Abundance, distribution and new records of scleractinian corals at Barrow Island and Southern Montebello Islands, Pilbara (Offshore) Bioregion

Z T RICHARDS [1*] & N L ROSSER [2†]

[1] *Western Australian Museum, Locked Bag 49, Welshpool DC, WA 6986, Australia.*

[2] *RPS Environment, 38 Station Street, Subiaco, WA 6008, Australia.*

* *Corresponding Author: ✉ zoe.richards@museum.wa.gov.au*

† *Current address: School of Animal Biology, University of Western Australia, 35 Stirling Highway, Crawley, WA 6009, Australia.*

The local abundance and distribution of scleractinian corals were documented near Barrow Island in the Pilbara (Offshore) Bioregion, Western Australia. Using a standard rapid ecological assessment method we recorded 204 species from 51 genera and as a result of this study we extend the known distribution range of 15 species. We find a high diversity of habitat types promotes high species richness, particularly among *Acropora* species. Our results confirm the existence of a unique suite of coral species in the Pilbara that is not recorded in the Oceanic Shoals (Offshore) or Pilbara (Nearshore) Bioregions. The Pilbara has a rich coral fauna that is often overlooked and the Barrow/Montebello Islands group may provide a high latitude refuge for some coral species including 39 species that are listed as Vulnerable on the IUCN red list of threatened species.

KEYWORDS: biodiversity, corals, demography, hermatypic, IUCN, local extinction.

INTRODUCTION

The status of coral-reef ecosystems is closely related to the health, abundance and diversity of hermatypic (reef-building) scleractinian corals which engineer the structural framework of the reef, contribute to primary production and nutrient recycling, and provide microhabitat and food for a wide diversity of coral reef species (Done *et al*. 1996; Paulay 1997; Knowlton & Rohwer 2003). In order to effectively safeguard scleractinian (hard) corals, it is important to have baseline demographic data about the structure and composition of communities across multiple scales, because this enables changes to be detected, and helps community responses to impact or management action to be disentangled from natural stochastic processes (Willis & Birks 2006).

In Australia, the majority of coral demographic studies have been undertaken on the east coast (Babcock 1991; Hughes 1996; Connell *et al*. 1997; Hughes *et al*. 1999; DeVantier *et al*. 2006) and the demography of coral communities on the west coast of Australia is less well-documented. Nevertheless, reef systems are well-developed in Western Australia ranging from extensive high-latitude reefs (e.g. Houtman Abrolhos) to immense fringing reef systems (e.g. Ningaloo and the Kimberley) to offshore atolls (e.g. Scott and Seringapatam Reefs). The latitudinal extent of coral communities in Western Australia has expanded and contracted in response to climate change since the Pleistocene. It is predicted that coral species that currently occur in tropical locations will migrate south in response to future climate change and potentially persist in higher latitude 'temperature refugia' (Greenstein & Pandolfi 2008). Thus it is imperative that such potential refuges are identified and protected (Fabricius *et al*. 2007).

For species to migrate south from tropical locations in Western Australia it is necessary for them to pass through the Pilbara region. Currently, coral communities in the Pilbara region are relatively undisturbed due to a low level of urbanisation (DEC 2007). Initial investigations suggest the Pilbara region makes a significant contribution to Western Australia's coral biodiversity (Marsh 1997, 2000; Veron & Marsh 1988; Veron 1993; Blakeway & Radford 2004; Griffith 2004). However, there is a notable lack of quantitative information about the ecological structure of coral communities in this region. Existing studies from inshore locations suggest that the composition of coral communities varies considerably in response to wave exposure, natural turbidity and current movements (Semeniuk *et al*. 1982; Blakeway & Radford 2004). Where wave energy is high and there are low to moderate levels of turbidity, *Acropora* predominates. As the level of turbidity increases, the dominant community shifts towards other types of coral such as *Porites, Pavona* and Faviidae, and where turbidity is very high, *Turbinaria* predominates.

Here, we examine the biodiversity and local demographic patterns of scleractinian corals at 14 sites in the vicinity of Barrow Island, located in the Pilbara (Offshore) Bioregion on the North West Shelf of Australia. We report new biogeographic information and highlight the Pilbara as a significant centre of coral diversity at regional, national and international scales. Finally we discuss demographic patterns that are relevant to the effective management of coral biodiversity.

METHODS

Site description

Barrow Island lies ~1200 km north of Perth and 56 km from the coastline on the North West Shelf of Western

Australia (20.82°S, 115.39°E). Barrow Island is the largest of a group of islands (which includes the Montebello and Lowendal Islands) that are formed by a long shallow bank of Miocene limestone with Pleistocene carbonate reef deposits (Veron & Marsh 1988).

The Barrow, Montebello and Lowendal Islands occur within the Pilbara (Offshore) (PIO) Bioregion (IMCRA 2006). The PIO Bioregion occurs in waters seaward of 10 m depth contour between North West Cape and the Montebello Islands (Figure 1). The PIO Bioregion occurs offshore from the Pilbara (Nearshore) Bioregion, although it is not to be confused with the Oceanic Shoals (Offshore) Bioregion which occurs seaward of the North West Shelf.

Coral-reef ecosystems in the PIO Bioregion are considered unique due to the complexity of substrate types, oceanographic conditions and habitat diversity (IMCRA 1998; Brewer *et al*. 2007; DEC 2007). Tides in the Barrow Island region are semidiurnal, (two high tides and two low tides per day) and the tidal range varies significantly around the island with a maximum spring tide on the east coast over 4 m and <2.5 m on the west coast. Sea-surface temperatures in the area vary from 23°C to 29°C (Chevron Australia 2011) and there are frequent cyclones in the region (e.g. four tropical cyclones were recorded near Barrow Island during the 2010/2011 cyclone season).

Survey design and analysis

Coral-biodiversity surveys were conducted at 14 sites in the vicinity of Barrow Island. Twelve sites were surveyed along a north–south gradient on the eastern side of Barrow Island, one protected back-reef habitat was surveyed on the western side of the island and one site was surveyed at the southern Montebello Islands (Figure 2; Appendix 1). A standard method of rapid ecological assessment (DeVantier *et al*. 1998; Kospartov *et al.* 2006) was undertaken by snorkel. Coral communities were documented to a maximum depth of 10 m, encompassing an area of ~150 m radius. At each site, surveys were conducted for 120 minutes, or until species saturation was reached (i.e. until no new species were recorded for a 15 minute period).

