FIRST RECORD OF THE ALIEN MACROALGAE, *RIVULARIA ATRA* AND *POLYSIPHONIA OPACA*, ON THE LIBYAN COASTLINE WITH SPECIAL REFERENCE TO THEIR BIONOMICS

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Abstract. This investigation documents the presence of the alien macroalgal species *Rivularia atra* Roth ex Bornet & Flahault (Rivulariaceae: Nostocales) and *Polysiphonia opaca* (C. Agardh) Moris & De Notaris (Rhodomelaceae: Ceramiales) for the first time on the Libyan coastline. Of 7 investigated sites along Al-Jabel Al-Akhdar coastline during summer 2013 and winter 2014, three sites were invaded by *R. atra* and one site by *P. opaca*. The percent cover and relative frequency – as measures of abundance -of *R. atra* (15-24% and 40-70% respectively) were higher than those of *P. opaca* (8% and 17 % respectively). The investigation revealed that *R. atra* and *P. opaca* inhabited not only the rocky substrates but also the limpet *Patella caerulea* and that the two species do not thrive in polluted habitats. Statistical analysis showed a highly significant effect of season, site and their interaction on the physico-chemical characteristics of water. The results concluded that the nature of substrate as well as the extent of pollution may be major modifiers of algal distribution, since the non-polluted bare rocky shore was the favorite habitat for the alien species *R. atra* and *P. opaca*. Therefore, these species are promising indicators for water quality.
Keywords: *alien species, Libyan coast, Limpet, Polysiphonia opaca, Rivularia atra.*

Introduction

The spread and colonization of alien species in new locations outside their native range is called biological invasion (Elton, 1958). Recently, this phenomenon has become increasing worldwide because of globalization of trade and travel, colonization and human exploration (Keller et al., 2011). Marine alien species are considered one of the major drivers of biodiversity change as a result of the global change in marine ecosystems (Keller et al., 2011). Alien species cause alterations in ecosystem functioning, with serious economic impacts (Pimentel et al., 2000). Alien macroalgae have a competitive advantage over native macroalgae due to their fast growth, which enables them to outgrow other animals or native macroalgae. Furthermore, they are able to reduce the species number, percent cover and diversity of the local macroalgal community (Piazzi et al., 2003). They can exhibit aggressive invasive behavior and significant ecological pressure on marine communities (Sala et al., 2011). For example, the alga *Caulerpa racemosa* var. *cylindracea* invaded the seagrass *Posidonia oceanica* meadows along much of the Mediterranean coastline (Montefalcone et al., 2010).

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Polysiphonia funebris and *P. subulifera* have been recorded as alien species in Morraco coast (Hassoun et al., 2015). *Polysiphonia* species are frequently distributed in diverse habitats extending from intertidal and shallow subtidal waters to deeper waters, from cold waters to tropical waters (Hollenberg, 1968; Womersley, 1979) and from low salinity habitats to highly saline ones (Fralick and Mathieson, 1975). *Polysiphonia opaca* is particularly abundant in summer and productive in spring–summer; while other species of *Polysiphonia* are best developed and most reproductive in winter and spring (Rindi and Cinelli, 2000). Likewise, the cyanobacterial alga *Rivularia* has a wide substrate specificity and can tolerate fluctuations in temperature, salinity and pH (Khojal et al., 1984**)**. Some species of *Rivularia* have been reported to inhabit the calcareous rocky shore of Alps (Germany/Austria) (Schlagintweit et al., 2004) as well as the hard shells of some gastropods such as limpets. The limpet (*Patella ulyssiponensis*) in particular had by far greater influence on macroalgal cover than did the other species of grazing gastropods (O'Connor and Crowe, 2005**)**; and this can be related to the large rough surface of its striated shell which enable algae to anchor and thrive on it (El-Adl and Bream, 2013).

According to the updated checklists, a total of 986 alien species were recorded in the Mediterranean Sea by December 2012; sorted as follows: 775 in the Eastern basin, 308 in the Western basin, 249 in the Central basin and 190 in the Adriatic Sea (Zenetos et al., 2012). Being located on the central basin of the Mediterranean Sea, Libya is considered a reservoir for alien species (Bazairi et al., 2013). However, there is a shortage of data regarding alien species in the Libyan coast because of the lack of extensive survey of algal species in this region. The list of Libyan alien marine species was updated by Bazairi et al. (2013) who reported 63 marine alien species along the Libyan coastline, including 5 Rhodophytes and 5 Chlorophytes. Also, El-Adl (2014) recorded 6 new algal species for the first time in the Libyan algal flora.The present study aims at documenting the occurrence of new alien macroalgal species in the area of Al-Jabel Al-Akhdar within the Libyan coastline and to investigatesomeof their bionomics, their relationship with the limpet *Patella caerulea* and the pollution status of the area.

Materials and Methods

Study area

The study area involved seven sites along the Mediterranean coast of Al-Jabel Al-Akhdar, Libya for a distance of 74 km (*Fig. 1*). Samples from water and algae were collected twice a year (in summer 2013 and winter 2014) as illustrated in *Table 1*. The seven sites were chosen to reflect different degrees of water pollution and nature of substrate.

Table 1.*General characteristics of the 7 sites of study along Al-Jabel Al-Akhdar coastline, Libya.*

Site	Location	Latitude	Longitude	Distance from S1
S1	RasHailal	32°53'2"N	22°11'8"E	--
S2	Susa port	32°54'11"N	21°57'50"E	≅20.7 Km
S3	Susa sewage discharge	32°54'7"N	21°57'41"E	≅21 Km
S4	Susa desalination plant	32°53'47"N	21°54'31"E	≅53 Km
S5	Al-Hamama	32°53'47"N	21°54'3"E	≅59 Km

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S6	Al-Hanyaa sewage discharge	32°50'30"N	21°31'11"E	≅71 Km
S7	Al-Hanyaa	32°49'50"N	21°30'20"E	≅74 Km

