Available online at www.elixirpublishers.com (Elixir International Journal)

Biosciences

Elixir Biosciences 161 (2021) 55780-55796

ISSN: 2229-712X

Monetary Potential and Bio-prospecting of Marine macroalgae from the Coastline of Andhra Pradesh, India

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ARTICLE INFO

Article history:

Received: 24 July 2021;

Received in revised form:

28 November 2021;

Accepted: 8 December 2021;

Keywords

Andhra Pradesh,
Biological values,
Economic importance,
Seaweeds,
Utilization.

ABSTRACT

Marine macroalgae (seaweeds) are renewable resources of our Earth and make a substantial contribution to marine biodiversity. Seaweeds are presently considered as the plant-based and alternative form of food, due to the presence of nutrients including carbohydrates, protein, vitamins, and minerals as well as a rich source of health-promoting compounds to control or cure the wide spectrum of disorders and diseases. About 11, 000 species of seaweeds have been reported worldwide. Among them, *ca* 221 of seaweed is cost-effectively important and utilized in the various broad fields of science. In India, a total of 865 species of seaweeds, belonging to 234 genera were reported so far from the various coastal states. In respect of this, the current study was endeavored to itemize the presence of therapeutically and economically significant seaweeds from the coastline of Andhra Pradesh. A total number of 112 stations were selected to furnish the inventory of marine macroalgae between March 2017 and August 2019. Based on the perusal of literature survey, a sum of 58 species found to be the monetary potential with bio-prospecting capability and being used for biological activities including antibacterial antiviral, antifungal anticoagulant antitumor, anti-inflammatory, etc. Further, the present study reviews and enumerates the consumption and utilization of seaweeds correlation with their nutritional range, economic, and biological values.

Introduction

The marine macroalgae are macroscopic creatures, ranging from unicellular to multicellular and prevalently known as seaweeds. Typically, they are epilithic and grow on solid substrates such as rocks, bedrocks, pebbles, mollusc shells, and corals. Chlorophyceae (Green), Phaeophyceae (Brown), and Rhodophyceae (Red) are the three classes, categorized according to their nature of color, storage of reserve food, components of the cell wall, and type of reproduction and photosynthetic pigments (Myslabodski, 2001).

They are the promising renewable, living, plant-based, and sustainable resources of our Earth. Act as keystone components to ecological, economic, and scientific pieces of a county. Many of them are potentially important and can be used in the broad field of science such as Food Industry, Pharmaceuticals, Textiles, Dyes, Biotechnology, Tissue culture, Paper industry, Biofuel, Cosmetics, Fodder for animals and fishes, Biofertilizer, Phytoremediation, etc. Factually, a total of 221 (1.1%) species of seaweeds were evidenced for their commercial utilization on nourishments (145 species) and phycocolloids (110 species) (Sahoo, 2000).

In the recent periods, a total of 72, 500 algal taxa (including varieties, forma, etc.) were recorded, of which 44,000 species were scientifically flagged worldwide (Guiry, 2012). Among them, seaweeds constitute about 11, 000 taxa and composed of Rhodophyceae with about 7,000 species, followed by Phaeophyceae with 2,000 species and Chlorophyceae with 1,500 species (http://www.seaweed.ie/). Whilst, occurrence of 865 species of seaweeds, belonging to 234 genera have been cited from the various coastline of India (Rao & Gupta, 2015; Palanisamy & Kumar, 2020) and 80 taxa have been recorded from the coastline of Andhra Pradesh (Rao and Sreeramulu, 1970).

Andhra Pradesh contains the second-largest coastline (*ca* 973Km) among the states of India, next to Gujarat. It comprises various kinds of rocky bodies, which may perform as the suitable substratum to enormous diversity of marine macroalgae. The rocky bodies stretched from Visakhapatnam to the Srikakulam districts. A sum of 122 taxa of marine algae (including micro algae) have been recorded from Andhra Pradesh by several workers in different periods and merely surveyed the coastline of Visakhapatnam (Sreeramulu, 1952 & 1953; Rao & Sreeramulu, 1964; Rao, 1969; Rao and Sreeramulu, 1970; Rao *et al.*, 1983; Anon, 1984; Chennubhotla, 1992; Rao *et al.*, 2011; Kaliaperumal & Chennubhotla, 2015; Sowjanya & Sekhar, 2015).

However, the evidence on seaweeds and their bio prospects from the coastline of Andhra Pradesh are sporadic, rare and inattentive too. In this view, this present study is subjected to provide a detailed account of the monetary potential and bio-prospecting of marine macroalgae based on scrutiny of literature.

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Materials & Method

Andhra Pradesh is geographically positioned between 12°41' - 19° 07'N latitude and 69°37' - 84°44'E longitude. Among the other coastal states of India, Andhra Pradesh has got a coastline of around ***c***.973 km, running from Pulicat Lake (Nellore district) in the south to Donkuru (Srikakulam District) in the North. The study area is divided into three major zones *i.e.,* South (Nellore, Guntur, and Prakasam), middle (Krishna, West Godavari, and East Godavari), and north (Visakhapatnam, Srikakulam, and Vizianagaram). The offshore rocky plateaus stretch from Srikakulam district to Visakhapatnam district with enormous diversity of seaweeds and the remaining coastline is endowed with sand beach (Fig. -1; Plate: 1-4).

A sum of 112 localities was sited and surveyed for the collection of seaweeds during low tides in different seasons from March 2017 – August 2019. The seaweed samples were collected from sub-tidal and inter-tidal zones. All the possible substrate such as rocks, bedrocks, artificial cement boulders, cliffs, calcareous mollusks, shells, and coastal wastes like nets, plastics, cloths, etc. were accessed. The collected samples were preserved using standard methodologies of Wet Preservation (Liquid preservation) and Dry Preservation (Herbarium). The identification of the seaweeds done by referring to standard literature, protologue, pictorial guides, monograph and books such as *Phaeophyceae in India* (Misra, 1966); *Phycologia Indica: The Icons of Indian Seaweeds* Vol.– I & II (Srinivasan, 1969, 1973); *Rhodophyta* Vol.– I & II (Desikachary 1990, 1998); *Catalogue of the Benthic Marine Algae of the Indian Ocean* (Silva *et al.,* al., 1996); *Algae of India and Neighboring Countries I. Chlorophyta* (Krishnamurthy, 2000); *Phaeophyceae of India and Neighbourhood* (Krishnamurthy & Baluswamy, 2010); *Pictorial Guide to Seaweeds of Gulf of kachchh, Gujarat* (Kamboj *et al.,* 2019). Further, the current format of the result is provided on the basis of literature collection.

Result

The present study reveals the presence of 58 taxa with monetary potential and bio-prospecting activities. Among them Chlorophyceae is the predominant class with 24 taxa; Phaeophyceae and Rhodophyceae represents with 17 taxa in each class. Genera like *Ulva* (7 taxa), *Caulerpa* (5 taxa), *Gracilaria* (6 taxa) *Padina* (7 taxa), *Sargassum* (5taxa) are endowed with maximum potential of economic and therapeutic properties. The account on the economic and therapeutic importance of seaweeds were discussed as below (**Table 1 –Table 6**)

Edible / Fodder Seaweeds

Seaweeds are considering as the optimized source and valuable supplementary food with proteins, lipids, carbohydrates, minerals, and antioxidants (Kilinc *et al.* 2013; Rao *et al.,* 2007). In recent days, about 15 - 20 edible seaweeds are promoted in Europe (Dawczynski *et al.,* 2007). Seaweeds have been endorsed as vegetables and condiments in France (Kilinc *et al.,* 2013). The extract from the *Ulva* species is used in the preparation of Halva (Halvah or Halwa) in southern parts of Tamil Nadu (Rao *et al.,* 2009, 2016). Also, they serve as fodder because of their high nutritional value. In Andhra Pradesh**,** 21 seaweeds were itemized here with their potential importance on edible and fodder based on the literature survey (**Table 2**)

Polysaccharides Producing Seaweeds

Agar, carrageenan and alginates are the important hydrocolloids derived from brown and red seaweeds. These hydrocolloidal polysaccharides are significantly importance and used for nourishment, preparation of medicines in pharmaceutical industries and biotechnological industries due to their distinct biochemical properties as gelling agents, thickeners or stabilizing and emulsifying agents (Yaphe, 1984). The important and commonly occurring Agarophytes in India are *Gelidiella acerosa*, *Gracilaria edulis*, *G. crassa*, *G. verrucosa*, *G. corticata* and *G. foliifera* **(**Chennubhotla *et al*., 1991; Rao, 1978). Moreover, occurrence of the 18 seaweeds reported towards the biochemical properties and commercial important from the coastline of Andhra Pradesh (**Table 3**)

Seaweeds as Fertilizer & Pesticides

Extracts of seaweed would be the alternative source of bio-fertilizers, in order to avoid the excessive application of fertilizers and improving the uptake through the roots or leaves (Mugnai *et al.,* 2008). Seaweeds and their derivatives in different format are utilized as fertilizer in the coastal zones (Kalimuthu *et al.,* 1987). Extracts of seaweeds contain plant growth hormones, regulators, promoters, carbohydrates, amino acids, antibiotics, and vitamins (Erulan *et al.,* 2009). Application of seaweed extracts increase the seed germination percentage, uptake of nutrients, growth (Immanuel and Subramanian, 1999); promote high yield of crops (Anantharaj & Venkatesalu, 2002); enhance the resistance against diseases (Jayaraman *et al.,* 2011) and optimized drought tolerance (Kumar & Mohan, 2000). Kaliaperumal & Chennubhotla (2017) reviewed effect of 40 species of seaweeds in crop cultivation. In our present investigation we found 19 species of seaweeds towards the source of fertilizer and 5 species recognized with pesticide activities (**Table 4 & 5**).

Antimicrobial Activities of Seaweeds

Various kind of antimicrobial compounds were extracted from the marine environment more than those in the terrestrial which are against to the human pathogens in marine (Ireland *et al.,* 1988). Among them, seaweeds lodged an immense attention due to the existence of bioactive compounds (Manilal *et al.,* 2010). They have been familiarized as prospective bases with enormous biological activities includes anti-microbial, antioxidant, anticancer, anti-inflammation etc. Investigation on antimicrobial, antibacterial, antifungal, antiviral, antibiotic, antioxidant and anticancer activities of different species seaweeds have been studied by several researches in different decades. In our present study, a number of 28 seaweed species have been endowed with antimicrobial activities against 42 pathogens; their significant effects are tabulated below based on literature survey (**Table 6**).

