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STANDING STOCK OF SEAWEEDS IN SUBMERGED HABITATS ALONG THE KARACHI COAST, PAKISTAN: AN ALTERNATIVE SOURCE OF LIVELIHOOD FOR COASTAL COMMUNITIES

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Abstract

Seaweeds are widely used as an alternate source of livelihood for coastal communities in different countries. Submerged habitats with nutrient-rich coastal waters along the Pakistan coast have rich algal stocks. With few exceptions, studies on seaweeds in Pakistan are mostly confined to intertidal areas. We have conducted preliminary surveys at Buleji, along the Karachi coast to access existing standing stocks of seaweeds. Samples were collected by SCUBA diving. Relative species abundances were determined using quadrat techniques. Overall, 17 species of macroalgae were recorded belonging to 2 major groups (Phaeophyceae 12, Rhodophyceae 5) and 6 families. Except diving site 6, the communities were dominated by *Sargassum* species. The majority of the recorded species had wide distribution ranges. Distribution patterns were mainly controlled by habitat type, depth, oceanographic conditions, and the nature of the sites. Many of the recorded species are commercially important. It is expected that further underwater surveys will help in exploring more algal beds along this coastline. A sustainable use of this algal biomass can provide an alternative source of income for coastal communities. Moreover, Pakistan has a long coastline with different geomorphic features; in this regard seaweed aquaculture in coastal areas especially near big cities can insert positive ecological impacts on coastal ecosystems as well as on the economic conditions of the coastal communities.

Key words: Submerged, Karachi coast, Seaweed, Coastal community, Livelihood.

Introduction

Seaweeds are considered as important alternative source of livelihood for the coastal communities (Crawford, 2002; Hill *et al.,* 2012; Rebours *et al.,* 2014). Apart from a livelihood, seaweeds provide an important source of food fiber, vitamins, lipids, minerals, ash, protein, phytochemicals and polyunsaturated fatty acids suitable for human use (Ruperez, 2002; Sanchez-Machado *et al.,* 2004; Matanjun *et al.,* 2009; Gomez-Ordonez *et al.,* 2010; Mohamed *et al.,* 2012). In many countries of Asia, seaweeds are widely used as an alternative source of food, while in the west, they are mostly used as means of phycocolloids, industrial and gelling agents for food items (Mabeau & Fleurence, 1993; Zemke-White & Ohno, 1999). About 83% of the seaweeds are used as vegetables, while17% are being utilized in different applications e.g. feed preservatives, animal fodder, fertilizers, biotechnological and medical equipment (McHugh, 2003; Zimmermann *et al.,* 2005; Craigie, 2011; Ehrhart *et al.,* 2013; Kolanjinathan *et al.,* 2014: Yende *et al.,*2014). A variety of seaweeds products directly or indirectly used by humans have an approximate value of US$ 5.5 to 6 billion per year (Bixler & Porse, 2011; Kilinc *et al.,* 2013). Approximately 220 species of algae are cultivated worldwide. Among them about 94.8% of the seaweed aquaculture production is provided by only 6 genera, namely, *Pyropia, Saccharina, Undaria, Eucheuma, Kappaphycus, and Gracilaria* (Suo & Wang 1992; Perez *et al.,* 2007; Pereira & Yarish, 2008; Chopin & Sawhney, 2009; Wang *et al.,* 2013; Ramirez *et al.,* 2014).

Seaweeds are generally divided into 3 main groups (Chlorophyta, Phaeophyceae, Rhodophyceae). Among Chlorophyta (green seaweeds), *Codium fragile*, *Caulerpa lentillifera* and *Ulva* species are particularly considered as good sources of food supplements (carbohydrates, vitamins, protein, minerals, and fiber) with low lipid concentration (Wong & Cheung, 2000; Ortiz *et al.,* 2006; Matanjun *et al.,* 2009; Ortiz *et al.,* 2009; Holdt & Kraan, 2011). Many species of *Ulva* are recommended as food for human and animals in Europe (Ortiz *et al.,* 2006; Bocanegra *et al.,* 2009). Many species belonging to Phaeophyceae (e.g. *Macrocystis pyrifera*; *Himanthalia elongata, Bifurcaria bifurcata, Saccharina latissima, Sargassum polycystum, Sargassum echinocarpum*, *Sargassum obtusifolium*, *Dictyota* spp.) and Rhodophyceae (e.g. *Gracilaria* spp., *Pyropia* spp., *Palmaria* sp., *Gigartina pistillata, Gelidium* spp., *Mastocarpus stellatus, Eucheuma* spp.) have valuable edible contents (Mc Lachlan *et al.,* 1972; Mc Dermid & Stuercke, 2003; Ortiz *et al.,* 2009; Matanjun *et al.,* 2009; Gomez-Ordonez *et al.,* 2010; Wang *et al.,* 2013) and well known for their economic, medicinal, biological and environmental significance (Chapman, 1980; Rizvi & Shameel, 2003; Diaz-Pulido & McCook, 2008; Chopin & Sawhney, 2009; El Gamal, 2010; Kilinc *et al.,* 2013). Besides commercial and nutritive values, seaweeds also play an important role in maintaining food-webs (Adey, 1998). Seaweeds beds are considered as an important nursery and feeding grounds for invertebrate and vertebrate fauna (Levin & Hay, 1996; Epifanio *et al.,* 2003; Okuda, 2008; Win, 2010). Seaweeds also serve as indicators of biodiversity changes in their environment, induced by human activities or nature (Chopin & Sawhney, 2009). Moreover, seaweed aquaculture in coastal areas provide positive ecological impacts on coastal ecosystems by improving water quality by absorbing inorganic nutrients and heavy metals discharged though different means (industrial, domestic sewage and intensive shrimp and finfish fed aquaculture, etc.) (Bryan, 1969; Rosenberg & Ramus, 1984; Lignell *et al.,* 1982; Chopin *et al.,* 2001).

