Research article

Richard V. Dumilag*, Ferdinand S. Dumago, Rea Kissel R. Cabudoy, Mark Christian E. Peralta, Camille C. Li, Glenn Cedrick V. Gamus, Rose Glendelyn T. Romero, Sandra L. Yap, Michael Y. Roleda, Paul John L. Geraldino, Heroen Verbruggen, Frederik Leliaert, Stefano G.A. Draisma, Lawrence M. Liao and Gerald T. Kraft

The Ulvophyceae (Chlorophyta) of eastern Sorsogon, Philippines, including *Halimeda magnicuneata* sp. nov. (Bryopsidales)

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Abstract: The marine algal flora of eastern Sorsogon has been intensively collected and is generally considered as the richest in the Philippines. A trend of species records in the area has been dominated by rhodophytes (red algae) with significantly fewer similar studies for other algal groups (green and brown algae). In this study we present an updated catalogue of the green seaweeds (Ulvophyceae) of eastern Sorsogon. A checklist, including notes on taxonomy, is given of the 103 species. Twenty-six species are newly recorded locally of which five represent new records for the Philippines: *Avrainvillea amadelpha*, *Caulerpa buginensis*, an unidentified *Caulerpa* species, *Codium* cf. *latum*, and one taxon new to science. The new species is described as *Halimeda magnicuneata* Verbruggen *et* Dumilag based on morpho-anatomy and DNA sequence data. The number of ulvophycean species recorded in eastern Sorsogon is found to be the highest in the Philippines. This may be a result of the high collection effort in the region, as well as eastern Sorsogon's diverse habitats providing favourable conditions for a wide range of seaweed species.

Keywords: checklist; distributional record; green algae; macroalgae; Philippines; Sorsogon.

***Corresponding author: Richard V. Dumilag**, Institute of Oceanography and Environmental Science, Mindanao State University, Tawi-Tawi College of Technology and Oceanography, Boheh Sallang, Sanga-Sanga, Bongao, Tawi-Tawi, 7500, Philippines, E-mail: rvdumilag@msutawi-tawi.edu.ph. https://orcid.org/0000-0002-7590-0009
Ferdinand S. Dumago, Rea Kissel R. Cabudoy, Mark Christian E. Peralta, Camille C. Li, Glenn Cedrick V. Gamus, Rose Glendelyn T. Romero and Sandra L. Yap: Department of Biological Sciences, Institute of Arts and Sciences, Far Eastern University, Nicanor Reyes Sr. St., Sampaloc, Manila, 1015, Philippines
Michael Y. Roleda: The Marine Science Institute, College of Science, University of the Philippines, Diliman, Quezon City, 1101, Philippines
Paul John L. Geraldino: Department of Biology, University of San Carlos, Cebu City, 6000, Philippines
Heroen Verbruggen: School of Biosciences, University of Melbourne, Parkville, Victoria, 3010, Australia
Frederik Leliaert: Meise Botanic Garden, Nieuwelaan 38, Meise, 1860, Belgium; Phycology Research Group, Biology Department, Ghent University, Krijgslaan 281-S8, Ghent, 9000, Belgium
Stefano G.A. Draisma: Excellence Center for Biodiversity of Peninsular Thailand, Department of Biology, Faculty of Science, Prince of Songkla University, Hat Yai, Songkhla, 90110, Thailand
Lawrence M. Liao: Graduate School of Integrated Sciences for Life, Hiroshima University, 1-4-4, Kagamiyama, Higashi-Hiroshima, 739-8528, Japan
Gerald T. Kraft: School of Biosciences, University of Melbourne, Parkville, Victoria, 3010, Australia; Tasmanian Herbarium, College Road, Sandy Bay, Tasmania, 7005, Australia

1 Introduction

Sorsogon province (Figure 1) is located at the southeasternmost tip of Luzon Island, Philippines. The area intercepts the latitudes between 12°75′N and 13°02′N and longitudes at 123°E to 124°E. Sorsogon rims the southernmost border of peninsular Bicol, an allochthonous oceanic island which drifted northwards until its amalgamation unto the southeastern edge of greater Luzon Island, about 45 million years ago (Hall 1997 2002). Its eastern region straddles the embayment along the shallow San Bernardino Strait, an expanse that receives the offshoots of the nutrient-rich waters of the North Equatorial Current (NEC) from the Pacific basin, before its diversion into the Visayan seas (Gordon et al. 2011). Although not rigorously tested, the geographical location of eastern Sorsogon, together with its complex paleogeographical history, climate, and coastal physiography, contributes to its abounding marine biodiversity. The seafloor of eastern Sorsogon is primarily composed of volcanic basalt where extensive biogeochemical activities allow the hosting of a more diverse algal flora than in places with coral or calcareous substrata (Kraft, personal observation). Claims about the seaweed diversity in this area being the richest and most varied in the Philippines (Kraft et al. 1999; Trono 1975) have gone largely unchallenged. For more than five decades, the area has received continued attention from many phycologists around the world, including those studying the local flora (e.g., Dumilag et al. 2014, 2018; Kraft 1969; Kraft et al. 1999; Trono 1975 1976) and the taxonomy or biogeography of tropical taxa (e.g., Boo et al. 2016; Gabriel et al. 2017; Payo et al. 2013; Santiañez et al. 2018; Wiriyadamrikul et al. 2013).

The town of Bulusan, situated at the mid-eastern point of Sorsogon, is one of the long-time favourite collecting sites in the province, if not the entire Philippines. Specimens collected from this area formed the basis for the description of seven new species, namely *Cubiculosporum koronicarpis* Kraft (Kraft 1973), *Ptilophora scalaramosa* (Kraft) R.E.Norris (Norris 1987), *Rhipiliopsis carolyniae* Kraft (Kraft 1986a), *Corynocystis prostrata* Kraft (Kraft et al. 1999), and *Betaphycus philippinensis* Doty (Doty 1995), now relegated to synonymy under *Betaphycus gelatinus* (Esper) Doty ex P.C.Silva (Dumilag 2018), and *Halymenia tondoana* O.DeClerck *et* Hernández-Kantún (Hernández-Kantún et al. 2012), as well as one subspecific taxon, *Eucheuma arnoldii* var. *alcyonida* Kraft (Kraft 1972), now *Mimica arnoldii* var. *alcyonida* (Kraft) Santiañez *et* M.J.Wynne (Santiañez and Wynne 2020).

