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Kimberley marine biota. Historical data: introduction and methods

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ABSTRACT – The Kimberley region is currently undergoing substantial growth in industrial and general human use. The region is recognised as relatively pristine with a high diversity of habitats and species, but there is little published information on the marine biodiversity. Australian museums and herbaria are the repositories of species diversity datasets and voucher specimens collected over many decades (1880s to present). We have collated data on marine plants, sponges, cnidarians (predominately hard and soft corals), free living worms (predominately polychaetes), crustaceans, molluscs, echinoderms, brachiopods, ascidians and fishes from five Australian natural science collections. We identified >50,000 specimen records of approximately 6,000 shallow water marine species from the Project Area. The scope and methods adopted for this project are outlined here.

KEYWORDS: natural history collections, species inventory, Kimberley Project Area, baseline, NW Australia, biodiversity

INTRODUCTION

Knowing which species occur in an area is fundamental to many aspects of biological, conservation and environmental research, providing a baseline dataset to inform conservation and policy decisions, as well as to monitor both human and climate induced change (O'Connell et al. 2004; Sloan and Bartier 2009; Pyke and Ehrlich 2010). As such, it is vital information for the successful management of an area, including the development of marine protected areas and the preparation of environmental impact assessments. The study of taxonomy underpins this endeavour as it is the discipline responsible for defining, describing and understanding what constitutes a species and therefore informs distribution patterns (Cotterill 1995; Boero 2010).

Museums and herbaria are the repositories of species diversity datasets and voucher specimens (Cotterill 1995; Ponder et al. 2001; Sloan and Bartier 2009; Pyke and Ehrlich 2010; Appeltans et al. 2012; Huisman and Miller 2013). These collections provide a permanent record of the presence of a species in space and time (Cotterill 1995). The importance of natural science collection data to support biodiversity research and conservation planning is being increasingly recognised (Pyke and Ehrlich 2010). However, there are limitations to the available data, including bias in collecting effort (both taxonomic and geographic), taxonomic ambiguity and inadequate or poorly defined spatial coverage (Ponder et al. 2001; Funk and Richardson 2002; Graham et al. 2004).

The northern Australian coastline is recognised as having been exposed to minimal human impact (Halpern et al. 2008). Biodiversity is likely to be high in the region and a gradient in species diversity has been shown for a number of taxa (fishes, corals and echinoderms) along the Western Australian coastline, with higher diversity of species occurring in lower latitudes, including the Kimberley (Marsh and Marshall 1983; Wilson and Allen 1987; Veron and Marsh 1988; Hutchins 1999). However, there are few publications on species present in the region and much of this information is contained in specialist taxonomic literature. Currently, the region is undergoing substantial growth in industrial and other human use, including oil and gas extraction, fishing, aquaculture, and tourism (Wood and Mills 2008) and proposed marine protected areas (Department of Environment and Conservation 2009). Baseline marine biological data to characterise the values and assets in the region are required (Wood and Mills 2008).

The Western Australian Museum (WAM) has undertaken ten marine biological expeditions to locations within the Kimberley region since 1976 (Western Australian Museum 1981; Berry 1986;

Wells 1989; Morgan 1992; Berry 1993; Wells et al. 1995; Walker et al. 1996; Bryce et al. 1997; Walker 1997; Bryce 2009). These surveys have visited many areas of the Kimberley coast, inshore islands, and continental shelf edge atolls with varying taxonomic, spatial and temporal coverage. The specimens collected during these expeditions, along with those from other surveys, or from incidental collecting over the last century (1880s to present), are housed in Australian natural science collections, primarily in Western Australia. However, the majority of these datasets and their interpretation are not readily accessible to resource managers and researchers interested in the marine biological values of the region. To address this gap in our knowledge the WAM instigated an extensive data compilation of marine species (excluding vertebrates except for fishes) known from the region.

AIMS

To collate the records of shallow water (<30 m) marine flora and fauna (restricted to fishes and invertebrates) from the Kimberley Project Area as defined below, with relevant associated voucher specimens lodged in Australian natural science collections (1880s–2009), and to provide commentary on general trends in diversity patterns and collection gaps, both spatial and taxonomic, for these taxa.

METHODS

STUDY AREA, TAXONOMIC AND COLLECTION SCOPE

The Kimberley Project Area (henceforth 'Project Area') is defined by the coordinates 19.00°S 121.57°E; 19.00°S 118.25°E; 12.00°S 129.00°E; 12.00°S 121.00°E, with the coastline forming a natural inshore boundary. This irregular polygon stretches north along the coast from Cape Jaubert, south of Broome, to the Western Australia/Northern Territory border, and extends westward beyond the 1000 m bathymetric contour to include the continental shelf edge atolls (Hibernia Reef to Imperieuse Reef, northernmost to southernmost respectively) of the Sahul Shelf (Figure 1). Wilson (2014) has reviewed the habitats, geology and historical exploration of the Project Area.

