VERTICAL DISTRIBUTION AND BIOMASS OF MACROALGAE IN THE INTERTIDAL ROCKY SHORE OF TAJURA, LIBYA

Abdulfattah Elfituri[1*], Rania Kafu[2], Hana Abohbell[3], and Najla Abushaala[4]

[1] Marine Biology Research Center of Tajura, Libya
[2,4] University of Tripoli, Libya
[3] University of Sabratha, Libya
[*] elfituri74@gmail.com

Abstract

This study was an initial step toward understanding the qualitative and quantitative of macro-algae in the intertidal rocky shore of Tajura. In total, 24 species of macro-algae (6 Chlorophyta, 6 Phaeophyceae, and 12 Rhodophyta) were identified in the intertidal zone. All species were distributed to one or two of the three levels (high tide, mid tide, and low tide) except *U. Linza*, *U. lactuca*, *C. compressa*, *H. muscifarmus*, *L. obtuse*, and *J. rubens* which, were found in each level of the intertidal zones. Both mid and low tide was the main habitats for the growth, and abundance of seaweeds, most of them belonging to Rhodophyta. In contrast, high tide was less diversity and biomass, with a complete absence of Phaeophyceae. The total biomass in the study area was 158 g dw/m^2, whereas Rohdophyta had the highest biomass (94.8 g dw/m^2). In addition, the biomass showed a clear difference between the three levels; the highest biomass (317.9g dw/m2) was observed in the low tidal zone and the lowest biomass (57.16g dw/m^2)was observed in the high tidal zone. Finally, the annual dominant species by biomass in the intertidal rocky shore of Tajura were *C. compressa* (36.8g dw/m^2) and *L. obtusa* (24.7g dw/m^2).

Keywords: Macroalgae; Seaweeds; Diversity; Biomass; Libya.

Introduction

Marine macro-algae are photosynthetic, non-vascular plants that contain chlorophyll and pigment, also known as seaweeds or benthic algae, which are found from intertidal to shallow water and sub-tidal zones. Seaweeds are divided into three major groups: Chlorophyta (green algae), Phaeophyta (brown algae), and Rhodophyta (red algae) (Koch et al., 2013). In the marine ecosystem, algae are at the top of the food chain, and any changes in the patterns of these habitat-forming organisms create changes in the food web (Bates & DeWreede, 2007). Foster et al. (1985) found that the shallow rocky and sub-tidal zones (0 - 30 m) include more seaweed species than other marine habitats, which are high in stable habitats and unpolluted areas (Piazzi et al., 2002; Arevalo et al., 2007). Macro-algal community structures are generally analysed by species composition, and variation in biomass, which are parameters that respond to environmental conditions (Murray & Littler, 1984; Prathep, 2005; Wells et al., 2007; Choi et al., 2008).

However, only qualitative studies of Libyan seaweed have been published. The first study on Libyan seaweeds was done in 1878 by Ascherson (Nizamuddin et al., 1979), followed by (DeToni & Levi,1888; De Toni, 1892 & 1895; Ardissone, 1893; De Toni & Forti, 1913 & 1914; Lemoine, 1915; Raineri, 1920 & 1921; Pampanini, 1931; Nizamuddin et al.,1979; Huni & Aravindan, 1984; Nizamuddin, 1985 & 1987; Nizamuddin & Godeh 1989, 1990 a, b, c; Godeh et al., 1992; Nizamuddin & Godeh, 1993; Nizamuddin and El-Menifi, 1993; Said & Godeh, M. 2008; Said et al., 2010 & 2013; Godeh et al., 2009, 2010, 2011 & 2017). This work aims to qualitative and quantitative studies on seaweeds in the intertidal rocky shore of Tajura.

