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Review Paper

Seaweeds: Are these weeds or resources?

Sudhir Kumar Yadav

Botanical Survey of India, CGO Complex, Kolkata, West Bengal, India

Corresponding author: skyadavbsic@gmail.com (**ORCID ID:** 0000-0003-2812-3347)

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ABSTRACT

The term '*Seaweed*' consists of two words *i.e. Sea* and *Weeds,* and literally means any weed-like organisms found in the seas. Taxonomically, it includes marine macroalgae, which grow exclusively in marine habitats and estuaries. The word '*Seaweed*' is a misnomer, and should not be considered a *weed* at all, rather, it is one of the potential marine living resources in the world. Seaweeds constitute one of the important components of the marine flora, along with other microalgae, mangroves, and seagrasses, and play an essential role in the marine ecological food chains, oxygen enrichment, carbon sequestration, detoxification, and climate change mitigation. Besides, it has high economic potential in food, fodders and various industrial sectors. Worldwide, about 11,000 seaweeds are reported, among which about 221 are documented as economically important and crucial in various forms. Therefore, the term *seaweed* should not be considered as *weed*, rather alternatively termed as '*Sea-plants*' or *'Marine plants'*. However, because of the popularity of the term, the name *seaweed* is more relevant and considered as an important marine natural resource. The present article briefly deals with the general introductory and economic aspects of the seaweeds.

HIGHLIGHTS

- Seaweeds are the marine macro algae, one of the essential components of marine flora and biodiversity.
- It plays an important role in the marine ecological food chains, oxygen enrichment, carbon sequestration, detoxification, and climate change mitigation.
- It is one of the potential marine living resources which need to be explored, documented, and utilized sustainably for the welfare of the humanity.

Keywords: Seaweeds, Chlorophyceae, Phaeophyceae, Rhodophyceae, Resources, Marine

The term '*Seaweed*' is a combination of two words *i.e. Sea* and *Weeds*, and literally means *any weed like organisms that grow in the seas*. Taxonomically, it refers to the *marine macroalgae* which grow exclusively in the marine habitats and estuaries regions of the world. A weed is usually defined as any unwanted plant that grows profusely at any place and time. The word '*Seaweed*' is a misnomer, and should not be considered a *weed* at all, instead it is one of the potential marine living resources in the world and maybe alternatively termed as '*Sea-plant*' or *Sea-vegetable*' (Bast, 2014). These plants are adapted to grow exclusively in marine ecosystems on rocks, coralline beds, reefs, pebbles, shells, and dead corals and as epiphytes on other plants such as seagrasses in the shallow intertidal sub-tidal and deep sea areas. In the plant kingdom, morphologically, it shows a wide range of variations, starting from smaller algae like *Centroceras, Polysiphonia* etc. to the giant kelp algae like *Sargassum, Fucus* etc. Taxonomically, seaweeds are classified into three groups, *viz.* Chlorophyceae (green algae), Phaeophyceae or Heterokontophyceae (brown algae), and Rhodophyceae (red algae), based

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upon the photosynthetic pigments, colors, and reserve food materials (Fig. 1,2,3).

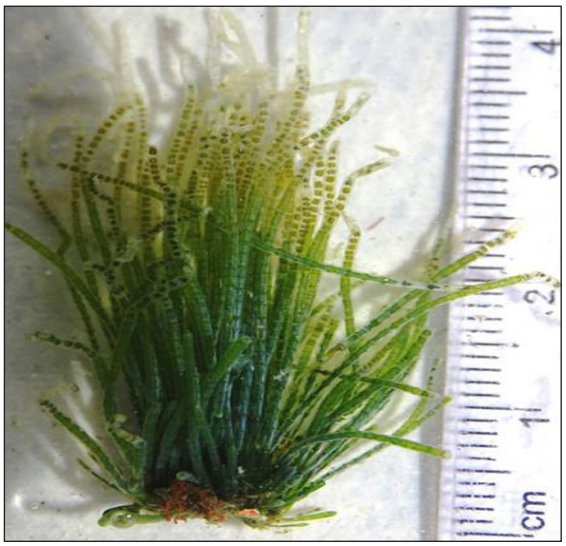

Fig. 1: *Chaetomorpha antennina* (Bory) Kuetz. - a green seaweed

Fig. 2: *Padina tetrastromatica* Hauck - a brown seaweed

Fig. 3: *Centroceras clavulatum* (*C. Agardh*) Mont. - red seaweed

The kelp forests, primarily dominated by a dense growth of large-size brown seaweeds like *Sargassum, Fucus, Macrocystis* etc., under the marine ecosystems, are highly productive marine habitats and provide multiple ecological, economic, and cultural ecosystem services (Steneck and Johnson, 2014). As seaweeds grow in harsh saline environment, they develop many protective secondary metabolites and mechanisms to survive and adapt in such situations. Besides, it possesses many bioactive compounds such as proteins, peptides, fatty acids, antioxidants, vitamins, and minerals, which exhibit a variety of therapeutic and economic potential potentials. Therefore, considering the importance of these bioresources, *life below water* is recognized as one of the critical components under the Sustainable Development Goals (SDG) of the United Nations.

