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Marine Biodiversity of the Kimberley 1880s–2009

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Kimberley marine biota. Historical data: marine plants

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ABSTRACT – Here, we document 308 species of marine flora from the Kimberley region of Western Australia based on collections held in the Western Australian Herbarium and on reports on marine biodiversity surveys to the region. Included are 12 species of seagrasses, 18 species of mangrove and 278 species of marine algae. Seagrasses and mangroves in the region have been comparatively well surveyed and their taxonomy is stable, so it is unlikely that further species will be recorded. However, the marine algae have been collected and documented only more recently and it is estimated that further surveys will increase the number of recorded species to over 400. The bulk of the marine flora comprised widespread Indo-West Pacific species, but there were also many endemic species with more endemics reported from the inshore areas than the offshore atolls. This number also will increase with the description of new species from the region. Collecting across the region has been highly variable due to the remote location, logistical difficulties and resource limitations. Consequently, large portions of the region remain inadequately sampled, and within the Western Australian Herbarium collections much material awaits identification.

KEYWORDS: natural history collections, species inventory, Kimberley Marine Bioregion, biodiversity, NW Australia, baseline, macroalgae, seagrass, mangrove

INTRODUCTION

Baseline marine biodiversity information to inform conservation and environmental management decisions (Pyke and Ehrlich 2010) is particularly important in the Kimberley region of Australia as it is not only an area of great conservation value, but also of extensive developments in oil and gas, and fishing and aquaculture (Department of Environment and Conservation 2009).

Australian natural science institutions, including the Western Australian Museum (WAM) have undertaken marine biodiversity surveys of the species in the Kimberley Project Area (see Methods). However, much of the data are not readily accessible, being either unpublished or in specialist taxonomic literature, so WAM initiated a data compilation of all marine organisms that will assess the state of marine biodiversity knowledge.

MARINE FLORA

This contribution deals with historical collections of the marine benthic flora of the Kimberley Project Area. This group includes all attached photosynthetic organisms ('plants' in the broad sense) and is comprised of submerged seagrasses and macroalgae, and the intertidal mangroves. Only partially included in this study are photosynthetic bacteria (cyanobacteria or blue-green algae), as the group is in dire need of revision and most records are unreliable.

As photosynthetic primary producers, the marine benthic flora, along with the phytoplankton and symbiotic zooxanthellae, form the foundation for the complex food web that occurs in all marine ecosystems. In addition to this essential role, the benthic flora provide habitat for numerous faunal and floral organisms, give structural support by consolidating reefs and contribute substantially

to the sediment budget. Therefore they form a significant component of all marine ecosystems. As sessile photosynthetic organisms they are also susceptible to environmental perturbation, particularly changes in water quality such as increased turbidity.

The *raison d'être* for collecting and studying marine plants is essentially the same as that for all biodiversity investigations: the accumulation of knowledge. Very little is known about the diversity and ranges of these organisms, particularly in remote areas as defined by the Kimberley Project Area. Elsewhere marine plants are economically important and some are used as food (e.g. *Porphyra* or 'nori'), as food additives, or in industrial processes. Several marine plants are also serious pests and have been introduced, accidentally or intentionally, to regions outside their native ranges. Once established, these pests are virtually impossible to eradicate so it is important the native flora are well documented and monitored for possible pest incursions (Huisman et al. 2008). Some species (e.g. *Undaria pinnatifida* or 'wakame') are not only economically important as a food source, but also serious pests outside their native ranges.

HISTORY OF MARINE FLORAL COLLECTING IN THE KIMBERLEY PROJECT AREA

Published historical records of marine plants in the Project Area are very scant. The voyages of discovery undertaken by British and French expeditions in the 1800s either rarely collected marine plants or, if they were collected, the specimens were not included in published reports. So although limited historical collections may be housed in overseas herbaria, these are not addressed in the present publication.

WAM and the Western Australian Herbarium (official abbreviation PERTH) have undertaken a number of surveys of marine flora in the Project Area since the 1970s (Table 1). Surveys of the mangrove flora were undertaken in conjunction with bird surveys at 83 sites between Cambridge Gulf in the Kimberley and Shark Bay in the Gascoyne region of Western Australia between 1973 and 1982, with 14 species of mangroves collected from 25 locations in the Kimberley (Johnstone 1990). In 1995, 12 species of mangroves were recorded at sites along the southern Kimberley coast (Hanley 1995) and 14 species were recorded in the eastern Kimberley (Saenger 1996).

Five species of seagrasses were collected during the 1991 survey of Kimberley islands and reefs (Walker 1992). Seagrasses were also surveyed along the southern Kimberley coast by Walker in 1994, where she recorded eight species of seagrasses and commented on the extensive seagrass beds at Sunday and Tallon Islands being the largest in the Kimberley (Walker 1995). Only three species of

seagrasses were recorded during the 1995 survey to the eastern Kimberley (Walker 1996) and along the central Kimberley coast in 1996 (Walker 1997). As there was no overlap in the species a total of six species were recorded from these two expeditions. Huisman et al. (2009) recorded three seagrasses from the shelf edge atolls, but an earlier record of *Thalassodendron ciliatum* from Scott Reef by Walker and Prince (1987) brings the atoll total to four. Pike and Leach (1997) and Brown and Skewes (2005) recorded five species of seagrasses at Ashmore Reef. In an earlier publication, Walker and Prince (1987) summarised the seagrass diversity in north-western Australia, recording a total of 12 species from the Kimberley, and none of the recent surveys have increased that number.

In a compendium of records of marine algae from northern Australia, Lewis (1984, 1985, 1987) included some 800 species, only nine of which were attributed to the north Western Australian coast, and of that small number none were from the Kimberley Project Area. Thus, until relatively recently, the marine algal flora of the Kimberley region was virtually unknown. Subsequent collections and publications have increased the number of species known (e.g. Phillips et al. 1993; King and Puttock 1994; Huisman 2002, 2006; Leliaert et al. 2007; Leliaert et al. 2008; Huisman et al. 2009), but the greater proportion of recent collections remains unpublished. Expeditions to the southern (1994), eastern (1995) and central (1996) Kimberley recorded 72, 90 and 70 species of macroalgae, respectively (Walker 1997). More recently, 117 species of macroalgae were recorded from the shelf edge atolls (Huisman et al. 2009), and a survey of the benthic flora of Gourdon Bay and the Dampier Peninsula recorded one seagrass and 43 algal species (Table 1), including one possible new species and two new records of algae for Western Australia (Keesing et al. 2011).

AIM

To synthesise records of shallow water (<30 m) marine flora (macroalgae, seagrass and mangrove) species in the Kimberley region of Australia that are verified by specimens lodged in herbarium collections (1880s–2009) and to provide commentary on diversity trends, taxonomic and collection gaps of the flora in the region.

METHODS

The Project Area encompasses an area west and north of the Kimberley coast (south of Broome to the Western Australia-Northern Territory border) extending beyond the 1000 m bathymetric contour, with the coastline forming a natural inshore boundary, as shown in Figure 1 (see Sampey et al. 2014 for a full description of the study area).

TABLE 1 Number of species of marine flora taxa groups sampled during main survey expeditions in the region and presented as reports. Number in parentheses is the number of locations. *Total number from report, but data not included in our species list as the tables were incomplete in the report.

Survey year	Blue-green algae	Red algae	Brown algae	Green algae	Seagrasses	Mangroves	Reference
1973–1982						14 (25)	Johnstone 1990
1991					5 (5)		Walker 1992
1994	3 genera*	28*	21*	23*	8 (14)	13 (8)	Hanley 1995; Walker 1995
1995		37 (11)	18 (7)	35 (23)	3 (3)	11 (11)	Saenger 1996; Walker 1996
1996		34 (15)	14 (9)	22 (19)	3 (7)		Walker 1997
1997–2001					5 (1)		Brown and Skewes 2005
2006	3 (2)	65 (3)	9 (3)	40 (12)	4 (3)		Huisman et al. 2009
2008		28 (4)	7 (3)	8 (3)	1 (2)		Keesing et al. 2011

The marine flora documented here essentially forms an artificial assemblage united by habitat rather than phylogeny. Included are ‘higher’ plants (seagrasses and mangroves, the latter also an artificial assemblage), algae (Rhodophyta, Phaeophyceae, Ulvophyceae) and blue-green algae (Cyanobacteria).

The methodology follows that outlined by Sampey et al. (2014). Marine flora data were sourced from the PERTH database (data extracted February 2010) and the species lists presented in seven reports (Table 1; Johnstone 1990; Walker 1992, 1995, 1996, 1997; Hanley 1995; Saenger 1996; Brown and Skewes 2005; Huisman et al. 2009). Species lists for seagrasses and macroalgae in the 1994 survey report (Walker 1995) were incomplete and only 4 of the 22 stations were printed, but there were specimens lodged in PERTH that are included in our dataset. The marine flora recorded by the 2008 CSIRO survey along the Dampier Peninsula and Gourdon Bay (Keesing et al. 2011) were made available only late in the preparation of this dataset, so we have not included the species or locations in this present dataset. The specimens from that collection will be incorporated into the PERTH collection and database when resources are available.

Species names represent a hypothesis that is subject to change as new information (morphology, genetic, behaviour, distribution ranges) is discovered (Gaston and Mound 1993). The species names and taxonomic placement of the records

in the dataset were checked in an endeavour to present the currently accepted name and resolve synonymies and old combinations, but the specimens were not re-examined for this study (for full details see Sampey et al. 2014). Species names were checked for current taxonomic placement and validity using a variety of online resources (ABRS 2011; Cowan 2011; Guiry and Guiry 2011; The International Plant Names Index 2011; Western Australian Herbarium 2011) and relevant recent publications.

