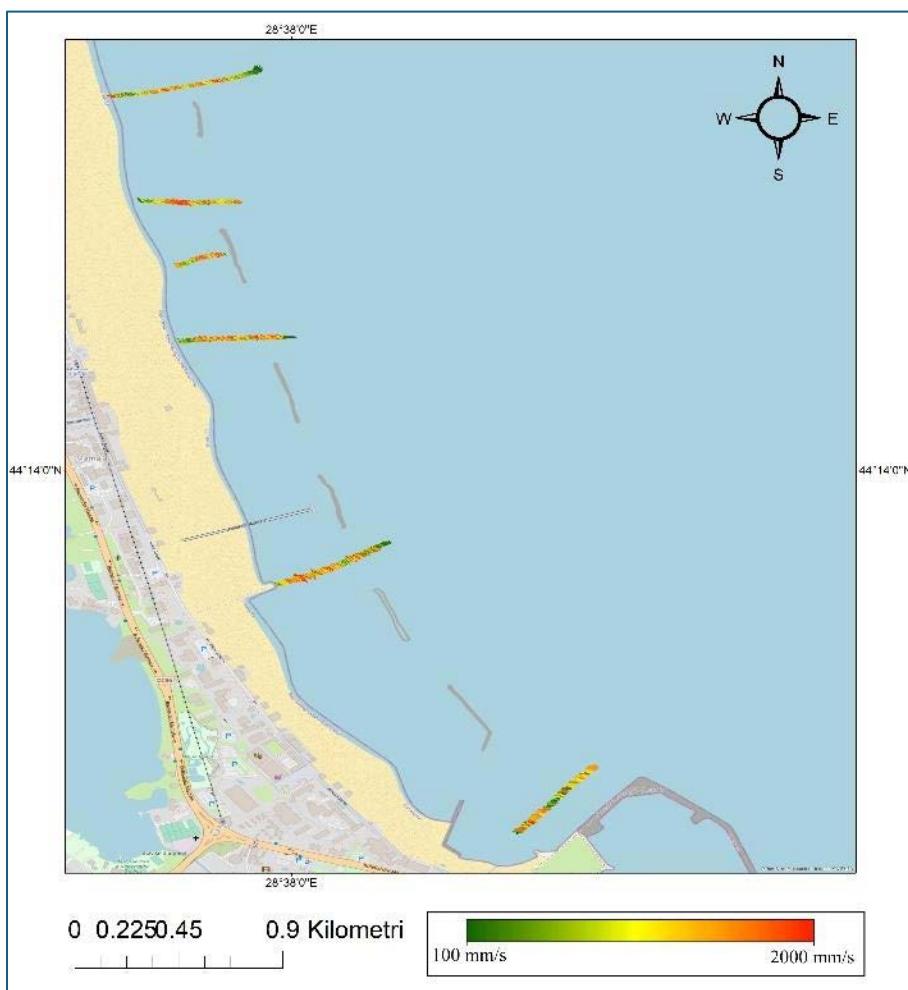


Fig. 5. Mamaia southern protected sector - measured values of surface currents, measured on profiles, measurement session 17.08.2022

The regular tendency of current patterns (almost parallel to the shore), especially for NE sector storms, produces a strong current near the southern jetty. Currents moving offshore in the gaps between longitudinal breakwater structures are also more significant.

The coastal current measurements session from 17.08.2022, carried in Mamaia Bay, shows measured currents on the profile, having averaged values between 0.1 and 0.8m/s (Fig. 5(a) and (b)), with intensifications up to 1.1m/s in the areas adjacent to the longitudinal protection system, break-wave type. We noticed that in the case of summer, low circulation regime, the local cyclonic circulation is induced in the sheltered bathing areas, following the shoreline in very shallow waters, the strong currents were developing, in the vicinity of the marine obstacles, such as the longitudinal breakwater system.