Anticancer/Antitumor/Anti-proliferative/Cytotoxicity

Studies and researches are also indicated that marine algae constitute a promising source of novel compounds with potential as human therapeutic agents (Pereira, 2011). The therapeutic activities of seaweeds on tumor express the resistant properties by controlling accumulation of tumor cell using polysaccharides from various brown, green, and red algae (Ramberg *et al*., 2010). Several studies conclude that compounds extracted from seaweed could be an effective anticancer agent. As the result of our survey, some of the seaweeds with their outcome on cancer cells were furnished in **Table 7**.

Nutritional Importance

In recent decades, seaweed-based food additives are commonly utilized in the preparation of fast food (Dhargalkar & Verlecar, 2009). They are rich in resistant protein and dietary fiber (Mamatha *et al.,* 2007) and valuable food source

as they contain protein, lipids, vitamins and minerals (Soriano *et al.,* 2006). The nutritional properties of seaweeds are poorly known and normally are evaluated from the chemical composition (Mabeau & Fleurence, 1993). They are termed as medical food of the 21st century because of the presence of minerals, vitamins, trace elements and bioactive potential substances (Khan & Sachin, 2003). In view of the above facts, few of the chlorophyceae members are presented with their nutritional stuffs (**Table 8**)

Antioxidant Activities

Many types of macroalgae contain a wide range of bioactive compounds that have the antioxidant potential. Those kinds of compounds have been treated as active elements for humans and animal health uses. Bioactive composites that are most extensively include sulfated polysaccharides aminarin, fucoidan, β-glucans and phlorotannins. Seaweeds also known to be a rich source of antioxidant compounds and play an important role in prevention of cell damages. Some of the seaweeds along with their antioxidant potential are enumerated in detail (**Table 9**).

Discussion

In recent times, seaweeds are noteworthy resources of our nature due to the fact of their distribution, diversity and wide range of utilization in the broad spectrum of science. They render the socio-economic rewards to the coastal communities in the term of commercial aquaculture (Mantri *et al.,* 2020). Seaweeds resources, correlates with current challenges, identification gap, endemism, economic importance, therapeutic potential, threats, need of cultivation, future scopes of India were subjected and deliberated in different decades by several researchers (Rao & Mantri, 2005; Yadav *et al.,* 2015; Kaliaperumal & Chennubhotla, 2015; Kamboj *et al.,* 2019; Ganesan *et al.,* 2019; Mantri *et al.,* 2020; Palanisamy & Kumar, 2020; Yadav, 2020).

The attention on the seaweed diversity in Andhra Pradesh was began by Sreeramulu (1952 & 1953) at the coastline of Visakhapatnam. Subsequently, Rao & Sreemulu (1964 & 1970) reported the ecological aspects, vertical zonation, seasonal succession, and taxonomy of 80 taxa from the coastline of Visakhapatnam. *Liagora visakhapatnamensis* (1969) *& Ulva uniseriata* (Bast & Rani, 2019) were the novel species reported from Andhra Pradesh. Meanwhile, remarkable annotations on the seasonal growth, phenology, and spore shedding of red algae and brown algae were examined by various authors (Kaliaperumal & Chennubhotla, 2015).

Though the coastline of Andhra Pradesh is naturally endowed with 134 taxa, miserable volume on the bio-prospecting potential of seaweeds such as biochemical & phytochemical composition, phycocolloid contents (Agar-agar & Alginic acid) vitamin – B, C, D, E - complex, B-carotene, chlorophyll a, b & c, Nitrate, phosphate & silicate, nutritional composition, benefits poly saturated fatty acids, antimicrobial activities were assessed since 1950s to till date (Rao 1978; Sarojini & Sharma, 1999; Sarojini & Subbarangaiah, 1999; Sarojini & Lakshiminarayana; 2009; Sarojini & Uma Devi, 2014; Rao and Chatterjee, 2014; Sarojini & Sujatha, 2015; Periasamy *et al.,* 2016; Periyasamy & Subba Rao, 2017). In total, 291 species of seaweeds are commercially utilized in wide range across 43 countries (Tiwari & Troy, 2015) and 58 taxa are recognized currently from the coastline of Andhra Pradesh.

Conclusion

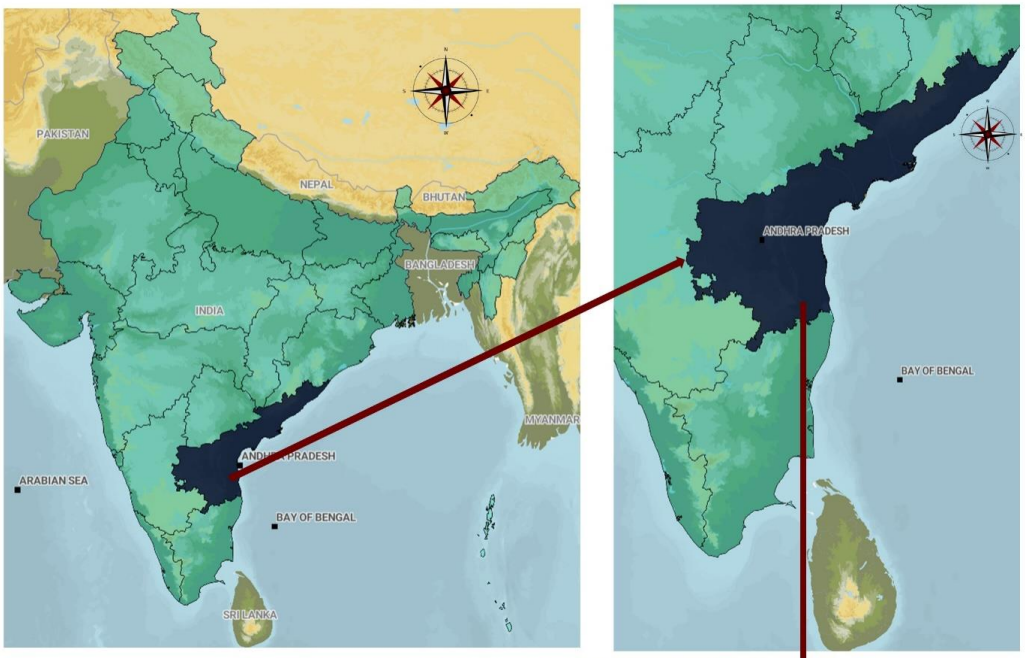
The coastline of Andhra Pradesh is highly sensitive and susceptible to both natural and anthropogenic threats that causes the declining of seaweed diversity. The major factors influencing the marine biodiversity are climate changes with reference to the biotic and abiotic components (Palanisamy & Kumar, 2020). Sowjanya & Sekhar (2015) highlighted the absence of 41 taxa over the coastline of Andhra Pradesh due to the changes in the ecological and environmental conditions in intertidal zone and coastal geomorphology. Conservation measurement on seaweeds is very limited and often for selective genera due to their commercial values in Tamil Nadu, Kerala, and Gujarat (Palanisamy & Kumar, 2020). Field cultivation were subjected only for 3 species (*Gracilaria corticata, Hypnea valentiae* and *Kappaphycus alvarezii*) at the shoreline of Bay of Bengal of Andhra Pradesh (Periasamy *et al.,* 2016; Periyasamy & Subba Rao, 2017). The occurrence of seaweeds in the coastline of Andhra Pradesh was sited with 70 localities and represented with 134 taxa of which 58 has been recognized for their potential source in various spectrum of science. This present attempt would be the basic platform for the researchers to extend their research on different aspects in future.

Hence it is essential to frame the conservation policies of seaweeds in Andhra Pradesh in order to protect these natural treasures from habitat destructions. Cultivation process such as Long-line rope method, single- rope floating raft techniques, vegetative propagation method, fixed off bottom culture, Floating raft/cage culture are appropriate solution to maintain the seaweed diversity in balance. Further the GIS mapping could be done throughout the coastal states for the regular monitor of seaweeds. The marine environments are the peerless ecosystems of our earth, supporting the life systems for enormous organisms. Therefore, conservation of these unique habitats of the earth should be considered in sustainable way for future prosperity.

Acknowledgement

The authors express sincere gratitude to Dr. A.A. Mao, Director, BSI, Kolkata and Dr M. U. Sharief, Scientist – E & HoO, BSI, SRC, Coimbatore for their support and encouragements. Also, they are grateful to MoEF & CC, New Delhi for their financial assistance under AICOPTAX Scheme.