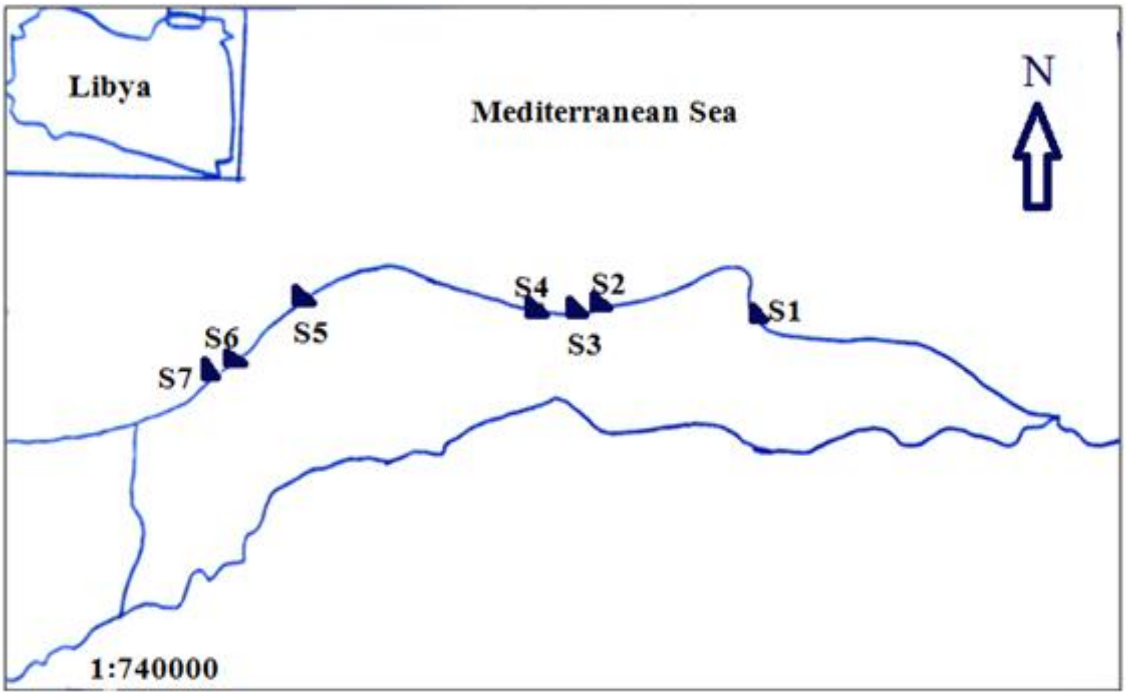

Figure. 1. *Map of Al-Jabel Al-Akhdar coastline, Libya showing the7sites of study.*

Sampling activities

Estimation of algal abundance in the field

Algal abundance was determined according to the point interception quadrat technique **(**Krebs, 1989**)**; using10 m long wire subdivided into 1 m intervals with three sampling units (each was a circle of 25 cm diameter) at each interval, thus summing to a total of 30 sampling unites over the whole wire. Algal abundance was estimatedin terms of the algal percent cover within each sampling unit and the relative frequency of occurrence among the sampling units. According to DAFOR scale (James, 2007), the % cover was categorized into the following classes: dominant (D) >70%, abundant (A) 40-70%, frequent (F) 10-40%, occasional (O) 3-9 % and rare (R) 0-2%**.** The relative frequency of each macroalgal species was calculated according to the following formula:

$$\text{Relative frequency} = \frac{\text{Number of sampling units with the species occurrence}}{\text{The total number of sampling units}} \times 100$$

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Collection of samples

Collection of water and algal samples was done during low tide in summer 2013 and winter 2014. Algal specimens were collected, rinsed thoroughly with seawater in situ, placed in plastic jars and immediately transferred to the laboratory. Water temperature and pH were determined in the field by using a thermometer and a Horizon pH meter respectively. Total Dissolved Solids (TDS) and Dissolved Oxygen (DO) were determined in the laboratory according to APHA (1996).

Treatment and identification of algal samples

Algal specimens were put in a large container with filtered seawater prior to preservation in 4% formalin in seawater until use. The nomenclature of algal species was carried out according to the World Register of Marine Species (WoRMS Editorial Board, 2014) and AlgaeBase (Guiry and Guiry, 2014).

Assessment of water quality

Water quality was assessed based on the level of DO (*Table 2)* according to the Applied Algal Research Laboratory Physical and Chemical Score (AARLPC score) (Lorraine and Vollenweider, 1981).

Table 2. *AARLPC score for DO and its corresponding water quality.*

DO Value (mg l^{-1})	Score	Water quality
>8	<0.1	Very clean
7-8	0.2 - 0.29	Clean
6-7	0.3- 0.39	Moderately clean
5-6	0.4- 0.49	Slightly polluted
4-5	0.5 - 0.59	Moderately polluted
3-4	0.6-0.69	Polluted
2-3	> 0.7	Very polluted

Statistical analysis

Analysis of variance and correlation analysis were performed by using SPSS version 22 (2012). The effect of main factors (site and season) and their interactions were assessed by performing two-way ANOVA. Mean separation was done according to the Duncan's multiple range test at $p \leq 0.05$. The correlation among physico-chemical characteristics of water as well as between water characteristics and algal abundance was evaluated by employing the Pearson's correlation coefficient. The similarity between the studied sites was estimated by performing Cluster analysis (Bray-Curtis similarity index). Data calculated as percentage were arcsine transformed to ensure homogeneity of variance.

Results

Species characterization

The cyanobacterium *R. atra* was visually distinguishable at the studied sites as a dark olive-green to brownish gelatinous hemispherical or sub-spherical colonies, covering

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the rocky shore (*Fig. 2 A – F*). In addition *R. atra* grew on the limpet *Patella caerulea* at S1, S5 and S7. Filaments of the alga are densely packed in radial or parallel rows. The filament is whip-like with a basal heterocyst and terminating with a well-developed colorless hair at the apex, extending beyond the surface of mucilage and gradually attenuated from base to apex (*Fig. 3*).

