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Therapeutic potentials of marine macro algae of Karnataka

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ABSTRACT

Marine macro algae, popularly known as 'seaweeds' are one of the potential marine resources and play an important role in the marine ecosystems. Globally, ca 221 of seaweeds are economically important and commercially utilized in various forms including 145 species for food / fodder and 110 species for phycocolloid production, of which 125 species are from India (Sahoo, 2000). In the present paper, the authors conducted extensive field explorations along the coastline of Karnataka and made thorough review of literature pertaining to therapeutic potential of marine algae and enumerated totally 34 taxa of seaweeds, consisting of 11 Chlorophyceae, 7 Phaeophyceae and 16 Rhodophyceae were found economically important. Among its potential uses, 22 species are edible and 11 can be used as fodder and manures (SLF), 14 species are having pharmaceutical values, and 18 species are of industrial importance for the production of agar-agar, algin, alginic acid, carageenans etc. Many of the marine macro algae act as an important source of natural bioactive molecules like Kahalalide F, Caulerpenzyne, Sulfated polysachharides, Domoic acid, Kainik acid etc., which are of pharmaceutical importance like antiallergic, antimicrobial, antioxidant and even in the treatment of lung cancer, tumours and AIDS (Smit, 2004). Therefore, this paper highlights the therapeutic potentiality of 14 species of seaweeds from Karnataka coast.

Keywords: Marine Macro Algae, Karnataka, Therapeutic potential.

INTRODUCTION

India with a coastline of *ca* 7,500 km and Exclusive Economic Zone (EEZ) of *ca* 2.5 million sq km, accounts for about 8 % of the global biodiversity (Oza, 2005). The state of Karnataka (11°31'–18°45'N latitude and 74°12'–78°40'E longitude) is well known for its beautiful forests and rich biodiversity. It is endowed with a coastline of *ca* 320 km in length (12°45'–15°00'N latitude and 74°00 –75°00'E longitude) and spread into 3 districts *i.e.* Uttara Kannada, Udupi and Dakshina Kannada. The coastline of Karnataka, also known as Karavali stretches, is almost narrow, interrupted at numerous points by rivers, rivulets, creeks, lagoons, cliffs, sanddunes and beaches and supports a large number of marine flora and fauna. The northern coast is rocky while the southern coast is sandy with scattered rocks and several beaches.

Marine macro algae, popularly known as *seaweeds,* are the important components of the marine biodiversity. About 20,000 species of seaweeds are distributed throughout the world, of which 221 are commercially important and utilized in various ways such as 145 species for food and 110 species for phycocolloid production (Sahoo, 2000). The importance of seaweed resources in the form of local medicines were known in the south east Asian countries like China, Japan etc. as early as 3000 BC. A perusal of literature also suggests that Romans used marine algae for healing of wounds, rashes etc., whereas the British used *Porphyra* in order to prevent Scurvy diseases during long voyage. In India however, the commercial utilization of seaweeds were initially limited mainly for the production of Phycocolloids such as agar-agar, algin etc. (Kaladharan & Kaliaperumal, 1999). But in recent years, there are considerable numbers of reports on the sporadic studies on the economic and pharmaceutical aspects of marine algal resources in India (Chennubhotla & al. 1981, 1987; Kaliaperumal & al., 1992, 1995; Subramanian & al. 1999; Kaliaperumal, 2000, 2003, 2016; Chennubhotla & al., 2011, 2013 a & b; Anantharaman & al. 2016; Kaliaperumal & Chennubhotla, 2017).

The information on seaweed resources of Karnataka coast is very sporadic and limited. Agadi (1985, 1986) made the first attempt to study the distribution of marine macro algae from Karnataka coast and reported 43 species of seaweeds. Untawale & al. (1989) reported the presence of 65 species of seaweeds belonging to 42 genera from the northern Karnataka coast. Ambiye & Untawale (1992) studied the correlative study on algal flora of the Lakshadweep islands and Karnataka coast. NAAS (2003) and Venkataraman & Wafar (2005) reported only 39 species of seaweeds belonging to 52 genera and 28 families from the coastline of Karnataka. Rao & Mantri (2006) in a review article on Indian seaweeds also quoted only 43 species of seaweeds from Karnataka coast. Recently, Kaladharan & al. (2011) published an assessment studied on the coastal and marine floral diversity of Karnataka and documented 78 species of seaweeds from the Karnataka coast. Yadav & Palanisamy (2018) reported the new distributional record of *Martensia fragilis* Harv. from Vannali coast of Karnataka. Ashwini & Shantharam (2018) published a report on the economical aspects of two species of seaweeds *i.e.Gracilaria*

corticata and *Chaetomorpha antennina* from Surathkal coast. However, there is no any comprehensive account on the therapeutic aspects of the seaweed resources of Karnataka coast. Therefore, the present study highlights the therapeutic potentials of seaweed resources of Karnataka coast.

Materials and Methods

Study area

In the present study, *ca* 320 km long coastline of Karnataka was extensively surveyed during low tide for the period of April 2014 – March 2017 to enumerate the seaweeds for their therapeutic potential (**Fig. 1**). The coastline shows wide range of variations because of the presence of rocky terrains of the Western Ghats, rivers, rivulets, cliffs etc. and supports considerable number of marine algal diversity. During exploration, the geo location of the area was recorded using portable GPS. The field photographs showing the nature and seaweed habits at the coast (**Plate 1**) were taken using NIKON camera.

