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Benthic Macroalgae of Shark Bay, Western Australia

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Abstract

One hundred and sixty one taxa of benthic macro-algae are reported from Shark Bay, Western Australia, growing either on subtidal rock platforms, on the extensive sandflats that dominate the bay, or as epiphytes on seagrasses and other algae. In addition many species survive as drift algae amongst the seagrass beds. Tropical taxa predominate. The Rhodophyta are represented by the greatest number of taxa, but these tend to be inconspicuous epiphytes. Members of the Chlorophyta are the most conspicuous in most areas, with *Penicillus nodulosus* and *Polyphysa peniculus* the most common species. *Polyphysa peniculus* dominates the high salinity areas south of the Faure Sill. The brown algae *Hormophysa cuneiformis* and *Dictyota furcellata* were also common in high salinity areas. Benthic algal species richness was lower in areas of high salinity.

Introduction

Shark Bay, Western Australia, is a shallow sedimentary environment dominated by seagrass meadows [predominantly *Amphibolis antarctica* (Labill.) Sonder *ex* Aschers.] which cover up to 30% of its subtidal surface area (Walker *et al.* 1988). These extensive meadows have formed shoals (Davies 1970) which result in restricted oceanic exchange. High evaporation and low precipitation in the area (Logan and Cebulski 1970) result in a salinity gradient from 35‰ in the northern reaches of Shark Bay to 70‰ in the inner southern sections (Logan and Cebulski 1970, Smith and Atkinson 1983). The high salinities recorded in the inner reaches of Shark Bay have previously been found to be negatively correlated with productivity of seagrass (Walker 1985), species richness and community structure of macroalgal epiphytes (Kendrick *et al.* 1988) and percent cover, growth and development of encrusting epiphytic Corallinaceae (Harlin *et al.* 1985).

The seagrass meadows host a large number of species of epiphytic algae (Harlin *et al.* 1985, Kendrick *et al.* 1988) which numerically dominate the algal flora of the area. However, benthic macro-algae can also be found growing on occasional subtidal rock (limestone-sandstone) platforms and extensive sandflats which occur throughout the bay, and as drift within seagrass meadows. This paper lists the benthic macroalgae collected from a variety of localities and habitats within Shark Bay, and concludes the series describing the subtidal flora of the area (Harlin *et al.* 1985, Walker *et al.* 1988, Kendrick *et al.* 1988).

Material and Methods

Surveys throughout Shark Bay (26°S, 114°E) were made using SCUBA and snorkel during March, June, August, October and December 1982, August 1985, February and May 1986 and August 1988. Benthic algae were sampled from the eleven locations shown in Figure 1. The distribution of benthic algae within Shark Bay is based on these locations only. Locations 2, 6, 7, 8 and 9 (islands) were sampled during August 1982. Transects were laid out perpendicular to the shore on rock substratum and species presence sam-

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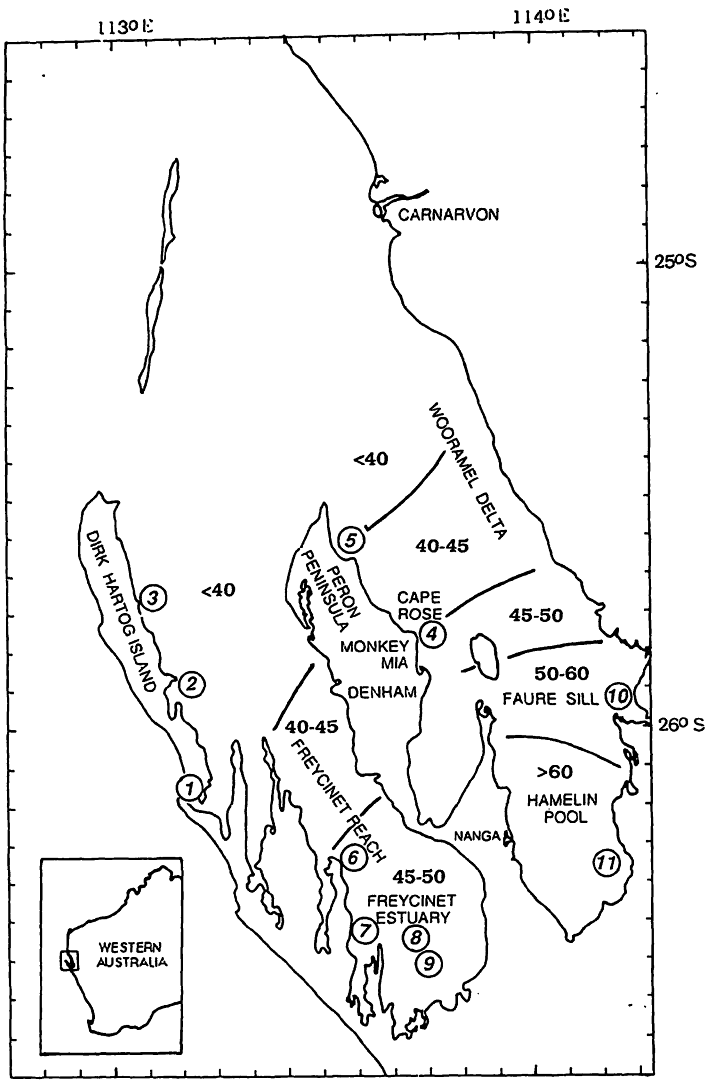

