Journal of Coastal Life Medicine

journal homepage: www.jclmm.com

Original article doi:10.12980/jclm.4.2016j5-231

A compiled checklist of seaweeds of Sudanese Red Sea coast

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ARTICLE INFO

Article history:
Received 20 Nov 2015
Received in revised form 17 Dec 2015
Accepted 12 Jan 2016
Available online 19 Jan 2016

Keywords:
Checklist
Seaweeds
Red Sea
Sudan

ABSTRACT

Objective: To present an updated and compiled checklist of Sudanese seaweeds as an example for the region for conservational as well as developmental purposes.
Methods: The checklist was developed based on both field investigations using line transect method at 4 sites along the Red Sea coast of Sudan and review of available studies done on Sudanese seaweeds.
Results: In total 114 macroalgal names were recorded and were found to be distributed in 16 orders, 34 families, and 62 genera. The Rhodophyceae macroalgae contained 8 orders, 17 families, 32 genera and 47 species. The Phaeophyceae macroalgae composed of 4 orders, 5 families, 17 genera, and 28 species. The 39 species of the Chlorophyceae macroalgae belong to 2 classes, 4 orders, 12 families, and 14 genera. The present paper proposed the addition of 11 macroalgal taxa to be included in Sudan seaweeds species list. These include 3 red seaweed species, 1 brown seaweed species and 7 green seaweed species.
Conclusions: This list is not yet inclusive and it only represents the macroalgal species common to the intertidal areas of Sudan Red Sea coast. Further investigation may reveal the presence of more species. While significant levels of diversity and endemism were revealed for other groups of organisms in the Red Sea region, similar work still has to be performed for seaweeds. Considering the impact of climate change on communities' structure and composition and the growing risk of maritime transportation through the Red Sea particularly that may originate from oil tankers as well as that may emanate from oil exploration, baseline data on seaweeds are highly required for management purposes.

1. Introduction

The Red Sea is reported to exhibit one of the highest levels of endemism in marine organisms and also to represent an evolutionary incubator that may occasionally contribute species to the Indian Ocean[1]. This endemism has been attributed to the gradient in some environmental parameters as well as to the isolation of the Red Sea due to some geomorphological features[2]. Although some recent reports have revised and/or reviewed the genetic diversity and endemism of Red Sea corals, fishes, and coral fishes[1-4], the diversity and endemism in Red Sea seaweeds which was reported to constitute 9% are yet remained to be reinvestigated for accuracy. Physico-chemical parameters of the Red Sea influence the composition and the structure of the existing macroalgal communities. These may include surface water temperature and salinity that exhibit a marked gradient from north to the south. Along the Sudanese Red Sea the sea water temperatures in near shore areas range from 26.54 to 32.97 ℃ with a maximum of 45 ℃ inside sheltered lagoons[3]. Average surface salinities are 38‰ and range from 40‰ to 45‰ due to the limited influx of fresh water and high evaporation rates along the Red Sea. Salinities are also higher in near shore areas and during the summer for the same reasons. Therefore, the Red Sea is known as one of the warmest, most saline, and most oligotrophic marine ecosystems on earth[5]. In majority of the Sudanese Red Sea, the water is highly transparent, sometimes as deep as 70 m. The tidal pattern is characterized with a central

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The journal implements double-blind peer review practiced by specially invited international editorial board members.

Foundation Project: Supported by the Faculty of Marine Science and Fisheries, Red Sea University, Sudan (Grant No. RSU-2014\SewRes).

node near Jeddah, with increasing tidal amplitude moving away from this point to the north or to the south. According to some of these parameters, the Red Sea is subdivided into three regions, the northern, the central, and the southern. Therefore, some of the Southern Red Sea seaweeds species are typically tropical and some of the Northern Red Sea species may belong to those of slightly cooler waters. The species of the Central Red Sea occur at the boundary between the two groups. Red Sea seaweeds are characterized with a clear seasonality in accordance with changes in seasonal surface water temperature[6].

Sudan coast extends for 750 km on the central part of the western coast of the Red Sea. The climate in this part is of tropical arid nature. The geomorphology of the Sudanese coast is characterized with coastal lagoons, embayments and coral reef formations. The sediment in the intertidal zone is largely of limestone nature except where some coastal embayments receive the seasonal discharges of coastal streams. In these embayments mangrove stands are prominent feature and they help to build sediment of muddy sandy nature. At the vicinity of this particular environment seaweed lawns are found.

Very few and scattered studies were done on the seaweeds along the Sudanese Red Sea coast. The first floristic study was in 1980 and the next and last was undertaken in 1993. Elhag and Karim investigated the association of macroalgae in small area in Suakin with zonation and seasonality[7]. They listed 16 macroalgal species and genera from the area composed of 8 taxa of Chlorophyceae and 4 taxa for both Phaeophyceae and Rhodophyceae macroalgae. In the eighties several studies were carried out on coral reef ecosystems of the Sudan. These studies included seaweeds as a one of the major reef components. Vine and Vine profiled and located the important members of sessile flora associated with Sudanese coral reef[8]. Elhag provided a list of 60 taxa of seaweeds from Sanganeb Atoll, including 16 genera and species of Chlorophyta, 12 taxon of Phaeophyta, 25 of Rhodophyta, and 7 belonging to cyanobacteria[9].