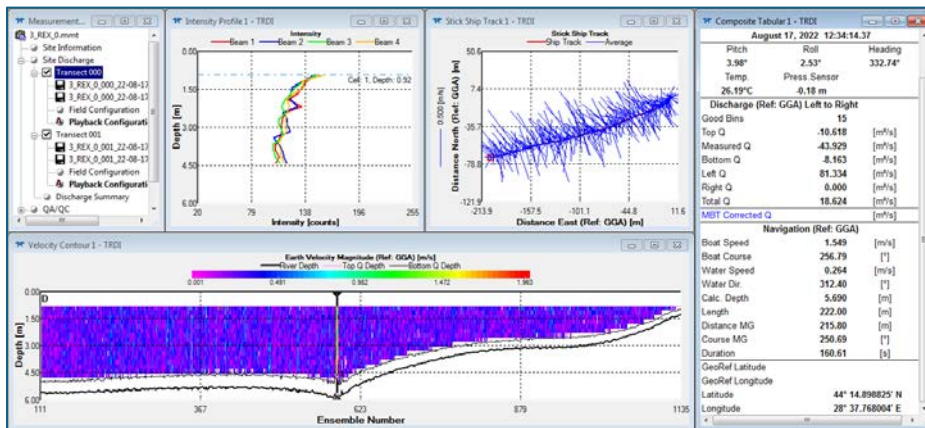


Fig. 5(a). Current profile made in the Central Mamaia sector/REX Hotel area – 17.08.2022

Therefore, for the area of the delimitation groin of the first stage of sand-nourishment of carried out for the Mamaia southern shore sector, the variation of the currents in the water column shows the intensification of the current in the breakwater area.

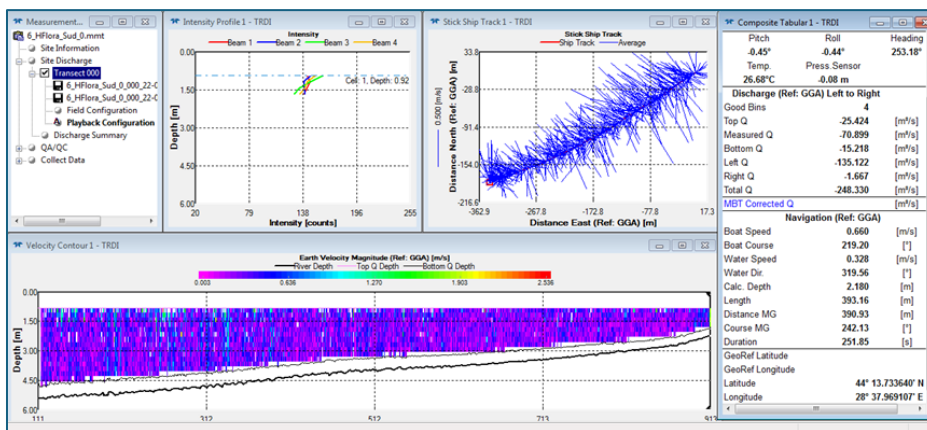


Fig. 5(b). The profile of the currents on the gap between second and third longitudinal breakwaters of the Mamaia South sector

For the middle bay area, the modified bathymetric profile can be observed, in the shadow area of the last longitudinal protection breakwater, in a situation of hydrodynamic calm, specific to the warm season (Fig. 5(b)) - variable currents at very reduced intensity (10 – 20 cm/s), and the predominance of southern currents on the profile, as well as the seaward orientation of the currents formed on the openings of the longitudinal protection system.

Moreover, concomitant with the current measurement sessions carried out in the perimeter of the Mamaia’s bathing areas, the presence of the temperature sensor of SPOT-1622 (SofarOcean Spotter) and respectively, supervised by the continuous daily monitoring of coastal water temperature, based on laboratory measurement of water samples,

the variability of the main physicochemical parameters of water quality was realized on profiles: temperature and salinity, measured with the Yşi Castaway CTD (Fig. 6(a) and (b)).