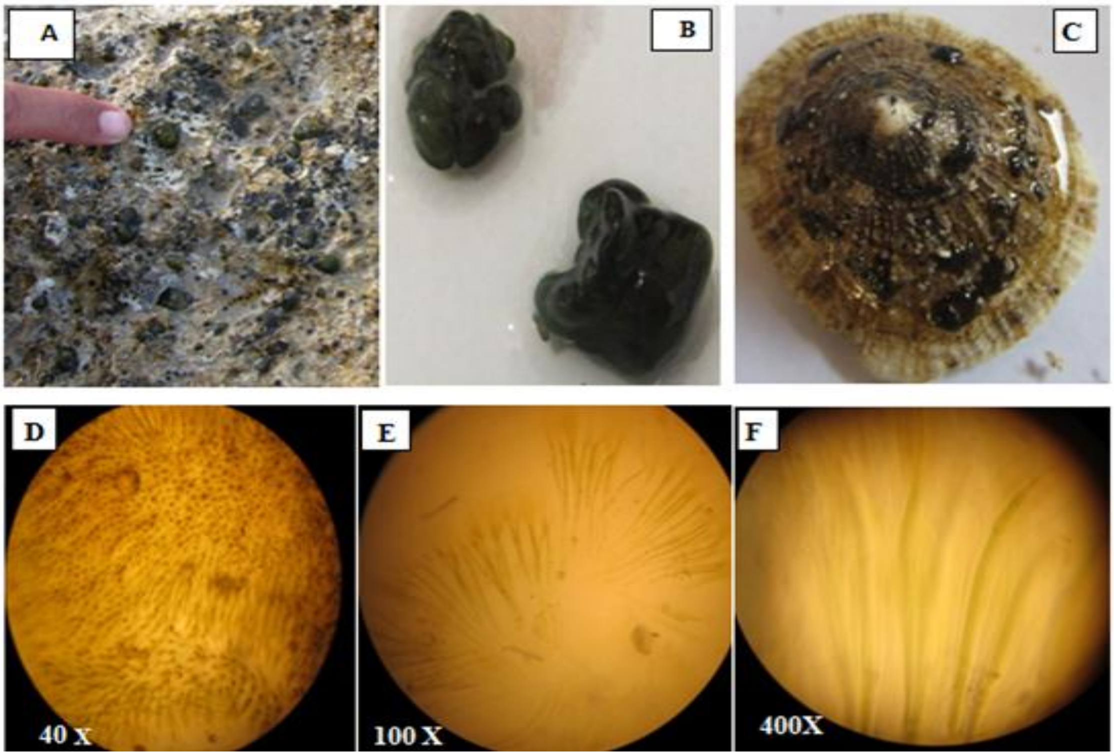

Figure 2. *Rivularia atra. A) Several colonies growing on rocky shore in natural habitat. B) Natural view of colonies. C) Natural view of R. atra as epizoic on Patella caerulea. D and E) Magnified filaments (40X) & (100X). F) Magnified view showing thallus and heterocyst.*

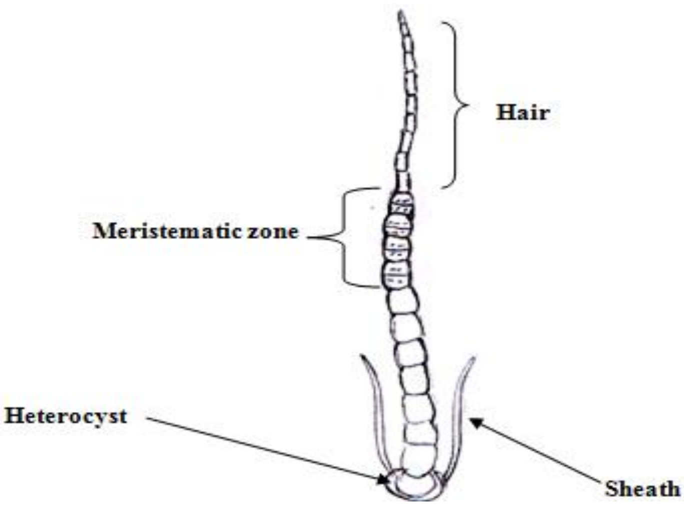

Figure 3*.Structure of a single trichome of Rivularia atra.*

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Polysiphonia opaca was recorded on Al-Hanyaa rocky shore (S7) in the form of clumps of bright brownish red filamentous thallus for the first time during early summer 2013. The filament is soft and highly branched, with short lateral branches and colourless filamentous appendages (trichoblasts) at the top (*Fig. 4 A*- D). The main axis is differentiated into nodes and internodes. The thalli of *P. opaca* had been frequently encountered on limpets (epi-*Patella caerulea* growth).

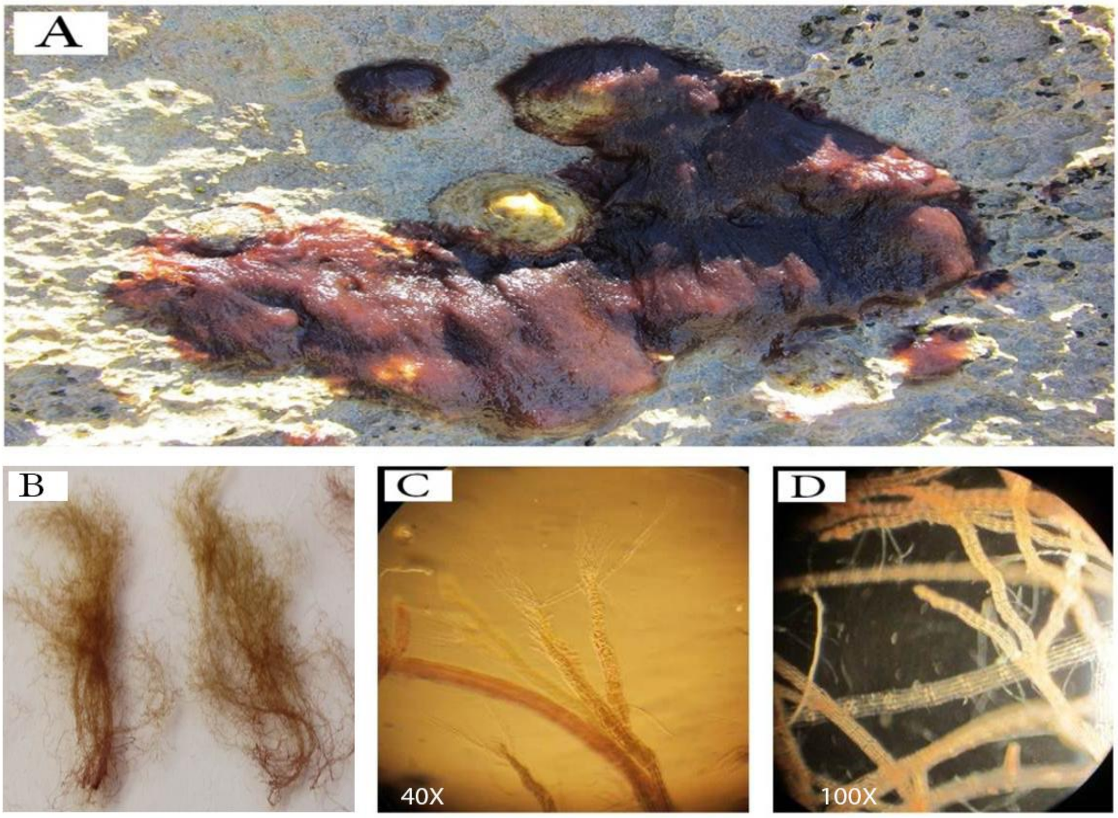

Figure 4. *Polysiphonia opaca. A) Assemblages growing on rocky shore in natural habitat as well as epizoic on Patella caerulea. B) Natural view of thallus. C)Tetraspores and Colourless filamentous appendages (trichoblasts) (40X). D) Magnified view of filaments (100X).*

