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ULVA SPECIES FROM THE ROMANIAN BLACK SEA COAST – BETWEEN GREEN BLOOMS AND NATURE'S CONTRIBUTION TO PEOPLE

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ABSTRACT

Ulva species have a worldwide distribution and remarkable ability to develop under various conditions, being considered an important natural resource that is under-exploited along the Romanian Black Sea coast. These green algae, involved in green tides observed worldwide, have also a remarkable potential as prolific sources of bioactive compounds with potential health benefits and a wide range of applications in food, feed, pharmaceutical, nutraceutical, cosmetic, or biofuel industries. The study aims to analyze the quantitative variability of *Ulva* spp. during 2019 - 2023, in order to highlight the areas with algal agglomerations. These are also areas where potential algal deposits can develop during summer season. This fresh biomass can be selectively collected and valorized, thus supporting the circular economy. The sampling method was the classic one (square method/20x20 cm) from 14 stations along Pescarie towards Vama Veche, at depths between 0 to 3 m deep. Among all *Ulva* spp., *Ulva rigida* and *Ulva intestinalis* quantitatively distinguished during the study period, being also the main components of algal deposits. The highest mean wet biomasses were recorded in the southern part, as follows: *U. rigida* – a maximum value of 2200 g/m^2 at 2 Mai; *U. intestinalis* – max. value of 700 g/m^2 at Eforie South. Furthermore, a review of species' main bioactive compounds, emphasizing their potential health benefits, will also be provided.

Keywords: green algae, *Ulva* spp., biomass, valuable compounds

INTRODUCTION

"Green tides" is a phrase typically used to refer to an ecological disaster caused by the excessive proliferation, growth, and aggregation of large green algae in seawater under certain environmental conditions. Green tides events began in the 1960s and 1970s, and frequently broke out on a large scale in the coastal waters of many countries. These events have become a worldwide problem for the marine ecological environment (Cui *et al*. 2023). Green macroalgae are by far the most common macroalgae in blooms, although some are composed of red (Division Rhodophyta) and brown (Division Phaeophyta) macroalgae. Green tides involve a wide diversity of sites, macroalgal species, consequences, and possible causes (Ye *et al.,* 2010). Green filamentous macroalgae of the genus *Cladophora* grow and form green tides also, both in seas with low salinity (for example, the Baltic Sea) and in freshwaters, lakes, and rivers. Along with *Ulva*, the bloom of natural waters caused by *Cladophora* has acquired a global character (Gladyshev and Gubelit, 2019).

The formation of blooms of filamentous and/or thin foliose macroalgae are frequently a consequence of coastal eutrophication. Macroalgae with these morphologies have a high surface area to volume ratio that enables them to rapidly uptake nutrients for greatly increased growth, if favorable bathymetric, temperature, and light conditions exist. Also, these blooms interfere with coastal commercial and recreational activities. Bloom-forming macroalgal species can be found within the phyla Chlorophyta, Heterokontophyta, and Rhodophyta, but most macroalgal blooms, including the largest ever recorded, are caused by Chlorophyta species, such as those within the genus *Ulva* Linnaeus (Guidone and Thornber, 2013). *Ulva* sp. is one of the most cosmopolitan algae, adapted to high and low temperatures, and as an *''r selected''* species is also opportunistic, creating ''green waves" in some parts of the world. Light, temperature, salinity, nutrients, oxygen, and microbiomes have a big influence on their reproduction, growth, and density in the ecosystems (Costa *et al.,* 2024).

Ulva blooms damage marine ecosystems and impair local tourism. According to Dominguez and Loret (2019), the first *Ulva* bloom to be described was in Belfast (in the north of Ireland) at the end of the nineteenth century. *Ulva* blooms were well-studied in the Laguna of Venice from 1930, with an unexplained decrease observed after 1990. Since 1980, *Ulva* blooms have been observed worldwide, from Galicia to Tokyo Bay, including the American and Australian continents. However, the largest events in the world to date have been the green tides observed in the Yellow Sea for ten consecutive years from 2007 and covering 10% of the Yellow Sea. In Europe, Brittany's north coasts have the biggest *Ulva* blooms (Dominguez and Loret, 2019).

Although "Green tides" is not a suitable term to describe the situation of algae along the Romanian Black Sea coast, the implications being much wider, there are these seasonal, cyclical ''Green blooms'' that describe much better these phenomena that occur mainly during the summer season. The development of green algae of such magnitude as those described worldwide have not been reported for the Romanian coast of the Black Sea until present. However, seasonal episodes of abundant development, with formations of algal deposits, occur periodically during the summer season. Although they do not consist exclusively of *Ulva* spp. (*Cladphora* species are also to be found), *Ulva* remains principal components of algal deposits.