Methods

Study Area

In the present study, an investigation was conducted at the intertidal rocky shore of Tajura, which is about 20km east of Tripoli (Libya), GPS location is 32.896432 N, 13.348550 E. The shore is a typical sandstone rock-platform (about 2500m² during extreme low water) with rock pools Figure (1.a). During the study period seawater temperature (19 ^{o}C) and salinity (36.6 ppt) were measured by NaCl Meter HI 931100 and Nutrients No_3^- (0.4 mg/L), No_2^- (0.003 mg/L) and, Po_4^- (2.1 mg/L) were measured by Environmental Testing Photometer HI 83206.

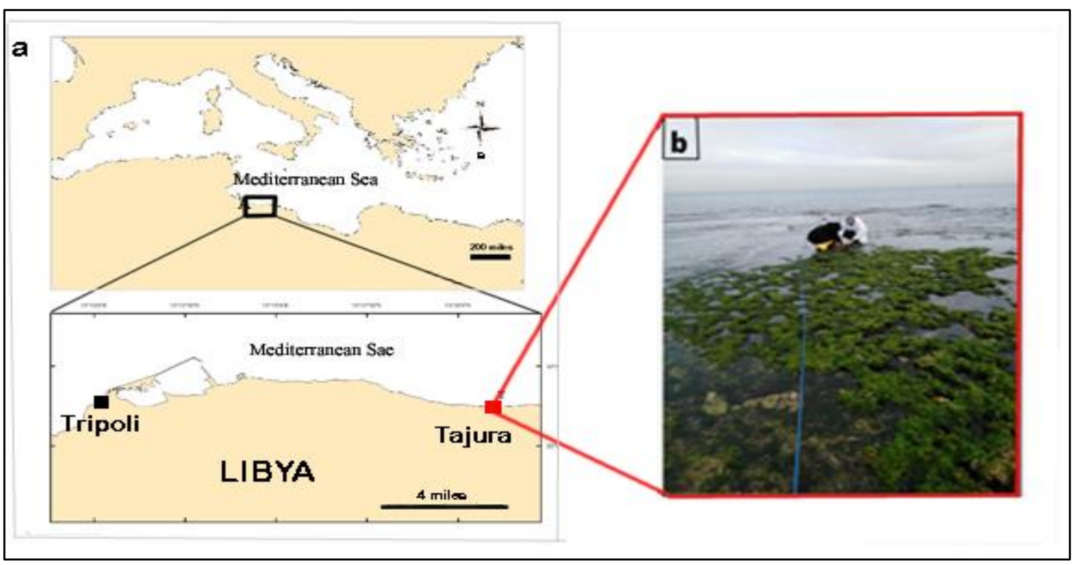

Figure (1): Map of the Study Area (a), Line Transect on Sandstone Platform at Intertidal Zone of Tajura (Libya).

Sampling

Lines that transect perpendicular to the shore line were used randomly to investigate vertical distribution and biomass of macro-algae during March 2021 Figure (1.b). Four replicates of quadrats 25 x 25cm Figure (2) were placed at each intertidal level (high tide, mid tide and low tide). Macro-algae or seaweeds within each quadrat were removed and transported to the lab and frozen immediately to prevent their degradation. After washing and separating species in each quadrat, seaweeds were identified by using identification keys of (Nizamuddin ***et al***., 1979; Nizamuddin, 1991; Riedl, 1991; Fischer ***et al***., 2007). In order to determine dry weight (biomass), macro-algae in each quadrat were dried in an oven at 70°C for 24h (Fatemi ***et al.***, 2012) and then weighed to the nearest 0.001g using an analytical balance namely PM600 made by Mettler-toledo Ltd. Biomass calculated as grams dry weight per square meter (gdw/m^2).

Figure (2): Macroalgal Quadrat ((25 x 25cm) at Low Intertidal Zone of Tajura Rocky Shores. *Caulerpa racemosa* (Ca), *Gelidium crinale* (Ge), *Gracilaria verrucosa* (Gr), *Gigartina acicularia* (Gi), *Colpomenia sinousa* (Co), *Corallina mediterranea* (Cor), *Cystoseira compressa* (Cy), *Jania rubens* (Ja), *Hypnea muscifarmus* (Hy), *Laurencia obtuse* (La), *Sargassum vulgare* (Sa), *Ulva lactuca* (Ul).

