

Diversity of Green Seaweeds along the Coast of Karachi

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Abstract The seasonal diversity and species richness of marine benthic green algae or seaweeds belonging to the phylum Chlorophyta found at Karachi coast were studied in present study. At Karachi coast the green seaweeds occupy a large area and show great variation in their types and species composition. Total 48 green species of seaweeds belong to 9 genera 7 families 6 orders and 2 classes were collected from intertidal areas of Karachi coast (Buleji, Manora, Hawks Bay, Sandspit, Korangi Creek, Cape Monze, Paradise Point, Pacha and Rehri) during January 2009 to December 2009. Total 500 individuals examined, representing 9 genera i.e., *Enteromorpha*, *Ulva*, *Chaetomorpha*, *Bryopsis*, *Codium*, *Caulerpa*, *Halimeda*, *Udotea*, *Valoniopsis*. From the present observation, it's clear that Buleji and Manora are the more productive sites as compared to other sites. There was great variation in number of species in different genus. All these forty-eight studied species were found attached and in epilithic condition. There is much monthly variation found in species richness at Karachi coast during study period. The present study showed that the high values of species richness and abundance of seaweeds were observed during winter season (December to February).

Keywords Green seaweeds; Diversity; Karachi coast; Seasonal variation

Background

The interest in marine algae both attached and drifted has been mainly due to its importance in nutritive and industrial implication both in past and present. Nowadays seaweed plays a considerable role in the economy of develop and developing nation. According to an estimate 16% of total yield of marine wet fisheries comprised of seaweed and they are the sixth largest money earning commodity among mariculture products (Qari, 2002). Seaweed has all essential elements and nutrients required for growth and maintenance. Most of the seaweeds are used as a part of food. Seaweeds are also used as a fodder, raw material for various industrial processes especially pharmaceutical application. A number of seaweed species have been used in medicine for different kinds of treatment (Chapman and Chapman, 1980).

Pakistan has a coastline of 120 km extending from Sir Creek on the Indian Site to Gwadar bay on the Iranian border. The coast is divided into two parts. The Makran coast from the Hub River to the border of Iran has narrow shelf and pockets of mangroves. The Sindh Karachi coast extends to Sir Creek on the Indian border. There is 105,400 square nautical miles area of marine resources for commercial exploitation (Tirmizi and Kazmi, 1983).

Karachi is located between 66°59' E and latitude 24°48' N on the northeastern boarder of the Arabian Sea. Karachi beaches are muddy, rocky and sandy. The tides at Karachi are average type and with a minimum and maximum range of 1.0 ft to 10 ft, semi diurnal type about 4 million cubic meters water enters and leaves the channel during each tidal cycle (Saifullah, 1973). Salinity ranges between 34‰-36‰ and temperature between 18-30°C (Qari and Siddiqui, 2005; Qari and Siddiqui, 2006). To study the marine plant resource and their products, North Arabian Sea is a unique place for photosynthetic biomass (Thompson and Tirmizi, 1988).

All studied coastal sites Sandspit, Buleji, Hawks Bay, Paradise Point, Pacha, Cape Monze, Manora, Korangi Creek and Rehri inhabit a variety of marine benthic algae (Shameel and Tanaka, 1992). Although a lot of work has been done on their taxonomy, distribution, morpho-ecological studies, chemical and biochemical composition and Phycochemistry (Anand, 1940; Anand, 1943; Saifullah, 1973; Shameel and Moazzam, 1982; Shameel, 1987; Qari,

1988; Qari and Qasim, 1988; Qari and Qasim, 1993; Qari and Siddiqui, 1993; Qari and Qasim, 1994; Nizamuddin, 1999; Nizamuddin and Fahim, 2000; Shameel et al., 2000; Qari and Siddiqui, 2001; Qari and Siddiqui, 2005; Qari and Siddiqui, 2010; Qari et al., 2014; Qari, 2017; Qari et al., 2018) but there is still need to study in detail as to fill up the some of the gap in the information that exist.