The study on the floristic composition of the Sudanese seaweeds is very imperative at this point of time due to some national, regional, and international rationales. These may include remarkable coastal development along the Sudanese Red Sea coast, the hazards stemmed from the maritime transportation of oil through the Red Sea, and the membership of Sudan to the Convention on Biological Diversity. However, and more particularly, because floristic studies on seaweeds flora of Sudan are sporadic and scattered in various types of publications, some of which may not be readily accessible, the present paper aimed to reveal the floristic diversity of seaweeds of Sudan Red Sea coast for conservational and management purposes and to include recent nomenclatural changes in seaweeds names. It compiled, revised, and updated existing records on Sudan seaweeds to produce a preliminary checklist of the Sudanese seaweeds based on field investigations and literature reviews.

2. Materials and methods

The methods performed to investigate the floristic diversity of seaweeds along the Sudanese Red Sea coast included field investigation to record existing taxa and critical review of the available literatures on Sudan seaweeds.

2.1. Study sites

Field investigations were performed during the winter (October to March) according to the guidelines described by Baker and Wolff[10]. Upper intertidal and mid subtidal areas at 4 sites along the Sudanese Red Sea coast were investigated during December 2009, January 2010, March 2014, April 2015 to examine seaweeds lawns and to record existing species. Brief description of these sites is provided below.

2.1.1. Darah Embayment

Darah Embayment is situated 36.7 km to the north of Port Sudan Harbour at 37°12'19" E and 20°23'50" N. Generally, the site is exposed to wave action and characterized with a hard coralline bottom intermitted with sand.

2.1.2. Abuhashish area

This site is found at about 2 km north of Port Sudan Harbour entrance. The subtidal area in this site is wide with shallow water depth less than 150 cm and soft bottom with scattered boulders.

2.1.3. Kilo 8 Embayment

This site is 8 km from Port Sudan Railway Station just at the southern outskirts of the city between 19°35'40" E and 19°36'40" E, and 37°14'54" N and 37°14'55" N. The substrate of this site is a mixture of mud and silt due to precipitation of fine sediment particles brought by the seasonal flash floods.

2.1.4. Sheikh Ibrahim Embayment

This locality is situated at about 35 km south to Port Sudan Harbour at 18°56' N and 37°24' E. This embayment is protected from the wave action and receives frequent freshwater discharges. It hosts a mangrove stand that contributes to the sand silty nature of the sediment.

2.2. Sampling

The line transect method described by English *et al*. was followed[11]. At each location, 3 transects perpendicular to shoreline were located; a square quadrat (25 cm × 25 cm) was tossed 4 times randomly every 10 m at the both sides of the transect and species inside the quadrat were listed. Some specimens were taken to the laboratory for further examination. However, to accommodate the patchy distribution of seaweeds in some sites, random sampling was

also performed.

2.3. Morpho-anatomical measurements

Morphological measurements were done on fresh specimens and were done 3 times on the same specimen to the nearest millimeter. Measured attributes included total plant length, width, and thickness. For the red algal samples cross sections were made with a razor under the stereomicroscope, and sections were stained with aniline blue then examined under the microscope.

2.4. Taxonomic identification

The taxonomic identification of the macroalgal specimens collected during this investigation was confirmed with authentic phycological literature[12-18].

2.5. Literature review and seaweeds checklist compilation

Seaweeds list compilation was based on reviewing previous records on Sudanese seaweeds. Both an online and desk searches were performed to obtain the records. The online search was done with the following keywords: seaweeds, Sudan, Red Sea in Google scholar. The desk search was carried out at the libraries of Faculty of Marine Science and Fisheries and the Marine Research Institute of the Red Sea University, Port Sudan, Sudan. The documents obtained from searches were used to produce a single and an alphabetically arranged checklist. The taxon names were listed as they were originally cited with no verification. Then, this list was compared with seaweeds list developed from the field surveys undertaken during this investigation. Missing taxa were included and the list was checked for duplications. Further, the list was examined to remove synonyms and invalid taxa according to Guiry and Guiry[19]. Therefore, and particularly for *Sargassum* species, only records with binomials were included in the list when other records include incomplete names.

3. Results

Tables 1–3 include the taxa of Sudanese marine macroalgae produced from compilation of the previous records and this investigation. The tables composed of 16 orders, 34 families, and 63 genera. The Rhodophyceae macroalgae (Table 1) contained 8 orders, 17 families, 32 genera and 47 species. The Phaeophyceae macroalgae (Table 2) composed of 4 orders, 5 families, 17 genera, and 28 species. The 39 species of the Chlorophyceae macroalgae (Table 3) belong to 2 classes, 4 orders, 12 families, and 14 genera. In total the current Sudanese macroalgal flora contained 114 taxa. Eleven taxa were not found in any records on Sudan seaweeds; therefore they were included in this list as new additions. These included 3 red macroalgae, one brown macroalgae, and 7 green macroalgae. Following is the description of these additional taxa.

Table 1
List of taxa of marine red macroalgae of Sudan.

