



Mangrove associated seaweeds in Sundarban Biosphere Reserve, West Bengal, India

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Abstract

Seaweeds refer to the marine macro algae and constitute an important component of the marine biodiversity. The Sundarban Biosphere Reserves is one of the renowned mangrove forests and a UNESCO heritage site in the Bay of Bengal. The present paper deals with a preliminary study on marine macro algae found in association with mangroves in the Sundarban mangrove area. During the present survey, eight species of seaweeds, comprising of six species under Chlorophyceae and two species under Rhodophyceae have been documented and described in detail.

Keywords: Marine Biodiversity, Seaweeds, Sundarban, Taxonomy.

Introduction

India, with a coastline of *c.* 7500 km length, is endowed with a variety of coastal habitats that support significant coastal plant diversity including marine algae (seaweeds, microbes), seagrasses and mangroves. The marine macro algae are popularly known as *seaweeds*. However, it should not be considered as ‘weed’, rather it is one of the important components of the marine biodiversity and plays an important role as primary producer in the marine food chains and sustainability of the marine ecosystems. It usually grows on rocks, pebbles, dead corals, mollusc shells, coastal wastes like ropes, nets, and also on mangroves and other plants as epiphytes in the shallow, intertidal and sub-tidal zones of the marine ecosystems.

The conservation of biodiversity is a matter of global concern and therefore, its proper exploration and documentation from all the possible habitats, whether

terrestrial or aquatic, are prerequisite for effective conservation. The perusal of literature pertaining to the marine macro algal diversity of the Indian coast reveals that the diversity of seaweeds in West Bengal coast is very less as compared to the southern parts of the Indian coastlines. Among the Indian maritime states, Tamil Nadu coast shows the highest diversity of seaweeds with 282 species (Anon., 2012; Ganesan & al., 2019), followed by Maharashtra with 240 species (Piwalatkar, 2010), Gujarat with 198 species (Jha & al., 2009), Kerala with 147 taxa (Palanisamy & Yadav, 2015), Karnataka with 105 taxa (Yadav & Palanisamy, 2020), Goa with 90 taxa of seaweeds (Palanisamy & Yadav, 2019), Andaman & Nicobar islands with 80 species (Muthuvelan & al., 2001), Diu island with 70 species (Mantri & Rao, 2005), Andhra Pradesh with 65 species (Anon., 1984) and Odisha with 14 species (Sahoo & al., 2003). This may be because of the lack of availability of suitable rocky substrata, because seaweeds are mostly lithophilic in nature, and proper nutrition along with other reasons.

The coastline of West Bengal is c. 220 km long and located in the northern part of the east coast of India in the Bay of Bengal (Figure 1). The study of literature shows that there are many reports sporadically available on the algal diversity of west Bengal coast by various researchers (Naskar & Santra, 1985; Santra & Pal, 1988; Pal & al., 1988; Chattopadhyay & al., 1995; Pal, 2000; Naskar & al., 2000; Mukhopadhyay & Pal, 2002; Sen & Naskar, 2003; Saptati & al., 2012; Sengupta & Pal, 2016; Yadav & Majumdar, 2020; Yadav & al., 2020). Sen & al. (2003) reported few new reports on benthic algae from the Sundarban mangrove forest. Chakraborty & Santra (2008) studied the biochemical composition of eight species of

benthic algae from Sundarban regions. Satpati & al.(2012) reported 9 taxa of marine macro algae, including two species of Chlorophyceae and seven species of Rhodophyceae from the Sundarban Mangrove forest. Recently, Sengupta & Pal, 2016 reported 3 taxa of seaweeds from the Sundarbans and studied its nutrient remediation potential. In the present paper, we have attempted to provide updated information on the diversity and distribution of seaweeds, found growing mainly in association with mangroves in the Indian Sundarban region, along with description, based on the survey and study of fresh collection of algae and the scrutiny of relevant literature.

