

Diversity and distribution of marine benthic algae and seagrasses in the tropical Kimberley, Western Australia

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ABSTRACT – The algal and seagrass diversity at 177 marine survey stations in the Kimberley region, Western Australia (<30 m depth) was assessed, to establish species inventories and describe community structures. A total of 296 species of marine benthic algae and seagrasses were recorded, comprising 72 Chlorophyta (green algae), 4 Magnoliophyta (seagrasses), 35 Ochrophyta (brown algae) and 185 Rhodophyta (red algae). The generic diversity of the marine flora was largely typical for tropical Indo-Pacific coral reefs, but as the region was previously underexplored numerous new species were discovered. Records were grouped according to general location (Inshore, Midshelf, Ashmore and Hibernia Reefs, Rowley Shoals), with the greatest diversity recorded for Inshore (229 spp.), followed by the Rowley Shoals (102 spp.), Ashmore and Hibernia reefs (84 spp.), and Midshelf (40 spp.). Of the recorded taxa, 47% (140 spp.) were exclusively found inshore, 1% (3 spp.) exclusively Midshelf, 10% (29 spp.) exclusively at the Rowley Shoals, and 5% (16 spp.) exclusively at Ashmore and Hibernia reefs. Only 10 species were common to all general locations. Specimens collected during the survey formed the basis for the recognition of 52 new species and 4 taxonomic reassignments.

KEYWORDS: Indian Ocean, Kimberley Marine Bioregion, Algae, Seagrasses, Taxonomy, Woodside Collection Project

INTRODUCTION

Between 2009 and 2014, the Western Australian Museum undertook a series of baseline marine biota surveys in the Kimberley region of north-west Western Australia, with the aim of assessing the species diversity of a broad range of taxa, including fish, mobile invertebrates such as crustacea and echinoderms, and immobile invertebrates such as sponges and coral. As part of these surveys the marine flora (or ‘seaweeds’) were also collected and assessed, with the aim of establishing baseline data for the region and supplementing existing collections held in the Western Australian Herbarium. ‘Flora’ for the purposes of this contribution include the seagrasses, green algae and red algae (all Kingdom Plantae), plus the brown algae (Kingdom Chromista). The photosynthetic blue-green algae (Cyanobacteria), phytoplankton and mangroves were not assessed.

Historical collections of marine flora from the region were assessed by Huisman and Sampey (2014) and the value of establishing specimen-based inventories was described by Moore et al. (2020), particularly in relation to the present surveys. A general introduction to the surveys, plus descriptions of broader methodology were described by Bryce et al. (2018a,b) and will not be repeated here.

AIMS

The aim of this study was to record the biodiversity of the shallow water (<30 m) algal and seagrass flora in the Kimberley region of Western Australia over a wide range of habitats and locations.

MATERIALS AND METHODS

The survey locations and general field methods are described in detail in Bryce et al. (2018a) and

Bryce et al. (2018b). Algal and seagrass collections were made by intertidal reef walks or subtidal SCUBA dives covering a range of depths to 30 m. Specimens were pressed while fresh, with small portions dried in silica gel for DNA analysis or 5% formalin/seawater for later microscopic examination, or in the case of encrusting coralline algae washed and air-dried.

As these surveys often represented the first opportunities to collect marine flora at remote Kimberley locations, it was decided to maximise biodiversity by collecting at a range of depths, rather than along a transect at a single depth. As was noted for octocorals (Bryce et al. 2018b), overall biodiversity was always higher than transect biodiversity, and this would also be expected for the flora.

Collections made during the six expeditions were processed as herbarium vouchers and lodged in the Western Australian Herbarium (PERTH) and collection details entered into WAHERB, the specimen database of the WA Herbarium. Collections were made by Huisman (2010, 2011, 2013), Dixon (2009, 2012) and Belton (2014). A total of 852 records were added. These primarily represent the larger macroalgae that were suitable for pressing or boxing. Smaller filamentous species were prepared as microscope slides; where these represented new taxa they have been added to the PERTH database, but many slide-mounted specimens are yet to be incorporated. Additional records have been drawn from Huisman et al. (2009) for the Rowley Shoals and Huisman (2015, 2018). Results of these and earlier surveys of the marine algae of tropical Western Australia are presented in two volumes of the 'Algae of Australia' series (Huisman 2015, 2018) and images of the larger algae are included in Huisman (2019).

There is a fundamental problem in assessing biogeography based on these collections of algae. Many species are small and filamentous, often

epiphytic, and cannot be identified reliably in the field. The recording of epiphytic species is generally undertaken during post-expedition examination of larger taxa and as such is essentially serendipitous. Thus, there is a high potential for bias based on incomplete taxon sampling, with the smaller epiphytes going unnoticed and thus not recorded. Similarly, crustose species (such as encrusting coralline algae and the Peyssonneliaceae) are difficult to collect and identify. Many of the species in these groups are essentially cryptic and not distinguishable in the field, and in most cases the collections were identified based on post-expedition DNA sequence analyses (for example see Dixon 2018). It is highly unlikely that the full complement of crustose species was collected from each locality and as such records of these species are also potentially biased.

RESULTS

A total of 296 species of marine benthic algae and seagrasses are recorded herein (Table 1). These comprise 72 Chlorophyta (green algae), 4 Magnoliophyta (seagrasses), 35 Ochrophyta (brown algae) and 185 Rhodophyta (red algae). Here, as in Bryce et al. (2018b), the collection sites are divided into four categories and the species present are listed in Table 1. Examples of species recorded are presented in Figures 1–3. The greatest species diversity (216 spp.) was recorded for the Kimberley Inshore, with lower diversities at the Rowley Shoals (81 spp.), Ashmore and Hibernia Reefs (62 spp.) and the Midshelf (31 spp.). This trend undoubtedly reflects a greater diversity of Inshore habitats, but any conclusions must be tempered by the caveats concerning recording bias indicated earlier, plus the differences in collection effort. Of the 179 sites visited, 110 were Inshore, 57 were offshore (Ashmore and Hibernia Reefs, Rowley Shoals) and only 12 were Midshelf.