Fig. 1. Map of Shark Bay, W. A. showing sampling locations and haloclines (in ‰): 1-South Passage; 2-Egg Island; 3-Sandy Point; 4-Monkey Mia; 5-Herald Bight; 6-Charlie Island; 7-Double Island; 8-White Island; 9-Salutation Island; 10-Gladstone Inlet; 11-Hamelin Pool.

pled at intervals of 0.5 m with 0.1255 m^2 quadrats. Locations 4, 5, 10 and 11 were sampled during 1982, 1985 and 1988 both quantitatively using haphazardly placed 0.1225 m^2 quadrats and with qualitative surveys. Locations 1 and 3 were surveyed during 1988. Because of the variety of sampling techniques employed locations were grouped into geographical regions representing regions with different salinity regimes. Some taxa were not present at any of the eleven locations sampled intensively, but nonetheless were recorded from Shark Bay and therefore are included in the species list. All samples of algae were preserved in 6% formalin in seawater, salinity was measured at every survey location and observations on substratum, depth, current regime, depositional environment and exposure were recorded. Voucher specimens of all taxa collected were deposited in the herbaria at Murdoch University and The University of Western Australia.

Drift algae were observed throughout the bay and studied in detail at Monkey Mia during June, August and October 1982. Biomass of dominant species of drift algae in subtidal seagrass communities was determined from 12 quadrats, each 0.1225 m^2, sampled within seagrass beds.

Results

One hundred and sixty one taxa of algae are reported from Shark Bay (Table I), including 30 taxa of Chlorophyta, 24 taxa of Phaeophyta and 107 taxa of Rhodophyta. The distribution of benthic algae determined from the sampling locations shown in Figure 1 indicated that species richness decreased with increases in salinity within Shark Bay (Table I).

Collections of epiphytes were made on the pneumatophores of the mangrove *Avicennia marina* during 1986. *Ulvaria oxysperma, Caloglossa leprieurii, Spyridia filamentosa, Bostrichia moritziana, B. radicans* and *B. tenella* ssp. *flagellifera* were identified from these collections.

Five species dominated the drift algal flora: *Laurencia majuscula, Laurencia filiformis, Vidalia spiralis, Digenia simplex* and *Eucheuma speciosum.* Distribution of drift algae was patchy. Mean biomass ($\pm$ standard deviation) was 152.5 ($\pm$ 248.5) and 223 ($\pm$ 357) g dry weight m^{-2} in *Amphibolis antarctica* and *Posidonia australis* beds respectively.

Discussion

The benthic algae of Shark Bay were not predominantly temperate as was the case with the seagrasses (Walker *et al.* 1988) and seagrass epiphytes (Kendrick *et al.* 1988). The majority of taxa are either of tropical (*e.g. Digenia simplex, Galaxaura rugosa, Portieria hornemannioides, Dictyopteris plagiogramma,* all *Caulerpa* spp. and *Halimeda* spp.) or cosmopolitan distributions (*e.g. Enteromorpha intestinalis, Solieria robusta, Anotrichium tenue*). Certain species previously thought to be restricted to the south-west of Western Australia are also present (*e.g. Cryptonemia kallymenioides*) but their apparent localized distribution prior to the present survey was no doubt due to the lack of collections from north-western Australia.