Species were identified *in situ* to species level wherever possible; otherwise a voucher specimen was collected for subsequent identification at the Museum of Tropical Queensland. Species names were interpreted according to Veron (2000) and Wallace (1999). One unidentified species has been designated as *Acropora arafura,* a new species recently described by Carden Wallace (Wallace *et al*. 2012).

The relative abundance of each species was ranked on a five-point scale adapted from a DAFOR scale which is commonly used in flora and fauna surveys and broadly analogous to a logarithmic scale: 1, rare (1, 2 colonies); 2, infrequent (3–5 colonies); 3, frequent (6–20 colonies); 4, common (21–50 colonies); 5, dominant (51+ colonies) (Jongman *et al*. 1995; DeVantier *et al*. 1998). These ordered variables have a relative magnitude interpretation, so a mean difference of 1 corresponds approximately to a log difference in abundance. When large stands were encountered, every 1 m^2 was treated as two colonies.

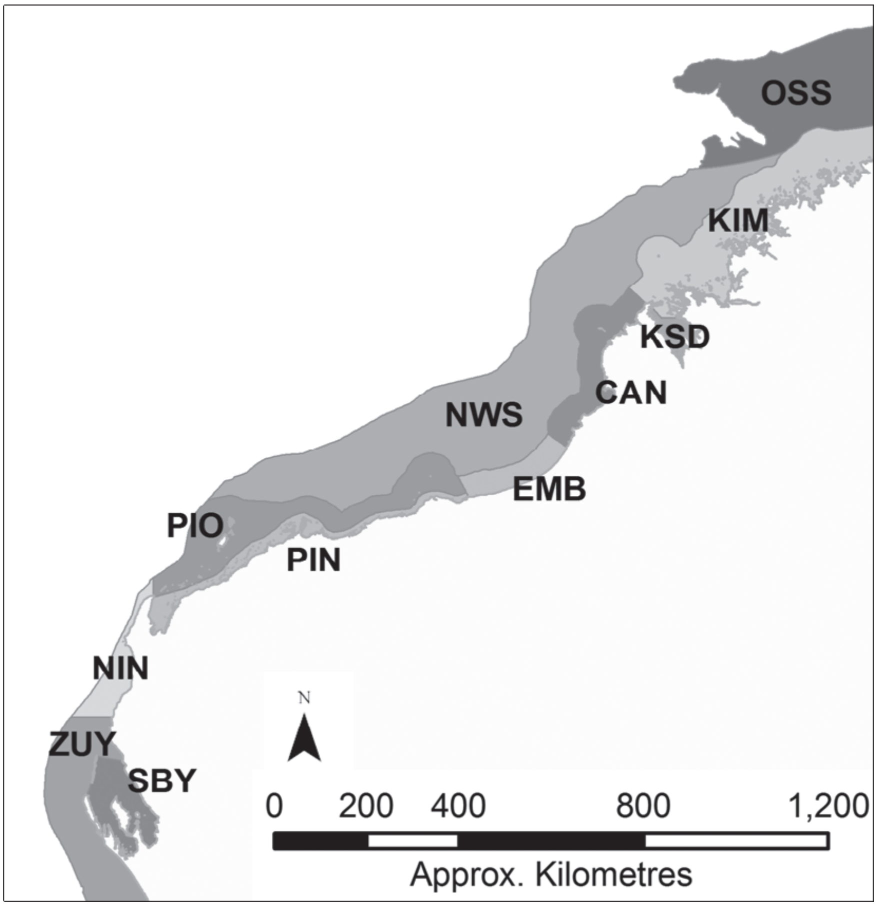

Figure 1 Map of the bioregions in north Western Australia as delineated by IMCRA (1998). Bioregions are: OSS, Oceanic Shoals; KIM, Kimberley; NWS, North West Shelf; KSD, King Sound; CAN, Canning; EMB, Eighty Mile Beach; PIN, Pilbara (Nearshore); PIO, Pilbara (Offshore); NIN, Ningaloo; ZUY, Zuytdorp; SBY, Shark Bay.

