Seasonal variations in biomass and species composition of seaweeds along the northern coasts of Persian Gulf (Bushehr Province)

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This study was carried out to evaluate the seasonal variations of seaweed biomass and species composition at six different sites along the coastal areas in Bushehr Province. Sampling depths varied among sites, from 0.3 to 2.0 m below mean sea level. A total of 37 (i.e., 10 Chlorophyta, 12 Phaeophyta and 15 Rhodophyta) seaweed species were collected. Studies were conducted for quantifying the seaweeds during four seasons from October 2008 until July 2009. During present research, *Ulva intestinalis* and *Cladophora nitellopsis* of green, *Polycladia myrica*, *Sirophysalia trinodis* and *Sargassum angustifolium* of brown and *Gracilaria canaliculata* and *Hypnea cervicornis* of red seaweeds showed highest biomass in coastal areas of Bushehr Province. The Cheney's ratio of 2.1 indicated a temperate algal flora to this area. All sites exhibited more than 50% similarity of algal species, indicating a relatively homogenous algal distribution. Total biomass showed the highest value of 3280.7 ± 537.8 g dry wt m^{-2} during summer and lowest value of 856.9 ± 92.0 g dry wt m^{-2} during winter. During this study, the highest and lowest seaweed biomass were recorded on the site 2 (2473.7 ± 311.0 g dry wt m^{-2}) and site 5 (856.7 ± 96.8 g dry wt m^{-2}), respectively.

1. Introduction

The Persian Gulf is a shallow semi-enclosed sea, bordered by Iran, Iraq, Kuwait, Saudi Arabia, Bahrain, Qatar, United Arab Emirates (UAE), and Oman. It has a surface area of 239,000 km^2, a mean depth of 36 m (maximum depth is in the Strait of Hormuz ∼100 m), and an average volume of 8630 km^3 (Reynolds 1993). The ecologic significance of the entire area is that it functions as a reservoir that provides adjacent coasts with eggs, larvae and organisms; thereby maintaining a biological inventory which otherwise would not be so rich.

Bushehr Province is stretched along the Iranian coast of the Persian Gulf and has 625 km of shoreline. Mostly, coastal zone of Bushehr Province is characterised by consolidated sediments favouring the development of rich algal flora. There is limited research about algal flora in this area (e.g., Sohrabi

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and Rabii 1997); while in other parts of the Persian Gulf, the study on algal flora has been conducted by several researchers (e.g., Basson 1979a, 1979b; Basson *et al* 1989; Dadolahi and Savari 2005). The objective of this study is focused on the biomass estimation together with species composition of marine algae along the coastal areas of Bushehr Province.

2. Materials and methods

Field study was conducted at the Bushehr Province located in the northern coast line of the Persian Gulf at six sites (table 1; figure 1). Permanent markers were placed at each site to allow for relocation in subsequent sampling effort. At each site, nine random samples from different tidal areas (upper, mid and infra littoral) were collected in each season (October 2008; January, May and July 2009) for understanding the seasonal differences in the composition and biomass of the algal flora. Algal samples were collected by hand from the intertidal zone during low tide. A 50 × 50 cm quadrate was marked with a square metal frame (Dawes 1998; Dadolahi and Savari 2005) and all algal samples were collected within this area. For the biomass study the samples were weighed (dry weight) with a digital balance to the nearest 0.01 g. The biomass was estimated both in grams dry weight m^{-2} and in percentage, for each algal species. Physicochemical parameters were measured in the field using WTW (Wissenschaftlich Technische Werkstätten) Model Sentx-97 instrument for temperature, salinity, dissolved oxygen, pH and WTW-Lf-597 for conductivity.

Algal species were identified using standard identification keys (e.g., Basson 1979a, 1979b; Begum and Khatoon 1988; Al-Hassan and Jones 1989; Basson *et al* 1989; Sohrabi and Rabii 1997). Nonparametric statistical analysis (Kruskal–Wallis one-way analysis of variance) was used during this study. Two-way analysis of variance (ANOVA) was employed to compare the season and division of seaweeds and the interactions between them. Tukey's HSD test was run to compare annual biomass of three classes for each site. The calculation of ecological indices, Shannon–Wiener diversity index (based on $\log_{10}$), the Margalef species richness index, the Simpson's dominance index, as well as the Pielou's evenness index were based on a methodology adapted to the macroalgal by Belegratis *et al* (1999). The number and percentage of taxa shared by different sites were calculated as per cent similarity (C) values using the Czekanowski coefficient (Mathieson and Penniman 1986).