Taxa	No. of species	Synonym and Reference
Subclass: Florideophycidae		
Order: Ceramiales		
Family: Ceramiaceae		
Genus: *Centroceras* Kutzing		
Centroceras sp.	1	[9]
Genus: *Ceramium* Roth		
Ceramium sp.	2	[9]
Ceramium sp.	1	[7]
Family: Dasyaceae		
Genus: *Dasya* C. Agardh		
Dasya sp.	1	[9]
Family: Delesseriaceae		
Genus: *Martensia* K. Hering		
Martensia sp.	1	[9]
Family: Rhodomelaceae		
Genus: *Acanthophora* J. V. Lamouroux		
Acanthophora spicifera (M. Vahl) Borgessen	1	This paper
Acanthophora sp.	1	[9]
Genus: *Chondria* C. Agardh		
Chondria sp.	1	[9]
Genus: *Digenea* C. Agardh		
Digenea simplex (Wulfen) C. Agardh	1	[20,21]
Genus: *Herposiphonia* Nageli		
Herposiphonia sp.	2	[9]
Genus: *Laurencia* J. V. Lamouroux		
Laurencia obtusa (Hudson) J. V. Lamouroux	1	[20]
Laurencia obtusa var. *divaricata* Yamada	1	[22] as *Laurencia divaricata* J. Agardh
Laurencia pinnatifida J. Agardh	1	[22]
Laurencia sp.	1	[7]
Laurencia sp.	3	[9]
Genus: *Leveillea* Decaisne		
Leveillea jungermannioides (Hering & G. Martens) Harvey	1	[20] and [22] as *Polyzonia jungermannioides* J. Agardh
Leveillea sp.	1	[9]
Genus: *Lophocladia* (J. agardh) F. Schimtz		
Lophocldia lallemandii (Montagne) F. Schmitz	1	[20]
Genus: *Polysiphonia* Greville		
Polysiphonia utricularis Zanardini	1	[20]
Polysiphonia sp.	2	[9]
Genus: *Palisada* K. W. Nam		
Palisada perforata (Bory de Saint-Vincent) K. W. Nam	1	[7,20,22] as *Laurencia papillosa* (C. Agardh) Greville; [12] as *Chondrophycus papillosus* (C. Agardh) D. J. Garbary & J. T. Harper
Family: Spyridiaceae		
Genus: *Spyridia* Harvey		
Spyridia filamentosa (Wulfen) Harvey	1	[20,22]
Spyridia sp.	2	[9]
Genus: *Tolypiocladia* Sonder		
Tolypiocladia sp.	1	[9]
Order: Corallinales		
Family: Corallinaceae		
Genus: *Choreonema* F. Schmitz		
Choreonema thuretii (Bornet) F. Schmitz	1	[20]
Genus: *Corallina* Linnaeus		
Corallina sp.	2	[9]
Genus: *Neogoniolithon* setchell & L R. Mason		
Neogoniolithon oblimans (Heydrich) P. C. Silva.	1	[22] as *Goniolithon myriacarpon* Foslie and [20] as *Neogoniolithon myriocarpum* (Foslie) Setchell & L R. Mason
Genus: *Jania* J. V. Lamouroux		
Jania rubens (Linnaeus) J. V. Lamouroux	1	[9,20]

(*continued on next page*)

Table 1 (*continued*)

Taxa	No. of species	Synonym and Reference
Jania tenella (Kutzing) Grunow	1	[20,22] as *Corallina tenella* Kutzing
Jania sp.	1	[9]
Genus: *Lithophyllum* Philippi		
Lithophyllum kotschyanum f. *affine* (Foslie) Foslie	1	[20,22] as *Lithophyllum affine* (Foslie) Foslie
Lithophyllum fasciculatum (Lamarck) Foslie	1	[20]
Lithophyllum sp.	1	[9]
Family: Hapalidiaceae		
Genus: *Lithothamnion* Heydrich		
Lithothamnion crispatum Hauck	1	[20]
Genus: *Mesophyllum* Me. Lemoine		
Mesophyllum expansum (Philippi) Cabioch & M. L. Mendoza	1	[20] as *Pseudolithophyllum expansum* (Philippi) Me. Lemoine
Genus: *Phymatolithon* Foslie		
Phymatolithon calcareum (Pallas) W. H. Adey & D. L. McKibbin		[20] as *Lithothamnion polymorphum* (Linnaeus) Areschoug
Order: Cryptonemiales		
Family: Cryptonemiaceae		
Genus: *Halymenia* C. Agardh		
Halymenia floresii (Clemente) C. Agardh	1	[20]
Order: Gigartinales		
Family: Cystocloniaceae		
Genus: *Hypnea* J. V. Lamouroux		
Hypnea valentiae (Turner) Montagne	1	[20,22]
Family: Dumontiaceae		
Genus: *Dudresnaya* P. L. Crouan & H. M. Crouan		[20]
Dudresnaya verticillata (Withering) Le Jolis	1	[20]
Family: Solieriaceae		
Genus: *Sarconema* Zanardini		
Sarconema filiforme (Sonder) Kylin	1	[12,20] as *Sarconema furcellatum* Zanardini
Order: Gracilariales		
Family: Gracilariaceae		
Genus: *Gracilaria* Greville		
Gracilaria foliifera (Forsskal) Borgesen	1	This paper
Gracilaria sp.	1	This paper
Order: Nemiales		
Family: Galaxauraceae		
Genus: *Tricleocarpa* Huisman & Borowitzka		
Tricleocarpa fragilis (Linnaeus) Huisman & R. A. Townsend	1	[20] as *Galaxaura oblongata* (J. Ellis &Solander) J.V. Lamouroux
Order: Gelidiales		
Family: Gelidiaceae		
Genus: *Gelidium* J. V. Lamouroux		
Gelidium corneum (Hudson) J. V. Lamouroux	1	[20,22]
Gelidium crinale (Hare ex Turner). Gaillon	1	[20]
Family: Gelidiellaceae		
Genus: *Gelidiella* Feldmann & G. Hamel		
Gelidiella acerosa (Forsskal) Feldmann & G. Hamel	1	[20,22] as *Gelidium rigidum* Greville
Family: Liagoraceae		
Genus: *Liagora* J. V. Lamouroux		
Liagora turneri Zanardini	1	[20]
Order: Rhodymeniales		
Family: Champiaceae		
Genus: *Chylocladia* Geville		
Chylocladia verticillata (Lightfoot) Bliding	1	[20] as *Lomentaria squarrosa* Kutzing