TABLE 1 Species of algae and seagrasses recorded from the Kimberley survey area. Names in bold are species newly described or revised taxonomically based on specimens collected during these surveys.

Taxa	Kimberley Inshore	Midshelf	Ashmore and Hibernia Reefs	Rowley Shoals
CHLOROPHYTA				
Family: Anadyomenaceae				
<i>Anadyomene plicata</i> C. Agardh, 1823	1			1
<i>Anadyomene wrightii</i> Harv. ex J.E. Gray, 1866				1
Family: Boodleaceae				
<i>Boodlea composita</i> (Harv.) Brand, 1904	1		1	1
<i>Boodlea vanbosseae</i> Reinbold, 1905		1	1	1

Taxa	Kimberley Inshore	Midshelf	Ashmore and Hibernia Reefs	Rowley Shoals
<i>Cladophoropsis vaucheriiformis</i> (Aresch.) Papenf., 1958	+			
<i>Phyllocladon anastomosans</i> (Harv.) Kraft & M.J. Wynne, 1996				+
<i>Phyllocladon orientale</i> (A. Gepp & E. Gepp) Kraft & M.J. Wynne, 1996				+
Family: Bryopsidaceae				
<i>Bryopsis pennata</i> J.V. Lamour., 1809	+			
Family: Caulerpaceae				
<i>Caulerpa agardhii</i> Weber Bosse, 1898	+			
<i>Caulerpa chemnitzia</i> (Esper) J.V. Lamour., 1809	+			+
<i>Caulerpa corynephora</i> Mont., 1842	+			
<i>Caulerpa cupressoides</i> (Vahl) C. Agardh, 1817	+		+	+
<i>Caulerpa cylindracea</i> Sond., 1845	+			
<i>Caulerpa filicoides</i> Yamada, 1936			+	
<i>Caulerpa lamourouxii</i> (Turner) C. Agardh, 1817	+			
<i>Caulerpa lentillifera</i> J. Agardh, 1837	+		+	+
<i>Caulerpa macrodisca</i> Decne., 1842	+			
<i>Caulerpa racemosa</i> (Forssk.) J. Agardh, 1873	+		+	+
<i>Caulerpa serrulata</i> (Forssk.) J. Agardh, 1837	+	+	+	+
<i>Caulerpa sertularioides</i> (S.G. Gmelin) M. Howe, 1905	+			
<i>Caulerpa taxifolia</i> (Vahl) C. Agardh, 1817	+		+	+
<i>Caulerpa urvilleana</i> Mont., 1845			+	+
<i>Caulerpa verticillata</i> J. Agardh, 1847	+		+	
<i>Caulerpa webbiana</i> Mont., 1837	+	+	+	+
Family: Cladophoraceae				
<i>Chaetomorpha indica</i> (Kütz.) Kütz., 1849	+			
<i>Cladophora catenata</i> Kütz., 1843	+		+	
<i>Cladophora</i> sp.	+	+		
<i>Lychaete herpestica</i> (Mont.) M.J. Wynne, 2017	+		+	+
Family: Codiaceae				
<i>Codium arabicum</i> Kütz., 1856	+			+
<i>Codium dwarkense</i> Børgesen, 1947	+			+
<i>Codium geppiorum</i> O.C. Schmidt, 1923	+			+
<i>Codium strangulatum</i> Chacana & P.C. Silva, 2015				+
Family: Dasycladaceae				
<i>Bornetella oligospora</i> Solms., 1892	+			
<i>Neomeris bilimbata</i> Koster, 1937	+	+		+
<i>Parvocaulis parvulus</i> (Solms) S. Berger, Fettweiss, Gleissberg, L.B. Liddle, U. Richt., Sawitzky & Zuccarello, 2003	+			
Family: Derbesiaceae				
<i>Derbesia attenuata</i> E.Y. Dawson, 1954	+			
Family: Dichotomosiphonaceae				
<i>Avrainvillea amadelpha</i> (Mont.) A. Gepp & E. Gepp, 1908	+			+
<i>Avrainvillea erecta</i> (Berk.) A. Gepp & E. Gepp, 1911	+			

Taxa	Kimberley Inshore	Midshelf	Ashmore and Hibernia Reefs	Rowley Shoals
Family: Dictyosphaeriaceae				
<i>Dictyosphaeria cavernosa</i> (Forssk.) Børgesen, 1932	+	+	+	+
<i>Dictyosphaeria versluysii</i> Weber Bosse, 1905	+	+	+	+
<i>Valoniopsis pachynema</i> (G. Martens) Børgesen, 1934	+		+	
Family: Halimedaceae				
<i>Halimeda cylindracea</i> Decne., 1842	+		+	
<i>Halimeda discoidea</i> Decne., 1842	+	+		+
<i>Halimeda distorta</i> (Yamada) Hillis-Col., 1968	+	+	+	+
<i>Halimeda gigas</i> W.R. Taylor, 1950	+		+	
<i>Halimeda gracilis</i> J. Agardh, 1887			+	+
<i>Halimeda heteromorpha</i> N'Yeurt, 2006	+			
<i>Halimeda lacunalis</i> W.R. Taylor, 1950				+
<i>Halimeda macroloba</i> Decne., 1841	+		+	+
<i>Halimeda macrophysa</i> Askenasy, 1888				+
<i>Halimeda micronesica</i> Yamada, 1941		+	+	+
<i>Halimeda minima</i> (W.R. Taylor) Hillis-Col., 1968	+		+	+
<i>Halimeda opuntia</i> (L.) J.V. Lamour., 1816	+		+	+
<i>Halimeda taenicola</i> W.R. Taylor, 1950			+	
<i>Halimeda tuna</i> (J. Ellis & Sol.) J.V. Lamour., 1816	+			
<i>Halimeda velasquezii</i> W.R. Taylor, 1962	+		+	
<i>Halimeda xishaensis</i> C.K. Tseng & M.L. Dong, 1980	+		+	
Family: Rhipiliaceae				
<i>Rhipidosiphon javensis</i> Mont., 1842			+	
<i>Rhipilia nigrescens</i> Coppejans & Prud'homme, 1990	+			
<i>Rhipiliopsis echinocaulos</i> (Cribb) Farghaly, 1986				+
<i>Rhipiliopsis papuensis</i> Coppejans, De Clerck & Leliaert, 1999	+			
Family: Siphonocladaceae				
<i>Boergesenia forbesii</i> (Harv.) Feldmann, 1938	+	+		
Family: Udoteaceae				
<i>Tydemania expeditionis</i> Weber Bosse, 1901			+	
<i>Udotea argentea</i> Zanardini, 1858	+			
<i>Udotea flabellum</i> (J. Ellis & Sol.) M. Howe, 1904	+			
<i>Udotea glaucescens</i> J. Agardh, 1887	+			+
<i>Udotea orientalis</i> A. Gepp & E. Gepp, 1911	+			
Family: Ulvaceae				
<i>Ulva flexuosa</i> Wulfen, 1803	+			+
<i>Ulva kraftiorum</i> Huisman, 2015	+			
Family: Ulvellaceae				
<i>Ulvella lens</i> P. Crouan & H. Crouan, 1859	+			
Family: Valoniaceae				
<i>Valonia fastigiata</i> J. Agardh, 1887				+
<i>Valonia ventricosa</i> J. Agardh, 1887		+	+	+