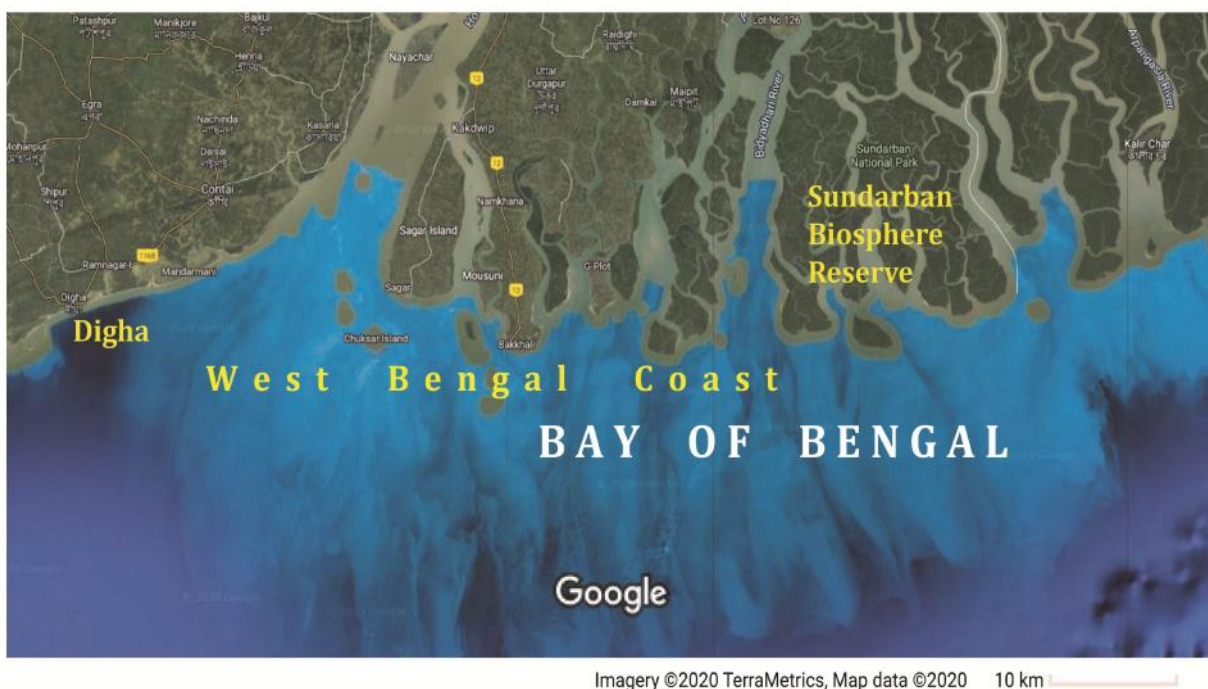


Fig. 1: Map of west Bengal coastline showing the location of Sundarban Biosphere Reserve.

Materials and Methods

Area of study

The present study has been done in the Sundarban Biosphere Reserve (SBR), which is one of the world's renowned mangrove sites (Figure 2). It supports 34 species of true mangroves and 40 mangrove associated plant species (Chakraborty, 2011). Because of the unique ecosystem and support to the biodiversity, Sundarban area was declared as UNESCO heritage site in the year 1987 and as a Biosphere Reserve by the Government of India in the year 1989 and was included in the global network of Biosphere Reserves

under MAB program in 2001. Spreading in over 10,200 sq km of area of Mangrove Forest, c. 4200 sq km falls in India while c. 6000 sq km is in Bangladesh. It is the world's largest delta, formed by the rivers of the Ganges, Brahmaputra, Meghna and many other rivers, and situated on the lower end of the Ganges in the Bay of Bengal (Satpati & al., 2012).

Field exploration and collection of seaweeds

For study and collection of fresh seaweed samples, a field exploration was undertaken to four different islands in the Sundarban Biosphere Reserve during the low tides in the month of January, 2020.



Fig. 2: A panoramic view of mangrove forest in Sundarban Biosphere Reserve.

With the approval of the SBR authority and the help of local guides, the authors visited various algal sites and collected fresh algal samples from various possible algal habitats in the mangrove forests. The seaweeds were found growing on various parts of the mangroves like pneumatophores, barks, branches (Figure 3 and 4) and decayed wooden pieces (Yadav & al., 2020). The seaweed samples were collected carefully from all these possible substrata. While making collection, important field details such as habit, habitats, nature of the field and its GPS position (using GARMIN 12 channel XL), and vegetation patterns etc. were recorded and photographed using digital camera (Nikon COOLPIX L120).