3.1. Acanthophora spicifera (M. Vahl) Borgesen

Thallus erect, terete, reddish brown, brittle, palmate-shaped and up to 20 cm in length with irregular branching. Main branches have numerous short, spinose, determinate branchlets irregularly shaped and radially arranged. There are no spines on main axes. The plant grows from a large, irregularly shaped holdfast.

Table 2

List of taxa of marine brown macroalgae of Sudan.

Taxa	No. of species	Synonym and Reference
Class: Phaeophyceae		
Order: Dictyotales		
Family: Dictyotaceae		
Genus: *Dictyota* J. V. Lamouroux		
Dictyota dichotoma (Hudson) J. V. Lamouroux	1	[9,20]
Dictyota dichotoma var. *intricata* (C. Agardh) Greville	1	[20]
Genus: *Dictyopteris* J. V. Lamouroux		
Dictyopteris sp.	1	[9]
Genus: *Gymnosorus* J Agardh		
Gymnosorus collaris (C. Agardh) J. Agardh	1	[20] as *Zanardinia collaris* (C. Agardh) J. Agardh
Genus: *Lobophora* J. Agardh		
Lobophora variegata (J. V. Lamouroux) Womersley ex. E. C. Oliveira	1	[20] as *Pocockiella variegata* (J. V. Lamouroux) Papenfuss
Lobophora sp.	1	[9] as *Pocockiella* sp.
Genus: *Padina* Adanson		
Padina pavonica (Linnaeus) Thivy	1	[7,9,20]
Genus: *Stypopodium* Kutzing		
Stypopodium schimperi (Kutzing) M. Verlaque & Boudouresque	1	[22] as *Zonaria schimperi* Kutzing
Order: Ectocarpales		
Family: Chordariaceae		
Genus: *Eudesme* J. Agardh		
Eudesme virescens (Carmichael ex Berkeley) J. Agardh	1	[20,22] as *Castagnea virescens* Thuret
Family: Ectocarpaceae		
Genus: *Ectocarpus* Lyngbye		
Ectocarpus siliculosus J. Ag.	1	[22]
Ectocarpus sp.	1	[9]
Family: Scytosiphonaceae		
Genus: *Chnoospora* J. Agardh.		
Chnoospora sp.	1	[9]
Genus: *Colpomenia* (Endlicher) derbes & Solier		
Colpomenia sinuosa (Mertens ex Roth) Derbes & Solie	1	[20]
Genus: *Hydroclathrus* Bory de Saint-Vincent		
Hydroclathrus clathratus (C. Agardh) M. A. Howe	1	[20,22] as *Hydroclathrus cancellatus* Bory de Saint-Vincent
Order: Fucales		
Family: Sargassaceae		
Genus: *Cystoseira* C. Agardh		
Cystoseira amentacea (C. Agardh) Bory de Saint-Vincent	1	[20]
Cystoseira sp.	1	[7]
Genus: *Hormophysa* Kutzing		
Hormophysa cuneiformis (J. F. Gmelin) P. C. Silva	1	This paper
Genus: *Polycladia* Montagne		
Polycladia myrica (S.G.Gmelin) Draima, Ballesteros, F.Rousseau & T.Thibaut	1	[7,20] as *Cystoseira myrica* (S. G. Gmelin) C. Agardh
Genus: *Sargassum* C. Agardh		
Sargassum acinarium (Linnaeus) Setchell	1	[20] as *Sargassum linifolium* C. Agardh
Sargassum dentifolium (Turner) C. Agardh	1	[20,22]
Sargassum latifolium (Turner) C. Agardh	1	[22]
Sargassum notarisii Zanardini	1	[22] as *Sargassum crispum* C. Agardh
Sargassum subrepandum (Forsskal) C. Agardh	1	[20,22]
Sargassum vaysierianum var. *assarkense* Grunow	1	[20]
Genus: *Turbinaria* V. L. Lamouroux		
Turbinaria decurrens Bory de Saint-Vincent	1	[7,9,20]
Turbinaria elatensis W. RR. Tylor	1	[9,20]
Turbinaria triquetra (J. Agardh) Kutzing	1	[20]
Order: Sphacelariales		
Family: Sphacelariaceae		
Genus: *Sphacelaria*		
Sphacelaria rigidula Kutzing	1	[20] as *Sphacelaria furcigera* Kutzing

Table 3
List of taxa of marine green macroalgae of Sudan.