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Table I. Species list of both benthic and epiphytic algae found in Shark Bay, W. A. (E – epiphytic; B – benthic) including distribution of benthic algae along the salinity gradient (values in ‰):
Dirk Hartog Island (Dirk H. Island) includes sampling locations 1, 2, 3; Hopeless Reach (Hope. Reach) includes sampling locations 4 and 5; Freycinet Estuary (Freyc. Estuary) includes sampling locations 6, 7, 8, 9; Gladstone Inlet (Glad. Inlet) = sampling location 10; Hamelin Pool (Ham. Pool) = sampling location 11.

Sampling locations Salinity range				Dirk H. Island 36–40	Hope. Reach 40–45	Freyc. Estuary 45–50	Glad. Inlet 50–55	Ham. Pool 55–60
CHLOROPHYTA								
Caulerpales	*Caulerpa cupressoides* (Vahl) C. Agardh		B		+	+		
	C. lentillifera J. Agardh		B		+	+	+	+
	C. racemosa var. *clavifera* (Turner) Weber-van Bosse		B	+		+		
	C. racemosa var. *uvifera* (Turner) Weber-van Bosse		B	+				
	C. papillosa J. Agardh		B		+	+	+	
	C. sertularioides (Gmelin) Howe		B	+				
	Halimeda incrassata (Ellis) Lamouroux		B	+				
	H. simulans Howe		B					
	H. tuna (Ellis *et* Solander) Lamouroux		B	+				
	Pencillus nodulosus (Lamouroux) Blainville		B	+	+	+	+	
	Udotea argentea Zanardini		B	+	+	+		
Derbesiales	*Bryopsis plumosa* (Hudson) C. Agardh		B	+				
Codiales	*Codium duthieae* Silva *in* Silva *et* Womersley		B	+				
	C. harveyi Silva *in* Silva *et* Womersley		B	+				
	C. spongiosum Harvey	E	B	+		+		
Dasycladales	*Acetabularia calyculus* Lamouroux *in* Qouy *et* Gaimard		B		+		+	+
	Polyphysa peniculus (R. Brown *ex* Turner) C. Agardh		B		+		+	+
Cladophorales	*Chaetomorpha valida* (Hooker *et* Harvey) J. Agardh.	E	B	+	+	+		
	Cladophora feredayi Harvey		B	+		+		
	C. flexuosa Harvey	E	B	+	+	+		
	C. vagabunda (Linnaeus) van den Hoek		B					
	C. valonioides Sonder	E		+				
	Cladophora sp.		B					
	Microdictyon umbilicatum (Velley) Zanardini	E	B		+			
	Rhizoclonium sp.		B	+		+		
Ulvales	*Enteromorpha clathrata* (Roth) Greville		B					
	Enteromorpha intestinalis (Linnaeus) Nees	E	B	+	+	+		
	Ulva australis Areschoug		B					
	Ulva lactuca Linnaeus	E	B	+	+	+		
	Ulvaria oxysperma (Kützing) Bliding	E						
Total Chlorophyta		30		18	12	13	5	3
PHAEOPHYTA								
Sphaceleriales	*Sphacelaria rigidula* Kützing	E	B			+		
	S. tribuloides Meneghini	E	B	+				
Ectocarpales	*Ectocarpus siliculosus* (Dillwyn) Lyngbye	E	B	+		+		
	Hincksia sp.		B	+				

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Table I. (continued)