Some phycologist also made valuable contribution to the taxonomy of green algae of Karachi coast, e.g. Shameel (1978a) added to the list of *Caulerpa* one more species and presented an ecological account of all the 13 known species, other important investigation made by him were on the family Chaetophoraceae of Karachi coast (Shameel, 1978b). Other significant studies made on the taxonomy of green algae are: Nizamuddin and Begum (1973), Saifullah and Nizamuddin (1977), Zahid et al. (1983) and Amjad and Shameel (1993a; 1993b). Apart from Karachi coast a few studies have also been made on the occurrence of algae including green seaweeds from the adjacent coast of Lasbela (Shameel, 1987; Shameel et al., 1989). A check list of marine planktonic and benthic algae of Pakistan has been published by Shameel and Tanaka (1992), which includes 27 genera and 90 species of green algae. Shameel and Shaukat (1992) also carried a taxometric study out three related species of *Caulerpa*. Recently a new classification of algae was proposed in which also marine Chlorophyta included (Shameel, 2001).

From the foregoing literature survey, it becomes apparent that these investigations are highly inadequate for the understanding of modern position of green seaweeds distribution and occurrence of the individual plant. Therefore, it is essentially needed to conduct a thorough and detailed study of the diversity and seasonal variation in distribution and habitat ecology of green seaweeds growing along the coast of Karachi.

1 Results and Discussion

A total of 48 species of seaweeds belong to 9 genera, 7 families, 6 orders and 2 classes were identified in the intertidal areas from different coast (Buleji, Cape Monze, Hawks Bay, Korangi Creek, Manora, Paradise Point, Pacha, Rehri and Sandspit) of Karachi during the study period January 2009 to December 2009 (Table 1). The present work showed that Pakistan coast especially Karachi coast has mostly rocky and sandy beaches that are rich in seaweeds species. Among 48 species thirty-nine species were collected from Buleji, thirty-four from Manora, ten from Paradise Point, six from Sandspit, three from each Korangi Creek, Hawks Bay and Cape Monze and two from each Pacha and Rehri sites (Figure 1). The two coastal areas Buleji and Manora were found the more productive sites as compared to other sites.