As a result of rapid industrialization, depletion of fish stock and degradation of coastal ecosystems have occurred due to the use of destructive fishing techniques and rapid urbanization in coastal areas (Creel, 2003; Myers & Worm, 2003; Hutchings & Reynolds, 2004). Reduction in fish stock is a major cause of unemployment for the residents of coastal areas especially in developing countries, where people mainly rely on fishing to meet their daily necessities. To improve the economic conditions of poor fishermen and to reduce pressure on already overexploited fisheries, development of alternative means of incomes should be prevalent policy of the government. In many countries such as Indonesia, China, Kiribati, Malaysia and Philippines, seaweed farming has been adopted as an alternative source of income for coastal communities, while in Canada, Latin American countries such as Uruguay, Brazil, Mexico, Peru, Venezuela, Argentina and Chile, seaweeds are harvested by local communities as an alternative source of income (Ask & Azanza, 2002; Crawford, 2002; Sievanen *et al.,* 2005; Rebours *et al.,* 2014).

Pakistan has a long coastline (1050 km), starting from Sir Creek, India, to Jiwani near the border of Iran in the west with different geomorphic features (cliffs, terraces, sandy and rocky beaches, spits, headlands, raised beaches, stacks, creeks and mud flats etc) (Page *et al.,* 1979; Ali & Memon, 1995; Saifullah, 1999). The coastal communities mainly rely on fish resources to meet their daily expenditures. During the 20th century, an increase in coastal populations had a major effect on wild fish stock. The coastal waters of Pakistan have diverse and rich algal resources due to a warm climate and upwelling of nutrient-rich water (Shameel & Tanaka, 1992; Shoaib *et al.,* 2017). Discharge of domestic sewage is one of the sources of nutrient pollution along the coast especially near big cities like Karachi. Discharge of industrial effluents is also a major source of metal pollution (Hg, Zn, Cd, Pb, and Cr) along the Karachi coast. According to Nergis *et al.,* (2012), approximately 450,000 gallons of industrial and domestic sewage is being discharged daily into the sea through Layari and Malir rivers.

Annually, tons of algal biomass along the coast go to waste. About 13833 g/ m fresh seaweed biomass was noted solely from the intertidal areas of Buleji during winter monsoon (Hameed & Ahmed, 1999). Significant studies on ecology and taxonomy of seaweeds have been undertaken on a regional scale, while in Pakistan the studies are limited to intertidal areas and mainly focused on taxonomy, ecology and photochemistry (for example, Nizamuddin, 1964; Saifullah & Nizamuddin, 1977; Saifullah *et al.,* 1984; Memon *et al.*, 1991; Shameel, 1987; Shameel & Tanaka, 1992; Shameel *et al.,* 1996; Hameed & Ahmed, 1999; Rizvi & Shameel, 2003; Shameel, 2008; Haq *et al.,* 2011). Ali *et al.,* (2017), however, reported 36 species of macroalgae from submerged habitats along the Sindh coast of Pakistan for the first time and indicated the presence of large *Sargassum* beds along the coast of Sindh. Keeping in view these facts, the present study was undertaken with the following goals:1) recording the submerged distribution, diversity and abundance of macroalgal species from near-shore submerged habitats along the Karachi coast at Buleji, 2) to create awareness regarding their significance to local fishing communities and 3) to educate local communities regarding their utilization techniques (sustainable harvesting, preservation, marketing).

Materials and Methods

Study sites: Surveys for the present work were conducted at Buleji along the Karachi coast (Fig. 1). The rocky area of Buleji covers a distance of approximately 800 meters, located at 24°50’ N and 66°49’ E between Hawks Bay and Paradise Point. It is a triangular rocky platform of a wave-beaten shore with a slightly uneven profile and protruding out into the open Northern Arabian Sea. The middle and lower areas of the ledge are madeup of rather flat continuous rocks and comparatively small boulders. There is also an adjoining area toward the south-east, which is composed of mud, sand cobbles and occasional boulders. This site was selected on the basis of habitat features. Surveys were undertaken only during the winter monsoon (February, 2016) because during the summer monsoon, harsh water conditions do not permit safe diving.

Methods: SCUBA (self contained underwater breathing apparatus) diving was conducted at 7 diving sites (Buleji 1, Buleji 2, Buleji 3, Buleji 4, Buleji 5, Buleji 6 and Buleji 7) (Fig. 1). Underwater habitat features, observations including GPS coordinates at all sites were also chronicled (Table 1). Species abundance at each site was determined quantitatively by using 1 m^2 quadrat (Ali *et al.,* 2017). A total of 70 quadrats (10 at each site) were deployed randomly. Samples accumulated within each quadrat were collected and stored in the polythene bags. In situ images were taken using Fujifilm Fine Pix F550 EXR camera in an underwater housing. Samples brought to the laboratory were preserved in formalin (4%), mounted on herbarium sheets and stored at the Centre of Excellence in Marine Biology, University of Karachi, Pakistan, for future record. Samples were identified using descriptive information in the following literature (Shameel & Tanaka, 1992, Shaikh & Shameel, 1995, Carpenter & Niem, 1998, Nizamuddin & Aisha, 1996) and herbarium specimens present in the Center of Excellence in Marine Biology, University of Karachi, Pakistan.