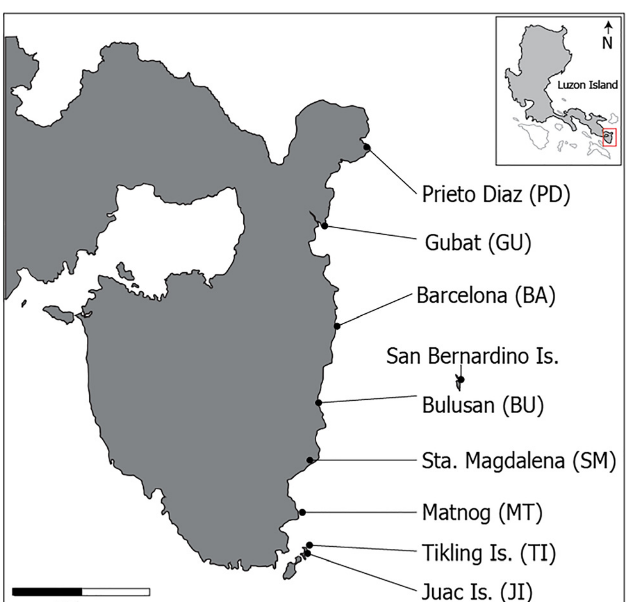

Figure 1: Collecting sites (abbreviations as used in main text in brackets) in eastern Sorsogon. The inset indicates the location of Sorsogon within the Philippines.

Initial documentation of seaweeds in southeastern Sorsogon was stimulated in part by an interest in its potentially exploitable resources (Kraft 1969; Taylor 1977), with some progress being made to understand the seaweed composition and diversity of the area (De Smedt et al. 2001; Kraft et al. 1999; Rollon et al. 2003; Trono 1972, 1975, 1976). Although most of the new species and records from eastern Sorsogon to date have centered on the Rhodophyta, particularly in Bulusan, the entire region is additionally well endowed with green and brown algae. The object of our present report turns to the green macroalgae, collectively regarded as belonging to the Ulvophyceae, a class representing an extraordinary diversity particularly in tropical and warm-temperate waters (Huisman and Saunders 2007). More than 1900 species are included in the class (Guiry and Guiry 2020), which are distributed in marine and brackish habitats around the world. A relatively smaller diversity (*ca.* 200 species) is also found in freshwater and terrestrial habitats, mainly known from temperate regions, but is likely much higher in tropical areas (Škaloud et al. 2018). Many ulvophyceans are of economic importance, among them are several species of *Caulerpa* such as *Caulerpa chemnitzia* (Esper) J.V.Lamouroux, *Caulerpa lentillifera* J.Agardh, and *Caulerpa racemosa* (Forsskål) J.Agardh that are widely consumed in the Indo-Pacific region (Gaillande et al. 2017). The aquaculture of *Ulva* spp. has aroused considerable interest lately because of its species' potential in mitigating major environmental impacts faced by marine food production systems (Bolton et al. 2016), e.g., coastal eutrophication due to extensive fish culture (Roleda and Hurd 2019). Other ulvoids have been suggested to be rich sources of pharmacologically active compounds (see Güven et al. 2010; Smith 2004).

Published and herbarium-specimen information on Ulvophyceae reported from eastern Sorsogon can be difficult to find, because most available information is dated, published in journals (e.g., Belleza and Liao 2007; Trono 1972a, 1975) or books (e.g., Trono 1997, 2004, 2017, 2018) of limited distribution or in the form of unpublished notes (e.g., Kraft 1969). No comprehensive work that compiles all the records of Ulvophyceae in eastern Sorsogon has been published, and it is only those studies by Trono (1972a 1975) that incorporate reliable species documentation of the Ulvophyceae. The aim of this study is to provide a comprehensive checklist of ulvophycean species occurring in eastern Sorsogon, Philippines, including taxonomic notes on the species. During the survey of herbarium specimens, we also examined a species of *Halimeda* that was previously recognised as new to science based on DNA sequence data (Verbruggen et al. 2009) but not yet formally described. We provide the species description in the present study.

2 Materials and methods

We bring together available data of ulvophycean species collected from eastern Sorsogon from peer-reviewed journal articles and books, open-access databases, and unpublished records from our own sampling conducted in recent years. Specimens were collected by hand during intertidal walks, wading or snorkeling in visited field sites. The collections were identified based on morphology and (where applicable) internal anatomy. For some specimens DNA barcodes were obtained in the framework of previous studies. Scientific names reported from old literature were updated with their current names and synonymies based on AlgaeBase (Guiry and Guiry 2020). For brevity, we hereafter refer to collection sites by abbreviations whenever they occur within particular areas (see Figure 1). The order of species presentation followed the taxonomic arrangement presented by Huisman (2015): Ulvales, Cladophorales, Bryopsidales, Dasycladales and subsequently by family and genus in alphabetical order. The recent proposal by Cremen et al. (2019) to merge the Rhipiliaceae and Udoteaceae with the Halimedaceae was applied.

Various herbaria and collections which house material referred to in this study include BR (formerly lodged at GENT), CEBU, FEUH, HO (specimens are in the process of being transferred from Kraft Herbarium), MICH, MSI, and NCU. Herbarium abbreviations follow Thiers (2020). Ancillary collections, usually in the form of fragments from each voucher specimen preserved in alcohol or silica gel (at least those from CEBU, FEUH and BR), have been stockpiled for future molecular analyses.

Eight major sampling sites in eastern Sorsogon were surveyed to collect samples of Ulvophyceae (Table 1). The total number of recorded species from each site was compared pairwise using Sørensen's similarity index (Sørensen 1948). The same index modified by Magurran (1988) was used to compare the species diversity in eastern Sorsogon with other regions in the Philippines.

3 Results

The species checklist of Ulvophyceae recorded in eastern Sorsogon, Philippines, is presented in Table 2 with notes as appropriate. A comprehensive reference of previous records in the area and a list of citations per site of all *exsiccatae* examined in this study are provided in Supplementary Table S1.

Twenty-six species are recorded for the first time in the area. *Avrainvillea amadelpha* (Montagne) A.Gepp *et* E.S.Gepp, *Caulerpa buginensis* E.Verheij *et* Prud'homme and an unidentified species of *Caulerpa* are new records for the Philippines. *Codium* cf. *latum* Suringar (Figure 2) is the only known flattened *Codium* so far known in the area and the first record of the species for the entire southeast Asia. The list also includes one species new to science, which we describe below.

Halimeda magnicuneata Verbruggen *et* Dumilag, sp. nov. (Figure 3)

Holotype: HV823, collected by Heroen Verbruggen in Dancalan, north of Bulusan, SW Luzon, Philippines on 11 February 2004, deposited at BR.

Holotype GenBank accessions: FJ624528 (*rbc*L), KT887750 (tuf*A*), FJ624604 (ITS nrDNA), FJ624488 (SSU nrDNA), FJ624554 (UCP3) and FJ624834 (UCP7).