Sampling locations / Salinity range				Dirk H. Island 36–40	Hope. Reach 40–45	Freyc. Estuary 45–50	Glad. Inlet 50–55	Ham. Pool 55–60
Scytosiphonales	*Colpomenia sinuosa* (Roth) Derbes *et* Solier *in* Castagne	E	B	+	+	+		
	Hydroclathrus clathratus (C. Agardh) Howe	E	B	+	+	+		
Dictyotales	*D. dichotoma* (Hudson) Lamouroux	E	B	+		+		
	D. ciliolata Kützing		B	+				
	Dictyota furcellata (C. Agardh) J. Agardh	E	B	+	+	+	+	+
	Dictyopteris plagiogramma (Montagne) Vickers		B					
	Dictyopteris sp.		B	+				
	Lobophora variegata (Lamouroux) Womersley		B	+	+	+		
	Padina sanctae-crucis Boergesen		B					
	Padina sp.	E	B	+				
	Stypopodium flabelliforme Weber-van Bosse		B	+				
Fucales	*Caulocystis uvifera* (J. Agardh) C. Agardh	E	B	+	+	+		
	Cystoseira trinodis (Forsskäl) C. Agardh	E	B	+	+	+		
	Hormophysa cuneiformis (Gmelin) Silva	E	B		+	+	+	+
	Platythalia angustifolia Sonder		B		+			
	Sargassum decurrens (R. Brown *in* Turner) C. Agardh	E	B		+			
	S. flavicans (Mertens) C. Agardh	E	B		+	+		
	S. spinigulerum Sonder		B	+		+		
	S. varians Sonder	E	B		+	+		
	S. verruculosum (Mertens) J. Agardh		B	+		+		
Total Phaeophyta		24		16	11	14	2	2
RHODOPHYTA								
Acrochaetiales	*Audouinella daviesii* (Dillwyn) Woelkerling		B	+				
	A. microscopica (Naegeli) Woelkerling	E						
Nemalionales	*Galaxaura collabens* J. Agardh		B	+				
	G. rugosa (Ellis *et* Solander) Lamouroux		B	+				
	Liagora sp.	E	B		+			
Bonnemaisoniales	*Asparagopsis taxiformis* (Delile) Trevisan		B	+				
Gelidiales	*Gelidiella acerosa* (Forsskäl) Feldmann *et* Hamel		B	+				
	Gelidium pusillum (Stackhouse) Le Jolis		B	+				
	Pterocladia capillacea (Gmelin) Bornet *in* Bornet *et* Thuret		B	+				
Corallinales	*Amphiroa anceps* (Lamark) Decaisne		B	+				
	Amphiroa sp.		B	+				
	Fosliella cruciata Bressan	E						
	F. cymodocea (Foslie) Jones *et* Woelkerling	E						
	Haliptilon roseum (Lamarck) Garbary *et* Johansen	E						
	Jania micrarthrodia Lamouroux.	E	B	+				
	Jania sp.	E						
	Melobesia membranacea (Esper) Lamouroux	E						
	Metagoniolithon stelliferum (Lamark) Weber-van Bosse	E	B		+			
	Neogoniolithon sp.		B					
	Pneophyllum caulerpae (Foslie) Jones *et* Woelkerling	E						

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Gigartinales		*Ceratodictyon spongiosum* Zanardini		B	+				
		Cryptonemia kallymenioides (Harvey) Kraft *in* Scott, Wetherbee *et* Kraft		B		+			
		Dicranema revolutum (C. Agardh) J. Agardh	E		+		+		
		Eucheuma speciosum J. Agardh	E	B		+			
		Gracilaria harveyana J. Agardh	E	B	+	+			
		Gracilaria sp.		B		+			
		Grateloupia filicina J. Agardh var. *luxurians* A. *et* E. S. Gepp		B	+				
		Hypnea musciformis (Wulfen) Lamouroux	E	B	+	+	+		
		H. pannosa J. Agardh		B					
		H. valentiae (Turner) Montagne	E						
		Mychodea pusilla (Harvey) J. Agardh	E						
		Plocamium sp.		B	+		+		
		Portieria hornemannioides (Lyngbye) Silva		B	+				
		Solieria robusta (Greville) Kylin		B		+			
Rhodymeniales		*Botryocladia leptopoda* (J. Agardh) Kylin		B		+			
		Coelarthrum sp.		B					
		Champia affinis (Hooker *et* Harvey) J. Agardh	E						
		Champia sp. 1		B	+	+			
		Champia sp. 2		B	+				
		Rhodymenia australis (Sonder) Harvey	E	B	+		+		
Ceramiales	Delesseriaceae	*Caloglossa leprieurii* (Montagne) J. Agardh	E						
		Hypoglossum heterocystideum (J. Agardh) J. Agardh	E	B	+				
		Martensia elegans Hering		B	+				
		Platysiphonia intermedia (Grunow) Wynne	E						
		P. miniata (J. Agardh) Boergesen	E						
		Platysiphonia sp.	E						
	Dasyaceae	*Dasya* sp.	E	B	+	+	+		
		Heterosiphonia callithamnion (Sonder) Falkenberg	E	B	+				
		H. crassipes (Harvey) Falkenberg		B	+				
		H. wurdemannii (Bailey) Falkenberg		B	+				
		Heterosiphonia sp.	E						
	Ceramiaceae	*Acrothamnion preissii* (Sonder) Wollaston	E						
		Aglaothamnion cordatum (Boergesen) Feldman-Mazoyer		B	+				+
		Anotrichium tenue (C. Agardh) Naegeli	E	B	+	+			
		Antithamnion armatum (J. Agardh) De Toni	E		+	+			
		A. divergens (J. Agardh) J. Agardh	E						
		Antithamnionella tasmanica Wollaston		B	+	+			
		Antithamnionella sp.		B		+			
		Centroceras clavulatum (C. Agardh) Montagne	E	B	+	+	+		
		Ceramium australe Sonder	E	B	+	+	+		
		C. codii (Richards) Mazoyer		B	+	+			
		C. flaccidum (Kützing) Ardissone	E						
		C. puberulum Sonder	E						
		C. shepherdii Womersley	E						
		Crouania capricornica Saenger *et* Wollaston		B					+
		Griffithsia ovalis Harvey	E						
		Griffithsia sp.		B	+				