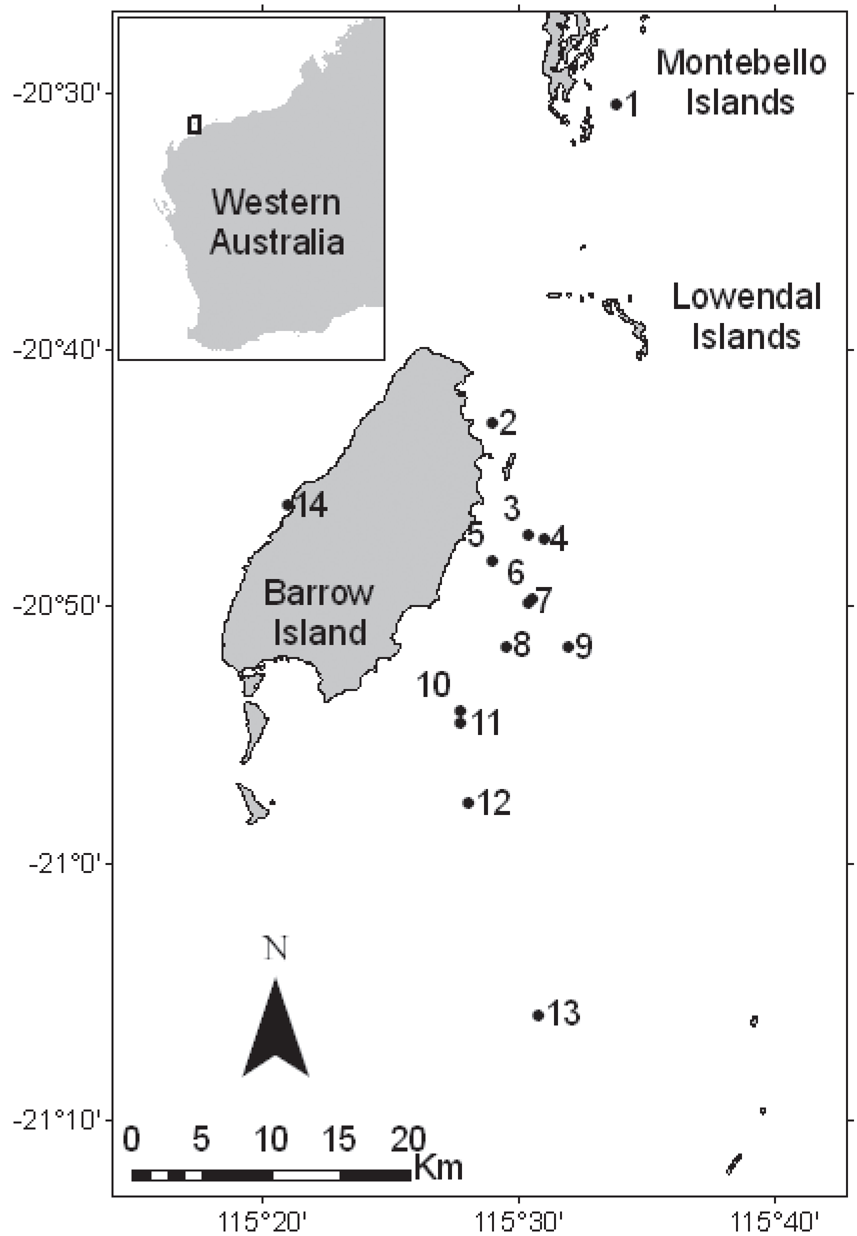

Figure 2 Map of study sites in the vicinity of Barrow/Montebello Islands that are located 56 km off the Pilbara coast on the North West Shelf of Western Australia.

Species accumulation curves were calculated for each location using the 'vegan' library in R using the function 'specaccum' with jack-knifed standard errors (Oksanen *et al.* 2009). This provided a graphical check of whether sampling was sufficient to detect rare members of the assemblage. The threatened status of coral species were downloaded from the IUCN Red List of threatened species (www.iucnredlist.org).

RESULTS

A total of 204 species from 51 genera of scleractinian corals was recorded (Tables 1, 2). We report here 15 new taxonomic records (Table 3), including five for Australia, five for Western Australia and five for the North West Shelf. The species accumulation curve approached an asymptote indicating this dataset provides a good representation of the coral diversity in shallow reef locations near Barrow Island (Figure 3), although additional survey sites are likely to be needed to fully represent the wider diversity present in the PIO Bioregion because an additional 41 species recorded by Marsh (2000) from the Montebello Islands were not recorded in the present survey.

Site-specific species richness varied from a minimum of 50 species along the western side of Barrow Island to a maximum of 103 species at the southern Montebello Islands (Figure 4). The level of diversity along the eastern side of Barrow Island was relatively homogeneous but the proportional composition of different genera changed from *Acropora*-dominated communities in the north to *Porites*-dominated communities in the south.

Except for Site 14 on the west coast, characteristic fringing reef habitats such as reef flats and slopes were not immediately evident. Moreover survey sites consisted of isolated patch reef habitat with low-medium rugosity surrounded by soft-bottom inter-reefal habitat dominated by *Echinopora, Merulina* and *Pectinia*. Two sites (2 and 3)

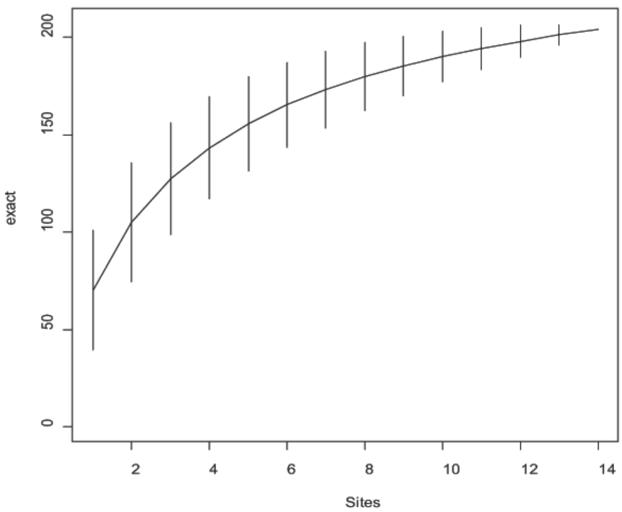

Figure 3 Species accumulation curve shows that this dataset is a good representation of the coral diversity in the vicinity of Barrow/Montebello Islands as the species accumulation curve approaches an asymptote.

in the northeast of the island were dominated by corymbose *Acropora* and branching *Acropora* thickets. Of particular interest are sites on the southeast of the island where very large *Porites* colonies (>8 m greater diameter) were common. At these *Porites*-dominated sites, additional species (such as faviids, mussids and corymbose acroporids) colonised bare parts of the upper colony surfaces.

Of the 51 genera recorded, the most species-rich genera were *Acropora* (47 spp.), *Montipora* (19 spp.) and *Favia* (12 spp.) (Figure 5). The most abundant genera (in terms of the number of colonies) were *Acropora, Porites* and *Montipora*. Two species were recorded at all 14 sites (*Lobophyllia hemprichii* and *Pocillopora damicornis*); however they did not predominate at any site (Table 2). Species that were numerically dominant (i.e. over 51 colonies per site) and locally widespread (recorded at 10 or more sites) were *Porites lutea, Echinopora lamellosa, Merulina ampliata* and *Pectinia lactuca*. Four other species—*Porites australiensis, Acropora muricata, Acropora nasuta* and *Porites cylindrica*—were also locally widespread (present at 10 or more sites) and sometimes