Taxa	Kimberley Inshore	Midshelf	Ashmore and Hibernia Reefs	Rowley Shoals
MAGNOLIOPHYTA				
Family: Cymodoceaceae				
<i>Thalassodendron ciliatum</i> (Forssk.) Hartog, 1970			+	+
Family: Hydrocharitaceae				
<i>Halophila decipiens</i> Ostenf., 1902	+		+	
<i>Halophila ovalis</i> (R. Br.) Hook.f., 1858	+		+	+
<i>Thalassia hemprichii</i> (Ehrenb.) Asch., 1871	+		+	+
OCHROPHYTA				
Family: Acinetosporaceae				
<i>Feldmannia indica</i> (Sond.) Womersley & A. Bailey, 1970	+			
<i>Feldmannia irregularis</i> (Kütz.) Hamel, 1939	+			
Family: Chordariaceae				
<i>Nemacystus decipiens</i> (Suringar) Kuck., 1929	+			
Family: Dictyotaceae				
<i>Canistrocarpus cervicornis</i> (Kütz.) De Paula & De Clerck, 2006	+			
<i>Dictyopteria australis</i> (Sond.) Askenasy, 1888	+			
<i>Dictyopteria repens</i> (Okamura) Børgesen, 1924		+		
<i>Dictyopteria woodwardia</i> (Turner) C. Agardh, 1817	+			
<i>Dictyota ciliolata</i> Kütz., 1859	+			
<i>Dictyota friabilis</i> Setch., 1926	+	+		+
<i>Dictyota</i> sp.	+		+	
<i>Lobophora variegata</i> (J.V. Lamour.) Oliviera, 1977	+			+
<i>Padina australis</i> Hauck, 1997	+			
<i>Padina boryana</i> Thivy in W.R. Taylor, 1966				+
<i>Padina</i> sp.	+	+	+	+
<i>Spatoglossum macrodontum</i> J. Agardh, 1882	+			
<i>Styopodium flabelliforme</i> Weber Bosse, 1913	+			+
Family: Sargassaceae				
<i>Hormophysa cuneiformis</i> (J.F. Gmel.) P.C. Silva, 1987	+			
<i>Sargassopsis decurrens</i> (Turner) Trevis., 1843	+			
<i>Sargassum aquifolium</i> (Turner) C. Agardh, 1820	+			
<i>Sargassum ilicifolium</i> (Turner) C. Agardh, 1820	+		+	
<i>Sargassum ligulatum</i> C. Agardh, 1824	+			
<i>Sargassum linearifolium</i> (Turner) C. Agardh, 1820	+			
<i>Sargassum marginatum</i> (C. Agardh) J. Agardh, 1848	+			
<i>Sargassum polycystum</i> C. Agardh, 1824	+			
<i>Sargassum rasta</i> R.R.M. Dixon & Huisman, 2015	+			
<i>Sargassum swartzii</i> C. Agardh, 1820	+			
<i>Sirophysalis trinodis</i> (Forssk.) Kütz., 1849	+			
<i>Turbinaria conoides</i> (J. Agardh) Kütz., 1860	+			
<i>Turbinaria gracilis</i> Sond., 1845	+			
<i>Turbinaria ornata</i> (Turner) J. Agardh, 1848	+		+	+

Taxa	Kimberley Inshore	Midshelf	Ashmore and Hibernia Reefs	Rowley Shoals
Family: Scytosiphonaceae				
<i>Colpomenia sinuosa</i> (Roth) Derbès & Solier, 1851	+			
<i>Hydroclathrus clathratus</i> (C. Agardh) Howe, 1920	+	+	+	+
<i>Rosenvingea intricata</i> (J. Agardh) Børgesen, 1914	+	+		+
Family: Sphacelariaceae				
<i>Sphacelaria novae-hollandiae</i> Sond., 1845				+
<i>Sphacelaria rigidula</i> Kütz., 1843	+			
RHODOPHYTA				
Family: Acrochaetiaceae				
<i>Acrochaetium liagorae</i> Børgesen, 1915	+	+		
Family: Acrosymphytaceae				
<i>Acrosymphyton taylorii</i> I.A. Abbott, 1962		+	+	
Family: Bonnemaisoniaceae				
<i>Asparagopsis taxiformis</i> (Delile) Trevisan, 1845	+	+		+
Family: Callithamniaceae				
<i>Aglaothamnion cordatum</i> (Børgesen) Feldm.-Maz., 1941	+	+	+	+
<i>Crouania dampieriana</i> Huisman, 2018	+			
<i>Crouania eliseae</i> C.W. Schneider, 2004	+			
<i>Seirospora orientalis</i> Kraft, 1988	+			+
Family: Caulacanthaceae				
<i>Pseudocaulacanthus spinescens</i> Huisman, 2018				+
Family: Ceramiaceae				
<i>Antithamnionella graeffei</i> (Grunow) Athanas., 1996	+			
<i>Balliella crouanioides</i> (Itono) Itono & Tak. Tanaka, 1973	+			
<i>Balliella subcorticata</i> Itono & Tak. Tanaka, 2018				+
<i>Centroceras gasparrinii</i> (Menegh.) Kütz., 1849	+			+
<i>Ceramium aduncum</i> Y. Nakam., 1950	+			
<i>Ceramium affine</i> Setch. & N.L. Gardner, 1930	+			
<i>Ceramium cingulatum</i> Weber Bosse, 1923	+			
<i>Ceramium codii</i> (H. Richards) Feldm.-Maz., 1938	+			+
<i>Ceramium isogonum</i> Harv., 1855			+	
<i>Ceramium macilentum</i> J. Agardh, 1894				+
<i>Ceramium phillipsiae</i> Huisman, 2018				+
<i>Ceramium pseudocodii</i> Huisman, 2018				+
<i>Ceramium subdichotomum</i> Weber Bosse, 1923	+			
<i>Corallophila kleiwegii</i> Weber Bosse, 1923				+
<i>Gayliella fimbriata</i> (Setch. & N.L. Gardner) T.O. Cho & S.M. Boo, 2008				+
<i>Gayliella macrotricha</i> (Feldm.-Maz.) Huisman, 2018				+
<i>Gayliella transversalis</i> (Collins & Herv.) T.O. Cho & Fredericq, 2008	+			+