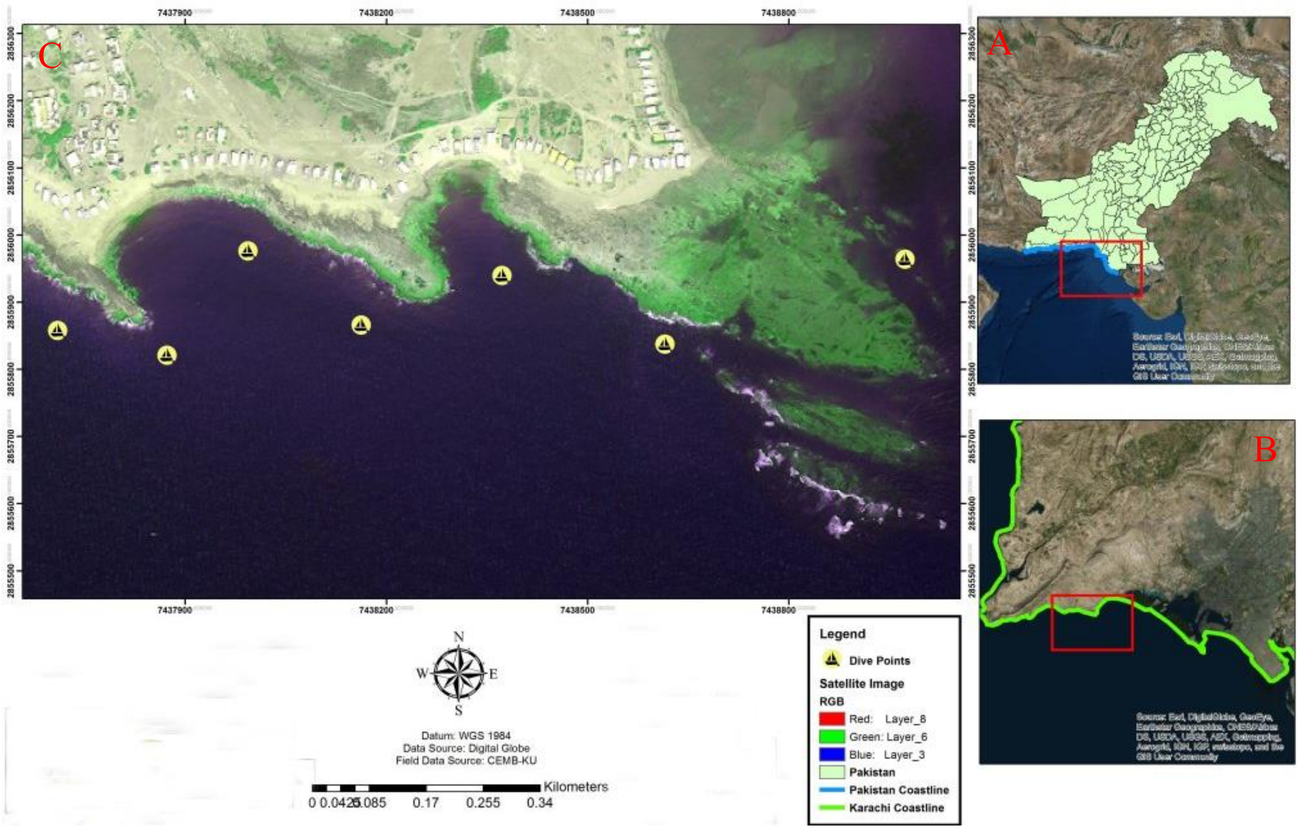

Fig. 1. A: Map of the entire coast of Pakistan; B: Karachi coast; C: Diving sites at Buleji.

Physical parameters of sea water that include temperature, dissolved oxygen, pH and salinity were recorded in triplicate from each sampling site. Dissolved oxygen was determined using EZDO 7031 DO/ temperature meter. Salinity was measured using a refractometer (Atago, Japan), while pH was determined using a Hanna HI98107 pH meter. The instruments were used according to the manufacturers' instructions. Triplicate water samples were collected for nutrient analysis (nitrite, nitrate, phosphate and ammonia). Water samples for nutrient analysis were collected from a single central point because the study area was quite small (three quarters of a kilometer). The samples were kept in an ice box and brought to the laboratory. Samples were analyzed following the method of Strickland & Parsons (1972).

Seminars were conducted to raise the socio-economic importance of seaweeds in the local community. A training workshop was also conducted to train the fishermen regarding seaweeds, sustainable harvesting, marketing and preservation techniques.

Statistical analysis: The links between sites were examined using cluster analysis based on square root transformation and Bray-Curtis similarity index. Group average linkage techniques were used for the construction of dendrogram. To exhibit the data, multi-dimensional scaling (MDS) ordinations were used (Bray & Curtis, 1957; Clarke, 1993; Clarke & Warwick, 2001. Multivariate analyses were conducted using PRIMER v.6 software (Clarke & Gorley, 2006).