The most common *Ulva* species that can be found throughout the year along the Romanian Black Sea coast are *Ulva rigida, U. intestinalis, U. flexuosa, U. linza, U. compressa, U. prolifera*. Among these, *Ulva rigida* and *U. intestinalis* quantitatively distinguished during 2019 - 2023. It is well known that sea lettuce (*Ulva* spp.), with its worldwide distribution and remarkable ability to grow rapidly under various conditions, are among the main opportunistic macroalgae responsible for the occurrence of macroalgal blooms in coastal waters. Considering that marine macroalgae can supply feedstock for biorefineries for the production of food ingredients, chemicals, fuels, pharmaceuticals and more, utilizing abundant marine resources for the benefit of the bioeconomy of the future (Zollmann *et al.*, 2023), this fresh biomass can be selectively collected and valorized, thus supporting the circular economy at national level. Several studies have demonstrated *Ulva's* bioactive compounds and their antioxidant effect on several health parameters, since *Ulva* species are a promising and versatile reservoir of bioactive ingredients, potentially revolutionizing various industries such as food, pharmaceuticals, and cosmetics (Putra *et al*., 2024; Wosnitza and Barrantes, 2006).

Considering the mentioned above, the study aims to characterize the spatial distribution of *Ulva* spp. and to analyze the quantitative variability of these species during 2019 - 2023, in order to highlight the areas with algal agglomerations. The present work will provide a baseline study by presenting the specific qualitatively and quantitatively situation of *Ulva* spp. in the last years along the Romanian Black Sea coast.

MATERIALS AND METHODS

Summer season is considered to be the most suitable for bio assessment of green algae. Accordingly, field surveys were conducted between July – early September, coinciding with the maximum macroalgae biomass along the Romanian Black Sea coast. A total number of 419 samples were collected from 14 stations along Pescarie towards Vama Veche (Fig. 1). Green, red and brown algae were also identified in these samples, but only *Ulva* spp. were considered for this study. Jupiter, Saturn, Mangalia_1, 2 Mai_1, Vama Veche_1 represent areas where sampling was performed inside *Gongolaria barbata* canopies, as the main habitat-forming species from the Romanian coast.

The sampling method was the classic one (square frame method, 20x20 cm), at depths between 0 to 3 m, rocky substrate, upper infralittoral zone. At each sampling point, all macroalgae (including the basal part), were collected within 3 replicates quadrats per depth range. Once in the laboratory, algal biomass was rinsed with freshwater to remove sediments, debris, and other organisms. Following the taxonomic identification, the biomasses were weighted, after removing excess water, in order to obtain the wet biomass for each morphology.

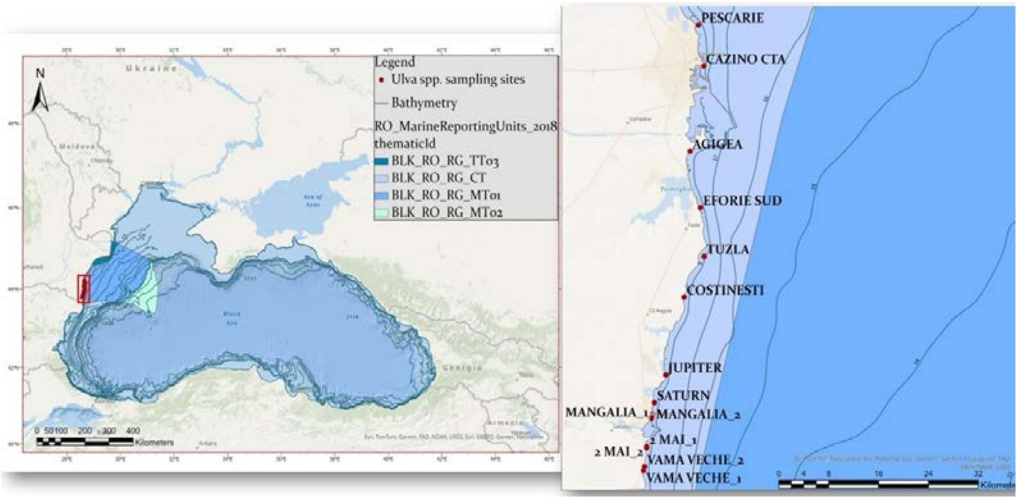

Fig. 1. *Ulva* spp. sampling sites along the Romanian Black Sea coast

Statistical analysis of data was performed using PRIMER 7 (v.7.0.23) (Clarke and Warwick, 2001) and XLSTAT 2023.1.6. (Lumivero, 2024). Normal distribution and homogeneity of variances were established before each statistical analysis using Shapiro-Wilk Normality Test and One-sample variance test/Two-tailed test. Since normality and homogeneity criteria were not met, the non–parametric Kruskal–Wallis (two-tailed test) was selected and applied to wet biomass data. The significance level was set at $p < 0.05$, with higher achieved significance levels ($p < 0.01$ and $p < 0.001$) presented separately. Mean biomass variation among different areas and time periods was displayed using ''Matrix display'' task in PRIMER software.