SPATIAL INFORMATION, COLLECTION DETAILS AND MAPPING

As described by Sampey et al. (2014) data from all sources were collated into a single database. Location and collection details were checked and verified. The location of the specimen records were visualised using ARCGIS v9, ArcMap v9.3 and outliers in particular were examined and the latitude and longitude corrected or the record excluded as appropriate. Maps of species richness and sampling effort were generated for each main location. Since species richness patterns are highly dependent on sampling effort, we calculated the number of collecting events at a location to provide an indication of relative sampling effort. A collecting event was defined by the season and year of collecting and the full list of locations, latitude and longitude and other relevant collection information is provided in Table 2 of Sampey et al. (2014).

BIOGEOGRAPHIC AND HABITAT CODING

Species were coded for their known habitat and biogeographic range to provided extra information for researchers and managers.

Biogeography codes used were:

- Western Australian endemic (WA). Currently only known from Western Australian waters, often from the type locality only; may eventually prove to be a northern Australian endemic with more collecting effort.
- Northern Australian endemic (NA). Found throughout tropical Australian waters.
- Australian endemic (A). Found throughout tropical and temperate Australian waters.
- Indo-Australian (IA). Found throughout Australian and Indonesian waters, may extend to the Philippines and for some species Japan.
- Indian Ocean (IO). Restricted to the Indian Ocean.
- Indo-West Pacific (IWP). Found throughout the Red Sea, Indian and Western Pacific Oceans.
- Indo-Pacific (IP). Found throughout the Red Sea, Indian Ocean and throughout the Pacific Ocean.
- Tropicopolitan (T). Found throughout all tropical oceans.
- Circum-global (C). Found throughout all oceans in both tropical and temperate waters.

A species may be restricted to certain habitat types within its distribution range. The species in this dataset were coded for their preferred habitat, if known, as follows:

- Intertidal (superscript i). Species is found in the intertidal zone.
- Subtidal (superscript s). Species is found in the subtidal zone.
- Hard Substrate (H). Species is found associated with hard substrates (e.g. rock, coral, rubble).
- Soft Substrate (S). Species is found associated with soft substrates (e.g. sand, mud).
- Epiphytic (EP). Always found in an external association with a particular species of marine plant.
- Endophytic (EnP). Always found in an internal association with a particular species of marine plant, i.e. living within a marine plant.
- Unknown (U).

Combinations of these codes were used as appropriate.

RESULTS

NUMBER OF SPECIMENS IN COLLECTIONS

A total of 1431 registered specimen lots of marine flora were retained in this dataset (Table 2). These included green algae (353, 24.5%), blue-green algae (6, 0.5%), brown algae (284, 20%), red algae (502, 35%), seagrasses (107, 7.5%), and mangroves (179, 12.5%) (Table 2). Many lots were excluded from the present dataset either because they were freshwater species collected in streams, waterholes or rivers in the Kimberley and therefore not relevant to our project, or because of incomplete identification (1,342 lots, Table 2).

TABLE 2 Number of registered specimen lots of Kimberley Project Area marine flora housed in the PERTH collections. Included are those lots that were identified to species or able to be distinguished as a separate species and excluded are those lots that were incompletely identified or from freshwater locations.

Division	Common name	Included	Excluded
Not specified	Algae	-	201
Cyanophyta	Blue-Green Algae	6	6
Rhodophyta	Red Algae	502	365
Heterokontophyta	Brown Algae	284	309
Chlorophyta	Green Algae	353	236
Magnoliophyta: Liliopsida	Seagrasses	107	212
Magnoliophyta: Magnoliopsida	Mangroves	179	13
Total		1431	1342

The oldest specimen records of each marine flora taxa in the region that were present as specimens at the PERTH were the grey mangrove, *Avicennia marina* collected from Roebuck Bay in 1889, the seagrass *Thalassia hemprichii* from Cartier Island in 1977 and the algae *Halimeda opuntia* and *Hypnea spinella* collected from the fringing reef at Cartier Island by K.F. Kenneally in 1977.

With interest in the region's flora only relatively recent, so far very few new marine taxa have been based on Kimberley type specimens, but this will change with the publication of a north-western Australian algal flora currently in preparation and including descriptions of at least 50 new species (Huisman, in preparation). A Russian expedition in 1978 resulted in the description of a new genus and species of coralline red algae, *Rhizolamellia collum*

from Scott Reef (Shevejko 1982), and the species *Liagora walkerae* was described from Cassini Island by Huisman (2002).

SPECIES RICHNESS AND COLLECTING EFFORT

A total of 308 species of marine flora were recorded in our dataset for the Project Area. These included green algae (88 species, 28.5%); blue-green algae, (6 species, 2%), brown algae, (39 species, 12.5%), red algae (145 species, 47%); seagrasses (12 species, 4%); and mangroves (18 species, 6%); Table 3). These proportions are relatively typical, with the red algae the most speciose, followed by the green and brown algae. No mangroves have been recorded from the offshore atolls in the Project Area as suitable habitat does not occur.

TABLE 3 Species of marine flora recorded from the Project Area.

Taxa	Biogeographic code	Habitat code	Inshore	Mid shelf	Offshore
CYANOPHYTA (Blue-Green Algae)					
Family: Rivulariaceae					
<i>Calothrix</i> sp.		EP	•		
Family: Symphyonemataceae					
<i>Brachytrichia quoyi</i> (Agardh) Bornet & Flahault, 1886	C	H ⁱ	•		
Family: Nostocaceae					
<i>Anabaena</i> sp.		U	•		
Family: Oscillatoriaceae					
<i>Lyngbya majuscula</i> (Dillwyn) Harvey, 1833	C	H ⁱ /EP	•		•
Family: Phormidiaceae					
<i>Symploca hydroides</i> (Harvey) Kützing, 1849	C	H ⁱ /EP			•
Family: Pseudanabaenaceae					
<i>Leptolyngbya crosbyana</i> (Tilden) Anagnostidis & Komárek, 1988	IWP	H ^s			•
RHODOPHYTA (Red Algae)					
Family: Erythrotrichiaceae					
<i>Erythrotrichia carnea</i> (Dillwyn) Agardh, 1883	C	EP	•		
Family: Bonnemaisoniaceae					
<i>Asparagopsis taxiformis</i> (Delile) Trevisan, 1845	C	H ^{is}	•		•
Family: Callithamniaceae					
<i>Aglaothamnion cordatum</i> (Børgesen) Feldmann-Mazoyer, 1941	T	H ^s /EP			•
<i>Crouania attenuata</i> (Agardh) Agardh, 1842	C	H ⁱ /EP			•
<i>Ptilocladia yuenii</i> Abbott, 1993	IWP	EP	•		
<i>Seirospora orientalis</i> Kraft, 1988	NA	EP			•
Family: Ceramiaceae					
<i>Antithamnion antillanum</i> Børgesen, 1917	T	EP			•
<i>Antithamnionella</i> sp.		EP			•
<i>Balliella subcorticata</i> (Itono) Itono & Tanaka, 1973	IWP	H ^s			•
<i>Centroceras clavulatum</i> (Agardh) Montagne, 1846	C	H ^{is} /EP	•		•
<i>Ceramium codii</i> (Richards) Feldmann-Mazoyer, 1938	C	EP			•

Taxa	Biogeographic code	Habitat code	Inshore	Mid shelf	Offshore
<i>Ceramium macilentum</i> Agardh, 1894	C	EP			•
<i>Ceramium vagans</i> Silva, 1987	C	EP			•
<i>Ceramium krameri</i> South & Skelton, 2000	IWP	EP			•
<i>Corallophila apiculata</i> (Yamada) Norris, 1993	IWP	EP			•
<i>Gayliella flaccida</i> (Kützinger) Cho & McIvor, 2008	C	EP			•
Family: Dasyaceae					
<i>Dasya</i> sp.		H ^s	•		
<i>Heterosiphonia crassipes</i> (Harvey) Falkenberg, 1901	IWP	H ^s	•		
<i>Heterosiphonia crispella</i> (Agardh) Wynne, 1985	C	EP			•
Family: Delesseriaceae					
<i>Hypoglossum</i> sp.		EP	•		
<i>Martensia fragilis</i> Harvey, 1854	T	H ⁱ	•		
<i>Martensia pavonia</i> (Agardh) Agardh, 1863	T	H ⁱ	•		
<i>Vanvoorstia coccinea</i> Agardh, 1863	IWP	H ^s	•		
<i>Vanvoorstia spectabilis</i> Harvey, 1854	IWP	H ^s	•		
<i>Zellera tawallina</i> Martens, 1868	IWP	H ^s	•		•
Family: Rhodomelaceae					
<i>Acanthophora dendroides</i> Harvey, 1855	IWP	H ^s	•		
<i>Acanthophora muscoides</i> (Linnaeus) Bory, 1828	T	H ^s	•		
<i>Acanthophora spicifera</i> (Vahl) Børgesen, 1910	T	H ^{is}	•		•
<i>Acrocystis nana</i> Zanardini, 1872	IWP	H ⁱ	•		
<i>Amansia rhodantha</i> (Harvey) Agardh, 1841	IWP	H ^s	•		
<i>Bostrychia tenella</i> (Lamouroux) Agardh, 1863	C	H ⁱ	•		
<i>Chondria armata</i> (Kützinger) Okamura, 1907	IWP	H ^{is}	•		
<i>Digenea simplex</i> (Wulfen) Agardh, 1822	T	H ⁱ	•		
<i>Endosiphonia spinuligera</i> Zanardini, 1878	IWP	H ^s	•		
<i>Exophyllum wentii</i> Weber-van Bosse, 1911	IWP	H ^s	•		
<i>Herposiphonia secunda</i> (Agardh) Ambronn, 1880	C	EP			•
<i>Laurencia brongniartii</i> Agardh, 1841	T	H ^s	•		
<i>Laurencia heteroclada</i> Harvey, 1855	IWP	H ^s	•		
<i>Laurencia intricata</i> Lamouroux, 1813	T	H ^s	•		
<i>Laurencia majuscula</i> (Harvey) Lucas, 1935	C	H ^{is}	•		
<i>Laurencia similis</i> Nam & Saito, 1991	IWP	H ⁱ	•		
<i>Leveillea jungermannioides</i> (Hering & Martens) Harvey, 1855	IWP	H ⁱ /EP	•		•
<i>Lophocladia</i> sp.		EP	•		
<i>Neosiphonia poko</i> (Hollenberg) Abbott, 2002	IWP	EP			•
<i>Palisada parvipapillata</i> (Tseng) Nam, 2007	IWP	H ⁱ	•		
<i>Palisada perforata</i> (Bory) Nam, 2007	C	H ⁱ	•		
<i>Polysiphonia blandii</i> Harvey, 1862	A	EP	•		
<i>Polysiphonia subtilissima</i> Montagne, 1840	C	EP	•		
<i>Spirocladia barodensis</i> Børgesen, 1933	IWP	H ^{is}	•		
<i>Tolypocladia calodictyon</i> (Kützinger) Silva, 1952	IWP	H ^{is}	•		
<i>Tolypocladia glomerulata</i> (Agardh) Schmitz, 1897	IWP	H ^{is} /EP	•		•
<i>Vidalia melvillii</i> (Agardh) Schmitz, 1895	IO	H ^s	•		
Family: Sarcomeniaceae					
<i>Platysiphonia delicata</i> (Clemente) Cremades, 1990	C	EP			•
<i>Sarcomenia</i> sp.		U	•		
Family: Spyridiaceae					
<i>Spyridia filamentosa</i> (Wulfen) Harvey, 1833	C	H ^{is} /EP	•		•