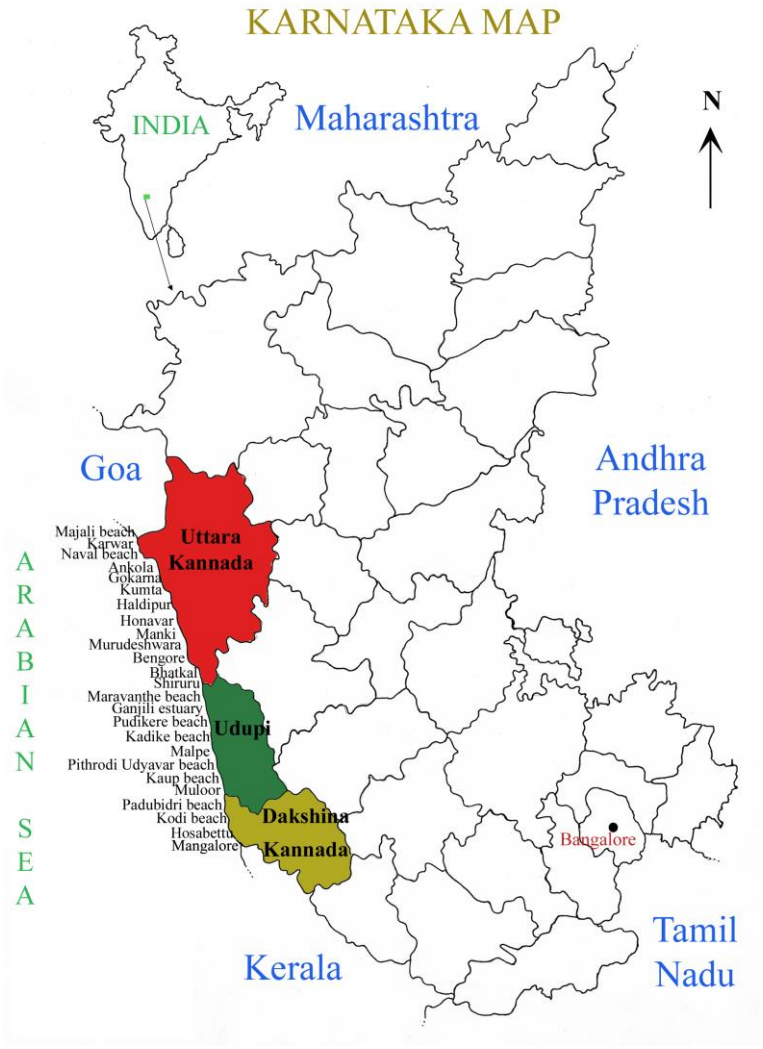


Fig 1 Map of Karnataka Coast

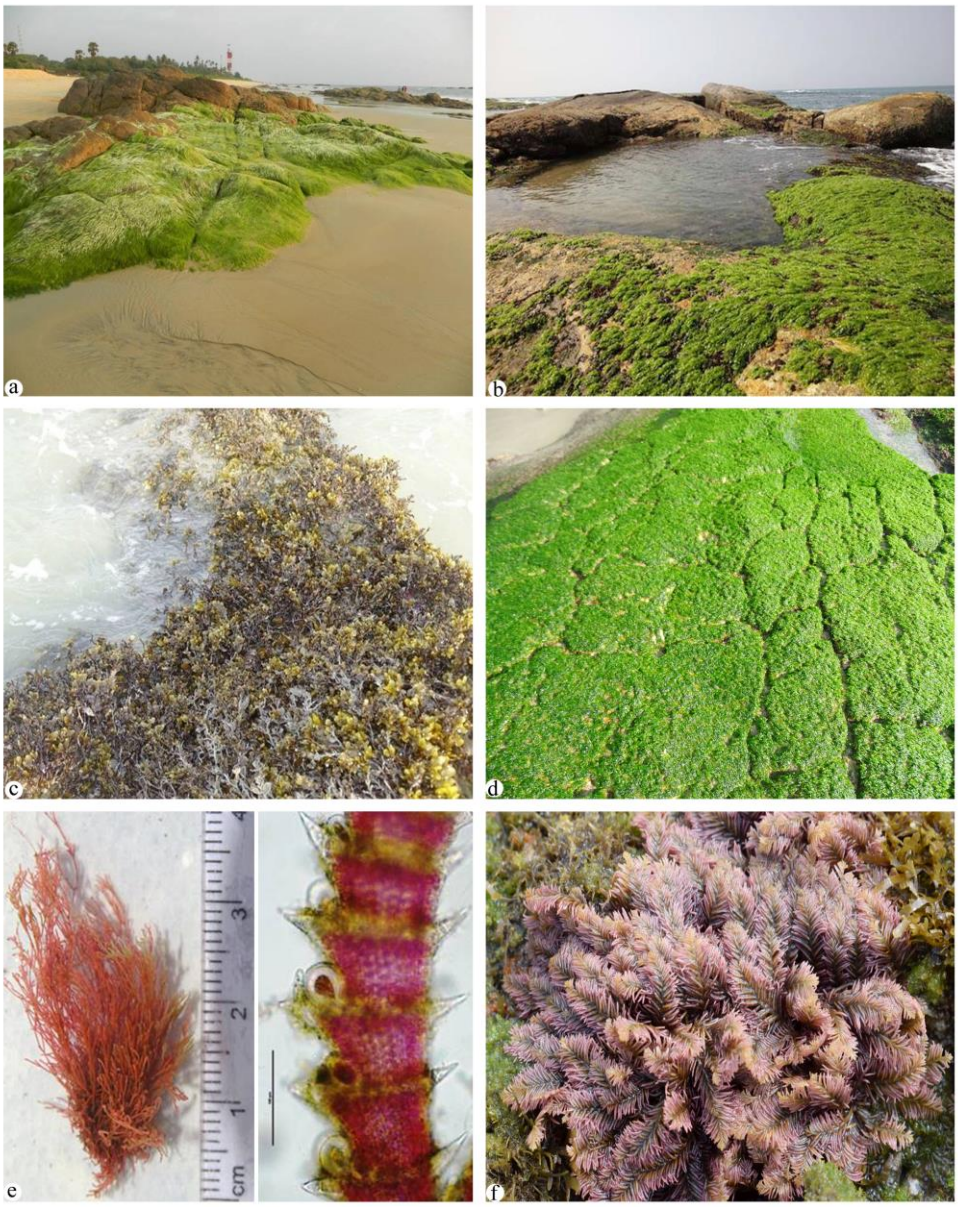


Plate 1. a. Luxuriant growth of green seaweeds at Surathkal coast; b. Rocky habtats supporting excellent growth of seaweeds at Gorte coast; c. Mixed growth of seaweeds at St. Mary's island, Malpe; d. *Ulva compressa* L.; e. *Centroceras clavulatum* (C. Agardh) Mont.; f. *Chondria armata* (Kuetz.) Okamura