RESULTS AND DISCUSSION

During the study period, the quantitative analysis was performed on the basis of the two quantitatively dominant species, respectively *U. rigida* and *U. intestinalis,* since these, among all *Ulva* species, were the ones that developed the most, forming abundant populations in shallow waters. Throughout our surveys, *U. rigida* and *U. intestinalis* were nearly always the main components of *Ulva* mats from shore. The macroalgal growth and biomass are directly controlled by nutrient availability in most temperate coastal waters (Kokabi *et al.* 2016). Out of the two species, *U. rigida* was the one forming the highest wet biomasses. Similar situation was also reported in other seas (Chávez-Sánchez *et al.,* 2017).

For *U. rigida*, Shapiro-Wilk's test showed that wet biomass values significantly deviate from a normal distribution during the study period (W = 0.749, $p = 0.0001$, $p < 0.05$). One-sample variance test, used to assess homogeneity of variances for biomass, showed that data differed markedly among the study periods (Chi-square = 442.326, $p = 0.0001$, $p < 0.05$). Therefore, Kruskal-Wallis combined with a multiple pairwise comparisons (Dunn's post-hoc test), was applied to test if there were any differences regarding the biomass evolution during 2009 - 2023 along the Romanian coast. Non-parametric Kruskal-Wallis's test showed statistically significant differences between study years ($p = 0.0001$, $p < 0.05$), as seen in Figure 2. At the same time, non-parametric Kruskal-Wallis's test showed that there were no significant differences between 2019 and 2023 regarding biomass values ($p > 0.05$) (Fig. 2); Bonferroni corrected significance level: 0.005.

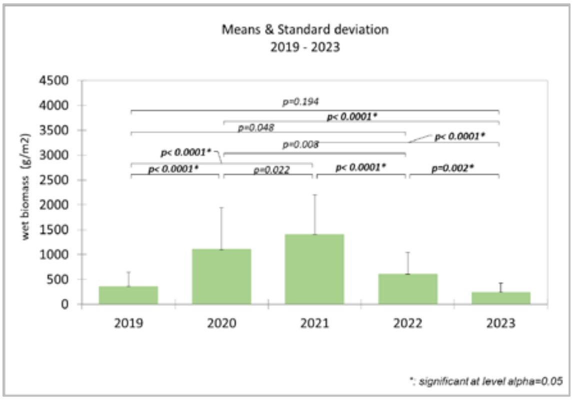

Fig. 2. Kruskal-Wallis test with Dunn's post-hoc test showing significance of differences between groups (*U. rigida*)

U. rigida responds quickly to the variability of environmental factors, hence this different evolution of wet biomass during the study period. Although the species developed high biomasses every year, the highest values were recorded in 2021 (maximum of 3800 g/m^2 in Vama Veche) and 2020 (a maximum observation of 3300 g/m^2 in Eforie South). Starting with 2022, a decrease in biomass values, compared to previous years, was noticed (Fig. 3). As stated by Guidone and Thornber (2013), these spatial and temporal fluctuations indicate that even between eutrophic sites within close proximity, small abiotic or biotic differences, or stochasticity, may lead to markedly different *Ulva* biomass evolution. It is also known that changes in biomass could be attributed to seasonal changes, mainly in temperature, light intensity, water movement, and nutrients. When these variables are appropriate, the release of propagules takes place; when propagules settlement occurs, they give rise to macroalgal blooms (Chávez-Sánchez *et al*., 2018). For example, *Ulva* biomass is known to show a direct link with nitrogen concentrations (Keesing *et. al.,* 2016).

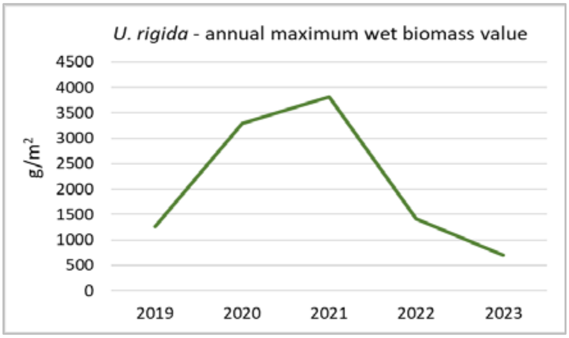

Fig. 3. *U. rigida* - maximum wet biomass value (g/m^2) recorded each year

The photophilic association *Ulva - Cladophora* is characteristic for the warm season, and the main dominant species such as *U. rigida, U. intestinalis, Cladophora vagabunda* are extremely competitive, able to occupy the same ecological niche. Sometimes, under the influence of different ecological factors (e.g., temperature, amount of nutrients) one species can develop more abundantly at the expense of another. This is the case of *Cladophora* species that sometimes, compared to *Ulva* spp., thrive on hard substrate in shallow waters.