Habitat: The type locality is a complex system of crevices shoreward of an exposed coralline reef off Bulusan, Sorsogon, Philippines. The crevices, which are 5–10 m deep and have many vertical walls and overhangs, are sheltered from full wave forces but subject to moderate wave surges. *H. magnicuneata* was growing on rocky substrate on the vertical walls of the crevices.

Description: Thalli attach to rocky substrata by means of a holdfast disc composed of an intricate network of rhizoidal siphons. The cylindrical to narrow wedge-shaped basal segment is smaller and thicker than the other segments, which are entirely flattened and measure (17-)19–23(-27) mm in length and (15-)17–20(-23) mm in width. The majority of large, flattened segments is *ca*. 10% longer than wide and is broadest above their middle (at ca. 60–70% from the base). They are wedge-shaped to almost round and lightly calcified.

Medullar siphons are (95-)110–130(-140) µm thick. Subnodal siphons fuse in 2′s or 3′s. The siphons directly above the fusion are (500-)790–1100(-1500) µm long. The cortex consists of two utricle layers, very rarely 3. Peripheral utricles are (39-)42–48(-50) µm in surface diameter and (55-)60–65(-75) µm high. Adjacent peripheral utricles attach to one another at their tips and show an irregular polygonal pattern in surface view, with medium-thickness cell walls and the occasional fusion between adjacent utricles. Secondary utricles are markedly inflated and measure (60-)75–100(115) µm in diameter and (95-)120–160(-185) µm in height. They carry 4–8 peripheral utricles.

Phylogeny: Refer to the phylogenetic analysis of Verbruggen et al. (2009) as inferred from a concatenated alignment of *rbc*L, *tuf*A, UCP3, UCP7, 18S, and ITS sequences. The node "*H. 'magnicuneata'*" refers to the holotype material HV823 from Bulusan, Sorsogon, Philippines.

Distribution: *Halimeda magnicuneata* confirmed occurrences are so far from Sorsogon, Philippines and Barrow Island, Western Australia.

Table 1: Geographical coordinates and description for the eight study sites surveyed in this study.

Site (abbreviation)	Specific collection site(s)	Coordinates	Description
Prieto Diaz (PD)	Brgy. Poblacion	13°02′33″ N, 124°12′0″ E	Tide flat is bedrock covered with coarse sand. Chlorophytes are dominated by Bryopsidales and Dasycladales. Ochrophytes are dominated by Fucales and Dictyotales. A few rhodophytes primarily Corallinales are scattered around while *Gelidiella acerosa* (Forsskål) J.Feldmann *et* G.Hamel was found throughout the area.
Gubat (GU)	Rizal beach	12°53′42″ N, 124°08′11″ E	Intertidal area to the east of popular Rizal Beach, composed of shallow-water coral rubble and sand, interspersed with seagrass.
Barcelona (BA)	Barcelona Channel	12°52′05″ N, 124°09′05″ E	Tide flat is bedrock covered with coarse sand and rocks. Chlorophytes are dominated by Bryopsidales. Ochrophytes are found in the deeper portion of the reef dominated by *Turbinaria ornata* (Turner) J.Agardh. Rhodophytes found throughout the transect are primarily Corallinales and *G. acerosa*.
Bulusan (BU)	In front of Villa Celeste Resort, Brgy. Dancalan	12°46′00″ N, 124°08′20″ E	Upper intertidal flat is bedrock with coral rubble. From 10-100 m the hard substrate is covered with coarse sand and rubble with seagrasses. Co-occurring seaweeds are dominated by Bryopsidales (*Caulerpa*, *Halimeda*, *Udotea* and *Avrainvillea*). Ochrophytes are dominated by Fucales (*Sargassum*, *Turbinaria* and *Hormophysa*). A few rhodophytes observed are primarily Corallinales.
	Brgy. Dapdap	12°45′10″ N, 124°08′27″ E	Vast intertidal area adjacent to town proper marked by wide sandbars which join seaward with tracts of reef tops surrounding some deep interconnected lagoons. Gelidioids and eucheumatoids dominate the reef flats, with larger foliose rhodophytes and green algae found on lagoon walls where surge channels provide vigorous water exchanges.
	San Bernardino Is.	12°45′07″ N, 124°16′56″ E	Basaltic rocky island on the northern entrance of San Bernardino Strait, 16 km east of Bulusan town proper. Sampling done at west and southwest leeward sides, marked by shallow surge channels with sandy bottom perpendicular to the coast. Dense *Sargassum* beds with numerous understorey red algae, with *Chnoospora minima* (Hering) Papenfuss forming a belt on the shallowest reaches.
Sta. Magdalena (SM)	Olango Beach	12°39′17″ N, 124°07′23″ E	A flat consisting of white coarse sand, dominated by seagrasses with some boomies and coral rubble scattered all around. This area completely exposed during low tide. Strong waves are observed during monsoon season. Toward the end of the flat is a mixture of *Sargassum* patches and live corals.
	Brgy. San Rafael	12°39′36″ N, 124°07′52″ E	A semi-enclosed bay, with generally a similar physiognomy as Olango Beach. The first 30–40 m has sandy-rocky bottom dominated by a mixture of seagrasses and green seaweeds, *viz.* members of Siphonocladaceae and Dasycladales. Particularly during low tide, strong waves battered reef edges causing surf splashes.
Matnog (MT)	Brgy. Tabunan	12°34′39″ N, 124°05′33″ E	Narrow intertidal ca. 600 m southwest of ferry port. Sandy to rocky substrate with dense seagrass patches on reef before drop off ca. 180 m from the coast.
Tikling Is. (TI)	East side of Tikling Is.	12°35′02″ N, 124°07′41″ E	Island with coarse sandy and rocky shoreline. Substrate within the 100 m transect is predominantly coarse sandy rocky with coral rubble. Chlorophytes are dominated by Dasycladales and Bryopsidales while Ulvales was found throughout the transect. Rhodophytes primarily belong to Gigartinales.
Juac Is. (JI)	North east side of Juac Is.	12°33′18″ N, 124°07′11″ E	Island with rocky shoreline. The intertidal and reef flat littered with coral rubble from the shore up to 50 m distance. Dominant seaweed species belong to Gigartinales and Dasycladales. The upper subtidal from 60 to 100 m, diverse seaweed flora are associated with live corals, with patches of dense *Caulerpa racemosa* cover.

Table 2: Checklist and distribution of species of Ulvophyceae recorded from eastern Sorsogon, Philippines with some notes on selected taxa.

