Long Term Quantitative Variation of the Main Opportunistic Macroalgae Species Along the Romanian Black Sea Coast *(Oana Marin)*	"Cercetări Marine" Issue no. 52 Pages 78-90	2022
DOI: 10.55268/CM.2022.52.78		

LONG TERM QUANTITATIVE VARIATION OF THE MAIN OPPORTUNISTIC MACROALGAE SPECIES ALONG THE ROMANIAN BLACK SEA COAST

Oana Marin
National Institute for Marine Research and Development "Grigore Antipa", 300 Mamaia Blvd., RO -900591, Constanta, Romania
E-mail: omarin@alpha.rmri.ro

ABSTRACT

Opportunistic macroalgae are those species with an accentuated reproductive capacity, able of generating significant algal deposits during summer season. Opportunistic species associations are an important component of the upper infralittoral rock with variable annual green and red macroalgae habitat, sub-type of the broad habitat infralittoral rock and biogenic reef. For a better overview of the evolution of these species, a long data series (2009 – 2021) was analysed. Samples were collected from depths between 0 and 8 m, along Năvodari towards Vama Veche, where opportunistic species experience an abundant development especially during summer season. In the last decade, quantitatively dominant were the green algae of the genera *Ulva* (mainly *U. rigida*, with a biomass variation between 5 and 2500 g/m^2) and *Cladophora* (mainly *C. vagabunda*, with a biomass variation between 3 and 2800 g/m^2). At Agigea, *U. rigida* recorded high biomass values (the largest *U. rigida* field can be found here, with a spatial distribution between 1 and 3 m depth), whilst Eforie proved to be more favorable for the development of *Cladophora* spp. Regarding the quantitative evolution of the opportunistic species, 4 scenarios have emerged during 2009 - 2021: during 2009 summer season, the dominant quantitative genus was *Ulva*; 2010 summer came with abnormal high water temperatures and nutrients values, extreme factors that proved favorable for the development of *Cladophora* species; starting with 2014 until 2019, the quantitative dominance returned to *Ulva* spp., but with lower biomass values compared to *Cladophora* spp. Starting with 2019, a new increase of *Cladophora* biomass was recorded.
Keywords: opportunistic macroalgae, wet biomass, annual green and red algae

AIMS AND BACKGROUND

Present paper aims to present the last decade quantitative evolution of the main opportunistic macroalgal species from the Romanian Black Sea coast. Macroalgal opportunistic species are of great interest due to their cosmopolitan character and mass development capacity, causing undesirable disturbances for the tourism sector during summer season.

In the last decade, during warm season, green algae have been quantitatively dominant along the Romanian coast. However, this is not an

unusual situation for the Romanian coast, even more, it's actually characteristic, as massive developments of some species with short vegetation period have been recorded since the 1970s. Even then, there were wet biomass estimates of over 2000 g/m^2 (Țigănuș, 1979). The current quantitative situation of opportunistic species is similar to that period.

Following the analysis of samples collected between 2009 – 2021, the quantitative dominance of opportunistic species of the genera *Ulva, Cladophora* and *Ceramium,* among the seasonal algae, was noticed. These species form the defining photophilic association *Ulva* - *Cladophora* - *Ceramium* characteristic in the last decade for the Romanian coast. This feature imprints an accentuated character of uniformity to the submerged macrophytic vegetation. These species are also the main components of macroalgal deposits formed on shore during summer season. The mass development of these species is cyclical and is considered a consequence of seasonal environmental factors, namely high-water temperature and favorable transparency degree, together with an increased amount of nutrients that stimulate their development. Benthic communities (including macroalgae), compared to planktonic ones, respond more slowly to marine environment disturbances, therefore, in order to have a proper overview of the ecological evolution of macroalgal communities, the assessment included a longer period of time. In case of these species with a fast development cycle and short vegetation period, a constant monitoring and long-term biological data sets acquisition are required for a proper evaluation and a complete image of their structural changes over time.

EXPERIMENTAL

During warm seasons 2009 – 2021, in the Romanian Black Sea coastal waters the phytobenthic communities were monitored from Năvodari towards Vama Veche (Fig. 1), where opportunistic species experience an abundant development especially during summer season. Three replicate samples were taken in each sampling point from the rocky infralittoral community, at each depth gradient (0 to 8 m), using a square frame of 20x20 cm and a scraper. The fresh biological material was further processed in the laboratory from a qualitative (macroscopic and microscopic biological identification) and quantitative (wet biomass) point of view, according to a standard methodology (Minicheva *et al.,* 2015; Berov *et al.,* 2018). A total number of 953 samples was processed during 2009 – 2021 study period. The analysed habitat was upper infralittoral rock with variable annual green and red macroalgae, sub-type of the broad habitat infralittoral rock and biogenic reef. Statistical analysis of the data was performed using PRIMER 7 (v.7.0.17) (Clarke *et al.,* 2015) and XLSTAT 2021.3.1. (Addinsoft, 2021).