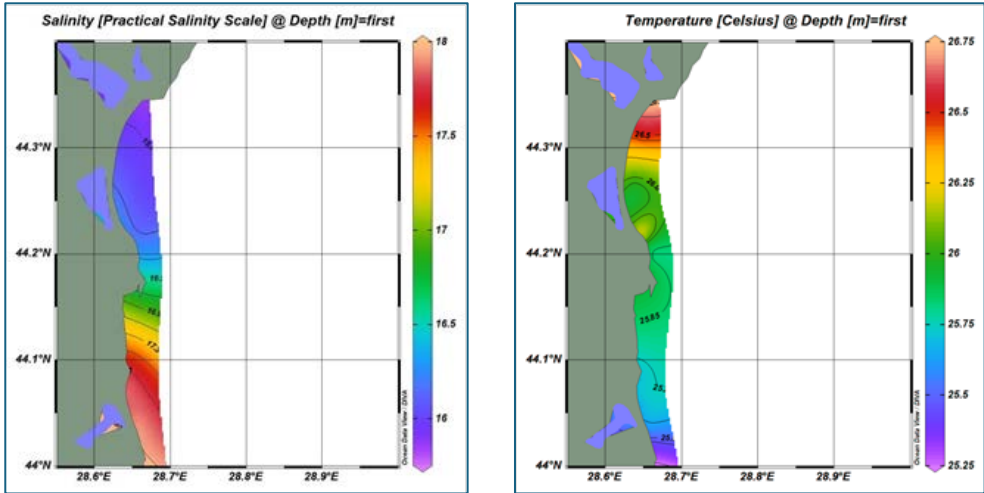


Fig. 6 (a) and (b). Variability of seawater temperature and salinity in the surface layer of tourist bathing areas, from Romanian southern shore unit (regional scale representation in Ocean Data View – ODV 4.0)

At the regional scale, the influence of the marine obstacles determined by the existence of maritime port jetties of Midia and Constanta Ports, reflect the influence of the Danube's freshwater plume as well as the induces changes on the arranges shore, in the considered summer season.

In the area of interest, encompassing the touristic littoral, the water quality (Fig. 7) of the bathing areas the investigation shows that the sea surface temperature measured in water sample at the shore against offshore area (using Spotters from SofarOcean/wave riders), considering the shelter effect of the longitudinal protection system as well the heating effect in shallow waters, as well as variation of the physicochemical parameters in the vicinity of the coastal sand belts or sand barriers.

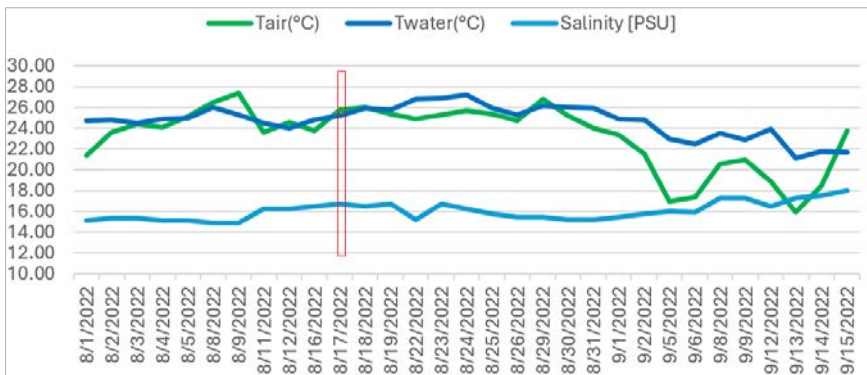


Fig. 7. The main water quality parameters for touristic summer season measured at shore in coastal shallow area of area of central sector of Mamaia (daily sampled at 8:00 in the morning)

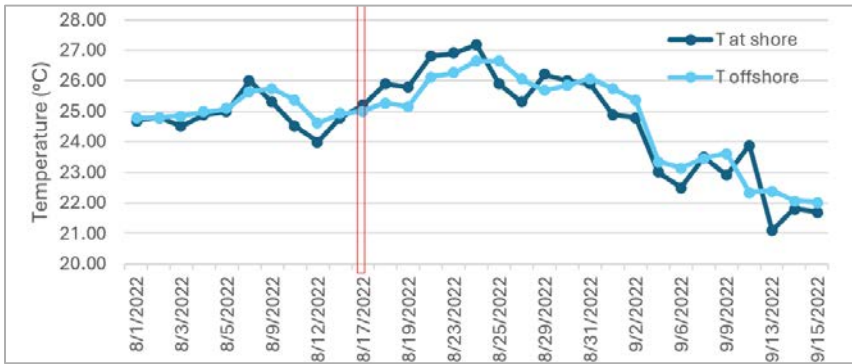


Fig. 8. Variation of the sea surface temperature at shore (Mamaia stations) and offshore (1NM seaward from the shoreline, in southern area of Mamaia Bay)