Taxa	Kimberley Inshore	Midshelf	Ashmore and Hibernia Reefs	Rowley Shoals
Family: Champiaceae				
<i>Champia pseudoparvula</i> Huisman & G.W. Saunders, 2018	+			
<i>Champia stipitata</i> Huisman, 2000	+			
<i>Champia subcompressa</i> Huisman & G.W. Saunders, 2018	+			
<i>Coelothrix irregularis</i> (Harv.) Børgesen, 1920	+		+	+
Family: Corallinaceae				
<i>Jania pedunculata</i> J.V. Lamour., 1816	+			+
<i>Jania spectabilis</i> (Grunow) J.H. Kim, Guiry & H.G. Choi, 2007	+			
Family: Corynocyttaceae				
<i>Corynocyttis prostrata</i> Kraft, 1999			+	+
Family: Corynomorphaceae				
<i>Corynomorpha prismatica</i> (J. Agardh) J. Agardh, 1876	+			
Family: Cystocloniaceae				
<i>Hypnea charoides</i> J.V. Lamour., 1813	+			
<i>Hypnea pannosa</i> J. Agardh, 1847	+		+	
Family: Dasyaceae				
<i>Dasya frutescens</i> Harv., 1855	+			
<i>Dasya</i> sp.	+		+	
<i>Heterosiphonia crassipes</i> (Harv.) Falkenb., 1901	+			
Family: Delesseriaceae				
<i>Hypoglossum anomalum</i> M.J. Wynne & D.L. Ballant., 1986	+			
<i>Hypoglossum caloglossoides</i> M.J. Wynne & Kraft, 1985	+			
<i>Martensia millarii</i> Huisman, 2018	+	+	+	
<i>Vanvoorstia spectabilis</i> Harv., 1854	+			
<i>Zellera tawallina</i> G. Martens, 1866	+	+	+	
Family: Dumontiaceae				
<i>Dudresnaya hawaiiensis</i> R.K.S. Lee, 1963			+	
<i>Gibsmithia indopacifica</i> D. Gabriel, Draisma & Fredericq, 2017		+	+	+
<i>Gibsmithia larkumii</i> Kraft, 1986		+	+	
Family: Etheliaceae				
<i>Ethelia denizotii</i> K.R. Dixon, 2015	+			
Family: Faucheaceae				
<i>Gloioderma iyoense</i> Okamura, 1934	+	+	+	
Family: Galaxauraceae				
<i>Actinotrichia coccinea</i> Huisman, G.H. Boo & S.M. Boo, 2018			+	+
<i>Actinotrichia fragilis</i> (Forssk.) Børgesen, 1932	+			+
<i>Dichotomaria sibogae</i> (Weber Bosse) Huisman, G.H. Boo, S.M. Boo & S.-M. Lin, 2018	+	+	+	+
<i>Galaxaura elongata</i> J. Agardh, 1876	+			
<i>Galaxaura glabriuscula</i> Kjellm., 1900	+	+	+	+
<i>Galaxaura indica</i> Huisman, G.H. Boo & S.M. Boo, 2018			+	

Taxa	Kimberley Inshore	Midshelf	Ashmore and Hibernia Reefs	Rowley Shoals
<i>Galaxaura pacifica</i> Tanaka, 1935			+	
<i>Tricleocarpa fastigiata</i> (Decne.) Huisman, G.H. Boo & S.M. Boo, 2018			+	
Family: Gelidiaceae				
<i>Pterocladia caerulescens</i> (Kütz.) Santel. & Hommers., 1997	+			
Family: Gelidiellaceae				
<i>Gelidiella acerosa</i> (Forssk.) Feldmann & Hamel, 1934	+		+	+
<i>Gelidiella fanii</i> S.-M. Lin, 2008	+			
Family: Gracilariaceae				
<i>Gracilaria canaliculata</i> Sond., 1871	+		+	
<i>Gracilaria salicornia</i> (C. Agardh) E.Y. Dawson, 1954	+			
<i>Gracilaria vieillardii</i> P.C. Silva, 1987	+		+	
<i>Gracilaria webervanbosseae</i> Huisman & G.W. Saunders, 2018	+			
<i>Hydropuntia urvillei</i> Mont., 1842	+			
Family: Halymeniaceae				
<i>Halymenia maculata</i> J. Agardh, 1885	+			
<i>Halymenia malaysiana</i> P.L. Tan, P.E. Lim, S.-M. Lin & Phang, 2018	+			
<i>Halymenia villosa</i> Huisman & De Clerck, 2018	+			
Family: Hapalidiaceae				
<i>Lithothamnion proliferum</i> Foslie, 1904	+			
<i>Lithothamnion sonderi</i> Hauck, 1883				+
<i>Melobesia tomitaroi</i> Kloczkova, 1987	+			
<i>Mesophyllum</i> cf. <i>funafutiense</i> (Foslie) Verheij, 1993	+			
<i>Rhizolamellia colli</i> Shevejkó, 1982			+	+
Family: Hydrolithaceae				
<i>Hydrolithon farinosum</i> (J.V. Lamour.) Penrose & Y.M. Chamb., 1993				+
<i>Hydrolithon boergesenii</i> (Foslie) Foslie, 1909	+	+		
Family: Hymenocladaceae				
<i>Asteromenia exanimans</i> G.W. Saunders, C.E. Lane, C.W. Schneid. & Kraft, 2006	+			
<i>Asteromenia kimberleyensis</i> Huisman & G.W. Saunders, 2018	+			
<i>Asteromenia poeciloderma</i> Huisman & G.W. Saunders, 2018				+
Family: Kallymeniaceae				
<i>Leiomenia imbricata</i> Huisman & G.W. Saunders, 2017			+	
<i>Leiomenia lacunata</i> Huisman & G.W. Saunders, 2017			+	
<i>Rhytymenia maculata</i> (Weber Bosse) Huisman & G.W. Saunders, 2016			+	
Family: Liagoraceae				
<i>Dotyophycus damaru</i> Huisman & S.-M. Lin, 2018	+			
<i>Ganonema farinosum</i> (J.V.Lamour.) K.C. Fan & Yung C. Wang, 1974	+			