Abundance of species

Abundance of *R. atra* was estimated in terms of percent cover and relative frequency. The spatial variability in algal abundance was either significant (relative frequency) or highly significant (percent cover). *Fig.5* shows the cover percentage of the two algal species at S1, S5 and S7 since the two species were almost absent from the other sites. Most of the substrate (68%) was bare at S7 with 24 % abundance of *R. atra* (frequent) and 8% abundance of *P. opaca* (occasional). At Ras Hailal (S1) and Al-Hamama (S5), a further greater area (84.5%) was bare and only *R. atra* was recorded, with percent cover of 15.5% on average for the two sites. Although the total coverage of *R. atra* was generally low, yet the alga was scattered randomly over a large area.

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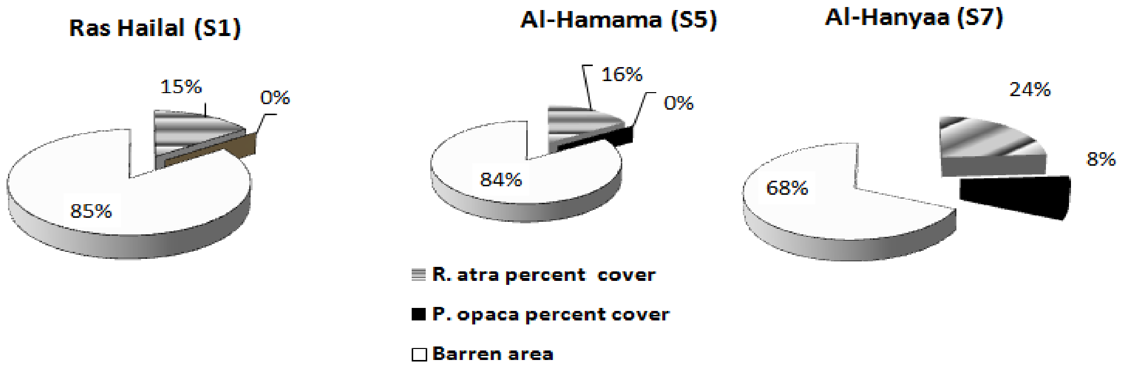

Figure 5.*Cover percentage of P. opaca and R. atra at three sites on Al-Jabel Al-Akhdar coastline, Libya.*

The algal distribution exhibited a marked spatial variation, where the presence of the alien algae *R. atra* and *P. opaca* was restricted to the rocky substrates. *R. atra* was widely spread in most of the upper intertidal zones of the rocky shore at S1, S5 and S7, with a high relative frequency ranging from 40% at S1 to 70% at S7, whereas *P. opaca* was recorded only at S7 where it exhibited a patchy distribution of low frequency (17%) at the lower intertidal zone (*Table 3*). Both species invaded the coexisting *Patella caerulea* to form *Rivularia-Patella* associations at S1, S5 and S7 and *Polysiphonia-Patella* associations at S7, causing marked shell softness compared with the healthy shells of the non-invaded animal.

Table 3. *Relative frequency (% of total sampling units) of R. atra and P. opaca in the study area along Al-Jabel Al-Akhdar coastline, Libya. Each value is the mean of 3 replicates ± SE. Means with common letters are not significantly different at p≤0.05.*

	S1	S2	S3	S4	S5	S6	S7	Zone
R. atra	40±9.4[a]	_	_	_	60±9.5[b]	_	70±13[c]	Upper intertidal zone
P. opaca	_	_	_	_	_	_	17	Lower intertidal zone

There was an appreciable growth of a variety of macroalgal species such as *Laurencia papillosa*, *L. obtusa* and *Cystoseira compressa* away from *R. atra* and *P. opaca* at S1, S5 and S7, with no growth around the two alien species.

Substrata characterization

Table 4 shows that percentage of rock in the substratum of the studied sites ranged between a minimum of 10% at S2 and a maximum of 95 % at S4, with a relatively high rock content at S1, S5, S6 and S7 but a fairly low content along with soft organic bottom as at S3. So the nature of substratum at S1, S4, S5, S6 and S7 was rocky whereas it was clayey sand at S2 and S3. Based upon the pollution status, S2 had a mild level of pollution due to fishing activities; S3 and S6 were moderately polluted due to sewer pipes which participate in formation of the soft organic bottom especially at S3

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while S4 is exposed to powerful wave action as well as thermal pollution and salt discharge from a desalinization plant.

Table 4. *Substratum composition and pollution status of the7 studied sites along Al- Jabel Al-Akhdar coastline, Libya.*

Sites	S1	S2	S3	S4	S5	S6	S7
% Rocks	90	10	20	95	90	80	90
% Sand	10	80	50	5	10	20	10
% Clay	0	10	30	0	0	0	0
Substratum nature	Rocky	Sandy	Clayey sand	Rocky	Rocky	Rocky	Rocky
Pollution status**	Clean	Mild level of pollution due to fishing wastes	Moderate pollution Due to sewers	Clean subjected to thermal pollution	Clean	Moderate pollution Due to sewers	Clean

***Pollution status was based on the mean values of DO and the corresponding AARLPC scores.*

Water physico-chemical characteristics

Two-way ANOVA revealed significant ($p \leq 0.05$) to highly significant ($p \leq 0.01$) effects of season and site and their interaction on physico-chemical characteristics of water; with greater effect of season than of site (*Table 5*). Water temperature of the studied sites reflected the expected seasonal variation with high values (29.7°C) in summer and low values (17.4°C) in winter (*Table 6*).