Collection and preservation of marine macro algae

During the study period, more than 1600 field numbers of marine macro algae were collected from a total of 125 field localities along the coast. All the collected marine algal specimens were thoroughly processed and herbarium sheets were prepared following the standard procedures. All the specimens were examined carefully under the light and computer attached stereo microscopes (Nikon SMZ1500 and Nikon Eclipse 50*i*). The taxonomic descriptions were made based on their morphological and anatomical characters. The identification of the specimens and nomenclature were made as per standard literatures.

Review of literature

Almost all the relevant references pertaining to the economical aspects, especially therapeutic importance of marine macro algae from India and abroad were thoroughly referred to study its economic potentials. These references were collected both offline as well as online modes from various journals.

RESULTS

Based on the study of fresh collections and review of previous works, a total of 34 species of seaweeds, consisting of 11 species of Chlorophyceae, 7 species of Phaeophyceae and 16 species of Rhodophyceae from

Karnataka coast were found economically important (**Table** I). These marine algae are of great economic potentials in various forms like therapeutical, food, fodders, manures / fertilizers, industrial etc. The analysis shows that 14 species are having pharmaceutical properties while 22 species are edible, 11 species can be used as fodder and manures (SLF), and 18 species are having industrial importance for the production of agar-agar, algin, alginic acid, carageenans etc. The therapeutic potentials of these marine algae are usually reflected in the form of antimicrobial, (antibacterial, antifungal), antioxidant, insecticidal, anticancerous activities because of the presence of particular secondary metabolites and bioactive compounds in it. In the recent years, it has become an important source of bioactive compounds in the field of Biotechnology. The detailed account of therapeutic properties of these marine algae may be presented as follows:

Table I. List of the economically important marine macro algae recorded in Karnataka coast

Sl. No.	Name of the taxa	Economic importance	Therapeutic properties	References
	CHLOROPHYCEAE			
1.	**ULVACEAE** *Ulva compressa* L.	Edible, Fodder, Medicinal	Antiallergic activities (anti anaphyllectic compounds).	Kaliaperumal & al., 1995; Shynu & al., 2013; Venkataraman & al., 2004.
2.	*Ulva fasciata* Delile	Edible, Fodder, Medicinal	Antibacterial activity	Sobha & al., 2008; Shynu & al., 2013; Chellaram & al., 2015.
3.	*Ulva lactuca* L.	Edible, Fodder, Medicinal, Manure	Insecticidal and fungicidal activity	Shynu & al., 2013; Abbassy & al., 2014.
4.	*Ulva reticulata* Forssk.	Edible, Medicinal	Antibacterial activity	Sobha *& al.*, 2008; Kaliaperumal *& al.*, 1995; Chellaram & al., 2015.
5.	*Ulva rigida* C.Agardh	Edible, Medicinal	Antioxidant activity	Kaliaperumal & al., 1995; Shynu & al., 2013; Gamze &al., 2012.
6.	**ACROSIPHONIACEAE** *Acrosiphonia orientalis* (J. Agardh) P.C. Silva	Medicinal		Manilal & al., 2012.
7.	**BRYOPSIDACEAE** *Bryopsis plumosa* (Huds.) C. Agardh	Edible, Fodder, Medicinal, Manure	Kahalalide F, which is useful for treatment of lung cancer, tumours and AIDS.	Shynu & al., 2013, Smit, 2004
8.	**CAULERPACEAE** *Caulerpa peltata* J.V. Lamour.	Edible, Fodder, Manure		Shynu & al., 2013
9.	*Caulerpa racemosa* (Forssk.) J. Agardh	Edible		Kaliaperumal & al., 1995; Sobha & al., 2008;
10.	*Caulerpa sertularioides* (S.G. Gmel.) M. Howe	Edible, Fodder, Manure		Kaliaperumal & al., 1995; Shynu & al., 2013
11.	*Caulerpa taxifolia* (Vahl) C. Agardh	Edible, Fodder, Medicinal, Manure	Caulerpenzyne, useful in controlling cellular growth.	Shynu & al., 2013; Smit, 2004
PHAEOPHYCEAE				
12.	**DICTYOTACEAE** *Dictyota bartayresiana* J.V. Lamour.	Edible, Fodder, Medicinal, Manure		Shynu & al., 2013
13.	*Lobophora variegata* (J.V. Lamour.) Womersley ex E.C. Oliveira	Industrial		Shynu & al., 2013
14.	*Padina gymnospora* (Kutz.) Sond.	Edible, Fodder, Industrial, Manure		Shynu & al., 2013
15.	*Padina tetrastromatica* Hauck	Edible, Fodder, Industrial, Manure		Sobha & al., 2008; Shynu & al., 2013
16.	**SARGASSACEAE** *Sargassum tenerrimum* J. Agardh	Edible, Manure, Industrial (Agaroid)		Kaliaperumal & al., 1995; Shynu & al., 2013
17.	*Sargassum wightii* Grev.	Edible, Fodder, Industrial (Algin)		Kaliaperumal & al., 1995; Sobha & al., 2008; Shynu & al., 2013
18.	*Turbinaria ornata* (Turner) J. Agardh	Edible, Industrial (Agaroid)		Kaliaperumal & al., 1995; Shynu & al., 2013

