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PHYTOBENTHOS - KEY BIOLOGICAL ELEMENT IN SHALLOW MARINE WATERS

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ABSTRACT

The present paper describes the situation of the macroalgal flora from the past years (2009-2012) along the Romanian Black Sea coast, from the qualitative and quantitative point of view. Key species (*Cystoseira barbata* and *Zostera noltei*) are characterized and their role for the communities inhabiting the shallow marine waters is highlighted. Also the pressures that have negatively affected the development of macroalgal flora over the years, leading to decline (in some cases irreversible) of some species are described. In order to answer to the requirements of the Water Framework Directive the biological element macroalgae is used and indicators able to characterize the water bodies from the ecological point of view are applied.

KEY WORDS: macroalgae, habitat, *Cystoseira barbata, Zostera noltei*

AIMS AND BACKGROUND

The submerse vegetation from the Romanian Black Sea waters represents a very important ecosystem component, being a substrate for the epiphytic algae, feeding and breeding area for invertebrates and fish, which carry-out their vital processes within the thickets formed by macrophytes (Fig.1). Macroalgae have a role in protecting the fauna against the disturbing water action, due to their flexible structure; they also offer a shelter against predators and excessive light. As macrophytes react to the changes in water quality, they can be used as bioindicators of eutrophication and considered good indicators for the long-term changes in the marine ecosystem (Sburlea et al., 2006). Marine macrophytes respond to environmental factors variations, the substrate quality and quantity of light

radiation permeated into the water column representing the primary factors necessary for their occurrence. Various anthropogenic activities (hydrotechnical constructions, accidental pollution with chemicals) have a negative influence, obviously first in the coastal algal belt (Sburlea & Bologa, 2006). The physical structure and hardness of the substrate are very important factors, since a disintegrating substrate under water action generates turbidity and reduce transparency, being unfavorable to the development of macroalgae (Sava, 2006).

Among the natural factors, particularly cold winters in the years 1971/1972, 1984/1985, the formed ice layers and extremely low water temperatures led to the extinction of many algal species and also their associated flora and fauna. The high water turbidity, eutrophication and even pollution of marine waters, favored over the time the disappearance of many macrophyte species and marine phanerogams, resulting in a drastic reduction of specific biodiversity.

Fig. 1 - Macroalgae - habitat for marine organisms

MATERIAL AND METHODS

The samples were collected from the following stations considered representative for the algal flora, along the coastal strip Năvodari - Vama Veche: Năvodari, Mamaia, Pescărie, Constanța Nord, Casino Constanța, Agigea, Eforie North, Eforie South, Tuzla, Costineşti, Mangalia, 2 Mai and Vama Veche. The stations presented a favorable substrate for the development of macroalgae, both natural (hard, rocky substrate) and artificial (dams). The survey followed both the northern (Năvodari - Agigea) and southern sector (Agigea - Vama Veche), in order to provide a detailed image of the macroalgae situation in the past years. Vertical sampling on different substrate types was performed, as it can be seen in the Table 1:

Table 1 - Stations, substrate type and sampling depth during 2009-2012 summer seasons

Station	Substrate type	Sampling depth
Năvodari	Natural rocky substrate Sandy-muddy substrate	1 m, 3 m, 2 m, 5 m
Mamaia	Natural rocky substrate Rocky artificial substrate - dam	1 m, 2 m, 3 m, 5 m
Pescărie	Natural rocky substrate	1 m, 3 m
Constanța North	Natural rocky substrate	1 m, 3 m
Casino Constanța	Natural rocky substrate	1 m, 2 m, 3 m, 4 m, 5 m
Agigea	Natural rocky substrate	1 m, 3 m, 4 m
Eforie North	Natural rocky substrate	1 m, 2 m, 3 m
Eforie South	Natural rocky substrate	1 m, 2 m, 3 m, 5 m
Tuzla	Natural rocky substrate	1 m, 2 m, 3 m, 5 m
Costineşti	Natural rocky substrate	1 m, 2 m, 3 m, 5 m
Mangalia	Natural rocky substrate Sandy substrate	1 m, 2 m, 3 m, 5 m
2 Mai	Natural rocky substrate	1 m, 2 m, 3 m, 5 m
Vama Veche	Natural rocky substrate	1 m, 2 m, 3 m, 4 m, 5 m

Current observations were centered on the qualitative and quantitative analysis of the samples collected during the summer season, between 2009 and 2012, from 13 stations at depths between 1 and 5 m. The sampling was performed on natural hard substrate and sandy substrate (for marine phanerogams). In some cases, the substrate was covered by mussel colonies (*Mytilus galloprovincialis*), so samples were also taken from the surface of

the mussel shells. Macroalgae samples were collected from an area of 20/20 cm and subsequently reported at square meter (Fig. 2).

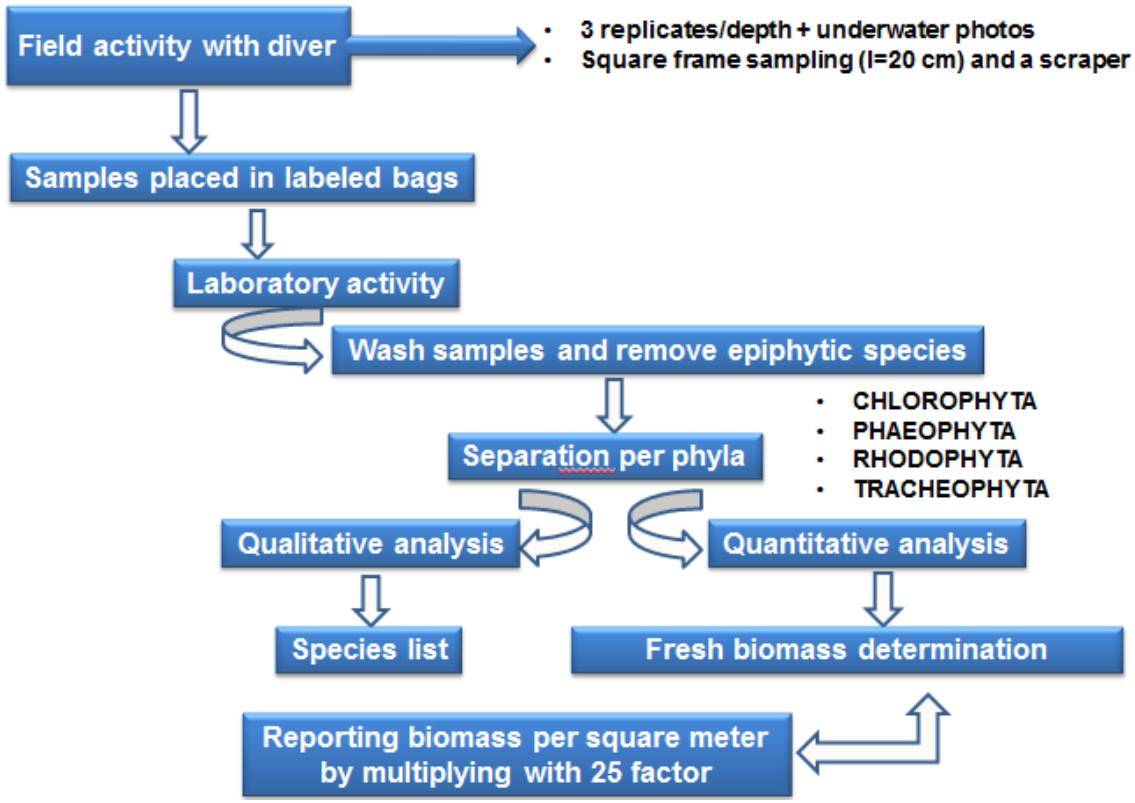

Fig. 2 - Schematic representation of the sampling method and analysis of phytobenthic samples