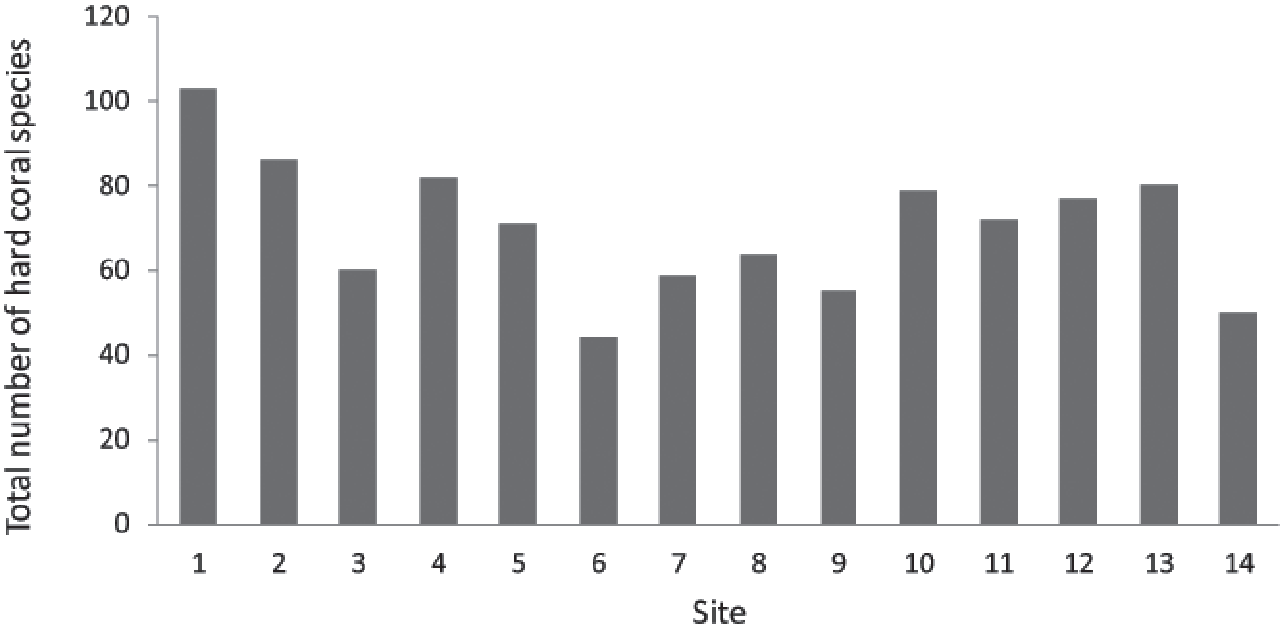

Figure 4 Species richness at the 14 survey sites in the vicinity of Barrow/Montebello Islands.

Table 1 Total number of hard coral species recorded in different regions of Western Australia.

Location	Lat/long	Species richness	Source
Ashmore Reef	12°15'S 123°02'E	275	Richards *et al*. 2009
Scott Reef	14°10'S 121°84'E	297	McKinney 2006
Bonaparte Archipelago	14°17'S 125°18'E	278	Z Richards, C Wallace, P Muir, J Veron, A Noreen, N Rosser & M Forde unpubl. data.
Rowley Shoals	17°20'S 119°20'E	188	Veron 2004
Dampier Archipelago	20°32'S 116°36'E	229	Griffith 2004
Montebello Islands	20°28'S 115°33'E	150	Marsh 2000
Barrow Island/South Montebello Island	20°82'S 115°39'E	204	This survey
Ningaloo Reef	22°40'S 113°39'E	217	Veron & Marsh 1988
Shark Bay	25°30'S 113°30′E	81	Veron 2004
Abrolhos Islands	28°43'S 113°47'E	192	Veron 2004
Geraldton	28°46'S 114°36'E	14	Veron 2004
Rottnest Island	32°00'S 115°31'E	19	Veron 2004

Table 2 The corals of Barrow Island/South Montebello Island with local pattern of occupancy denoted according to the number of sites occupied and the relative abundance at each site.

Species	No. of sites	Relative abundance	IUCN classification
Family Acroporidae			
Acropora aculeus (Dana 1846)	1	rare	Vu
Acropora acuminata (Verrill 1864)	3	rare to infrequent	Vu
Acropora anthocercis (Brook 1893)	1	rare	Vu
Acropora austera (Dana 1846)	8	rare to dominant	NT
Acropora cerealis (Dana 1846)	3	rare to infrequent	LC
Acropora arafura (Wallace, Done & Muir 2012)	9	rare to infrequent	Not assessed
Acropora cytherea (Dana 1846)	1	rare	LC
Acropora digitifera (Dana 1846)	3	rare to frequent	NT
Acropora divaricata (Dana 1846)	13	rare to frequent	NT
Acropora donei Veron& Wallace 1984	2	rare	Vu
Acropora florida (Dana 1846)	11	rare to frequent	NT
Acropora gemmifera (Brook 1892)	4	rare to infrequent	LC
Acropora glauca (Brook 1893)	4	rare to infrequent	NT
Acropora grandis (Brook 1892)	4	rare to infrequent	LC
Acropora horrida (Dana 1846)	1	rare	Vu
Acropora humilis (Dana 1846)	3	rare	NT
Acropora hyacinthus (Dana 1846)	5	rare to frequent	NT
Acropora insignis Nemenzo 1967	5	rare	DD
Acropora intermedia (Brook 1891)	6	rare to dominant	LC
Acropora latistella (Brook 1891)	4	rare	LC
Acropora listeri (Brook 1893)	1	rare	Vu
Acropora loripes (Brook 1892)	3	rare to infrequent	NT
Acropora lovelli Veron & Wallace 1984	3	rare	Vu
Acropora lutkeni Crossland 1952	4	rare	NT
Acropora microclados (Ehrenberg 1834)	1	rare	Vu
Acropora microphthalma (Verrill 1859)	2	rare to infrequent	LC
Acropora millepora (Ehrenberg 1834)	8	rare to common	NT
Acropora muricata (Linnaeus 1758)	11	rare to common	NT
Acropora nasuta (Dana 1846)	11	rare to common	NT
Acropora palmerae Wells 1954	1	rare	Vu
Acropora polystoma (Brook 1891)	2	rare	Vu
Acropora pulchra (Brook 1891)	3	infrequent	LC
Acropora robusta (Dana 1846)	2	rare	LC
Acropora samoensis (Brook 1891)	10	rare to infrequent	LC
Acropora sarmentosa (Brook 1892)	1	rare	LC
Acropora secale (Studer 1878)	3	rare to infrequent	NT
Acropora selago (Studer 1878)	3	rare	NT
Acropora solitaryensis Veron & Wallace 1984	3	rare	Vu
Acropora spicifera (Dana 1846)	7	rare to frequent	Vu
Acropora subulata (Dana 1846)	3	rare	LC
Acropora tenuis (Dana 1846)	10	rare to frequent	NT
Acropora valenciennesi (Milne Edwards & Haime 1860)	6	rare to infrequent	LC
Acropora valida (Dana 1846)	3	rare to infrequent	LC
Acropora verweyi Veron & Wallace 1984	1	rare	Vu
Acropora willisae Veron & Wallace 1984	3	rare to infrequent	Vu
Acropora yongei Veron & Wallace 1984	1	rare	LC
Astreopora gracilis Bernard 1896	1	infrequent	LC
Astreopora listeri Bernard 1896	2	rare	LC
Astreopora myriophthalma (Lamarck 1816)	6	rare to frequent	LC
Isopora brueggemanni (Brook 1893)	4	rare to frequent	Vu
Montipora aequituberculata Bernard 1897	7	rare to frequent	LC
Montipora crassituberculata Bernard 1897	3	rare to infrequent	Vu
Montipora danae (Milne Edwards & Haime 1851)	4	rare	LC
Montipora digitata (Dana 1846)	3	rare to frequent	LC
Montipora efflorescens Bernard 1897	4	rare	NT
Montipora foliosa (Pallas 1766)	1	rare	NT
Montipora grisea Bernard 1897	2	rare to infrequent	LC
Montipora hispida (Dana 1846)	8	rare to frequent	LC
Montipora incrassata (Dana 1846)	1	rare	NT
Montipora informis Bernard 1897	1	rare	LC
Montipora mollis Bernard 1897	2	rare	LC
Montipora monasteriata (Forskäl 1775)	2	rare	LC