RHODOPHYCEAE				
19.	**BANGIACEAE** *Porphyra kanyakumariensis* V. Krishnam. & Baluswami	Edible		Shynu & al., 2013
20.	**GELIDIACEAE** *Gelidium micropterum* Kutz.	Edible, Industrial (Agar)		Kaliaperumal & al., 1995; Shynu & al., 2013
21.	*Gelidium pusillum* (Stackhouse) Le Jolis	Industrial (Agar)		Kaliaperumal & al., 1995
22.	*Gelidiella acerosa*(Forssk.) J. Feldmann & G. Hamel	Industrial (Agar)		Kaliaperumal & al., 1995
23.	**GRACILARIACEAE** *Gracilaria corticata* (J. Agardh) J. Agardh	Industrial (Agar)		Kaliaperumal & al., 1995; Sobha& al., 2008; Shynu & al., 2013
24.	*Gracilaria corticata* (J. Agardh) J. Agardh var. *cylindrica* M.U. Rao	Industrial (Agar)		Kaliaperumal & al., 1995
25.	*Gracilaria foliifera* (Forssk.) Borgesen	Industrial		Shynu & al., 2013
26.	*Gracilaria verrucosa* (Huds.) Papenf.	Manure, Industrial (Agar)		Kaliaperumal & al., 1995; Shynu & al., 2013
27.	**HALYMENIACEAE** *Grateloupia filicina* (J.V. Lamour.) C.Agardh	Edible, Industrial (Carageenan)		Shynu & al., 2013; Sahu & Kumar, 2014
28.	*Jania adherens* J.V.Lamour.	Industrial		Shynu & al., 2013
29.	**HYPNEACEAE** *Hypnea musciformis* (Wulf.) J.V. Lamour.	Edible, Medicinal, Industrial (Carageenan)	Sulfated polysachharides, which inhibits TNBS induced intestinal damage in rats	Kaliaperumal & al., 1995; Pramitha & Lipton, 2013; Shynu & al., 2013; Brito &al., 2016.
30.	*Hypnea valentiae* (Turner) Mont.	Edible, Medicinal, Industrial (Carageenan)	Antibacterial activity	Kaliaperumal & al., 1995; Pramitha& Lipton, 2013; Shynu & al., 2013; Sodhganga.
31.	**RHODOMELACEAE** *Acanthophora spicifera* (Vahl.) Borgesen	Edible, Industrial (Agaroid)		Chennubhotla & al.,1987; Shynu & al., 2013
32.	*Centroceras clavulatum* (C. Agardh) Mont.	Medicinal	Domoic acid, kainik acid. These compounds are anthelminthic and insecticidal activities	Smit, 2004
33.	*Chondria armata* (Kuetz.) Okamura	Medicinal	Domoic acid, kainik acid	Smit, 2004
34.	*Laurencia.paillosa* (C. Agardh) Grev.	Medicinal	Domoic acid, kainik acid	Smit, 2004

CLASS: CHLOROPHYCEAE

FAMILY: ULVACEAE

1. **Ulva compressa** L., Sp. Pl. 2: 1163. 1753.

Enteromorpha compressa (L.) Nees, Horae Phys. Berol. Index 2: 123. 1820; Kaladharan & al. in J. Mar. Biol. Ass. India 53 (1): 125. 2011. **(Plate 1:d)**

Thallus light-yellowish green in colour, 2-10 cm long, hollow, profusely branched, lithophilic. Holdfast minute, discoid, attached firmly on rocky substrata in intertidal region. Stipe tubular, up to 1.5 mm long, simple or branched in the upper portion. Fronds many, tubular at base and gradually expanded and compressed towards apex, 1-8 × 0.2-1.2 mm, surface smooth, margins entire, apex obtuse to round, slightly transparent. *Microscopic*: Cells in surface view squarish-elongate or irregular, 15-30 µm across, 8-17 µm across in basal region, irregularly arranged, cell wall thin; cells in cross section 15-30 × 10-12 µm, sheath with equal thickness, up to 2 µm thick; uninucleate; chloroplast plate like with single pyrenoid.

Occurrence: Throughout the year. Common.

Distribution: Throughout Karnataka coast.

Therapeutic properties: Venkataraman & al. (2004) screened out the antiallergic properties of this species. They extracted various compounds from this species and made experiments on mice. The study revealed that it increases the IgE levels against ovalbumin and other many other allergens in mice and suggested that it has antiallegic and antiphylactic properties which can be used for therapeutic activities.

2. Ulva fasciata Delile, Fl. Egypt. Expl. Pl. 2: 297, Pl. 58. Fig. 5. 1813; Kaladharan & al. in J. Mar. Biol. Ass. India 53 (1): 125. 2011; P.S.N. Rao & Gupta, Algae India 3: 3. 2015.

Thallus dark-light green in colour, up to 50 (-120) cm long but can grow even up to 2 m long, leafy, ribbon shaped, mostly gregarious, tufted, lithophilic. Holdfast rhizoidal, tufted, firmly attached. Stipe foliaceous, simple or branched, up to 2.6 cm long and 1.2 cm wide. Fronds leafy, deeply divided into several linear blades; blades 1.5-5 cm wide, almost uniformly flattened in middle portion, surface smooth, membranous, irregularly lobed, gradually tapering towards apex; margins entire to frequently undulate; apex acute to obtuse. *Microscopic*: Cells in surface view polygonal - squarish, 12-20 µm across, irregularly arranged; in cross section thallus surface 90-115 µm thick towards base and 70-100 µm towards apex; cells palisade like, distromatic, 34-40 × 8-12 µm; separated with 8-15 µm thick middle layer, uninucleate, chloroplast plate like, pyrenoids 2 in each cell.