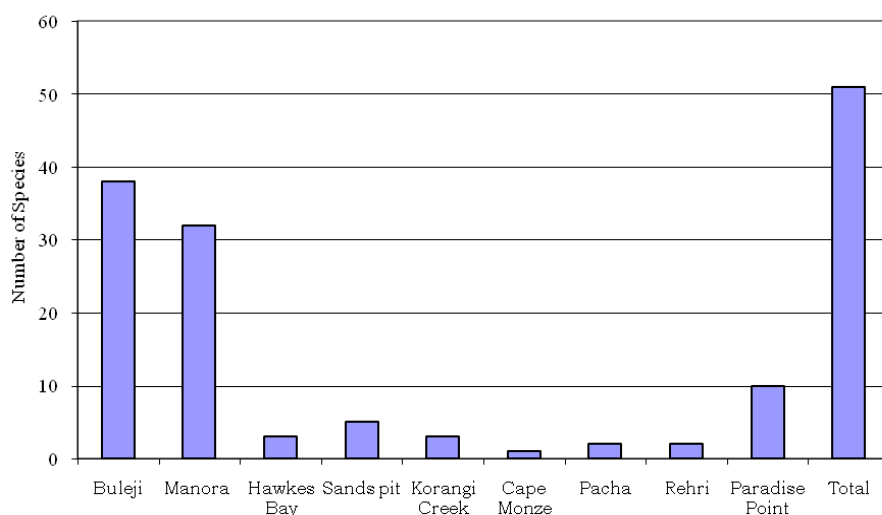


Figure 1 Total seaweed species collected from different sites of Karachi coast

Table 1 Total seaweed species collected from Karachi coast

S. NO.	Kingdom	Phylum	Class	Order	Family	Genus	Species
1	Protoctista	Chlorophyta	Siphonocladophyceae	Derbesiales	Derbesiaceae	<i>Bryopsis</i>	<i>B. corymbosa</i>
2		Green Algae					<i>B. hypnoides</i>
3							<i>B. pennata</i>
4				Caulerpales	Caulerpanceae	<i>Caulerpa</i>	<i>C. manorensis</i>
5							<i>C. peltata</i>
6							<i>C. racemosa</i>
7							<i>C. scalpelliformis</i>
8							<i>C. serrulata</i>
9							<i>C. chemnitzia</i>
10							<i>C. taxifolia</i>
11						<i>Halimeda</i>	<i>H. cuneata</i>
12							<i>H. tuna</i>
13					Udoteaceae	<i>Udotea</i>	<i>U. indica</i>
14				Siphonocladales	Valoniaceae	<i>Valoniopsis</i>	<i>V. pachynema</i>
15				Cladophorales	Cladophoraceae	<i>Chaetomorpha</i>	<i>C. antennina</i>
16							<i>C. aerea</i>
17							<i>C. crassa</i>
18							<i>C. spiralis</i>
19				Codiales	Codiaceae	<i>Codium</i>	<i>C. iyengarii</i>
20							<i>C. dwarkense</i>
21							<i>C. indicum</i>
22							<i>C. flabellatum</i>
23							<i>C. fimbriatum</i>
24							<i>C. laevigatum</i>
25							<i>C. bilobum</i>
26							<i>C. reductum</i>
27							<i>C. boergesenii</i>
28							<i>C. aliyaiiae.</i>
29							<i>C. fastigiatum</i>
30							<i>C. hawkesbayensis</i>
31							<i>C. scindicola</i>
32			Ulvophyceae	Ulvales	Ulvaceae	<i>Enteromorpha</i>	<i>E. compressa</i>
33							<i>E. clathrata</i>
34							<i>E. flexuosa</i>
35							<i>E. intestinalis</i>
36							<i>E. procera</i>
37							<i>E. prolifera</i>
38						<i>Ulva</i>	<i>Ulva fasciata</i>
39							<i>U. anandii</i>
40							<i>U. lactuca</i>
41							<i>U. bifrons</i>
42							<i>U. compressa</i>
43							<i>U. lobata</i>
44							<i>U. scandinavian</i>
45							<i>U. rotanda</i>
46							<i>U. rigida</i>
47							<i>U. indica</i>
48							<i>U. fenestrate</i>

Total numbers of individuals examined were 500 representing 9 genera i.e., *Enteromorpha*, *Ulva*, *Chaetomorpha*, *Bryopsis*, *Codium*, *Caulerpa*, *Halimeda*, *Udotea* and *Valoniopsis* (Table 1). There was great variation found in number of species in different genus. Total 6 species of *Enteromorpha*, 11 *Ulva*, 4 *Chaetomorpha*, 3 *Bryopsis*, 13 *Codium*, 2 *Halimeda*, 1 *Udotea* and 1 *Valoniopsis* are collected during the study period (Figure 2). There is no any new species is recorded in present investigation. All the studied species were already identified earlier in different times by different authors (Anand, 1940; Saifullah and Nizamuddin, 1977; Saifullah and Nizamuddin, 1992; Shameel and Shaukat, 1992; Amjad and Shameel, 1993a; Amjad and Shameel, 1993b; Aliya et al., 1994; Aliya and Shameel, 1996; Nizamuddin, 2001; Nizamuddin and Gul, 2005).