Note	Taxon[a]	Eastern Sorsogon site							
		PD	GU	BA	BU	SM	MT	TI	JI
	Ulvales								
	Ulvaceae								
	Ulva australis Areschoug				+	+			±
	Ulva clathrata (Roth) C.Agardh				±				
	Ulva flexuosa Wulfen				+	+			
	Ulva intestinalis Linnaeus			±					
	Ulva kylinii (Bliding) H.S.Hayden, Blomster, Maggs, P.C.Silva, Stanhope *et* Waaland			+	±				
	Ulva lactuca Linnaeus			+	+	+	±	±	±
	Ulva reticulata Forsskål	+		+	+	+	±	+	±
	Cladophorales								
	Anadyomenaceae								
	Anadyomene plicata C.Agardh				+	+	±	+	
	Microdictyon cf. *umbilicatum* (Velley) Zanardini[b]				+				
	Microdictyon okamurae Setchell	+				+			
1	Boodleaceae								
	Boodlea coacta (Dickie) G.Murray *et* De Toni[b]				+				
	Boodlea composita (Harvey) F.Brand				±	+	±	+	±
	Cladophoropsis vaucheriiformis (Areschoug) Papenfuss				+	+			
	Phyllodictyon anastomosans (Harvey) Kraft *et* M.J.Wynne				+	+			
2	*Struvea okamurae* Leliaert				+	+			
	Cladophoraceae								
	Chaetomorpha antennina (Bory) Kützing	+		+	±			+	+
3	*Chaetomorpha vieillardii* (Kützing) M.J.Wynne			+	+	+		+	
	Cladophora aokii Yamada				+				
4	*Cladophora quisumbingii* Manza			±	±				
5	*Cladophora vagabunda* (Linnaeus) Hoek[b]					+			
	Lychaete dotyana (W.J.Gilbert) M.J.Wynne				+	+			
	Dictyosphaeriaceae								
	Dictyosphaeria cavernosa (Forsskål) Børgesen				+	+	±		+
	Dictyosphaeria versluysii Weber Bosse				+	+	±	±	+
	Siphonocladaceae								
	Boergesenia forbesii (Harvey) Feldmann	+		+	+	+	±	+	+
	Valoniaceae								
	Valonia aegagropila C.Agardh				+	+	±	+	+
	Valonia fastigiata Harvey ex J.Agardh[b]				+	+			
	Valonia utricularis (Roth) C.Agardh				+				
	Valonia ventricosa J.Agardh				+		±		+
	Valoniopsis pachynema (G.Martens) Børgesen	±			+				
	Bryopsidales								
	Bryopsidaceae								
6	*Bryopsis pennata* J.V.Lamouroux			+	+	+			+
	Caulerpaceae								
	Caulerpa ambigua Okamura[b]								
7	*Caulerpa biserrulata* Sonder[b]				+	+			
	Caulerpa brachypus Harvey				+				
8	*Caulerpa buginensis* E.Verheij *et* Prud'homme[b, c]				+				
	Caulerpa chemnitzia (Esper) J.V.Lamouroux			+	+	+		+	
	Caulerpa cupressoides (Vahl) C.Agardh				+	+		+	+
9	*Caulerpa elongata* Weber Bosse				+	+		+	
	Caulerpa fergusonii G.Murray		+		+				
10	*Caulerpa filicoides* Yamada				±				
	Caulerpa lentillifera J.Agardh			+	+	+	±	+	±
	Caulerpa lessonii Bory			+	+		+		
	Caulerpa mexicana Sonder ex Kützing				+				

Table 2: (continued)

Note	Taxon[a]	Eastern Sorsogon site							
		PD	GU	BA	BU	SM	MT	TI	JI
	Caulerpa opposita Coppejans *et* Meinesz[b]				+				
	Caulerpa pickeringii Harvey *et* Bailey				+				
	Caulerpa racemosa (Forsskål) J.Agardh	+		+	+	+		+	+
	Caulerpa serrulata (Forsskål) J.Agardh		±	+	+	+		+	+
	Caulerpa sertularioides (S.G.Gmelin) M.Howe	+		+	+	+		+	+
	Caulerpa taxifolia (M.Vahl) C.Agardh	+		+	+	+			
	Caulerpa urvilleana Montagne				±		±	±	
11	*Caulerpa* sp.[b, c, d]				+				
	Codiaceae								
	Codium arabicum Kützing				+				
	Codium bartlettii C.K.Tseng *et* W.J.Gilbert	+		+	+	+			
	Codium edule P.C.Silva		+	+	+	+			
	Codium geppiorum O.C.Schmidt[b]					+			
12	*Codium* cf. *latum* Suringar[b, c, d]					+			
	Codium platyclados R.Jones *et* Kraft				+	+			
13	*Codium* cf. *tenue* Kützing			+	+				
	Dichotomosiphonaceae								
14	*Avrainvillea amadelpha* (Montagne) A.Gepp *et* E.S.Gepp[b, c]				+				
	Avrainvillea erecta (Berkeley) A.Gepp *et* E.S.Gepp				+	+			
	Avrainvillea lacerata J.Agardh	+		+	+		±	+	+
	Avrainvillea longicaulis (Kützing) G.Murray *et* Boodle				±				
	Avrainvillea nigricans Decaisne			±	+				
	Avrainvillea obscura (C.Agardh) J.Agardh				+	+			
	Halimedaceae								
	Chlorodesmis fastigiata (C.Agardh) S.C.Ducker	+			+	+		+	
	Halimeda bikinensis W.R.Taylor[b]				+				
15	*Halimeda borneensis* W.R.Taylor	±		±					
	Halimeda cylindracea Decaisne	+			+	+			
16	*Halimeda discoidea* Decaisne	+	+		+	+			
17	*Halimeda distorta* (Yamada) Hillis-Colinvaux				+				
	Halimeda fragilis W.R.Taylor[b]		+		+				
18	*Halimeda gigas* W.R.Taylor	+	+	+	+				
19	*Halimeda gracilis* Harvey ex J.Agardh		+		+				
	Halimeda incrassata (J.Ellis) J.V.Lamouroux[b]				+				
	Halimeda lacunalis W.R.Taylor[b]				+				
	Halimeda macroloba Decaisne			+	±				
20	*Halimeda macrophysa* Askenasy				+	+			
	Halimeda magnicuneata Verbruggen *et* Dumilag sp. nov.				+				
21	*Halimeda melanesica* Valet				+				
22	*Halimeda minima* (W.R.Taylor) Hillis-Colinvaux				+	+			
	Halimeda opuntia (Linnaeus) J.V.Lamouroux	+		±	+	+	±	+	+
	Halimeda taenicola W.R.Taylor				±				
23	*Halimeda velasquezii* W.R.Taylor			+	+	+	±		+
	Rhipidosiphon javensis Montagne				+				
24	*Rhipilia crassa* A.J.K.Millar *et* Kraft				±				
25	*Rhipilia nigrescens* Coppejans *et* Prud'homme				+				
26	*Rhipilia orientalis* A.Gepp *et* E.S.Gepp				+				
27	*Rhipiliopsis carolyniae* Kraft				+				
	Tydemania expeditionis Weber Bosse			+	+	+			
	Udotea argentea Zanardini[b]				+				
	Udotea indica A.Gepp *et* E.S.Gepp[b]				+				
	Udotea occidentalis A.Gepp *et* E.S.Gepp				+				
	Udotea orientalis A.Gepp *et* E.S.Gepp	+		+	+	+			