Figure – I (Map) : Coastline of Andhra Pradesh



Coastal districts of Andhra Pradesh

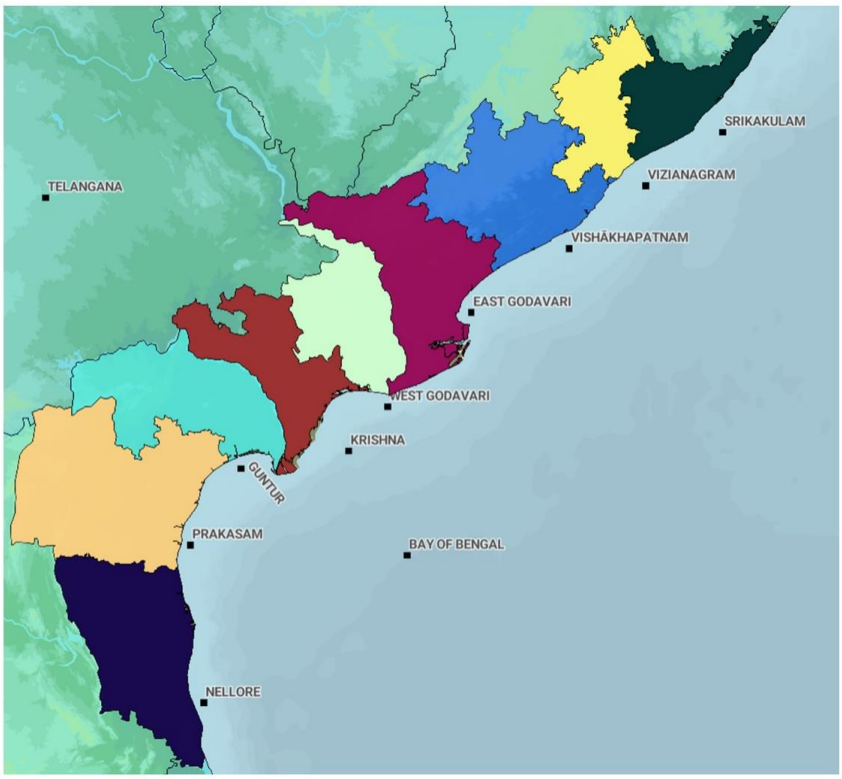
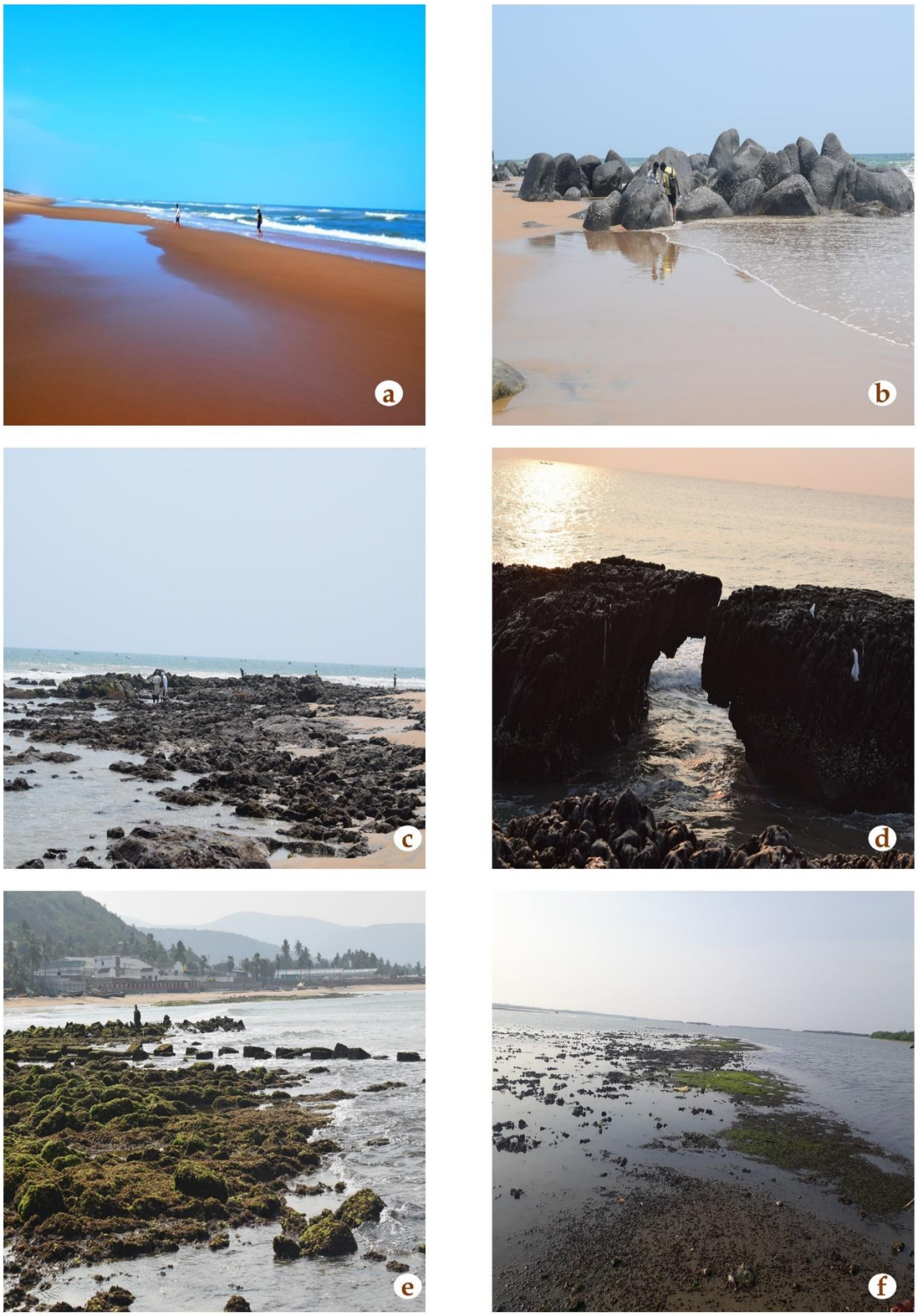
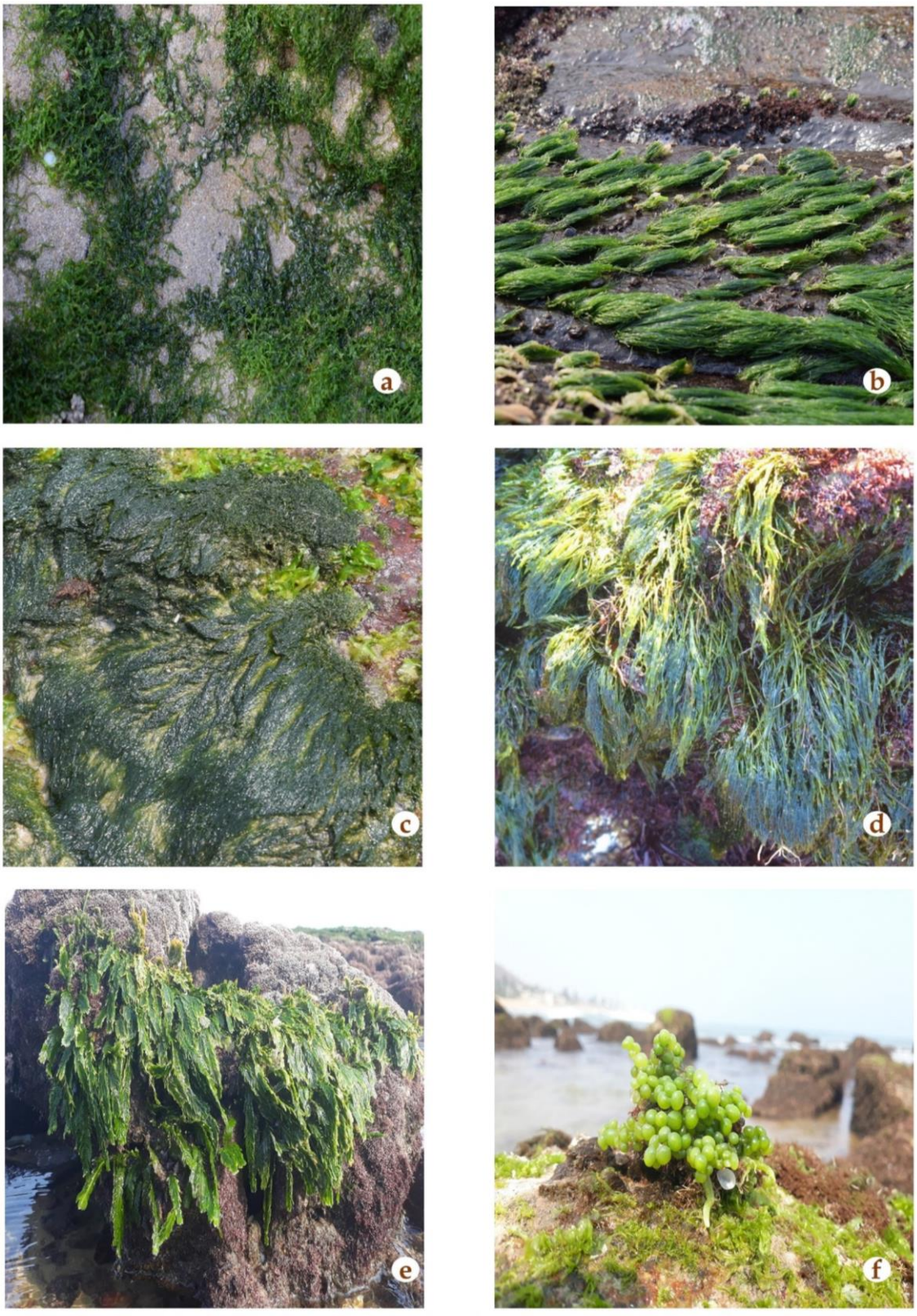


PLATE – 1: NATURE OF THE COAST



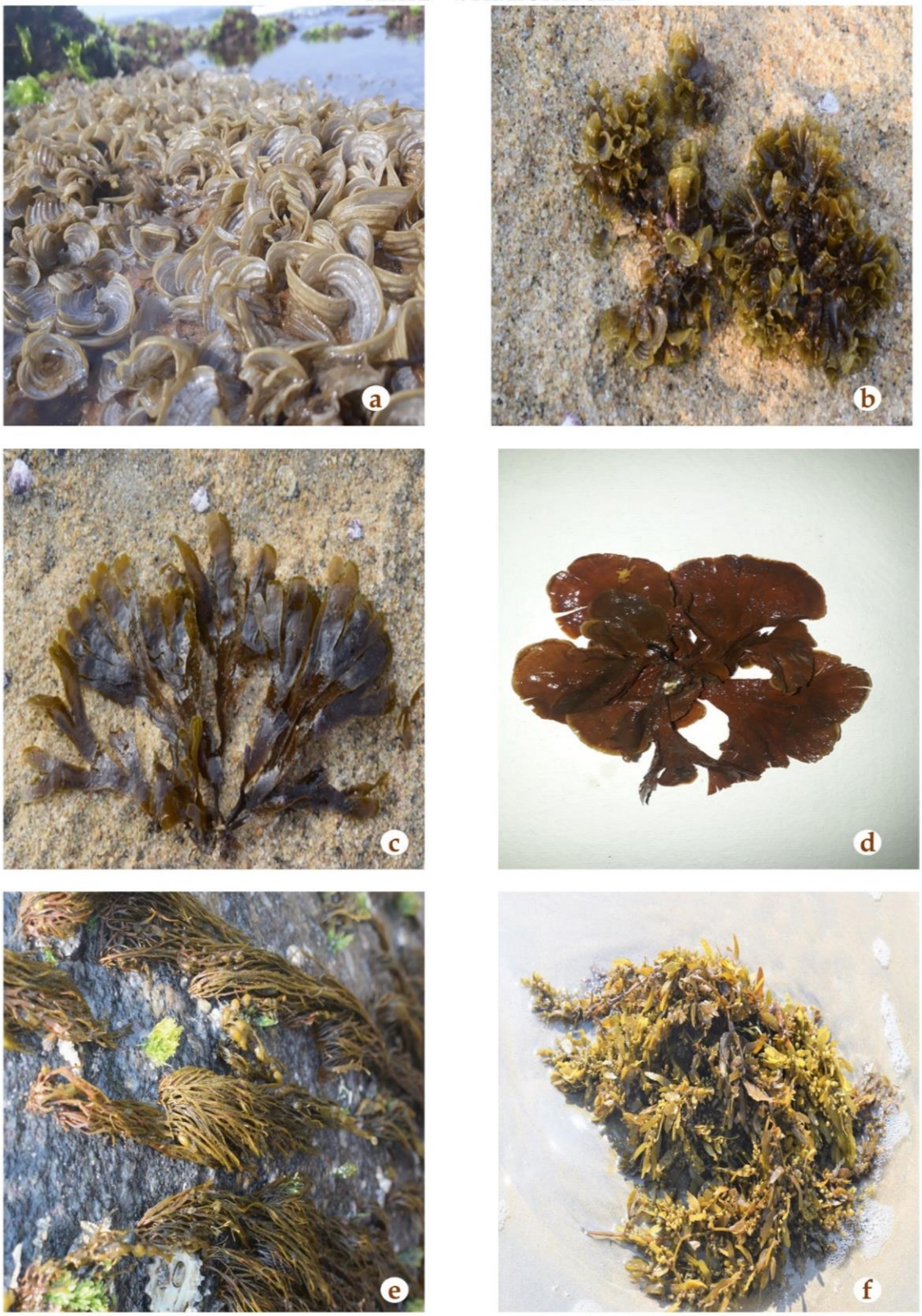
a: Sandy coast at Baruva**; b:** Scattered rocky patches at Lakshimipuram**; c:** Dissected rocky outcrops at Bandaruvanipeta**; d:** Coastline of Thotkakonda with arches of cultural relic**; e**: Eroded, calcified and multi-facets out crops at Mangamaripeta**; f:** Exposure of Pulicat lake during the low tide**.**