RESULTS AND DISCUSSION

Qualitative and quantitative analysis

During the study period (2009-2012), based on the qualitative analysis, 33 taxa were identified, assigned to the following phyla: 14 species of Chlorophyta, 4 of Phaeophyta, 12 Rhodophyta taxa (9 species and 3 varieties) and 3 marine phanerogams (Tracheophyta) (Table 2):

Table 2 - Species list (2009 - 2012)

Chlorophyta	Phaeophyta	Rhodophyta	Tracheophyta
Bryopsis plumosa	*Cystoseira barbata*	*Callithamnion corymbosum*	*Stuckenia pectinata*
Chaetomorpha aerea	*Ectocarpus siliculosus*	*Ceramium diaphanum*	*Zannichelia palustris*
Cladophora albida	*Punctaria latifolia*	*Ceramium diaphanum var. elegans*	*Zostera noltei*
Cladophora laetevirens	*Scytosiphon lomentaria*	*Ceramium rubrum var. barbatum*	
Cladophora sericea		*Ceramium rubrum var. tenue*	
Cladophora vagabunda		*Ceramium virgatum*	
Ulothrix implexa		*Colaconema thuretii*	
Ulva compressa		*Corallina officinalis*	
Ulva flexuosa		*Hildenbrandia rubra*	
Ulva linza		*Lomentaria clavellosa*	
Ulva lactuca		*Pyropia leucosticta*	
Ulva intestinalis		*Polysiphonia elongata*	
Ulva prolifera			
Urospora penicilliforms			

Between 2009 and 2012, along the Romanian coast, the eurithermal and opportunistic species belonging to the phylum Chlorophyta have dominated, both quantitatively and qualitatively, characterized by a fast development cycle and abundant proliferation. The species of the *Ulva* genus are among the first macrophytes to colonize the substrate from coastal waters with a high content of nutrients. This may be due to their simple morphology and remarkable reproductive capacity (Sava, 2006). Along all study periods, *Ulva lactuca* (sea lettuce) was a constant presence, both in the north and in the south, but developed high biomasses along the coastal strip 2 Mai - Vama Veche, where it forms the association *Cystoseira barbata - Ulva lactuca*, particularly important for the marine ecosystem, enriched with various faunal elements (Fig.3).

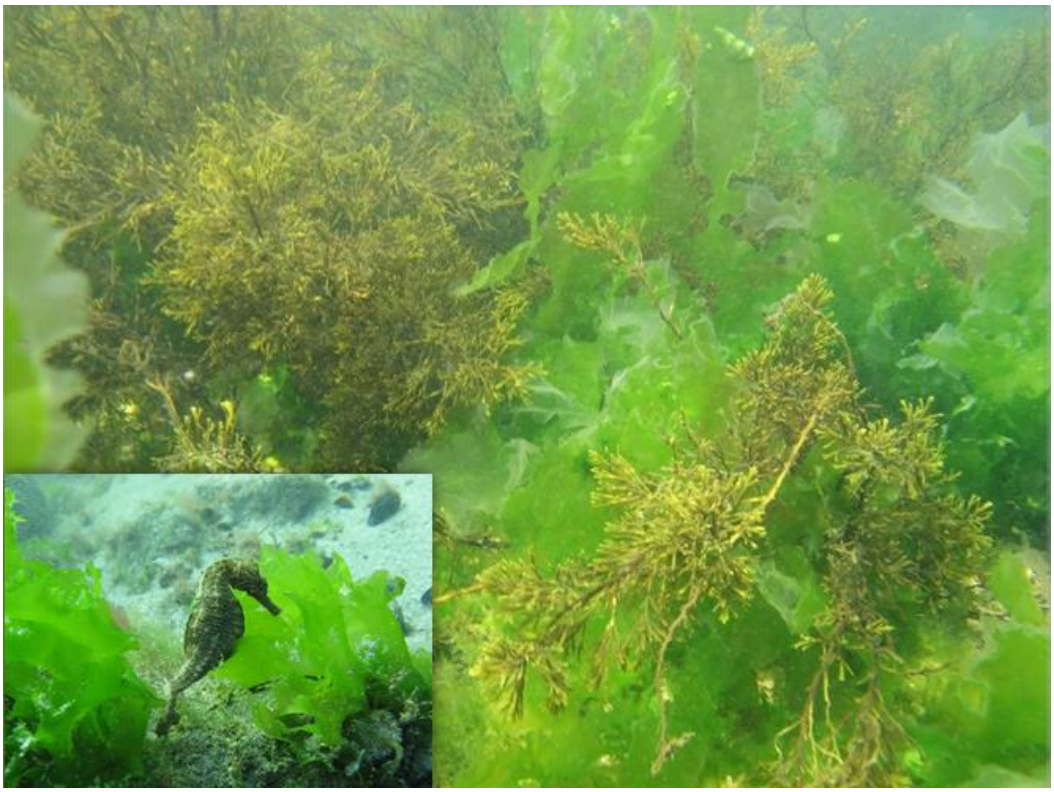

Fig. 3 - The association *Cystoseira barbata - Ulva lactuca*

The following *Cladophora* species were identified in the Romanian coastal waters: *Cladophora vagabunda, C. sericea, C. laetevirens, C. albida.* Most of the *Cladophora* species are able to find a suitable habitat almost everywhere: in basins and less hydrodynamic lagoons, but also in exposed areas, in sunny or heavily shaded areas, on hard substrate, but sometimes even on sandy or muddy substrate (Vasiliu, 1984). These are opportunistic species that have experienced an intense development in the past years. They were also encountered during the study as epiphytes on *Cystoseira barbata* and *Zostera noltei*, having sometimes a negative effect on the development of these species, suffocating and preventing the photosynthesis processes of these two key species. As *Ulva* spp.,

Cladophora is also able to grow on several types of substrates, but prefers the rough, hard substrate. Being included into the opportunistic group, its occurrence on shallow rocks indicates the nutrient enrichment of waters, sometimes even pollution (Sava, 2006). Among all the species of the genus, *Cladophora vagabunda* was a constant presence throughout the study period in both northern and southern sector.

Red algae were dominated by the *Ceramium* species (Fig. 4), annual elements that thrive on rocky substrate during summer and sometimes can be found in association with green algae of the genus *Ulva* (often *U. lactuca* and *U. intestinalis*). Between 2009 and 2012 in the Romanian waters the following species were identified: *Ceramium diaphanum*, *Ceramium diaphanum* var. *elegans*, *Ceramium virgatum*, and some varieties, as *C. rubrum* var. *barbatum* and *C. rubrum* var. *tenue.* The numerous fine branches of the *Ceramium* thalli represent a suitable environment for micro and meiofauna (Müller et al., 1969).