Preservation of seaweed samples

The collected seaweed samples were first washed cautiously and kept in the plastic containers and zipped covers. The washed samples were poisoned in 4% Formalin and 1% Ethyl Alcohol. The poisoned samples were carefully preserved in wet form while few of them were also preserved in dry form *i.e.* in the form of herbarium specimens ((Figure 3, G-H), following the standard herbarium techniques (Srinivasan, 1969; Dhargalkar & Kavlekar, 2004). All the collected samples were assigned with particular field numbers.

Identification of seaweeds

The processed samples were examined carefully and identified following the field observation and standard references such as *Phycologia Indica: The Icons of Indian Seaweeds* (Srinivasan 1969, 1973); *Rhodophyta* (Desikachary & al., 1990, 1998); *Catalogue of the Benthic Marine Algae of the Indian Ocean* (Silva & al., 1996); Krishnamurthy, 2000; Kraft, 2007 and other online resources such as Algaebase, (<http://www.algaebase.org>), WoRMS (<http://www.marinespecies.org>) and Macroalgal Herbarium Portal (<http://macroalgae.org>). All these preserved samples are deposited at the Central National Herbarium (CAL), Botanical Survey of India, Howrah, India.



Fig. 3: **Seaweed habitats:** **A.** Dense mangroves forest serving as habitats for seaweeds growth; **B-E.** Stems and roots of mangroves supporting as substrata for seaweeds; **F.** *Ulva compressa* L. growing on a small scattered rock; **G-H.** Preservation of seaweed specimens (wet form); **I.** A herbarium specimen (dry form).

Results and Discussion

During the present study, eight species of seaweeds, comprising of six species under Chlorophyceae and two species under Rhodophyceae were recorded, which are described taxonomically with specific notes.

Class: Chlorophyceae

Family: Ulvaceae

This family is represented by 13 genera in world (Guiry, 2020) and 2 genera in India i.e. *Enteromorpha* and *Ulva* (Rao & Gupta, 2015). Hayden & al (2003) published a molecular account of these two genera and opined that *Enteromorpha* and *Ulva* are paraphyletic in origin and thus, synonymised the genus *Enteromorpha* under *Ulva*. Therefore, as referred in most of the recent literature, only genus *Ulva* has been treated here under this family.

Ulva L.

1. *Ulva clathrata* (Roth) C. Agardh, Disp. Alg. 2: 23. 1811; P.S.N. Rao & R.K. Gupta, Algae India 3: 2. 2015. *Enteromorpha clathrata* (Roth) Grev., Alg. Brit. 16: 181. 1830; V. Krishnam., Alg. India Neighb. Countr. Chlorophycota 1: 89. 2000. *Conferva clathrata* Roth, Cat. Bot. Fasc. 3: 175. 1806.

Type locality: Fehmarn, SW Baltic.

Thallus light green in colour, 2-3 cm long (in young stage), tubular in nature, hair like, profusely branched. Holdfast minute, discoid, firmly attached on substrata. Stipe tubular, minute, indistinct. Fronds hairy, tubular, 0.3-2 mm in diameter, apex obtuse or acute. Microscopic: Cells in surface view elongate, irregularly arranged, 18-36 × 8-15 µm, thin walled; cells in cross section squarish, 7-15 µm across.

Specimens examined: West Bengal: Sundarban BR, 12.01.2020, S.K. Yadav & K. Majumdar 91113, 91115 (CAL).

Distribution: INDIA: Andaman & Nicobar Islands, Goa, Gujarat, Kerala, Karnataka, Lakshadweep Islands, Maharashtra, Tamil Nadu and West Bengal.

2. *Ulva compressa* L., Sp. Pl. 2: 1163. 1753; P.S.N. Rao & R.K. Gupta, Algae India 3: 2. 2015. *Enteromorpha compressa* (L.) Nees, Horae Phys. Berol. Index 2: 123. 1820; P.C. Silva & al., Cat. Benth. Mar. Alg. Ind. Ocean: 729. 1996; V.

Krishnam., Alg. India Neighb. Countr. Chlorophycota 1: 90. 2000; Yadav & Majumdar in *J. Algal Biomass Utiln.* 11(1): 29. 2020.

Type locality: Europe (probably Bognor, Sussex, England).