Statistical Analyses

One-Way ANOVA analysis was employed to explore significant differences in biomass and species among three levels of the intertidal zone (high tide, mid tide and low tide) followed by the Tukey test. Statistical analysis was performed by Microsoft Excel and SPSS.

Results and Discussion

Vertical Distribution of Macro-algae

In total, 24 species of marine macro-algae were collected and identified in the intertidal zone of Tajura Table (1). Outputs of the One-Way ANOVA test revealed a significant difference ($p < 0.05$) in the total number of species between classes: green algae (Chlorophyta), brown algae (Phaeophyta), and red algae (Rhodophyta). Chlorophyta and Phaeophyta each contributed 25% to the total numbers of species, while Rhodophyta was more diverse (12 species) with a percentage of 50% of the total number of species. The total number of Rhodophyta species is divided by the total number of Rhodophyta species (R/P ratio). The R/P ratio of Tajura coast was (2.0) which is less than findings of Shtewi & Hana, (2015) at the western coast of Libya (2.5) and more than Godeh ***et al***., (2009) at the eastern coast of Libya (1.45). Most of the Mediterranean coasts ranged between 2.0 and 3.8 (Ben Maiz, ***et al***., 1987), probably due to the several factors that control seaweeds and seagrass distribution and growth, like salinity, pH, temperature, light intensity, nutrients, and type of bottom (rocky or sandy) in addition to marine pollution (Wilhm, 1975; El-Ayouty ***et al***., 1999 and Lenz, ***et al***., 2007). On the other hand, the total number of Chlorophyta in the current study was similar to Tolmeta and Sert coasts 5 - 6 species as reported by (Said ***et al***., 2010 and Godeh ***et al***., 2017).

Also, statistical analysis showed important differences in the number of species ($p < 0.05$) between levels of the tidal zone (low, mid, and high tide) Table (1). Both mid-tide and low tide were the main habitats for the growth and abundance of algae; 17-19 species were recorded at these levels and most of them belong to Rhodophyta. This observation may be due to medium and low tide zones immersed with water for a longer period than high tide zone which is exposed to direct sunlight. The complete absence of Pheophyceae in the high tidal zone was unexpected during the period study, which may be due to their high sensitivity to changes in the environment and specifically to human impacts and polluted water. According to Wilhm, (1975) & El-Ayouty ***et al***., (1999) who evaluated that the decrease in the number of species and the increase in the number of individuals is a characteristic feature of polluted water. In the current study, all species were confined to one or two of the three levels (high tide, mid-tide, and low tide) except *Ulva Linza*, *Ulva lactuca*, *Corallina* *mediterranea*, *Hypnea muscifarmus*, *Laurencia obtuse* & *Jania rubens* which were found in each level of the tidal zones.

Biomass

The total biomass in the intertidal zone of Tajura was 156.18 grams dry weight per square meter (gdw/m^2). The average biomass of Chlrophyta, Pheophyceae and Rohdophyta were significantly different ($p < 0.05$) between these groups Table (1). Rohdophyta had the highest biomass (94.26g dw/m^2) and followed by Pheophceae (46.18g dw/m^2) and Chlrophyta (16.74g dw/m^2). This result was more than reported by Fatemi ***et al***., (2012) at the Persian Gulf.

Table (1): Macro-Algal Species and their Biomass in Intertidal Rocky Shore of Tajura Coast, Libya.