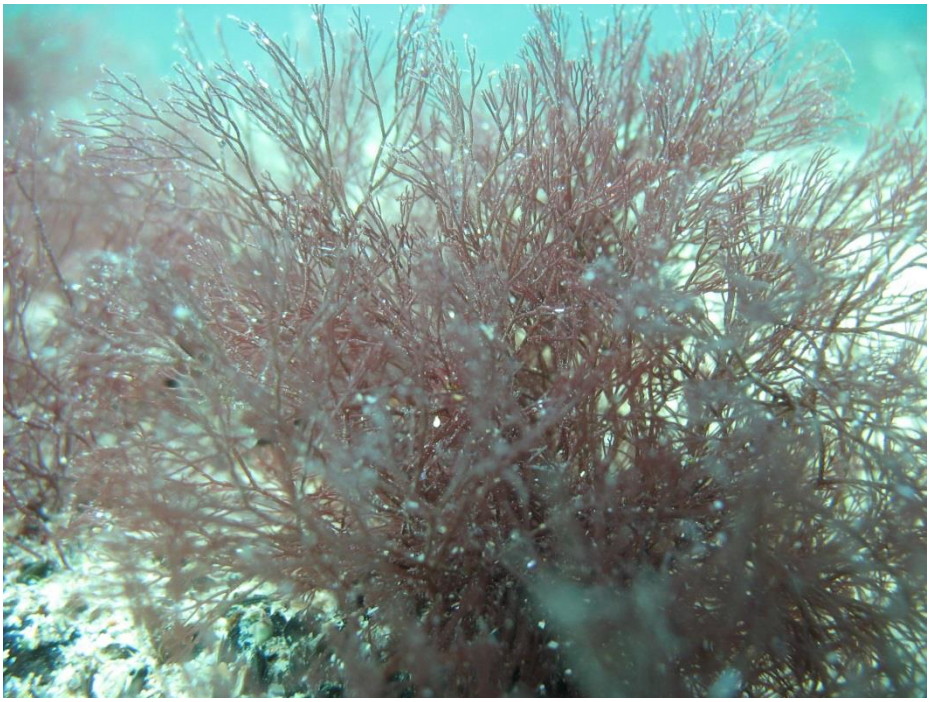

Fig. 4 - *Ceramium virgatum*

Ceramium species are opportunistic, capable of developing considerable biomasses, fact explained by their high reproductive capacity, both asexual and sexual, so, during favorable conditions in summer, sometimes the hard substrate was entirely covered by these species (Sava & Bologa, 2008). The opportunism of these species derives from the fact that several types of substrate are preferred for development, so in addition to the rocky one, they can grow on mussel shells (both living and dead), on dams and even on vegetal substrate (other algae). The epiphytism is preferred by this genus, growing on *Cystoseira* thalli, *Zostera* leaves and even on the surface of smaller species such as *Ulva* or *Cladophora* species. Switching to epiphytism provides also protection for this species against the effect

of waves and currents. Epiphytes play an important role, their occurrence leading to a higher degree of complexity of the algal substrate, a key condition for the fixation of the epibiotic diatoms and for sheltering the associated fauna (Müller et al.,1969).

Another constant presence throughout the study was *Callithamnion corymbosum*, a small species which does not develod notable biomasses, commonly recorded at depths between 3 to 5 m, both on hard substrate and as epiphyte on *Zostera noltei* leaves. During the summer, *Zostera* was strongly epiphyted by *Colaconema thuretii*, a very small red alga species. *Hildenbrandia rubra*, an encrusted, perennial species was found on the shore stones, but also on *Rapana* shells in the southern part of Romanian waters. This species is particularly resistant to wave action, due to its strong adhesion to the substrate and can withstand extended emersion periods and salinity and temperature variations.

An important occurrence during the study was *Lomentaria clavellosa*, a species identified both in 2010 and 2011 at Costineşti and 2 Mai. This species was reported as being present at the Romanian shore since 2003 (Sava et al., 2003). The occurrence of this species, considered rare for the Romanian waters, which in the past used to form a complex association, is particularly important, indicating a slight regeneration of benthic vegetation. In the past, these red algae had larger dimensions and formed the association *Lomentaria clavellosa - Antithamnion cruciatum*, which used to mark the lower limit of the attached algal macrophyte vegetation in the Romanian coastal waters. This lower depth varies from 7-8 m down to 13-15 m in the southern part of the Romanian Black Sea. The indicative species was *Lomentaria clavellosa* and, below 11 m, where this species no longer appears, *Antithamnion cruciatum*. Within this group, a single association was present - *Lomentaria clavellosa - Antithamnion cruciatum* - enriched by seasonal elements: *Bryopsis hypnoides, Ceramium elegans* f. *longearticulata* (for the northern sector) and for the sector Mangalia - Vama Veche - *Bryopsis hypnoides* and *Callithamnion granulatum*. At Tuzla and Costineşti, at depths of 10-12 m, fragmented populations of *Phyllophora nervosa* were identified. On stones and mussels, two encrusted red algae - *Dermatolithon cystoseirae* and *Cruoriella dubyi* - were found (Bavaru, 1977). The disappearance of this complex association led also to the disappearance of these species from the Romanian waters.

During winter and early spring, the following stenothermal species were identified: *Urospora penicilliformis, Ulothrix implexa, Punctaria latifolia, Ectocarpus siliculosus, Scytosiphon lomentaria, Pyropia leucosticta*. Some of them, with the onset of warm season, showed an interesting stenothermy behavior. Thus, as the water temperature increased, these species have retreated to deeper horizons where the environment was still favorable to their physiological processes. It is the case of *Scytosiphon lomentaria, Bryopsis plumosa,* that were identified between 3 and 5 m, in early summer, or passed to epiphytism on larger species (on *Polysiphonia denudata, Ceramium* sp.). When the seawater temperature reached higher values these species have disappeared, only to reappear later when conditions are suitable to their existence, this being the cycle of benthic vegetation.

The quantitative analysis revealed the clear quantitatively dominance of the green algae, followed by the red ones, a tendency maintained in past years at the Romanian Black Sea coast (Fig. 5).