Taxa	Kimberley Inshore	Midshelf	Ashmore and Hibernia Reefs	Rowley Shoals
<i>Ganonema robustum</i> Huisman & S.-M. Lin, 2018			+	+
<i>Hommersandiohyphycus kraftii</i> Huisman & S.-M. Lin, 2018			+	+
<i>Izziella vulcanensis</i> Huisman & S.-M. Lin, 2018		+		
<i>Liagora ceranoides</i> J.V. Lamour., 1816	+			
<i>Macrocarpus perennis</i> (I.A.Abbott) S.-M. Lin, S.Y. Yang & Huisman, 2018	+			
<i>Neoizziella asiatica</i> S.-M. Lin, S.Y. Yang & Huisman, 2011	+			
<i>Titanophycus saundersii</i> Huisman & S.-M. Lin, 2018			+	
<i>Trichogloea requienii</i> (Mont.) Kütz., 1847		+	+	
<i>Yoshizakia indopacifica</i> S.-M. Lin, Huisman & Payri, 2013	+			
Family: Lithophyllaceae				
<i>Amphiroa crassa</i> J.V. Lamour., 1824	+			
<i>Amphiroa foliacea</i> J.V. Lamour., 1824	+			
<i>Amphiroa fragilissima</i> (L.) J.V. Lamour., 1816	+			+
<i>Amphiroa tribulus</i> (J. Ellis & Sol.) J.V. Lamour., 1816	+			+
<i>Lithophyllum kaiseri</i> (Heydr.) Heydr., 1897	+			
<i>Lithophyllum longense</i> Hern.-Kant., P.W. Gabrielson & R.A. Towns., 2018	+			
<i>Titanoderma pustulatum</i> (J.V. Lamour.) Nägeli, 1858	+			
Family: Lomentariaceae				
<i>Ceratodictyon intricatum</i> (C. Agardh) R.E. Norris, 1987				+
<i>Ceratodictyon scoparium</i> (Mont. & Millardet) R.E. Norris, 1987		+		
<i>Ceratodictyon spongiosum</i> Zanardini, 1878	+		+	
Family: Mastophoraceae				
<i>Mastophora multistrata</i> Keats, 2009	+			+
<i>Mastophora rosea</i> (C. Agardh) Setch., 1943	+			
Family: Nemastomataceae				
<i>Predaea laciniosa</i> Kraft, 1984		+		+
<i>Predaea sophieae</i> Huisman, 2018	+			
<i>Predaea weldii</i> Kraft & I.A. Abbott, 1971		+	+	+
Family: Peyssonneliaceae				
<i>Incendia cryptica</i> K.R. Dixon, 2018	+			
<i>Incendia homosorora</i> K.R. Dixon, 2018	+	+		
<i>Incendia undulata</i> K.R. Dixon, 2013				+
<i>Peyssonnelia atricolor</i> K.R. Dixon, 2018	+			
<i>Peyssonnelia clathrata</i> K.R. Dixon, 2018	+			
<i>Peyssonnelia confluens</i> K.R. Dixon, 2018	+			
<i>Peyssonnelia impermia</i> K.R. Dixon, 2018	+			
<i>Peyssonnelia pseudostrata</i> K.R. Dixon, 2018	+			+
<i>Peyssonnelia rainboae</i> K.R. Dixon, 2018	+			
<i>Peyssonnelia tenuiderma</i> K.R. Dixon, 2018	+			
<i>Peyssonnelia webervanbosseae</i> K.R. Dixon, 2018	+			
<i>Polystrata erupta</i> K.R. Dixon, 2018	+			
<i>Polystrata kimberleyensis</i> K.R. Dixon, 2018	+			