The areas where *U. rigida* developed the highest biomasses in the upper infralittoral were those from the southern part of the Black Sea coast, namely Agigea, Eforie South, Tuzla, Costinesti, 2 Mai and Vama Veche (Fig. 4). The areas where sampling was performed inside *G. barbata* canopies - Jupiter, Saturn, Mangalia_1, 2 Mai_1, Vama Veche_1 - are the areas where *U. rigida* developed the lowest biomasses. In these areas, *U. rigida* is an associated species of the key-habitat brown alga *G. barbata*.

The most extensive *Ulva* populations (mainly formed by *U. rigida* in association with *U. intestinalis*) were found in the southern part of the Romanian Black Sea coast: Agigea, Eforie South, Tuzla, Costinesti. The highest mean biomass values (as an average value between 0 to 3 m deep) were recorded at 2 Mai, with a maximum observation of 2200 g/m^2 (in 2021). High values were also reported in Eforie South - maximum observation of 1900 g/m^2 (in 2020), Agigea and Costinesti, with a maximum value of approx. 1500 g/m^2 (also during summer of 2020).

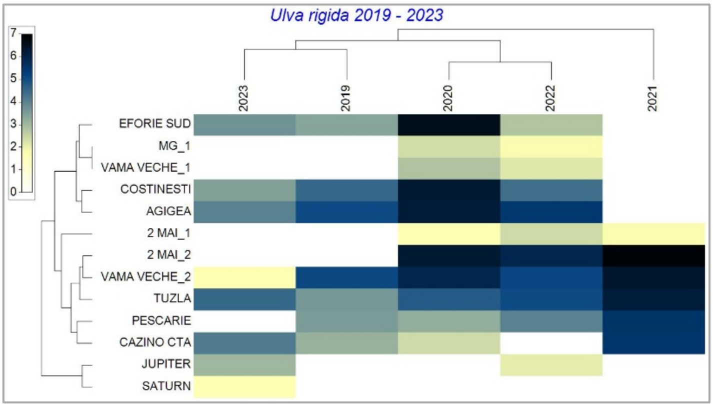

Fig. 4. Wet biomass variation along the sampling sites. Data are expressed as fourth root-transformed mean values for 0 – 3 m depth. The intensity of scale color is proportional to the biomass (expressed as g/m^2, wet biomass). White indicate species' absence and lightly colored areas indicate low biomass values at that site

Large expanse of hard substrate on the southern coast of the Black Sea available for algal attachment, also contributes to the optimal development of *Ulva* species in these areas. To check whether there are differences regarding the biomass values between these areas, Kruskal-Wallis combined with a multiple pairwise comparisons (Dunn's post-hoc test) was applied on raw data. Statistical assessment showed significant differences (p = 0.0001, p < 0.05) (Fig. 5); Bonferroni corrected significance level: 0.0033.

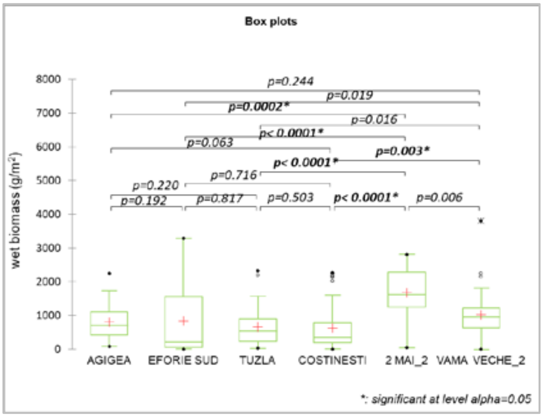

Fig. 5. Kruskal-Wallis test with Dunn's post-hoc test showing significance of differences between groups (*U. rigida*)

Among these stations, the extreme southern part (2 Mai towards Vama Veche) was significantly different during 2019 – 2023, as represented in Figure 6. In these stations, the species developed the highest biomasses during 2019-2022, decreasing, however, in summer 2023. Overall, *Ulva*'s biomass varied significantly amongst sites and as mentioned above, the coastal area Agigea – Costinesti represents the area where *U. rigida's* populations are most developed. Consequently, algal deposits are common during summer in these bloom impacted sites, since it is well known that temperature has a strong influence on *Ulva* germination and vegetative growth (Keesing *et. al.,* 2016).