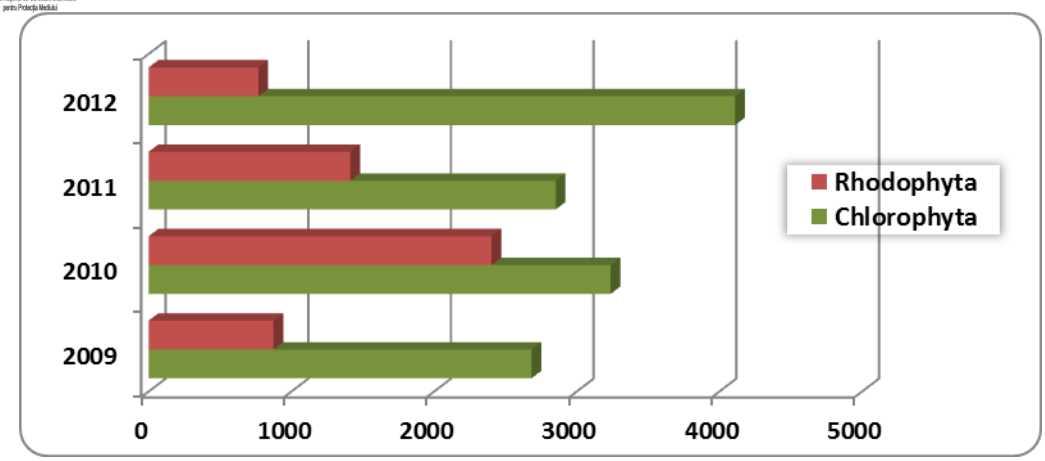

Fig. 5 - Average fresh biomass values for summer seasons 2009-2012

In 2009, the species that dominated the shallow hard substrate were *Ulva lactuca* and *Ceramium elegans*, capable of developing biomasses over 1,000 g/m^2: *Ulva lactuca* - 1,600 g/m^2 at Casino/3 m, *Ceramium elegans* - 1,320 g/m^2 at Costineşti/5 m and the maximum of the study period - 2,100 g/m^2 registered at Mangalia/3 m. *Ulva flexuosa* developed a considerable biomass of 1,500 g/m^2, becoming the dominant species at Costineşti at 0.5-1 m. *Ulva intestinalis* was a constant presence in 2009, sometimes in association with *U. compressa* (as identified at Mangalia) and developed high biomasses, up to 1,300 g/m^2. In late July 2009, species as *Ulva lactuca*, *U. flexuosa* and *U. intestinalis* have dominated all the analyzed profiles, with biomasses approaching and even exceeding 1,000 g/m^2. Generally, *U. lactuca* showed the highest biomass in the southern part, where it forms an important association with the brown alga *Cystoseira barbata*, fundamentally important for the shallow marine life. The intense proliferation of *Ulva* species is due to its ability to populate various artificial substrates in absence of the rough natural ones. They are able to populate hard compact rocks, gravels, shells and even fine or coarse sands (Vasiliu, 1984).

The red algae presented significantly lower biomasses compared to the green ones; a single genus proliferated during the warm seasons - *Ceramium*. *C. diaphanum* var. *elegans* developed both on rocky substrate and as principal epiphyte on the elastic *Cystoseira barbata* thalli. In the northern sector, at Casino Constanța it was the dominant species on hard substrate (600 g/m^2) in association with scattered *Callithamnion corymbosum* thalli, starting at 4 m depth. The highest quantities of *Ceramium* (*C. virgatum* in association with *C. diaphanum*) were recorded in Constanța North (up to 2,000 g/m^2).

In 2010, at the beginning of the warm season the occurrence of cosmopolitan, opportunistic species, capable of developing considerable biomass during summer can be noted (*Ulva intestinalis, U. compressa, Cladophora vagabunda, Ceramium virgatum*). In the northern part of the Romanian littoral, *Ceramium* was a constant presence in all analyzed stations, with the following representatives: *Ceramium virgatum, C. diaphanum var. elegans, C. diaphanum, C. rubrum* var. *barbatum, C. rubrum* var. *tenue.* Among *Cladophora* species, *C. vagabunda* presented the highest biomass (400 g/m^2) and was generally identified in association with specimens of *C. sericea*.

The biomass of opportunistic species (both green and red algae) generated by a limited number of species, but with a very high developing capacity, decreased gradually with the depth (Fig. 6.). Thus, between 0 and 3 m, the recorded values were the highest, knowing that this is a normal response of benthic vegetation to environmental conditions (high water temperature, large amount of nutrients, favorable water transparency). Starting with 4 m depth the macroalgae distribution is sparser, and at 5 m only red algae, scattered distributed on mussels shells were identified. The following taxa were reported at those deeper horizons: *Callithamnion corymbosum, Ceramium virgatum, Ceramium diaphanum, Polysiphonia denudata*, but with very low biomasses, up to 100 g/m^2.

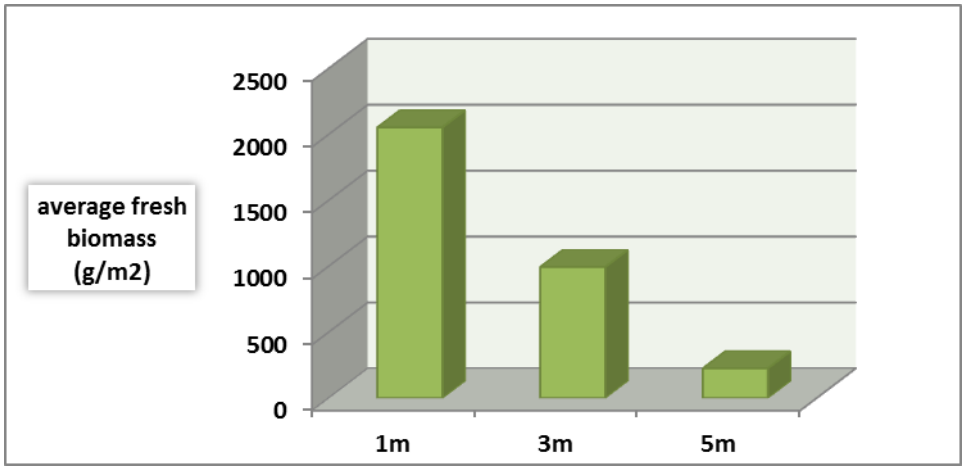

Fig. 6 - Average fresh biomasses (depth distribution) for opportunistic species during summer 2010

During the summer of 2011, the genus that quantitatively dominated was *Cladophora* (Fig. 7), with fresh biomasses exceeding on some profiles 2,000 g/m^2. In addition, the macroalgal deposits sometimes formed along the shore were composed up to 90% of *Cladophora* species. High biomass values were reported at Eforie South (where the dominant species was *C. sericea* - 1,300 g/m^2) and Costineşti (where the highest biomass values were recorded). At the latter station the hard substrate between 0 and 3 m depth was covered by *C. vagabunda* in association with *C. albida*, with biomass values over 2,000 g/m^2 between 0-2 m decreasing to about 1,000 g/m^2 at deeper horizons.

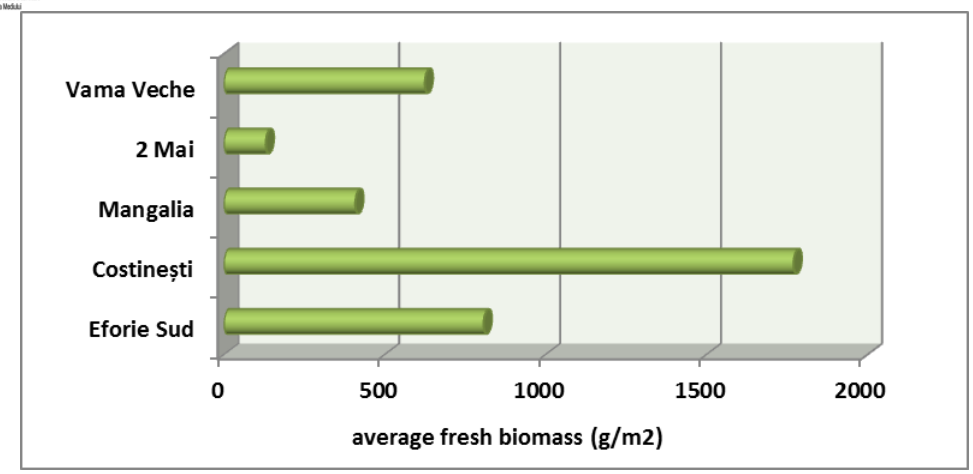

Fig. 7 - Average fresh biomass values for *Cladophora* sp. during summer 2011

Among *Ulva* species in the collected samples in 2011 - *Ulva lactuca*, *U. intestinalis* and *U. compressa* were present, their biomasses being quantitatively reduced. *U. lactuca* associated to *Cystoseira barbata* field developed more intensely along the 2 Mai - Vama Veche coastal strip, amounting a biomass of 300 g/m^2 between 1 and 2 m at 2 Mai, and approx. 260 g/m^2 between 2 and 3 m at Vama Veche. In the other analyzed stations, Eforie South and Costineşti, respectively, the *Ulva* genus was quantitatively poorly represented and the substrate has been widely covered by *Cladophora* species.