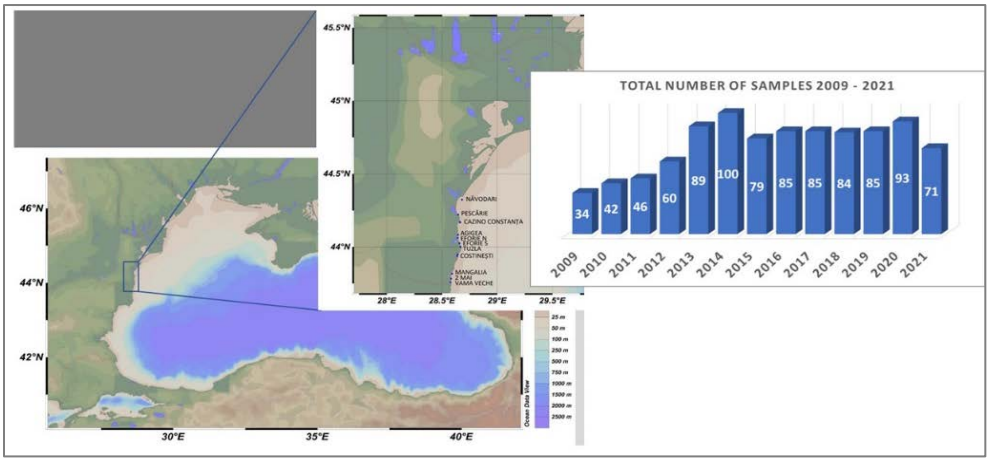


Fig. 1. Macroalgae sampling map and number of collected samples per year

RESULTS AND DISCUSSION

In coastal waters, the determining floral character of upper infralittoral rock with variable annual green and red macroalgae habitat is defined by the photophilic association *Ulva – Cladophora – Ceramium.* Based on our analysis, among these genera, the quantitative dominant species during 2009-2021 were *Ulva rigida* C. Agardh, 1823, *U. intestinalis* Linnaeus, 1753, *Cladophora vagabunda* (Linnaeus) Hoek, 1963 and *Ceramium virgatum* Roth, 1797 (shade plot based on square root transformed data) (Fig. 2).

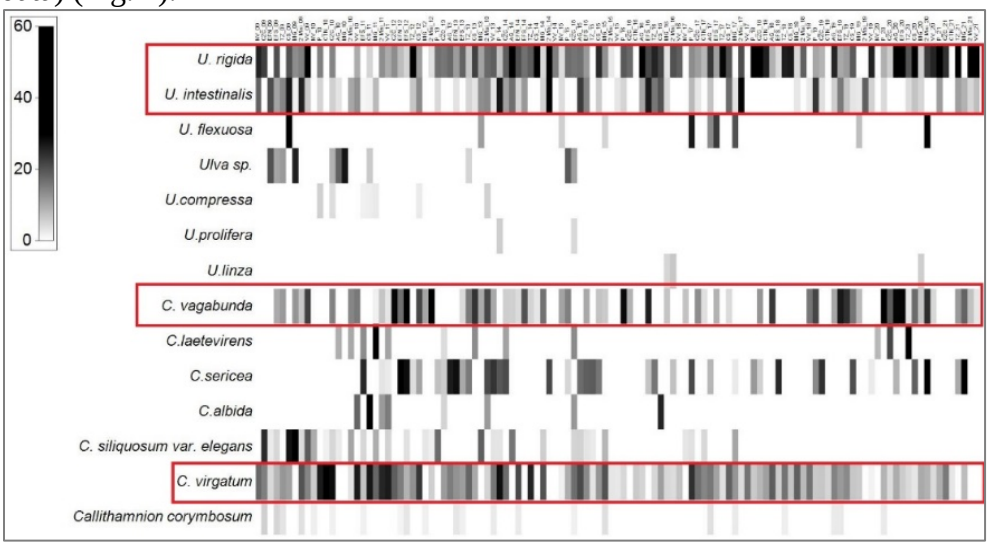


Fig. 2. Wet biomass variation of the opportunistic species during summer seasons 2009 – 2021

The presence of these 4 species is noticeable at all monitored stations, with one exception, namely Constanta North. In this area, *C. vagabunda* did not experienced the same abundant development as in other sampling areas, whilist *U. intestinalis* was absent (Fig. 3). The explanation consists in the specificity of the area. In Constanța North there is a small stone platform, interrupted by sandy areas, on which, at least for the time being, clusters of *Coccotylus brodiaei* (perennial important species with high ecological value occurring mostly in this particular area) are thriving. In Constanța North, opportunistic species experienced a more reduced development compared to other coastal areas. For the last 13 years, MDS configuration shows a 75% similarity between all 12 constantly monitored sampling stations along the Romanian Black Sea coast (square root transformed data was used for this analysis) (Fig. 3).