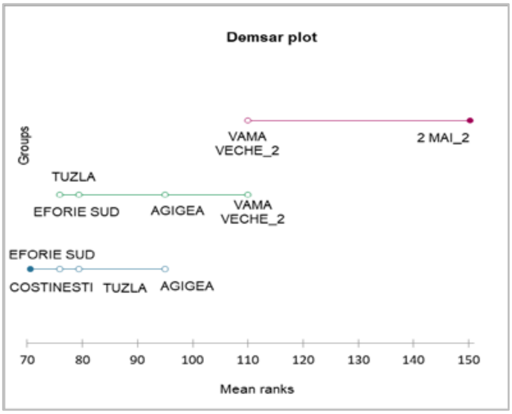

Fig. 6. Demsar significance diagram for *U. rigida* quantitatively dominant Stations between 2019 – 2023

For *U. intestinalis*, Shapiro-Wilk's test showed that wet biomass values significantly deviate from a normal distribution during the study period (W = 0.293, p = 0.0001, $p < 0.05$). One-sample variance test showed that data differed markedly among the study periods (Chi-square = 432.687, p = 0.0001, $p < 0.05$). Considering these, Kruskal-Wallis combined with a multiple pairwise comparisons (Dunn's post-hoc test), was applied to test if there were any differences regarding the biomass evolution during 2019-2023 along the Romanian coast. Non-parametric Kruskal-Wallis's test showed statistically significant differences between study years (p = 0.0002, $p < 0.05$), as seen in Figure 7; Bonferroni corrected significance level: 0.005. Similar to *U. rigida*, there were no statistically significant differences between 2019 and 2023 regarding biomass values.

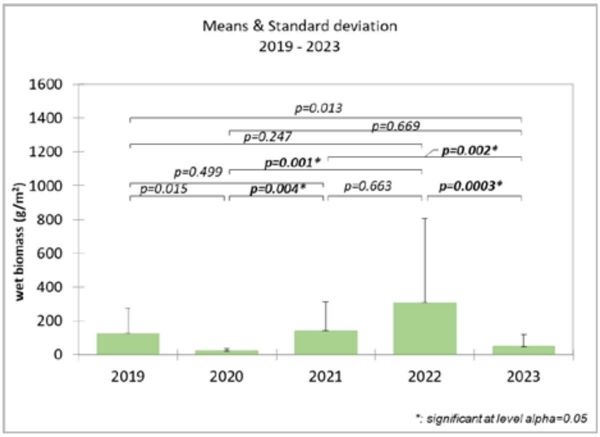

Fig. 7. Kruskal-Wallis test with Dunn's post-hoc test showing significance of differences between groups (*U. intestinalis*)

For the Romanian coast, the biomasses developed by *U. intestinalis* are lower compared to those of *U. rigida*. For *U. intestinalis,* the highest values were recorded in 2022 (1700 g/m^2), and the lowest in 2020 (50 g/m^2). Also, for this species, similar to *U. rigida*, the downward trend in biomass values was observed in 2023, compared to previous years (Fig. 8).

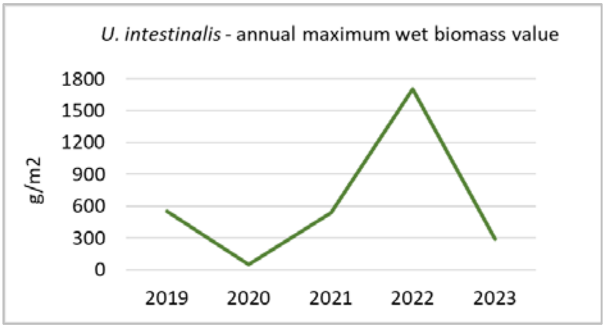

Fig. 8. *U. intestinalis* - maximum wet biomass value recorded each year

The quantitative variability of *Ulva* species has multiple causes, such as nutrient variations, nitrogen-phosphorus ratio, seawater temperature fluctuations, phytoplankton blooms. In summer of 2023, along the Romanian coast, an upwelling phenomenon occurred, which led to a drastic decrease of sea water temperature, with possible influences on the development cycle of the *Ulva* species, hence the slightly lower biomasses compared to previous years. Pescarie, Eforie South, Tuzla, 2 Mai_2 were the areas where *U. intestinalis* developed high biomasses during our study (Fig. 9). At Jupiter, Saturn, Mangalia_1, Vama Veche_1, the species was the main epiphyte of *G. barbata.*