Taxa	Biogeographic code	Habitat code	Inshore	Mid shelf	Offshore
Family: Wrangeliaceae					
<i>Anotrichium tenue</i> (Agardh) Nägeli, 1862	C	H ^{is} /EP	•		•
<i>Griffithsia heteromorpha</i> Kützing, 1863	T	EP			•
<i>Haloplegma duperreyi</i> Montagne, 1842	T	H ^{is}			•
<i>Haloplegma preissii</i> (Harvey) Montagne, 1845	A	H ^{is}	•		
<i>Spongoclonium caribaeum</i> (Børgesen) Wynne, 2005	C	H ^{is} /EP	•		
<i>Tiffaniella cymodoceae</i> (Børgesen) Gordon-Mills, 1972	IO	EP			•
<i>Wrangelia elegantissima</i> Norris, 1994	IWP	H ⁱ	•		
Family: Corallinaceae					
<i>Amphiroa beauvoisii</i> Lamouroux, 1816	C	H ^{is}	•		
<i>Amphiroa foliacea</i> Lamouroux, 1824	T	H ^{is}	•		
<i>Amphiroa fragilissima</i> (Linnaeus) Lamouroux, 1816	T	H ^{is}	•		•
<i>Amphiroa gracilis</i> Harvey, 1855	IWP	H ^s	•		
<i>Hydrolithon farinosum</i> (Lamouroux) Penrose & Chamberlain, 1993	C	H ^{is} /EP	•		•
<i>Hydrolithon gardineri</i> (Foslie) Verheij & Prud'homme van Reine, 1993	IP	H ^{is}			•
<i>Hydrolithon munitum</i> (Foslie & Howe) Penrose, 1996	T	H ^{is}			•
<i>Hydrolithon onkodes</i> (Heydrich) Penrose & Woelkerling, 1992	T	H ^{is}			•
<i>Hydrolithon samoense</i> (Foslie) Keats & Chamberlain, 1994	C	H ^{is}			•
<i>Jania adhaerens</i> Lamouroux, 1816	C	EP	•		•
<i>Jania micrarthrodia</i> Lamouroux, 1816	C	EP	•		
<i>Lithophyllum insipidum</i> Adey, Townsend & Boykins, 1982	IWP	H ^{is}	•		
<i>Lithophyllum kotschyianum</i> Unger, 1858	T	H ^{is}	•		•
<i>Lithophyllum pygmaeum</i> (Heydrich) Heydrich, 1897	IWP	H ^{is}	•		
<i>Lithophyllum tamiense</i> (Heydrich) Foslie, 1900	IWP	H ^{is}			•
<i>Lithothamnion proliferum</i> Foslie, 1904	IWP	H ^s			•
<i>Mastophora rosea</i> (Agardh) Setchell, 1943	IWP	H ⁱ	•		
<i>Rhizolamellia collum</i> Shevejkó, 1982	WA	H ^s			•
Family: Gelidiaceae					
<i>Gelidiella acerosa</i> (Forsskål) Feldmann & Hamel, 1934	T	H ⁱ	•		•
<i>Gelidium</i> sp.		H ⁱ	•		
<i>Pterocladia caerulescens</i> (Kützing) Santelices & Hommersand, 1997	T	H ^{is}	•		•
Family: Areschougiaceae					
<i>Erythroclonium</i> sp. nov.	WA	H ^s	•		
Family: Caulacanthaceae					
<i>Catenella nipae</i> Zanardini, 1872	IWP	H ⁱ /EP	•		
Family: Corynocyttaceae					
<i>Corynocyttis prostrata</i> Kraft, 1999	IWP	H ^s			•
Family: Corynomorphaceae					
<i>Corynomorpha prismatica</i> (Agardh) Agardh, 1876	IWP	H/S ^s	•		
Family: Dumontiaceae					
<i>Gibsmithia hawaiiensis</i> Doty, 1963	IWP	H ^s			•
Family: Hypneaceae					
<i>Hypnea cornuta</i> (Kützing) Agardh, 1851	C	H ^{is}	•		
<i>Hypnea pannosa</i> Agardh, 1847	T	H ^{is}	•		
<i>Hypnea spinella</i> (Agardh) Kützing, 1847	C	H ^{is}	•		•
<i>Hypnea valentiae</i> (Turner) Montagne, 1841	C	H ^{is}	•		
Family: Kallymeniaceae					
<i>Kallymenia</i> sp.		H ^s			•

Taxa	Biogeographic code	Habitat code	Inshore	Mid shelf	Offshore
Family: Peyssonneliaceae					
<i>Peyssonnelia inamoena</i> Pilger, 1911	C	H ^s			•
Family: Rhizophyllidaceae					
<i>Portieria hornemannii</i> (Lyngbye) Silva, 1987	IWP	H ^s	•		•
Family: Solieriaceae					
<i>Betaphycus speciosum</i> (Sonder) Doty ex Silva, 1996	WA	H ^{is}	•		
<i>Eucheuma arnoldii</i> Weber-van Bosse, 1928	IWP	H ⁱ	•		
<i>Eucheuma denticulatum</i> (Burman) Collins & Hervey, 1917	T	H ^{is}	•		
<i>Kappaphycus alvarezii</i> (Doty) Doty ex Silva, 1996	IWP	H ⁱ	•		
<i>Sarconema filiforme</i> (Sonder) Kylin, 1932	IWP	H ^{is}	•		
<i>Solieria robusta</i> (Greville) Kylin, 1932	IWP	H ^{is}	•		
Family: Gracilariaceae					
<i>Gracilaria arcuata</i> Zanardini, 1858	IWP	H ^{is}	•		
<i>Gracilaria canaliculata</i> Sonder, 1871	IWP	H ^{is}	•		
<i>Gracilaria edulis</i> (Gmelin) Silva, 1952	C	H ^{is}	•		
<i>Gracilaria salicornia</i> (Agardh) Dawson, 1954	IWP	H ⁱ	•		
<i>Gracilaria textorii</i> (Suringar) De Toni, 1895	IP	H ^{is}	•		
<i>Gracilaria vieillardii</i> Silva, 1987	IWP	H ⁱ	•		
<i>Hydropuntia urvillei</i> Montagne, 1842	IWP	H ⁱ	•		
Family: Halymeniaceae					
<i>Halymenia durvillei</i> Bory, 1828	IWP	H ^s	•		
<i>Halymenia floresii</i> (Clemente) Agardh, 1817	C	H ^s	•		
Family: Hildenbrandiaceae					
<i>Hildenbrandia rubra</i> (Sommerfelt) Meneghini, 1841	C	H ⁱ	•		
Family: Galaxauraceae					
<i>Actinotrichia fragilis</i> (Forsskål) Børgesen, 1932	IWP	H ^s	•		•
<i>Dichotomaria marginata</i> (Ellis & Solander) Lamarck, 1816	T	H ^s	•		•
<i>Dichotomaria obtusata</i> (Ellis & Solander) Lamarck, 1816	T	H ^s	•		
<i>Galaxaura filamentosa</i> Chou, 1945	T	H ^{is}	•		
<i>Galaxaura rugosa</i> (Ellis & Solander) Lamouroux, 1816	T	H ^{is}	•		•
<i>Scinaia tsinglanensis</i> Tseng, 1941	IWP	H ^s	•		
<i>Tricleocarpa cylindrica</i> (Ellis & Solander) Huisman & Borowitzka, 1990	T	H ^s	•		•
<i>Tricleocarpa fragilis</i> (Linnaeus) Huisman & Townsend, 1993	T	H ^s	•		
Family: Liagoraceae					
<i>Akalaphycus</i> sp.		H ^s	•		
<i>Ganonema borowitzkae</i> Huisman, 2002	WA	H ^{is}	•		
<i>Ganonema farinosum</i> (Lamouroux) Fan & Wang, 1974	T	H ^{is}	•		•
<i>Ganonema pinnatum</i> (Harvey) Huisman, 2002	T	H ^{is}	•		•
<i>Liagora ceranoides</i> Lamouroux, 1816	T	H ^{is}	•		•
<i>Liagora divaricata</i> Tseng, 1941	IWP	H ^{is}	•		
<i>Liagora walkerae</i> Huisman, 2002	WA	H ⁱ	•		
<i>Titanophycus validus</i> (Harvey) Huisman et al., 2006	T	H ^{is}			•
<i>Trichogloea requienii</i> (Montagne) Kützing, 1847	T	H ^s	•		
<i>Yamadaella caenomyce</i> (Decaisne) Abbott, 1970	T	H ⁱ	•		
Family: Nemastomataceae					
<i>Predaea laciniosa</i> Kraft, 1984	IWP	H ^s			•
<i>Predaea weldii</i> Kraft & Abbott, 1971	T	H ^s			•
Family: Schizymeniaceae					
<i>Platoma cyclocolpum</i> (Montagne) Schmitz, 1889	C	H ^s			•
<i>Titanophora pikeana</i> (Dickie) Feldmann, 1942	IWP	H ^s			•