In 2012, among the green algae high biomass values were developed by *Cladophora vagabunda* (1,800 g/m^2) and *C. sericea* (1,700 g/m^2) (Fig. 8), and among the red ones - *Ceramium rubrum* var. *barbatum* (approx. 1,000 g/m^2). These species were identified during the whole summer season, both in samples and in shore deposits, especially in the northern sector, as in the south the *Ulva* ssp. (*U. lactuca* - 1,200 g/m^2, *U. intestinalis* - 770 g/m^2) associated to the *Cystoseira barbata* fields in these areas, predominated.

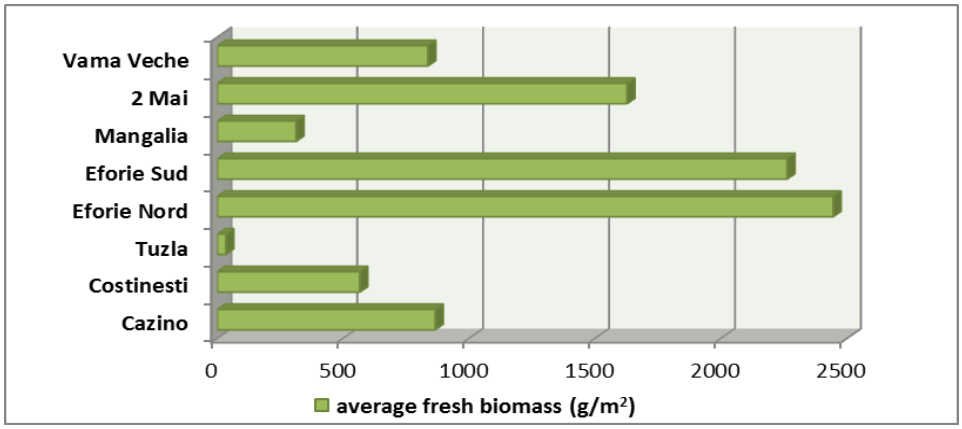

Fig. 8 - Average fresh biomass values for *Cladophora* sp. during summer 2012

Following the application of the *ratio between perennial and opportunistic species* index, the dominance of perennial species in the southern part of the Romanian coast was observed, where these species developed appreciable fresh biomasses due to favorable ecological factors in those areas (Fig. 9).

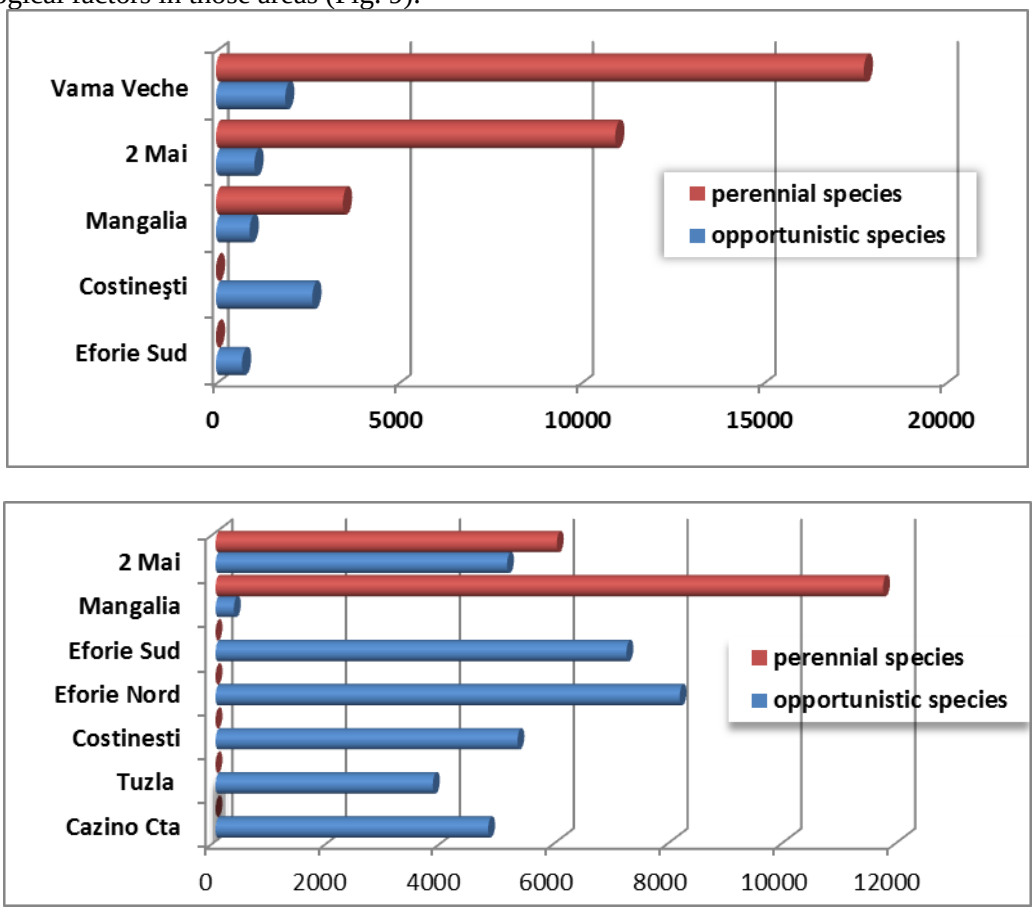

Fig. 9 - The ratio between perennial and opportunistic species biomasses, in 2011 (up) and 2012 (down)

Key species for the Romanian Black Sea waters

The brown alga *Cystoseira barbata* has a particular ecological importance for the marine ecosystem, as it constitutes protecting environment, feeding and breeding place for fish juveniles, and also for many marine invertebrates. The elastic substrate and yet firm enough represented by *Cystoseira* thalli, the complex structure of branches offers an ideal fixing place for various macrophytes, both photophyles (bringing them closer to the water surface) and scyaphyles (growing in the shade of *Cystoseira* thallus) (Müller et al., 1969). All these facts recommend *Cystoseira* areas as important ecological niche in the life of marine ecosystem. This species was previously encountered in association with *Cystoseira crinita* f. *bosphorica*, but the sea ice occurred in 1972 and the very low water temperatures

registered affected the photosynthetic activity and the reproduction of those species. The negative effects extended also to the associated subcoenosis *Cystoseira barbata* - *Mytilus galloprovincialis* fauna and flora. The ice blocks were present on the water surface until the beginning of March 1972 and after their melting (after the ice melting, from the thalli of more than 1 m remained only a small portion with the holdfast) other extreme phenomena followed - powerful storms which threw huge amounts of *Cystoseira* and mussels on the shore (measured at 20 - 25,000 tons) (Fig. 10).

Fig. 10 - Large amounts of *Cystoseira* thrown on the shore in Vama Veche after the winter storm in 1972 (photo Vasiliu, 1984)

In fact, the drastic decline of the species can be attributed to the cumulative action of two factors, namely the presence of ice blocks and the low water temperatures, which disrupted the photosynthetic activity. Following these extreme phenomena, *Cystoseira* stocks were reduced by 80% (Vasiliu & Muller, 1973) (Fig. 11).