Macroalgae	High Tide	Mid Tide	Low Tide	Mean Biomass
Chlorophyta				
Caulerpa racemose	-	-	0.56	
Cladophora prolefera		1.76	0.6	
Cladophora sp.	0.16	-	-	
Ulva compressa	+	0.72		
Ulva linza	15.3	0.04	0.28	
Ulva lactuca	7.84	18.4	1.56	
USM (Ch)	**(23.3)^b**	**(20.9)^b**	**(3.0)^a**	**(15.74)^b**
Phaeophyceae				
Colpomenia sinousa	-	0.04	1.24	
Cystoseira compressa	-	-	110.6	
Dictyota dichotoma	-	-	9.16	
Dictyotpteris membranacea	-	0.04	0.48	
Sargassum vulgare	-	-	12.9	
Padina pavonia	-	0.28	3.8	
USM (Ph)	**(0)**	**(0.36)^b**	**(138)^a**	**(46.18)^c**
Rhodophyta				
Acanthophora najadiformis	16.6	1.84	-	
Corallina mediterranea	0.6	0.88	23.2	
Ceramiumciliatum	-	5	-	
Gelidium crinale	-	-	22.5	
Gracilaria verrucosa	-	27.4	16.1	
Hypnea muscifarmus	0.2	0.32	10.96	
Gigartina acicularia	0.16	0.12	31.64	
Laurencia obtuse	12.6	16.7	44.84	
Rytiphlaea tinctoria	-	0.32	-	

Porphyra leucosticte	-	-	0.01	
Plocamium cartilagineum	-	0.08	0.12	
Jania rubens	3.7	19.5	27.4	
USM (Rh)	**33.9[b]**	**72.16[c]**	**176.8[a]**	**(94.26)[a]**
Total biomass				**(156.18)**
Total biomass at each level	**57.16[b]**	**93.44[c]**	**317.9[a]**	
Total number of species at each level	**8[b]**	**17[a]**	**19[a]**	
(-) means absent; USM (Ch) = Total biomass of Chlorphyta; USM (Ph)=Total biomass of Phyophyceae; USM (Rh)= Total biomass of Rhodophyta. Different letters show significant differences.				

In addition, the result of the total biomass at each level (High tide, mid tide and, low tide) revealed low tidal zone had a maximum biomass 317.9g dw/m^2 Table (1), followed by mid tide (93.44g dw/m^2), while high tide zone was least biomass (57.16g dw/m^2). Direct sunlight, wave and temperature are the most important factors affecting the distribution and growth of macro-algae. Furthermore, the biomass showed clearly different (p <0.05) between classes at three levels except Chlorophyta at high tide and low tide was similar Table (1).

Also, the biomass of an individual species was different in the intertidal zone of Tajura Figure (3). *Cystoseira compressa* had maximum biomass (36.8gdw/m^2), followed by *Laurencia obtusa* (24.7gdw/m^2), *Jania rubens* (16.8gdw/m^2), *Gracilaria verrucosa* (14.5gdw/m^2), *Gigartina acicularia* (10.6gdw/m^2), *Ulva lactuca* (9.2gdw/m^2), *Corallina mediterranea* (8.2gdw/m^2), *Gelidium crinale* (7.5g dw/m^2), *Acanthophora najadiformis* (6.1gdw/m^2) and *Ulva linza* (5.2gdw/m^2). While the other species were recorded biomass less than 5gdw/m^2. Depending on biomass, the dominant species in the intertidal zone of Tajura were *C. compressa*, followed by *L. obtuse* and *Jania rubens*.