Taxa	No. of species	Synonym and Reference
Class: Chlorophyceae		
Order: Dasycladales		
Family: Polyphysaceae		
Genus: *Acetabularia* J. V Lamouroux		
Acetabularia sp.	1	This paper
Class: Ulvophyceae		
Order: Bryopsidales		
Family: Bryopsidaceae		
Genus: *Bryopsis* J. V. Lamouroux		
Bryopsis corymbosa J. Agardh	1	[20] as *Bryopsis implexa* De Notaris
Bryopsis plumosa (Hudson) C. Agardh	1	[20]
Bryopsis plumosa var. *hypnoides* (Lamouroux) Kutzing	1	[22] as *Bryopsis plumosa* Kutzing
Family: Caulerpaceae		
Genus: *Caulerpa* J. V. Lamouroux		
Caulerpa chemnitzia (Esper) J. V. Lamouroux	1	[22] as *Caulerpa peltata* Lam. f. *typica* & [20] as *Caulerpa racemosa* var. *peltata* (J. V. Lamouroux) Eubank
Caulerpa cupressoides var. *lycopodium* Weber-van Bosse	1	[20]
Caulerpa denticulata Decaisne	1	[20] as *Caulerpa scalpelliformis* var. *denticulata* (Decaisne) Weber-van Bosse
Caulerpa racemosa (Forsskal) J. Agardh	1	[22] as *Caulerpa racemosa* var. *unifera* J. Agardh; [7,20]
Caulerpa racemosa var. *macrophysa* (Sonder ex Kutzing) W. R. Taylor	1	This paper
Caulerpa selago (Turner) C. Agardh	1	[12]
Caulerpa serrulata (Forsskal) J. Agardh	1	[7,9,20]
Family: Codiaceae		
Genus: *Codium* Stackhouse		
Codium tenue (Kutzing) Kutzing	1	[20]
Codium tomentosum Stackhouse	1	[20]
Codium sp.	2	[9]
Family: Dichotomosiphonaceae		
Genus: *Avrainvillea* Decaisne		
Avrainvillea amadelpha (Montagne) A. Gepp & E. S. Gepp	1	[20]
Avrainvillea erecta (Berkeley) A. Gepp & E. S. Gepp	1	[20]; [22] as *Avrainvillea papuana* G. Murray & Boodle
Avrainvillea lacerata Harvey ex J. Agardh	1	[22]
Family: Halimedaceae		
Genus: *Halimeda* J. V. Lamouroux		
Halimeda cylindracea Decaisne	1	This paper
Halimeda discoidea Decaisne	1	[12]
Halimeda monile (J. Ellis and Solander) J. V. Lamouroux	1	[22] as *Halimeda incrassata* f. *monilis* (J. V. Lamouroux) Barton
Halimeda macroloba Decaisne	1	This paper
Halimeda opuntia (Linnaeus) J. V. Lamouroux	1	[12,22] as *Halimeda opuntia* f. *triloba* Barton
Halimeda tuna (J. Ellis and Solander) J. V. Lamouroux	1	[7,9,20]
Family: Udoteaceae		
Genus: *Flabellia* Reichenbach		
Flabellia petiolata (Turra) Nizamoddin	1	[20] as *Udotea minima* Ernst
Genus: *Udotea* J. V. Lamouroux		
Udotea argentea Zanardini	1	[20,22]
Udotea sp.	2	[7]
Order: Cladophorales		
Family: Boodleaceae		
Genus: *Boodlea* G. Murray & De Toni		
Boodlea sp.	2	[9]
Genus: *Cladophoropsis* Borgesen		
Caldophoropsis sp.	1	[9]
Family: Cladophoraceae		
Genus: *Chaetomorpha* Kutzing		
Chaetomorpha linum (O. F. Muller) Kutzing.		[20]
Chaetomorpha sp.	1	[9]
Genus: *Cladophora* Kutzing		
Cladophora sp.	1	[9]
Cladophora prolifera (Roth) Kutzing	1	[9]
Family: Siphonocladaceae		
Genus: *Dictyosphaeria* Decaisne		
Dictyosphaeria cavernosa (Forsskal) Borgesen	1	[22] as *Dictyosphaeria favulosa* Decaisne; [7,9,12]
Family: Valoniaceae		
Genus: *Valonia* C. Agardh		
Valonia aegagropila C. Agardh	1	[20]
Valonia ventricosa J. Agardh	1	This paper
Order: Ulvales		
Family: Ulvaceae		
Genus: *Ulva* Linnaeus		
Ulva compressa Linnaeus	1	[2,7,12,21]
Ulva intestinalis (Linnaeus) Nees	1	This paper
Ulva lactuca Linnaeus	1	[20]
Ulva reticulata Forsskal	1	This paper