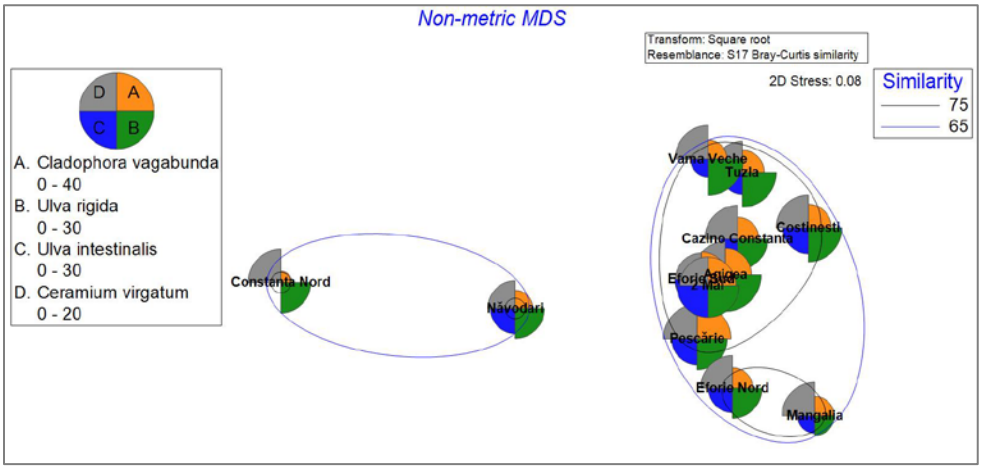


Fig. 3. Non-metric Multi-Dimensional Scaling (*n-MDS*) configuration for the main dominant opportunistic species

Excluding the dominant *U. rigida* and *U. intestinalis*, other representatives of the genus *Ulva*, like *U. flexuosa*, *U. prolifera*, *U. compressa* and *U. linza*, were also observed, though with lower biomass values and patchy distribution. For *U. rigida*, the variations were within quite wide limits, from a minimum of 5 g/m^2 to a maximum of 2510 g/m^2. The minimum value was recorded when the species became part of the epiphytic flora for the perennial species *Treptacantha barbata.* Present on both rocky natural and vegetal substrate, *U. rigida* is a constant presence along the Romanian coast during both warm and cold season. Between 2009 and 2021, *U. rigida* recorded 5 periods with a more pronounced development: 2009, 2014, 2018 and more recently, in 2020 and 2021. The absolute maximum of the study period was at Vama Veche in 2009 (2510 g/m^2), within the southern

Romanian coast characteristic association, *T. barbata - U. rigida*. High values were also observed in Agigea (2100 g/m^2 in 2014; respectively 1500 g/m^2 in 2020), Costinesti (1550 g/m^2 in 2020) and Vama Veche (1600 g/m^2 in 2021). Also, another extreme value (1700 g/m^2) was reported during summer of 2018 at Cazino Constanța. The massive development of the species at Agigea is in normal intervals, as in this area the largest field of *U. rigida* from the Romanian coast is located, within 1 to 3 meters depth.

Biomass variability degree was maintained within wide limits for *Ulva intestinalis* as well, with values ranging from a minimum of 2.5 g/m^2 up to a maximum of 890 g/m^2. Following *U. rigida*, *U. intestinalis* is the second representative of the Ulvaceae family with a constant presence during the warm season, being reported both on natural rocky substrate, as well as an epiphytic species. The maximum value was recorded at 2 Mai (890 g/m^2 in 2014), when the species experienced an intense development along with *U. rigida*. In fact, both *U. rigida* and *U. intestinalis* are commonly found in association, having similar ecological requirements, hence the intense simultaneous development. Another high value was observed in Pescărie (750 g/m^2 also in 2014). High biomass values were also reported in Eforie North (425 g/m^2) and Eforie South (700 g/m^2), as this part of the Romanian shore is dominated during summer season by the photophilic association *U. intestinalis – C. vagabunda.*

Cladophora species are known to be cosmopolitan elements, experiencing an abundant development especially during summer season. Among the representatives of the genus, *C. vagabunda* and *C. sericea* were the most thriving species of the last decade. Also is worth mentioning *C. albida* and *C. laetevirens*, spread mostly towards the southern part of the Romanian coast, although with lower biomass values and a punctiform distribution comparing to the two mentioned above species. For *C. vagabunda*, the variation of wet biomass was between a minimum of 3 g/m^2 (as an epiphytic species on *Treptacantha* thalli) and a maximum of 2800 g/m^2 (recorded in 2020, at Pescarie). Other high biomass values were reported in Eforie South (1000 g/m^2 in 2012) and 2 Mai (1600 g/m^2, also in 2012). The abundant development of these species at Eforie is not an anomaly, as the area is known to be conducive to the massive development of *Cladophora* opportunistic species, mainly as a consequence of local environmental conditions (first and foremost, an increased amount of nutrients in these areas). On the opposite side, the lowest biomass values were recorded at Constanta North, Mangalia and Vama Veche (Fig. 4).