Table 2: (continued)

Note	Taxon[a]	Eastern Sorsogon site							
		PD	GU	BA	BU	SM	MT	TI	JI
	Dasycladales								
	Dasycladaceae								
	Bornetella nitida Munier-Chalmas ex Sonder	+	+	+	+	+			
	Bornetella oligospora Solms-Laubach[b]				+				
	Bornetella sphaerica (Zanardini) Solms-Laubach		+		+	+	±	+	
	Neomeris annulata Dickie[b]				+				
	Neomeris vanbosseae M.Howe[b]		+		+	+			
	Halicoryne wrightii Harvey			+	+				
	Polyphysaceae								
	Acetabularia dentata Solms-Laubach[b]				+	+			
	Acetabularia major G.Martens				+				
	Acetabularia ryukyuensis Okamura *et* Yamada[b]				+				
	Parvocaulis exiguus (Solms-Laubach) S.Berger, Fettweiss, Gleissberg, Liddle, U.Richter, Sawitzky *et* Zuccarello[b]				+	+			
	Parvocaulis parvulus (Solms-Laubach) S.Berger, Fettweiss, Gleissberg, Liddle, U.Richter, Sawitzky *et* Zuccarello[b]				+	+			

PD: Prieto Diaz, GU: Gubat, BA: Barcelona, BU: Bulusan, SM: Sta. Magdalena, MT: Matnog, TI: Tikling Is., JI: Juac Is. (see Table 1).
"+", taxon with actual specimen examined in this study; "±" material cited from literature.

1. Most Philippine specimens, though no representative was collected from Sorsogon, identified morphologically as *Boodlea montagnei* (Harvey *ex* J.E.Gray) Egerod, *Boodlea siamensis* (now *B. composita*), and *Phyllodictyon anastomosans* belong to "*Boodlea* sp. 10", a widespread Indo-Pacific species (Leliaert et al. 2009).
2. Phylogenetic inferences from partial LSU and ITS sequences including a specimen (HEC12301) collected from BU indicated that *Chamaedoris orientalis* Okamura *et* Higashi should be recognised as a species of *Struvea* (Leliaert et al. 2007). Due to the peculiar phenotypic traits of *S. okamurae* relative to other traditionally known members of *Struvea*, the description of the genus was emended in Leliaert et al. (2007).
3. Wynne (2011) proposed the name *C. vieillardii* to serve for what was previously known in tropical seas as *Chaetomorpha crassa* (C.Agardh) Kützing.
4. *Cladophora quisumbingii* has been applied to a species only known from the Philippines. This species was briefly described by Manza (1939) based on an unnumbered specimen collected by R. C. McGregor from Batan Island, Batanes, northern Philippines, dated June 1907. *Cladophora quisumbingii* exhibits branches arranged dichotomously at the base, becoming di-tetrachotomous at midregion and tapered to narrow apical divaricate ends. Its main axes measured 300–400 μm while the apical branches were 150–200 μm, making this taxon relatively coarse as compared with most *Cladophora* species. Manza's description did not include any illustrations. The original material was deposited at the Herbarium of Bureau of Science in Manila but lost at the beginning of World War II. Silva et al. (1987) argues that a specimen in Berkeley (UC 1402218) is the lectotype. The first illustration for this species is provided by Trono (2018).
5. *Cladophora vagabunda* is a species-complex that is widespread from tropical to temperate waters (Boedeker et al. 2016). Tropical representatives are genetically distinct from temperate *C. vagabunda* (type from England) and likely represent a different species.
6. A preliminary molecular phylogenetic analysis in *Bryopsis* showed considerable conflict between morphological and phylogenetic species definitions (Hollants et al. 2013). A Philippine specimen identified as *B. pennata* was found to belong to '*Bryopsis* sp. 28', a pantropical clade including a wide morphological diversity.
7. The morphological entity *Caulerpa biserrulata* represents at least two distinct species and one of those is *C. brachypus*. The *C. brachypus* specimen from Cangaluyan Is., Pangasinan, Philippines in Famà et al. (2002) was re-examined and identified as *C. biserrulata* (Wynne et al. 2009). Nonetheless, it belongs to a clade with typical *C. brachypus*.
8. On MICH 679831 (Kraft #359) there are four mounted specimens with pallid coloured thalli with quite distinctive oppositely arranged rounded ramuli. At the bottom of the sheet was handwritten by H. Ohba in pencil, dated 29 May 1998, "Coppejans and Prud'homme van Reine's new species from Indonesia or Papua New Guinea". The species to which Ohba was referring is *C. buginensis*.
9. The definitive taxonomic traits for *C. webbiana* have been shown to overlap with *C. elongata*. This has been seen particularly among Philippine samples (Dumilag et al. 2019), thus molecular confirmation is recommended.
10. *Caulerpa filicoides* generally has 2–3 super-imposed whorls on a longer stipe, i.e. 5–15 mm, while another related Indo-Pacific species, *Caulerpa andamanensis* (W.R.Taylor) Draisma, Prud'homme et Sauvage has a single whorl of branchlets on a short stipe, i.e. up to 2 mm (Draisma et al. 2014). Trono (2018) described his material from BU following the former criterion.
11. Refer to the Discussion section.
12. Refer to the Discussion section.
13. Huisman (2015) noted that reported specimens under the name *Codium tenue* from the Philippines and the Marshall Islands probably belong to different species and require molecular confirmation.
14. Refer to the Discussion section.