$$C = \frac{2w}{a + b}$$

where w is the number of taxa in common at both sites, a is the number of taxa at the one site and b is the number of taxa at the second site. The nature of the entire seaweed flora was also compared to the one reported from the other parts of the Persian Gulf using Cheney's floristic ratio (Mathieson and Penniman 1986; Kaldy *et al* 1995; Dadolahi and Savari 2005).

$$\text{Floristicaffinity} = \frac{(R - C)}{P} = \frac{\text{Number of Rhodophyta spp.} + \text{Number of Chlorophyta spp.}}{\text{Number of Phaeophyta spp.}}$$

where a value <3.0 indicates a temperate flora, a value >6.0 indicates a tropical flora, and intermediate values represent mix floristic affinity.

3. Results

The results of physicochemical parameters are presented in table 2. Temperature ranged from 14.8° to 39.8°C during winter and summer seasons, respectively. The highest (43 ppt) and lowest (32 ppt) salinity values were recorded at summer and autumn seasons, respectively. During the study period, seaweed samples constituted a total 37 species (table 3). The diversity of the seaweed species showed a declining trend from site 1 towards site 6. The results of average biomass

Table 1. *Characteristics of the sampling sites.*

Site no.	Total biomass (g dry wt m^{-2})	Slope	Tidal area (m)	Kind of substrate
Site 1	2105.6	Low	800	Sandy and rocky
Site 2	2473.7	Low	1000	Gravel and rocky
Site 3	1964.8	Low	700	Rocky
Site 4	2176.3	Relatively steep	400	Rocky
Site 5	856.7	Steep	200	Almost sandy
Site 6	939.0	Relatively low	600	Sandy and muddy

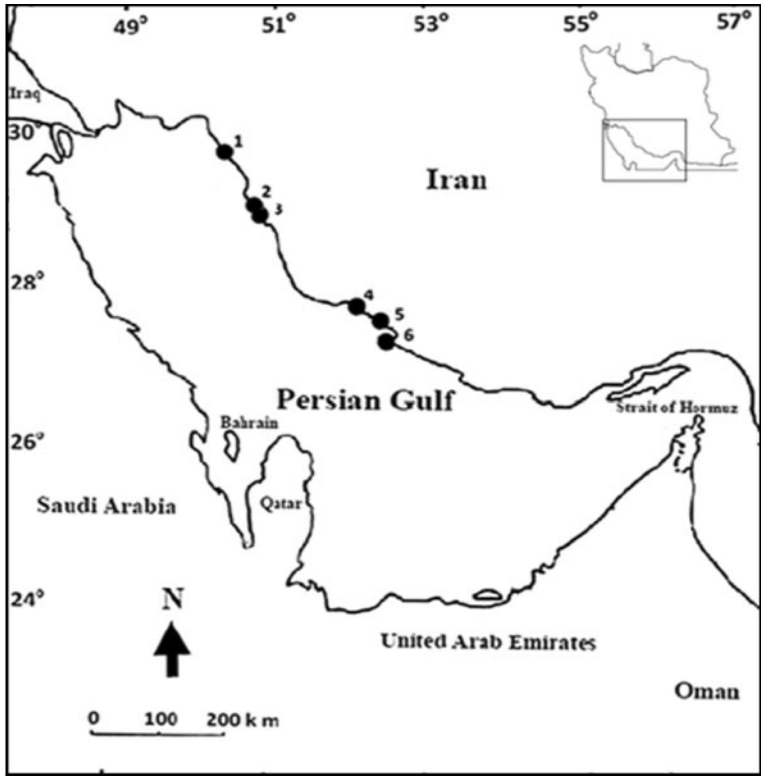

Figure 1. Numbers 1 to 6 indicate sampling sites along the northern part of the Persian Gulf.

and per cent values of seaweed in each site and in each season along with mean total biomass are presented in tables 4 and 5. Mean maximum (308.8 g dry wt m^{-2}) biomass of green seaweeds was found during autumn and the minimum value (100.8 g dry wt m^{-2}) in spring with respective relative biomass values of 27% and 6%. Sites 1 and 4 showed the highest annual mean biomass of 248.1 and 364.9 g dry wt m^{-2} respectively. Whereas, the lowest annual mean biomass of 54.8 g dry wt m^{-2} was observed in site 6 (table 4). The most abundant green alga was *Ulva intestinalis,* showing the highest biomass during all seasons (except in summer) with maximum and minimum values of 162.5 and 27.3 g dry wt m^{-2} during autumn and winter, respectively (table 5). The Shannon–Wiener diversity index of green seaweeds during different seasons ranged from 0.51 to 1.55. Pielou's evenness index was relatively same in different seasons. Meanwhile, Simpson's dominance index was generally low with mean value around 0.42. However, Margalef species richness index showed maximum value of 1.08 during summer (table 6).