Taxa	Biogeographic code	Habitat code	Inshore	Mid shelf	Offshore
Family: Piheliaceae					
<i>Pihiella liagoraciphila</i> Huisman, Sherwood & Abbott, 2003	T	EnP			•
Family: Plocamiaceae					
<i>Plocamium</i> sp.		H ^s	•		
Family: Champiaceae					
<i>Champia parvula</i> (Agardh) Harvey, 1853	T	H ^{is}	•		
<i>Champia stipitata</i> Huisman, 2000	NA	H ^{is}	•		
<i>Coelothrix irregularis</i> (Harvey) Børgesen, 1920	T	H ⁱ			•
Family: Hymenocliadiaceae					
<i>Asteromenia</i> sp. nov.	WA	H ^s			•
Family: Lomentariaceae					
<i>Ceratodictyon intricatum</i> (Agardh) Norris, 1987	C	H ^{is}			•
<i>Ceratodictyon scoparium</i> (Montagne & Millardet) Norris, 1987	C	H ^{is}	•		
<i>Ceratodictyon spongiosum</i> Zanardini, 1878	IWP	H ⁱ	•		•
Family: Rhodymeniaceae					
<i>Botryocladia leptopoda</i> (Agardh) Kylin, 1931	IWP	H ^{is}	•		
<i>Coelarthrum opuntia</i> (Endlicher) Børgesen, 1937	IWP	H ^s	•		
Family: Sebdeniaceae					
<i>Sebdenia flabellata</i> (Agardh) Parkinson, 1980	T	H ^s	•		
PHAEOPHYCEAE (Brown Algae)					
Family: Dictyotaceae					
<i>Canistrocarpus cervicornis</i> (Kützinger) De Paula & De Clerck, 2006	T	H ^{is} /EP	•		
<i>Canistrocarpus crispatus</i> (Lamouroux) De Paula & De Clerck, 2006	T	H ^{is}	•		
<i>Dictyopteris australis</i> (Sonder) Askenasy, 1888	IP	H ^{is}	•		
<i>Dictyopteris repens</i> (Okamura) Børgesen, 1924	IP	H ^{is}			•
<i>Dictyopteris woodwardia</i> (Brown ex Turner) Agardh, 1817	IWP	H ^s	•		
<i>Dictyota ciliolata</i> Sonder ex Kützinger, 1859	C	H ^{is}	•		
<i>Dictyota friabilis</i> Setchell, 1926	T	H ^s			•
<i>Lobophora variegata</i> (Lamouroux) Womersley ex Oliveira, 1977	C	H ^{is}	•		•
<i>Padina australis</i> Hauck, 1887	IP	H ^{is}	•		
<i>Padina boryana</i> Thivy, 1966	T	H ^{is}	•		•
<i>Padina sanctae-crucis</i> Børgesen, 1914	T	H ^{is}	•		
<i>Spatoglossum asperum</i> Agardh, 1894	IWP	H ^s	•		
<i>Spatoglossum macrodontum</i> Agardh, 1882	IWP	H ^s	•		
<i>Stoehospermum polypodioides</i> (Lamouroux) Agardh, 1848	IWP	H ^{is}	•		
<i>Stypopodium flabelliforme</i> Weber-van Bosse, 1913	IP	H ^{is}	•		•
Family: Acinetosporaceae					
<i>Feldmannia indica</i> (Sonder) Womersley & Bailey, 1970	C	H ^{is} /EP	•		
Family: Ectocarpaceae					
<i>Hincksia mitchelliae</i> (Harvey) Silva, 1987	C	H ^{is} /EP	•		
Family: Pylaiellaceae					
<i>Bachelotia antillarum</i> (Grunow) Gerloff, 1959	C	H ⁱ	•		
Family: Cystoseiraceae					
<i>Sirophysalis trinodis</i> (Forsskål) Kützinger, 1849	IWP	H ^{is}	•		
<i>Hormophysa cuneiformis</i> (Gmelin) Silva, 1987	C	H ^{is}	•		
Family: Sargassaceae					
<i>Sargassopsis decurrens</i> (Brown ex Turner) Trevisan, 1843	IWP	H ^s	•		
<i>Sargassum flavicans</i> (Mertens) Agardh, 1820	IWP	H ^s	•		

Taxa	Biogeographic code	Habitat code	Inshore	Mid shelf	Offshore
<i>Sargassum ilicifolium</i> (Turner) Agardh, 1820	IWP	H ^s	•		
<i>Sargassum ligulatum</i> Agardh, 1824	WA	H ^s	•		
<i>Sargassum oligocystum</i> Montagne, 1845	IWP	H ^s	•		
<i>Sargassum peronii</i> Agardh, 1820	IWP	H ^s	•		
<i>Turbinaria conoides</i> (Agardh) Kützing, 1860	IWP	H ^{is}	•		
<i>Turbinaria gracilis</i> Sonder, 1845	IWP	H ^s	•		
<i>Turbinaria ornata</i> (Turner) Agardh, 1848	IP	H ^{is}	•		•
Family: Neoralfsiaceae					
<i>Neoralfsia expansa</i> (Agardh) Lim & Kawai, 2007	T	H ⁱ	•		
Family: Chnoosporaceae					
<i>Chnoospora implexa</i> Agardh, 1848	IP	H ⁱ	•		
<i>Rosenvingea intricata</i> (Agardh) Børgesen, 1914	T	H ⁱ	•		•
<i>Rosenvingea nhatrangensis</i> Dawson, 1954	IWP	H/S ⁱ	•		
<i>Rosenvingea orientalis</i> (Agardh) Børgesen, 1914	T	H ⁱ	•		
Family: Scytosiphonaceae					
<i>Colpomenia sinuosa</i> (Roth) Derbes & Solier, 1851	C	H ^{is} /EP	•		
<i>Hydroclathrus clathratus</i> (Agardh) Howe, 1920	C	H ^{is}	•		•
Family: Sphacelariaceae					
<i>Sphacelaria rigidula</i> Kützing, 1843	C	H ^{is} /EP	•		
<i>Sphacelaria tribuloides</i> Meneghini, 1840	C	H ^{is} /EP			•
Family: Sporochneaceae					
<i>Sporochneus comosus</i> Agardh, 1824	IWP	H ^s	•		
CHLOROPHYTA (Green Algae)					
Family: Bryopsidaceae					
<i>Bryopsis indica</i> Gepp & Gepp, 1908	IP	H ⁱ	•		
<i>Bryopsis pennata secunda</i> (Harvey) Collins & Hervey, 1917	T	H ⁱ	•		
<i>Pseudobryopsis hainanensis</i> Tseng, 1936	IWP	H ⁱ /EP	•		
Family: Caulerpaceae					
<i>Caulerpa cactoides</i> (Turner) Agardh, 1817	IWP	H ^{is} /S ⁱ	•		
<i>Caulerpa cupressoides</i> (Vahl) Agardh, 1817	T	S ⁱ	•		•
<i>Caulerpa fergusonii</i> Murray, 1891	IWP	H/S ⁱ	•		
<i>Caulerpa lentillifera</i> Agardh, 1837	IWP	H ^s /S ^{is}	•		•
<i>Caulerpa mexicana</i> Sonder ex Kützing, 1849	T	S ^{is}	•		
<i>Caulerpa peltata</i> Lamouroux, 1809	T	H ^{is}	•		
<i>Caulerpa racemosa clavifera</i> (Turner) Weber-van Bosse, 1909	T	H ^{is}	•		
<i>Caulerpa racemosa corynephora</i> (Montagne) Weber-van Bosse, 1898	T	H ⁱ	•		
<i>Caulerpa racemosa laetevirens</i> (Montagne) Weber-van Bosse, 1898	T	H ⁱ	•		
<i>Caulerpa racemosa lamourouxii</i> (Turner) Weber-van Bosse, 1898	T	H/S ⁱ	•		
<i>Caulerpa racemosa macrodisca</i> (Decaisne) Weber-van Bosse, 1898	T	H ^s	•		
<i>Caulerpa racemosa racemosa</i> (Forsskål) Agardh, 1873	T	H ^{is}	•		
<i>Caulerpa racemosa turbinata</i> (Agardh) Eubank, 1946	T	H ^{is}	•		
<i>Caulerpa serrulata</i> (Forsskål) Agardh, 1837	T	H ^{is}	•		•
<i>Caulerpa sertularioides</i> (Gmelin) Howe, 1905	T	S ^{is}	•		
<i>Caulerpa taxifolia</i> (Vahl) Agardh, 1817	T	S ^{is}	•		•
<i>Caulerpa verticillata</i> Agardh, 1847	T	S ^{is}	•		•
<i>Caulerpa webbiana</i> Montagne, 1837	T	H ^s			•
Family: Chaetosiphonaceae					
<i>Blastophysa rhizopus</i> Reinke, 1889	C	EnP			•