For *C. sericea*, the variation of the wet biomass values was within wide limits, similar to other opportunistic species, between a minimum of 5 g/m^2 (in Mangalia, in 2017) and a maximum of 2200 g/m^2 (also in Mangalia, but in 2021). The species followed the same pattern of other related species,

with a more intense development during summer 2010. Other high values were reported in 2012 in Eforie South (800 g/m2) and in 2013, in Agigea (700 g/m2) and Eforie North (780 g/m^2) (Fig. 4). Starting with 2020, the slightly higher quantitative development trend, was also observed for *C. sericea.*

Among the red algae, the species of the order Ceramiales, especially those of *Ceramium* (mainly *C. virgatum* and *C. siliquosum* var. *elegans*) and *Callithamnion corymbosum*, distinguished as frequency of occurrence in samples and quantitative dominance. *C. virgatum* varied between a minimum of 3 g/m^2 (in Navodari, in 2015) and a maximum of 970 g/m^2 (in Constanța North, in 2010). The lowest wet biomass values were recorded in Eforie North - Eforie South area, the area being much more favorable to the development of *Cladophora* populations, with highly competitive substrate species compared to red algae. Other high biomass values were reported at Casino Constanța in 2010 (800 g/m^2), at Costinesti in 2011 (730 g/m^2), at Pescărie in 2014 (780 g/m^2) and at Mangalia in 2015 (730 g/m^2). Although high, these values are normal for the summer season and for the areas where they were recorded. At Cazino Constanța, the continuous stone platform and the favorable transparency allow an optimal development of *Ceramium* spp. and *Callithamnion corymbosum*. *Ceramium* spp. have an opportunistic character and the transition to an epiphytic existence (mainly on *T. barbata*) is a preference of these species. This canopy-forming brown alga, with a morphological complex thallus, provides protection against waves and currents and allows *Ceramium* specimens to increase in size and thus develop a higher biomass.

For *C. siliquosum* var. *elegans,* the annual differences in wet biomass variations were generally reduced, with one exception - an absolute maximum recorded in 2009 in Mangalia port area (1500 g/m^2). The area allowed a massive development of this small red alga, due to favorable local conditions: substrate, transparency and of course, nutrients availability. The minimum recorded value was 2.5 g/m^2 (2 Mai, summer 2012). Except for the extreme value from Mangalia port, the maximum of the period was in Costinesti, during summer 2009 (760 g/m^2). An intense development of this species was also observed in Casino Constanța (600 g/m^2), Pescărie (300 g/m^2), Agigea (250 g/m^2) and Vama Veche (360 g/m^2) (Fig. 4). Along Eforie North - Eforie South, *C. siliquosum* var. *elegans* and *C. virgatum* presented the lowest wet biomass values. In general, in recent years, *C. siliquosum* var. *elegans* thrived along Pescărie - Casino Constanța and towards the southern part of the Romanian shore, along Mangalia to Vama Veche. Due to its reduced dimensions, *Callithamnion corymbosum* did not develop noticeable biomasses during the study period, but was a constant presence at depths between 1 to 5 meters, both on natural hard substrate and as an epiphyte on

Zostera noltei and *T. barbata*

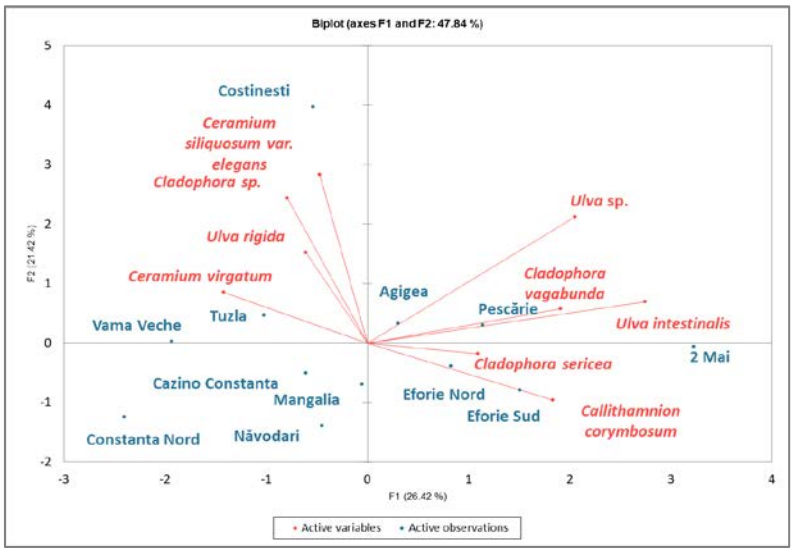


Fig. 4. Principal Component Analysis (PCA) based on quantitative distribution of dominant opportunistic species during 2009 - 2021