The annual mean biomass of Phaeophyta was maximum at sites 2 (1297.2 g dry wt m^{-2}) and 4 (1277.0 g dry wt m^{-2}) followed by site 1 (1139.3 g dry wt m^{-2}) and site 3 (899.7 g dry wt m^{-2}). Whereas, minimum values of 418.2 g dry wt m^{-2} was observed at site 5 (table 4). The brown seaweeds showed mean maximum biomass (2033.5 g dry wt m^{-2}) during summer and minimum biomass (337.1 g dry wt m^{-2}) in winter with the respective relative biomass values of 62% and 39% (table 4). *Sirophysalis trinodis* and*Polycladia myrica* were most abundantly represented having maximum biomass values of 861.8 and 634.9 g dry wt m^{-2} in summer respectively (table 5). During different seasons, Shannon–Wiener diversity index in Phaeophyta showed higher than the Chlorophyta. Pielou's evenness index was relatively same as Chlorophyta. The Simpson's dominance index showed minimum value of 0.15 in spring. However, Margalef species richness index showed maximum value of 1.54 during spring (table 6).

Red algae showed a maximum mean biomass of 1076.3 g dry wt m^{-2} during summer and minimum value of 155.5 g dry wt m^{-2} in autumn with respective relative biomass values of 33% and 14%. Annual mean maximum biomass of Rhodophyta was found at sites 2 (938.3 g dry wt m^{-2}), 3 (903.0 g dry wt m^{-2}) and followed by site 1 (718.2 g dry wt m^{-2}). Meanwhile, minimum value of 341.3 g dry wt m^{-2} was observed at site 5 (table 4). Among all Rhodophyta species, *Geracilaria canaliculata* showed maximum abundance in all seasons with average maximum biomass of 284.9.g dry wt m^{-2}

Table 2. *Results of physicochemical parameters (±s.d) during different seasons and sites.*

Site no.	Autumn				Winter				Spring				Summer			
	Temp. (°C)	pH	Cond. (S/m)	Sal. (‰)	Temp. (°C)	pH	Cond. (S/m)	Sal. (‰)	Temp. (°C)	pH	Cond. (S/m)	Sal. (‰)	Temp. (°C)	pH	Cond. (S/m)	Sal. (‰)
Site 1	33 ± 1	8.2 ± 0.3	58 ± 2	34 ± 2	15 ± 0	7.9 ± 0.1	43 ± 2	35 ± 3	24 ± 1	7.8 ± 0.2	50 ± 2	39 ± 2	34 ± 1	8.0 ± 0.4	61 ± 3	34 ± 2
Site 2	35 ± 1	8.5 ± 0.2	60 ± 2	32 ± 1	20 ± 1	8.3 ± 0.4	46 ± 3	35 ± 2	29 ± 1	7.3 ± 0.3	46 ± 3	39 ± 3	40 ± 2	8.4 ± 0.7	62 ± 2	40 ± 4
Site 3	33 ± 2	8.8 ± 0.3	57 ± 3	32 ± 2	19 ± 1	8.5 ± 0.3	46 ± 2	39 ± 3	28 ± 1	7.3 ± 0.5	48 ± 2	42 ± 2	38 ± 1	8.2 ± 0.2	61 ± 5	41 ± 3
Site 4	38 ± 1	8.4 ± 0.2	57 ± 2	37 ± 1	21 ± 1	8.1 ± 0.5	47 ± 1	34 ± 2	29 ± 1	7.4 ± 0.6	51 ± 3	42 ± 3	40 ± 2	8.5 ± 0.1	58 ± 2	43 ± 2
Site 5	34 ± 2	8.7 ± 0.1	57 ± 1	36 ± 2	19 ± 2	8.4 ± 0.4	46 ± 2	38 ± 3	29 ± 0	7.7 ± 0.3	49 ± 2	33 ± 3	34 ± 2	8.7 ± 0.3	57 ± 3	38 ± 2
Site 6	39 ± 1	8.6 ± 0.2	58 ± 1	37 ± 2	18 ± 1	8.3 ± 0.2	48 ± 3	34 ± 3	28 ± 1	7.9 ± 0.1	52 ± 2	39 ± 4	36 ± 2	8.2 ± 0.2	60 ± 6	41 ± 2

in summer (table 5). The Shannon–Wiener diversity index during different seasons in Rhodophyta was generally high. Pielou's evenness index showed mean value around 0.82. However, Simpson's dominance index showed generally low value compared to others. Margalef species richness index showed high with maximum value of 1.66 during summer (table 6).