Results

Seaweed communities: Seventeen species (12 Phaeophyceae and 5 Rhodophyceae) of macroalgae were recorded belonging to 2 major groups and 6 families. A detailed list of the species with relative abundance is given in Table 2, Fig. 2 (A-B), which also shows occurrence of the species at each site. Except for dive site 6, the communities were dominated by *Sargassum* species (many with medicinal value) while species used as food by humans such as *Ulva* species were not present in the submerged habitats. Excluding *Polycladia indica* (synonym *Cystoseira indica*) and *Dictyota dichotoma*, the rest of recorded species (*Botryocladia leptopoda*, *Coelarthrum opuntia*, *Solieria robusta*, *Meristotheca papulosa*, *Ceramium* sp., *Dictyota dichotoma*, *Padina pavonica*, *Spatoglossum asperum*, *Stoechospermum polypodioides*, *Stypopodium shameelii*, *Stypopodium zonale*, *Sargassum lanceolatum*, *Sargassum aquifolium*, *Sargassum cinctum*, *Sargassum swartzii*, *Colpomenia sinuosa*) have been reported earlier from different sites along the Sindh coast with their distribution ranges by Ali *et al.*, (2017) (Table 3). *Polycladia indica*, hasa limited distribution and is mainly present in coastal areas of Gujrat, India, Arabian-Persian Gulf, southern part of Iran and Oman (Wynne & Jupp, 1998; Kureishy *et al.*, 1995; Silva *et al.*, 1996; Kumar *et al.*, 2011; John & Al-Thani, 2014; Fariman *et al.*, 2016; Niamaimandi *et al.*, 2017; Guiry & Guiry, 2018). *Dictyota dichotoma*, though reported from across the globe but mainly confined to Mediterranean Sea and north-east Atlantic Ocean (De Clerck, 2003: Tronholm *et al.*, 2010; Guiry & Guiry, 2018).

Table 1. General observations along with GPS coordinates and respective depth recorded at each site.

Site name	GPS positions	Depth (m)	Observations
Buleji 1	24^{O} 50' 331" N, 66^{O} 49' 526" E	3-18	The site was located approximately 100 m off from shoreline. From shoreline to approximately 150 m, a gradual increase in depth was noted (~ 3 m). But after 3 m, there is an abrupt increase in depth (~ 18 m). The habitat up to 3 m consisted of a rocky bed but at 18 m, mostly consisted of surging rocks. The habitat at approximately at 3 m depth consisted of a rocky bed. Seaweeds were found associated with the depth gradient. Up to 3 m, the community was dominated by *Sargassum lanceolatum,* whileat a greater depth, few specimens of *Botryocladia leptopoda*,*Coelarthrum opuntia*, *Ceramium* sp, *Solieria robusta*, *Stypopodium shameelii*, *Stypopodium zonale*, and *Meristotheca papulosa* were counted
Buleji 2	24^{O} 50' 269" N, 66^{O} 49' 333" E	10	The dive site was located approximately 70 m off from shoreline. The habitat was rocky with uplifted rocks and gullies. The area was thickly populated by *Sargassum aquifolium* (approximately 95% cover).
Buleji 3	24^{O} 50' 319" N, 66^{O} 49' 202" E	3-5	The site reflected the features of a bay. The surveyed area was about 15 m off from shore line. The habitat was characterized by uneven but smooth rocks and boulders with sandy pockets. *Sargassum swartzii* was observed as dominant species with about 50 % cover. The other species, such as *Botryocladia leptopoda*, *Coelarthrum opuntia*, *Stypopodium shameelii* and *Stypopodium zonale*, were found occasionally distributed at marginal sites
Buleji 4	24^{O} 50' 283" N, 066^{O} 49' 089" E	2-4	The site was about 50 m off from shore line. The bottom at this site was rocky in the form of a ridge, extending in an east-west direction with a sandy platform on the southern side. The dominant species was*Sargassum* (70 % cover) with occasionally distributed species such as *Stypopodium zonale*, *Colpomenia sinuosa*, *Dictyota dichotoma*, *Spatoglossum asperum*, *Padina pavonica* and *Stoechospermum polypodioides*
Buleji 5	24^{O} 50' 337"N, 66^{O} 48' 998"E	2-4	Seaweed communities and habitat features at this site was similar to dive site 4
Buleji 6	24^{O} 50' 261" N, 66^{O} 48' 933" E	8	The site was located about 50 m offshore. The substratum was mostly rocky with uplifted rocks, gullies, underhangs and few sandy patches. The dominant species was *Stypopodium shameelii* (30 % cover) followed by *Botryocladia leptopoda* (10 % cover) and *Coelarthrum opuntia* (10 % cover)
Buleji 7	24_{O} 50' 279" N, 66_{O} 48' 845" E	10	Habitat was rocky with gently uplifted rocks. *Sargassum* species were dominant (60 % cover) followed by *Coelarthrum opuntia* (10% cover), *Stypopodium shameelii, Spatoglossum asperum*, *Polycladia indica, Solieria robusta* and *Stoechospermum polypodioides*. No significant invertebrate fauna was observed at any site; however, Sindh domicile fish *Neopomacentrus sindensis* was observed at most sites

Table 2. List of macroalgal species recorded from submerged habitats at Buleji.