Hazardous phenomena developing in bathing areas

Identification of the critical risk areas for drowning in the bathing areas of the tourist resorts Mamaia and Eforie, was developed through a remote observation effort to detect the turbulence fields associated with certain hydrodynamic metrics of sea currents (stream energy gradients) in close connection with wave deflection in specific shallow waters, in the areas of coastal bars formation (Diaconeasa, 2009). This is the case of the rip currents, known as jet type currents, formed from the breaking zone to offshore, in the case of direct wave incidence on the coast. This type of currents in bathing areas are responsible for both the transverse transport of sediments and numerous casualties/drowning incidents that occur in bathing areas, during the summer season (on average, 20 cases annually along the Romanian littoral) (Diaconeasa & Petrisoiaia, 2016).

For the Eforie area, located in immediate vicinity of the Constanta Port, for which a record high percentage has been reported, of drowning incidents, a systematic observation has been initiated using a precision webcam at fixed position, in a bid to identify the maximum risk areas and determine a visual indicator from UAV aerial/webcam images (Fig. 9, Fig. 10).



Fig.9. Identification of Rip Current Using Webcam, Eforie North – Belona Beach, 18.05.2022, at 15:00

Given the fact that these currents present specificities in their formation regime, as well as in their stabilization on certain shore sectors, they can be identified through aerial remote observations (Fig. 10) (Niculescu *et al.*, 2017).



Fig. 10. The appearance of a rip current in the southern area of the Techirghiol coastal belt (May 2018) supplying the turbulence fields in bathing areas, photographed with the help of an UAV

The remote observations were completed to create vulnerability maps for the natural and protected touristic bathing areas, as well as detailed maps of areas with irreversible losses/material damage caused by storms in critical zones of hydrodynamic process development (such as rip currents, freak waves, etc) (Lungu *et al.*, 2015).

CONCLUSIONS

Based on the studies conducted, significant changes in coastal water bodies near the sea-land interface were determined during the summer season of 2022, induced by large-scale marine processes including the southern sectors of Mamaia and Eforie, exhibiting several coastal hydrodynamic processes that varied in intensity and duration:

- Changes in marine/coastal physical and chemical parameters were determined within the limits of climatological variability (with values corresponding to the average variability range), showing some typical developments in built shore system.
- The maximum recorded of the littoral currents velocities were 0.8 – 1.1 m/s in the coastal areas of transitional shore system of Romania., particularly near the protection breakwaters.
- The identified occurrence of the rip currents in shallow water extents of the natural and sand nourished beaches for touristic use, also, in the adjacent areas to coastal protection jetties

The intensity of hydrodynamic processes in the bathing areas along the Romanian tourist coast leads to hydro-morphological processes on the adjacent coast, specifically an intensification of erosion processes and mobility of submerged sandbars

in the shallow water zone, as well as increased sediment transport near the coastal protection works against erosion.

Spatial analyses, conducted at different temporal scales, of the distribution and variability over time of hydrodynamic processes in relation to the variability of oceanographic physical parameters and the influence of anthropogenic activities with impact on the marine and coastal zone; identifying vulnerable areas by using specific indicators of density/occurrence of rip currents; the integration of some hydro-morphological evolution models that will be applied to the Romanian coast, in particular in vulnerable areas and of significant impact.

Thus, permanent hydrographical changes can occur due to changes in the thermal or salinity regimes of the bathing areas of the pocket beaches, as well as the waves and currents in water column or in its spatial patterns, inducing the changes of the coastal waters turbidity in complex-arranged shore sectors.

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