(*continued on right column*)

Table 3 (*continued*)

3.2. Gracilaria foliifera (Forsskal) Borgesen

Thallus erect, flat, cartilaginous, strap shaped, caespitose, dichotomously branched, up to 16 cm in length with width varing from base (3 to 9 mm) to apex (2 mm), and reddish to dark brown color. Thallus margins with horizontal secondary branches. Stipe cylindrical, 1 to 1.5 cm in length, 3 to 5 mm in thickness, arising from a discoid rhizoid. Frond in transverse section consists of cortex of 1 layer of small pigmented cells and medulla of large elongated parenchyma cells. Transition of cells from medulla to cortex abrupt. Cystocarp protruding, spherical, scattered on both side of thallus, without or with slight constriction at the base.

3.3. Gracilaria sp.

Thallus terete, erect, or partially pendant, cartilaginous, solitary or caespitose, regularly dichotomous to subdichotomous and scund, 4 to 8 cm in length, 3 to 4.5 mm in thickness, light red to dark purple in color, arising from a disc like holdfast of 1 cm in diameter. Thallus margins smooth occasionally with secondary branches; primary branches may form secondary rhizoids when come in contact with solid objects. Apex of branches obtuse. Frond in transverse section consists of cortex 1 to 2 layers of small pigmented cells, and medulla of large roundish parenchyma cells in young plants, hexagonal or pentagonal in mature ones. Transition of cells from medulla to cortex abrupt. Cystocarp protruding, spherical, scattered on both side of thallus.

3.4. Hormophysa cuneiformis (J. F. Gmelin) P. C. Silva

Thallus erect, stiff, yellow brown, ranges from 19 to 47.3 cm in length and attached to substratum with cone-like stolon. Stolon gives rise to 11 to 33 primary branches. Stipe of the primary branches is cylindrical and 0.5 to 1.4 cm in length. The frond of the primary branches is three-winged at the upper part, articulated with dentate margins. Aerocysts intercalarily developed in the center of the fronds causing the articulated appearance. Secondary branches pinnately or verticilately arranged.

3.5. Acetabularia sp.

Thallus erect, green, 11 cm in length. Vertical stalk composed of periodically repeated whorls of flattened caps. Caps made up of fused rounded elongated rays. Cap diameter ranged from 3 to 5 mm.

3.6. Caulerpa racemosa var. macrophysa (Sonder ex Kutzing) W. R. Taylor

Thallus is differentiated into a cylindrical, prostrate, creeping stolon and erect assimilative branches, and attached by rhizoids. The stolon

thickness ranges from 0.2 to 1.6 mm. The erect assimilative branches are 5.5 to 10 cm in length, highly branched, bearing hemispherical ramelli which are spirally or pinnately arranged around the terete rachis.

3.7. Halimeda cylindracea Decaisne

Thallus erect to pendant, light green, palmate shape, total length up to 23 cm, constructed of articulated sequence of calcified cylindrical segments. Segment average width is 0.45 cm, average length 0.66 cm, average thickness 1.3 cm. Branching sympodial. Stipe short, compressed, 1.33 cm in length, arising from a bulbous holdfast 5.5 cm in length, with adhering sand particles.

3.8. Halimeda macroloba Decaisne

Thallus erect to pendant, whitish green, about 15 cm in total length. Thallus is constructed of articulated sequence of flat calcified lobes. Lobe width ranges from 1.33 cm to 2.50 cm; lobe length ranges from 1.04 cm to 2.10 cm. Stipe average length is 1.38 cm, arising from discoid holdfast. Branching in single plane.

3.9. Ulva intestinalis (Linnaeus) Nees

Fronds are bright green, unbranched cylindrical tubes attached with a terete stipe to small discoid holdfast. Frond length ranges between 10 to 13 cm; frond width ranges between 3 to 7 mm and widens towards the rounded apex.

3.10. Ulva reticulata Forsskal

Thallus is a net-like or reticulate sheet attached to substratum by very small disc-like holdfast or found floating. Thallus is bright green in colour, smooth, and slippery in texture. Thallus total length is greater than 10 cm. Holes are of varying sizes.

3.11. Valonia ventricosa J. Agardh

Thallus is a single elongated sphere, olive green in colour, and full of watery liquid.

4. Discussion

As the case in tropical environment, the number of red seaweeds species (47) surpasses that of the brown (28) and green seaweeds (39) on the list. Of the red algal orders, the order Ceramiales was the most diverse containing 23 species of the 46 ones. Within this order, the members of the known largest red algal family Rhodomelaceae were prominent. Then, the coralline red algae of the family Corallinaceae (order: Corallinales) were the next diverse represented by 9 species. The present red algae list of Sudan contained some agarophytes (*e.g*. *Gelidium* and *Gracilaria* species) and carrageenophytes (*e.g. Hypnea* species) species. However, species known of their nutritional value were absent. This might reflect and emphasize the oligotrophic nature of the Red Sea.