PLATE – 2: CHLOROPHYCEAE



a: *Ulva intestinalis* L.; **b**: *Chaetomorpha antennina* (Bory) Kuetz.; **c:** *Cladophora glomerata (L.)* Kuetz.; **d:** *Bryopsis plumosa* (Huds.) C.Agardh; **e:** *Caulerpa taxifolia* (M.Vahl) C.Agardh; **f:** *Caulerpa racemosa* (Forssk.) J.Agardh

PLATE – 3: PHAEOPHYCEAE



a: *Padina pavonica* (L.) Thivy; **b**: *Padina tetrastromatica* Hauck ; **c:** *Stoechospermum marginatum* (C.Agardh) Kuetz. **d:** *Lobophora variegata* (J.V.Lamour.) Womersley ex E.C.Oliveira; **e:** *Chnoospora minima* (Hering) Papenf.; **f:** *Sargassum wightii* Grev.

PLATE – 4: RHODOPHYCEAE

a: *Gracilaria corticata* (J.Agardh) J.Agardh; **b**: *Gracilaria edulis* (S.G. Gmelin) P.C. Silva; **c:** *Gelidiella acerosa* (Forssk.) Feldmann & Hamel; **d:** *Gelidium pusillum* (Stackh.) Le Jolis **e:** *Amphiroa fragilissima* (L.) J.V.Lamour.; **f:** *Grateloupia lithophila* Børgesen.

Table 1. Seaweeds of Andhra Pradesh with their potential aspects

S. No	Importance of Seaweeds	Total Number of the taxa
1.	Edible/Fodder	21
2.	Polysaccharides Producing Seaweeds	18
3.	Fertilizer	19
4.	Pesticides	05
5.	Antimicrobial activities	28
6.	Anticancer /Cytotoxicity activities	18
7.	Antioxidant Activities	21
8.	Nutritional Importance	13

Table 2. List of the edible/ fodder seaweeds of Andhra Pradesh, India

S.No	Name of the seaweeds	Sources
1	*Monostroma latissimum*	Bast *et al*., 2009
2	*Ulva compressa*	Kaliaperumal *et al*., 1995; Shynu *et al.*, 2013
3	*Ulva fasciata*	Sobha *et al*., 2008; Shynu *et al*., 2013
4	*Ulva lactuca*	Kaliaperumal *et al*., 1995; Shynu *et al.*, 2013
5	*Ulva quilonensis*	
6	*Bryopsis plumosa*	
7	*Caulerpa peltata*	
8	*Caulerpa racemosa*	Kaliaperumal *et al*., 1995; Sobha *et al.*, 2008
9	*Caulerpa sertularioides*	
10	*Caulerpa taxifolia*	Shynu *et al.*, 2013
11	*Padina australis*	Yan *et al*., 2007
12	*Padina gymnospora*	Shynu *et al*., 2013
13	*Padina tetrastromatica*	Sobha *et al*., 2008; Shynu *et al*., 2013
14	*Sargassum polycystum*	Matanjun *et al*., 2008
15	*Sargassum tenerrimum*	Kaliaperumal et al., 1995; Shynu *et al.*, 2013
16	*Sargassum wightii*	
17	*Gelidium micropterum*	
18	*Gracilaria edulis*	
19	*Hypnea musciformis*	Kaliaperumal *et al*., 1995;
20	*Hypnea valentiae*	
21	*Acanthophora spicifera*	Chennubhotla *et al*., 1987; Shynu *et al*., 2013

Table 3. List of Polysaccharides producing seaweeds with their derivatives

S. No.	Name of the seaweeds	By-product	Sources
1	*Gelidiella acerosa*	Agar-Agar	Thomas *et al*., 1977
2	*Gelidium pusillum*		Redekar & Raje, 2000
3	*Gracilaria corticata*		Rao, 1970
4	*Gracilaria corticata* var. *cylindrica*		Vimalabai *et al*., 2003
5	*Gracilaria edulis*		Kaliaperumal *et al*., 1987
6	*Gracilaria foliifera*		Vimalabai *et al*., 2003
7	*Gracilaria verrucosa*		Thomas *et al*., 1977
8	*Acanthophora spicifera*	Agroid	Parekh *et al*., 1989
9	*Grateloupia filicina*		Arunkumar *et al*., 2014
10	*Hypnea musciformis*	Carrageenan	Rao, 1969
11	*Hypnea valentiae*		
12	*Dictyota dichotoma*		Redekar & Raje, 2000
13	*Padina boergesenii*		Kaliaperumal *et al*., 1989
14	*Padina pavonica*		Kaliaperumal *et al*., 1990
15	*Padina tetrastromatica*	Alginic acid	Rao, 1978
16	*Sargassum cinereum*		Kappanna *et al*., 1962
17	*Sargassum vulgare*		Rao, 1978
18	*Stoechospermum marginatum*		Kaliaperumal *et al*., 1990

Table 4. List of Seaweeds with their significant effect on plants

Name of the seaweeds	Crop	Significant effect	Sources
1. *Gelidiella acerosa*	*Eleusine coracana*	Induce maximum germination, root and shoot growth.	Immanuel & Subramanian, 1999
2. *Ulva intestinalis*	*Sesamum indicum*	Increase germination, root, shoot length and chlorophyll content.	Gandhiyappan & Perumal, 2001.
3. *Sargassum wightii*	*Mangifera indica*	Effective for early induction of flowering	Shankaraswamy & Neelavathi, 2016
4. *Gracilaria edulis*	*Ablemoschus esculentus* *Zea mays* *Phaseolus mungo*	Higher growth, fruiting, flowering, germination, growth and development.	Ramshubramanian *et al*.,2004; Lingakumar *et al*., 2004

5. *Padina tetrastomatica* 6. *Stoechospermum marginatum*	*Camellia sinensis*	Biostimulants to increase the productivity and quality of tea	Thevanathan *et al*., 2005
7. *Ulva lactuca*	*Abelmoschus esculentus* *Vigno mungo* *Pisum sativum*	Ameliorating effect on seeds under salt stress to promote growth. positive result on the growth and yield	Ramamoorty *et al*., 2006; Divya *et al*., 2015
8. *Ulva fasciata* 9. *Caulerpa racemosa*	*Cyamopsis tetragonoloba*	Producing appreciable yield of the crop	Xavier *et al*., 2007
10. *Chaetomorpha linum*	*Vigno mungo* *Solanum melongena* *Solanum lycopersicum*	Growth promoting activity	Sethi & Adhikary 2009
11. *Sargassum wightii*	*Arachis hypogaea*	Increase in height and number of branches of the plant.	Sridhar & Rengasamy, 2010
12. *Pandina pavonia* 13. *Dictyota dichotoma*	*Vigna radiata*	Induce the seed germination and growth	Bai *et al*., 2011
14. *Cheilosporum spectabile* 15. *Caulerpa scalpelliformis*	*Eudrilus eugeniae*	Promote growth and soil fertility.	Karthick *et al*., 2013
16. *Hypnea musciformis*	*Abelmoschus esculentus* *Solanum lycopersicum* *Capsicum annuum*	Induce maximum germination, number of leaves and flowering.	Rao & Chatterjee, 2014
17. *Caulerpa racemosa*	*Ocimum sanctum*	Shows great impact in the increase of growth and biochemical parameters.	Uthirapandi, *et al*., 2018
18. *Acrosiphonia orientalis* 19. *Gracilaria verrucosa*	*Abelmoschus esculentus* *Solanum lycopersicum*	Induce the seed germination percentage and also growth percentage	Kumar *et al*., 2018

Table 5. Effects of Seaweed pesticides

Name of the seaweed	Effect	Sources
1. *Sargassum vulgare*	Inhibit/control the growth of *Fusarium sambucinum* and *Fusarium solani* the most aggressive and frequent causal agents of potato	Ammar, *et al*., 2017
2. *Bryopsis pennata*	Strong larvicidal, ovicidal as well as oviposition repellence properties against *Aedes aegypti* and *A. albopictus*	Yu *et al*. 2015
3. *Gracilaria edulis* 4. *Ulva intestinalis* 5. *Chaetomorpha linum*	Showed best germination rate and pesticidal activity at lower concentration (20%) against *Artemia larvae* and *Rice beetles*	Gayathri *et al*., 2016.