Taxa	Biogeographic code	Habitat code	Inshore	Mid shelf	Offshore
Family: Codiaceae					
<i>Codium arabicum</i> Kützing, 1856	IWP	H ⁱ	•		•
<i>Codium dwarkense</i> Børgesen, 1947	IO	H ⁱ	•		•
<i>Codium geppiorum</i> Schmidt, 1923	T	H ⁱ	•		
<i>Codium repens</i> Crouan & Crouan, 1905	T	H ⁱ	•		
<i>Codium spongiosum</i> Harvey, 1855	T	H ⁱ	•		
Family: Derbesiaceae					
<i>Derbesia tenuissima</i> (Moris & De Notaris) Crouan & Crouan, 1867	C	H ⁱ /EP	•		
Family: Halimedaceae					
<i>Halimeda cuneata</i> Hering in Krauss, 1846	IP	H ⁱ	•		
<i>Halimeda cylindracea</i> Decaisne, 1842	IWP	S ^{is}	•		•
<i>Halimeda discoidea</i> Decaisne, 1842	T	S ^{is}	•		•
<i>Halimeda distorta</i> (Yamada) Hillis-Colinvaux, 1968	IWP	H ^s			•
<i>Halimeda incrassata</i> (Ellis) Lamouroux, 1816	T	S ⁱ	•		
<i>Halimeda lacunalis</i> Taylor, 1950	IWP	H ⁱ	•		
<i>Halimeda macroloba</i> Decaisne, 1841	IWP	S ^{is}	•		•
<i>Halimeda macrophysa</i> Askenasy, 1888	IWP	H ^s			•
<i>Halimeda minima</i> (Taylor) Hillis-Colinvaux, 1968	IWP	H ^{is}			•
<i>Halimeda opuntia</i> (Linnaeus) Lamouroux, 1816	T	H ⁱ	•		•
<i>Halimeda simulans</i> Howe, 1907	T	S ⁱ	•		
<i>Halimeda taenicola</i> Taylor, 1950	IWP	H ^s	•		
<i>Halimeda tuna</i> (Ellis & Solander) Lamouroux, 1816	C	H ^s	•		•
<i>Halimeda velasquezii</i> Taylor, 1962	IWP	H ^{is}	•		
Family: Udoteaceae					
<i>Avrainvillea amadelpa</i> (Montagne) Gepp & Gepp, 1908	IWP	S ⁱ			•
<i>Avrainvillea erecta</i> (Berkeley) A.Gepp & E.Gepp, 1911	IWP	S ⁱ	•		
<i>Avrainvillea longicaulis</i> (Kützing) Murray & Boodle, 1889	T	H ⁱ	•		
<i>Chlorodesmis</i> sp.		U	•		
<i>Penicillus nodulosus</i> (Lamouroux) Blainville, 1830	NA	S ^{is}	•		
<i>Rhipidosiphon javensis</i> Montagne, 1842	T	H ⁱ			•
<i>Rhipilia crassa</i> Millar & Kraft, 2001	IWP	H ^s			•
<i>Rhipilia nigrescens</i> Coppejans & Prud'homme van Reine, 1990	IWP	H ^s			•
<i>Rhipiliopsis echinocaulos</i> (Cribb) Farghaly, 1986	IWP	H ^s			•
<i>Udotea argentea</i> Zanardini, 1858	IWP	S ^s	•		
<i>Udotea flabellum</i> (Ellis & Solander) Howe, 1904	T	S ^s	•		
<i>Udotea glaucescens</i> Agardh, 1887	IWP	S ^s	•		•
<i>Udotea orientalis</i> Gepp & Gepp, 1911	IWP	U	•		
Family: Chaetophoraceae					
<i>Uronema marinum</i> Womersley, 1984	IWP	EP			•
Family: Anadyomenaceae					
<i>Anadyomene plicata</i> Agardh, 1823	IWP	H ⁱ	•		•
<i>Anadyomene wrightii</i> Harvey ex Gray, 1866	IWP	H ⁱ			•
<i>Microdictyon okamuriae</i> Setchell, 1925	IWP	H ^s			•
<i>Microdictyon umbilicatum</i> (Velley) Zanardini, 1862	IWP	H ^s	•		
<i>Phyllodictyon anastomosans</i> (Harvey) Kraft & Wynne, 1996	T	H ^s			•
<i>Phyllodictyon orientale</i> (Gepp & Gepp) Kraft & Wynne, 1996	IWP	H ^s			•
Family: Cladophoraceae					
<i>Chaetomorpha indica</i> (Kützing) Kützing, 1849	T	EP	•		
<i>Cladophora aokii</i> Yamada, 1925	IWP	H ⁱ	•		

Taxa	Biogeographic code	Habitat code	Inshore	Mid shelf	Offshore
<i>Cladophora catenata</i> (Linnaeus) Kützing, 1843	T	H ^{is}	•		
<i>Cladophora coelothrix</i> Kützing, 1843	C	H ^{is}			•
<i>Cladophora herpestica</i> (Montagne) Howe, 1914	C	H ^{is}	•		•
<i>Cladophora socialis</i> Kützing, 1849	C	H ⁱ			•
Family: Siphonocladaceae					
<i>Boergesenia forbesii</i> (Harvey) Feldmann, 1938	IWP	H ⁱ	•		•
<i>Boodlea composita</i> (Harvey) Brand, 1904	T	H ⁱ	•	•	•
<i>Boodlea vanbosseae</i> Reinbold, 1905	IWP	H ⁱ		•	•
<i>Cladophoropsis sundanensis</i> Reinbold, 1905	T	H ^{is}			•
<i>Cladophoropsis vaucheriiformis</i> (Areschoug) Papenfuss, 1958	IWP	H ⁱ	•		
<i>Dictyosphaeria cavernosa</i> (Forsskål) Børgesen, 1932	T	H ^{is}	•		•
<i>Dictyosphaeria versluysii</i> Weber-van Bosse, 1905	T	H ^{is}			•
Family: Valoniaceae					
<i>Valonia aegagropila</i> Agardh, 1823	T	H ^s	•		
<i>Valonia fastigiata</i> Agardh, 1887	T	H ^s			•
<i>Valonia ventricosa</i> Agardh, 1887	T	H ^s			•
<i>Valoniopsis pachynema</i> (Martens) Børgesen, 1934	T	H ⁱ	•		
Family: Dasycladaceae					
<i>Bornetella oligospora</i> Solms-Laubach, 1892	IWP	H ^s	•		
<i>Bornetella sphaerica</i> (Zanardini) Solms-Laubach, 1892	IWP	H ^s	•		
<i>Neomeris bilimbata</i> Koster, 1937	IWP	H ^s			•
<i>Neomeris vanbosseae</i> Howe, 1909	IP	H ^s	•		
Family: Polyphysaceae					
<i>Acetabularia caliculus</i> Lamouroux in Quoi & Gaimard, 1824	C	H ^s	•		
Family: Ulvaceae					
<i>Ulva clathrata</i> (Roth) Agardh, 1811	C	H ⁱ	•		
<i>Ulva flexuosa</i> Wulfen, 1803	C	H ⁱ	•		•
<i>Ulva prolifera</i> Müller, 1778	C	H ^{is} /EP			•
<i>Ulva ralfsii</i> (Harvey) Le Jolis, 1863	C	H ⁱ /EP	•		•
MAGNOLIOPHYTA: LILIOPSISIDA (Seagrasses)					
Family: Hydrocharitaceae					
<i>Enhalus acoroides</i> (Linnaeus) Royle, 1839	IWP	S ^s	•		
<i>Halophila decipiens</i> Ostenfeld, 1902	T	S ^s	•		•
<i>Halophila minor</i> (Zollinger) den Hartog, 1957	IWP	S ^s	•		
<i>Halophila ovalis</i> (Brown) Hooker, 1859	IWP	S ^s	•		•
<i>Halophila spinulosa</i> (Brown) Ascherson, 1875	IWP	S ^s	•		
<i>Thalassia hemprichii</i> (Ehrenberg) Ascherson, 1871	IWP	S ^{is}	•		•
Family: Cymodoceaceae					
<i>Cymodocea angustata</i> Ostenfeld, 1916	WA	S ^s	•		
<i>Cymodocea serrulata</i> (Brown) Ascherson & Magnus, 1870	IWP	S ^s	•		
<i>Halodule pinifolia</i> (Miki) den Hartog, 1964	IWP	S ^s	•		•
<i>Halodule uninervis</i> (Forsskål) Ascherson, 1882	IWP	S ^s	•		
<i>Syringodium isoetifolium</i> (Ascherson) Dandy, 1939	IWP	S ^s	•		
<i>Thalassodendron ciliatum</i> (Forsskål) den Hartog, 1970	IWP	S ^{is}	•		•
MAGNOLIOPHYTA: MAGNOLIOPSISIDA (Mangroves)					
Family: Euphorbiaceae					
<i>Excoecaria agallocha</i> Linnaeus, 1759	IWP	S ⁱ	•		
<i>Excoecaria ovalis</i> Endlicher, 1833	NA	S ⁱ	•		

Taxa	Biogeographic code	Habitat code	Inshore	Mid shelf	Offshore
Family: Acanthaceae					
<i>Acanthus ebracteatus</i> Vahl, 1791	IWP	S ⁱ	•		
Family: Avicenniaceae					
<i>Avicennia marina</i> (Forsskål) Vierhapper, 1907	IWP	S ⁱ	•		
Family: Sonneratiaceae					
<i>Sonneratia alba</i> Smith, 1816	IWP	S ⁱ	•		
Family: Bombacaceae					
<i>Camptostemon schultzei</i> Masters, 1872	IA	S ⁱ	•		
Family: Combretaceae					
<i>Lumnitzera racemosa</i> Willdenow, 1803	IWP	S ⁱ	•		
Family: Lythraceae					
<i>Penphis acidula</i> Forster & Forster, 1775	IWP	S ⁱ	•		
Family: Myrtaceae					
<i>Osbornia octodonta</i> Mueller, 1862	IWP	S ⁱ	•		
Family: Plumbaginaceae					
<i>Aegialitis annulata</i> Brown, 1810	IA	S ⁱ	•		
Family: Myrsinaceae					
<i>Aegiceras corniculatum</i> (Linnaeus) Blanco, 1837	IWP	S ⁱ	•		
Family: Rhizophoraceae					
<i>Bruguiera exaristata</i> Ding Hou, 1957	IA	S ⁱ	•		
<i>Bruguiera parviflora</i> Griffith, 1836	IWP	S ⁱ	•		
<i>Ceriops tagal</i> (Perrottet) Robinson, 1908	IWP	S ⁱ	•		
<i>Rhizophora stylosa</i> Griffith, 1854	IWP	S ⁱ	•		
Family: Rubiaceae					
<i>Scyphiphora hydrophylacea</i> Gaertner, 1806	IWP	S ⁱ	•		
Family: Meliaceae					
<i>Xylocarpus granatum</i> Koenig, 1784	IWP	S ⁱ	•		
<i>Xylocarpus moluccensis</i> (Lamarck) Roemer, 1846	IWP	S ⁱ	•		

Marine flora data are available for 116 locations in the Kimberley Project Area (Table 4, Figures 1–3). Species richness ranged from 127 (at One Arm Point) to one (at 17 coastal locations) (Table 4, Figure 2). Collecting effort was highly variable with 33 collecting events occurring at One Arm Point and one event at 77 locations (Table 4, Figure 3).