Glimpses of seaweeds diversity

Globally, about 72,500 algae have been estimated to occur, of which about 45,000 algae have been reported (Guiry, 2012). Among these, seaweeds or marine macroalgae constitute about 11,000 taxa of seaweeds, which include *c.* 7,200 taxa of Rhodophyceae, 2,000 taxa of Phaeophyceae, and 1,800 taxa of Chlorophyceae (http://www.seaweed.ie). India, being a peninsular country, is endowed with a coastline of about 7500 km in length and an Exclusive Economic Zone (EEZ) of about 2.5 million sq km. The perusal of the literature reveals that the first seaweed that had been, perhaps, described from the Indian Ocean was a specimen of *Amphiroa* (Rhodophyta) collected by Hermann in 1672 (Sahoo *et al.* 2001). With diverse habitats, the Indian coastline support about 865 taxa of seaweeds (Table 1), comprising 442 taxa of Rhodophyceae under 151 genera, 212 taxa of Chlorophyceae under 46 genera, and 211 taxa of Phaeophyceae under 50 genera (Rao and Gupta, 2015).

Table 1: Seaweed diversity

Class	No. of taxa in the World	No. of taxa in India
Chlorophyceae	1800	212
Phaeophyceae	2000	211
Rhodophyceae	7200	442
Total	**11000**	**865**

Besides, the Indian coast also supports about 125 taxa of seaweeds, which are possibly endemic (Oza and Zaidi, 2001). Although the seaweed resources of many parts of the country are explored well, there are many areas, such as the Islands of Andaman & Nicobar and the Lakshadweep Islands which are unexplored or sporadically explored. Therefore, the diversity of seaweed resources may fluctuate accordingly.

Seaweeds as resources

Worldwide, more than 42 countries in the world, particularly the south East Asian countries like China, North Korea, South Korea, Japan, Philippines, Chile, Norway, Indonesia, USA etc. are actively involved in the commercial utilization of seaweed resources. About 4, 00,000 tonnes of seaweeds such as *Porphyra* (for Nori), *Laminaria* (for Kombu), Undaria (for Wakame) are cultivated and harvested annually throughout the world (Braune and Guiry, 2011). Globally, about 221 taxa of seaweeds are recognized as economically significant, of which about 45 taxa are for food and 110 taxa for phycocolloid production (Chennubhotla, 1977; Chennubhotla *et al*. 2013; Nedumaran and Arulbalachandran, 2014). Many edible seaweeds are the potential source of bioactive metabolites and nutraceuticals, vitamins, and minerals such as Calcium, Potassium, Magnesium, Iron etc., and its integration into the regular diet may boost immunity against several diseases, including COVID-19, through multiple mechanisms (Choudhary *et al.* 2021; Tamama 2021). Besides, seaweeds and other marine flora play an essential role in global carbon sequestration from the atmosphere and mitigation of the impact of climate change and global warming (Mashoreng *et al.* 2019). Seaweed cultivation is a -negative crop with a high potential in climate change mitigation (Duarte *et al*. 2017). It is estimated that roughly half of the oxygen production on Earth comes from the ocean (https://oceanservice.noaa.gov).