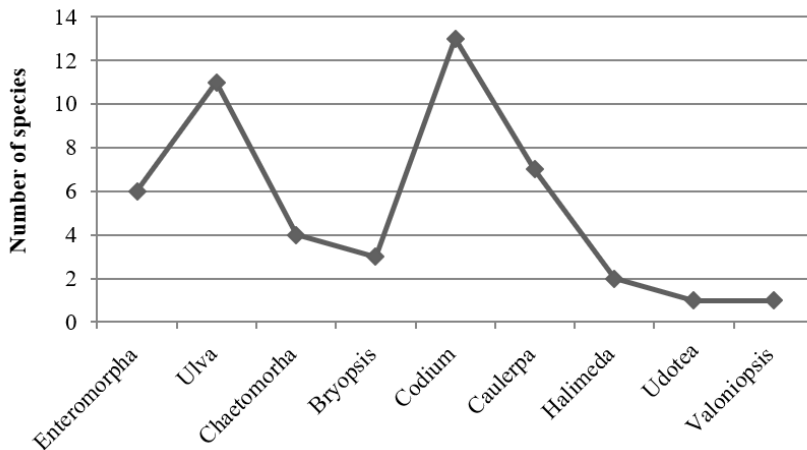


Figure 2 Total number of species collected from different genus

The seasonal variations in number of individuals of seaweeds at Karachi coast are shown in Table 2 and Figure 3. The total number of individuals were high in the month of January (114) and March (113) where as low in the month of September (4). The *Enteromorpha* (4.8%) is found at the coast of Karachi (Figure 4). There were six species of *Enteromorpha* (*Enteromorpha intestinalis*, *Enteromorpha compressa*, *Enteromorpha flexuosa*, *Enteromorpha prolifera*, *Enteromorpha clathrata*, *Enteromorpha procera*) collected in present study. Anand (1940) found five and Saifullah and Nizamuddin (1992) nine species of *Enteromorpha*. The most abundant species of *Enteromorpha* in present study were *Enteromorpha intestinalis* (37.5%) and *Enteromorpha clathrata* (33.3%) collected from Buleji, Korangi creek, Manora and Sandspit.

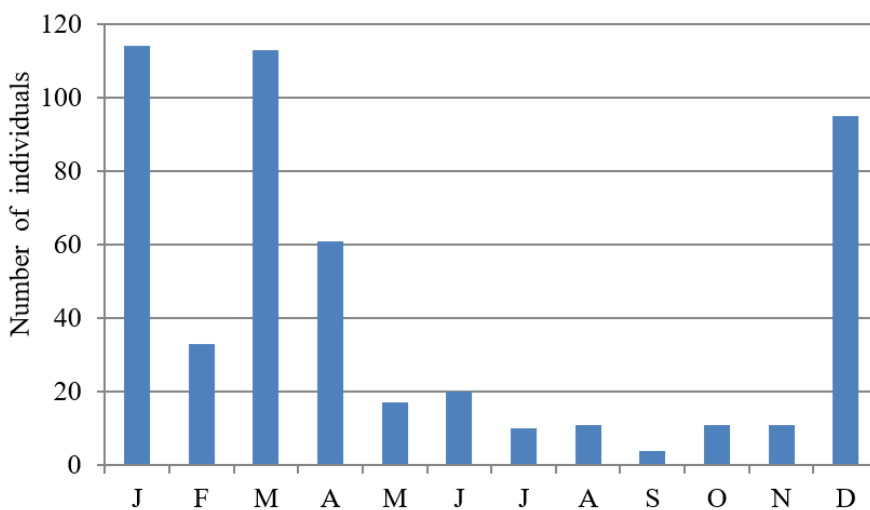


Figure 3 Seasonal variation in the total number of individual at different coast of Karachi

Table 2 Seasonal variation in number of individuals of seaweeds at coast of Karachi