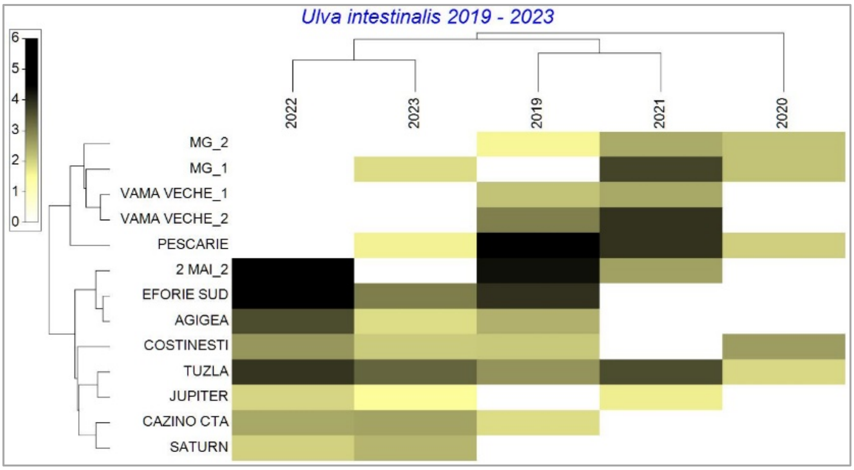

Fig. 9. Wet biomass variation along the sampling sites. Data are expressed as fourth root-transformed mean values for 0 – 3 m depth. The intensity of scale color is proportional to the biomass (expressed as g/m^2, wet biomass). White indicate species' absence and lightly colored areas indicate low biomass values at that site

The highest mean biomass values (as an average value between 0 to 3 m deep) were recorded at Eforie South, with a maximum observation of 715 g/m^2 (in 2022), and 2 Mai, with a maximum observation of 640 g/m^2 (also in 2022). At Pescarie, well developed populations of *U. intestinalis*, sometimes in association with *U. rigida*, thrive in extremely shallow waters. Therefore, in this area the biomass produced by *U. intestinalis* was high, with a maximum value of 550 g/m^2 recorded in 2019.

As in the case of *U. rigida*, the differences regarding the biomass values among sampling sites were also checked. In this case, Kruskal-Wallis combined with multiple pairwise comparisons (Dunn's post-hoc test) were applied on raw data. Statistical assessment showed significant differences (p = 0.012, $p < 0.05$) (Fig. 10); Bonferroni corrected significance level: 0.0083.

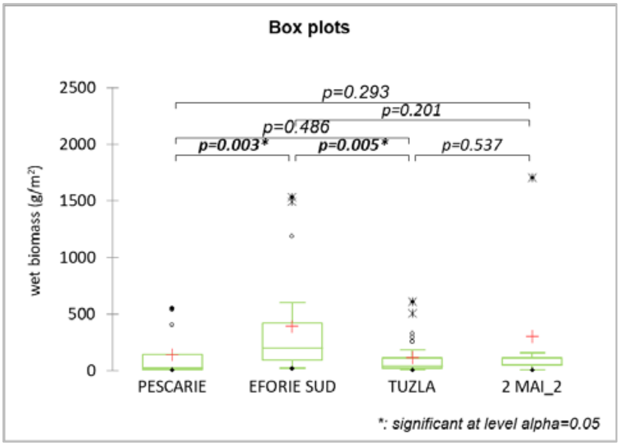

Fig. 10. Kruskal-Wallis test with Dunn's post-hoc test showing significance of differences between groups (*U. intestinalis*)

Among these stations, Eforie South and 2 Mai_2 were significantly different during 2019 – 2023, as represented in Figure 11. In these areas, *U. intestinalis* developed the highest biomass during the study.

Out of the two quantitative dominant species (namely *U. rigida* and *U. intestinalis*), the presence of other two *Ulva* tubes was also noticed: *U. flexuosa* and *U. linza.* Although they are common species, usually found in association with *U. rigida* and *U. intestinalis*, they rarely develop extremely high biomasses or form monospecific algal deposits.

For *U. flexuosa,* formation of dense mats depends heavily on changes in water temperature and oxygenation. Water movement and fluctuations in water level are physical processes which have an impact on the growth of thalli and the development of macroalgal blooms (Rybak and Gąbka, 2018). The least abundant species was *U. linza*, whose presence was sporadic with no obvious pattern, suggesting that this species was displaced by the abundance of the other dominant species or because of some environmental factors, as stated by Chávez-Sánchez and colab. (2017) in a similar study conducted for a subtropical bay of the Gulf of California.

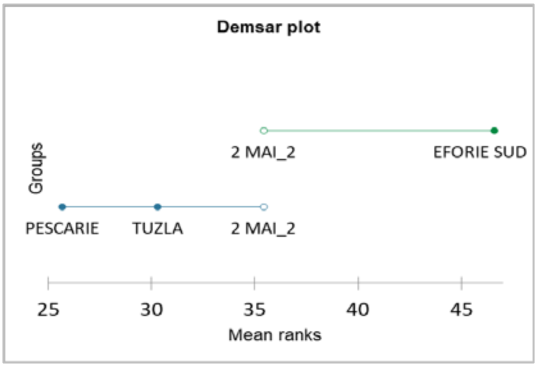

Fig. 11. Demsar significance diagram for *U. intestinalis* quantitatively dominant stations between 2019 – 2023