As a consequence of the abnormal ecological conditions recorded in July 2010, an abundant development of *Chaetomorpha aerea* (green algae of the family *Cladophoraceae*) was observed in Mangalia, inside upper-infralittoral rock dominated by *T. barbata* habitat. The species formed a dense felt above the shallow water layer, decreasing water transparency and limiting the photosynthesis process of *T. barbata*. However, the extreme phenomenon was singular, after that period it was no longer reported. The 2010 summer season was an atypical period, with negative consequences for the phytobenthic communities, and even for the entire marine ecosystem.

Analyzing the situation of the last decade and comparing the annual wet biomass values, it was observed that the quantitatively dominant species were the chlorophytes *U. rigida*, *C. vagabunda* and *C. sericea* (these species developed the highest biomasses among all opportunistic annual species) (Fig. 5). The abundant development of this limited number of species is due to their high degree of opportunism, the capacity of a development without a preference for a certain type of substrate (natural, hard anthropogenic or vegetal) and favorable conditions during the season warm. The problem is that all these species, when they develop as epiphytes, have a negative influence on the perennial key species, limiting their physiological activity.

Regarding the quantitative evolution of the opportunistic species, 4 scenarios have emerged during 2009 – 2021. During the first scenario, under development in 2009 summer season, the dominant quantitative genus was *Ulva*.

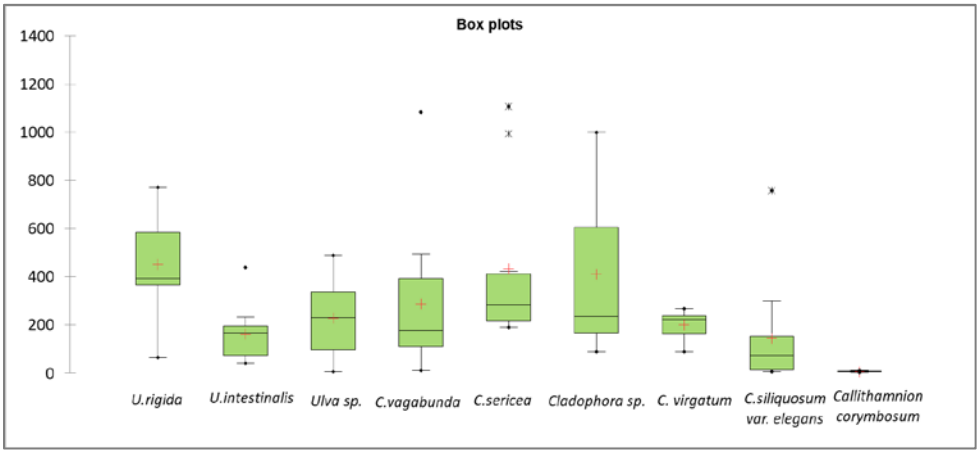


Fig. 5. Average wet biomass variation for the main dominant opportunistic species

The onset of 2010 summer season coincided with the beginning of the second scenario that lasted until 2014. 2010 came with abnormal high-water temperatures (even in September there were maximum values of 28˚C), salinity and nutrients values, extreme factors that proved favorable for the development of *Cladophora* spp., extremely resistant and competitive species. Significant algal deposits, 90% formed of *Cladophora* species, were present along the coastline during the entire summer season. In other words, from 2010 till 2013, *Cladophora* spp. experienced a much more abundant development compared to *Ulva* spp. Starting with 2014 until 2019, the quantitative dominance returned to *Ulva* spp., but with lower biomass values compared to *Cladophora* spp. Starting with 2019, a new increase in *Cladophora* wet biomass was recorded. However, biomass values as high as those developed during summer 2010, have not been reached yet.

Following the qualitative and quantitative analysis, the constancy of 14 opportunistic species (green and red algae - Fig.2) along all sampling stations, was observed. This aspect led to a similarity of 60% between the sampling stations referring to the qualitative structure and quantitative evolution of algal communities (based on square root transformed data) (Fig. 6).