S. No.	Name of Species	J	F	M	A	M	J	J	A	S	O	N	D	Total
1	<i>Enteromorpha intestinalis</i>		4	5										9
2	<i>Enteromorpha compressa</i>	1											1	2
3	<i>Enteromorpha flexuosa</i>							1						1
4	<i>Enteromorpha prolifera</i>		2											2
5	<i>Enteromorpha clathrata</i>			3					3				2	8
6	<i>Enteromorpha procera</i>												2	2
7	<i>Ulva indica</i>		5								4		4	13
8	<i>Ulva fasciata</i>						20							20
9	<i>Ulva rigida</i>			1										1
10	<i>Ulva lactuca</i>	4												4
11	<i>Ulva fenestrata</i>	5												5
12	<i>Ulva scandinaviana</i>			1										1
13	<i>Ulva anandii</i>	4												4
14	<i>Ulva lobata</i>			1	1									2
15	<i>Ulva bifrons</i>			5									4	9
16	<i>Ulva compressa</i>	1		1	1									3
17	<i>Ulva rotunda</i>			3	2									5
18	<i>Chaetomorpha spiralis</i>			20	10				6					36
19	<i>Chaetomorpha antennina</i>	16					9						10	35
20	<i>Chaetomorpha crassa</i>	12	10											22
21	<i>Chaetomorpha aerea</i>	15	12											27
22	<i>Bryopsis hypnoides</i>	5										10	6	21
23	<i>Bryopsis corymbosa</i>												4	4
24	<i>Bryopsis pennata</i>				20								10	30
25	<i>Codium bilobum</i>			1									1	2
26	<i>Codium fimbriatum</i>	12		10									9	31
27	<i>Codium flabellatum</i>			6									5	11
28	<i>Codium laevigatum</i>			5	2									7
29	<i>Codium scindicola</i>												1	1
30	<i>Codium indicum</i>	4		3	3									10
31	<i>Codium reductum</i>			2	3									5
32	<i>Codium fastigiatum</i>			3										3
33	<i>Codium hawkesbayensis</i>			4	2									6
34	<i>Codium iyengarii</i>	5											2	7
35	<i>Codium dwarkense</i>	6												6
36	<i>Codium boergesenii</i>			2									2	4
37	<i>Codium aliyaiiae</i>			1								1		2
38	<i>Caulerpa racemosa</i>			16	17									33
39	<i>Caulerpa chemnitzia</i>	1		2									1	4
40	<i>Caulerpa taxifolia</i>	2		18		15								35
41	<i>Caulerpa manorensis</i>	7				2								9
42	<i>C. serrulata</i>	12											2	14
43	<i>Caulerpa peltata</i>	2							2	1				5
44	<i>Caulerpa scalpelliformis</i>												16	16
45	<i>Halimeda tuna</i>									2	2		1	5
46	<i>Halimeda cuneata</i>									1	1		1	3
47	<i>Udotea indica</i>										2		11	13
48	<i>Valoniopsis pachynema</i>										2			2

The genus of *Ulva* contributes 13.4% and total eleven species of *Ulva* (*Ulva indica*, *Ulva fasciata*, *Ulva rigida*, *Ulva lactuca*, *Ulva fenestrata*, *Ulva scandinavian*, *Ulva anandii*, *Ulva lobata*, *Ulva bifrons*, *Ulva compressa* and *Ulva rotunda*) were collected in whole study period (Figure 4). The most abundant species of *Ulva* was *Ulva fasciata* (29.8%) collected from different sites (Buleji, Manora and Paradise Point) and *Ulva rigida* (1.5%) and *Ulva Scandinavian* (1.5%) were rare collected from Buleji. Anand (1940) found three, Saifullah and Nizamuddin (1992) nine, Amjad and Shameel (1993a; 1993b) nine, Shahnaz and Shameel (2007) five species of *Ulva*. The *Chaetomorpha* (24%) was found in large quantity in winter season (December to January) (Table 2 and Figure 4). There were four species of *Chaetomorpha* (*Chaetomorpha spiralis*, *Chaetomorpha antennina*, *Chaetomorpha crassa* and *Chaetomorpha aerea*) collected. The most abundant species were *Chaetomorpha spiralis* (30.1%) *Chaetomorpha antennina* (29.1%) collected from Buleji and Manora. In previous studies Anand (1940) and Aliya and Shameel (1996) found four and two species of *Chaetomorpha* respectively. There were three species of *Bryopsis* (11%) i.e., *Bryopsis hypnoides*, *Bryopsis corymbosa* and *Bryopsis pennata* collected from Paradise Point, Rehri and Buleji. Anand (1940) found two, Aliya and Shameel (1996) one and Aliya et al. (1994) one species of *Bryopsis*. The most abundant species was *Bryopsis pennata* (54.55%).