Species	Family	Group	B. 1	B.2	B. 3	B.4	B.5	B. 6	B. 7
Botryocladia leptopoda	Rhodymeniaceae	Rhodophyceae	++		+			+++	
Coelarthrum opuntia	Rhodymeniaceae	Rhodophyceae	++		+			++	+
Solieria robusta	Solieriaceae	Rhodophyceae	+						+
Meristotheca papulosa	Solieriaceae	Rhodophyceae	++						
Ceramium sp.	Ceramiaceae	Rhodophyceae	+++						
Dictyota dichotoma	Dictyotaceae	Phaeophyceae			++	++	+++		
Padina pavonica	Dictyotaceae	Phaeophyceae				++			
Spatoglossum asperum	Dictyotaceae	Phaeophyceae			+	+	+		+
Stoechospermum polypodioides	Dictyotaceae	Phaeophyceae				++	++		++
Stypopodium shameelii	Dictyotaceae	Phaeophyceae	++	+	+		+	+++++	++
Stypopodium zonale	Dictyotaceae	Phaeophyceae	+		+	+	+		
Polycladia indica (*Cystoseira indica*)	Sargassaceae	Phaeophyceae							+
Sargassum lanceolatum	Sargassaceae	Phaeophyceae	++++++		+	++			++
Sargassum aquifolium	Sargassaceae	Phaeophyceae		++++++		++	++		++
Sargassum cinctum	Sargassaceae	Phaeophyceae				+++	+++		++
Sargassum swartzii	Sargassaceae	Phaeophyceae			++++	++	++		
Colpomenia sinuosa	Scytosiphonaceae	Phaeophyceae			++	++	++		

Abundance rating is as follow: ++++++ Up to 600 plants; +++++ up to 400 plants; ++++ up to 200 plants; +++ up to 100 plants; ++ up to 40 plants and + up to 15 plants. Abbreviations used as: B1-B7; Buleji sites 1-7

Table 4. Seawater physical parameters (n = 3) ± SE recorded from 7 dive sites at Buleji along the Karachi coast.

	B1		B1		B3		B4		B5		B6		B7	
	M	± SE	M	± SE	M	± SE	M	± SE	M	± SE	M	± SE	M	± SE
Salinity (‰)	34.93	0.18	34.83	0.23	35.00	0.13	35.00	0.10	35.07	0.09	35.00	0.05	35.17	0.14
DO (mg/l ± 0.2)	06.23	0.14	06.03	0.09	05.00	0.12	06.07	0.10	06.50	0.12	06.23	0.17	06.66	0.08
pH	07.53	0.05	07.70	0.24	07.30	0.23	07.60	0.20	07.70	0.05	07.80	0.05	07.96	0.08
Temperature(^{o}C ± 0.2)	23.50	0.05	23.87	0.24	23.90	0.23	23.70	0.20	23.90	0.06	23.80	0.05	23.53	0.08

M=Mean
SE= Slandered error

Table 3. List of macroalgal species recorded from submerged habitats along the Sindh coast of Pakistan. Modified from Ali *et al.*, (2017).

Species name	Group	Family
Dictyota dichotoma	Phaeophyceae	Dictyotaceae
Dictyota implexa		
Dictyota hauckiana		
Stoechospermum polypodioides		
Stypopodium shameelii		
Stypopodium zonale		
Spatoglossum asperum		
Lobophora variegata		
Padina pavonica		
Sargassum cinctum		Sargassaceae
Sargassum aquifolium		
Sargassum ilicifolium		
Sargassum lanceolatum		
Sargassum swartzii		
Colpomenia sinuosa		Scytosiphonaceae
Iyengaria stellata		
Meristotheca papulosa	Rhodophyceae	Solieriaceae
Solieria robusta		
Scinaia hatei		
Botryocladia leptopoda		Rhodymeniaceae
Coelarthrum opuntia		
Tricleocarpa fragilis		Galaxauraceae
Galaxaura sp.		
Asparagopsis taxiformis		Bonnemaisoniaceae
Halymenia porphyroides		Halymeniaceae
Ceramium sp.		Ceramiaceae
Amphiroaanceps		Corallinaceae
Calliblepharis sp.		Cystocloniaceae
Codium decorticatum	Chlorophyta	Codiaceae
Codium fragile		
Codium indicum		
Codium latum		
Caulerpa chemnitzia		Caulerpaceae
Caulerpa scalpelliformis		
Caulerpa taxifolia		
Udotea indica		Udoteaceae

Cluster analysis of macroalgal communities showed that sites 4-5 and 1-6 formed well defined clusters at about 85 and 75 % similarity level, while sites 2, 7 and 3 formed separate clusters at about 25%, 35% and 62% similarity levels (Fig. 3). An MDS ordination indicated that at most sites algal communities were similar (Fig. 4). The stress value was 0.05. According to Clarke & Warwick (2001), a stress value of 0.05 in MDS analyzes indicates the outstanding representation of the data.

Seawater physico-chemical parameters: No significant variations were noted in seawater physical parameters. The minimum and maximum average salinity observed at various sites was 34.5 ‰ and maximum 35‰, respectively. However, a slight deviation was recorded in average minimum and maximum dissolved oxygen (DO) values that were observed as 5 mg/l and 6.9 mg/l, respectively. On the other hand, no considerable variation in pH values and temperature were observed. The pH values of the sea water ranged between 7.3 and 7.9, while temperature varied between 23.3ºC and 24.5ºC at various collection sites. Variations in physical parameters might be due to the different nature of sites, data recording time and prevailing climatic conditions. The list of all physical parameters is mentioned in Table 4. Regarding inorganic nutrients, high concentration of nitrate (0.28) followed by ammonia (0.19), phosphate (0.08), nitrite (0.02) were recorded. All data regarding nutrient concentration are shown in Fig. 5.

Community response: A large number of participants from the local community attended the training workshop, conducted on the harvesting and processing of seaweeds and marketing techniques organized by some of the author.