Table 2 (cont.)

Species	No. of sites	Relative abundance	IUCN classification
Montipora peltiformis Bernard 1897	6	rare to infrequent	NT
Montipora stellata Bernard 1897	1	rare	LC
Montipora tuberculosa (Lamarck 1816)	6	rare to infrequent	LC
Montipora turgescens Bernard 1897	5	rare to infrequent	LC
Montipora turtlensis Veron & Wallace 1984	2	rare	Vu
Montipora undata Bernard 1897	6	rare to infrequent	NT
Montipora verrucosa (Lamarck 1816)	3	rare	LC
Family Agariciidae			
Gardineroseris planulata Dana 1846	1	frequent	LC
Leptoseris explanata Yabe & Sugiyama 1941	1	rare	LC
Leptoseris mycetoseroides Wells 1954	1	rare	LC
Pachyseris rugosa (Lamarck 1801)	6	rare to infrequent	Vu
Pachyseris speciosa (Dana 1846)	9	infrequent to common	LC
Pavona clavus (Dana 1846)	2	rare	LC
Pavona decussata (Dana 1846)	5	rare to infrequent	Vu
Pavona duerdeni Vaughan 1907	2	rare	LC
Pavona explanulata (Lamarck 1816)	2	rare to infrequent	LC
Pavona maldivensis (Gardiner 1905)	1	rare	LC
Pavona varians Verrill 1864	2	rare to infrequent	LC
Pavona venosa (Ehrenberg 1834)	1	rare	Vu
Family Dendrophyliidae			
Turbinaria bifrons Brüggemann 1877	2	rare	Vu
Turbinaria mesenterina (Lamarck 1816)	6	rare to frequent	Vu
Turbinaria patula (Dana 1846)	2	rare	Vu
Turbinaria peltata (Esper 1794)	2	rare	Vu
Turbinaria reniformis Bernard 1896	10	rare to frequent	Vu
Family Euphylliidae			
Euphyllia ancora Veron & Pichon 1979	2	rare	Vu
Euphyllia glabrescens (Chamisso & Eysenhardt 1821)	1	rare	NT
Physogyra lichtensteini (Milne Edwards & Haime 1851)	2	rare	Vu
Plerogyra sinuosa (Dana, 1846)	3	rare	NT
Family Faviidae			
Caulastrea curvata Wijsmann-Best 1972	5	rare to frequent	Vu
Cyphastrea chalcidium (Forskål 1775)	5	rare to infrequent	LC
Cyphastrea microphthalma (Lamarck 1816)	12	rare to frequent	LC
Cyphastrea serailia (Forskål 1775)	3	rare to infrequent	LC
Diploastrea heliopora (Lamarck 1816)	5	rare to common	NT
Echinopora ashmorensis Veron 1990	4	rare to frequent	Vu
Echinopora lamellosa (Esper 1795)	12	rare to dominant	LC
Favia favus (Forskål 1775)	3	rare to infrequent	LC
Favia helianthoides Wells 1954	3	rare	NT
Favia laxa (Klunzinger 1879)	2	rare	NT
Favia maritima (Nemenzo 1971)	2	rare	NT
Favia matthaii Vaughan 1918	4	rare to infrequent	NT
Favia maxima Veron, Pichon & Wijsman-Best 1972	1	rare	NT
Favia pallida (Dana 1846)	11	rare to frequent	LC
Favia rotumana (Gardiner 1899)	4	rare	LC
Favia rotundata Veron, Pichon & Wijsman-Best 1972	8	rare	NT
Favia speciosa Dana 1846	8	rare to frequent	LC
Favia stelligera (Dana 1846)	4	rare to infrequent	NT
Favia veroni Moll & Borel-Best 1984	4	rare	NT
Favites abdita (Ellis & Solander 1786)	10	rare to infrequent	NT
Favites acuticollis (Ortmann 1889)	1	infrequent	NT
Favites chinensis (Verrill 1866)	3	rare	NT
Favites complanata (Ehrenberg 1834)	4	rare	NT
Favites flexuosa (Dana 1846)	2	rare	NT
Favites halicora (Ehrenberg 1834)	12	rare to frequent	NT
Favites paraflexuosa Veron 2000	1	rare	NT
Favites pentagona (Esper 1794)	5	rare to infrequent	LC
Favites russelli (Wells 1954)	3	rare	NT
Favites stylifera (Yabe & Sugiyama 1937)	3	rare	NT
Goniastreaaspera Verrill 1905	3	rare to frequent	LC
Goniastrea australensis (Milne Edwards & Haime 1857)	9	rare to infrequent	LC