Occurrence: Throughout the year. Common.

Distribution: Throughout Karnataka coast.

Therapeutic properties: Chellaram & al. (2015) screened out the antibacterial properties of this species and found it positive against human pathogenic bacteria. The crude acetone and methanol extracts showed significant antibacterial activity against 10 human pathogens. Therefore, these compounds can be extracted on large scale and utilised for various therapeutic purposes.

3. Ulva lactuca L., Sp. Pl. 2: 1163. 1753; Kaladharan & al. in J. Mar. Biol. Ass. India 53 (1): 125. 2011; P.S.N. Rao & Gupta, Algae India 3: 3. 2015.

Thallus light-dak green in colour, up to 10 cm long, leafy, tufted, translucent, membranous, rosette like, lithophilic. Holdfast minute, discoid, attached firmly on rocky substratum, sometimes epiphytic on mollusc shells. Stipe small, simple or branched. Fronds foliaceous, surface smooth, thin, delicate, much broader and obovate in young stage, rounded, lanceolate to irregularly proliferated into several small lobes at maturity; margins undulated, wavy or ruffled; apex acute to obtuse. *Microscopic*: Cells in surface view usually polygonal, 7-15 µm across, thick walled, irregularly arranged; in cross section cells usually rectangular, uninucleate; chloroplast cup shaped, with one or two pyrenoids.

Occurrence: Monsoon and post-monsoon seasons. Moderate.

Distribution: Karnataka: Dakshina Kannda (Someshwar, Surathkal and Kapu) and Uttara Kannada (Golte, Belekeri, Tadri and Majali) districts.

Therapeutic properties: Abbassy & al. (2014) from Egypt reported that *Ulva lactuca* has insecticidal and fungicidal properties. The biochemical extracts of acetone, chloroform, ethanol, methanol, petroleum ether etc. were tested against the mosquito larvae in *Culex pipiens*, Cotton leafworm *Spodoptera littoralis*, phytopathogenic fungi *Aspergillus niger*, *Penicillium digitatum* and *Rhizoctonia solani.* Therefore, this species can be taken into consideration for its insecticidal and fungicidal properties.

4. Ulva reticulata Forssk. Fl. Aegypt.-Arab. 187. 1775; Kaladharan & al. in J. Mar. Biol. Ass. India 53 (1): 125. 2011; P.S.N. Rao & Gupta, Algae India 3: 3. 2015.

Thallus light-dark green in colour, up to 20 cm long, leafy, profusely perforated, net like or reticulate, membranous, often convoluted, lithophilic. Holdfast minute, sometimes unrecognisable, attached lightly on rocky and muddy substrata, sometimes free floating in the intertidal pools and backwater areas with domestic sewage outlets. Stipe foliaceous, divided into several distinct laciniae with microscopic serration. Fronds leafy, lamina prominently perforated with a number of laciniae (holes); lacinae usually oval, circular or rectangular, sometimes exceeding the blade network, margins entire or sometimes with microscopic teeth around; apex acute to obtuse. *Microscopic*: Cells in surface view mostly polygonal to rectangular, thick walled, 6-18 µm across; in cross section cells elongate, 18-28× 10-19 µm, compact, middle layer up to 6 µm thick; cell cuticle 3-5 µm thick; uninucleate; chloroplast plate like, with 1or 2 pyrenoids.

Occurrence: Monsoon season. Rare.

Distribution: Karnataka: Uttara Kannda district.

Therapeutic properties: Chellaram & al. (2015) screened out the antibacterial properties of this species and found it positive against 10 human pathogenic bacteria. Therefore, these compounds can be extracted on large scale and utilised for various therapeutic purposes.

5. Ulva rigida C. Agardh, Spec. Alg. 1(2): 410. 1823; Kaladharan & al. in J. Mar. Biol. Ass. India 53 (1): 125. 2011; P.S.N. Rao & Gupta, Algae India 3: 3. 2015.

Ulva lactuca L. var. *rigida* (C. Agardh) Le Jol. in Mem. Soc. Imp. Sci. Nat. 10: 38. 1893.

Thallus dark light-yellowish green, up to 18 cm long, leafy, leathery, ovate in young stage, later becomes broadly orbicular to deeply lobed, forming small rosette like structure, lithophilic. Holdfast minute, discoid, distinct, attached firmly on rocky substratum. Stipe small, foliaceous, solid, tapering towards base. Fronds foliaceous, ovate, orbicular to slightly lobed, tufted, up to 5 cm wide; margins entire, undulated or slightly serrate; apex obtuse or acute. *Microscopic*: Cells in surface view usually polygonal, thick walled, 6.5-18 µm across, irregularly arranged; in cross section, cells palisade like or elongate, 20-45 × 10-20 µm, compactly arranged, separated by 4-8 µm thick middle layer; cell cuticle upto 4 µm thick; uninucleate; chloroplast cup shaped with 1, rarely 2 pyrenoids.

Occurrence: Monsoon and post-monsoon seasons. Moderate.

Distribution: Throughout Karnataka coast.

Therapeutic properties: Yildiz & al. (2012) carried out biochemical analysis of this species and found that *Ulva rigida* showed the high total phenolic, vitamin E, and total carotene content. Therefore, it has antioxidant molecules that can be helpful in the treatment of diseases caused due to oxidative deterioration. Chellaram & al. (2015) screened out the antibacterial properties of this species and found it positive against human pathogenic bacteria.

FAMILY: ACROSIPHONIACEAE

6. Acrosiphonia orientalis (J.Agardh) P.C.Silva, in P.C.Silva & al., Cat. Benth. Mar. Alg. Ind. Ocean: 754. 1996; P.S.N. Rao & Gupta, Algae India 3: 4. 2015. *Anadema orientalis* J. Agardh, Ofvers Kongl. Vetensk.-Akad. Forh. 3: 103. 1846.