15. Record of *Halimeda simulans* M.Howe in Trono (1975, 1997) was considered by Huisman (2015) to be *H. borneensis*.
16. Verbruggen et al. (2005) reported specimens matching *Halimeda cuneata* f. *digitata* E.S.Barton from several places in the Philippines, but when sequenced these clearly belong within *H. discoidea*. Voucher HV827 collected from BU was confirmed molecularly by Verbruggen et al. (2005).
17. Voucher HV767 from BU was confirmed molecularly by Verbruggen et al. (2009).
18. Most samples identified as *H. tuna* in the Indo-Pacific are small plants of *H. gigas*. The presence of *H. tuna* anywhere in the Philippines, therefore, is unlikely, as this species occurs only in the Mediterranean and another cryptic species in the Atlantic (Kooistra et al. 2002, Dijoux et al. 2012). The voucher HV769 from BU was confirmed molecularly by Verbruggen et al. (2009) as *H. gigas*.
19. Voucher HV824 from BU was confirmed molecularly by Verbruggen et al. (2009).
20. Voucher HV822 from BU was confirmed molecularly by Verbruggen et al. (2009).
21. Vouchers HV790 and HV818 from BU were confirmed molecularly by Verbruggen et al. (2005).
22. *Halimeda copiosa* Goreau et E.A.Graham is strictly an Atlantic species. Indo-Pacific samples identified as *H. copiosa* were molecularly assigned to the *H. minima* complex, which has not been found outside the Indo-Pacific. Voucher HV791 from BU was confirmed molecularly by Verbruggen et al. (2009).
23. Vouchers HV68 and HV779 from BU were confirmed molecularly by Verbruggen et al. (2009).
24. A single specimen, NSW419105, collected from BU, was regarded as one of the syntype specimens of this species by Millar and Kraft (2001).
25. Molecularly confirmed by Verbruggen et al. (2009) from BU.
26. Molecularly confirmed by Verbruggen et al. (2009) from BU.
27. The type specimen (MELU, K492), was collected from BU (Kraft 1986).

[a]Detailed specimen information presented in Supplementary Table S1.
[b]New record for eastern Sorsogon, Philippines.
[c]New record for the Philippines.
[d]New record for southeast Asian waters.

Table 3 shows the similarities of Ulvophyceae record matrix constructed for each site with Sørensen's similarity index. The number of species per site varied between 10 and 96 with the highest record from BU, as would be expected considering that the greatest sampling effort was in this site over the past five decades, as compared to the other sites (Figure 4). The ulvophycean flora of eastern Sorsogon represents the highest count with consistently low similarity index as compared to any other region within the Philippines (Table 4).

4 Discussion

Our list treats over 50% of the known species of Ulvophyceae reported for the Philippines (as referenced in Ang et al. 2013 with 197 species). Many recent taxonomic changes, often based on molecularly-assisted alpha taxonomic studies, have been incorporated in our present records of Ulvophyceae from eastern Sorsogon. Most ulvophycean taxa that have been reported as new from the area are long known to have wide distributions in many regions in the Philippines (see Silva et al. 1987). Detection of some of these taxa would pass unnoticed by previous surveys, in part due to professional unfamiliarity with species assignment especially those whose key taxonomic characters overlap with other taxa (e.g., *Valonia fastigiata* Harvey ex J.Agardh as to *Valonia utricularis* (Roth) C.Agardh, *Caulerpa biserrulata* Sonder to *Caulerpa brachypus* Harvey, and *Halimeda tuna* (J.Ellis et Solander) J.V.Lamouroux to *Halimeda gigas* W.R.Taylor). Considering their small size, it is possible that *Acetabularia dentata* Solms-Laubach, *Parvocaulis exiguus* (Solms-Laubach) S.Berger, Fettweiss, Gleissberg, Liddle, U.Richter, Sawitzky *et* Zuccarello, and *Parvocaulis parvulus* (Solms-Laubach) S.Berger, Fettweiss, Gleissberg, Liddle, U.Richter, Sawitzky *et* Zuccarello have been previously overlooked in the area.

This study has resulted in an increased number of Ulvophyceae species recorded from the Philippines.

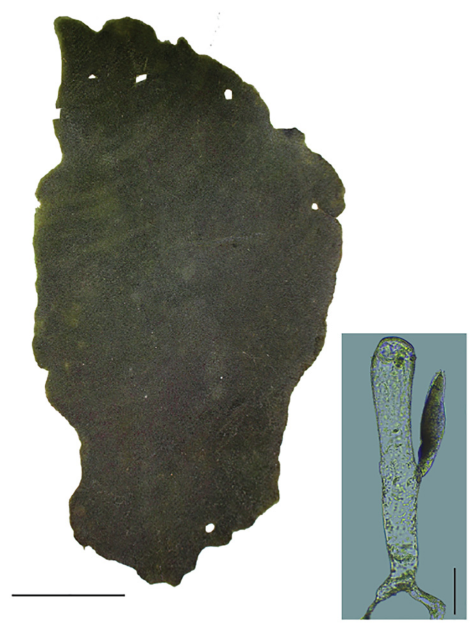

Figure 2: *Codium* cf. *latum*. (2) Habit of pressed specimen of *Codium* cf. *latum*, FEUH217, scale = 3 cm. An inset showing its utricle bearing lateral gametangia, scale = 100 μm.

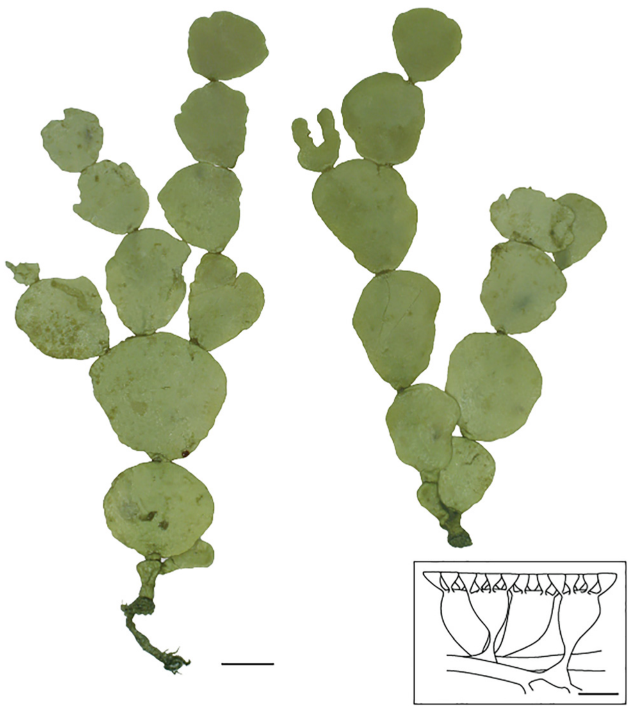

Figure 3: *Halimeda magnicuneata* Verbruggen *et* Dumilag sp. nov. Holotype specimen of *Halimeda magnicuneata*, HV823, scale = 1 cm. A diagram showing its cortical utricles, scale = 100 µm.

A. amadelpha, *C. buginensis*, and one unknown species of *Caulerpa* are first records for the Philippines.

Avrainvillea amadelpha, originally described from Madagascar, is widely distributed in the tropical Indo-West Pacific, with several records in southeast Asia. Its occurrence in the Philippines is therefore not unexpected. Although identifying *A. amadelpha* can be difficult (Wade et al. 2018), it can however be distinguished from the morphologically similar species *A. lacerata* J.Agardh. In the latter species, the stipes are more distinct and the blades composed of tightly woven filaments resulting in a papery texture (Coppejans et al. 2017).