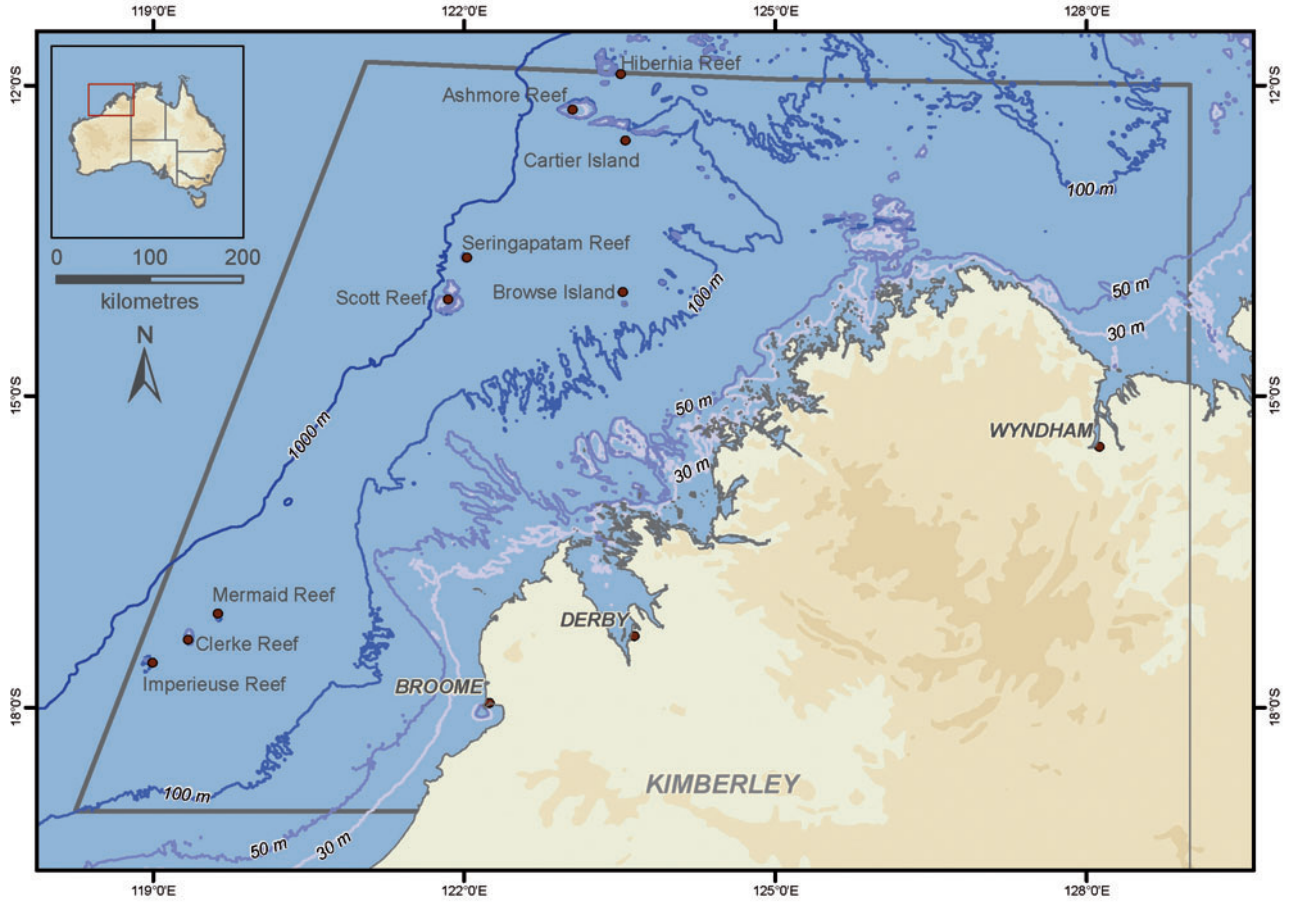

FIGURE 1 Map of the Kimberley Project Area (marked in grey), Western Australia.

The taxonomic groups included marine plants (seagrasses, mangroves and macroalgae), sponges (Porifera), cnidarians (predominately hard corals with limited data on soft corals and non-anthozoan groups, such as hydroids, sea pens and sea jellies), free living worms (predominately polychaetes), crustaceans (mainly decapod crustaceans and barnacles with some data on isopods, amphipods and stomatopods), molluscs (predominately macromolluscs >10 mm), echinoderms, brachiopods, bryozoans, ascidians, and fishes. Henceforth our category of 'other marine invertebrates' includes non-polychaete worms (such as sipunculans, oligochaetes, flatworms, and leaches), cnidarians other than soft and hard corals (such as sea pens, zoanthids, hydroids and sea jellies), bryozoans, brachiopods and ascidians.