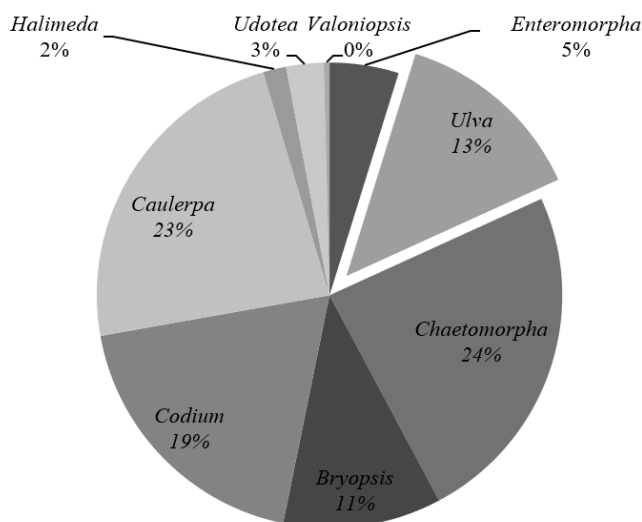


Figure 4 Percentage composition of different genera at Karachi coast

The *Codium* is very vast group (19%) found at the coast of Karachi in large amount with thirteen species (*Codium bilobum*, *Codium fimbriatum*, *Codium flabellatum*, *Codium laevigatum*, *Codium scindicola*, *Codium indicum*, *Codium reductum*, *Codium fastigiatum*, *Codium hawkesbayensis*, *Codium iyengarii*, *Codium dwarkense*, *Codium boergesenii* and *Codium aliyaiae*) (Figure 4). From the Table 2, it is clear that most of the *Codium* species found in winter season (December to January). The most abundant species was *Codium fimbriatum* (32.6%) collected from Buleji, Manora and Paradise Point. Nizamuddin (2001) described thirty species of *Codium* including thirteen studied species and few new taxa from North coast of the Arabian Sea (Pakistan). Anand (1940) found four, Nizamuddin (2001) thirty, Aliya and Shameel (1996) three and Aliya et al. (1994) three species of *Codium*.

There were seven species of *Caulerpa* (23.2%) collected (*Caulerpa racemosa*, *Caulerpa chemnitzia*, *Caulerpa taxifolia*, *Caulerpa manorensis*, *Caulerpa sertularioides*, *Caulerpa peltata* and *Caulerpa scalpelliformis*) (Figure 4). The most abundant species was *Caulerpa chemnitzia* (32.6%). Anand (1940) found four, and Aliya and Shameel (1996) five, and Aliya et al. (1994) five species of *Caulerpa*.

The *Halimeda* (1.6%), *Udotea* (2.6%) and *Valoniopsis* (0.4%) were found in very small quantity at the coast of Karachi (Figure 4). Only two species of *Halimeda* were identified in present study (*Halimeda tuna* 62.5% and *Halimeda cuneata* 37.5%). *Udotea indica* was found only in two months where as *Valoniopsis pachynema* was found only in one month of the year (Table 2). It is also noticed from the observation of Table 2 that *Halimeda* and *Udotea* species were found only in months September, October and December. The previous studies described only one species of *Halimeda* (Anand, 1940), and *Valoniopsis* (Anand, 1940; Aliya and Shameel, 1996).

All forty-eight studied species were found attached and in epilithic condition. It is also noted that *Caulerpa* and *Chaetomorpha* species were occurred at soft substratum. From the results of present study, it is observed that species collected from different sites showed a significant variation in sites, habitat, structures and occurrence. The months of March (22) and January (18) were rich in seaweeds species and the months of May to July were poor in seaweeds species (Figure 5). There is greater monthly variation found in species richness at Karachi coast (Figure 6). The value of species richness (S) varied from 0.044-6.444. The highest value was recorded in the month of January (6.444), March (5.022) and December (4.311) and low in July (0.044).