Species composition for six sites is as follows: Chlorophyta is represented by 10 species, of which *Cladophora nitellopsis, Chaetomorpha californica* and *Cladophoropsis membranacea* are common to all sites; Phaeophyta constitutes 12 species of which, *Padina austeralis, Sargassum angustifolium, Polycladia myrica* and *Sirophysalis trinodis* are common to all sites; Rhodophyta is composed of 15 species, *Hypnea cervicornis, Champia parvula, Laurencia snyderia, Acanthophora spicifera, Geracilaria canaliculata* and *Jania rubens* being common in all sites. During this study, the Shannon–Wiener diversity index along different sites showed relatively high with mean value of 2.43. Pielou's evenness index showed generally low values. Meanwhile, Simpson's dominance index was relatively low with mean value around 0.21. On the other hand, Margalef species richness index ranged from 1.84 to 3.85 at sites 5 and 3, respectively (table 7).

4. Discussion

The biomass as well as species composition of seaweeds largely depend on season, population structure and several other ecological factors (Thakur *et al* 2008). This study indicated that the brown seaweeds had maximum distribution along the northern coastlines of the Persian Gulf (Bushehr Province). Probably, it might be due to the environmental conditions (e.g., long tidal area, type of substratum and less exposure to wind and wave actions) suitable for the growth of seaweed. Among all sites, higher Shannon–Wiener diversity index, Pielou's evenness index and Margalef richness species were observed at sites 1–4 compared to other sites (table 7). It is evident from the data, that Phaeophyta and Rhodophyta showed maximum biomass during summer and minimum biomass of Phaeophyta and Rhodophyta was observed during winter and autumn, respectively. Meanwhile, Chlorophyta showed maximum and minimum biomass during autumn and spring, respectively. However, among all seasons the lower species diversity (higher Shannon–Wiener diversity index, Pielou's evenness index, and lower Simpson's dominance value) was observed during cold seasons (table 8).

In this study, based on three different parts of intertidal zone, Chlorophyta, Phaeophyta and

Table 3. *Species abundance of seaweeds along the northern coast of the Persian Gulf.*

Species	Sampling sites					
	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6
Chlorophyta						
Ulva intestinalis Linnaeus	++	+++	++	++	++	++
Ulva compressa Linnaeus	−	+++	−	++	+	−
Ulva clathrata (Roth) C Agardh	−	+++	++	++	−	+
Cladophora nitellopsis Børgesen	+	+	+	−	+++	++
Cladophora sericioides Børgesen	++	+	++	+	−	+
Chaetomorpha californica F S Collins	++	+	+	+	+	++
Cladophoropsis memberanceae (Hofman Bang ex C Agardh) Børgesen	++	−	−	−	−	++
Rhizoclonium implexum (Dillwyn) Kützing	+++	+	++	+++	−	−
Caulerpa sertularioides (S G Gmelin) M A Howe	−	+	+	+	−	−
Avrainvillea calathina Kraft and Olsen-Stojkovich	−	−	+	+++	−	−
Phaeophyta						
Dictyota implexa (Desfontaines) J V Lamouroux	−	+++	++	−	−	−
Padina australis Hauck	++	+	++	+	+	+
Padina pavonica (Linnaeus) Thivy	+	++	+++	++	−	−
Padina tetrastromatica Hauck	−	−	−	−	−	+++
Sargassum angustifolium C Agardh	+	++	+	+++	−	−
Sargassum vulgare C Agardh	−	−	−	+++	++	−
Sargassum ilicifolium (Turner) C Agardh	+++	−	+	+	−	−
Polycladia myrica (S G Gmelin) Draima, Ballesteros, F Rousseau and T Thibaut	+	++	+	+++	+	++
Stephanocystis neglecta (Setchell and N L Gardner) Draisma, Ballesteros, F Rousseau and T Thibaut	−	−	+++	−	−	−
Sirophysalis trinodis (Forsskal) Kützing	+	+	++	++	+	−
Iyengaria stellata (Børgesen) Børgesen	−	+++	+	++	−	+
Colpomenia sinuosa (Mertens ex Roth) Derbès and Solier	+	++	+++	+	−	−
Rhodophyta						
Sarconema filiforme (Sonder) Kylin	+	+++	+	−	++	+
Gelidiella acerosa (Forsskål) Feldmann and G Hamel	++	+	++	+	+	++
Hypnea spinella (C Agardh) Kützing	++	+++	+	+	+	+
Hypnea cornuta (Kützing) J Agardh	+	−	++	++	+	+
Champia globulifera Børgesen	−	−	−	++	++	−
Champia parvula (C Agardh) Harvey	++	++	++	++	+	+
Laurencia snyderae var. *guadalupensis* E Y Dawson	+++	++	+++	+	−	+
Laurencia obtuse var. *delilii* (C Agardh) Zanardini	+++	−	+	−	−	−
Laurencia snyderae E Y Dawson	+	−	+++	−	−	−
Acanthophora spicifera (M Vahl) Børgesen	++	+	+++	+	−	−
Acanthophora muscoides (Linnaeus) Bory de Saint-Vincent	−	+	+	+	−	−
Gracilaria canaliculata Sonder	−	+++	++	+	−	−
Gracilaria folifera (Forsskål) Børgesen	−	+++	+	−	−	−
Gracilaria corticata (J Agardh) J Agardh	−	+	++	−	−	−
Jania rubens (Linnaeus) J V Lamouroux	+++	++	++	−	−	−