Thallus light green in colour, 2-6 cm long (young stage), tabular- compressed. Holdfast small, discoid, loosely attached on substrata. Fronds compressed below and gradually expanded above, 2-6 cm long and 0.2-4 mm wide, surface smooth, apex obtuse. Microscopic: Cells in surface view squarish-elongate or irregular, 10-30 µm across, irregularly arranged, cell wall thin; cells in cross section 10-26 × 8-4 µm, sheath up to 2 µm thick. (Figure 3, F)

Notes: This is one of the edible seaweeds and used as *salad, soup* etc. in many parts of the world (Jha & al. 2009). Therapeutically, it exhibits *anti allergic* properties (Venkataraman & al., 2004).

Specimens examined: West Bengal: Sundarban BR, 11.01.2020, S.K. Yadav & K. Majumdar 91101 (CAL); 12.01.2020, S.K. Yadav & K. Majumdar 91110 (CAL).

Distribution: INDIA: Andaman & Nicobar Islands, Andhra Pradesh, Goa, Gujarat, Kerala, Karnataka, Lakshadweep Islands, Maharashtra, Odisha, Tamil Nadu and West Bengal.

3. *Ulva lactuca* L., Sp. Pl. 2: 1163. 1753; Satpati & al. in *J. Algal Biomass Utiln.* 3(4): 47. 2012; P.S.N. Rao & R.K. Gupta, Algae India 3: 3. 2015; Hughey & al. in *J. Phycol.* 55 :503. 2019. *Ulva fasciata* Delile, Fl. Egypt. Expl. Pl. 2: 297, Pl. 58. Fig. 5. 1813; P.C. Silva & al., Cat. Benth. Mar. Alg. Ind. Ocean: 743. 1996; P.S.N. Rao & R.K. Gupta, Algae India 3: 3. 2015.

Type locality: In Oceano" [Atlantic Ocean].

Thallus light-dark green in colour, 1-5 cm long (young stage), foliose. Holdfast rhizoidal, minute, loosely attached on substrata. Fronds foliaceous, compressed below and flattened upward, blades 2-4 × 0.5-1 cm, surface smooth, membranous; margins entire - undulate; apex acute to obtuse. Microscopic: Cells in surface view polygonal-squarish, 8-16µm across; in cross section thallus surface 60-110 µm thick; cells palisade like, distromatic, compactly arranged, 28-40 × 6-12µm. (Figure 4, A)



Fig. 4: **Seaweeds in Sundarban BR:** **A.** *Ulva lactuca* L. (young stage); **B.** *Ulva flexuosa* Wulfen; **C.** Dense growth of *Catenella* on mangroves stems; **D.** *Catenella caespitosa* (With.) L. Irvine; **E.** *Catenella nipae* Zanardini.

Notes: In most of the literature *Ulva lactuca* and *U. fasciata* have been treated separately as two distinct taxa. However, based on the molecular studies and genetic analysis *U. fasciata* have been synonymised recently under *U. lactuca* (Hughes & al., 2019). This is one of the common seaweeds along the Indian coast and usually found growing luxuriantly during the monsoon and post-monsoon seasons.

It has high economical potential as it as an edible alga and used in the form of salad and soups in some parts of the world and also in aquaculture and poultry industry (Jha & al. 2009).

Specimens examined: West Bengal: Sundarban BR, 11.01.2020, S.K. Yadav & K. Majumdar 91103 (CAL); 12.01.2020, S.K. Yadav & K. Majumdar 91117 (CAL).

Distribution: INDIA: Andaman & Nicobar Islands, Andhra Pradesh, Goa, Gujarat, Kerala, Karnataka, Lakshadweep Islands, Maharashtra, Puducherry, Tamil Nadu and West Bengal.

4. *Ulva flexuosa* Wulfen, Crypt. Aquat. 3:1. 1803. *Enteromorpha flexuosa* (Wulfen) J. Agardh, Algern. Syst. 3: 126. 1883; P.S.N. Rao & R.K. Gupta, Algae India 3: 1. 2015; Yadav & Majumdar in *J. Algal Biomass Utiln.* 11(1): 29. 2020.