Box plot analysis showed clear quantitative dominance of green algae along the sampling areas. Uncharacteristic values (outliers) were also observed, recorded mainly by chlorophytes at Pescarie, Constanta North, Agigea, Mangalia and 2 Mai (Fig. 7a). It should be mentioned, however, that these uncharacteristic values, generated by *U. rigida*, *C. sericea* and *C. vagabunda* fall within the normal limits of the quantitative variance for the opportunistic species along the Romanian Black Sea coast and do not constitute special or unique situations. For the Romanian coast, the mass

development of a limited number of opportunistic species has a seasonal cyclic character (strictly during the summer season), in accordance with the surrounding environment or seasonal changes.

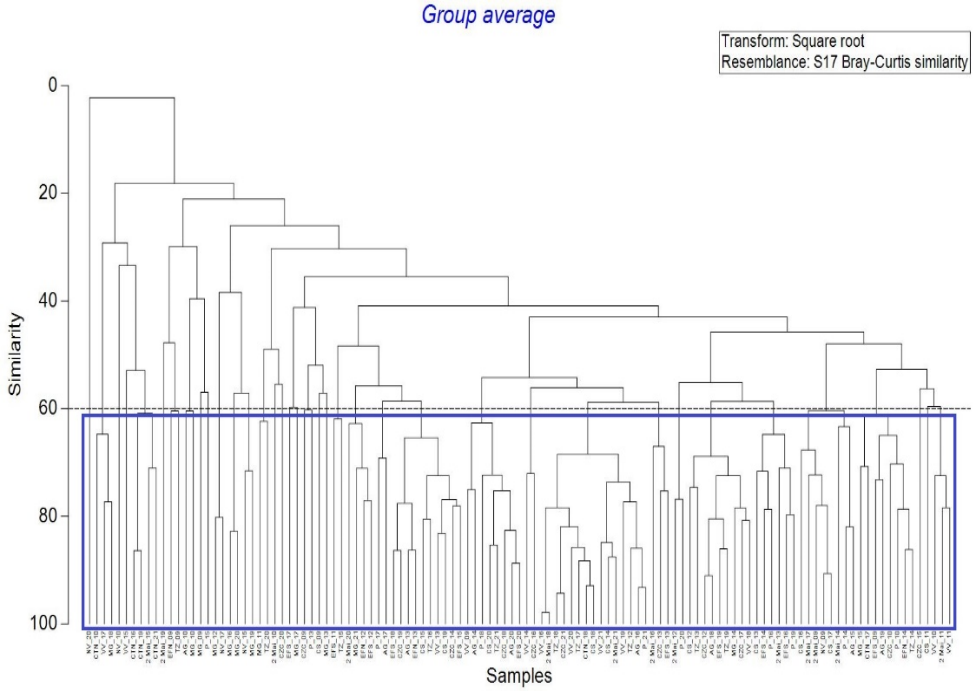
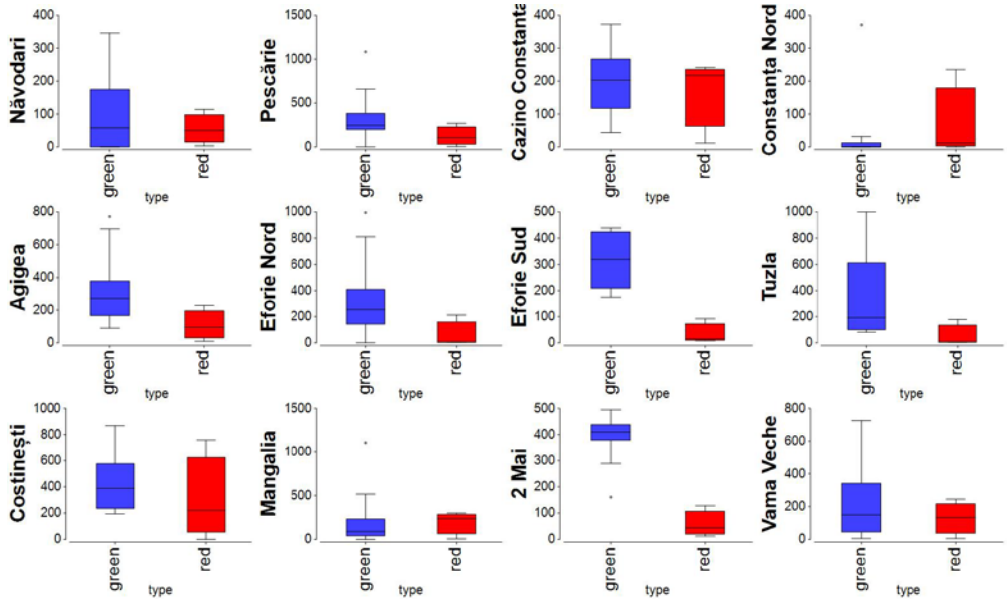