Taxa	Kimberley Inshore	Midshelf	Ashmore and Hibernia Reefs	Rowley Shoals
<i>Ramicrusta appressa</i> K.R. Dixon, 2013	+			
<i>Ramicrusta melanoidea</i> K.R. Dixon, 2018	+			
<i>Seiria magnifusa</i> K.R. Dixon, 2018	+			
<i>Sonderophycus fervens</i> K.R. Dixon, 2018	+			
Family: Porolithaceae				
<i>Dawsoniolithon conicum</i> (E.Y. Dawson) Caragnano, Foetisch, Maneveldt & Payri, 2018	+			
<i>Dawsoniolithon gabrielsonii</i> R.A. Towns. & Huisman, 2018	+			+
<i>Floiophycus walteradeyi</i> R.A. Towns. & Huisman, 2018				+
<i>Porolithon imitatum</i> R.A. Towns. & G.W. Saunders, 2018	+			+
<i>Porolithon maneveltdtii</i> R.A. Towns. & Huisman, 2018	+			+
<i>Porolithon pachydermum</i> (Foslie) Foslie, 1909	+			
<i>Porolithon penroseae</i> R.A. Towns. & P.W. Gabrielson, 2018	+			+
Family: Rhizophyllidaceae				
<i>Contarinia pacifica</i> (Børgesen) Denizot, 1968				+
<i>Contarinia ventriglandis</i> K.R. Dixon, 2018	+			
<i>Portieria hornemannii</i> (Lyngb.) P.C. Silva, 1987	+	+	+	
Family: Rhodomelaceae				
<i>Acanthophora ramulosa</i> Kütz., 1843	+			
<i>Acanthophora spicifera</i> (Vahl) Børgesen, 1910	+		+	+
<i>Amansia rhodantha</i> (Harv.) J. Agardh, 1841	+			
<i>Bostrychia tenella</i> (J.V. Lamour.) J. Agardh, 1863	+			
<i>Chondria armata</i> (Kütz.) Okamura, 1907	+			
<i>Chondria dangeardii</i> E.Y. Dawson, 1954	+			
<i>Chondria minutula</i> Weber Bosse, 1923				+
<i>Chondria transversalis</i> Børgesen, 1938	+			
<i>Digenea simplex</i> (Wulfen) C. Agardh, 1822	+			
<i>Herposiphonia elongata</i> M. Masuda & K. Kogame, 2000				+
<i>Herposiphonia mermaidensis</i> Huisman, 2018				+
<i>Laurencia brongniartii</i> J. Agardh, 1841	+			
<i>Laurencia dendroidea</i> J. Agardh, 1852	+			
<i>Laurencia similis</i> K.W. Nam & Y. Saito, 1991	+			
<i>Leveillea jungermannioides</i> (E. Hering & G. Martens) Harv., 1855	+		+	
<i>Lophocladia</i> sp.	+	+		
<i>Melanothamnus ferulaceus</i> (J. Agardh) Díaz-Tapia & Maggs, 2017	+			
<i>Melanothamnus quadratus</i> (Hollenb.) Huisman, 2018	+			
<i>Melanothamnus upolensis</i> (Grunow) Díaz-Tapia & Maggs, 2017	+			
<i>Palisada perforata</i> (Bory) K.W. Nam, 2007	+			
<i>Polysiphonia beltoniorum</i> Huisman, 2018	+			
<i>Polysiphonia kimiae</i> Huisman, 2018	+			
<i>Spirocladia loochooensis</i> (Yendo) T. Yoshida, 1989	+			
<i>Tolypocladia calodictyon</i> (Kütz.) P.C. Silva, 1952	+		+	

Taxa	Kimberley Inshore	Midshelf	Ashmore and Hibernia Reefs	Rowley Shoals
<i>Tolypocladia glomerulata</i> (C. Agardh) F. Schmitz, 1897	+		+	
<i>Vidalia melvillii</i> (J. Agardh) F. Schmitz, 1895	+			
Family: Rhodymeniaceae				
<i>Botryocladia leptopoda</i> (J. Agardh) Kylin, 1931	+			
<i>Botryocladia skottsbergii</i> (Børgesen) Levring, 1943		+	+	
<i>Chamaebotrys boergesenii</i> (Weber Bosse) Huisman, 1996	+			+
<i>Coelarthrum opuntia</i> (Endl.) Børgesen, 1937	+			
Family: Schizymeniaceae				
<i>Titanophora pikeana</i> (Dickie) Feldmann, 1942			+	
Family: Scinaiceae				
<i>Scinaia tsinglanensis</i> C.K. Tseng, 1941	+	+		
Family: Sebdeniaceae				
<i>Cryptocallis dixoniorum</i> Huisman & G.W. Saunders, 2018	+			
<i>Sebdenia polydactyla</i> (Børgesen) M.P. Balakr., 1961	+			
Family: Solieriaceae				
<i>Betaphycus speciosus</i> (Sond.) P.C. Silva, 1996	+			
<i>Eucheuma arnoldii</i> Weber Bosse, 1928	+		+	
<i>Eucheuma denticulatum</i> (Burm.f.) Collins & Herv., 1917	+			
<i>Solieria robusta</i> (Grev.) Kylin, 1932	+			
Family: Spongitaceae				
<i>Neogoniolithon brassica-florida</i> (Harv.) Setch. & L.R. Mason, 1943	+			+
Family: Sporolithaceae				
<i>Sporolithon episoredion</i> (W.H. Adey, R.A. Towns. & Boykins) Verheij, 1992				+
Family: Spyridiaceae				
<i>Spyridia filamentosa</i> (Wulfen) Harv., 1833	+			+
Family: Stylonemataceae				
<i>Stylonema alsidii</i> (Zanardini) K.M. Drew, 1956			+	
Family: Tsengiaceae				
<i>Tsengia flammaea</i> Huisman & G.W. Saunders, 2018			+	
Family: Wrangeliaceae				
<i>Anotrichium tenue</i> (C. Agardh) Nägeli, 1862	+		+	+
<i>Grallatoria reptans</i> M. Howe, 1920	+			
<i>Griffithsia heteromorpha</i> Kütz., 1863	+			
<i>Griffithsia schousboei</i> Mont., 1839	+			
<i>Haloplegma duperreyi</i> Mont., 1842			+	+
<i>Spongoclonium caribaeum</i> (Børgesen) M.J. Wynne, 2005	+			
<i>Wrangelia</i> sp.	+	+	+	
Family: Yamadaellaceae				
<i>Yamadaella australis</i> Huisman & S.-M. Lin, 2018	+			
<i>Yamadaella caenomyce</i> (Decne.) I.A. Abbott, 1970	+			