Table 5._Two-way ANOVA showing the effects of season, site and their interaction on water physico-chemical properties of the studied sites along Al-Jabel Al-Akhdar coastline, Libya._

Variable and source of variation	df	F	Sig.
Temp.			
Season	1	24546.470	.000
Site	6	1.476	.242
Season * Site	6	2.145	.098
pH			
Season	1	615.409	.000
Site	6	9.518	.000
Season * Site	6	3.498	.018
TDS			
Season	1	725.742	.000
Site	6	11.775	.000
Season * Site	6	5.018	.003
DO			
Season	1	1033.104	.000
Site	6	285.220	.000
Season * Site	6	32.140	.000

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Table 6. *Water physico-chemical characteristics (Mean ± SE) and water quality of the 7 studied sites along Al- Jabel Al-Akhdar coastline, Libya. Means with common letters are not significantly different at P ≤ 0.05.*

	Temp °C	pH	TDS (g l^{-1})	DO (mg l^{-1})	Water quality
			Summer 2013		
S1	29.4±0.21ab	8.1 ± 0.14a	38.2±0.07ab	6.5±0.14ab	Moderately clean
S2	29.7±0.21a	8.2±0.07ab	38.1±0.0abc	6.2±0.14b	Moderately clean
S3	29.2±0.07bc	8.4 ± 0.07bc	36.2±0.07g	4.3±0.07cd	Moderately polluted
S4	29.7±0.14a	8.1±0.07a	38.4±0.07a	6.6±0.21a	Moderately clean
S5	29.3±0.14abc	8.4±0.07bc	37.6±0.07d	4.6±0.07c	Moderately polluted
S6	29.4±0.21ab	8.6±0.07c	36.7±0.28f	4.3±0.07cd	Moderately polluted
S7	29.4±0.42ab	8.6±0.14c	37.4±0.21de	6.6±0.28a	Moderately clean
			Winter 2014		
S1	17.7±0.28ab	7.2±0.14c	34.6±0.07bc	8.1±0.07bc	Very clean
S2	17.5±0.35abcd	7.3±0.14bc	34.5±0.07bcd	8.3±0.07abc	Very clean
S3	17.4±0.14bcd	7.3±0.07bc	34.1±0.14d	5.1±0.21de	Moderately polluted
S4	17.4±0.35bcd	7.5±0.21ab	34.8±0.64abc	8.4±0.14ab	Very clean
S5	17.4±0.14bcd	7.4±0.07abc	34.9±0.07ab	8.3±0.07abc	Very clean
S6	17.6±0.14abc	7.6±0.07a	34.4±0.07cd	5.4±0.28d	Moderately polluted
S7	17.9±0.07a	7.5±0.07ab	35.1±0.14a	8.6±0.14a	Very clean

Although the spatial variation in temperature was however limited, yet S3 recorded the lowest temperatures while S2 and S4 recorded the highest values. The spatial variations in pH, TDS and DO were greater than that in temperature; where the lowest pH (7.2) was recorded at S2 in winter but the maximum pH (8.6) was at S6 and S7 in summer (*Table 6*). The spatial variability in TDS was comparable to that in pH; with the highest value (38.4 g l^{-1}) was at S4 in summer, while the lowest value (34.1 gl^{-1}) was at S3 in winter. DO exhibited the greatest spatial variability and the second greatest seasonal variability after temperature; where its value was generally higher in winter than in summer and was particularly highest at S7 in winter (6.8 mg gl^{-1}) but lowest (4.3 mg g l^{-1}) at S3 and S6 in summer. Based on AARLPC score for DO, all sites were very clean during winter, except for S3 and S6 which might be classified as moderately polluted. In summer, moderately clean water was encountered at S1, S2, S4 and S7; while the other sites were moderately polluted.

The Pearson correlation coefficient revealed highly significant correlations ($P \leq 0.01$) among the physico-chemical characteristics of water (*Table 7*). Temperature was positively correlated with both pH and TDS but negatively correlated with DO; whereas pH was positively correlated with TDS but negatively correlated with DO. The physico-chemical characteristics of water (except temperature) showed highly significant positive correlation with percent cover of *R. atra*, but weak correlation with relative frequency except the highly significant correlation between the latter and TDS.

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Table7. *Pearson correlation coefficients among the measures of physico-chemical characteristics of water as well as between physico-chemical characteristics of water and abundance of R. atra (in terms of % Cover and Relative frequency)at the studied sites along Al-Jabel Al-Akhdar coastline, Libya.*

	% Cover	Relative frequency	Temp.	pH	TDS	DO
% Cover	1					
Relative frequency	.617	1				
Temp.	.651	.086	1			
pH	.813**	.640	.930**	1		
TDS	.827**	.885**	.935**	.805**	1	
DO	.940**	.666	-.549**	-.608**	-.348	1

** Correlation is significant at the 0.01 level.

Based on the mean values of the obtained physico-chemical characteristics, Bray-Curtis similarity index showed high similarity (> 96%) between the sites of the study in general (*Fig.6*). Among the seven sites, S1 and S4 exhibited the strongest similarity (> 99%) and shared similarity with S2, S5 and S7 (> 97%). On the contrary, S3 and S6 were distinct from the other sites despite their high similarity to each other (> 98%).

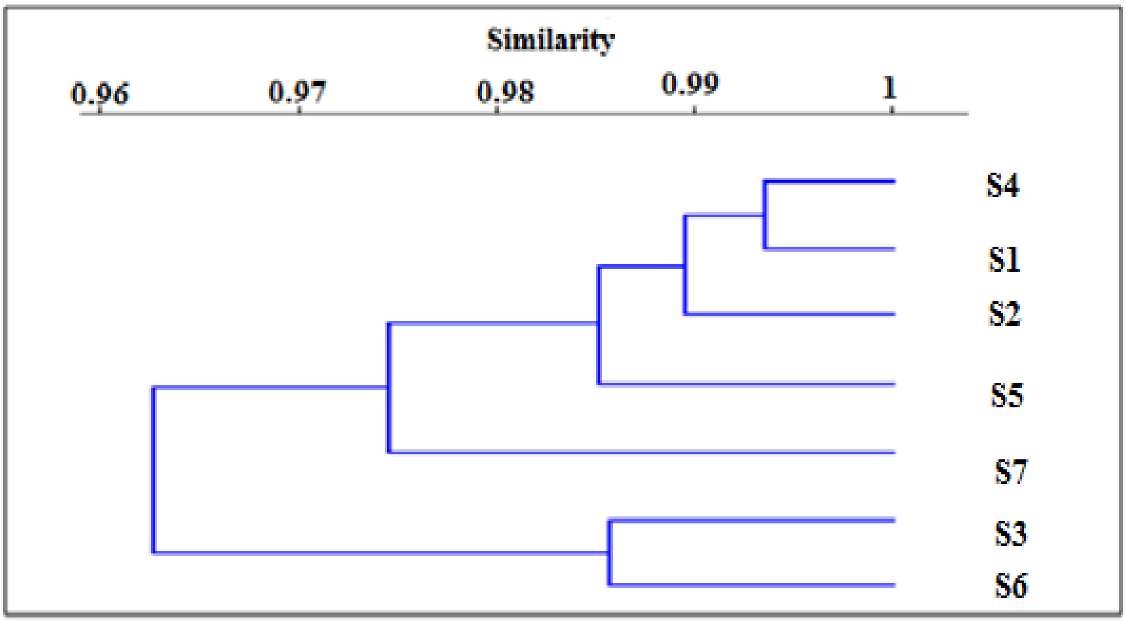

Figure6. *Bray-Curtis similarity analysis of physico-chemical parameters showing the similarity level between the 7 studied sites along Al-Jabel Al-Akhdar coastline, Libya.*