Regarding the biomass evolution of these two tubular *Ulva* species, *U. flexuosa* developed high biomasses only locally, in the southern part of the Romanian coast. For example, in Mangalia, during summer of 2019, the species recorded a mean biomass value of approx. 100 g/m^2. As an exception, at 2 Mai, *U. flexuosa* presented a seasonal bloom during summer of 2020, developing high biomass values of almost 4000 g/m^2. This abundant development was strictly local and was not later noticed during our study. In the case of *U. linza*, the wet biomass was much lower, with a notable development only in Mangalia, in 2020 (< 100 g/m^2) (Fig. 12). Looking at the overall succession of *U. rigida, U. intestinalis, U. flexuosa,* and *U. linza* along the Romanian Black Sea coast, our results indicate that there were zones where species grew together, but there were also zones where a clear predominance of some of these species could be observed. *Ulva* blooms along the Romanian coast are mainly multi-species, with *U. rigida* displaying the highest presence, cover and recruitment, followed by *U. intestinalis.* Throughout the study period, regarding the quantitative evolution, similar patterns amongst *Ulva* blades and *Ulva* tubes were observed, as these species have similar ecological requirements. By virtue of their simple morphology and broad physiological tolerances, these macroalgal species are able to utilize these elevated nutrient levels and out-compete other seaweeds as well as seagrasses. The rapid and extensive growth of *Ulva* spp. can therefore be commonly used as an indicator of nutrient enrichment and eutrophication of shallow-water systems (Romano *et al.,* 2003).

Although sometimes *Ulva* spp. can be problematic for touristic activities, recent research has shown multiple benefits of these species. *Ulva* contains commercially valuable components susceptible of being exploited for cosmetic, pharmaceutical, chemical, food and energy applications. The biomass due to this alga collected on beaches every year is beginning to be valorized to produce valuable compounds. However, attempts to valorize *Ulva* collected on beaches lead to different problems, such as contamination with sands and pollutants from different origins. In this regard, the valorization of *Ulva* wastes will remain difficult for sensitive domains such as pharmaceutical drugs, cosmetics or food, due to contaminants that have to be eliminated (Dominguez and Loret, 2019).

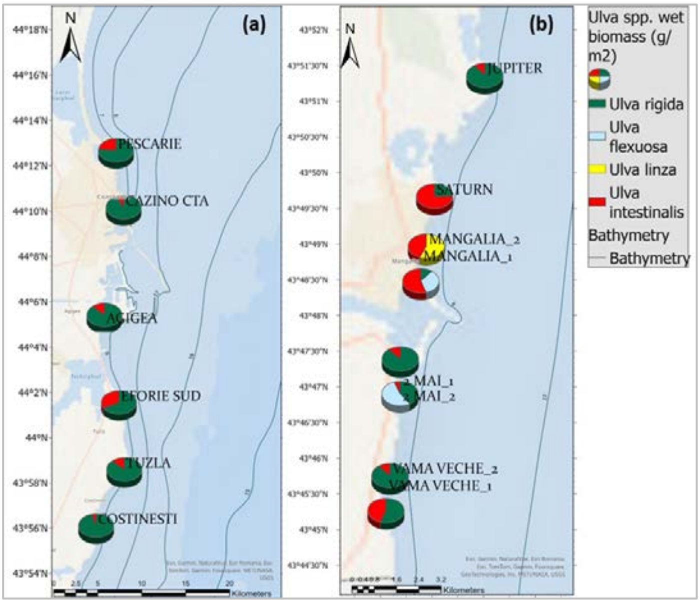

Fig. 12. Wet biomass proportion in shallow waters for *Ulva* species between 2019 – 2023 at each sampling site: Pescarie – Costinesti (a) and Jupiter – Vama Veche (b)

Natural harvest involves the collection of wild-grown sea lettuce from coastal areas, such as shorelines, but it depends on seasonality (Putra *et al*., 2024) along the Romanian coast. It is important, however, to verify that the concentrations of heavy metals, pesticides and polycyclic aromatic hydrocarbon are under regulation limits (Dominguez and Loret, 2019) before the biomass is used. Cuomo and colab. (1995) proposed biotransformation into compost as a feasible technology for utilizing large quantities of *Ulva* biomass. Biotransformation into compost (aerobic fermentation) appears to be the simplest biotechnology and probably the most appropriate, from an economic point of view, for supporting a large-scale *Ulva* biomass harvesting biomass. The principal objective of the composting process is the aerobic treatment of biodegradable organic waste in order to obtain humified organic matter for agricultural purposes. Experiments on composting *Ulva* biomass have been carried out in Brittany (France) and in Venice (Italy). Utilization of compost in agricultural soil is an excellent disposal method and also provides an organic substrate for microbial flora. However, the heavy metals content could be a limiting factor and also plant tolerance and phytotoxicity should be tested (Cuomo *et al.,* 1995). Later on, Wosnitza and Barrantes (2005) proposed *Ulva* composts to be used as soil conditioner for field cultures, especially for soils with lack of micronutrient iron (Wosnitza and Barrantes, 2006).