Economically, seaweeds are one of the most important marine natural resources and have been used by human beings in various forms, such as food and fodder, as early as 2500 years ago (Tseng, 2004). However, in recent times, it has been getting considerable attention because of its cosmopolitan distribution, renewable nature, and wide range of applications (Ganesan *et al*. 2019; Mantri *et al*. 2020). In India, the attention on algal research got momentum only during the end of 19th century by Prof. M.O.P. Iyengar (1886–1966), *the father of Indian Algology*. Later, for the economic aspects of seaweeds, Thivy (1960) made the first attempt to study the distribution of a few economically essential seaweeds. Thereafter, many researchers made significant contributions and reported on various aspects of seaweeds from different parts of the Indian coast. The perusal of the literature reveals that among the 865 taxa of seaweeds reported from India, about 94 taxa are recognized with economic potential in various forms like food, fodder, pharmaceuticals, nutraceuticals, and raw materials in various industries (Yadav *et al.* 2015; Yadav, 2020). The edible seaweeds are mainly served in *recipes, salads, soups, jellies* and *vinegar dishes*. They mainly belong to the members of chlorophyceae such as *Ulva, Cladophora, Brypsis, Caulerpa,* etc. Similarly, many species of seaweeds are a rich source of macronutrients, particularly dietary fiber, and micronutrients, and are used to enhance the nutritional quality of animal feed (Michalak and Mahrose, 2020). The common seaweeds which are used as fodder are *Monostroma, Ulva, Cladophora, Bryopsis, Caulerpa, Dictyopteris, Padina, Sargassum, etc.* Besides, seaweeds are the natural sources of raw materials for many industries. Phycocolloides, a colloid-like gelatinous substance, is extracted from the red and brown seaweeds. The three essential phycocolloides are *agar-agar*, *alginates,* and *carrageenans*, widely used in biochemical laboratories and industries. Agar, Agarose, and Carrageenan are mainly extracted from red seaweeds like *Gelidium, Gelidiella, Gracilaria,* etc., whereas *Alginate,* also known as *Algin* or *Alginic acid,* is extracted from the brown seaweeds *Sargassum, Turbinaria, Cystoceira, Dictyota, Padina, Hormophysa, Colpomenia, Spatoglossum, Stoechospermum* etc. (Anantharaman and Balasubramanian, 2010). *Kappaphycus alvarezii*, another important red seaweed, is an important source of *Kappa-Carrageenan* and biodiesel. It is also popularly known as '*Pepsi Paasi*' (*Pepsi Seaweed*) in the Mandapam regions of Tamil Nadu, where it is being cultivated by PepsiCo Holdings India Pvt. Ltd (Bast, 2014). Many species of seaweeds, such as *Dictyopteris, Padina, Sargassum* etc., are used as biofertilizers in the form of Seaweed Liquid Fertilizers (SLF). Therefore, seaweeds are a potential marine resource (Table 2).

Table 2: Seaweed as resources

Ecological importance:
• *Acts as primary producers in the food chain.*
• *Provide breeding ground and shelter for many aquatic fauna.*
• *Maintains oxygen level (DO) in the aquatic ecosystems.*
• *The Kelp forests in the ocean are very productive and act as underwater nurseries for marine fauna.*
• *Carbon Sequestration*
• *Heavy metals and toxicity removal by trapping*
• *Acts as bio indicators in the aquatic ecosystems*
Economical importance:
• *Globally, about 221 taxa of seaweeds are recognized with economic potential.*
• ***Food:** About 145 taxa of seaweeds (mostly green seaweeds like Ulva, Cladophora, Brypsis, Caulerpa etc.) are edible and used in the form of recipes, salads, soups, jellies and vinegar dishes etc.*
• *Natural source of bioactive metabolites and nutraceuticals, vitamins and minerals such as Calcium, Potassium, Magnesium, Iron etc.*
• ***Fodder:** The commonly used seaweeds as fodder are Monostroma, Ulva, Cladophora, Bryopsis, Caulerpa, Dictyopteris, Padina, Sargassum etc.*
• *Phycocolloid: A gelatinous substance extracted from the red and brown seaweeds.*
• *Agar-agar, Alginates and Carrageenans are the common phycocolloid with great biochemical and industries importance.*
• *Agar, Agarose and Carrageenan are mainly extracted from the red seaweeds like Gelidium, Gelidiella, Gracilaria etc.*
• *Alginate (Algin or Alginic acid) is extracted from the brown seaweeds like Sargassum, Turbinaria, Cystoceira, Dictyota, Padina, Hormophysa, Colpomenia, Spatoglossum, Stoechospermum etc.*
Climate Change mitigation:
• *Carbon Sequestration*
• *Heavy metals and toxicity removal by trapping*
Bio fuel production
Bio fertilizers / Seaweed Liquid Fertilizers (SLF)

CONCLUSION

Seaweeds are not weeds but rather one of the potential marine living resources and an integral part of our biodiversity. It plays a vital role in the sustainability of marine ecosystems, oxygen enrichment, carbon sequestration, detoxification, and climate change mitigation on the one hand. On the other hand, it is endowed with many economical values such as food, fodder, and in industries. India, being a peninsular country, has a rich diversity of seaweeds, which need to be explored well, documented, and utilized sustainably in the line of *green economy* for the welfare of humankind.

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