Species	No. of sites	Relative abundance	IUCN classification
Goniastrea edwardsi Chevalier 1971	3	rare to infrequent	LC
Goniastrea favulus (Dana 1846)	3	rare to frequent	NT
Goniastrea pectinata (Ehrenberg 1834)	12	rare to frequent	LC
Goniastrea retiformis (Lamarck 1816)	9	rare to common	LC
Leptastrea pruinosa Crossland 1952	1	rare	LC
Leptastrea purpurea (Dana 1846)	5	rare	LC
Leptastrea transversa Klunzinger 1879	2	rare	LC
Leptoria phrygia (Ellis & Solander 1786)	5	rare to infrequent	NT
Montastrea colemani Veron 2000	2	rare	NT
Montastrea curta (Dana 1846)	9	rare to infrequent	LC
Montastrea salebrosa (Nemenzo 1959)	1	rare	Vu
Moseleya latistellata Quelch 1884	2	rare	Vu
Oulophyllia bennettae (Veron & Pichon 1977)	3	rare	NT
Oulophyllia crispa (Lamarck 1816)	3	rare	NT
Platygyra acuta Veron 2000	9	rare	NT
Platygyra daedalea (Ellis & Solander 1786)	10	rare to frequent	LC
Platygyra lamellina (Ehrenberg 1834)	8	rare to infrequent	NT
Platygyra pini Chevalier 1975	13	rare to frequent	LC
Platygyra ryukyuensis Yabe & Sugiyama 1936	5	rare to infrequent	NT
Platygyra sinensis (Milne Edwards & Haime 1849)	13	rare to infrequent	LC
Platygyra yaeyamaensis Eguchi & Shirai 1977	1	rare	Vu
Plesiastrea versipora (Lamarck 1816)	3	rare	LC
Family Fungiidae			
*Fungia scruposa*Klunzinger 1879	1	infrequent	LC
Fungia fungites (Linneaus 1758)	1	frequent	NT
Fungia repanda Dana 1846	9	rare to frequent	LC
Halomitra pileus (Linnaeus 1758)	1	rare	LC
Herpolitha limax (Houttuyn 1772)	8	rare to infrequent	LC
Lithophyllon undulatum Rehberg 1892	9	rare to infrequent	NT
Podabacia crustacea (Pallas 1766)	8	rare to frequent	LC
Polyphyllia talpina (Lamarck 1801)	1	rare	
Family Merulinidae			
Hydnophora exesa (Pallas 1766)	11	rare to infrequent	NT
Hydnophora grandis Gardiner 1904	6	rare to infrequent	LC
Hydnophora microconos (Lamarck 1816)	1	rare	NT
Hydnophora pilosa Veron 1985	9	rare to frequent	LC
Hydnophora rigida (Dana 1846)	5	rare to infrequent	LC
Merulina ampliata (Ellis & Solander 1786)	12	rare to dominant	LC
Merulina scabricula Dana 1846	7	rare to frequent	LC
Scapophyllia cylindrica Milne Edwards & Haime 1848	1	rare	LC
Family Mussidae			
Acanthastrea echinata (Dana 1846)	7	rare	LC
Acanthastrea hemprichii (Ehrenberg 1834)	2	rare	Vu
Acanthastrea subechinata Veron 2000	1	rare	NT
Blastomussa merleti Wells 1961	2	rare	LC
Lobophyllia corymbosa (Forskål 1775)	12	rare to infrequent	LC
Lobophyllia diminuta Veron 1985	6	rare to frequent	Vu
Lobophyllia flabelliformis Veron 2000	2	rare	Vu
Lobophyllia hemprichii (Ehrenberg 1834)	14	rare to frequent	LC
Lobophyllia robusta Yabe & Sugiyama 1936	5	rare to infrequent	LC
Scolymia australis (Milne Edwards & Haime 1849)	1	rare	LC
Symphyllia radians Milne Edwards & Haime 1849	3	rare	LC
Symphyllia recta (Dana 1846)	5	rare	LC
Family Oculinidae			
Galaxea astreata (Lamarck 1816)	13	rare to frequent	Vu
Galaxea fascicularis (Linnaeus 1767)	10	rare to frequent	NT
Family Pectiniidae			
Echinophyllia aspera (Ellis & Solander 1788)	9	rare to infrequent	LC
Echinophyllia orpheensis Veron & Pichon 1980	5	rare to infrequent	LC
Mycedium elephantotus (Pallas 1766)	5	rare to infrequent	LC
Mycedium robokaki Moll & Borel-Best 1984	1	rare	LC
Oxypora glabra Nemenzo 1959	7	rare to frequent	LC
Oxypora lacera Verrill 1864	11	rare to infrequent	LC
Pectinia lactuca (Pallas 1766)	12	rare to dominant	Vu
Pectinia paeonia (Dana 1846)	6	rare to common	NT

Table 2 (cont.)

Species	No. of sites	Relative abundance	IUCN classification
Family Pocilloporidae			
Pocillopora damicornis (Linnaeus 1758)	14	rare to frequent	LC
Pocillopora verrucosa (Ellis & Solander 1786)	5	rare to infrequent	LC
Seriatopora caliendrum Ehrenberg 1834	7	rare to frequent	NT
Stylophora pistillata Esper 1797	6	rare to frequent	NT
Stylophora subseriata (Ehrenberg 1834)	1	rare	LC
Family Poritidae			
Goniopora burgosi Nemenzo 1955	1	rare	Vu
Goniopora lobata Milne Edwards & Haime 1860	8	rare to infrequent	NT
Goniopora stokesi Milne Edwards & Haime 1851	2	rare	NT
Goniopora tenuidens (Quelch 1886)	2	rare	LC
Porites annae Crossland 1952	10	rare to infrequent	NT
Porites australiensis Vaughan 1918	12	rare to common	LC
Porites cylindrica Dana 1846	10	infrequent to common	NT
Porites lichen Dana 1846	5	rare to frequent	LC
Porites lutea Milne Edwards & Haime 1851	13	infrequent to dominant	LC
Porites nigrescens Dana 1846	9	rare to frequent	Vu
Porites rus (Forskål 1775)	5	rare to frequent	LC
Porites solida (Forskål 1775)	2	rare to infrequent	LC
Family Siderasteridae			
Coscinaraea columna (Dana 1846)	4	rare	LC
Psammocora contigua (Esper 1797)	10	rare to frequent	NT
Psammocora digitata Milne Edwards & Haime 1851	5	rare	NT
Psammocora nierstraszi van der host 1921	1	rare	LC
Psammocora obtusangula (Lamarck 1816)	1	rare	NT

[a] The global threatened status of each species is noted according to IUCN categories and criteria: Vu, vulnerable; NT, near threatened; LC, least concern; DD, data deficient.