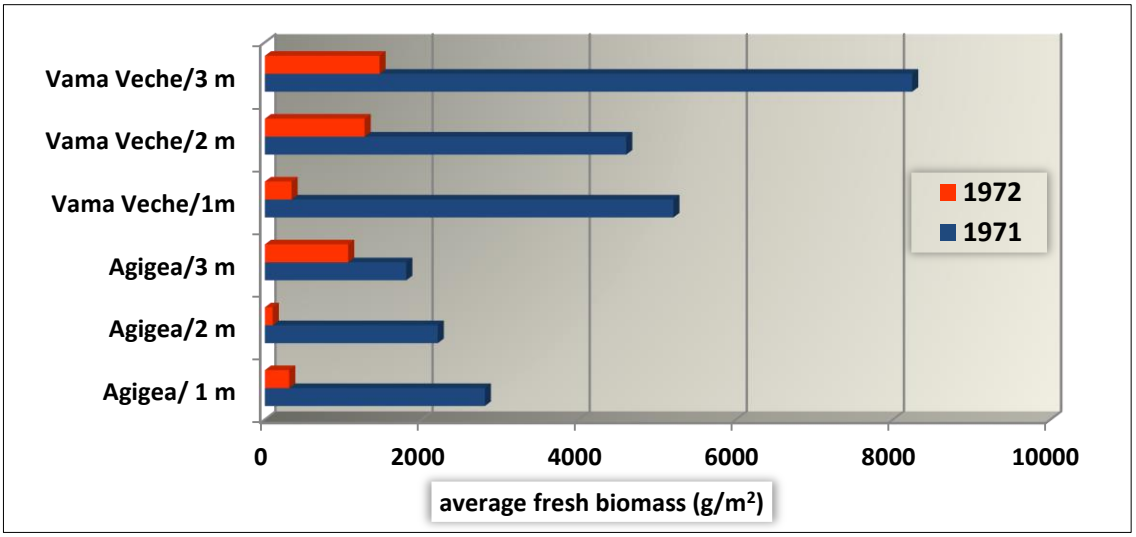

Fig. 11 - *Cystoseira* stocks decline in the northern and southern Romanian sector between 1971 and 1972

Although there were sea ice phenomena in previous years, the *Cystoseira* fields used to recover, but after this episode this perennial species was not able to regenerate anymore due to the intense anthropogenic pressures manifested in the beginning of the 1970s. The germs and young plants were unable to develop and restore the destroyed vegetation in coastal waters with high turbidity as a result of discharging at sea the excavated soil from various constructions or from unconsolidated cliffs affected by erosion. The high degree of eutrophication, even pollution, after the waste water or industrial discharge, caused the destruction of the juvenile development stages, thus depriving the shallow waters of the most valuable species both of ecological (shelter for a rich aquatic fauna) and economic importance (*Cystoseira* was used as source for valuable substances - alginic acid) (Bavaru, 1981).

Cystoseira fields had an important role in the amortization of shock waves and their reduction favored the re-suspension of sediments, the increased in water turbidity, with negative effects especially to sensitive organism. Another consequence of the decline of these species was the reduction in macroalgae biodiversity, as *Cystoseira* represented the host plant for the epiphytic species, that could only develop on its elastic thalli. As a result, species such as *Sphacellaria cirrhosa, Feldmannia irregularis, Stilophora rhizoides, Corynophlaea umbellata, Cladostephus verticillatus, Kylinia* ssp. disappeared. The disappearance or reduction of *Cystoseira* fields also led to the decline of some fish species which used to find here shelter and feeding habitat. Thus, in that period one of the main links of life in shallow littoral zone was almost destroyed (Bavaru, 1972) and also the specific diversity was reduced. Another important role of this species is given by the branched appearance of the thallus, which attenuates the wave action, also the vertical position in water prevents the sediment silting of diatoms, thus allowing the development of colonial microphytes (Müller et al., 1969).

Currently a restoration of this perennial species was noticed, and *Cystoseira barbata* may be found in the southern part of the Romanian coast, in Mangalia, 2 Mai and Vama Veche, forming well-developed fields. The regeneration of this species was possible because the area between 2 Mai and Vama Veche is declared a marine reserve, so human activities are limited and therefore their impact on this species are also limited. The substrate is a fundamental factor in the development of this species and is necessary to present some fundamental physical characteristics - to be hard and rough for the anchoring of algae with a strong holdfast. Also the level of water transparency must be high in order for this species to develop its biological processes. Under current conditions, *Cystoseira barbata*, a photophyle species, is stationed within the upper layers (identified in the study period between 1 and 3 m). Furthermore, in the literature, the depth of 5.5 m is recognized as being the maximum depth where this species can develop at the Romanian seaside, with an optimum between 1 and 3 m (Vasiliu, 1984). Although it is adapted to an intense hydrodynamism, it develops well in sheltered areas from Mangalia and 2 Mai, where high biomasses were recordered.

Cystoseira barbata was present at Mangalia in the superior water layers (from 0.5 to 2 m). Between 0 and 1 m the biomass is about 5,000 g/m^2, and between 2 and 3 m this value decreases to 1,400 g/m^2, as the substrate becomes mixed and the sandy one begins favorable to the development of *Zostera noltei*. At 2 Mai, the fresh average biomass was high, ranging between 6,000 g/m^2 at 0-1 m, to reach even 12,000 g/m^2 at the lower limit distribution of the field, where the environmental conditions are more stable. At Vama Veche the highest biomass values for *Cystoseira* were recorded, knowing that in this part a large regenerated *Cystoseira* field exists from the past years. Vama Veche is known from the past decade studies as the area where *the large Cystoseira field* was present. Currenlty, here *Cystoseira barbata* has recovered to a certain extent and forms true underwater thickets that provide shelter for fish larvae and juveniles, and feeding and breeding place for various other species.

At Vama Veche, *Cystoseira barbata* was identified in large individuals of approx. half a meter long, with a rich epiphytic flora, formed of species that grow abundantly during the summer - *Ulva* (*U. intestinalis, U. flexuosa, U. compressa*), *Cladophora vagabunda.* The dominant epiphytes were *Ceramium diaphanum* var. *elegans* and *C. virgatum*, that developed intense over the entire surface of *Cystoseira* thallus. By its presence, *Cystoseira* increases the plant primary production, influencing the composition of fish and benthic fauna (Müller et al., 1969), and all this recommends this alga as a key species for the benthic life.

A conclusion for all 4 years (2009-2012) is that this perennial species is currently in a stable condition and although the developed biomasses are incomparable with the existing ones before the 1970s (between 1970 and 1971 the stocks were estimated at 4,900-5,500 tons fresh biomass - Vasiliu, 1984), in the current environment conditions, both natural and anthropogenic, *Cystoseira barbata* is in a recovery process, though it remains highly sensitive to anthropogenic activities (e.g. dam construction, harbors, excavations).

Fig. 12 - *Zostera noltei* meadow at Mangalia

Another key species for the shallow marine ecosystem is considered to be the seagrass *Zostera noltei*. In the past, along the Romanian shore it used to form true underwater meadows in association with *Zostera marina,* at Agigea, Eforie South and Mangalia. Those species have suffered a drastic decline over the decades as a result of uncontrolled dredging activities and due to the reduction of water transparency following the suspension from various anthropogenic activities. Due to their occurrence in the upper layers (1-3 m) the suspension affects profoundly these perennial plants, preventing to develop the photosynthesis process. Suspensions (from harbors or cliff development) have triggered hypoxia and even anoxia processes, with lethal effects on seagrass populations. The suspensions directly influence the communities through:

- light penetration limitation into the water layers and selective retention, depending on the size and chemical structure of the particles.
- siltation processes, deposition of suspensions on benthic substrate.