Table 6. Antimicrobial Activities of seaweeds against the pathogens

Name of the seaweeds	Organism	Sources
Ulva fasciata	*Escherichia coli* *Stapylococcus aureus* *Staphylococcus epidermidis* *Streptococcus faecalis* *Candida albicans* *Salmonella enteritis*	Oranday *et al*., 2004
Ulva compressa	*Vibrio alginolyticus* *Pseudomonas aeruginosa* *Aeromonas hydrophila* *Edwardsiella tarda* *Pseudomonas fluorescens*	Choudhury *et al*., 2005
Ulva linza	*Staphylococcus aureus* *Streptococcus epidermidis* *Streptococcus faecalis* *Bacillus subtilis* *Pseudomonas aeruginosa* *Enterobacter cloacae* *Escherichia coli* *Candida albicans*	Tüney *et al*., 2006
Ulva intestinalis *Ulva lactuca* *Gelidiella acerosa* *Gracilaria corticata* *Stoechospermum marginatum* *Caulerpa racemosa* *Caulerpa scalpelliformis*	*Bacillus cereus* *Micrococcus flavus* *Citrobacter freundii* *Klebsiella pneumoniae* *Pseudomonas testosterone*	Nair *et al*., 2007

Dictyota dichotoma.	*Escherichia coli* *Enterobacter aerogenes* *E. coli O157:H7* *Staphylococcus aureus* *Micrococcus luteus* *Enterococcus faecalis*	Taskin *et al*., 2007
Jania rubens	*Staphylococcus aureus* *Staphylococcus epidermidis* *Streptococcus faecalis* *Bacillus cereus* *Bacillus subtilis* *Pseudomonas aeruginosa* *Enterobacter cloacae* *Escherichia coli* *Candida albicans*	Karabay-Yavasoglu *et al*., 2007
Bryopsis plumosa *Chaetomorpha antennina* *Grateloupia filicina* *Centroceras clavulatum*	*Candida albicans* FC1 (of HIV infection) *Streptococcus* PC1 *Enterococcus faecalis* PC2 *Staphylococcus epidermidis* PC3 *Escherichia coli* PC4 *Micrococcus luteus* PC5 *Bacillus subtilis* PC6 *Pseudomonas aeruginosa* PC7 *Klebsiella pneumoniae* PC8 *Proteus mirabilis* PC9 *Staphylococcus aureus* PC10	Shanmughapriya *et al*., 2008
Gracilaria edulis	*Stapylococcus aureus* *Vibrio cholera* *Shigella dysenteriae* *Shigella boydii* *Salmonella Paratyphi* *Pseudomonas aeruginosa* *Klebsiella pneumoniae*	Vallinayagam *et al*., 2009
Dictyopteris australis *Amphiroa fragilissima* *Caulerpa peltata* *Caulerpa taxifolia*	*Bacillus subtilis* *Escherichia coli* *Pseudomonas* sp. *Streptococcus pyogenes* *Stapylococcus aureus* *Proteus vulgaris* *Klebsiella pneumoniae* *Candida albicans*	Kotnala *et al*., 2009
Hypnea musciformis.	*Escherichia coli* *Pseudomonas aeruginosa* *Staphylococcus aureus* *Klebsiella pneumoniae*	Kolanjinathan & Stella, 2009
Acrosiphonia orientalis	White Spot Syndrome Virus (shrimp pathogen)	Manilal & el., 2009
Halimeda opuntia	*Pseudomonas aeruginosa* *Escherichia coli* *Proteus vulgaris* *Serratia marcescens* *Staphylococcus aureus* *Micrococcus luteus* *Enterococcus feacalis* *Bacillus subtilis* *Bacillus cereus* *Bacillus megaterium* *Candida albicans* ATCC 44831 *Candida utilis* *Saccharomyces cerevisiae*	Selim, 2012
Chaetomorpha linum	*Staphylococcus aureus* *Bacillus cereus* *Escherichia coli* *Proteus mirabilis* *Klebseilla pneumoniae* *Salmonella typhimurium*	Senthilkumar & Sudha, 2012
Acanthophora spicifera *Padina tetrastromatica*	*Aspergillus terrus* *Aspergillus fumigatus* *Gibberline* sp *Alternaria* sp *Ganoderma* sp	Radhika & Priya, 2016
Padina pavonica	*Escherichia coli* *Pseudomonas aeruginosa* *Staphylococcus aureus* *Enterococcus faecalis*	Hlila *et al*., 2017

Table 7. Cell line/organism report towards the anti-proliferative/anti-tumor/anticancer activities of seaweeds

Name of the seaweeds	Cell Line/Organism	Significant effect	Sources
Ulva intestinalis *Rhizoclonium riparium*	HeLa (Human cervical cancer cell line) T cells [Human embryonic kidney (HEK) cell line]	Anti-proliferative activity Treated cells became round with blebbing with condensed nuclei.	Paul and Kundu, 2013
Ulva lactuca	Human leukemia cells (U 937)	Regulating the tumor genesis & expresses 50% growth inhibition.	Lakmal *et al*., 2014.
Jania rubens	Hepatocellular Carcinoma Cell Lines (HepG2)	Anticancer activity LC_{50} value of 8.61 µg/mL .	El-Saharty *et al.*, 2018
Hypnea musciformis	Caco-2 (Colon cancer cell line cell line)	Anticancer activity Arrested cell growth in G phase (57.6%)	Alghazeer *et al*., 2016
Gelidiella acerosa *Acanthophora spicifera*	DAL (Dalton's Ascitic Lymphoma cells)	Anticancer activity Reduced the cancer cell count. Reduces the tumour weight and hence increased the life span of cancer induced mice.	Duraikannu *et al*., 2014
Gracilaria corticata *Ulva fasciata*	MCF-7 MDA-MB-23 HeLa HepG2 HT-29	Apoptosis Activity Increased from 18 to 78 %. Inhibit the growth of cancer cells and induce apoptosis in human breast cancer in time and dose depended manner	Namvar *et al*., 2013
Amphiroa fragilissima	Lung cancer cell A549	Anticancer activity Increasing activity inhibit/decrease the cell viability.	Shyamala *et al*., 2014
Dictyopteris australis *Padina tetrastromatica* *Stoechospermum marginatum*	Artemia salina nauplii (Brine shrimp)	Cytotoxicity Causing cytotoxic at 100 $mgml^{-1}$ at 18 and 24 h.	Vinayak *et al*., 2011
Caulerpa taxifolia	*Sk-N-Sh Cell line*	Antiproliferative Caulerpenyne affect the microtubule, cause cell death.	Barbier *et al*., 2001
Chaetomorpha crassa *Caulerpa racemosa*	*Pomyelocytic leukemia* (HL-60) *Human lung carcinoma* (A549) *Mouse melanoma* (B16F10)	Anticancer activity Significant effect on the cell inhibition and apoptotic body formation	Lakmal *et al*., 2014

Table 8. Nutritional composition of some Chlorophyceae members

Name of Species	Protein	Lipid	Carbohydrate	Vit-C	Calorific value	Sources
Ulva fasciata	22.7 ± 0.22	-	32.0 ± 0.04	0.38 ± 0.04	-	Ganesan *et al*., 2020
Ulva compressa	15.5 + 0.79	0.83 + 0.32	54.63 + 1.35	3.23 + 0.98	19.41 + 1.21	Rupapara *et al*., 2017
Ulva prolifera	15.53 + 0.96	0.5 + 0.1	52.57 + 0.61	2.1 + 0.87	37.21 + 1.27	
Ulva flexuosa	17.29 ± 1.24	-	30.10 ± 0.18	0.36 ± 0.02	-	
Boodlea composita	8.48 + 0.86	1.55 + 0.41	26.25 + 1.56	1.25 + 0.52	31.17 + 1.14	
Bryopsis plumosa	9.65 + 0.57	1.23 + 0.21	23.12 + 1.69	1.11 + 0.24	69.25 + 3.48	
Caulerpa racemosa	12.3 + 1.22	1.12 + 0.11	24.23 + 2.13	0.99 + 0.33	92.97 + 5.97	
Caulerpa scalpelliformis	14.83 + 0.44	1.83 + 0.4	24.6 + 2.1	1.02 + 0.21	92.97 + 7.66	
Caulerpa sertularioides	14.77 + 1.01	1.67 + 0.25	28.13 + 0.85	1.27 + 0.17	18.09 + 1.21	
Caulerpa taxifolia	11.27 + 0.21	1.37 + 0.38	23.97 + 0.81	0.92 + 0.09	1.19 + 0.87	
Chaetomorpha crassa	7.87 + 1.18	1.47 + 0.25	29.47 + 1.42	1.08 + 0.19	17.93 + 1.24	
Cladophora glomerata	9.55 + 1.14	0.65 + 0.21	27.65 + 2.15	1.27 + 0.11	8.21 + 0.88	
Codium dwarkense	7.73 + 0.42	0.57 + 0.15	43.15 +1 .35	1.97 + 0.21	23.13 + 1.27	

Table 9. Antioxidant activities of Seaweeds with their absorption value

Name of the algae	Extract	Absorption value (%)	Sources
Chaetomorpha antennina	Methanol	17.32	Sumathi *et al*., 2012
Chaetomorpha linum	Methanol	18.177	Farasat *et al*., 2013
Chaetomorpha aerea	Methanol	11.923	
Chaetomorpha brachygona	Methanol	10.751	
Chaetomorpha crassa	Methanol	10.906	
Caulerpa scalpelliformis	Methanol	21.34	Sumathi *et al*., 2012
Valoniopsis pachynema	Methanol	63.5	Kavitha *et al*., 2015

Bryopsis plumosa	Ethanol	13.9	Dharmesh *et al*., 2014
Padina pavonica	Acetone	74.28	Hlila *et al*., 2017
Dictyopteris australis	Ethanol	32.2	Dharmesh *et al*., 2014
Dictyota dichotoma	Methanol	13.28	Lima *et al*., 2016
Padina gymnospora	Methanol	84.96	Priya & Khora, 2014
Padina tetrastromatica	Methanol	34.66	Kokilam *et al*., 2013
Stoechospermum marginatum.	Methanol	15.02	Esmaeili & Khakpoor, 2012
Sargassum wightii	Methanol	20.0	Kokilam *et al.*, 2013
Chnoospora minima	Methanol	29.3	
Amphiroa fragilissima	Ethyl Acetate	64.00	Shyamala *et al*., 2014
Gracilaria edulis	Ethanol	32.21	Murugan *et al.*, 2012
Grtacilaria corticata	Ethanol	66.41	Ashwini & Manjula, 2017
Hypnea musciformis	Methanol	69.54	Lavanya et al., 2016

References

Alghazeer, R., Ibrahim, A., Abdulaziz1, A., and Abouamer, K., (2016). In-vitro Antioxidant Activity of Five Selected Species of Libyan Algae. International Journal of Medicine and Pharmaceutical Research. 4(1): 1-9.