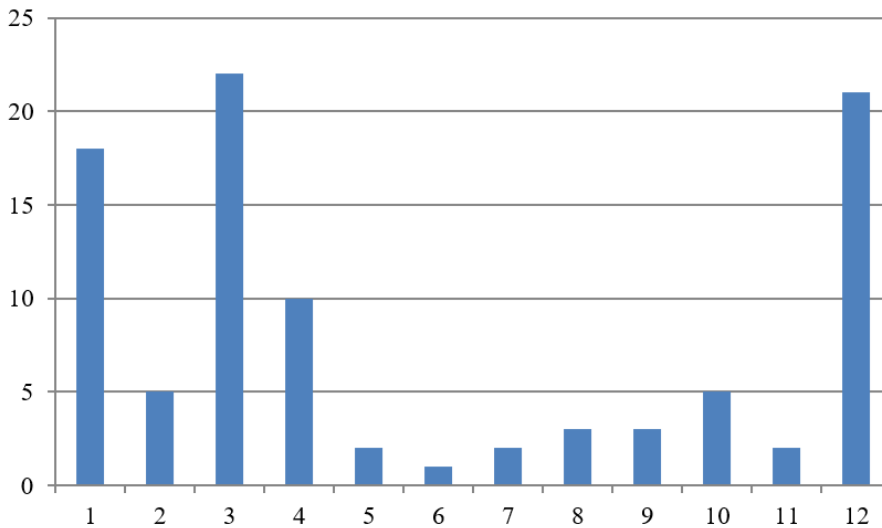


Figure 5 Seasonal variation in the total number of species at different coast of Karachi

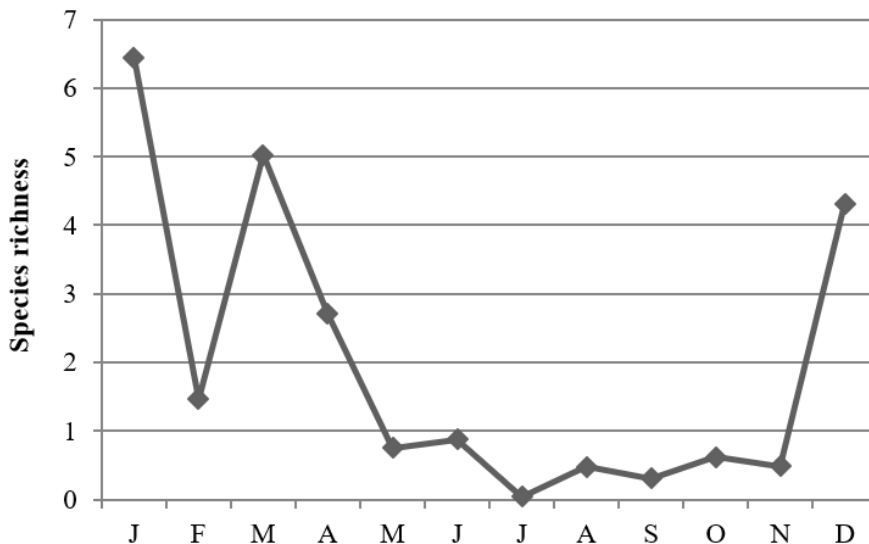


Figure 6 Monthly variation in species richness (S) at Karachi coast during January 2008-December 2009

The positive significant correlation was found in between species of same genus (*E. prolifera* and *E. intestinales* ($r^2=0.580$); *Ulva scandinavian* and *Ulva rotanda* ($r^2=0.817$); *Ulva compressa* and *Ulva rotanda* ($r^2=0.757$)) and different genus (*Ulva rigida* and *E. intestinales* ($r^2=0.758$); *Enteromorpha compressa* and *Chaetomorpha crassa* ($r^2=0.744$); *Ulva rigida* and *Codium boergesenii* ($r^2=0.674$); *Ulva fenestrata* and *Caulerpa manorensis* ($r^2=0.960$); *Valoniopsis pachynema* and *H. tuna* ($r^2=0.629$)). The present study showed that the abundance of seaweeds and high values of species richness were observed during winter (December to February) season. From literature survey it is found that during winter season all hydrographic conditions (salinity, temperature pH and dissolve oxygen) were suitable for the growth of seaweeds (Qari and Siddiqui, 2005; Qari and Siddiqui, 2006). During the

study epifloral species that were attached on studied green seaweeds were called *Sargassum boveanum*, *Polysiphonia ferulacea* and *Gracilaria corticata*. Beside the epifloral species some epifaunal species are also found, attached on seaweed called *Cantharus spiralis*, *Thais cannifera*, *Terebradus sumieri*, and *Polychaetes worms*.

2 Materials and Methods

Collection were made along the different beaches Buleji, Manora, Hawks Bay, Sandspit, Korangi Creek, Cape Monze, Paradise Point, Pacha and Rehri of Karachi coasts during the January 2009 to December 2009 at low tide. The sea at all studied coastal sites are very calm and quiet from October to March and very rough during the monsoon. Most of coastal sites are quite popular picnic and relaxation spots of Karachi.