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Table I. (continued)

Sampling locations / Salinity range				Dirk H. Island 36–40	Hope. Reach 40–45	Freyc. Estuary 45–50	Glad. Inlet 50–55	Ham. Pool 55–60
	Haloplegma preissii Sonder	E						
	Ptilocladia australis (Harvey) Wollaston	E						
	P. vestita (Harvey) Wollaston		B	+				
	Spyridia dasyoides Sonder	E	B	+	+	+	+	
	Spyridia filamentosa (Wulfen) Harvey	E	B					+
	Spyridia velasquezii Trono	E						
	Tiffaniella cymodoceae (Boergesen) Gordon	E						
	Wrangelia plumosa Harvey	E						
	W. argus (Montagne) Montagne		B					
	Wrangelia sp.	E						
Rhodomelaceae	*Acanthophora dendroides Harvey*		B					
	Acanthophora spicifera (Vahl) Boergesen		B	+	+	+		
	Bostrichia moritziana (Sonder *ex* Kützing) J. Agardh.	E						
	B. radicans (Montagne) Montagne *in* Orbigny	E						
	B. tenella ssp. *flagellifera* (Post) R. J. King *et* Puttock	E						
	Chondria minutula Weber-van Bosse	E	B					
	Chondria sp. 1	E		+		+		
	Chondria sp. 2		B					
	Coelocionium umbellulum (Harvey) Falkenberg	E						
	Dasyclonium flaccidum (Harvey) Kylin		B	+	+			
	Digenia simplex (Wulfen) C. Agardh		B		+	+	+	
	Herposiphonia secunda (C. Agardh) Ambronn f. *tenella* (C. Agardh) Wynne	E						
	Herposiphonia sp.	E						
	Laurencia brongniartii J. Agardh		B	+				
	L. filiformis (C. Agardh) Montagne	E	B	+	+	+	+	
	L. majuscula (Harvey) Lucas	E	B	+	+	+	+	+
	L. papillosa (Forsskal) Greville		B	+				
	L. shepherdii Saito *et* Womersley	E	B			+		
	Leveillea jungermannioides (Martens *et* Hering) Harvey	E	B	+				
	Lophocladia harveyi (Kützing) Schmitz		B		+			
	Neurymenia fraxinifolia (Mertens *ex* Turner) J. Agardh		B		+			
	Polysiphonia abscissoides Womersley	E	B	+		+		
	P. amphibolis Womersley	E						
	P. decipiens Montagne	E						
	P. ferulacea Suhr *ex* J. Agardh		B	+				+
	P. infestans Harvey	E						
	P. scopulorum Harvey	E	B	+				
	P. sertularioides (Grateloup) J. Agardh	E						
	Tolypiocladia glomerulata (C. Agardh) Schmitz	E	B	+		+		
	Vidalia spiralis Lamarck	E	B		+	+		
Total Rhodophyta		107		48	27	17	4	5
Total taxa		161		82	52	44	11	10