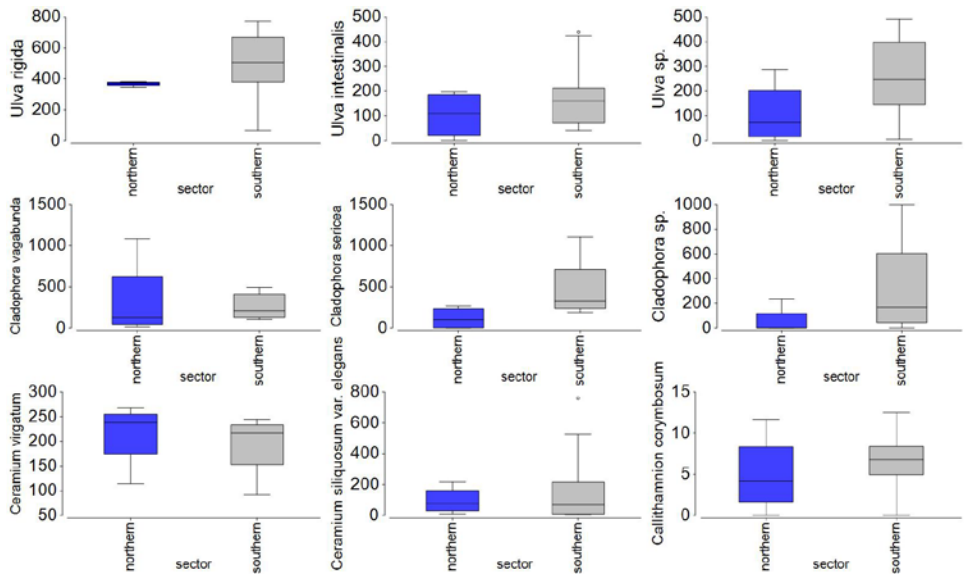
Fig. 6. Bray – Curtis similarity based on opportunistic species wet biomass variation during 2009 - 2021

Comparative analysis of northern and southern sectors showed a more abundant development of opportunistic species towards the southern sector since more favorable environmental conditions for the proliferation of algal flora are encountered in these areas compared to the northern part (Fig. 7b) So, during summer season, the southern part is characterized by well-developed turf-forming macroalgae, a mixture of filamentous and tubular species, mostly green ones.

Multivariate analysis of similarities (ANOSIM) was applied, a non-parametric test that tests the null hypothesis - no notable differences in the quantitative evolution of the dominant opportunistic species during study period and between sampling stations. The analysis rejected this theory, accepting the alternative theory instead. In conclusion, multivariate analysis of similarities (ANOSIM) based on raw 2009 – 2021 wet biomass data (square root transformed data), showed no significant differences regarding the quantitative variability of opportunistic species during the study period ($r = 0.15$) (Fig. 8a) and between sampling areas ($r = 0.095$) (Fig. 8b).