Bulejis located between Hawks Bay and Paradise Point, near fisher village. This is the triangular rocky plate Island. Boulders of various sizes are visible but mostly near the higher watermarks standing on a rocky base, pebbles, gravel, sand etc. Large number of seaweeds is found at Buleji comparatively other beaches of Karachi coastal areas. Manora is a small rocky and sandy island (2.5 km²). The rocky shore of Manora has many varieties of sea weeds. Hawks Bay is situated a couple of kilometers away from Sandspit. It is a sandy beach with natural beauty, spreading over a length of about 5 km and mostly used as picnic point. Hawks Bay is one of the few beaches in the world, where green marine turtles come to lay eggs. The site of Sandspit is situated south west of Karachi. It is also rocky and white sandy area where many sandy pits have found. Remarkable variety of marine algae and crabs are found here. It has an unusual rocky formation. During monsoon season high tides often cross over and enter into the backwater mangrove area, and refurbish the sediments with coastal sand.

Korangi Creek is the worst pollution affected section of the Karachi coast, where the effluents from Korangi, Landhi, Karachi Export Processing Zone, Bin Qasim Industrial Area, and Pakistan Steel Mill are directly discharged into the sea. Untreated waste water disposal by two major industrial establishments LITE (Landhi Industrial Trading Estate) & SITE (Sind Industrial Trading Estate) in the Korangi Creek through a poorly maintained drainage network (Abbas, 2006). In addition to industrial effluents, discharges from Bhains (buffalo) Colony cattle farms and domestic sewage from residential areas also ends up in the Korangi Creek system (Abbas et al., 2013). Cape Monze is relatively stable rocky beach with 10-12 meter high cliffs, located near the Hub River and Gadani Beach in Karachi. White sand is the most unique feature of the Cape Monze beach.

Paradise Point is covering distances of about 800 meters. The coast is open to sea front and the wave action is intense all along the coast. The rocky ledge of Paradise Point is mostly wave swept shore (Qari and Siddiqui, 2010). Pacha is the three thousand meters long sandy beach is located off Paradise Point. The beach is marked by the presence of 12-156 meters high cliffs. Effect of high wave action may be seen in the form of erosion. Rehri is one of the neighbor's hoods of Bin Qasim Port and supports a large community of fishermen. Its environment comprises of coastal area of Bin Qasim district which includes the union council of Rehri and Ibrahim Haidery besides the two Settlements of Chasma Goth and Lath Basti (Shahzad et al., 2009).

The sampling method (Chapman, 1964) was used for estimating the seaweeds quantum. Five quadrates of 1 m² sizes were randomly selected in the intertidal zone of each beach. All the seaweeds species were handpicked in each quadrate. In the laboratory seaweeds were washed with seawater followed by fresh water to remove adhering impurities, epiphytes and epifauna. Collected material were preserved and taxonomically investigated. The specimens were identified with the help of authentic available literatures (Anand, 1940; Smith, 1955; Silva, 1979; Shameel, 1992; Qari and Qasim, 1993; Nizamuddin, 2000; Gul et al., 2006).

3 Conclusion

On the basis of results obtained in the present investigation and those reported previously by Saifullah and Nizamuddin (1977; 1992), Qari and Qasim (1988; 1994), Aliya et al. (1994), Aliya and Shameel (1996) and Qari (2002), it may be concluded that occurrence and quantity of seaweeds species vary from time to time. The highest quantities of seaweeds were found in winter season i.e., winter period is best for cultivation of seaweeds growth. It

is concluded that the present study will be most helpful for all researchers of marine science because the present study is presenting the diversity and abundance of seaweed species. The present study also showed that which month having maximum number of species for collection, harvesting and cultivation. In Pakistan it is necessary to harvest seaweeds on large scale because due to dearness all food items cannot easily purchase. So it is suggested that we should take advantage from our coastal resources i.e., luxuriant growth of seaweeds vegetation.

Author's contributions

EK carried out the field and lab work. RQ designed, interpreted the data, made figures, statistical analysis, and drafted the manuscript. Both authors EK and RQ read and approved the final manuscript.

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