Thallus dark-muddy green in colour, up to 8 cm long, caespitose, remiform, bushy, growing gregariously, profusely branched, corymbose, lithophilic. Holdfast small, discoid, attached firmly on calcareous bedrocks in intertidal zones. Stipe up to 2 cm long, stalked, tufted, profusely branched. Fronds repeatedly branched, cylindrical, uniseriate, filamentous, 2-5 cm long and up to 1.6 mm in diameter; branching pseudo-dichotomous or trichotomous sometimes alternate, margins entire, apex acute. *Microscopic*: Cells in surface view cylindrical or elongated, basal and middle cells 0.8-2.6 mm long, 110-310 µm broad, apical cells 200-980 × 90-250 µm, uniseriately arranged.

Occurrence: Usually Monsoon and post - Monsoon seasons. Rare.

Distribution: Karnataka: Udupi (St. Mary's island) and Uttara Kannda (Golte, Madiyendri, Majali and Mundoli) districts.

Therapeutic properties: Manilal & al. (2009) reported that the polysaccharide extracted from this species shows antiviral activity against the shrimp pathogen White Spot Sundrome Virus (WPSV). Thus it can be utilised as a prophylactic drug in shrimp disease management.

FAMILY: BRYOPSIDACEAE

7. Bryopsis plumosa (Huds.) C. Agardh, Spec. Alg. 1(2): 448.1823; Kaladharan & al. in J. Mar. Biol. Ass. India 53 (1): 125. 2011; P.S.N. Rao & Gupta, Algae India 3: 9. 2015. *Ulva plumosa* Huds., Fl.Angl. 2: 571. 1778.

Thallus light to olive green in colour, tubular with sparingly branches, feathery, small, up to 12 cm long, siphonous, epilithic. Holdfast small, rhizoidal, stoloniferous, firmly attached. Stipe stalked, tubular or cylindrical, 140-310 µm in diameter. Fronds numerous and directly arise from the holdfast, tubular with feathery appearance, main axis cylindrical to terete, 140-420 µm in diameter, erect, irregularly tapering towards apex, sparingly branched; branches erect, naked below and regularly plumose above, usually distichous; pinnules cylindrical, linear-lanceolate, distinctly constricted at base, gradually or irregularly becoming shorter with round apices. *Microscopic*: Pinnules short, 50-650 × 45-90 µm.

Occurrence: Usually post - Monsoon season. Moderate.

Distribution: Throughout Karnataka coast.

Therapeutic properties: Smit (2004) reported that the species of Bryopsis has a unique bioactive compound called Kahalalide F, which is very much effective in treatment of AIDS cases and also in lung cancer. Therefore, this compound is of high significant value for its therapeutic properties.

FAMILY: CAULERPACEAE

8. Caulerpa taxifolia (Vahl) C. Agardh, Syn. Alg. Scand. 23. 1817; Kaladharan & al. in J. Mar. Biol. Ass. India 53 (1): 125. 2011; P.S.N. Rao & Gupta, Algae India 3: 13. 2015. *Fucus taxifolius* Vahl in Skr. Naturhist.-Selsk. 5(2): 36. 1802.

Thallus yellow-dark green in colour, rhizomatous, up to 15 (- 20) cm long, tufted, growing as patches and forming thick mat like structures, prostrate, stoloniferous, epilithic. Holdfast rhizoidal, colourless, stout, often loosely attached on rocky substrata. Fronds consist of creeping stolons and erect assimilators. Stolon stalked, slender, 0.5-2 mm in diameter, colourless to light green in older regions, tufted, branched. Assimilators usually

arranged at intervals of 0.5-3 cm long, foliose to slightly feathery, compressed, 4-12 (-20) cm long and up to 1.4 cm broad, simple or branched with densely arranged ramuli; ramuli linear to sickle shaped, flexible, slightly curved upward, usually longest in middle portion, opposite-distichous and densely arranged, entire, 0.5-4.5 × 0.2-0.5 mm, ramuli at apex usually dense and forked. *Microscopic*: In cross section, thallus siphonous, coenocytic, traversed internally by a network of trabeculae; rhizoids up to 7 mm long; cell wall lightly lamellated, trabaculae thin, filamentous, 2-5 µm in diameter.

Occurrence: Post monsoon season. Common.

Distribution: Throughout Karnataka coast.

Therapeutic properties: Smit (2004) reported that a chemical substance *Caulerpenyne* - a sesquiterpene, extracted from this species has been found very active against pancreatic lipase. It also has cytotoxicity towards human cell lines and exhibits anticancerous, antitumour and antiproliferative properties (Fischel & al., 1995; Barbier & al., 2001). Therefore, it has significant therapeutic values in the treatment of pancreatic cancer.

CLASS: PHAEOPHYCEAE
FAMILY: DICTYOTACEAE

9. Dictyota bartayresii J.V. Lamour. in J. Bot. (Desv.) 2: 43. 1809; Kaladharan & al. in J. Mar. Biol. Ass. India 53 (1): 125. 2011. *Dictyota bartayrensensis* J.V. Lanour. in Nouv. Bull. Sci. Soc. Philom, Paris 1: 331. 1809.

Thallus llight-yellowish brown in colour, foliose, 6-15 (-20) cm long, ribbon or strap like, bushy, tufted, epilithic. Holdfast discoid, firmly attached on rocky substrata. Stipe flat, up to 2 cm long and 2-3 mm broad. Frond foliose, almost uniformly flattened, usually up to 15 (-20) cm long and 2-6 cm wide, regularly dichotomously branched in upper region, surface membranous, smooth; margins entire; apices simple or equally to unequally forked, acute to occasionally obtuse. *Microscopic*: Cells in surface view usually rectangular, compact; in cross section, thallus consists of a single layered superficial cells enclosing the central medullary cells. Sporangia scattered over thallus surface, 30-90 µm across; antheridia usually club shaped, oogonia spherical.