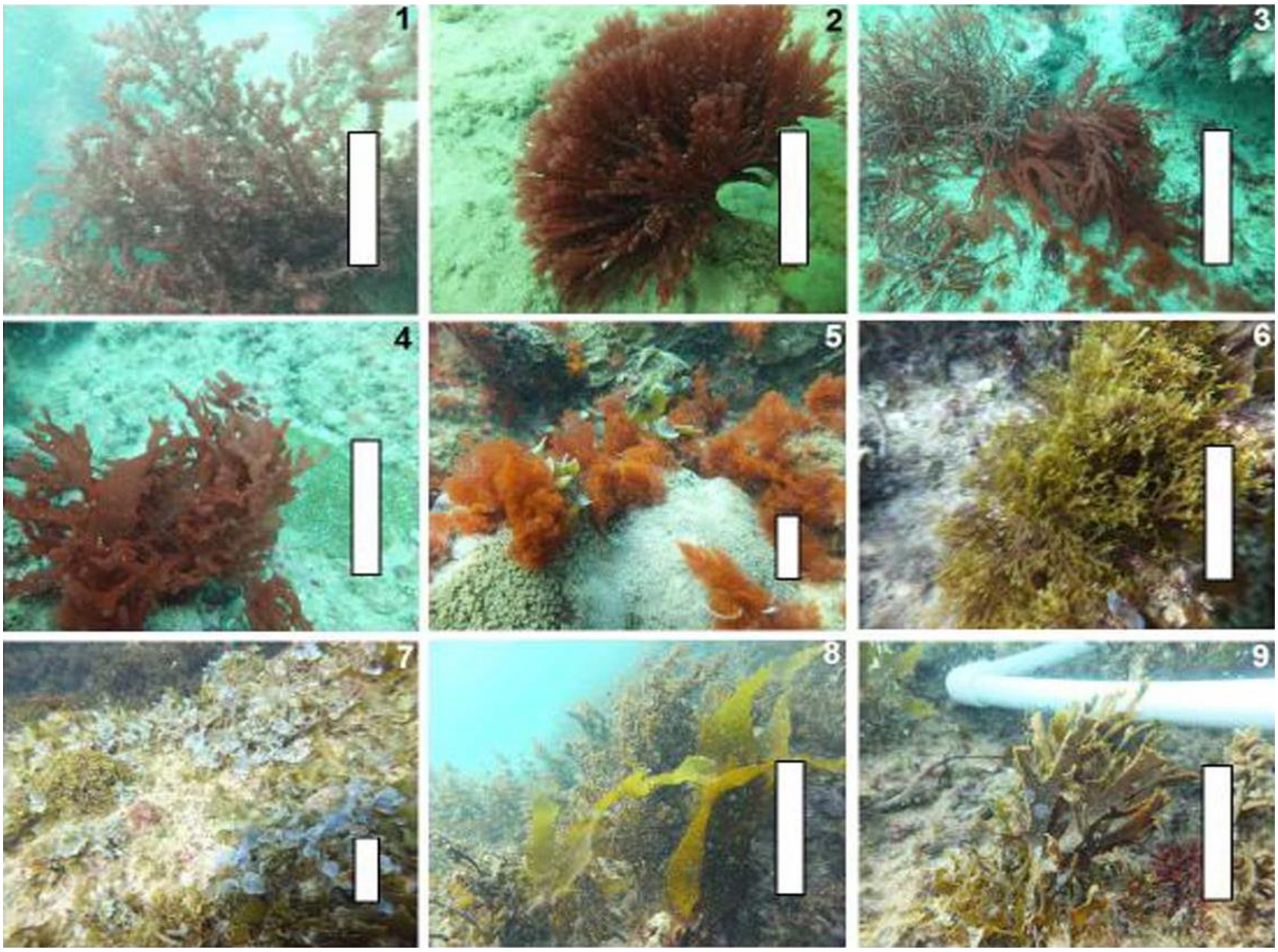

Fig. 2(A). Macroalgal species recorded from 7 diving sites at Buleji along the Karachi coast, Pakistan. 1) *Botryocladia leptopoda;* 2) *Coelarthrum opuntia;* 3) *Solieria robusta;* 4) *Meristotheca papulosa;* 5) *Ceramium* sp.; 6) *Dictyota dichotoma;* 7) *Padina pavonica;* 8) *Spatoglossum asperum;* 9) *Stoechospermum polypodioides*.

Discussion

The presence of rich *Sargassum* beds might be due to the feasible physiochemical conditions and large tidal area at most of the sites that dissipate wave energy. The shifting of small-sized algae towards marginal environments at *Sargassum*-dominated sites was mainly due to the shading caused by *Sargassum* species. Dominance of small-sized algae, e.g., of *Botryocladia leptopoda, Coelarthrum opuntia and Stypopodium shameelii* at site 6, may be associated with high wave action, the size of the plants, morphology and flexibility. It is apparent that the species distribution and diversity patterns at these sites showed resemblance with those mentioned in coastal waters of Sindh, and the factors controlling distribution patterns has already been discussed (Ali *et al.,* 2017).