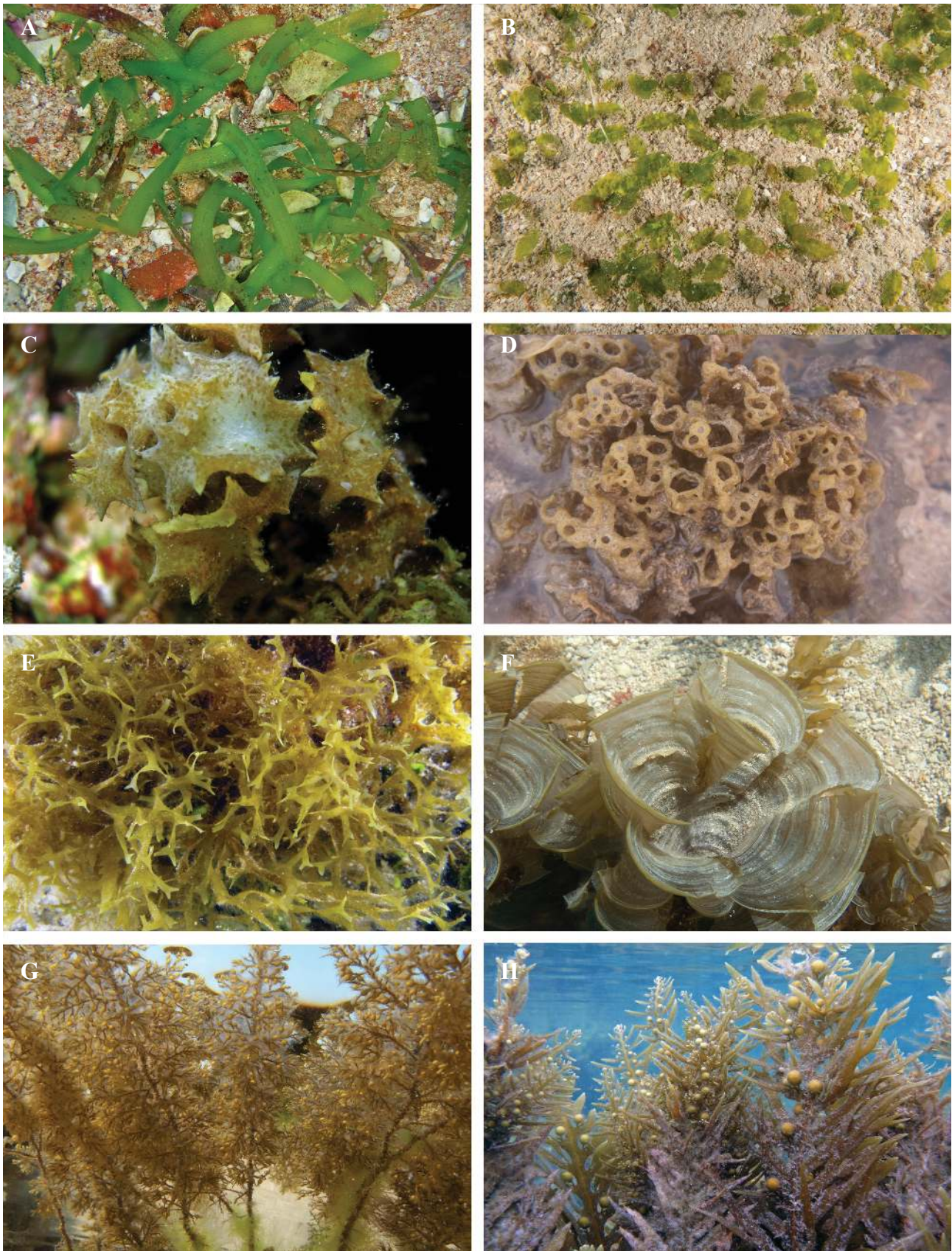


FIGURE 1 Species of seagrasses and brown algae from the Kimberley survey area: A) *Thalassia hemprichii* (Hydrocharitaceae); B) *Halophila decipiens* (Hydrocharitaceae); C) *Turbinaria ornata* (Sargassaceae); D) *Hydroclathrus clathratus* (Scytosiphonaceae); E) *Canistrocarpus cervicornis* (Dictyotaceae); F) *Padina australis* (Dictyotaceae); G) *Sirophysalis trinodis* (Sargassaceae); H) *Sargassopsis decurrens* (Sargassaceae).



FIGURE 2 Species of green algae from the Kimberley survey area: A) *Halimeda minima* (Halimedaceae); B) *Caulerpa serrulata* (Caulerpaceae); C) *Tydemania expeditionis* (Udoteaceae); D) *Cladophoropsis vaucheriiformis* (Boodleaceae); E) *Caulerpa filicoides* (Caulerpaceae); F) *Valonia ventricosa* (Valoniaceae); G) *Codium arabicum* (Codiaceae); H) *Dictyosphaeria versluysii* (Dictyosphaeriaceae).