Ammar, N., Abdallah, A.R.B, Jabnoun-Khiareddine, H., Nefzi, A., Rguez, S., and Daami-Remadi, M., (2017). *Sargassum vulgare* extracts as an alternative to chemical fungicide for the management of Fusariumdryrot in potato. Journal of Agriculture and Food Research, 8(4):197.

Anantharaj, M., and Venkatesalu, V. (2002). Studies on the effect of seaweed extracts on *Dolichos biflorus*. Seaweed Research and Utilization. 24: 129- 137.

Anon, (1984). A report on the survey of marine algal resources of Andhra Pradesh 1979-1982.CSMCRl pp 1-8.

Kumar, A.S., Vivek, S., and Palanisamy, M., (2018). A Comprehensive Report on Seaweed Diversity from Northern Coastal Districts of Andhra Pradesh with New Addition. In the Book of Abstract of the International seminar on *Coastal and Marine Biodiversity and Conservation (ISCMBC-2018)"* organized by CAS in Marine Biology, Faculty of Marine Sciences, Parangipettai, Annamalai University. 32.

Arunkumar, K, A., Palanivelu and Darsis, A. (2014). Proximate composition, nutraceuticals constituents and fatty acid profile on GCMS of seaweeds collected from Balk Bay (Thondi), India. International Journal of Current Science 12: 57-71.

Ashwini, S., and Manjula, S., (2017). A Study on the Ethanolic Extracts of Red Seaweed- *Gracilaria corticata* (J.Agardh) J. Agardh, to Assess the Antiproliferative Activity and Morphological Characterization of Apoptosis on HeLa Cell lines. International Journal of Phytomedicine 9(3): 436-442.

Bai, R. N., Mary, C. and Kala, T. 2011. Effect of Seaweed concentrate of *Pavonia* on the growth and yield of a pulse crop. Pant Arch. 1: 117-120.

Barbier, P., Guise, S., Huitorel, P., Amade, P., Pesando, D., Briand, C., and Peyrot V. (2014) Caulerpenyne from *Caulerpa taxifolia* has an antiproliferative activity on tumor cell line SK-N-SH and modifies the microtubule network, Life Sciences, 70(4): 415-429.

Bast, F., and Rani, P. (2019). First report of uniseriate free-living *Ulva* species with description of new species *Ulva uniseriata* sp. nov (Chlorophyta, Ulvales). Indian Journal of Geo Marine Sciences 48(11): 1687-1691.

Bast, F., Hiraoka, M., and Okuda, K (2009) Spatiotemporal Sex Ratios of a Dioecious Marine Green Alga: *Monostroma latissimum* (Kützing) Wittrock. International Journal on Algae 11 (2):141-150.

Chennubhotla, V., Kaliaperumal, N. and Kalimuthu, S. (1987).Economically important seaweeds. CMFRI Bulletin, 41: 3-18.

Chennubhotla, V., Kaliaperumal, N., Kalimuthu, S., and Ramalingam, J., (1991). Commercially important seaweeds of India, their occurrence, chemical products and uses. Marine Fisheries information Service, CMFRI, 107:11-16.

Chennubhotla, V.S.K., (1992). A survey of seaweed resources of Andaman-Nicobar Islands, Visakhapatnam-Chilika lake region and Lakshadweep group of Islands. Final report on the ICAR Ad-hoc Scheme. 104.

Choudhury, S., Sree, A., Mukherjee, S., Pattnaik, P., and Bapuji, M. (2005). In Vitro Antibacterial Activity of Extracts of Selected Marine Algae and Mangroves against Fish Pathogens. Asian Fisheries Science 18: 285-294.

Dawczynski, C., Schubert, R., and Jahreis, G., (2007) Aminoacids, fattyacids and dietary fibre in edible seaweed products. Food Chemistry, 103: 891 – 899.

Desikachary, T.V., V. Krishnamurthy and M.S. Balakrishnan, (1990). Rhodophyta Vol. I. Madras Science Foundation, Chennai. pp.279.

Desikachary, T.V., V. Krishnamurthy and M.S. Balakrishnan, (1998). Rhodophyta Vol. II. Part–II B. Madras Science Foundation, Chennai. pp.359.

Dhargalkar, V.K. and Verlecar, X.N. (2009). Southern Ocean seaweeds: A resource for exploration in food and drugs. Aquaculture. 287: 229-242.

Dharmesh R., Chejara, Kondaveetia, S., Meena, R., and Siddhanta, A. K. (2014). Antioxidant activity and phytochemical analysis of a few Indian seaweed species. Indian Journal of Geo- Marine Sciences. 43 (4):507-518.

Divya, K., Mary Roja, N and S.B. Padal (2015). Influence of seaweed liquid fertilizer of *Ulva lactuca* on the seed germination, growth, productivity of *Abelmoschus esculentus* (L.). International Journal of Pharmacological Research. 5(12): 344-346.

Duraikannu, K., Shameem Rani, K., Anithajothi, R., Umagowsalya, G., and Ramakritinan, C. M., (2014). In- vivo anticancer activity of red algae (*Gelidiella acerosa* and *Acanthophora spicifera*). International Journal of Pharmaceutical Sciences and Research; 5(8):3347-3352.

El-Saharty, Abeer & Farghaly, Osman & Hamed, Abdel-Rahman & Noreldeen, and Hamada. (2018). Anti-cancer Activity of Some Marine Macroalgae in Hepatocellular

Carcinoma Cell Lines (HepG2). International Journal of Ecotoxicology and Ecobiology. 10(10): 1-10.

Erulan, V. S. P., Thirumaran, G., and Ananthan, G. (2009). Studies on the effect of *Sargassum polycystum* extract on the growth and biochemical composition of *Cajanus cajan* L. Journal of Agriculture and Environmental Sciences, 6: 392-399.

Esmaeili, A., and Khakpoor, M. (2012). Biological activities and chemical composition of solvent extracts of *Stoechospermum marginatum* (C. Agardh). Acta Biochim Polonica, 59(4):581-.585.

Farasat, M., Khavari-Nejad, R., Nabavi, S.M.B., and Namjooyan, F., (2013). Antioxidant Properties of Some Filamentous Green Algae (*Chaetomorpha* Genus). Brazilian Archives of Biology and Technology. 56: 921-927.

Gandhiyappan, K.; Perumal, P, (2001). Growth promoting effect of seaweed liquid fertilizer (*Enteromorpha intestinalis*) on the sesame crop plant. Seaweed Research and Utilization, 23: 23–25.

Ganesan, A. R, Tiwari, U., and Rajauria, G. (2019). Seaweed nutraceuticals and their therapeutic role in disease prevention. Food Science and Human Wellness. 8(3): 252-263.

Ganesan, A.R., Kowsalya, S., Balamuralikrishnan, B., Liu, W.C., Arasu, M.V., Al-Dhabi, N.A., and Duraipandiyan V., (2020). Evaluation of in vivo sub-chronic and heavy metal toxicity of under-exploited seaweeds for food application. Journal of King Saud University, 32 (1):1088–1095

Gayathri, P. K., Arun, D., Sripriya, R., Soniya, E., Vennila, R. and Felcitta Aarthi, R. (2016). Effects of four bio pesticides on three different species – A Comparative Study. Journal of Chemical and Pharmaceutical Sciences 9(3):1531-1534.

Guiry, M.D. (2012). How many species of Algae are there? Journal of Phycol. 48: 1057–1063.

Hlila, M.B., Majouli, K., Jannet, H.B., Aouni, M., Mastouri, M., and Selmi., B., (2017). Antimicrobial activity of Tunisian *Euphorbia paralias* L. Asian Pacific Journal of Tropical Biomedicine 7(7): 629-632.

http://www.seaweed

Immanuel, S.R., and Subramanian, S. K. (1999). Effect of fresh extracts and seaweed liquid fertilizers on some cereals and millets. Seaweed Research and Utilization, 21: 91-94.

Ireland, C.M., Roll, D.M., Molinsk, T.F., Mckee, T.C., Zarbriske, T.M. and Swersey, J.C. (1988). Uniqueness of the marine environment: categories of marine natural product from invertebrates In: D.G. Fautin, (ed.) Biomedical importance of marine organisms. California Academy of Sciences, San Francisco, pp: 41-58.

Jayaraman, J., Norrie, J. and Punja, Z.K. (2011). Commercial extract from the brown seaweed *Ascophyllum nodosum* reduces fungal diseases in greenhouse cucumber. Journal of Applied Phycology, 23: 353–361.

Kaliaperumal, N. and Chennubhotla, V.S.K., (2015). Studies on marine algae of Andhra Pradesh: A Review. Seaweed Research and Utilization, 37(2): 1 – 13.

Kaliaperumal, N. and V. S.K. Chennubhotla. (2017). Studies on value added products from Indian marine algae – A review. Seaweed Research and Utilization, 39(1): 1 – 9.

Kaliaperumal, N., Kalimuthu, S. and Ramalingam, J. R. (1990). Studies on phycocolloid contents from seaweeds of South Tamil Nadu coast. Seaweed Resources Utilization. 12 (1): 37–40.

Kaliaperumal, N., P. Kaladharan and S. Kalimuthu, (1989). Seaweed and seagrass resources. Bulletin of CMFRI. 43: 162–175.

Kaliaperumal, N., S. Kaliamuthu and Ramalingam, J.R., (1995). Economically important seaweeds. CMFRI special publication, 62: 1-35.

Kalimuthu, S., Chennubhotla, V. S. K., and Kaliaperumal, N. (1987). Economic important seaweeds of India. Seaweed Research and Utilization in India. CMFRI Bulletin. 41: 99.

Kamboj, R.D., Lopamudra Das, and Palanisamy, M., (2019). Pictorial Guide to Seaweeds of Gulf of kachchh, Gujarat. Published by GEEER Foundation. pp 376.

Kappanna, A.N., A. Visweswara Rao and Mody, I.C., (1962). Alginic acid content of some of the brown seaweeds of Sourashtra coast. Current Science, 31: 463-464.

Karabay-Yavasoglu, N., Sukatar, Atakan Ozdemir, Guven and Horzum, Zerrin. (2007). Antimicrobial activity of volatile components and various extracts of the red alga *Jania rubens*. Phytotherapy research, 21:153-156.

Kavitha, K., Mahalakshmi, K., and Manam, V.K., (2015). In Vitro Antioxidant Activity of Methanolic Extract of Green Alga *Valoniopsis Pachynema*. World Journal of Pharmaceutical Sciences, 3(10): 2088-2091

Khan, S., and Sachin, S., (2003). Seaweed Mariculture: Scope and Potential In India. 8:26-29.