Type locality: Diuno, near Triestle, Italy. (Plate 2: 3)

Thallus light green in colour, 3-20 cm long, tubular, flexuous in nature. Holdfast minute, discoid, firmly attached on substrata. Stipe tubular, indistinct. Fronds tubular to slightly flat and gradually becoming flexuous upward, 2-15 cm long and 0.2-6 mm wide; margins entire, apex obtuse to round. *Microscopic:* Cells in surface view polygonal to rectangular, 8-22µm across, irregularly arranged; in cross section thallus 15-20µm thick, cells usually rectangular, 14-25 × 12-20 µm wide. (Figure 4, B)

Notes: This is one of the common seaweeds and grows luxuriantly in the estuary regions during the monsoon and post monsoon seasons. Besides, it is an economically important seaweed, contains nourishing agents such as polysaturated fatty acids, minerals, vitamins, antioxidants and proteins and thus, used as food in Japan and other countries (Jha & al., 2009).

Specimens examined: West Bengal: Sundarban BR, 12.01.2020, S.K. Yadav & K. Majumdar 91109, 91112, 91118 (CAL).

Distribution: INDIA: Andaman & Nicobar Islands, Andhra Pradesh, Goa, Gujarat, Kerala, Karnataka, Lakshadweep Islands, Maharashtra, Odisha, Tamil Nadu and West Bengal.

5. *Ulva prolifera* O.F. Muell., Fl. Danica, 5: 7, Pl. DCCLXIII (763): fig. 1. 1778; P.S.N. Rao & R.K. Gupta, Algae India 3: 3. 2015. *Enteromorpha prolifera* (O.F. Muell.) J. Agardh, Algern. Syst. 3: 129. 1883.

Type locality: Denmark.

Thallus light-dark green in colour, tubular, hairy, 3-15 cm long, proliferated. Holdfast minute, discoid, attached firmly on substrata. Stipe slender, small. Fronds tubular throughout, proliferated into several minute hairy branches. *Microscopic:* Cells in surface view usually polygonal in shape, thin walled, 6-15 µm across, linear - irregularly arranged.

Notes: This is one of the common green seaweeds and usually found growing abundantly during the monsoon and post monsoon seasons in the estuary regions. Economically, it is an edible seaweed, used in the form of soup and salad and also cultivated artificially in Japan and several other south east Asian countries (Jha & al., 2009).

Specimens examined: West Bengal: Sundarban BR, 11.01.2020, S.K. Yadav & K. Majumdar 91102, 91104 (CAL).

Distribution: INDIA: Andaman & Nicobar Islands, Andhra Pradesh, Gujarat, Kerala, Karnataka, Lakshadweep Islands, Maharashtra, Tamil Nadu and West Bengal.

Family: Cladophoraceae

This family is represented by 12 genera in the world (Algaebase, 2020) and 7 genera in India (Rao & Gupta, 2015). It is typically recognised by its distinct filamentous thallus with or without branches.

Chaetomorpha Kuetz.

6. *Chaetomorpha aerea* (Dillwyn) Kuetz. in Sp. Al., 379. 1849; Oza & Zaidi, Rev. Checkl. Ind. Mar. Alg.: 157. 2001; Sfriso & al. in *Crypt. Alg.* 39(3): 300. 2018. *Chaetomorpha crassa* (C. Agardh) Kuetz., Phycol. Germ. 204. 1845; P.S.N. Rao & R.K. Gupta, Algae India 3: 4. 2015; Yadav & Majumdar in *J. Algal Biomass Utiln.* 11(1): 31. 2020. *Conferva aerea* Dillwyn, Brit. Conferv. Fasc., 80. 1806.

Type locality: Cromer, Norfolk, England.

Thallus dark-light green in colour, 3-10 cm long, filamentous, unbranched, irregularly coiled into entangled mass. Holdfast discoid, free floating or loosely entangled with substrata. Fronds filamentous, tufted, divided into several nodes and internodes, irregularly coiled.

Notes: This species is usually found offshore or loosely entangled with other objects in the estuary regions. Therapeutically, it is known to have antioxidant properties (Gazali & al., 2019). In most of the Indian literature, *Chaetomorpha crassa* has been treated as a distinct taxon. However, now it is synonymised under *C. aerea* (Sfriso & al., 2018; Guiry, 2020).

Specimens examined: West Bengal: Sundarban BR, 12.01.2020, S.K. Yadav & K. Majumdar 91116 (CAL).

Distribution: INDIA: Gujarat, Goa, Kerala, Karnataka, Lakshadweep Islands, Maharashtra, Tamil Nadu and West Bengal.