Discussion

The narrow spatial variation of water temperature is a consequence of the short distances between sites of study. In contrary, the marked seasonal variation could be attributed to the seasonal changes of air temperature which affect aquatic ecosystem temperature. This agrees with the findings of Barry et al. (1995) that the changes in water temperature are in accordance with changing in air temperature. Water temperature of the study sites was positively correlated with pH and TDS but negatively

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correlated with DO; which agrees with Oviatt et al. (1986) who revealed that changes in pH of marine systems correlate with changes in temperature, dissolved oxygen, and algal productivity.The slightly alkaline reaction of water at the different sites seems suitable for algal growth since Reid (1962) claimed that alkaline environments are generally more productive than acidic environments.

The relatively high level of TDS at S4 may be the result of the high load of salts in wastewater discharged from a desalination plant into the seawater. This salt discharge may impede growth of algal species since Solomon et al. (2007) reported that changes in seawater temperature and salinity may adversely affect the performance of marine species. The low DO concentration of water in summer may be due to the high surface water temperature (Sridhar et al., 2008), whereas the high levels in winter point to improved water quality in most sites during the cold season. The particular drop in DO at S3 and S6 might be attributed to biological oxygen consumption since the two sites were subjected to pollution from sewage discharge. This agrees with Oviatt et al. (1986) who claimed that low oxygen concentrations are characteristic of coastal waters receiving anthropogenic inputs such as sewage effluent or agricultural runoff. The maximum DO level at S7 evaluates this site to be the most clean one, followed by S1 and S5 which exhibited slightly polluted state. The overall high similarity between the sites of study could be attributed to the short distance of study area. Nevertheless, the close similarity between S3 and S6 and their distinction from the other sites could be attributed to the similar state of pollution in both sites despite the different nature of substratum.

Up to the late decades of the 19^{th} century, only 5 algal species were recorded along the coast of Libya by Piccone (1879). From there until now, many macroalgal species have been recorded by several authors (Nizamuddin et al., 1978; Godeh et al., 1992; Garreta et al., 2001; Bazairi et al., 2013; El–Adl, 2014); neither of them recorded the two target species, *R. atra* and *P. opaca*, on the Libyan coastline. In the present work we recorded *R. atra* and *P. opaca* for the first time on the Libyan coastline particularly at Al-Hanyaa rocky shore on Al-Jabel Al-Akhdar. It is quite probable that *P. opaca* invaded the Libyan coastline coming from Egypt since Garreta et al. (2001) recorded *P. opaca* in the Egyptian coastline and didn't record it in the Libyan coastline in their checklist of the Mediterranean seaweeds. Meanwhile, *R. atra* may probably come from the Atlantic Ocean according to suggestion of Rodríguez and Moliner (2010) in their study on the Asturias coast (North of Spain). Therefore, both species can be considered as new records in the Libyan coastline, with frequent associations with the limpet *Patella caerulea*. The growth of *R. atra* was scattered on the substrate, covering an appreciable area of the rocky shore and may extend to cover the substrate completely, forming coloured clouds on the rocky shores.

The abundance of *R. atra* in the upper intertidal zone may be attributed to its tolerance to fluctuations in temperature, salinity and pH in the upper eulittoral zone (Khojal et al., 1984). In this respect, Sihvonen et al. (2007) reported that *Rivularia* sp are capable of growing in relatively high salt concentrations because of its ability of trehalose synthesis which plays a role in maintenance of turgor under high salinity (Reed and Stewart, 1983). The *R. atra- Patella* association can be considered as epizoic and/or parasite relationship. This agrees with Hosmani and Nagendra (1980) who revealed that *Rivularia* can resort to other modes of nutrition as evidenced by its parasitic nature on the aquatic angiosperm *Griffithella hookeriana*. Similarly, *P. opaca* invaded the hard substrates at S7 as well as the *Patella* shell where it grows frequently

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on the limpet as epizoic species. This relationship may be sorted as a parasitism according to Ciciotte and Thomas (1997) who evidenced the specificity of *Polysiphonia* to its host and demonstrated partial dependence of *Polysiphonia* for amino acids, phosphates, and other mineral ions upon its *Ascophyllum* host. This nutritional relationship is supported by the luxurious growth of *P. opaca* on *Patella* compared with the poor growth apart from it.

The favorite substrates of *R. atra* and *P. opaca*; that is the limpet shell as well as the hard substratesofthe upper intertidal zone(*R. atra*) and lower intertidal zone (*P. opaca*) share a common feature of high content of $CaCO_3$. This suggests that lime is the controlling factor in distribution of the two species and agrees with the findings of Schlagintweit et al. (2004) who recorded two new species of *Rivularia* inhabiting the limestone of the northern calcareous Alps (Germany/ Austria) and with our findings that the sites S2, S3, S4 and S6 with no or low content of $CaCO_3$ had scarce growth of the two species. Although limpets feed on most local species of marine algae, they can also aid in spreading of algal species by transporting phoretic algal spores through their movement during high tide as suggested by Misra and Kundu (2005). Limpets also may provide macroalgae with the necessary nitrogenous and calcium compounds (Buschbaum, 2000). The outgrowth of both *R. atra* and *P. opaca* upon *Patella* over the Libyan coastline might be at the expense of the native algal species.

The fact that the two alien species prefer the rocky substrate at intertidal zones of the clean sites S1, S5 and S7 meanwhile avoiding the other polluted sites which were either polluted or with soft substrata points to sensitivity of the two species to pollution arising from anthropogenic activities. This agrees with Fredericq et al. (2000) who reported that the composition and richness of seaweed community vary according to nature of the site they inhabit, waves, tide and currents. Also Ruiz et al (2009) claimed that the number of non-native species is generally greater on hard substrate than on the soft sediment substrata. Fishing activities at S2, sewage flow at S3 and the soft clayey sandy nature of substrate at both sites seem to create unfavorable habitat for *R. atra* and *P. opaca*. This agrees with the findings of Ryther and Dunstan (1971) who, revealed that the nitrogenous wastes arising from sewage discharge are a critical factor limiting macroalgal growth. Despite of the stiff rocky nature of S4, this site is continuously exposed to powerful wave action as well as thermal pollution and higher load of salts from a desalinization plant which may impede *R. atra* and *P. opaca* growth. This agrees with the findings of Schembri et al. (2005) who emphasized that exposure to wave action, the nature of the substratum and its topography result in variation in the biotic assemblage of marine ecosystems.