Kılınc, B., Cirik, S., Turan, G., Tekogul, H., and Koru E., (2013). Seaweeds for Food and Industrial Applications. Food Industry. 735 – 748.

Kokilam, G., Vasuki, S. and Sajitha, N., (2013). Biochemical composition, alginic acid yield and antioxidant activity of brown seaweeds from Mandapam region, Gulf of Mannar. Journal of Applied Pharmaceutical Science, 3:99-104.

Kolanjinathan, K., and Stella, D., (2009). Antibacterial activity of ethanol extracts of seaweeds against human bacterial pathogens. Recent Research in Science and Technology, 1(1): 20-22.

Kotnala, S., Garg, A. and Chatterji, A., (2009). Screening for the presence of antimicrobial activity in few Indian seaweeds. Pertanika Journal of Tropical Agricultural Science, 32(1): 69-75.

Krishnamurthy, V., (2000). Algae of India neighboring Countries I. Chlorophycota- Oxford and IBH Publishing Co. Pvt. Ltd., p. 1- 198.

Krishnamurthy, V., and Baluswami, M., (2010). Phaeophyceae of India and Neighbourhood: Ectocarpales Sphacelariales, Dictyotales, Chordariales and Scytosiphoniales. Vol. I, Krishnamurthy Institute of Algology, Chennai. pp. 193.

Kumar, A.S., Vivek, S. and Palanisamy, M. (2018). An account on Marine Macro Algae of Northern Coastal Districts of Andhra Pradesh, India. In the abstract of National symposium on Current Trends in Plant Sciences held at MCC, Chennai on 22-23rd February.15.

Kumar, V., and Mohan, V. R. (2000). SLF application on recovery of drought stressed black gram. Seaweed Research and Utilization. 22: 89-91.

Lakmal, H.C., Samarakoon, K.W., Lee, W., Lee, J.-H., Abeytunga, D., Lee, H.-S. and Jeon, Y.-J., (2014). Anticancer and antioxidant effects of selected Sri Lankan marine algae. Journal of the National Science Foundation of Sri Lanka, 42(4), pp.315–323.

Lavanya, B.,Narayanan, N., and Maheshwaran, A. (2016). Pharmacological Studies on *Hypnea musciformis* (Wulfen) Lamouroux. International Journal of Advance Research, Ideas and Innovations in Technology 2(4): 1- 14.

Lima, R.L., Pires-Cavalcante, K.M.S., and Alencar, D.B., (2016). In vitro evaluation of antioxidant activity of methanolic extracts obtained from seaweeds endemic to the

coast of Ceara, Brazil. Acta Scientiarum. Technology, 38: 247.

Lingakumar, K., Jeyaprakash, R., Manimuthu, C. and Haribaskar, A. (2002). *Gracilaria edulis* - an effective alternative source as a growth regulator for *Zea mays* and *Phaseolus mungo*. Seaweed Research and Utilization. 24: 117-123.

Mabeau, S. and Fleurence, J. (1993). Seaweed in Food Products: Biochemical and Nutritional Aspects. Trends in Food Science and Technology, 4:103-107.

Mamatha, B.S., Namitha, K.K., Senthil, A., Smitha, J., Ravishankar, G.A., (2007). Studies on use of E*nteromorpha* in snack food. Food Chemistry, 101: 1707–1713.

Manilal, A., Sujith, S., Selvin, J., Kiran, G.S., Shakir, C., and Lipton, A.P., (2010). Antimicrobial potential of marine organisms collected from the southwest coast of India against multiresistant human and shrimp pathogens. Scientia Marina, 74: 287-296.

Manilal, A., Sujith, S., Selvin, J., Seghal, G., Kiran and Shakir, C. (2009). In vivo Antiviral Activity of Polysaccharide from the Indian Green Alga, *Acrosiphonia orientalis* (J. Agardh): Potential Implication in Shrimp Disease Management. World Journal of Fish and Marine Sciences 1 (4): 278-282.

Mantri, V.A. and Rao, P.V.S, (2005) Indian seaweed resources and sustainable utilization: Scenario at the dawn of a new century. Current Science, 91(2): 165-174.

Mantri, V.A., Kavale, Monica, G., Kazi, and Mudassar, A. (2020). Seaweed Biodiversity of India: Reviewing Current Knowledge to Identify Gaps, Challenges, and Opportunities. *Diversity* 12(1): 1-22.

Matanjun, P., Mohamed, S., and Mustapha, N.M. (2008). Antioxidant activities and phenolics content of eight species of seaweeds from north Borneo. J Appl Phycol 20, 367 – 373.

Misra, J.N. (1966). Phaeophyceae in India. ICAR, New Delhi. pp. 203.

Mugnai, S., Azzarello, E., Pandolfi, C., Salamagne, S., Briand, X., and Mancuso, S. (2008). Enhancement of ammonium and potassium root influxes by application of marine bioactive substances positively affects *Vitis vinifera* plant growth. Journal of Applied Phycology, 20: 177-182.

Murugan, Kavitha, Iyer and Vidhya. (2012). Antioxidant and Antiproliferative Activities of Marine Algae, *Gracilaria edulis* and *Enteromorpha lingulata*, from Chennai Coast. International Journal of Cancer Research. 8: 15-26.

Myslabodski, D. (2001) Great Sea Vegetables, 2 Park Drive, Suite 200, Rockland ME 04841, USA. Website: www.seavegetables.com.

Nair, R., Chabhadiya, R., and Chanda., S., (2007). Marine algae: screening for a potent antibacterial agent. Journal of Herbal Pharmacotherapy. 7(1): 73 – 86.

Namvar, F., Mohamad, R., Baharara, J., Zafar-Balanejad, S., Fargahi, F., and Rahman, H.S. (2013). Antioxidant, antiproliferative, and antiangiogenesis effects of polyphenol-rich seaweed (*Sargassum muticum*). BioMed Research International, 2013:1 – 9.

Oranday, M.A., Verde, M.J., Martínez-Lozano, S.J., and Waksman, N.H. (2004). Active fractions from four species of marine algae. International Journal of Experimental Botany.165-170.

Palanisamy, M., and Kumar, A.S., (2020). Marine Macro Algae. In: Chandra, K., Raghunathan, C., Mondal, T. (Eds.), Faunal Diversity of Biogeographic Zones: Coast of India. Zoological Survey of India, West Bengal. pp. 749-783.

Parekh, R.G., Doshi, Y.A., and Chauhan, V.D., (1989). Polysaccharides from marine red algae *Acanthophora spicifera, Grateloupia indica* and *Halymenia porphyroides*. Indian Journal of marine sciences. 18:139 – 140.

Paul, S. and Kundu, R. (2013). Antiproliferative activity of methanolic extracts from two green algae, *Enteromorpha intestinalis* and *Rizoclonium riparium* on HeLa cells. DARU Journal of Pharmaceutical Sciences 21(1):72.

Pereira, J., (2011). Legalizing euthanasia or assisted suicide: the illusion of safeguards and controls. Current Oncology, 18(2): 38-45.

Periyasamy, C., and Subba Rao, P.V. (2017). Growth rate and carrageenan yield of cultivated Kappaphycus alvarezii (Doty) Doty in the coastal waters of Bay of Bengal at Chepala Timmapuram, Andhra Pradesh, East coast of India. Journal of Applied Phycology, 29:1977–1987

Periyasamy, C., Rao, P.V.S, and Anantharaman, P. (2016) *Kappaphycus* cultivation - a boon for the livelihood of coastal fisherfolk in India. Seaweed Research and Utilization 38:75–83.

Priya, M.K. and Khora, S., (2014). Vitro antioxidant, antimicrobial, haemolytic and cytotoxic activity of brown alga *Padina gymnospora* from south east coast of India. Journal of Pure and Applied Microbiology 8(4):3155-3164.

Radhika, D and R. Priya. (2016). Antifungal activity of *Acanthophora spicifera, Padina tetrastomatica* and *Caulerpa scalpelliformis* against some fungal pathogens in crude and fractionated form. World Journal of Pharmacy and Pharmaceutical Sciences 5(3): 1155-1162.

Ramamoorthy, K., Sujatha, K., Sivasubramaniam, K. and Subburamu, K., (2006). Utilization of seaweed extract for enhancing yield in blackgram *Vigna mungo* L. Seaweed Research and Utilization. 29: 97-100.

Ramasubramanian, V., Sumathi, M. and Jeyaprakash, R. 2004. Effect of seaweed extract on the growth and biochemical characteristics ofmatch factory effluent treated *Ablemoschus esculentus* (L.) seedling. Seaweed Research and Utilization. 26: 147-153.

Ramberg, J.E, Nelson, E.D., and Sinnott, R.A., (2010) Immuno-modulatory dietary polysaccharides: A systematic review of the literature. Nutrition journal. 9(54) 1-22.

Rao G.M.N, Chatterjee, R (2014) Effect of seaweed liquid ertilizer from *Gracilaria textorii* and *Hypnea musciformis* on seed germination and productivity of some vegetable crops. Universal Journal of Plant Science 2: 115- 120.

Rao, G. N., and Chatterjee, R. (2014). Effect of Seaweed Liquid Fertilizer from *Gracilaria textorii* and *Hypnea musciformis* on Seed germination and productivity of some vegetable crops. Universal Journal of Plant Science, 2: 115-120.

Rao, K.R., (1969). Study on growth cycle and phycocolloid in *Hypnea musciformis* (Wulf.) Lamour. In: Proc. Fifty sixth Indian Sci. Congr. Bombay Part III. Abstracts. Calcutta. 269.

Rao, M., and Kaliaperumal, N. (1987). Diurnal periodicity of spore-shedding in some red algae of Visakhapatnam coast. Journal of Experimental Marine Biology and Ecology.106 (2): 193-199.

Rao, M.U., and Sreeramulu, T., (1970). An annotated list of the marine algae of Visakhapatnam (India). Botanical Journal of the Linnean Society 63: 23–45.

Rao, P. V.S, Periyasamy, C., Rama Rao, K., and Srinivasa Rao, A. (2016). Seaweed for Human Welfare. Seaweed Research and Utilization, 38: 1-12.

Rao, P.S.N. and R.K. Gupta, (2015). A checklist of Indian Marine Algae (Excluding Diatoms & Dinoflagellates). Algae of India, Vol 3: Botanical Survey of India, Kolkata. Pp.1–93.