+++: dominant; ++: average; +: meager, and −: absent.

Rhodophyta occupied the upper, mid and infra littoral to 70%, 51% and 53%, respectively. Probably this suggests that the distribution of algae depends on the pigment composition and light requirement by different algal groups. Long wavelengths (red and infrared) are absorbed in the top meters of water, as very short wavelengths (ultraviolet) so that light penetrating to below 10 m is mainly blue–green (Dadolahi and Savari 2005). The following zonation could be observed; green algae

Table 4. *Average biomass (g dry wt m^{-2}) and percent values of seaweed in the different seasons.*

	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Mean total biomass
Spring							
Chlorophyta	48.4 (3%)	125.0 (7%)	90.3 (4%)	282.3 (16%)	40.2 (10%)	18.6 (1%)	100.8 (6%)
Phaeophyta	593.0 (36%)	632.4 (33%)	532.6 (25%)	786.5 (44%)	185.4 (47%)	865.2 (42%)	599.2 (36%)
Rhodophyta	986.3 (61%)	1160.3 (61%)	1542.6 (71%)	704.3 (40%)	168.0 (43%)	1163.0 (57%)	954.1 (58%)
Total biomass	1627.7	1917.7	2165.5	1773.1	393.6	2046.8	1653.4
Standard error	271.9	298.9	429.8	156.2	45.8	342.8	247.7
C.V (%)	0.9	0.8	1.0	0.5	0.6	0.9	0.8
Summer							
Chlorophyta	306.0 (7%)	195.3 (4%)	82.3 (2%)	262.5 (6%)	67.0 (3%)	112.3 (9%)	170.9 (5%)
Phaeophyta	2698.0 (65%)	2865.1 (62%)	1974.0 (58%)	3126.3 (73%)	963.2 (48%)	574.6 (47%)	2033.5 (62%)
Rhodophyta	1145.4 (28%)	1582.3 (34%)	1323.7 (39%)	896.3 (21%)	978.2 (49%)	532.0 (44%)	1076.3 (33%)
Total biomass	4149.4	4642.7	3380.0	4285.1	2008.4	1218.9	3280.7
Standard error	700.7	770.9	554.9	868.5	301.3	147.5	537.8
C.V (%)	0.9	0.9	0.9	1.1	0.8	0.6	0.9
Autumn							
Chlorophyta	395.3 (27%)	519.2 (28%)	351.4 (33%)	305.0 (23%)	281.8 (27%)	N.D	308.8 (27%)
Phaeophyta	864.2 (60%)	1125.7 (60%)	582.2 (54%)	896.5 (66%)	524.1 (51%)	N.D	665.4 (59%)
Rhodophyta	186.7 (13%)	232.0 (12%)	147.5 (14%)	147.6 (11%)	219.0 (21%)	N.D	155.5 (14%)
Total biomass	1446.2	1876.9	1081.1	1349.1	1024.9	N.D	1129.7
Standard error	200.3	263.4	125.6	228.0	93.0	N.D	151.0
C.V (%)	0.7	0.7	0.6	0.9	0.5	N.D	0.7
Winter							
Chlorophyta	243.0 (20%)	113.3 (8%)	124.7 (10%)	72.0 (9%)	N.D	88.5 (18%)	106.9 (12%)
Phaeophyta	402.3 (34%)	565.8 (39%)	510.2 (41%)	298.7 (39%)	N.D	246.0 (50%)	337.1 (39%)
Rhodophyta	554.5 (46%)	778.7 (53%)	598.3 (49%)	389.4 (51%)	N.D	156.3 (32%)	412.9 (48%)
Total biomass	1199.8	1457.8	1233.2	760.1	N.D	490.8	856.9
Standard error	89.9	196.2	145.4	94.4	N.D	45.6	92.0
C.V (%)	0.4	0.7	0.6	0.6	N.D	0.5	0.6
Annual means							
Chlorophyta	248.1 (12%)	238.2 (10%)	162.1 (8%)	364.9 (17%)	97.2 (11%)	54.8 (6%)	
Phaeophyta	1139.3 (54%)	1297.2 (52%)	899.7 (46%)	1277.0 (59%)	418.2 (49%)	421.4 (45%)	
Rhodophyta	718.2 (34%)	938.3 (38%)	903.0 (46%)	534.4 (25%)	341.3 (40%)	462.8 (49%)	
Total biomass	2105.6	2473.7	1964.8	2176.3	856.7	939.0	
Standard error	257.4	311.0	246.4	280.1	96.8	129.7	
C.V (%)	0.6	0.7	0.7	0.7	0.6	0.7	