The large amount of suspensions shall entail a transparency reduction thus prevent spore attachment, germination and development of species. The morphology of the species varies depending on the amount of available light, the leaves having much larger dimensions where the water transparency is higher.

Zostera noltei serves as habitat for many invertebrates and fishes, who find here a feeding place, reproduction and defence, also fixing the substrate and improving water

quality, which is why the importance of this species for the marine ecosystem is so high. It is a photophylic species and at its base a series of organisms not requiring much light develop: various types of molluscs, nematodes, copepods that can also develop well among the epiphytes and along the surface of the rhizomes, many polichaetes are present, too. All these sustain the importance of these marine meadows as unique biocoenosis, of particularly ecological value. At present, *Zostera noltei* forms meadows in the northern sector, at Năvodari (in association with *Stuckenia pectinata*) and in the south, at Mangalia (Fig. 12), where it is widespread on sandy substrate, anchored through a repent rhizome and a rhizoids system.

Along leaves small epiphytic species were identified: *Cladophora*, *Ulva* (*U. intestinalis* and *U. compressa*), and from the rhodophytes *Colaconema thuretii*, *Ceramium elegans, C. diaphanum, Clalithamnion corymbosum.* The fresh biomass values for *Zostera noltei* were high, indicating that this species is currently in a regenerating period on Romanian coastline. It is observed that passing to deeper horizons the biomass values increase, because the environmental factors instability from shallow waters is no longer present and the development of this indicator species of less eutrophic waters is possible (Fig. 13.).

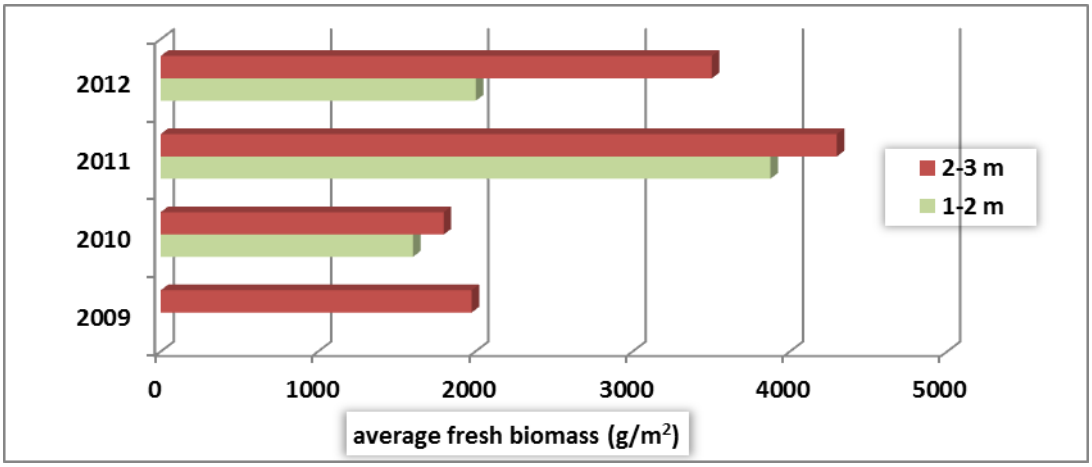

Fig. 13 - Fresh biomass values for *Zostera noltei* (2009 - 2012)

Because the biological element macroalgae responds to various factors (both natural and anthropogenic - Fig. 14.) they are considered to be good indicators of the quality of the marine environment.

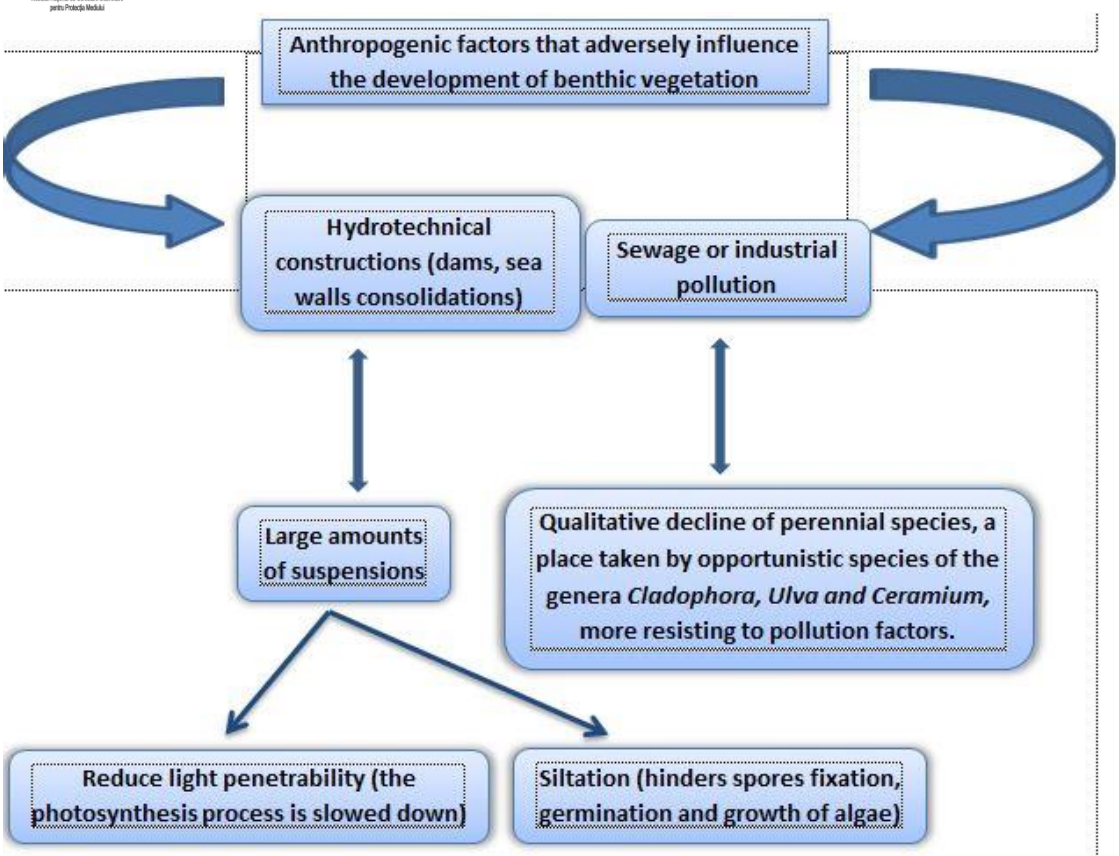

Fig. 14 - Anthropogenic factors and their influence on macroalgal flora

For the biological element macroalgae, in order to respond to the requirement of the Water Framework Directive, the Ecological Evaluation Index (EEI) expressed using the Ecological Quality Ratio index was applied. The EEI index was applied in a modified form, according to the Black Sea conditions (with a lower number of species comparing with other seas), so the results were expressed using the fresh biomass values, not the number of species as the original index requires (Dencheva, 2013; Orfanidis et. al., 2001). This index aims to characterize every analyzed station from an ecological point of view. Every species is classified into ecological groups according to its tolerance to environmental conditions, respectively Ecological Status Group I (ESG IA, ESG IB - perennial species - e.g. *Cystoseira, Zostera*), indicator of less polluted areas and Ecological Status Group II (ESG IIB, ESG IICa, ESG IICb - opportunistic species, capable to thrive in eutrophic areas, with a fast growing capacity (e.g. *Ceramium, Cladophora, Ulva*).