The absence of other macroalgal species near *R. atra* at the uppermost intertidal zone or near *P. opaca* at lower intertidal zone points to alteration of morphological features of the shore by the two alien species. This could be attributed to their ability, as alien species, to drive changes in physical environmental characteristics, functioning of the ecosystems and impact on food webs (Ehrenfeld, 2010). In addition, the high tolerance of *R. atra* to wide variations in salinity and temperature in the upper intertidal zone compared with the other macroalgal species such as *Laurencia optusa* and the probable ability of *P. opaca* in lower intertidal zone to secrete allellopathic compounds might contribute to the marked competing activity of the two species. This agrees with Råberg et al. (2005) who reported that, the exudates from *Polysiphonia* species appear to exert a negative effect on the reproduction of *Fucus vesiculosus*. These alien species might represent greater threat to native biodiversity than do pollution in the study area since

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the effects of marine pollution can be reversed by ameliorative actions, while the biological impact is irreversible (Carlton, 1989).

In 1992, Godeh et al. recorded 12 alien algal species on the Libyan coast; later on Bazairi et al. (2013) recorded another 10 alien species; and more recently El–Adl (2014) reported additional 6 alien species along the Libyan coastline. This points to the increasing number of exotic marine algal species in the Libyan coastline especially at Al-Jabel Al-Akhdar since earlier reports by Nizamuddin et al. (1978) and Godeh et al. (1992) did not detect any species belong to Cyanobacteria at Al-Jabel Al-Akhdar coastline.

Conclusions

Rivularia atra and *P. opaca* are considered as alien algal species on the Libyan coast. The two species inhabit not only the rocky substrates but also the limpet *P. caerulea*, this probably affects the native marine algal communities. The nature of substrate and pollution state may be major modifiers of algal distribution, where the non-polluted bare rocky shore is the favorite habitat for the alien species *R. atra and P. opaca.* This means that these species may be promising indicators for water quality.

REFERENCES

[1] APHA: American Public Health Association (1996): Standard Methods for the Examination of Water and Wastewater, 17th edn. American Public Helath Association, Washington, D.C.

[2] Barry, J.P., Baxter, C.H., Sagarin, R.D., Gilman, S.E. (1995): Climate-related, long-term faunal changes in a California rocky intertidal community. – Science 267: 672-675.

[3] Bazairi, H., Sghaier, Y. R., Benamer, I., Langar, H., Pergent, G., Bourass, E.M., Verlaque, M., Ben Soussi, J., Zenetos, A. (2013): Alien marine species of Libya: first inventory and new records in El-Kouf National Park (Cyrenaica) and the neighbouring areas. – Mediterranean Marine Science 14 (2):451-462.

[4] Buschbaum, C. (2000): Direct and indirect effects of *Littorina littorea* (L.) on barnacles I: growing on mussel beds in the Wadden Sea. – Hydrobiologia 440: 119-128.

[5] Carlton, J.T. (1989): Man's role in changing the face of the ocean: biological invasions and implications for conservation of near-shore environments. – Conservation Biology 3: 265-273.

[6] Ciciotte, S.l., Thomas, R.J. (1997): Carbon exchange between *Polysiphonia lanosa* (Rhodophyceae) and its brown algal host. – American Journal of Botany 84(11): 1614–1616.

[7] Ehrenfeld, J.G. (2010): Ecosystem consequences of biological invasions. – Annual Review of Ecology, Evolution, and Systematics 41: 59-80.

[8] El-Adl, M.F. (2014): New records of marine algal species collected from Al-Jabel Al-AKhdar coastline, Libya. – Egyptian Academic Journal of Biological Sciences: Microbiology 6 (2): 9-20.

[9] El-Adl, M.F., Bream, A.S. (2013): Associations between some macroalgal species and limpets at certain rocky intertidal zones of Al-Jabel AL-Akhdar coast, Libya. – Al-Azhar Bulletin of Science 24 (2):165-180.

[10] Elton, C.S. (1958): The Ecology of invasions by animals and plants. – University of Chicago Press: Chicago, USA.

[11] Fralick, R.A., Mathieson, A.C. (1975): Physiological ecology of four *Polysiphonia* species (Rhodophyta, Ceramiales). – Marine Biology 29: 29-36.

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/1401_249263
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[12] Fredericq, S., Phillips, N., Gavio, B. (2000): Observations on the macroalgae inhabiting deep-water Hard Bar communities in the northwestern Gulf of Mexico. – Gulf of Mexico Science, pp. 88-96.

[13] Garreta, G., A., Gallardob, T., Riberaa, M.A., Cormacic, M., Furnaric, G., Giacconec, G., Boudouresqued, C.F. (2001): Checklist of Mediterranean seaweeds. III. Rhodophyceae Rabenh. 1. Ceramiales Oltm, Walter de Gruyter Berlin New York. – Botanica Marina 44: 425-460.

[14] Godeh, M.M., Nizamuddin, M., Elmenifi, F.A. (1992): Marine algae from eastern coast of Libya (Cyrenaica). – Pakistan Journal of Botany 24 (1):11-21.

[15] Guiry, M.D., Guiry, G.M. (2014): AlgaeBase. World-wide electronic publication, National University of Ireland, Galway. http://www.algaebase.org.

[16] Hassoun, M., Salhi, G., Kazzaz, M., Riadi, H., Moussa, H. (2015): New records of *Polysiphonia sensu lato* from the Atlantic Ocean in Morocco. – Marine biodiversity 45: 1-7.

[17] Hollenberg, G.J. (1968): An account of the species of *Polysiphonia* of the Central and Western Tropical Pacific Ocean. II. Oligosiphonia. – Pacific Science 22: 198-207.

[18] Hosmani, S.P., Nagendra, C.R. (1980): *Rivularia aquatica* De Wilde as a parasite on *Griffithella hookeriana*. – Warm Current Science 49 (19): 751-752.

[19] James, T. (2007): Running a biological recording scheme or survey. A hand book to help scheme or society administrators. Report. National Biodiversity Network.