C.V: Coefficient of variation. N.D: No data.

Table 5. *Average biomass (g dry wt m^{-2}) of seaweeds species in four seasons.*

	Spring	Summer	Autumn	Winter	Total
Chlorophyta					
Ulva intestinalis	79.2	N.D	162.5	27.3	269.0
Ulva compressa	N.D	42.1	N.D	1.2	43.3
Ulva clathrata	N.D	N.D	30.2	5.2	35.4
Cladophora nitellopsis	57.0	24.0	0.3	42.9	124.2
Cladophora sericioides	N.D	12.9	44.0	9.6	66.5
Chaetomorpha californica	6.4	38.1	11.8	16.8	73.1
Cladophoropsis memberanceae	13.4	5.2	3.0	3.9	25.5
Rhizoclonium implexum	1.1	11.5	57.0	N.D	69.6
Caulerpa sertularioides	N.D	26.5	N.D	N.D	26.5
Avrainvillea calathina	N.D	10.5	N.D	N.D	10.5
Total biomass	157.1	170.8	308.8	106.9	743.6
Phaeophyta					
Dictyota implexa	N.D	N.D	15.8	N.D	15.8
Padina australis	16.7	4.3	81.8	8.5	111.3
Padina pavonica	2.9	109.5	39.2	N.D	151.6
Padina tetratromatica	11.1	6.1	N.D	N.D	17.2
Sargassum angustifolium	73.5	403.9	198.6	12.8	688.8
Sargassum vulgare	72.5	N.D	50.5	N.D	123.0
Sargassum ilicifolium	6.2	13.1	N.D	14.4	33.7
Polycladia myrica	291.2	634.9	249.1	129.2	1304.4
Stephanocystis neglecta	22.6	N.D	N.D	7.7	30.3
Sirophysalis trinodis	27.2	861.8	30.4	1.3	920.7
Iyengaria stellata	19.0	N.D	N.D	9.0	28.0
Colpomenia sinuosa	56.3	N.D	N.D	154.3	210.6
Total biomass	599.2	2033.6	665.4	337.2	3635.4
Rhodophyta					
Sarconema filiforme	29.0	20.9	N.D	6.7	56.6
Gelidiella acerosa	13.3	1.9	N.D	10.3	25.5
Hypnea spinella	48.2	245.3	2.4	48.8	344.7
Hypnia cornuta	N.D	8.8	55.4	41.3	105.5
Champia globulifera	N.D	12.9	N.D	N.D	12.9
Champia parvula	41.0	39.6	17.9	36.0	134.5
Laurencia snyderae	69.3	48.6	37.4	59.4	214.7
Laurencia obtuse	271.0	N.D	N.D	12.1	283.1
Laurencia snyderae	8.4	N.D	N.D	N.D	8.4
Acanthophora spicifera	158.0	126.4	13.4	39.5	337.3
Acanthophora muscoides	N.D	23.9	0.9	N.D	24.8
Gracilaria canaliculata	220.8	284.9	25.9	106.4	638.0
Gracilaria folifera	N.D	110.9	N.D	N.D	110.9
Gracilaria corticata	N.D	123.4	N.D	N.D	123.4
Jania rubens	95.1	28.9	2.2	52.4	178.6
Total biomass	954.1	1076.4	155.5	412.9	2598.9

N.D: No data.

were found in the upper intertidal, where chlorophyll was most efficient at absorbing light over a wide range of wavelengths; brown algae occurred further down, using fucoxanthin pigments where red light was scarce; red algae were found deeper, where phycoerythrin pigments were most efficient at absorbing the greener light.