Absence of *Ulva* species in underwater habitats might be due to the poor visibility contributed by algal blooms and the shading caused by *Sargassum* species. Light is an important factor necessary for the growth of *Ulva* species (Henley & Ramus, 1989; De Casablanca & Posada, 1998; Harrison & Hurd, 2001; Choi *et al.,* 2010). The rich growth of *Ulva* species in the intertidal areas on rocky ledges at Buleji between May and November supports the relation between light intensity and the growth of *Ulva* species in that during May to November, the temperature is quite high along the Pakistan coast (Shameel & Khan, 1990: Alam & Qasim, 1993; Hameed & Ahmad, 1999).The other factor regarding rich growth of *Ulva* species could be the presence of invertebrate grazers (crustaceans). It is evident that invertebrate grazers feeding on epiphytes in intertidal areas significantly improves light and nutrient conditions, resulting in a heavy growth of *Ulva* species (Brawley & Adey, 1981; Dudley, 1992; Jernakoff *et al.,* 1996; Fong *et al.,* 1997; Kamermans *et al.,* 2002). Many of the *Sargassum* species (e.g. *Sargassum illicifolium, Sargassum aquifolium, Sargassum lanceolatum*, *Sargassum swartzii, Sargassum cinctum*) and other species (e.g. *Codium indicum*, *Colpomenia sinuosa*, *Polycladia indica*, *Dictyota hauckiana, Dictyota dichotoma, Iyengaria stellata, Colpomenia sinuosa*, *Stoechospermum polypodioides, Stypopodium shameelii, Stypopodium zonale, Spatoglossum asperum, Codium fragile, Caulerpa taxifolia, Solieria robusta* and *Botryocladia leptopoda*) have food and medicinal values, and their extracts are widely used as cytotoxic and anti-inflammatory agents (Rao *et al.,* 1988; Wessels *et al.,* 1999; Ara *et al.,* 2005; Rizvi & Shameel, 2005; Ortiz *et al.,* 2009;Ayesha *et al.,* 2010; Haq *et al.,* 2011; Hong *et al.,* 2011; Kelman *et al.,* 2012; Rizvi & Valeem, 2012; Ahmed *et al.,* 2015; Hira *et al.,* 2017; Puspita *et al.,* 2017).

The above-mentioned *Sargassum* species are widely distributed in submerged rocky habitats along the Sindh coast, while the rest of the species, such as *Codium indicum*, *Colpomenia sinuosa*, *Polycladia indica*, *Dictyota hauckiana, Dictyota dichotoma, Iyengaria stellata, Colpomenia sinuosa*, *Stoechospermum polypodioides, Stypopodium shameelii, Stypopodium zonale, Spatoglossum asperum, Codium fragile, Caulerpa taxifolia, Solieria robusta* and *Botryocladia leptopoda*, have common to frequent and occasional distributions (Ali *et al.,* 2017). Similarly, more than 175 species of macroalgae are reported along the Balochistan coast of Pakistan (Shameel, 1987; Shameel *et al.,* 1996). It is expected that further underwater surveys will help in exploring more algal beds along the coast. Further positive efforts to explore for algal distribution in the coastal areas of Pakistan for sustainable use of the wide range of algal species are needed at this time.