Ulva spp. contains several bioactive compounds. These compounds encompass a spectrum of polysaccharides, phenolic compounds, fatty acids, pigments, minerals, and vitamins, collectively contributing to their nutritional and therapeutic potential (Putra *et al*., 2024)

Ulva has water-soluble and insoluble cellulose (38–52%) corresponding to structural polysaccharides with a major component called ulvan. This polysaccharide and its oligosaccharides have anti-viral, anti-tumour, anti-coagulant, anti-lipidique, hepato protective, immuno-stimulating, anti-depressant and anti-anxiolytic activities, and are increasingly requested for pharmaceutical and food applications (Dominguez and Loret, 2019; Costa *et al.,* 2024). Polysaccharides from *Ulva* possess antioxidant properties, helping to scavenge free radicals and protect cells from oxidative damage. It also displays anti-inflammatory effects by modulating inflammatory responses in the body. Moreover, these polysaccharides have been shown to have anticoagulant properties, making them potential candidates for applications in cardiovascular health and thrombosis prevention (Putra *et al*., 2024). In addition, ulvans are thermos reversible gels, with industrial applications in chemical, pharmaceutical, biomedical and agricultural areas. *Ulva* can be a source of essential amino acids, some of them, such as histidine, are found in levels comparable to those found in legumes and eggs (Dominguez and Loret, 2019). *Ulva*'s protein contains large levels of essential amino acids, making it a potentially valuable dietary protein source. Indeed, there is remarkable resemblance in the overall amino acid content of the alga and that of egg ovalbumin, such as histidine Costa *et al.,* 2024).

Ulva contains various fatty acids, contributing to its nutritional value and potential health benefits. Fatty acids are essential components of lipids and play important roles in human health and metabolism. The specific composition and concentrations of fatty acids in *Ulva* can vary depending on species, geographical location, and environmental conditions (Putra *et al*., 2024).

Ulva spp. have been reported to contain various carotenes, including 9-cis-β-carotene, all-trans-β-carotene, α-carotene, and other carotene isomers. Additionally, reported xanthophylls include lutein, violaxanthin, antheraxanthin, zeaxanthin, neoxanthin, and β-cryptoxanthin. In terms of commercial production, carotenoids are widely recognized for their antioxidative properties, which play a crucial role in counteracting the detrimental effects of free radicals, thereby mitigating oxidative stress and safeguarding cellular and tissue integrity. For that, they have an important role as food additives, animal feed, colorants, medications, and nutraceuticals. Beta-carotene is a precursor to vitamin A and is pivotal in preserving optimal vision and reinforcing the immune system. Lutein and zeaxanthin have a crucial role in sustaining optimal eye health by accumulating within the retina and offering protection against age-related macular degeneration and various other vision-related disorders. Bromophenols and flavonoids of green seaweeds have antioxidant activities. They have already been tested and proven in different species, such as *Ulva compressa, U. intestinalis, U. linza, U. pertusa, Capsosiphon fulvescens,* and *Chaetomorpha moniligera* (Costa *et al.,* 2024).

Ulva from green blooms could be used for a phytoremediation process of coastal water contaminated with bisphenol A. Agricultural utilization of *Ulva* extracts was reported to enhance the vegetative growth in bean plants under drought stress, limiting the lipid peroxidation, increasing the phenolic content and probably contributing to the enhancement of the antioxidant enzymatic activity. Also, the valorization of *Ulva* biomass to produce biofuels is attracting attention regarding three aspects:

bioremediation for the ecosystem, a renewable energy source and economic savings. *Ulva* blooms represent a non-competitive green source for production of biofuels and other commodity materials. Abundant recent studies have confirmed the potential of *Ulva* for biorefinery (Dominguez and Loret, 2019).

Some researchers observed that algae and marine plants have been estimated to be accountable for over 70% of the world's carbon storage. They were able to demonstrate that *Ulva* species had the greatest carbon capture capacity compared to algae belonging to the Chlorophyta, Phaeophyceae, and Rhodophyta. *Ulva* spp.s' quick development is related to its strong photosynthetic rates and high absorption capacity of carbon and nitrogen/nitrogen nutrients required for growth. There are several pathways and industries that can benefit from *Ulva* sp. biomass to promote the circular bioeconomy (Costa *et al.,* 2024).

CONCLUSIONS

During 2019 – 2023, the main components of algal deposits along the Romanian Black Sea coast were mainly formed by the green algae *Ulva* spp. and *Cladophora* spp. Amongst *Ulva* spp., *U. rigida* displayed the highest presence, cover and recruitment, followed by *U. intestinalis*, with the highest biomasses developed towards the southern part of the Romanian coast. As stated by Dominguez and Loret (2019), *Ulva* blooms will remain a source of troubles that could grow with increased global warming, and the Romanian Black Sea coast will not be an exception. However, it is in our power to valorize this algal mass from the beach for the benefit of society.

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