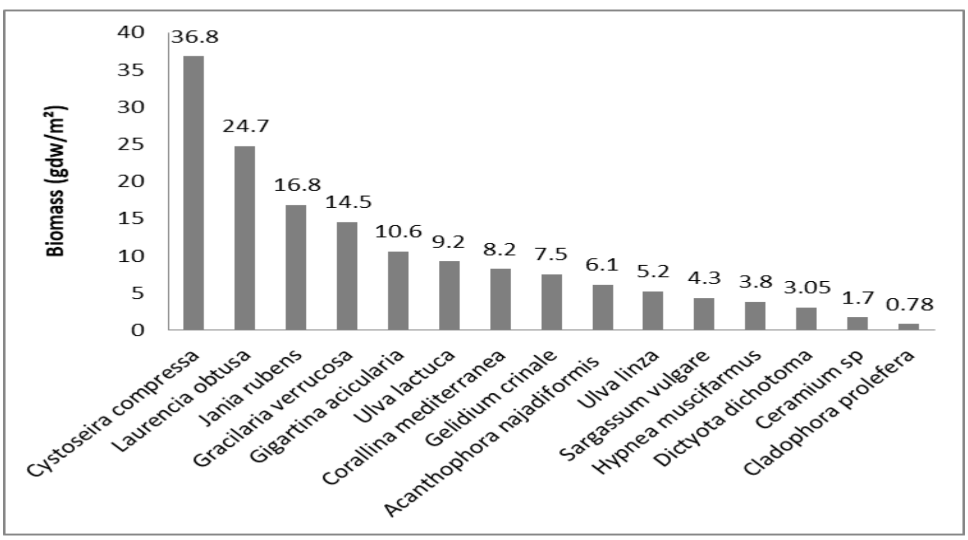

Figure (3):The Average Dry Weight (g/m^2) of Individual Species in the Intertidal Rocky Shore of Tajura Coast, Libya.

Conclusion

In conclusion, a total of 24 species of marine macro-algae were recorded in the intertidal zone of Tajura on March 2021. Rhodophyta was more diversity (12 species) and biomass (94.8 g).The mid tide and low tide zones were the main habitats for the growth and abundance of seaweeds (17 - 19 species with biomass 93.4 - 317g dw/m^2) most of them belonging to Rhodophyta. The maximum biomass was recorded by *C. compressa* (36.8g dw/m^2), followed by *L. obtusa* (24.7g dw/m^2), *J. rubens* (16.8g dw/m^2) and *G. verrucosa* (14.5g dw/m^2). This study was an initial step toward understanding the qualitative and quantitative of seaweed in the intertidal rocky shore of Libya. Therefore, future research is required on understanding the seaweeds community dynamics in a different area of Libyan especially, on biomass. Also, this study is a useful baseline that can be built our knowledge about Libyan seaweed.

Acknowledgment

The authors are grateful to the Marine Biology Research Centre (MBRC), Providing research facilities and continuous support.

References

- Ardissone, F. (1893). Note alla Phycologia mediterranea. Rend. R. Inst. Lombardo Sci. Lett. Ser. 2, 26: 674-690.

- Arevalo, R; Pinedo, S and Ballesteros, E. (2007). Changes in the composition and structure of Mediterranean rocky-shore communities following a gradient of nutrient enrichment: descriptive study and test of proposed methods to assess water quality regarding macroalgae. Mar. Pollut .Bull. 55, 104-113.

- Bates, R; DeWreede, E. (2007). Changes in seaweed biodiversity influence associated invertebrate epifauna. J. Exp. Mar. Biol. Ecol.344:206–14.

- Ben Maiz, N.; Boudouresque, C. F. and Ouahchi, F. (1987). Invetaire des algues ét phanerogames marines benthiques de la Tunisie. Istratto da "Giornale Botanico Italiano" Vol. 121, n. 5-6, 259-304.

- Choi, G. and Huh, H. (2008). Composition of marine algal community at the intertidal zone in Gwangyang Bay, South Sea, Korea. J Korean Fish Soc 41, 201-207.

- De Toni, B. (1892). Secondo pugilio di alghe tripolitane. Rend. R. Acc. Naz. Lincei (Roma). Ser. 5, 1: 140-147.

- De Toni, B. (1895). Terzo pugillo di algahe tripolitane. Rend. R. Acc. Naz. Lincei (Roma). Ser. 5, 5: 451-457.

- De Toni, B. and Forti, A. (1913). Contribution a la flore algologique de la Tripolitaine et de la Cyrenaique. Ann. Inst. Ocaenogr. 5:1-56.

- De Toni, B. and Forti, A. (1914). Plantae cellular-Algae, pp. 289-304. In: R.