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Eighty of the taxa of algae found in Shark Bay were epiphytic on the seagrass *Amphibolis antarctica*. Of these, over half (43 Taxa) have been reported both as epiphytes and as benthic algae. Ballantine and Humm (1975) and May *et al.* (1978) noted that epiphyte communities on seagrasses can include organisms which also occur on hard substratum but are found as epiphytes when available substratum is a limited resource. Thirty seven taxa were only found as epiphytes, 36 being Rhodophyta.

Algal distributions within the bay appear to correspond to a combination of salinity tolerance and substratum availability. Within the hypersaline area south of Faure Sill, *Polyphysa peniculus* is the dominant species, forming 'collars' around the stromatolites in Hamelin Pool. *Hormophysa cuneiformis* and *Dictyota furcellata* are also regularly present, but the other species recorded (*Caulerpa lentillifera, Aglaothamnion cordatum, Crouania capricornica*) occurred sporadically, and are probably at the extremities of their range. The low species richness in high salinity areas would seem to implicate salinity as a limiting factor. High salinities in Shark Bay have also been correlated with decreases in above-ground productivity of *Amphibolis antarctica* (Walker 1985), slow rates of growth and development of epiphytic crustose coralline algae (Harlin *et al.* 1985), and decreases in species richness of epiphytic algal communities on stems of *A. antarctica* (Kendrick *et al.* 1988). While salinity is a measure of total salts (grams of salts per kilogram of solution), it also describes biologically significant aspects of the physics and chemistry of water including total osmo-concentration (osmotic pressure), ion composition and density of water. High salinities have been shown to decrease growth (Munns *et al.* 1983), photosynthesis (Gordon *et al.* 1980, Lehnberg 1978) and respiration rates (Lehnberg 1978). More research as to the cause of the patterns in distribution and growth of the primary producers in relation to salinity within Shark Bay is needed.

Sustratum availability also plays a role in benthic algal distribution within Shark Bay. 'Hard ground', a diagenic feature of hypersaline basins, is common in the more saline areas of the Faure Sill and Hamelin Pool (Logan and Cubulski 1970), but did not support any benthic algae. On the seaward side of Faure Sill, where salinities are comparatively lower, algal species richness increases. Some of these areas are dominated by sandy substrata and where they are not colonized by seagrasses, sand colonising algae (rhizobenthos), most commonly *Penicillus nodulosus*, dominate. Localised rocky outcrops are restricted in area within Shark Bay. Intertidal and subtidal outcrops of the Peron sandstone occur in the channel off Monkey Mia, along Dirk Hartog Island and in the Freycinet Estuary. These areas support a diverse array of algae, suggesting that sustratum availability, rather than salinity, limits benthic algal distributions within Shark Bay. The most oceanic sampling locations, South Passage, Egg Island and Sandy Point, have a tropical flora, dominated by taxa such as *Galaxaura rugosa, Asparagopsis taxiformis, Laurencia* spp., *Lobophora variegata*, and *Hydroclathrus clathratus.*

Drift algae also play an important role as primary producers within seagrass beds. Virnstein and Carbonara (1985) found drift algal biomass to be greater than 3 times that of above ground biomass of seagrasses in the Indian River lagoon, Florida. They also found drift algae to be more important locally in terms of habitat, nutrient dynamics and primary production than the seagrasses. In Shark Bay, drift algae were abundant but patchy within seagrass beds. Drift algal biomass was only 34% and 26% of the mean above ground biomass of *Amphibolis antarctica* and *Posidonia australis* respectively (Walker and McComb 1988). All the drift algae collected were also found as epiphytes.

Although seagrasses are the most visually dominant organisms found in Shark Bay (Walker *et al.* 1988), macroalgae are a significant component within the system, occurring as epiphytes, drift algae associated with the seagrasses, occupying relatively rare rocky substrata or as rhizobenthos. These macroalgae show tropical biogeographical affinities and their local distribution within Shark Bay is correlated with salinity. However, the roles that these algae play, their contribution to production and nutrient cycling, and the factors controlling their distributions require further investigation.

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