Since all marine plants near the sea surface in fact receive more light than they require, they need protection from too much light at any wavelength rather than efficient mechanisms for absorbing it. It is now thought that pigment composition may be important in coping with differences in total amount of light received at different depths (i.e., under low light conditions seaweeds put more energy into pigment synthesis than under light conditions). Also, the tolerance to the combination of temperature and salinity varies from one algal

Table 6. *Ecological indices of three groups of seaweeds in the different seasons.*

	Autumn	Winter	Spring	Summer
Chlorophyta				
Shannon–Wiener diversity index	1.26	1.49	0.51	1.55
Pielou's evenness index	0.68	0.77	0.42	0.71
Simpson's dominance index	0.37	0.27	0.78	0.27
Margalef richness index	0.81	0.92	0.51	1.08
Phaeophyta				
Shannon–Wiener diversity index	1.62	1.50	2.07	1.11
Pielou's evenness index	0.75	0.64	0.80	0.68
Simpson's dominance index	0.25	0.31	0.15	0.42
Margalef richness index	0.83	1.10	1.54	0.77
Rhodophyta				
Shannon–Wiener diversity index	1.72	2.18	2.09	2.12
Pielou's evenness index	0.85	0.93	0.83	0.66
Simpson's dominance index	0.20	0.12	0.14	0.17
Margalef richness index	1.07	1.31	1.20	1.66

Table 7. *Ecological indices of seaweeds in different sampling sites.*

	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6
Shannon–Wiener diversity index	2.7	2.41	3.01	2.32	2.15	1.97
Pielou's evenness index	0.80	0.57	0.76	0.64	0.68	0.61
Simpson's dominance index	0.30	0.15	0.28	0.15	0.16	0.21
Margalef richness index	2.85	3.08	3.85	3.10	1.84	2.12

Table 8. *Ecological indices of seaweeds in different sampling periods.*

	Autumn	Winter	Spring	Summer
Shannon–Wiener diversity index	2.53	2.87	2.28	2.47
Pielou's evenness index	0.70	0.81	0.41	0.55
Simpson's dominance index	0.11	0.07	0.22	0.14
Margalef richness index	2.53	3.12	2.94	3.22

species to another, and this affects the zonation of the algae in the intertidal zone. The fluctuations of both temperature and salinity are highest at the upper limit of the intertidal zone and lowest at the lower limit of shore. As, Chlorophyta species (e.g., *Ulva*) were more scattered on the upper littoral area, they showed more resistance to tolerance of temperature and salinity, whereas, Rhodophyta could not tolerate these, compared to the Chlorophyta, so they are more abundant in the lower tidal areas as observed in this study.

The distribution of the algae within the Province of Bushehr is significantly affected by the steepness of the slope and by the substratum type. As mentioned earlier, the characteristics of the sampling sites are summarised in table 1. The algae have to attach to stable substrates in order to maintain their position and not to be washed away by the waves, tides, and currents. If the slope is steep and the structure is sandy (e.g., site 5), no seaweed can permanently attach to the structure, so, during biomass study, this site (5) showed low algal biomass compared to the other sites. On the other hand, northern parts of the study area including sites 1–4 are suitable for seaweeds to grow. Marine environment with moderate waves accommodates better growth conditions, resulting in higher biomass of seaweeds for those sites (i.e., 1–4).

According to South and Whittick (1987) the most obvious factors which might affect zonation is the tidal range and periodicity of seawater. In this study, the highest biomass and seaweed species were observed at sites with wide tidal zone (e.g., 1 and 2). Turna *et al* (2002) observed similar trend in subtropical areas. The finding in this study is different from the study in temperate areas by Trono

Table 9. *Results of correlation coefficient between total seaweeds biomass and density with physicochemical parameters.*

	Temperature (°C)	pH	Conductivity (S. m^{-1})	Salinity (‰)
Seaweed biomass	0.78*	0.12	0.49	0.14
Seaweed density	0.65*	0.17	0.41	0.43

*: Significant at 0.05 level.

Table 10. *Floristic affinity as determined by Cheney's* $(R+C)/P$ *ratio (Cheney 1977) from published floras along the Persian Gulf coasts.*

Location	C	P	R	$(R+C)/P$	Reference
Saudi Arabia	15	20	33	2.4	Basson (1979a, 1979b)
Bahrain	21	17	37	3.4	Basson *et al* (1989)
Kish Island	6	8	9	1.9	Dadolahi and Savari (2005)
Bushehr Province	10	12	15	2.1	Present study

and Tolentino (1993). The shallow sea (ensuring sufficient mixing, material and sunlight) and its gradual slope provided ideal conditions for seaweed to exist and grow at sites 1 and 2.