- De Toni, B. and Levi. D.(1888). Pugillo di algae tripolitane. Firenze.

- El-Ayouty, M; El-Essawy, A. and Said, A. (1999). The assessment of water quality of Enan and El-Abassa ponds, Egypt. Acta Hydrobiol, 41, 2, 117-137.

- Fatemi S, Ghavam MP, Rafiee F, Taheri MS. (2012). The study of seaweeds biomass from intertidal rocky shores of Qeshm Island, Persian Gulf. Int J Mar Sci Eng. 2:101–6.

- Fischer, W; Bauchot, L; Schneider, M. (2007). Fiches FAO d’identification des espèces pour les besoins de la pêche. (Révision 1). Méditerranée et mer Noire. Zone de pêche, 37, I. Végétaux et Invertébrés.

- Foster, S; Dean, A and Deyher, E. (1985). Subtidal techniques. In: Littler MM, Littler DS (eds) Handbook of phycological methods: ecological field methods: macroalgae. Cambridge University Press, Cambridge, pp 199–231.

- Godeh, M; El-Menifi ,O. and Said, A. (2009). Marine algae of Tobruk and Ain Ghazala coasts, Libya. Garyounis University Press. Journal of Science and Its Applications. Vol. 3, No. 1, pp 42-55.

- Godeh, M; Nizamuddin, M. and El-Menifi, F. (1992). Marine algae from eastern coast of Libya (Cyrenaica). Pak. J. Bot., 24: pp11-21.

- Godeh, M; Said, A; El-Menifi , O. and Zarmouh, M. (2017). Marine Algae of Sert Coasts, Libya. Benghazi University Press, Journal of Science and Its Applications. 5(1): pp 41-44.

- Godeh, M; Said, A; Zarmouh, M and El-Menifi, F. (2010). A List of Marine Rhodophyta of Benghazi coasts, Libya Egypt. J. Exp. Biol. (Bot.), Vol.6, No. 2, pp 93 – 97.

- Godeh, M; Said, A; Zarmouh, M and El-Menifi, F. (2011). Marine Phaeophyceae of Benghazi coasts, Libya. Journal of Sebha University- (Pure and Applied Sciences).Vol.10, No.1, pp 32-39.

- Huni, A. and Aravindan , C. (1984). A preliminary study of intertidal organisms on a rocky platform of Tajura coast near Tripoli (Libya). Libyan Journal of Science, Vol. 13, pp 1-8.

- Koch, M; Bowes, G; Ross, C. and Zhang, H.(2013). Climate change and ocean acidification effects on seagrasses and marine macroalgae. Glob. Chang. Biol. Vol 19, pp 103-32.

- Lemoine, P. (1915). Calcareous algae. Report on the Danish Oceanographical Expeditions 1908-10 to the Mediterranean and adjacent seas. Vol. II, Biology, K.I. 30 pp., 10 figs. 1 pl.

- Lenzi, M.; Franchi, E.; Giovani, P.; Micarelli, P.; Pera, G.; Roffilli, R.; Solari, D. And Silvano, F. (2007). Change in the phytobenthos settlement along the Santa Liberata coast (Southern Tuscany, Italy): Proceeding of the 3rd Mediterranean symposium on marine vegetation. 27-29 March 2007 - Marseilles. 88-95.

- Murray, N. and Littler, M. (1984). Analysis of seaweed communities in a disturbed rocky intertidal environment near Whites Point, Los Angeles, Calif., U.S.A. Hydrobiologia 116/117, pp 374-382.

- Nizamuddin, M. (1985). A new species of Cystoseira C. Ag. (Phaeophyta) from the eastern Part of Libya. Nova Hedwigia. Band 42. Braunschweig. J. Cramer pp.119-125.

- Nizamuddin, M. (1987). Observations on the genus *Flabellia* (Caulerpales, Chlorophyta). Nova Hehwigia. Vol. 44.pp 175 -188.