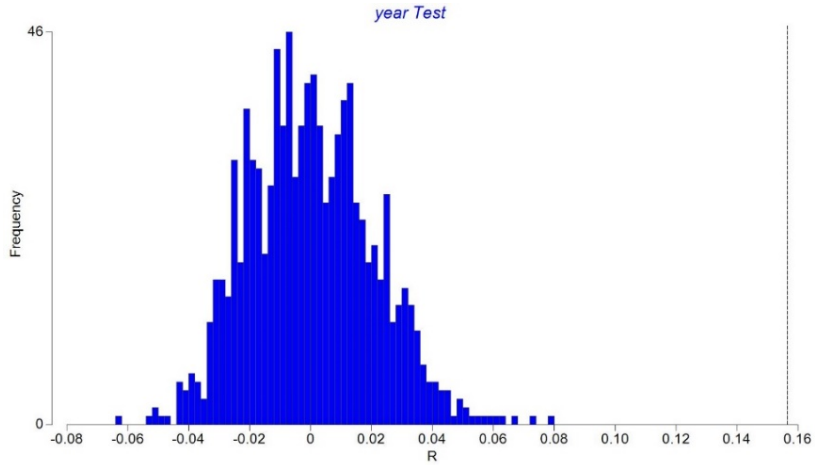
a. by sampling areas



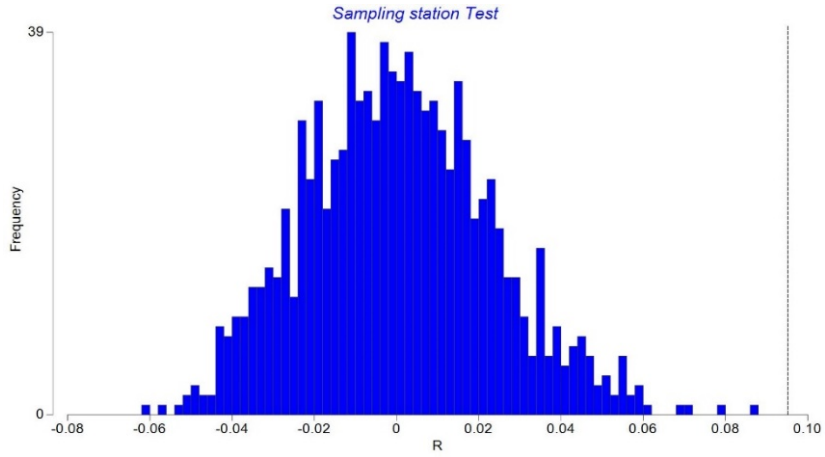
b. by sectors

Fig. 7. Quantitative variability of dominant opportunistic species by sampling areas (a) and by sectors (b)

In other words, the state of opportunistic macroalgal communities remained constant in the last 13 years, without abnormal explosive developments of some species, nor major qualitative changes in algal population structure.



a. during the study years



b. between sampling stations

Fig. 8. Multivariate analysis of similarities (ANOSIM) of wet biomass during the study years (a) and sampling stations (b)

The persistence and even the proliferation of a limited number of species along the Romanian coast (the case of *Ulva* spp., *Cladophora* spp. and *Ceramium* spp.) is due to their opportunistic character and strong resistance to adverse anthropogenic factors in comparison to sensitive

perennial species. The consequences of some unfavourable physico-chemical factors like high turbidity, nutrient enrichment on macroalgae development, will be different, in close correlation with the typology of species - opportunistic cosmopolitan species, or sensitive endangered species. These consequences may be insignificant for the opportunistic species and possibly significant for the perennial ones. In the case of opportunistic green and red algae, such as those thriving during summer season along the Romanian Black Sea coast, the regeneration process will be much faster considering their reproductive capacity and their rapid development cycle, even if there is a possibility that their physiological processes (reproduction and / or photosynthesis) may be temporary affected by natural or anthropogenic activities. Nevertheless, the consequences will have a short-term effect, so the restoration of these common species will be possible in a relatively short time, hence their mass development especially during warm season.

CONCLUSIONS

The assessment of the macroalgal communities during 2009 - 2021, based on 953 samples, led to various conclusions. Regarding the chlorophytes, the opportunistic species of *Cladophora*, *Ulva* and occasionally *Bryopsis plumosa* dominated qualitatively and quantitatively during the study period. Referring to rhodophytes, they were dominated by the opportunistic *Ceramium* spp., *Callithamnion corymbosum* and at some sampling stations, by *Carradoriella elongata* and *C. denudata.*

During the summer season, when it is considered to be the period of maximum quantitative development for the submerged vegetation along the Romanian coast, the opportunistic species of *Ulva*, *Cladophora* and *Ceramium* thrive, and became the main components of the algal deposits. The constancy of 14 opportunistic species of green and red algae was observed, which led to a similarity of 60% between sampling stations in accordance to the qualitative and quantitative structure of opportunistic algal communities.

Among these, during 2009 – 2021, Upper infralittoral rock with variable annual green and red macroalgae habitat was quantitatively dominated by two species – *U. rigida* and *C. vagabunda*. The qualitative and quantitative analysis of the collected samples from Navodari – Vama Veche highlighted that opportunistic macroalgal communities structure remained constant for the last decade, without explosive developments of some species, nor major qualitative changes.

Acknowledgement. The study has been supported by NUCLEU Program (INTELMAR), funded by the Ministry of Research, Innovation and Digitization, financing contract no. 45N/14.02.2019, project PN19260202.

REFERENCES

Addinsoft (2021), XLSTAT statistical and data analysis solution. New York, USA. https://www.xlstat.com.

Berov D., Todorov E., Marin O., Herrero S. F., (2018), Macroalgae and angiosperms ecological assessment methods in Coastal Black Sea Geographic Intercalibration Group.; EUR 20929556; Publications Office of the European Union, Luxembourg, ISBN 978-92-79-98336-8, doi:10.2760/28858, JRC114306. 38 pp.

Clarke K. R., Gorley, R. N. (2015), Getting started with PRIMER v7. PRIMER-E: Plymouth, Plymouth Marine Laboratory, 20.

Minicheva G., Afanasyev D., Kurakin A., (2015), Black Sea Monitoring Guidelines - Macrophytobenthos. 78 pp.

Țigănuș V., (1979), The associated fauna of the main macroalgae fields from the Romanian Black Sea coast. PhD Thesis. MEI, Institute of Biological Sciences. Bucharest.