Occurrence: Summer and post-monsoon seasons. Moderate.

Distribution: Karnataka: Udupi (St. Mary's island) and Uttara Kannda (Gorte, Mundoli and Talgode) districts.

Therapeutic properties: Chen & al. (2018) reported Pachydictyols (8ß-Hydroxypachydictyol A) - a diterpene, was extracted from this species. This chemical compound is known to have cytotoxicity and antiviral activities, which is of significant therapeutic potential.

CLASS: RHODOPHYCEAE
FAMILY: HYPNEACEAE

10. Hypnea musciformis (Wulfen) J.V. Lamour. in Ann. Mus. Hist. Nat. 20: 131. 1813; Palanisamy & al. in Seaweed Res. Utiln. 35(1&2): 26. 2013. *Fucus musciformis* Wulfen in Jacquin Coll. 3: 154, Pl. 14, fig. 3. 1789.

Thallus light-dark pinkish or brownish red in colour, cylindrical to slightly flattened, freely and irregularly branched with characteristic hook like apices, up to 30 cm long, tufted, epilithic. Holdfast small, usually discoid, up to 6 mm in diameter, firmly attached, occasionally free floating. Stipe up to 1.5 cm long and 0.5-2 mm wide, usually clothed with minute ramuli. Fronds cylindrical to slightly flattened, 4-30 cm long, alternate, opposite or irregularly branched, densely or sparsely covered with minute ramuli; ramuli develop in all directions, smooth or spinous, up to 5 mm long; surface usually rough; apex acute with distinctly hook like curves. *Microscopic*: Cells in surface view circular to slightly elongate, 4-10 µm across, compact. In cross section, thallus up to 1.6 mm thick, differentiated into outer cortex and central medullary regions; cortex 2-5-layered, cells spherical to slightly elongate, 15-85 µm across, progressively increasing from periphery towards centre; medulla cells comparatively large, 80-150 µm across, sparsely arranged. Spermatangia develop in chain usually near the base of the branchlets, swollen; cystocarps round or spherical, conspicuous; tetrasporangia usually on ultimate branches.

Occurrence: Throughout the year. Common.

Distribution: Throughout Karnataka coast.

Therapeutic properties: Brito & al. (2016) reported that this species has a specific secondary metabolite – *sulphated polysaccharide* (PLS), which has significant therapeutic potential against TNBS-induced intestinal damages in rats. Because of this, it may be useful in the treatment of inflammatory bowel treatment in human beings too.

11. Hypnea valentiae (Turner) Mont. in Ann. Sci. Nat. Bot. 2(16): 161. 1841; P.S.N. Rao & Gupta, Algae India 3: 49. 2015.*Fucus valentiae* Turner in Fuci, 2: 17, Pl. 78. 1808.

Thallus light-dark greenish-pinkish red in colour, cylindrical or terete to slightly flattened, usually 4-10(-20) cm long, caespitose, epilithic. Holdfast small, discoid, firmly attached on rocky substrata, occasionally free

floating. Stipe small, sometimes indistinct. Fronds up to 10 cm long ans up to 2 mm in diameter, gradually decreasing towards apex, usually alternate or irregularly branched, densely covered with spinous ramuli throughout, usually sparse towards the apex, branches and branchlets directed upward; spines 0.3-5.2 mm long; apex acute. *Microscopic*: In cross section, thallus up to 2 mm thick, multilayered, differentiated into outer cortex and central medullary layers; cortex 2-4-layered, progressively increasing from periphery towards centre; medulla cells usually 2-3-layered, usually circular to round. Thallus usually dioecious; cystocarps develop on branchlets.

Occurrence: Throughout the year. Moderate.

Distribution: Karnataka: Dakshina Kannada, Udupi (Uchila) and Uttara Kannda districts (Sedikuli, Shiroor coast, Gorte, Om, Vannali beach, Mundoli beach, Bhatkal.

Therapeutic properties: This is one of the economically important seaweeds and used for Carageenan production. Its extracts also contain carbohydrates, proteins (Pati & al., 2016). Hypnea valentiae is also known to have antibiotic potential against *Staphylococcus aureus*, *vibrio fischeri*, *V. alginolyticus*, *Pseudomonas aeruginosa* and *Micrococcus luteus* (Pramitha & Lipton, 2013).

FAMILY: CERAMIACEAE

12. Centroceras clavulatum (C. Agardh) Mont., Fl. Algerie: 140. 1846; Kaladharan & al. in J. Mar. Biol. Ass. India 53 (1): 125. 2011; P.S.N. Rao & Gupta, Algae India 3: 53. 2015. *Ceramium clavulatum* C. Agardh in Kunth: Syn. Pl. 1: 2. 1822. **(Plate 1: e)**

Thallus dark to pinkish red in colour, filamentous, up to 5 (-8) cm long, gregarious, erect, fragile, epilithic, occasionally epiphytic. Holdfast discoid, loosely attached. Stipe small, cylindrical, usually undifferentiated. Frond filamentous, dichotomously branched, up to 8 cm long; filaments differentiated into corticated nodes and internodes; surface smooth in internodal region, spinous in cortical regions. *Microscopic*: Internodal cells 80-400 × 100-150 µm, ultimate branches forcipate, slightly curved, 95-650 × 50-120 µm, cells in surface view rectangular to squarish, cells 7-14 × 6-12 µm across, compactly arranged towards apex; Nodal regions 20-55 µm × 100-150 µm, cells circular in outline, nodes bearing a whorl of 1-3-celled cortical spines; spines 25-50 × 10-30 µm.

Occurrence: During Monsoon and post-monsoon seasons. Moderate.

Distribution: Throughout Karnataka coast.