- Nizamuddin, M. (1991). The green marine algae of Libya. Elga, Bern. pp 1-11.

- Nizamuddin, M. and El-Menifi, F. (1993). A new species of the genus *Codium* (Chlorophyta-Codiales) from the eastern coast of Libya. Pak. J. Bot. Vol. 25, No. 2, pp 208-214.

- Nizamuddin, M.and Godeh M. (1989). *Stypopordium tubruqense* (Phaeophyta, Dictyotales), a new species from the Mediterranean Sea. Willdenowia, Vol. 18, pp 603-608.

- Nizamuddin, M. and Godeh, M. (1990a). A first record of the genus *Cottoniella Borgesen* (Ceramiales, Rhodophyta) from Libya. Pak. J. Bot. Vol. 25, No.1, pp 24-35.

- Nizamuddin, M. and Godeh, M. (1990b). Studies on the new species of *Cottoniella* from the coast of Libya. Pak. Jour. Bot. Vol. 22.pp 24-35.

- Nizamuddin, M. and Godeh, M. (1990c). Studies on the genera Chaetomorpha Kutz. and Rhizoclonium Kütz. Cldophorales-Cladophoraceae from the Libyan coast. National Herbarium Uni. Al-Fateh, Tripoli. Bull. ULT, Vol. 2, pp 11-37.

- Nizamuddin, M. and Godeh, M. (1993). Observations on *Taonia atomaria* F. ciliate (Lamour.) Nizamuddin. Pak. J. Bot. Vol. 25, No. 2, pp 199-207.

- Nizamuddin, M; West, A. and Menez, G. (1979). A list of marine algae from Libya. Bot. Mar., Vol. 22, pp 465-476.

- Pampanini, R. (1931). Prodromo della Cirenaica. Algae. pp.1-40.

- Piazzi, L; Pardi, G; Balata, D; Cecchi, E. and Cinelli, F. (2002). Seasonal dynamics of a subtidal north-western Mediterranean macro-algal community in relation to depth and substrate inclination. Bot Mar Vol. 45, pp 243-252.

- Prathep, A. (2005). Spatial and temporal variations in diversity and percentage cover of macroalgae at Sirinart marine national park, Phuket Province, Thailand. Sci Asia Vol. 31, pp 225-233.

- Raineri, R. (1920). Alghe della Cirenaica. Ann. R. Ist. Bot. Roma. Vol. 5, pp 45-52.

- Raineri, R. (1921). Corallinaceae del Littorale tripolaitane. Nuova Notarisia, Vol. 32, pp 133-149.

- Riedl, R. (1991). Fauna e flora del Mediterraneo. Franco Muzzio Editore, pp 777.

- Said, A. and Godeh, M. (2008). Marine algae of Tukra and Tolmeta coasts, Libya. Egyptian J. of Phycol. Vol. 9, pp 167-179.

- Said, A; Godeh, M. and El-Menifi, F. (2010). Marine algae of Derna, Susa and Tolmeta coasts, Libya. The Second International Conference on Phycology, Limnology and Aquatic Sciences. pp14-15.

- Said, A; Godeh, M. and El-Menifi, F; Zarmouh, M and Bleibi lo, M. (2013). Marine brown algae of Benghazi and Tripoli coasts, eastern and western Libya. Egypt. J. Exp. Biol. (Bot.), Vol. 9, No,1 , pp 49 - 53.

- Shtewi , O. and Hana, A. (2015). Marine algae of western coast of Libya (Zawia region). Al-Jameai Academic J.Vol. 22, pp 3-9.

- Wells, E; Wilkionson, M; Wood, P. and Scanlan, C. (2007). The use of macroalgal species richness and composition on intertidal rocky seashores in the assessment of ecological quality under the European water framework directive. Mar Pollut Bull Vol. 55, pp 151-161.

- Wilhm, J. L. (1975). Biological indicators of pollution- In: Whitton, B. A. (ed.), River ecology. - Blackwell. Oxford: pp. 375-400.