Table 3 New taxonomic records identified during these surveys.

Species	New record	Sites where species recorded
Acanthastrea subechinata Veron 2000	Australia	12
Favites acuticollis (Ortmann 1889)	Australia	14
Platygyra acuta Veron 2000	Australia	1,5,6,7,10,11,12,13,14
Platygyra yaeyamaensis Eguchi & Shirai 1977	Australia	1
Stylophora subseriata (Ehrenberg 1834)	Australia	1
Acanthastrea hemprichii (Ehrenberg 1834)	Western Australia	2,5
Hydnophora grandis Gardiner 1904	Western Australia	1,4,8,9,10,11
Lobophyllia robusta Yabe & Sugiyama 1936	Western Australia	4,5,10,11,13
Montastrea colemani Veron 2000	Western Australia	1,8
Montastrea salebrosa (Nemenzo 1959)	Western Australia	1
Psammocora obtusangula (Lamarck 1816)	North West Shelf	1
Goniopora burgosi Nemenzo 1955	North West Shelf	12
Mycedium robokaki Moll & Borel-Best 1984	North West Shelf	4
Pavona duerdeni Vaughan 1907	North West Shelf	10,11
Scolymia australis (Milne Edwards & Haime 1849)	North West Shelf	1

Table 4 Percentage of species in each abundance category

Abundance category	Percentage of species
Rare	44.1
Rare to infrequent	25.7
Rare to frequent	19.8
Rare to common	3.5
Rare to dominant	2.5
Infrequent	2.0
Infrequent to common	1.0
Frequent	1.0
Infrequent to dominant	0.5

common (between 21 and 50 colonies per site). Fifty-three percent of species were recorded as rare at the sites they occupied, while 32% of species were infrequent, 12% were frequent, 1.5% were common and only 1.2% were dominant (Table 4). Eighty-nine species were always recorded as rare and 35 of these rare species (17%) were recorded at a single site only (Table 2).

Coral genera that so far have not been recorded from the Barrow/Montebello Islands but are found on other reefs in Western Australia include *Anacropora*, *Stylocoeniella*, *Oulastrea*, *Cantharellus*, *Diaseris*, *Heliofungia*, *Sandolithia* and *Palauastrea*. However, it is important to

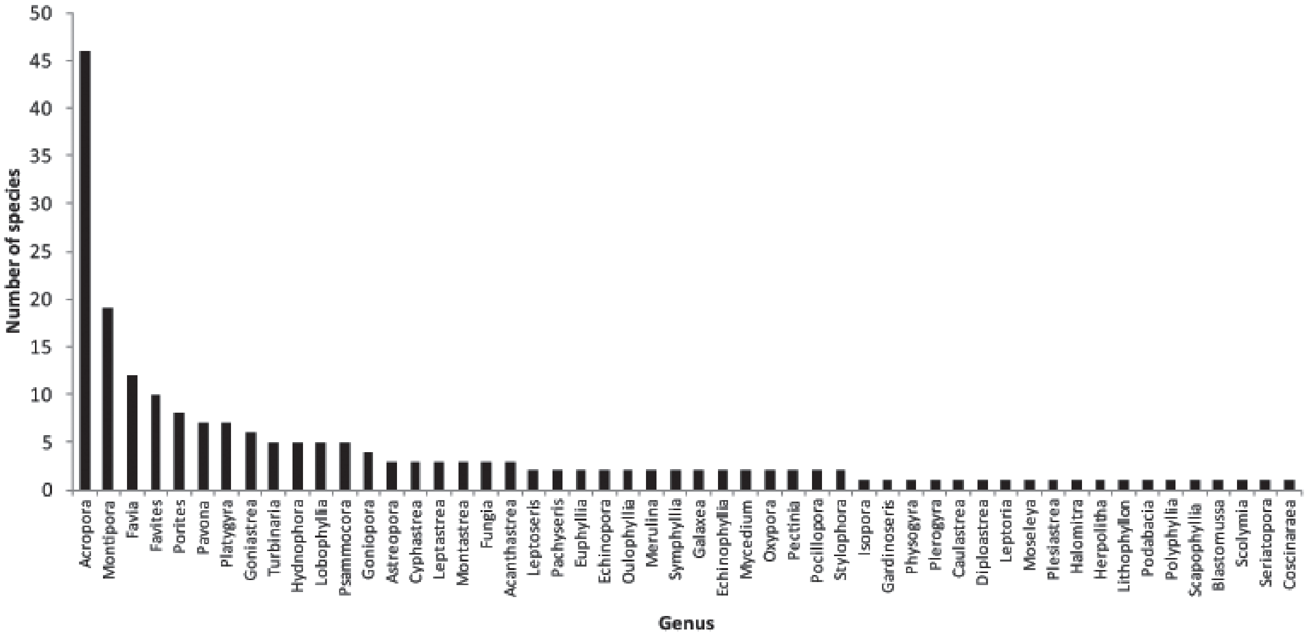

Figure 5 Number of species within each genus recorded in the present survey clearly shows *Acropora* and *Montipora* are the most species-rich genera followed by *Favia, Favites, Porites, Pavona* and *Platygyra.*

note that rare or cryptic species or those occurring beyond 10 m depth may not have been detected by our survey methodology. Thus, further surveys, particularly of the reef edge and reef slope habitats on the west coast of Barrow Island, may reveal additional species.