The number of flora taxa collected at any location was also highly variable. All floral taxa (blue-green, red, brown and green algae, seagrasses and mangroves) were collected at only two locations, One Arm Point and Sunday Island (Table 4). A single floral taxon was collected at 56 locations, red and brown algae at two locations (e.g. Salural Island and Hedley Island respectively), green algae and seagrasses at seven locations (e.g. Browse Island and Allora Island respectively), and mangroves only at 38 locations (e.g. Boongaree Island, Table 4).

More species have been reported from the Kimberley coast (inshore, 241 species) compared to the offshore atolls (124 species, Tables 3, 6, 7). Only two species have been recorded from the midshelf (Browse Island). However, collecting effort is also substantially different for these areas of the shelf, with more collecting of marine plants along the Kimberley coastline compared to the

offshore atolls or midshelf (81 collecting events versus 7 and 2 respectively, Table 4). Composition of the flora also varied across the shelf, with 185 species found only at inshore locations, 68 at offshore locations and 56 species at both inshore and offshore locations (Table 3).

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The majority of the species at both inshore and offshore locations were widespread Indo-West Pacific (IWP) species (102, 42% inshore, versus 41, 33% offshore, Table 5).

Endemicity was much higher along the Kimberley coast than at the offshore atolls. The proportion of endemics (all categories WA, A, and NA) along the Kimberley coast was twice the proportion of endemics at the offshore atolls (11, 5% inshore versus 3, 2.5% offshore, Table 5).

The majority of seagrass species were IWP (10 species), one tropicopolitan species and a single endemic, *Cymodocea angustata* Ostenfeld, 1916. The majority of mangrove species were wide ranging IWP (14 species), 3 species were IA, the only marine flora taxa in this category, and there was a single northern Australian endemic species, *Excoecaria ovalis* Endl., 1833 (Table 3).

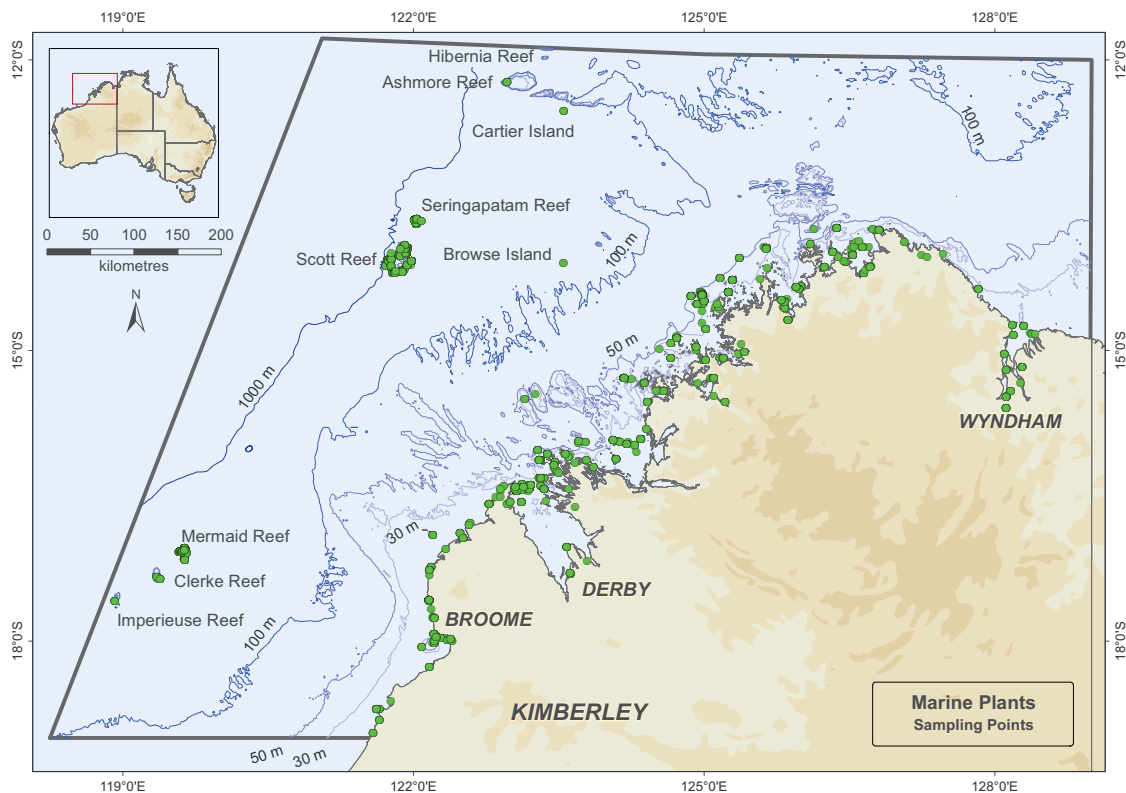


FIGURE 1 Location of records of marine flora in the Kimberley Project Area, Western Australia. The Project Area boundary is marked in grey. Map projection: GDA94, Scale: 1:6, 250,000.

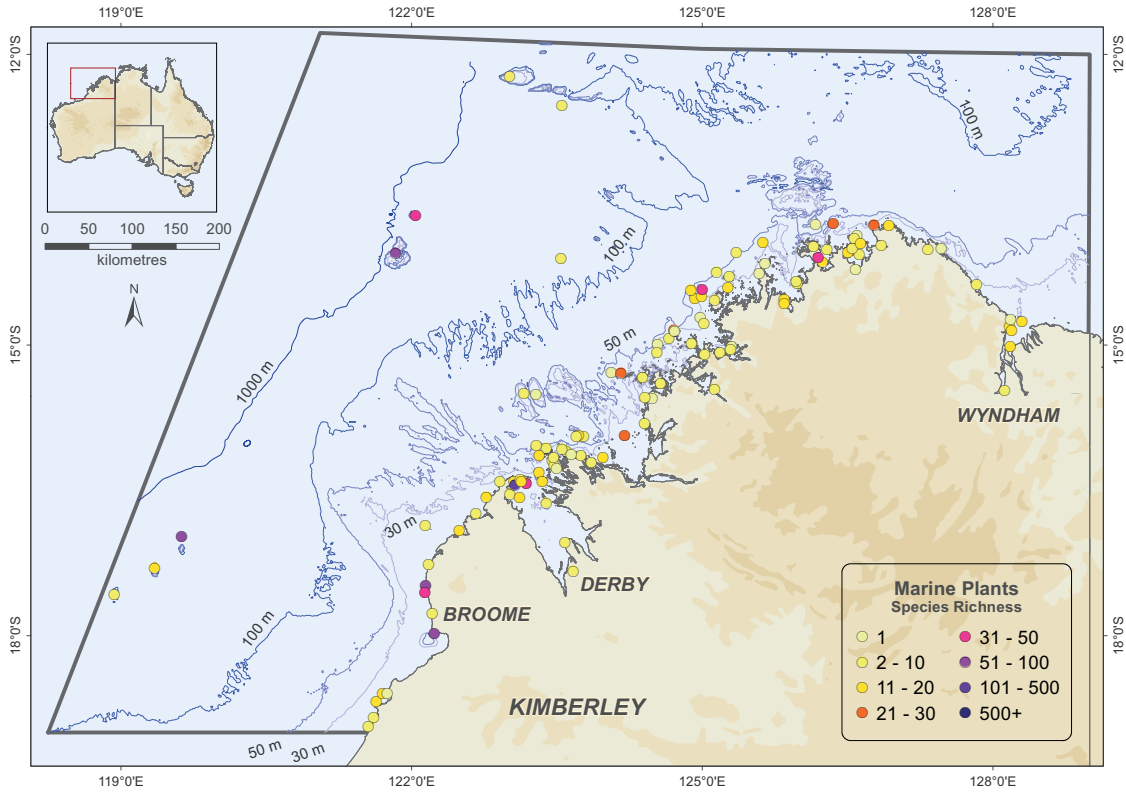


FIGURE 2 Species richness of marine flora for each main location. Map projection: GDA94, Scale: 1:6, 250,000.