Therapeutic properties: Gomez & al. (2010) screened out the antibacterial and anticancerous properties of this species. They isolated the strain Cc51 from this species, collected from the Mexican coast and found that it has anticancerous properties with IC_{50} values of 6.492. Besides, this species is also an important source of Domoic acid and other kanoids, and Kainic acid which are of high therapeutic importance (Smit, 2004).

FAMILY: RHODOMELACEAE

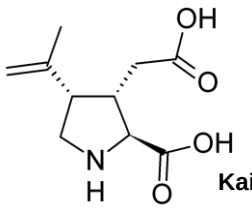
13. Chondria armata (Kuetz.) Okamura, Icon. Jap. Alg. 1: 69. 1907; Kaladharan & al. in J. Mar. Biol. Ass. India 53 (1): 125. 2011; P.S.N. Rao & Gupta, Algae India 3: 59. 2015. *Lophura armata* Kuetz. Tab. Phycol. 16: 2, pl. 3, figs. a,b. 1866. **(Plate 1: f)**

Thallus pinkish to violet red in colour, feathery, up to 8 (-10) cm long bushy, gregarious, tufted, epilithic. Holdfast minute, usually rhizoidal, firmly attached. Stipe small or indistinct. Frond remiform, usually 3-8 cm long, cylindrical to slightly flattened, in basal region, pinnately branched, covered with numerous ramuli; ramuli erect, spinous, up to 0.8 cm long, usually sub-distichously branched, densely arranged at distal end. Cystocarps develop on ramuli, usually subterminla in position.

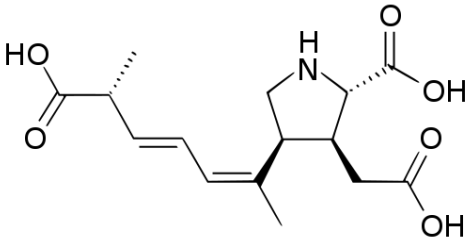
Occurrence: Post-monsoon season. Moderate

Distribution: **Karnataka**: Uttara Kannda district.

Therapeutic properties: Smit (2004) reported that *Chondria armata* has chemical components like Domoic acid and Kainic acid which has been used by the Japanese as an anthelmintic agent for centuries (Higa & Kuniyoshi, 2000; Takemoto & Daigo, 1958). Domoic acid and Kainic acid are potential neuroexcitatory amino acid agonist that acts by activating receptors for glutamate, the principal excitatory neurotransmitter in the central nervous system. Besides, Kanoides are also known to have insecticidal activities against houseflies and cockroaches (Maeda & al., 1986).



Kainic acid



Domoic acid

IUPAC names:

Kainic acid : (2*S*,3*S*,4*S*)-3-(Carboxymethyl)-4-prop-1-en-2-ylpyrrolidine-2-carboxylic acid

Domoic acid: (2*S*,3*S*,4*S*)-3-(Carboxymethyl)-4-[(1*Z*,3*E*,5*R*)-6-hydroxy-1,5-dimethyl-6-oxo-hexa-1,3-dienyl]pyrrolidine-2-carboxylic acid

FAMILY: RHODOMELACEAE

14. Palisada perforata (Bory) K.W. Nam, Algae, Korean J. Phycol. 22 (2): 53-55, 1 table. 2007. *Laurencia papillosa* (C. Agardh) Grev. Alg. Brit. 52. 1830; Kaladharan & al. In J. Mar. Biol. Ass. India 53 (1): 125. 2011.

Thales dark-brownish or pinkish red in colour, up to 12 cm long, slender cylindrical stips, bushy, tufted, epilithic. Holdfast usually discoidal, firmly attached. Fronds cartilaginous, cylindrical, erect, irregularly branched, decreasing in diameter from the primary to the tertiary branches; branched densely covered with minute wart tike outgrowths or tuberculi; secondary branches are 0.6-3 cm long. Reproductive bodies develop on fertile branches; fertile branches vetricose with dilated apices.

Occurrence: Summer season Rare

Distribution: Karnataka.

Note: This species has been included here based on the report by Kaladharan & al. 2011. However, during the present study, it could not be collected freshly.

Therapeutic properties: Smit (2004) reported that this species is also an important source of Domoic acid and other kanoids, and Kainic acid which are potential neuroexcitatory amino acid agonist that acts by activating receptors for glutamate, the principal excitatory neurotransmitter in the central nervous system. Thus, it is of high therapeutic importance.

DISCUSSION

Marine macro algae are the important marine natural resources with many economic potentials to be used by the human beings. Since times ago, it has been utilised by the natives in the south east Asian nations like China, Japan Philippines, Thailand, Korea etc. etc. The Europeans used *Porphyra* species to prevent scurvy and other vit. C deficiency diseases during voyages. Similarly species of *Corallina* and *Alsidium* were used as vermifuge whereas species of *Chondrus*, *Gracilaria*, *Gelidium*, *Pterocladia* used in order to treat various stomach and intestinal disorders. Presently, 221 economically important seaweeds are reported from worldwide, of which 125 are from India (Sahoo, 2000). The Indian coastline harbours about 865 species of marine macro algae (Rao & Gupta, 2015), of which around 107 species are reported from Karnataka coast. Of these, 34 species are known to have economic importance including 14 species with therapeutic values. In India, the research on the large scale extraction and utilization of marine resources in pharmaceutical field is inadequate unlike other countries. Many places in Karnataka like Gorte, St. Mary's island, Surathkal, Om beach, Talgode, Tadri, Honnavar, Vannali, Uchila, Karwar, Majali, sherikuli etc. are endowed with excellent rocky habitats which support the luxuriant growth of these seaweeds in particular seasons. However, because of the lack of the proper awareness among the locals, infrastructure and practical applications, these seaweed resources are still unused and unassessed. Therefore, this is one of the thrust areas which need proper attention in order to utilize the potentiality of these promising marine algal resources of the coastline for the welfare of the mankind.

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