DISCUSSION

This study is the first to record the relative abundance of corals in the PIO Bioregion in Western Australia and describes a community that, when compared with others in the region, has greater species diversity than currently recorded from the Pilbara (nearshore) Bioregion, but lower diversity than that recorded from the offshore atolls and Kimberley (Table 1). Importantly, this community contains 15 species that are not currently represented elsewhere in Western Australia, and in some cases, Australia (Table 3). A total of 204 species from 51 genera of scleractinian coral were recorded in this survey, and following Marsh (1997, 2000) raised the number of scleractinian species recorded from Barrow/Montebello Islands to 245. Thus, the coral communities of the PIO Bioregion make a significant contribution to Australia's biodiversity.

An important finding arising from the provision of abundance data in this study is that of the 204 species recorded in this survey, only eight species (4%) dominate the community (i.e. they were present at 10 or more sites with over 21 colonies counted at one or more sites: *Porties lutea*, *Echinopora lamellosa, Merulina ampliata, Pectinia lactuca, Porites australiensis, Acropora muricata, Acropora nasuta* and *Porites cylindrica*). Unfortunately few quantitative datasets exist to describe local patterns of species abundance in coral communities at other Pilbara locations, hence it is not currently possible to equivocally comment about whether this particular suite of dominant species is unique to this location, or whether these species reach a similar abundance elsewhere. Nevertheless, it is likely that the Barrow/Montebello Islands are important centres of abundance for these species.

In a global context, one of these dominant species (*Pectinia lactuca*) is classified as Vulnerable to extinction this century according to IUCN categories and criteria (Carpenter *et al*. 2008), hence the Barrow/Montebello Islands may prove to be a globally important sanctuary for this species. Thirty-eight other members of the Barrow/Montebello Island assemblage are listed as Vulnerable by the IUCN (Table 2) including four of the species whose range has been extended to the PIO Bioregion (*Acanthastrea hemprichii; Platygyra yaeyamansis; Montastrea salebrosa* and *Goniopora burgosi*). Other species of interest in the Barrow/Montebello Island community that are classified as vulnerable by the IUCN are *Acropora spicifera* and *Echinopora ashmorensis* which, in Australia, are known only from the west coast. All five of the *Turbinaria* spp. documented at Barrow/Montebello Islands are classified as Vulnerable, which is somewhat surprising as *Turbinaria* are often described as a hardy species (Fabricius *et al*. 2007).

Our results suggest that almost half of the coral species in the vicinity of Barrow Island have very small population sizes. Eighty-nine species (44%) recorded in this survey were rare (i.e. only one or two colonies recorded per site) (Table 4) and 35 species (17%) were not only rare, but occurred at a single site only (Table 2). Considering the majority of species in ecological communities are rare (Magurran & Henderson 2003), and that some populations of rare species persist over evolutionary time in low numbers, at least partly because their small local populations minimise densitydependant processes (e.g. disease outbreaks often occur among common species: Gaston 1994), it is not unusual to find a large number of rare species.

The suite of species recorded in this study suggests that there are marked cross-shelf differences in the composition of Pilbara communities. For example, at inshore sites near the Passage Island group (Onslow coastline), *Turbinaria, Favites, Platygyra, Goniopora* and *Lobophyllia* were the most abundant genera and there is very little representation of *Acropora* and *Pavona* (Z T Richards unpubl. data). At Barrow/Montebello Islands, the most abundant genera were *Acropora*, *Montipora* and *Porites*. These differences in community composition are most likely due to wave exposure and the level of suspended particulate matter in the water column (Marsh 1997; Blakeway & Radford 2005). While terrestrial run-off to the marine environment is generally low in the Pilbara region, input from rivers, and re-suspension of deposited sediments produces extremely turbid conditions in some areas (Margvelashvili *et al*. 2006). Given the dynamic and turbid conditions, it is apparent the many of the corals present in the Pilbara have adapted to a high sediment regime. Even though corals were traditionally thought to prefer clear water because light penetration benefits photosynthesis for their symbiotic dinoflagellates, new studies suggest that at high particle loads, corals gain energy by increasing their heterotrophic feeding (Anthony & Fabricius 2000). Hence, corals growing in the turbid areas of the Pilbara may offset the stress that accompanies high turbidity by changing their trophic mode, which sustains a positive energy balance in highly turbid conditions.

This survey adds many new species records to Western Australia, and highlights the fact that the Pilbara region has a rich coral fauna that is often overlooked. The diversity of habitats and isolated nature of many of the reefs around Barrow Island may provide a refuge for a number of coral species; however considering this community is dominated by only a small number of species with the majority of species occurring in low abundance, conservation plans for this region should be underpinned with quantitative data to accurately predict and protect species at risk.

ACKNOWLEDGEMENTS

This survey of the scleractinian coral fauna of Barrow Island was conducted as part of the Coastal and Marine Baseline State and Environmental Impact Report for the Western Australian Gorgon Gas Development. We thank Barry Wilson for fruitful discussions, Fiona Webster and Jay Hayes for their support in the field, and Mick Ashcroft for assistance with figure preparation. Funding and facilities for this study were provided by the Gorgon Joint Venture Participants [The Gorgon Project is operated by an Australian subsidiary of Chevron and is a joint venture of the Australian subsidiaries of Chevron (approximately 47 percent), ExxonMobil (25 percent) and Shell (25 percent), Osaka Gas (1.25 percent), Tokyo Gas (one percent) and Chubu Electric Power (0.417 percent)], RPS Environment and the Australian Museum. We also thank Journal reviewers Barry Wilson and Mike van Keulen for their comments.

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Received 24 May 2012; accepted 30 October 2012

APPENDIX 1 GPS CO-ORDINATES AND DEPTH OF EACH OF THE 14 STUDY SITES.

Site	Latitude (S)	Longitude (E)	Approximate water depth (m)
1	20°30.472'	115°33.829'	6.5
2	20°42.898'	115°29.001'	4.0
3	20°47.229'	115°30.363'	3.0
4	20°47.350'	115°30.477'	5.0
5	20°48.249'	115°28.961'	6.0
6	20°49.713'	115°30.507'	9.0
7	20°49.867'	115°30.384'	8.8
8	20°51.575'	115°29.544'	6.5
9	20°51.624'	115°31.976'	9.3
10	20°54.085'	115°27.755'	6.3
11	20°54.949'	115°27.756'	2.5
12	20°57.717'	115°28.067'	3.5
13	21°5.929'	115°30.810'	4.8
14	20°46.068'	115°21.001'	1.5