There are some other ecological factors that may influence seaweeds distribution. Some algal species are covered in a layer of mucilage (e.g., brown species) which leads to restricting water loss (Jagtap 1987) and they are more tolerant to air exposure. The upper zone is set by the ability of the plants to withstand desiccation, wave action and the lower limit by their ability to continue photosynthesis at increasing dim and turbid waters. Competition is inevitable where seaweeds with similar need overlap and resources are limited and predation or physical hardship is not high enough to keep the numbers of seaweeds low. All seaweeds have common requirements for nutrients, light, water, carbon dioxide and space, and interspecific competition can occur when any of these resources becomes scarce. Different species will perform best at different locations, each with ability to exclude the others from its optimal location. Thus species may replace one another along any pronounced environment gradient.

Both grazing and competition may play major roles in macroalgal development in coral reef areas (e.g., Persian Gulf). The remarkable factor in the growth control in some plant communities is grazing by herbivores (e.g., turtle), fish and invertebrates (molluscs and echinoderms). All the biological groups have discovered a possibility of adaptation, and algae in particular. Competition for space with other attached organisms (e.g., coral reefs) is one of the main factors controlling growth of the marine flora (Dawes 1981). The total absence of marine algae at greater depth of Bushehr may be attributed to dense coral communities. Corals may dominate in aggression and competition for space, light, and nutrient, and as a result, marine algae do not grow in their vicinity (Dadolahi and Savari 2005; Dawes 1981). It is reasonable to believe that this may have happened in Bushehr as, the coral density increase with depth in this area and competition between corals and seaweeds may be the reason for the elimination of seaweed from some parts of Bushehr Province areas.

In the present study, *Ulva intestinalis* and *Cladophora nitellopsis* of green and *Polycladia myrica, Sirophysalia trinodis* and *Sargassum angustifolium* of brown and *Hypnia cervicornis* and *Acanthophora spicifera* of red seaweeds showed maximum biomass in coastal areas of Bushehr Province. It could be noted that the highest (0.90%) and lowest (0.60%) coefficient of variations between three groups of seaweeds were observed during summer and winter, respectively (table 4). However, biomass of three groups of seaweeds stood at the lowest during cold seasons, probably reflecting the role of temperature in regulating the seasonal development of seaweed communities (Dawes 1981; Edwards and Kapraun 1973; Round 1981). Two-way ANOVA test did not show statistically significant interaction (season and division of seaweed) for biomass of seaweeds during different seasons. Kruskal Wallis one-way analysis of variance (ANOVA) showed significant variations in seasonal biomass of Chlorophyta and Rhodophyta ($P < 0.05$). In this study, some physicochemical parameters such as seawater temperature, pH, salinity and conductivity were measured during different seasons. Analysis of correlation coefficients between seasonal biomass and density by physicochemical parameters (table 9) showed significant positive correlation ($P < 0.05$) with seawater temperature. Moreover, annual seaweed biomass and density showed positive correlations with pH, salinity and conductivity.

One-way analysis of variance with Tukey's HSD test did not show any significant difference between mean biomass of seaweeds at each site, which may be attributed to homogenous distribution of seaweeds along the Bushehr Province coastal areas which is also confirmed by Czekanowski coefficient (similarity coefficient) analysis.

5. Conclusion

The number and percentage of taxa shared by different sites were summarised using the per cent similarity (C) values adapting the Czekanowski coefficient. More than 50% similarity of algal species between sites and the occurrence of almost all species indicate that the algal flora was fairly homogenous within a location and between sites. Cheney's floristic ratio of less than 3.0 revealed that seaweed flora is temperate (table 10), which was also described by Kaldy *et al* (1995). The seasonality of algal floras is often related to temperature and desiccation tolerance especially in warmer regions (Dawes 1981; Edwards and Kapraun 1973; Round 1981). The Persian Gulf is subjected to wide climate fluctuations, with surface water temperatures generally ranging from 12°C in winter to more than 40°C in the summer and salinity from 28 to 60 ppt. In more temperate regions, seasonal sea-surface temperature variation can be as much as 30°C. The relatively unstable temperature regime of Bushehr Province probably results in a general seasonality of the algal flora. From this study it was concluded that the most suitable season of the algal growth was during end of winter to middle of summer along the Bushehr Province coastal areas.

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