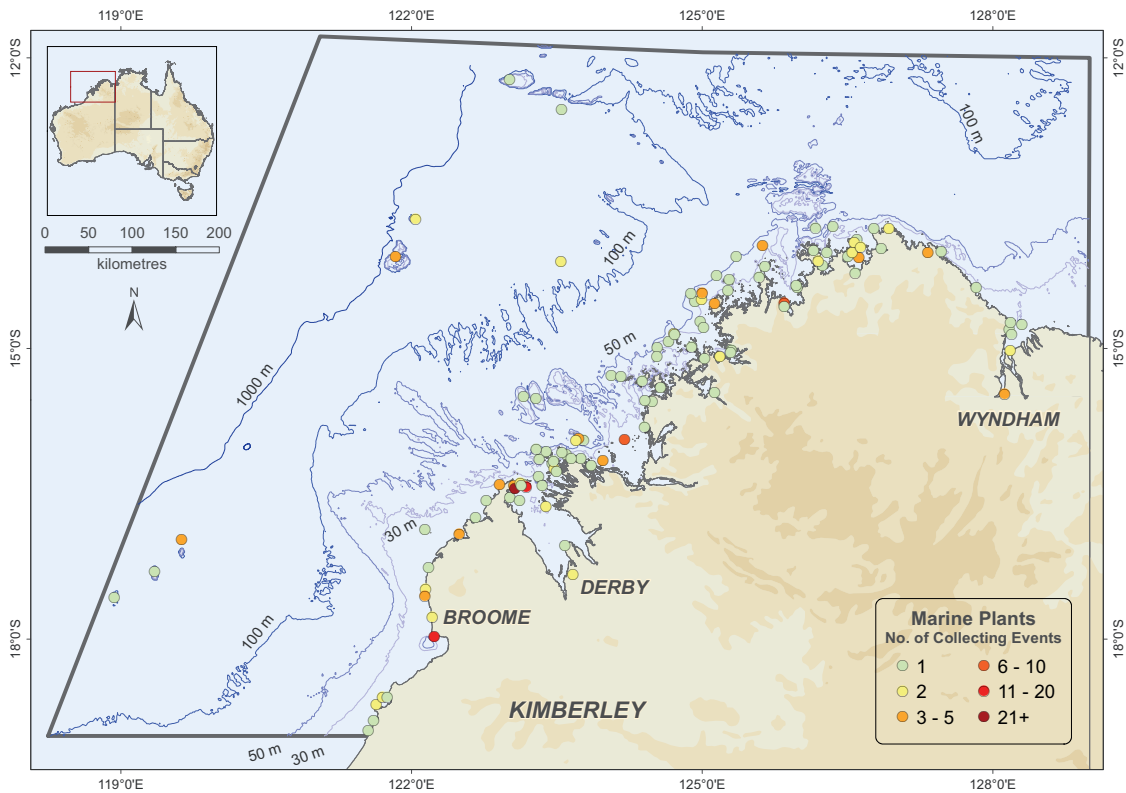


FIGURE 3 Number of collecting events for marine flora at each main location for which there are collections. This was based on a count of the season code and provides an indication of sampling effort. Map projection: GDA94, Scale: 1:6, 250,000.

TABLE 4 Species richness and number of collecting events at each location.

Location	Collecting year range	Species richness	No. coll. events	No. taxa	Blue-green algae	Red algae	Brown algae	Green algae	Seagrasses	Mangroves
Adele Island	1990	3	1	1				•		
Admiral Bay	–	5	1	1						•
Admiral Island	1994	7	1	3		•			•	•
Albert Islands	2007	14	1	3		•	•	•		
Allora Island	1985	1	1	1					•	
Ashmore Reef ^{OA}	–	5	1	1					•	
Augustus Island	1972	4	1	1						•
Beagle Bay	1959–1996	11	4	3				•	•	•
Bedford Island	1994	16	1	5		•	•	•	•	•
Berthier Island	1996–2007	12	2	5		•	•	•	•	•
Bigge Island	1972–2003	4	3	1						•
Boongaree Island	1973–1988	8	2	1						•
Broome	1889–2007	61	18	5		•	•	•	•	•
Browse Island ^{MS}	2006	2	2	1				•		
Caffarelli Island	1994	10	1	3		•	•		•	
Cambridge Gulf	1978–1995	18	2	4		•	•	•		•
Camden Sound	1967	1	1	1						•
Cape Bernier	1988	1	1	1						•
Cape Bertholet	1977	10	1	1						•
Cape Bossut	1977–1985	13	2	4		•	•	•		•
Cape Bougainville	–	3	1	1						•
Cape Domett	1995	14	1	3		•		•		•
Cape Dussejour	1978	1	1	1						•
Cape Jaubert	–	4	1	1						•
Cape Leveque	1977–2000	6	5	3			•		•	•
Cape Londonderry	1975–1995	19	2	5		•	•	•	•	•
Cape Talbot	1995	24	1	4		•	•	•		•
Cape Voltaire	1976	1	1	1						•
Careening Bay	1972	5	1	1						•
Carlia Island	–	8	1	1						•
Cartier Island ^{OA}	1977	3	1	3		•		•	•	
Cassini Island	1991–1996	18	3	4		•	•	•	•	
Champagny Island	1972	1	1	1						•
Churchill Reef	1996	1	1	1				•		
Clerke Reef ^{OA}	2007	11	1	3		•	•	•		
Cockatoo Island	2004	4	1	1				•		
Colbert Island	1993–1996	23	2	4		•	•	•	•	
Coronation Island	1972	8	1	1						•

Location	Collecting year range	Species richness	No. coll. events	No. taxa	Blue-green algae	Red algae	Brown algae	Green algae	Seagrasses	Mangroves
Cygnets Bay	1977	5	1	1						•
Darcy Island	–	8	1	1						•
De Freycinet Island	1996	1	1	1		•				
Derby	1971–1980	8	2	1						•
Drysdale River	1995	10	1	1						•
False Cape Bossut	2001	19	2	3		•	•	•		
Freshwater Bay	1995	8	1	1						•
Freshwater Cove	2001	3	1	1				•		
Gagg Island	1994	5	1	1					•	
Gibbings Reefs	1996	3	1	2		•		•		
Gregory Island	1994	12	1	5		•	•	•	•	•
Hedley Island	1996	2	1	1			•			
Heritage Reef	1996	6	1	3			•	•	•	
Hidden Island	1982–1994	5	2	3		•	•			•
Imperieuse Reef ^{FOA}	2007	6	1	4		•	•	•	•	
Irvine Island	1994	6	1	3		•	•		•	
Jackson Island	2003–2005	13	5	2		•		•		
James Price Point	1988–2009	76	2	5	•	•	•	•	•	
Jamieson Reef	1996	5	1	3		•	•	•		
Jar Island	1995	14	1	3		•	•	•		
Jones Island	1995	21	1	3		•	•	•		
Jussieu Island	1996	1	1	1			•			
King Edward River	1995	1	1	1				•		
King George River	1992–1995	9	2	1						•
King Sound	1977–1996	2	2	1						•
Kingfisher Island	1990–2001	13	3	3		•	•			•
Koolan Island	1993	3	1	1						•
Lacepede Islands	1986	6	1	2			•	•		
Lacrosse Island	1995	11	1	3		•		•		•
Lagrange Bay	–	1	1	1						•
Lamarck Island	1996	5	1	3		•	•	•		
Leonie Island	1985–2002	11	3	4		•	•	•	•	
Long Island	1982–1995	31	2	5		•	•	•	•	•
Lord Island	1994	3	1	2			•		•	
Louis Islands	1995	27	1	5		•	•	•	•	•
Mackenzie Anchorage	1995	13	1	2				•		•
Macleay Island	1994–1996	6	2	4	•	•	•			•
Maret Islands	1996–2007	38	4	4		•	•	•	•	
Mermaid Island	1994	16	1	5		•	•	•	•	•

Location	Collecting year range	Species richness	No. coll. events	No. taxa	Blue-green algae	Red algae	Brown algae	Green algae	Seagrasses	Mangroves
Mermaid Reef ^{OA}	2006–2007	64	3	4		•	•	•	•	
Montalivet Islands	1996	10	1	3		•	•	•		
Montgomery Reef	1987–2005	28	6	5		•	•	•	•	•
Myrmidon Ledge	1995	17	1	4		•	•	•		•
Napier Broome Bay	1921–1999	7	5	1						•
Naturalists Island	1997	1	1	1				•		
One Arm Point	1984–2006	127	33	6	•	•	•	•	•	•
Osborne Islands	1973	8	1	1						•
Packer Island	1977	11	1	1						•
Pender Bay	2008	3	1	1						•
Point Torment	–	9	1	1						•
Port Warrender	1976–2004	13	7	1						•
Prince Frederick Harbour	1984	7	1	1						•
Prince Regent River	1974	10	1	1						•
Prudhoe Islands	1996	12	1	3		•	•	•		
Quondong Point	2001	45	3	4		•	•	•	•	
Revely Island	1995	10	1	3		•	•	•		
Robroy Reefs	1996	11	1	3		•	•	•		
Salural Island	2003–2004	3	2	1		•				
Scorpion Island	1991	1	1	1					•	
Scott Reef ^{OA}	2006–2007	88	4	5	•	•	•	•	•	
Seringapatam Reef ^{OA}	2006	46	2	5	•	•	•	•	•	
Sir Graham Moore Island	1973–1975	3	2	2		•				•
Slate Islands	1996	7	1	4		•	•	•	•	
Sunday Island	1982–2005	37	11	6	•	•	•	•	•	•
Talbot Bay	1994	3	1	2			•		•	
Tallon Island	1994	11	1	4		•	•		•	•
Trent River	–	11	1	1						•
Troughton Island	1999	1	1	1						•
Vansittart Bay	1921–1984	2	2	1						•
Walsh Point	–	11	1	1						•
West Governor Island	1984–1995	17	2	4		•	•	•		•
Whirlpool Pass	1994	1	1	1					•	
White Island	1996	6	1	2		•	•		•	
Wildcat Reefs	1996	25	1	4		•	•	•		
Willie Creek	1978–2007	8	2	1						•
Woodward Island	1991	1	1	1					•	
Wyndham	1974–1978	4	3	1						•
Yankawingarri Island	1991	1	1	1					•	

TABLE 5 Number of species with each biogeographic code.

Biogeographic Code	Inshore	Midshelf	Offshore
-	10		2
WA	6		2
NA	3		1
A	2		
IA	3		
IO	2		2
IWP	102	1	41
IP	9		4
T	65	1	40
C	39		32
Total	202	2	92

TABLE 6 Number of species with each habitat code.

Habitat Code	Inshore	Midshelf	Offshore
EnP			2
EP	10		17
H/S ⁱ	3		
H/S ^s	1		
H ⁱ	48	2	15
H ⁱ /EP	6		5
H ^{is}	60		31
H ^{is} /EP	11		7
H ^{is} /S ⁱ	1		
H ^s	51		32
H ^s /EP			1
H ^s /S ^{is}	1		1
S ⁱ	22		2
S ^{is}	10		7
S ^s	13		4
U	4		
Total	241	2	124

HABITATS

The majority of the species surveyed in the Project Area were associated with hard substrates, 214 inshore versus 101 offshore for all combinations (H/Sⁱ, H/S^s, Hⁱ, Hⁱ/EP, H^{is}, H^{is}/EP, and H^s/S^{is}). A small proportion of species that occurred on hard substrates were also found on soft substrates (6 species, Tables 3, 6).