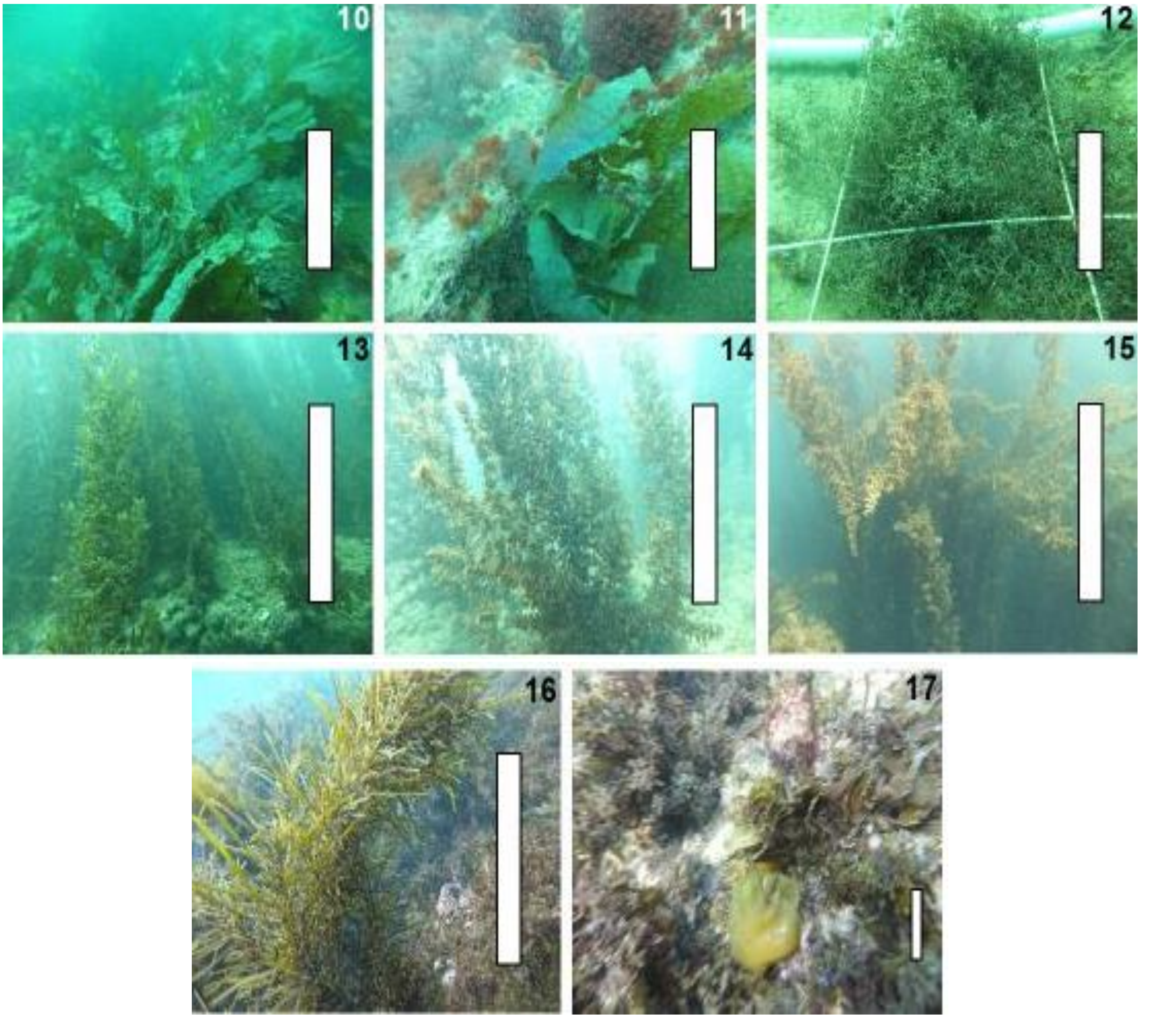

Fig. 2(B). Macroalgal species recorded from 7 diving sites at Buleji. 10) *Stypopodium shameelii;* 11) *Stypopodium zonale;* 12) *Polycladia indica;* 13) *Sargassum lanceolatum;* 14) *Sargassum aquifolium;* 15) *Sargassum cinctum;* 16) *Sargassum swartzii;* 17) *Colpomenia sinuosa*.

Conclusions

Coastal waters of Pakistan have a huge algal stock, but unfortunately they are not being utilized but are mostly wasted. Sustainable utilization of these precious natural resources can provide an alternative source of livelihood for coastal communities to improve their socioeconomic conditions. Furthermore, coastal seaweed aquaculture is recommended especially near heavily populated cities. This will provide habitats for fish growth and make positive ecological impacts on coastal ecosystems by improving water quality through minimizing eutrophication effects by absorbing the inorganic nutrients (nitrate, nitrite, phosphates, etc.) as well as heavy metals because many species of brown seaweeds have the ability to absorb heavy metals. The net economic output will improve the living conditions of the poor coastal communities.

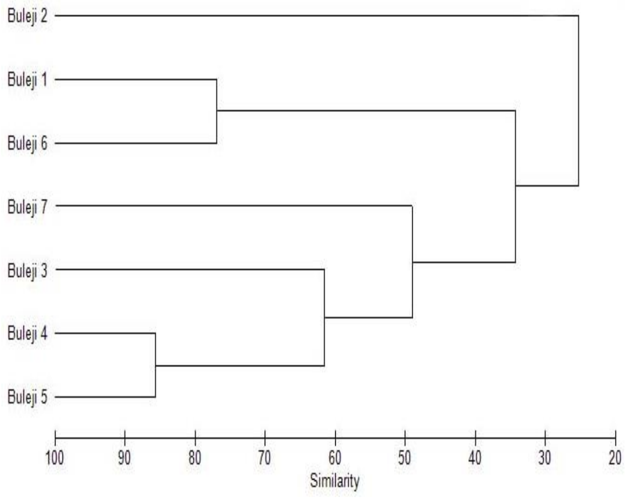

Fig. 3.Cluster analysis for macroalgal communities at 7 diving sites, based on square root transformation and Bray-Curtis similarity index.

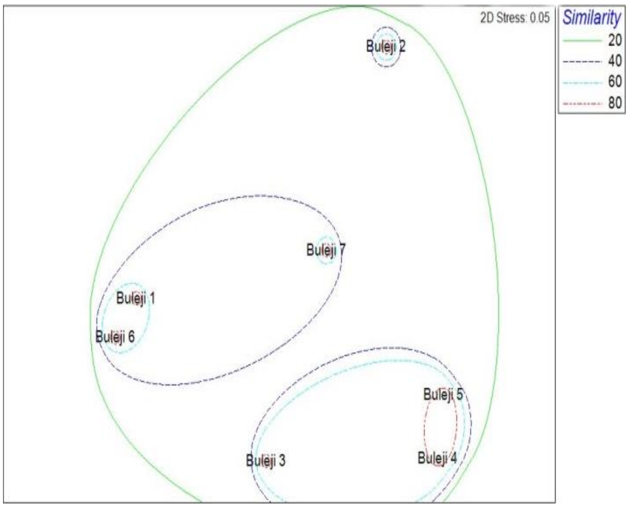

Fig. 4. Multi-dimensional scaling (MDS) for macroalgal communities conducted at 7 diving sites on the bases of square root transformation and Bray–Curtis similarity index.

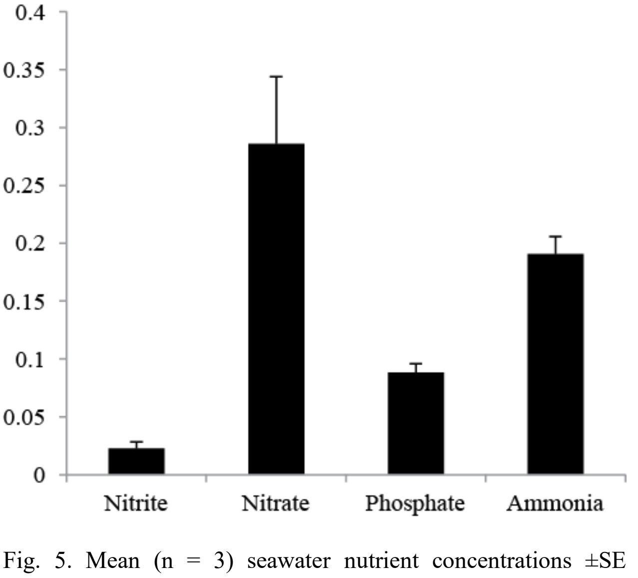

Fig. 5. Mean (n = 3) seawater nutrient concentrations ±SE recorded from a central point at Buleji along the Karachi coast.

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