Class: Rhodophyceae

Family: Caulacanthaceae

This family of red seaweeds is represented by 8 genera in the world (Algaebase, 2020) and 2 genera *i.e.* *Catenella* and *Caulacanthus* in India (Rao & Gupta, 2015). It is typically recognised by its pinkish to blackish red thallus, profusely branched and segmented into nodes and internodes. *Catenella* is usually found growing in the estuary regions (Yadav & al., 2018).

Catenella Grev.

7. *Catenella caespitosa* (With.) L. Irvine in Parke & P.S.Dixon in *J. Mar. Biol. Assoc. United Kingdom* 56: 590. 1976. Oza & Zaidi, *Rev. Checkl. Ind. Mar. Alg.*: 48. 2001; P.S.N. Rao & R.K. Gupta, *Algae India* 3: 48. 2015. *Ulva caespitosa* With., *Bot. Arr.* 735. 1776. *Catenella opuntia* (Gooden. & Woodw.) Grev. *Alg. Brit.* lxxiii, 166. 1830. *Catenella repens* (Lightf.) Batt., *J. Bot. (London)*. 40: 69. 1902; Satpati & al. in *J. Algal Biomass Utiln.* 3(4): 47. 2012.

Type locality: Side Rocks, Anglesey, Wales.

Thallus dark brownish - purple red in colour, foliose, 1-5 cm long, decumbent, attached by rhizoidal haptera. Holdfast fimbriate, firmly attached on substrata. Stipe small, indistinct. Fronds articulated, up to 4 cm long, profusely branched towards apex, branching regularly di-trichotomously towards tip, differentiated into nodes and internodes; internodal segments oblong to subcylindrical, 1-6 × 0.2-2 mm, apical segments slightly curved or sickle shaped, deeply constricted at nodes. *Microscopic:* Cells in surface view spherical-slightly elongate, 4-16 µm across. In cross section, thallus differentiated into outer cortical layer and central hollow or loosely medullary region.

(Figure 4, D)

Specimens examined: West Bengal: Sundarban BR, 12.01.2020, S.K. Yadav & K. Majumdar 91107 (CAL).

Distribution: INDIA: Goa, Gujarat, Maharashtra and West Bengal.

8. *Catenella nipae* Zanardini Mem. *R. Ist. Venet. Sci., Lett. ed Arti* 17: 143, pl. VI [6]: A, figs 1-7. 1872. Islam in *Bangladesh J. Bot.*, 2 (2): pl 5, fig 1-4. 1973; Sen & Naskar, 186, pl XXII, fig 139. 2003; P.S.N. Rao & R.K. Gupta, *Algae India* 3: 48. 2015; Satpati & al. in *J. Algal Biomass Utiln.* 3(4): 47. 2012.

Type locality: Sarawak, Borneo, Malaysia.

Thallus dark - brownish red in colour, foliose, fragile, 1-3 cm long, attached by minute rhizoidal haptera. Holdfast minute, fimbriate, loosely attached on substrata. Stipe small, indistinct. Fronds articulated, 0.8-2.5 cm long, sparsely branched below and profusely branched towards apex; branching irregularly di-trichotomously at tip, differentiated into nodes and internodes; internodal segments terete to slightly compressed, 1-4 × 0.1-3 mm, apical segments minute, dense, hairy, deeply constricted at nodes.

Microscopic: Cells in surface view usually spherical, 3-15 µm across. In cross section, thallus differentiated into outer cortical layer and central hollow medullary region. (Figure 4, E)

Specimens examined: West Bengal: Sundarban BR, 12.01.2020, S.K. Yadav & K. Majumdar 91108, (CAL).

Distribution: INDIA: West Bengal (Sundarban BR).

Conclusion

The Sundarban Biosphere Reserve (SBR) is the world's renowned mangrove forest and a UNESCO heritage site. The mangroves of the Sundarban support significant biodiversity. For effective conservation of these biodiversity, its proper documentation is prerequisite. In the present preliminary study, eight species of seaweeds, comprising of six species under Chlorophyceae and two species under Rhodophyceae have been enumerated, as a contribution towards the documentation of seaweeds of Sundarban Biosphere Reserve.

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 WoRMS (<http://www.marinespecies.org>)

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