The number of species that only occur on soft substrates was much lower, 51 species from inshore and 14 from offshore locations (Table 6). All mangrove and seagrass species were associated with soft substrates. All mangroves species (18) were in soft sediment intertidal areas.

Only two algae species were endophytic in other algae (EnP), the red alga *Pihiella liagoraciphila* Huisman, Sherwood and Abbott, 2003 occurred in various species of Liagoraceae, and the green *Blastophysa rhizopus* Reinke, 1889 in some soft-bodied red algae (Tables 3, 6). Forty eight species of algae were epiphytic, some also associated with hard substrate.

DISCUSSION

The present compendium and analysis provides a general overview of the Kimberley Project Area marine flora, but there are several caveats regarding the collection methods and post collection handling of specimens used to generate the results, notably:

1. Collecting effort is variable, depending on the location, the collector, and the conditions at the time of collection. Recent expeditions with WAM have standardised the methods, but many of the earlier collections were more haphazard.
2. The taxonomy of many groups is unresolved. This is due to several factors both practical and scientific, including a lack of available expertise, time constraints, and the now universal use of DNA sequencing, which is altering many taxonomic concepts. Recent surveys have incorporated the appropriate preservation of specimens for DNA extraction, but in the past all specimens were ritually preserved in formalin, thus making them unsuitable for such analyses. A typical example of the changes occurring is the filamentous red alga previously known as *Ceramium flaccidum* and thought to be morphologically variable and cosmopolitan in distribution. The study by Cho et al. (2008) incorporated DNA analyses to support their morphological observations and recognised seven species within the *C. flaccidum* complex, which they transferred to the new genus *Gayliella*. *Ceramium flaccidum sensu lato* was recorded for the Project Area offshore atolls by Huisman et al. (2009) and

generally throughout north-western Australia. Based on the conclusions of Cho et al. (2008) a re-examination of the specimens has revealed five species, including one new and two yet to be transferred from *Ceramium*. True *Ceramium flaccidum* (= *Gayliella flaccida*) does not occur in north-western Australia. Similar DNA sequence based revisions are occurring in a large number of taxa.

3. Much of the species diversity, particularly in the red algae, is due to the essentially microscopic epiphytes. These generally cannot be recognised while collecting, and only become apparent when larger species are examined in the laboratory. As a result, records of these species can be erratic and possibly not comparable between locations.
4. Many specimens cannot be named for a variety of reasons. Identification of many of the red algae requires reproductive material, and in most cases this cannot be assessed while collecting. It can, therefore, be a matter of luck if suitable material is collected. DNA sequencing assists this process considerably, but can only provide identification if a matching sequence of a reliably named specimen is available for comparison.
5. The marine flora of the Kimberley Project Area has not yet received the attention enjoyed by some faunal groups and has only relatively recently been collected and studied in any detail.

Given the above overarching limitations, it is almost impossible to recognise diversity patterns that are not compromised in some way, and the following broad discussion is perhaps most useful in highlighting collection gaps, both geographical and habitat.

SPECIES RICHNESS PATTERNS

A summary of macroalgal species richness for various regions in the Indo-West Pacific was given by Huisman et al. (2009: Table 3). The present dataset records 278 species, an increase on the number of Kimberley species recorded in that publication, but still undoubtedly an underestimate given the large number of excluded lots. Currently the first author is compiling an algal flora for tropical north-western Australia, anticipated to be published by the 'Australian Biological Resources Study' in 2015 (Huisman, in preparation). This publication will document the northern Gascoyne, Pilbara and Kimberley marine algal floras including full descriptions and illustrations of all red, green and brown algae from the region. The manuscript includes some 413 species (262 red algae, 55 brown

algae, 96 green algae) of which approximately 50 are new species. These new species are not represented in the present dataset. Verheij and Prud'homme van Reine (1993) recorded 452 species for Indonesia, and given the proximity and comparable range of habitats, the Project Area algal flora is likely to include a similar number.

Over the last two decades, the relatively static numbers of seagrasses and mangroves recorded for the region suggests that the known diversity is an accurate assessment of the flora. These groups do not include any inconspicuous taxa and are relatively taxonomically stable (at least for the Project Area species), so regional scale changes to the recorded diversity are unlikely. Compared to the macroalgae, for seagrasses (12 species) and mangroves (18 species) the diversity is low, but these groups are generally conspicuous and can dominate particular habitats. Relative to other Indo-West Pacific regions, the north-west seagrass diversity is the highest recorded (Walker and Prince 1987: Table 5).

Worldwide, some 72 species of mangrove are known and more than half of these can be found in Australia, where almost 18 per cent of the coastline is lined by mangroves. Western Australia supports approximately 2,500 square kilometres of mangroves, of which about 75 per cent occur in the Kimberley (Duke 2006). The present dataset includes 18 species for the region, one less than the number recorded by Duke (2006). This diversity is less than that known for north eastern Australia, but the region's mangroves occur in a diverse array of habitats, and are nevertheless of great conservation significance (Cresswell and Semeniuk 2011).

The Project Area includes seven IMCRA meso-scale bioregions (Commonwealth of Australia 2006) and therefore encompasses a variety of habitats, from sandy shores to offshore reefs. These regions were defined using biological and physical information, including the distribution of demersal fishes, marine plants and invertebrates, seafloor geomorphology and sediments, and oceanographic data (Commonwealth of Australia 2006). At this scale, the largest disjunct in the Kimberley Project Area marine flora is between the inshore islands and reefs and offshore atolls. The diversity of the offshore atolls is markedly lower, with some groups (such as mangroves) and genera (such as the brown alga *Sargassum*) absent entirely. Lack of suitable habitat can explain the absence of mangroves, but it is unclear why *Sargassum*, easily the dominant alga in the inshore Kimberley, is absent from the atolls. Studies by Schaffelke (1999) and Schaffelke and Klumpp (1998) on eastern Australian *Sargassum* species have demonstrated their increased growth with nutrient pulses and their use of particulate

matter as a nutrient source. Perhaps the offshore atolls are too far removed from land derived nutrients. Clearly further study is needed.

Species diversity can also be expected to vary within regions, as it is highly dependent on finer scale habitat variations. For macroalgae there are numerous examples of sites dominated by algae and with a high species diversity (usually intertidal/shallow subtidal reef flats), and also of others almost devoid of algae (usually moderate to deep subtidal, often with high turbidity). The habitat factors driving these fine scale variations cannot be assessed from the present historical dataset, but current and future WAM expeditions will assess a greater variety of physical and biological parameters.

COLLECTION GAPS

The Kimberley is a vast, remote wilderness. The limitations on marine collecting are numerous, including physical (tides, accessibility, turbid water, harsh climate), biological (sharks, crocodiles), financial (travel, boat charter), and health and safety (limited dive times). As such, it is inevitable that some areas have not been surveyed fully, if at all. Some, such as Ashmore Reef and Cartier Island, were visited by WAM prior to the participation of a marine botanist, and therefore represent significant spatial gaps in our knowledge of the marine flora. Certain habitats are equally under represented. Some, such as the deep seafloor, require specialised dredging equipment that can generally only be accommodated on dedicated surveys. Others, such as the subtidal inshore, are unlikely to be sampled due to safety concerns.

Of these gaps, those that can feasibly be sampled will be targeted during current WAM expeditions.

ENDEMISM

The present dataset records endemism at between 2.5 and 5%, but this is an underestimate as it does not include undescribed new taxa. Huisman (2011) estimated endemism in the north-western Australian macroalgal flora at approximately 10%, which encompasses all the taxa to be described in Huisman (in preparation) plus a few previously erected species and genera. This percentage is low relative to those recorded for the temperate southern Australian algal flora, which Womersley (1984) gave as 30% (green algae), 70% (brown algae) and 75% (red algae). This disparity is to be expected as many tropical species are broadly distributed, particularly in the Indo-West Pacific, and temperate regions typically have a greater proportion of endemic species. However, our documentation of this flora is still a work in progress and many specimens remain unidentified, this group

including the more 'difficult' taxa. As such, an accurate assessment of endemism can only be made once all the specimens are identified. Whether these taxa are truly endemic will require considerable work, including collections from further north in SE Asia. Assessing endemism in the marine flora is a difficult process and we should heed the cautionary words of Kraft (2007), who stated, 'Determining actual endemism among marine algae, particularly subtidal ones, is a greater challenge than it is for most terrestrial taxa, and claims made for the uniqueness of a region based on its number of endemic macroalgal species can easily prove not to be justified'.

FUTURE DIRECTIONS

The present dataset has highlighted several areas that are underrepresented in the Western Australian Herbarium's collection of marine algae, in particular. Filling these gaps during current WAM expeditions is therefore a high priority. Of comparable importance is the identification of the 1,342 (or close to 50%) of the Project Area specimens, which were excluded from the present assessment due to their incomplete identifications. These specimens potentially contain useful information about the marine flora of the Kimberley Project Area. Identification of these specimens is an ongoing task of the first author, but is a huge undertaking, which might consume his whole working life, and then some. Taxonomists regularly highlight dwindling resources and the lack of support for their work, and this malaise is true for marine floristic studies. Continued (or some!) funding support for these studies is essential.

Equally important is the incorporation of DNA sequencing as a tool enabling a greater degree of confidence in taxonomic studies. During recent WAM expeditions, specimens were curated specifically for DNA sequencing and it is envisaged that this aspect will continue to be a high priority during future expeditions.

Assessing distribution patterns amongst the marine flora, and the marine biota in general, will be greatly enhanced by the collection of targeted environmental data. Particularly relevant to the marine biota would be the assessment of the nutrient status at each site, plus detailed data on habitat and geomorphology. These data could feed into large scale biogeographic analyses for example, looking at the species occurring in the various IMCRA bioregions. At present, and highlighted by the gaps in the present dataset, this cannot be undertaken for the marine flora with any degree of confidence.

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