[20] Keller, R.P., Geist, J., Jeschke, J.M., Kühn, I. (2011): Invasive species in Europe: ecology, status, and policy. – Environmental Sciences Europe 23:23.

[21] Khojal, T.M., Livingstone, D., Whitton, B. A. (1984): Ecology of a marine *Rivularia* population. – Hydrobiologia 108: 65 -73.

[22] Krebs, C.J. (1989): Ecological methodology. Harper & Row, New York.

[23] Lorraine, L.J., Vollenweider, R.A. (1981): Summary report, the OECD cooperative programme on eutrophication, National Water Research Institute, Burlington.

[24] Misra, S., Kundu, R. (2005): Seasonal variations in population dynamics of key intertidal molluscs at two contrasting locations. – Aquatic Ecology 39 (3): 315–324.

[25] Montefalcone, M., Albertelli, G., Morri, C., Bianchi, C.N. (2010): Patterns of wide-scale substitution within meadows of the seagrass *Posidonia oceanica* in NW Mediterranean Sea: invaders are stronger than natives. – Aquatic Conservation: Marine and Freshwater Ecosystems 20: 507–515.

[26] Nizamuddin, M., West, J.A., Menez, E.G. (1978): A list of marine algae from Libya. – Botanica Marina 22: 465-476.

[27] O'Connor, N.E., Crowe, T.P. (2005): Biodiversity loss and ecosystem functioning: distinguishing between number and identity of species. – Ecology 86: 1783 -1796.

[28] Oviatt, C. A., Keller, A. A., Sampou, P. A., Beatty, L.L. (1986): Patterns of productivity during eutrophication: A mesocosm experiment. – Marine Ecology Progress Series 28: 69-80.

[29] Piazzi, L., Balata, D., Cecchi, E., Cinelli, F. (2003): Co-occurrence of *Caulerpa taxifolia* and *C. racemosa* in the Mediterranean Sea: inter-specific interactions and influence on native macroalgal assemblages. – Cryptogamie, Algologie 24:233–243.

[30] Piccone, A. (1879): Catalogo delle alghe raccolte durante lacrociere del cutter "Violante". Mem. R. Accademia Nazionale dei Lincei, Roma, Italy 4: 19-35.

[31] Pimentel, D., Lach, L., Zuniga, R., Morrison, D. (2000): Environmental and economic costs of non-indigenous species in the United States. – BioScience 50:53-65.

[32] Råberg, S., Berger-Jönsson, R., Björn, A., Graneli, E., Kautsky, L. (2005): Effects of *Pilayella littoralis* on *Fucus vesiculosus* recruitment: implications for community composition. – Marine Ecology Progress Series 289: 131-139.

[33] Reed, R.H., Stewart, W.D.P. (1983): Physiological responses of *Rivularia atra* to salinity: Osmotic adjustment in hyposaline media. – New Phytologist 95: 595-603.

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/1401_249263
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[34] Reid, K.G. (1962): Ecology of inland water and estuaries. Text book, VNR, New York, 375p.

[35] Rindi F., Cinelli, F (2000): Phenology and small-scale distribution of some rhodomelacean red algae on a western Mediterranean rocky shore. – European Journal of Phycology 35(2): 115-125.

[36] Rodríguez, C., Moliner, E. y. C.C. (2010): Checklist of benthic algae from the Asturias coast (North of Spain). – Boletín de Cienciasdel Real Instituto de Estudios Asturianos 51: 135-212.

[37] Ruiz, G.M., Freestone, A.L., Fofonoff, PW.,Simkanin, C. (2009): Habitat distribution and heterogeneity in marine invasions dynamics: The importance of hard substrate and artificial structure. – In: Wahl, M. (ed) Marine Hard Bottom Communities, Springer Berlin Heidelberg, Ecological Studies 206:321–332.

[38] Ryther, J.H., Dunstan, W.M. (1971): Nitrogen, phosphorus, and eutrophication in the coastal marine environment. – Science 12: 1008-1013.

[39] Sala, E., Kizilkaya, Z., Yildirim, D., Ballesteros, E. (2011): Alien marine fishes deplete algal biomass in the Eastern Mediterranean. – PLoS ONE 6 (2): e17356.

[40] Schembri, P.J., Deidun A., Mallia, A., Mercieca, L. (2005): Rocky shore biotic assemblages of the Maltese Islands (Central Mediterranean): A conservation perspective. – Journal of Coastal Research 21 (1): 157–166.

[41] Schlagintweit, F., Missoni, S., Lein, R., Gawlick, H.J. (2004): *Rivularia barmsteinensis* n. sp. and *Rivularia loseri* n. sp. two new Cyanophycean algae from the upper Jurassic–Lower Cretaceous of the Northern Calcareous Alps (Germany/Austria). – Jahrbuch der Geologischen Bundesanstalt. B.-A. 223-233.

[42] Sihvonen, L.M., Lyra, C., Fewer, P., Rajaniemi-Wacklin, P., Lehtimäki, J.M., Wahlsten, M., Sivonen, K. (2007): Strains of the cyanobacterial genera *Calothrix* and *Rivularia* isolated from Baltic Sea display cryptic diversity and are distantly related to *Gloeotrichia* and *Tolypothrix* . – FEMS Microbial Ecology l61: 74–84.

[43] Solomon, S., Qin, D., Manning, M., Chen, Z., Marquis, M., Averyt, K.B., Miller, H.L. (2007): Contribution of working group I to the fourth assessment report of the intergovernmental panel on climate change, 2007. Cambridge, United Kingdom and New York, NY, USA, 1007.

[44] SPSS Inc. (2012): Statistical package for the social sciences (SPSS) 20 for windows. Chicagoo, USA.

[45] Sridhar, R., Thangaradjou, T., Kannan, L. (2008): Comparative investigation on physico-chemical properties of the coral reef and seagrass ecosystems of the Palk Bay. – Indian Journal of Marine Sciences 37(2): 207-213.

[46] Womersley, H.B.S. (1979): Southern Australian species of *Polysiphonia* Greville (Rhodophyta). – Australian Journal ofBotany 27: 459-528.

[47] WoRMS Editorial Board (2014): World Register of Marine Species. Available from http://www.marinespecies. org at VLIZ.

[48] Zenetos, A., Gofas, S., Morri, C., Rosso, A., Violanti, D. (2012): Alien species in the Mediterranean Sea by 2012. A contribution to the application of European Union’s Marine Strategy Framework Directive (MSFD). Part 2. Introduction trends and pathways. Mediterranean Marine Science 13 (2): 328-352.

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