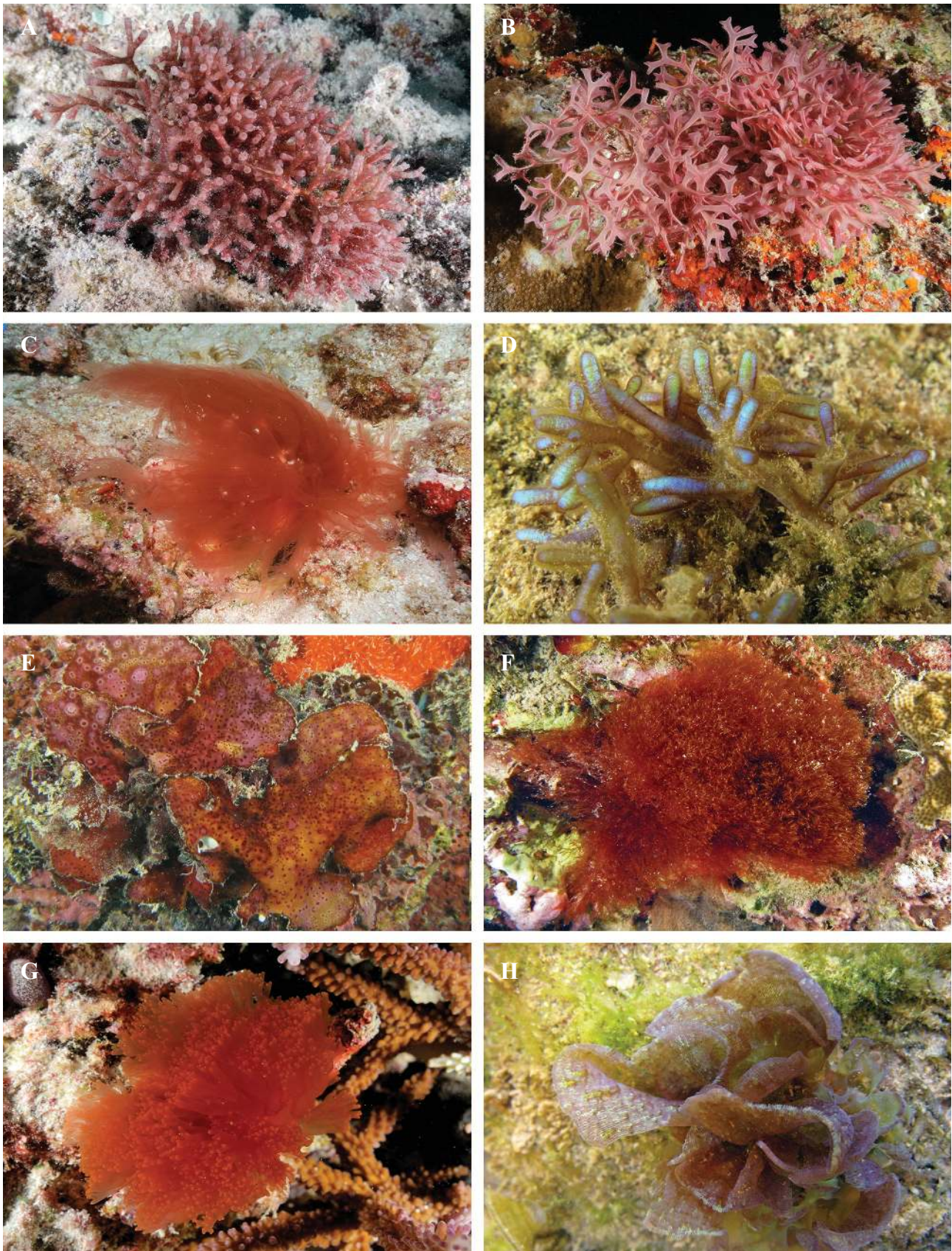


FIGURE 3 Species of red algae from the Kimberley survey area: A) *Galaxaura indica* (Galaxauraceae); B) *Dichotomaria sibogae* (Galaxauraceae); C) *Acrosymphyton taylorii* (Acrosymphytaceae); D) *Champia subcompressa* (Champiaceae); E) *Cryptocallis dixoniorum* (Sebdeniaceae); F) *Balliella crouanioides* (Ceramiaceae); G) *Tsengia flammea* (Tsengiaceae); H) *Martensia millarii* (Delesseriaceae).

DISCUSSION

The results of the present surveys were incorporated with earlier survey results (e.g., Belton et al. 2014; Huisman 2004; Huisman et al. 2009) into broader studies of the tropical NW Australian marine algal flora, including earlier Kimberley collections and collections from the Pilbara and Gascoyne coasts as far south as Coral Bay (just north of the Tropic of Capricorn). These were presented in two volumes of the 'Algae of Australia' series, the first describing the green and brown algae (Huisman 2015) and the second the red algae (Huisman 2018). Those publications recorded 68 genera and 171 species of green and brown algae and 158 genera and 351 species of red algae. The contents of Huisman (2015) did not include results of the Ashmore and Hibernia Reef survey and the later Rowley Shoals survey, but only two green algal species, *Caulerpa filicoides* and *Tydemania expeditionis*, were newly recorded for the region. Both species are relatively common on tropical Pacific reefs, but prior to the 2013 survey had not been recorded for the Western Australian coast.

Huisman and Sampey (2014) collated all historical records of marine plants from the Kimberley and recorded 308 species (88 Chlorophyta, 39 Ochrophyta, 145 Rhodophyta, 12 seagrasses, 18 mangroves and 6 Cyanobacteria). These totals are comparable to those based on our recent surveys, although mangroves and cyanobacteria were not recorded. However, there are notable changes in the species composition between the historical and recent records. These are primarily the result of taxonomic revisions and recognition of new species based on recent collections. Many of the historical records were of species considered to be widespread, but further study on recent specimens, often incorporating DNA sequence analyses, have revealed a greater diversity than previously recognised and a greater number of geographically restricted species. For example, the historical record of the Bahamian red alga *Dichotomaria marginata* (J. Ellis and Sol.) Lam. has been shown to be misapplied and is now referred to the Indonesian species *Dichotomaria sibogae* (Weber Bosse) Huisman et al. (Huisman et al. 2018). Similarly, *Gibsmithia hawaiiensis* Doty is now regarded to be restricted to the Hawaiian Islands and the Kimberley species is referred to *Gibsmithia indopacifica* Gabriel et al. (Gabriel et al. 2017).

Several of the newly recorded species collected in the recent surveys were originally described from more northern, non-Australian locations, particularly, and not unexpectedly, Indonesia. These species were based on collections made during the Dutch Siboga Expedition (1899–1900) to the Netherlands East Indies [= the Indonesian Archipelago] and described by Anna Weber-van

Bosse. Some 14 species are included in this group, some of which had not been recollected since the original expedition. The recent specimens have enabled a more detailed assessment of the Weber-van Bosse taxa, incorporating molecular and morphological analyses. An example is *Rhytymenia maculata*, which was described originally from Makassar Strait (off Borneo) by Weber-van Bosse (1928) as *Kallymenia maculata*. Molecular and morphological analyses revealed that this species is incorrectly placed in *Kallymenia* and the new genus *Rhytymenia* was erected for the species (Huisman et al. 2016).

The recognition of new species following DNA analyses has also had a significant impact, notably in some of the more 'difficult' groups such as the Peyssonneliaceae, a family of red algae comprising mostly encrusting taxa. The historical records included only a single species, whereas studies of the recently collected material revealed a staggering 17 species in six genera (Dixon, 2018). It is clear these surveys and recent activities have contributed substantially to our understanding of the Kimberley marine flora, but in many cases we have only scratched the surface and further surveys will undoubtedly reveal additional new and unrecorded species.

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