Rao, P.V.S, Ganesan, K., and Kumar, K.S. (2009) Seaweeds: A Survey of Research and Utilization. In: Algal Biology and Biotechnology (Eds.) Khattar, J.I.S., D. P. Singh and I. K. Gurpreet Kaur. International Publishing house, PVT Ltd. New Delhi, Banglore. pp 165-178.

Rao, P.V.S, Mantri, V.A., Ganesan, K., and Suresh Kumar, K. (2007). Seaweeds as a human diet: An emerging trend in the new Millennium. In Advances in Applied Phycology, R. K. Gupta and V. D. Pandey (Eds), Daya Publishing House, New Delhi. Pp 85-96.

Rao, P.V.S, Rao R.K., Nair, M.R.P, and K. Subbrangaiah (1983).A systematic list of marine algae from Andhra Pradesh and their distribution. In Marine plants. Seaweed Research and Utilization Association. Madras. pp. 29-34.

Rao, U.M, (1970). The economic seaweeds of India. Bulletin of CMFRI, 20: 1–68.

Rao, U.M. and Sreeramulu, T., (1963). Vertical zonation and seasonal variation in the growth of *Porphyra* on Visakhapatnam coast. Current Science. 32: 173-174.

Rao, U.M. and Sreeramulu, T., (1964). An ecological study of some intertidal algae of the Visakhapatnam coast Journal of Ecology 52: 595-616.

Rao, U.M. and Sreeramulu, T., (1969). *Liagora visakhapatnamensis*, a new species from India. Hydrobiologia 33: 201-208.

Rao, U.M., (1978). Seaweed resources of Andhra Pradesh. Seaweed Resources Utilization 3 (1): 51–55.

Redekar, P. D. and Raje, P. C. (2000). Alginic acid and agar agar content from the common seaweeds of Ratnagiri Coast (West Coast of India). Seaweed Research & Utilization, 22: 41–3

Rupapara, K. V., Vyas K. G., and Joshi N. H., (2017). Nutritive Properties of the Chorophyceae Seaweeds available at Gulf of Kutch, Gujarat, India. Indian Journal of Pure & Applied Biosciences, 5 (4): 174-179.

Sahoo, D., (2000). Farming the Ocean–Seaweeds Cultivation and Utilization. Aravali Books International (P.) Ltd., New Delhi. pp. 44.

Sarojini, Y and Subbarangaiah, G. (1999). Seasonal variation in biochemical composition of some macroalgae along Visakhapatnam, east coast of India.Phykos, 38(1&2):71-79.

Sarojini, Y., and Lakshminarayana, K. (2009). Seaweed Research and Utilization, 31: 127 – 134.

Sarojini, Y., and Sujatha, B. (2015).Quantitative analysis of photosynthetic pigments in five species belonging to Rhodophyceae and the effect of environmental variables on their distribution. Der Pharmacia Lettre, 7(7):97-101.

Sarojini, Y., and Uma Devi, K. (2014). The marine macro algae as potential source of nutritionally important polyunsaturated fatty acids. Der Pharmacia Lettre, 2014, 6 (6):348-351

Satya Rao, K., Prayaga Murty, P., and Narasimha Rao, G.M. (2011). Seasonal studies on marine algae of the Bhimili coast, East coast of India. Seaweed Research & Utilization 2(2): 69–82.

Selim, S., (2012). Antimicrobial, Antiplasmid and Cytotoxicity Potentials of Marine Algae *Halimeda opuntia* and *Sarconema filiforme* collected from Red Sea Coast. International Journal of Marine and Environmental Science, 6(1): 24-29.

Senthilkumar, P., and Sudha, S. (2012). Antioxidant and Antibacterial Properties of Methanolic Extract of Green Seaweed *Chaetomorpha linum* From Gulf of Mannar: Southeast Coast of India. Jundishapur Journal of Microbiology, 5(2), 411–415.

Sethi, S. K. and Adhikary, S. P. (2009). Effect of region specific *Rhizobium* in combination with seaweed liquid fertilizer on vegetative growth and yield of *Arachis hypogea* and *Vigna mungo*. Seaweed Research and Utilization. 31: 1-8

Shankaraswamy, J and Neelavathi, R. 2016. Effect of growth regulators, nutrients, seaweed extract and pruning on induction of early flowering in mango (*Mangifera indica*) cv. Kesar. The Indian Journal of Agricultural Sciences, 86, (9): 1175-1178.

Shanmughapriya, S., Manilal, A., Sujith, S., Selvin, J., Kiran, G.S., and Nataraja, K., (2008). Antimicrobial activity of seaweeds extracts against multi-resistant pathogens. Annals of Microbiology58 (3): 535–541.

Shyamala, V., Ebciba, C., Santhiya, R., and Nallamuthu, T., (2014). Phytochemical Screening and In Vitro Antibacterial,Antioxidant and Anticancer Activity of *Amphiroa Fragilissima* (Linneaus) J V Lamoroux. International Journal of Innovative Research in Science, Engineering and Technology (3(5): 12933- 12948.

Shynu, S. P., S. Shibu and V. Jayaprakash. (2013). The economically valuable seaweeds of Thirumullavaram, south west coast of Kerala. Journal of Aquatic Biology & Fisheries, 2 (1): 133- 237.

Silva, P.C., P.W. Basson and R. L. Moe, (1996). Catalogue of the Benthic Marine Algae of the Indian Ocean. University of California press, London. 1259 p.

Sobha, V., S. Santhosh, G. Ghita and E. Valsalakumar (2008). Food products from seaweeds of south Kerala coast. Seaweed Research and Utilisation, 30 (1&2): 199-203.

Soriano, E.M., Fonseca, P.C., Carneiro M.M.A., Moreira, W.S.C. (2006). Seasonal variation in the chemical composition of two tropical seaweeds. Bioresource Technology 97: 2402–2406.

Sreeramulu, T., (1952). On a *Porphyra* from Waltair Coast. Sci. CuZt. 18: 285-286.

Sreeramulu, T., (1953). A *Codium* from the Coromandel Coast. J. Indian bat. Sac. 32: 67-69.

Sridhar, S. and Ramasamy R., (2010). Significance of seaweed liquid fertilizer for minimizing chemical fertilizers and improving yield of *Arachis hypogaea* under field trial. Recent Research and Science Technology 2: 73-80.

Srinivasan, K.S., (1969). Phycologia Indica (Icones of Indian Marine Algae) Vol. I. Botanical Survey of India, Calcutta.

Srinivasan, K.S., (1973). Phycologia Indica (Icones of Indian Marine Algae) Vol. II. Botanical Survey of India, Calcutta.

Sumathi, S., Krishnaveni, Marimuthu. (2012). Preliminary Screening, Antioxidant and Antimicrobial potential of *Chaetomorpha antennina* and *Caulerapa scalpelliformis* invitro study. International journal of environmental sciences. 2: 2319 - 2327.

Taskin, E., Ozturk, M., Taskin, E., Kurt, O. (2007). Anti-bacterial activities of some marine algae from the Aegean Sea (Turkey). African Journal of Biotechnology, 6(24): 2746-2751.

Thevanthan, R., Rajarajan, R. and Bhavani, I. L. G., (2005). Liquid fertilizer preparation of marine macroalgae to enhance the yield and quality of tea. Seaweed Research and Utilization. 27: 117-123.

Thomas, P. C., (1977). Seasonal variation in the yield and physical properties of agar-agar from *Gracilaria verrucosa* (Hudson) Papenfuss. Seaweed Resources Utilisation 2 (2): 78–81.

Tiwari, B.K., and Troy, D.J. (2015). Seaweed Sustainability - Food and Non-Food Applications. in Tiwari, B.K., Troy, D.J., Eds.; Elsevier Inc.: NewYork, NY, USA.

Tüney Kızılkaya, Inci & Unal, Dilek & Sukatar, Atakan & Cadirci, Bilge. (2006). Antimicrobial Activities of the Extracts of Marine Algae from the Coast of Urla (‹zmir, Turkey). Turkish Journal of Biology. 30. 171-175.

Uthirapandi, V., Suriya, S., Boomibalagan,P., Eswaran, S., Ramya, S.S., Vijayan, N., and Kathiresan, D., (2018). Bio fertilizer potential of seaweed liquid extracts of marine macro algae on growth and biochemical parameters of *Ocimum sanctum.* Journal of Pharmacognosy and Phytochemistry, 7(3): 3528-3532.

Vallinayagam, K., Arumugam, R., Kannan, R.R., Thirumaran, G. and Anantharaman, P., (2009). Antibacterial activity of some selected seaweeds from Pudumadam coastal regions. Global Journal of Pharmacology, 3(1): 50-52.

Vimalabai, P.M.C., Sudhadevarani, S., and Nalina Devi, R., (2003). Carbohydrate and vitamin-C contents of some macroalgae of Tuticorin,Southeast coast of India. Seaweed Research and Utilization, 25(1): 47-53.

Vinayak, R.C., A.S. Sabu and A. Chatterji. (2011). Bioprospecting of a few brown seaweed for their cytotoxic and antioxidant activities. Evidence-Based Complementary and Alternative Medicine, 2011: 1-9.

Sowjanya, V.I., and Sekhar, R.P.S., (2015). A comparative study of seaweed flora over a period of time with reference to climate change in Visakhapatnam Coast, Andhra Pradesh, India. Advances in Applied Science Research, 6(6):187-193.

Xavier, G., Anthony, S., and Jesudass, L. L., (2007). Effect of seaweed extract on cluster bean. Seaweed Research and Utilization 29: 85-87.

Yadav, S.K. (2020). Medicinal prospective of seaweed resources in India: A review. Journal of Pharmacognosy and Phytochemistry 2020; 9(6): 1384-1390.

Yadav, S.K., Palanisamy, M., and Murthy, G. V. S., (2015). Economically Important Seaweeds of Kerala coast, India – A Review. Elixir Biosciences 82: 32147-32153.

Yan, X., Wang, W., Zhang, L., Zhao, Y., Xing, D., and Du, L., (2007). A high-performance liquid chromatography with UV-vis detection method for the determination of Brazilein in plant extract. Journal of chromatographic science, 45(4): 212-215.

Yaphe, W., (1984). Properties of *Gracilaria* agars. Hydrobiologia 116:171–174.

Yu, K.X., Wong, C.L.,Ahmad, R., and Jantan, I. (2015). Mosquitocidal and Oviposition Repellent Activities of the Extracts of Seaweed *Bryopsis pennata* on *Aedes aegypti* and *Aedes albopictus*. Molecules (Basel, Switzerland).20(8): 14082-102.