Caulerpa buginensis was described (as *C. buginense*) from a single specimen from southwest Sulawesi, Indonesia (Verheij and Prud'homme van Reine 1993). It is characterised by two opposite rows of overlapping, compressed, rounded ramuli. This is the second published record of this species and the first outside Indonesia. The specimen from Sorsogon differs from the type specimen by having shorter assimilators with up to six ramuli per rachis side, whereas the type specimen shows up to 21 ramuli pairs.

A sheet lodged at MICH number 679832 (Kraft #340) dated 04 June 1969 is accompanied by a labelled *"Caulerpa"* handwritten by its collector, G.T. Kraft, with annotations: "like slender (*Caulerpa*) *ashmeadii* ramellar (*sic* ramular) tips rounded; not apiculate" and "more lax and more slender than *ashmeadii*" (see http://macroalgae.org/portal). *Caulerpa ashmeadii* is described from Florida and is thought to be restricted to the Atlantic (Pattarach et al. 2019). It belongs to a clade with three other species that are limited to the Atlantic (Sauvage et al. 2014). A few doubtful records exist from the Indo-Pacific, but these have never been confirmed by molecular data (Pattarach et al. 2019). A specimen from Thailand initially identified as *C. ashmeadii* was molecularly identified as *Caulerpa macrodisca* (Decaisne) Weber Bosse (Pattarach et al. 2019). Otherwise, the Sorsogon specimen may represent the rare Indo-Pacific species *Caulerpa pinnata* C.Agardh or *Caulerpa lagara* Carruthers, Walker *et* Huisman, which both have terete ramuli without apiculi like *C. ashmeadii*, but ramuli are sparser than in *C. ashmeadii* (Carruthers et al. 1993; Greville 1853). Draisma et al. (2014) hypothesised that *C. lagara* is a synonym of *C. pinnata*. *C. pinnata* has been reported from Sri Lanka (type location) and the Red Sea, and *C. lagara* is known only from its type location in the Swan

Table 3: Pairwise values of Sørensen's similarity indices based on species composition of Ulvophyceae recorded among the eight sites in eastern Sorsogon.

Site	No. of Ulvophyceae species recorded	Paired site Sørensen's similarity index (S)						
		PD	GU	BA	BU	SM	MT	TI
Prieto Diaz (PD)	18							
Gubat (GU)	10	0.30						
Barcelona (BA)	30	0.72	0.40					
Bulusan (BU)	96	0.89	1.00	0.93				
Sta. Magdalena (SM)	50	0.67	0.60	0.60	0.92			
Matnog (MT)	16	0.29	0.10	0.53	1.00	0.88		
Tikling Is. (TI)	21	0.44	0.20	0.40	1.00	0.82	0.82	
Juac Is. (JI)	19	0.39	0.10	0.63	1.00	0.84	0.76	0.79

$S = N_{common}/(N_{less})$, where S represents index of similarity, N_{common} is the number of species held in common between paired sites, and N_{less} is the total number of species in a site with a lesser species count.

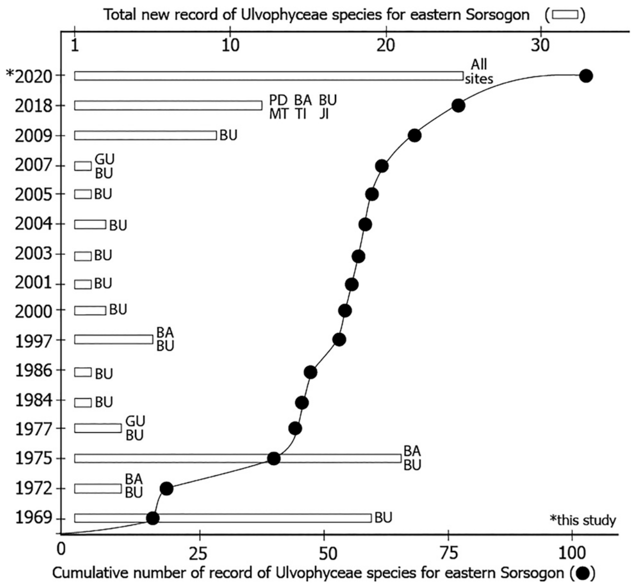

Figure 4: Species accumulation curve of Ulvophyceae taxa recorded for eastern Sorsogon. Study sites with report of Ulvophyceae species for each given year: PD: Prieto Diaz, GU: Gubat, BA: Barcelona, BU: Bulusan, SM: Sta. Magdalena, MT: Matnog, TI: Tikling Is., JI: Juac Is.

River, Western Australia, and was never reported since its description. However, currently there is no DNA sequence data available for *C. pinnata* and *C. lagara*.

The morphological features of the eastern Sorsogon *Codium* cf. *latum* suit the description of Okamura (1915) and Schmidt (1923) for the presence of slightly enlarged utricle apices and gametangia issued from the middle portion of the utricle. *Codium latum* is an entirely flattened erect species, described from Japan and reported from other regions in the north-western Pacific (Korea and Taiwan) and Indian Ocean, *viz.* Oman, Yemen, India, and Pakistan (Guiry and Guiry 2020). It constitutes a new record for the southeast Asian waters (i.e., not recorded from any area in this region, see Atmadja and Prud'homme van Reine 2014; Coppejans et al. 2017; Nguyen et al. 2013; Phang et al. 2019; Soe-Htun et al. 2009; Titlyanov et al. 2016); however, it is important to note that genetic analyses have shown that *C. latum* is not a monophyletic entity (Verbruggen et al. 2007), and the taxonomy of this species across its reported distribution requires revision based on molecular evidence.

The distinction of *H. magnicuneata* sp. nov. as a separate taxon was supported by previous molecular analyses (Verbruggen et al. 2009). It has been clear for some time that several species of *Halimeda* are not monophyletic entities

Table 4: Comparison of eastern Sorsogon Ulvophyceae flora among neighbouring areas within the Philippines.