In the Phaeophyceae algae, the family Sargassaceae of the order Fucales was the most diverse with the genus *Sargassum* represented by 6 species out of the 13 species recorded for the family. This family contains members with economic value as aliginophytes and/or as sources of value added products in pharmaceutical field such as *Sargassum* and *Cystoseira* species. Nevertheless, two members of the Dictyotales, *viz*. *Padina pavonica* and *Dictyota dichotoma* were more abundant in the field.

The members of the class Ulvophyceae dominated the green seaweeds along the Sudanese Red Sea coast with 39 species recorded for the class. The most diverse families in this class were Caulerpaceae and Halimediaceae respectively.

Generally, the calcareous macroalgae were well represented in the three classes of the macroalgae indicating the prevalence of favourable condition for coral reef formation. These algae are fast growing primary producers associated with coral reefs[23]. Their prominent presence is in congruence with the dominance of coral reef habitats in the Red Sea.

Several factors contribute to the scarcity of information on Sudanese seaweeds, including the inadequacy of sampling, collections, human resources, and the deposition of voucher specimens of the previous collections at overseas herbaria which hinder tracing back the identification. In fact the lack of a proper national herbarium is a major constrain in front of either revising or studying seaweeds in Sudan. Previous collections were made from few inshore locations therefore they might not provide sufficient information on the actual seaweed floral composition due to the patchy distribution of seaweeds along the Sudanese coast. The same situation has also been observed for the seaweeds of the Eritrean coast[12]. The Sudanese Red Sea coast has diverse habitats including shallow embayment, bays, coastal lagoons and coral reef to mention a few. Comprehensive surveys that cover all these habitats and deeper depths are required to provide an inclusive checklist on Sudanese seaweeds.

In addition, the comparatively low number of species reported from the Central Red Sea had lead to the hypothesis that this part was poorly or incompletely sampled. This could be attributed to the fact that most of the collections on Red Sea seaweeds were carried out around Sinai in the north and Dahlak in the south[6]. Therefore, they included few records of marine algae from the Central Red Sea (*e.g.* Sudanese coasts) as this part of the Red Sea was not a major stopover in the passageway of historic explorations of the Red Sea since most of these explorations were part of a trade journey or followed the trade route. Commonly, most of these journeys started either from the Red Sea coast of Egypt and cross the Red Sea by vessels to the Arabian coast and then to the Ethiopian coast, or they approached the Red Sea from the south, starting from the Cape of Good Hope then through the Strait of Bab el Mandeb.

However, and in our opinion, the major reason behind the scarcity of information on Sudanese seaweeds in particular and on that of the Red Sea in general is related to the resource perception from the socioeconomic perspective in the region. Unlike fisheries, seaweeds in Sudan are not known to have direct or indirect traditional or industrial utilization. Also, the resource is not known to be exported to other countries. In Sudan, although the sea cucumber

is not utilized locally, it has gained a significant economic and conservational value only because of the increased demand from the Asian countries. It is known that the socioeconomic value of a resource could flourish research and investigation as in the case of agarophytes and carrageenophytes.

On the other hand some natural oceanographic conditions may have influenced the diversity and abundance of seaweeds in the Central Red Sea compared with the northern and southern parts. The presence of natural barriers that was thought to influence the dispersal pattern in Red Sea was discussed and proposed by some authors[24,25]. One of these barriers is the narrow tidal amplitude around Jeddah-Suakin that thought to result in a latitudinal division across the Central Red Sea that might have influenced macroalgal distribution in this part. Additionally, the relatively narrow littoral zone in the Northern and Central Red Sea and the cooler surface water temperature moving to the north were also considered as influential factors on the dispersal of macroalgae in the Central Red Sea.

Taking into account the tropical arid nature and the semi-enclosure nature of the Red Sea, detailed investigations on the molecular, phylogenetic, and biochemical levels are required to comprehensively reveal the diversity of the seaweeds of this young ocean. The risk of invasive species brought by the discharge of ballast water of oil tankers passing through the Red Sea may highlight the imperativeness of seaweeds checklists, field guides, and monographs.

It is imperative to conclude that the present list represents macroalgal taxa common for the intertidal area of the Sudanese Red Sea coast. Further sampling of deeper depths may reveal the presence of more species. Therefore, this list should not be considered as an inclusive one.

Conflict of interest statement

We declare that we have no conflict of interest.

Acknowledgements

This work was supported by the Faculty of Marine Science and Fisheries, Red Sea University, Sudan with Grant No. RSU-2014\SewRes. Special thanks are due to Mr. Salah Omer, Mr. Mustafa M. Mustafa and Mr. Yasir Hassan for the genuine help during field work.

References

[1] DiBattista JD, Berumen ML, Gaither MR, Rocha LA, Eble JA, Choat JH, et al. After continents divide: comparative phylogeography of reef fishes from the Red Sea and Indian Ocean. *J Biogeogr* 2013; **40**: 1170-81.

[2] DiBattista JD, Choat JH, Gaither MR, Hobbs JPA, Lozano-Cortes DF, Myers RF, et al. On the origin of endemic species in the Red Sea. *J Biogeogr* 2016; **43**: 13-30.

[3] Klaus R. Coral reefs and communities of the Central and Southern Red Sea (Sudan, Eritrea, Djibouti, and Yemen). In: Rasul NMA, Stewart ICF, editors. *The Red Sea.* Berlin: Springer-Verlag; 2015.