For the EEI-EQR index calculation the average fresh biomass for the opportunistic species (ESG II) and for the sensitive ones (ESG I) is determined. A clear quantitative dominance of sensitive perennial species, to a particular station, means a high ecological status, knowing that these species can only develop in superior quality waters (e.g. *Cystoseira barbata, Zostera noltei*). The limits of this index are presented in the Table 3:

Table 3 - EEI limits and ecological state class (Dencheva, 2013)

Biomass proportions of sensitive and tolerant species	EEI	Ecological state class	EEI-EQR
80-100% ESG I; 0-20% ESG II	> 8-10	**High**	0.8-1
60-80% ESG I; 20-40% ESG II	> 6-8	**Good**	0.6-0.8
40-60% ESG I; 40-60% ESG II	> 4-6	**Moderate**	0.4-0.6
0-40% ESG I; 60-100% ESG II	> 2-4	**Poor**	0.2-0.4
0-100% ESGII Ca 0-100% ESGII (A+B)	0 -1 > 1-2	**Bad**	0-0.1 0.1-0.2

A low value of the index shows that opportunistic species have increased as a result of excessively large amounts of nutrients in the water or may indicate the presence of a pollution sources, knowing that certain opportunistic species are not sensitive to this factor. At the same time a low biomass of perennial species may suggest that in that area some pressures as siltation, smothering etc. may exist.

The final values obtained (2011 data) for each profile are shown in the chart below (Fig. 15.)

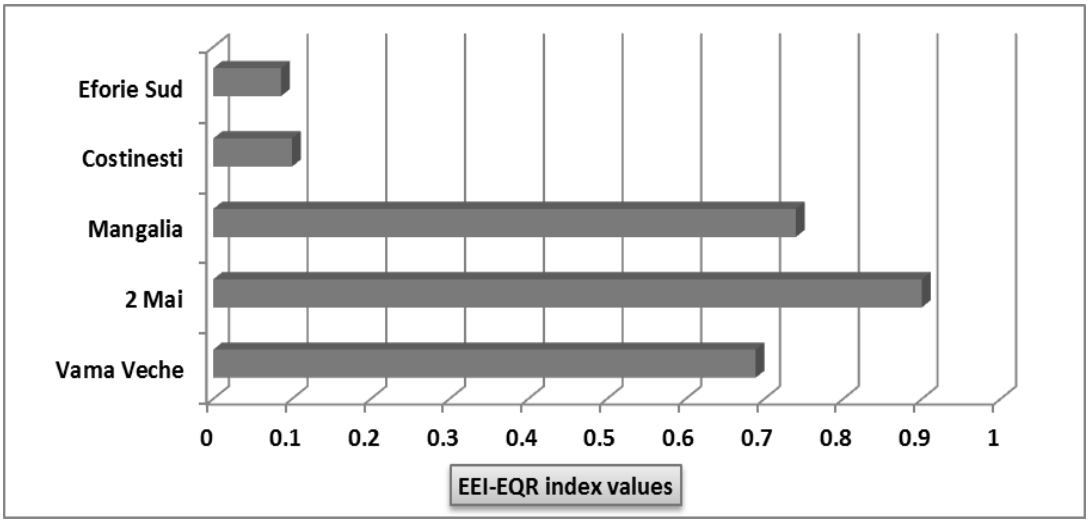

Fig. 15 - EQR-EEI index values, 2011

Under the conditions of the summer season 2011, the highest values were obtained in the southern part of the coast, along the Mangalia - Vama Veche coastal strip, due to the presence of perennial species *Cystoseira barbata* and *Zostera noltei* in appreciable quantities (Fig. 16). This high productivity due to above-mentioned key species involves a good water oxygenation, leading to the classification of the southern part of the coast in a superior ecological class. Thus, at Mangalia the index value was 0.74, considered to be *good ecological status* and at 2 Mai the highest value for EQR-EEI index was calculated - 0.9 - which leads to conclusion that this station is in a *high ecological status.* At Vama Veche, the index had also a high value - 0.68 - so here was considered to be a *good ecological status*. These aspects are supported by the fact that the area between 2 Mai and Vama Veche is declared marine reserve and therefore negatively human impact is limited, allowing the regeneration of the perennial species *Cystoseira barbata*. The biomasses developed by this species both at 2 Mai and Vama Veche were high in 2011, as shown in the previous analysis.

The absence of perennial species at Eforie South and Costineşti established that these areas are in *bad or poor ecological status*. In this area during the summer season only opportunistic species from the *Cladophora* genus have developed. At Eforie South the EQR-EEI index value was the lowest - 0,085 - here *Cladophora* (*C. laetevirens* and *C. sericea*) proliferated, the occurrence of the wastewater and increased tourist activities during the summer season had a negative impact on algal flora. At Costineşti a low value of EQR-EEI index of 0.1 - was recorded, too; in this location, the perennial species were not present and *C. vagabunda*, *C. albida*, *Ceramium virgatum*, *C. diaphanum* var. *elegans* developed abundantly.

Regarding the EI-EQR index for the 2012 data, for the southern part, Mangalia - 2 Mai - Vama Veche the values were high: 0.82 at Mangalia (*high ecological status)* and 0.62 at 2 Mai, where it is considered to be a *good ecological status* due to the presence of perennial species *Zostera* and *Cystoseira*, which provides a good water oxygenation and stabilize the substrate. For the other profiles, the index values were low, around 0.1, due to the absence of perennial species, which where not encountered there favorable development conditions (Fig. 16).

Marine waters of superior quality are specific for the Romanian southern coast, as proven by the restoration of the *Cystoseira* fields and *Zostera* meadows in those areas. Relevant in this respect are the EI-EQR index calculated values, which suggest the absence of major anthropogenic pressures with a negative impact on macroalgal development.

ex. EEI = 0.9 High Ecological Status (dominant association with perennial species)

ex. EEI = 0.1 Bad Ecological Status (dominant association with opportunistic species)

Fig. 16 - Aspects from an area with high (up) and a bad ecological status (down)

CONCLUSIONS

The analysis of the collected samples showed 33 taxa: 14 species of Chlorophyta, 4 of Phaeophyta, 12 of Rhodophyta and 3 of Tracheophyta. Comparing the current situation of the macroalage communities with that of the past decades, the most important change identified in the Romanian Black Sea waters, is the qualitative decline of the algal flora over the years. Between 2009 and 2012, the genera with highest development were *Cladophora*, *Ulva* and *Ceramium*. The key species *Cystoseira barbata* and *Zostera noltei* are in a regeneration period along the Romanian Black Sea shore. *Lomentaria clavellosa*, a rare species at the Romanian coast in the past years, was observed during the present study.

The Ecological Evaluation Index based on Ecological Quality Ratios (EEI-EQR) was applied for the biological element macrophytes, identifying the Romanian southern sector as one with superior marine water quality, sustained by the development of the *Cystoseira* field and *Zostera* meadow in those areas.

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