Site	References	N_b	N_{a+b}	C_s
Northern Luzon				
Batanes	Manza (1939), Cordero (1977)	48	28	0.37
Ilocos Norte	Cordero (1983), Hurtado-Ponce (1983), Marcos-Agngarayngay (1983), Agngarayngay et al. (2005)	56	31	0.39
Pangasinan	Domantay 1961, Trono and Ohno (1992)	46	36	0.48
Southwestern Luzon				
Batangas	Villones and Magdamo (1968), Velasquez et al. (1971), Trono and Ohno (1992), Trono and Ganzon Fortes (1980), Roleda et al. (2000)	45	34	0.46
Southeastern Luzon (Bicol Region)				
Albay	Mendoza and Soliman (2013), Camaya et al. (2014)	33	22	0.32
Catanduanes	Evangelista et al., 2015	64	43	0.51
Central Philippines				
Cebu	Liao and Sotto (1980), Modelo and Umezaki (1987), Belleza and Geraldino (2019)	67	45	0.53
Panay	Cordero (1987), Modelo and Umezaki (1987), Hurtado-Ponce et al. (1992), Luhan et al. (1992), Hurtado-Ponce et al. (1998)	57	43	0.54
Romblon	Clemente et al. (2017)	48	39	0.52
Palawan-Sulu Sea				
Palawan	Trono and Ang (1982), Modelo et al. (1989), Santiañez et al. (2015)	78	54	0.60
Sulu Sea Islands	Liao and Young, 2002	33	20	0.29
Western Mindanao				
Sulu (Siasi Is.)	Trono (1972b)	42	24	0.33
Tawi-Tawi	Trono (1972c), Puig-Shariff (2015), Dumilag (2019), Tahil and Liao (2019)	48	42	0.56
Zamboanga del Sur	Tito et al. (2000)	36	31	0.45

Sørensen's similarity index *sensu* Magurran (1988): $Cs=(2N_a + b)/(N_a + N_b)$, where N_a is the total number of Ulvophyceae species in eastern Sorsogon (n = 103); N_b is the total species count of the neighbouring site; N_{a+b} is the number of species held in common.

(Kooistra et al. 2002; Verbruggen et al. 2005), and in the Indo-Pacific, entities referred to as *H. tuna*, *H. cuneata,* and *H. discoidea* are particularly problematic (Verbruggen et al. 2005). *H. magnicuneata* shares features with several other species. In its anatomy, it resembles *H. discoidea*, with inflated secondary utricles bearing many primary utricles, but it differs from that species in having larger segments that are on average more top-heavy (maximum width closer to the top) than those of *H. discoidea*, although the variability in the latter species is large. The segments are somewhat reminiscent of the wedge-shaped *H. cuneata* but are wider and generally more rounded. Due to the large and thin segments it also has superficial similarities to *H. gigas*, but the segments of *H. magnicuneata* are more top-heavy than those of *H. gigas*. The inflated secondary utricles of *H. magnicuneata* make for a clear distinction from both *H. cuneata* and *H. gigas*.

The number of ulvophycean species of eastern Sorsogon constitutes the highest, so far, among other regions within the Philippines. The recent comparison, however, might be biased because other areas in the Philippines have been less sampled while those having available regional reports need updating as well. Studies on the red alga *Portieria hornemanii* (Lyngbye) P.C.Silva (Leliaert et al. 2018; Payo et al. 2013), have indicated that cryptic species diversity can be substantial and that species composition may differ strongly between regions in the Philippines. Intensive sampling in other areas, combined with DNA barcoding, will provide a more realistic view on species diversity in the Philippines.

The increased number of ulvophycean species in the area is consistent with the expectation of a gradual augmentation of species discovery based upon the integration of molecular-assisted taxonomic approaches, particularly in Bulusan, where most of the sampling have been conducted. While DNA barcoding of ulvophycean specimens has greatly improved the discrimination of taxa, an appreciation of the true extent of species richness will certainly remain dependent on the taxonomic expertise of active national and international researchers and the future generations of phycologists that they will be training. It is expected that far greater accuracy will be achieved in the determination of true species richness of the Sorsogon region and, indeed, all Philippine habitats, when rigorous morpho-anatomical, molecular, and ecological studies are thoroughly integrated in the coming years.

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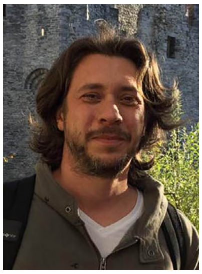
Bionotes

Richard V. Dumilag
Institute of Oceanography and Environmental Science, Mindanao State University, Tawi-Tawi College of Technology and Oceanography, Boheh Sallang, Sanga-Sanga, Bongao, Tawi-Tawi, 7500, Philippines
rvdumilag@msutawi-tawi.edu.ph
https://orcid.org/0000-0002-7590-0009

Richard V. Dumilag is currently the curator at the Mindanao State University Herbarium in Tawi-Tawi. His interest centers on the taxonomy of marine benthic algae in the Philippines.



Heroen Verbruggen
School of Biosciences, University of Melbourne, Parkville, Victoria, 3010, Australia

Heroen Verbruggen is an associate professor and Australian Research Council Future Fellow at the University of Melbourne. Research in his lab includes algal systematics and biodiversity, algal evolution, comparative algal genomics and environmental microbiology. For more information, see http://phycoweb.net
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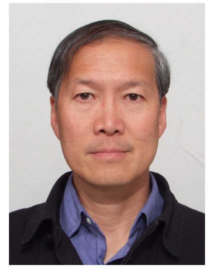
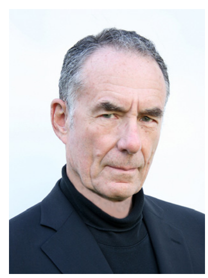
Frederik Leliaert
Meise Botanic Garden, Nieuwelaan 38, Meise, 1860, Belgium
Phycology Research Group, Biology Department, Ghent University, Krijgslaan 281-S8, Ghent, 9000, Belgium

Frederik Leliaert is a research director at the Botanic Garden Meise and visiting professor at Ghent University. He uses molecular, morphological, ecological and geographic data to resolve phylogenetic relationships, test species boundaries and explore the biogeographical history in marine macroalgae.



Lawrence M. Liao
Graduate School of Integrated Sciences for Life, Hiroshima University, 1-4-4, Kagamiyama, Higashi-Hiroshima, 739-8528, Japan

Lawrence M. Liao has studied and published on the seaweed diversity of Southeast Asia with particular focus on the Philippines. He is also interested in the study of seaweed community changes as affected by climatic and anthropogenic impacts. He is currently appointed as associate professor of aquatic botany at the new Graduate School of Integrated Sciences for Life which evolved from the Graduate School of Biosphere Science at Hiroshima University.



Gerald T. Kraft
School of Biosciences, University of Melbourne, Parkville, Victoria, 3010, Australia
Tasmanian Herbarium, College Road, Sandy Bay, Tasmania, 7005, Australia

Gerald T. Kraft was for 37 years the marine botanist at the University of Melbourne specialising in the taxonomy of marine macroalgae, with particular focus on southern Australia, Lord Howe Island and the southern Great Barrier Reef. His early work was on algal floras in the Philippines for an MSc at the University of Hawaii, to which institution he returned in 2012-2013 as the Wilder Professor. He is now associated with the Tasmanian Herbarium where he continues active research in collaboration with Prof. Gary W. Saunders of the University of New Brunswick.