[4] Randall JE. Seven new species of labrid fishes (*Coris*, *Iniistius*, *Macropharyngodon*, *Novaculops*, and *Pteragogus*) from the Western Indian Ocean. *J Ocean Sci Found* 2013; **7**: 1-43.

[5] Roder C, Berumen ML, Bouwmeester J, Papathanassiou E, Al-Suwailem A, Voolstra CR. First biological measurements of deep-sea corals from the Red Sea. *Sci Rep* 2013; doi: 10.1038/srep02802.

[6] Sheppard C, Price A, Roberts C. *Marine ecology of the Arabian region: patterns and processes in extreme tropical environment*. London: Academic Press; 1992, p. 10-28.

[7] Elhag AGD, Karim AGA. Zonation of seaweeds along a stretch on the Red Sea coast (Sudan). In: Proceedings of the Symposium on the Coastal and Marine Environment of the Red Sea, Gulf of Aden and Tropical Western Indian Ocean; 1980 Jan 9-14; Khartoum, Sudan. Khartoum: International Printing House; 1980, p. 420-452.

[8] Vine PJ, Vine MP. Ecology of Sudanese coral reef with particular reference to reef morphology and distribution of fishes. In: Proceedings of the Symposium on the Coastal and Marine Environment of the Red Sea, Gulf of Aden and Tropical Western Indian Ocean; 1980 Jan 9-14; Khartoum, Sudan. Khartoum: International Printing House; 1980, p. 87-140.

[9] El Hag AGD. Seaweed studies at Sanganeb Atoll. In: Krupp F, Turkay M, El Hag AGD, Nasr D, editors. *Comparative ecological analysis of biota and habitats in littoral and shallow sublittoral waters of the Sudanese Red Sea*. Senckenberg: Forschungsins Institute; 1993, p. 6-11.

[10] Baker JM, Wolff WJ. *Biological surveys of estuaries and coasts*. Cambridge: Cambridge University Press; 1897, p. 41-3.

[11] English SA, Wilkinson CR, Baker VJ. *Survey manual for tropical marine resources*. Queensland: Australian Institute of Marine Science; 1997, p. 368.

[12] Ateweberhan M, Prud'homme Van Reine WF. A taxonomic survey of seaweeds from Eritrea. *BLUMEA* 2005; **50**: 65-111.

[13] Abbott IA, Huisman JM. *Marine green and brown algae of the Hawaiian Island*. Honolulu: Bishop Museum Press; 2004, p. 1-45.

[14] De Clerck O, Coppejans E. Marine algae of the Jubail Marine Wildlife Sanctuary, Saudi Arabia. In: Krupp F, Abuzinada AH, Nader IA, editors. *A marine wildlife sanctuary for the Arabian Gulf: environmental research and conservation following the 1991 Gulf War Oil Spill*. Frankfurt: Riyadh and Senckenberg Research Institute; 1996, p. 199-289.

[15] Abbott IA. *Marine red algae of the Hawaiian Islands*. Honolulu: Bishop Museum Press; 1999, p. 477.

[16] Menez EG, Calumpong HP. *The genus Caulerpa from Central Visayas, Philippines*. Washington, D.C: Smithsonian Institution Press; 1982, p. 1-37.

[17] Bold HC, Wynne MJ. *Introduction to the Algae: structure and reproduction*. New Jersey: Prentice Hall; 1978, p. 675.

[18] Borgesen F. Some marine algae from Mauritius. III. Rhodophyceae. Part 2. Gelidiales, Cryptonemiales, Gigartinales. *Kongelige Danske Videnskabernes Selskab, Biologiske Meddelelser* 1943; **19**(1): 1-85.

[19] Guiry MD, Guiry GM. AlgaeBase. Galway: National University of Ireland. [Online] Available from: http://www.algaebase.org [Accessed on 24th August, 2015]

[20] Papenfuss GF. A history, catalogue, and bibliography of the Red Sea benthic algae. *Israel J Bot* 1968; **17**: 1-118.

[21] Guiry MD, Guiry GM. AlgaeBase. Galway: National University of Ireland. [Online] Available from: http://www.algaebase.org [Accessed on 24th December, 2014]

[22] Harvey-Gibson RJ. Reports on marine biology of the Sudanese Red Sea, Algae. *J Linn Soc London Zool* 1908; **IX**: 76–80.

[23] Vogel N, Fabricius KE, Strahl J, Noonan SHC, Wild C, Uthicke S. Calcareous green alga *Halimeda* tolerates ocean acidification conditions at tropical carbon dioxide seeps. *Limnol Oceanogr* 2015; **60**: 263-75.

[24] Zekeria ZA, Yohannes AT, Videler JJ. The distribution patterns of Red Sea Chaetodontid assemblages. In: Zekeria ZA, editor. *Butterflyfishes of the southern Red Sea: ecology and population dynamics*. Groningen: Rijksuniversiteit Groningen; 2003.

[25] Fine M, Gildor H, Genin A. A coral reef refuge in the Red Sea. *Glob Change Biol* 2013; **19**: 3640-7.