Data were sourced from published and unpublished species records, which are registered specimen vouchers maintained in natural science collections and databases from the Western Australian Museum (WAM), the Western Australian Herbarium (WAH), the Museum and Art Gallery of the Northern Territory (MAGNT), the Queensland Museum (QM) and the Australian Museum (AM). WAM collections were searched specifically for specimens collected from the Project Area. Voucher specimens not registered were added to a Project database, a copy of the existing Aquatic Zoology collection databases. For data sourced from the other institutions we relied on those already digitised in their respective databases; it is possible that unregistered material from the Project Area may reside in their collections and in overseas collections. If significant collections are available in overseas collections these will be referenced in the individual taxon papers.

The data from seven published manuscripts (Berry 1986; Johnstone 1990; Berry 1993; Brown and Skewes 2005; Russell et al. 2005; Willan 2005; Bryce 2009) and six unpublished reports (Wells 1989; Morgan 1992; Wells et al. 1995; Walker et al. 1996; Bryce et al. 1997; Walker 1997) were digitised with listed species names and locations added into the Project database (Appendix 1). Data from one additional survey report containing mangrove and mollusc species lists from a 1976 expedition to the Admiralty Gulf (Western Australian Museum 1981) were used but were not digitised into the project database.

The Project included records of marine and estuarine floral and faunal species collected in shallow waters (<30 m). This decision was made for two reasons. Firstly, the majority of the expeditions were intertidal and/or conducted on SCUBA to depths of 30 m. Secondly, the resources and timeframes of the project did not allow for inclusion of deep water species data.

TAXONOMIC CONSIDERATIONS

Nomenclatural changes are common in biology as a species name represents a hypothesis that can be revised as new information (e.g. morphological, genetic, behavioural, distributional) becomes available (Gaston and Mound 1993). Taxonomy is usually poorly resourced, which influences the quality and maintenance of taxonomic datasets (Cotterill 1995). We identified a number of nomenclatural issues, including:

- misspellings;
- misidentifications;
- names that, subsequent to the initial examination and identification, had been synonymised or revised or for which the taxonomic concept of the species had changed and it was no longer considered to be present in the area;
- altered generic placement;
- manuscript names, i.e. the name was never published and therefore cannot be used;
- undescribed species; and
- incorrect taxonomic placement.

To address these issues, species names were checked using a variety of resources, including the Zoological Catalogues of Australia, both printed and online versions (Hooper and Wiedenmayer 1994; Rowe and Gates 1995; Davie 2002a, 2002b; Hoese et al. 2006; ABRS 2011), online sources (Appeltans et al. 2010; Rees et al. 2011) and relevant taxonomic literature (e.g. Ng et al. 2008). Consultation with taxonomic experts was also undertaken to identify and correct current placement. The curator or collection manager responsible for the record and authors of manuscript names was also consulted to determine the nomenclatural status of a species.

A common practice in taxonomy is to use 'open nomenclature', i.e. qualifiers with a species name to indicate taxonomic uncertainty including '?', 'cf.' (compare with or to) and 'aff.' (affinity) (Bengtson 1988). Rationale for the use of these qualifiers includes:

- identifier was unfamiliar with the species;
- identification was preliminary but the resources to confirm the name were either not available or the database was not updated;
- specimen was damaged or juvenile with key features missing;
- characters differed from the published descriptions and variation was unknown;
- species was outside its known geographic range at the time of identification;

- specimen differed from the species description and the type specimen would need examination to verify the name; or
- the taxonomic group required substantial revision and identification was not possible.

These qualifiers created duplication of a species name in the database, thereby affecting estimates of species richness and other diversity measures calculated on these data. When all specimens had been examined by the same identifier these records can be interpreted as an additional species. However, when collating data collected over decades and identified by multiple researchers, interpretation of the numbers of species becomes problematical. This was addressed by making standardised decisions for each record to determine if it should be included in the dataset. If a species was known from the region then the qualifier was removed and the full identification accepted. The qualifier was retained if the species was unknown in the area or there were notes to indicate why the qualifier had been applied. If the qualified identification represented an additional species then the record was retained in the dataset. If not, then the record was excluded. This was a conservative approach and the numbers of species from the region are likely to be higher than we report.

SPATIAL INFORMATION, COLLECTION DETAILS AND MAPPING

Geographical data were standardised to the nearest named island, reef or coastal feature, henceforth 'location', as per EGaz, the electronic Gazeteer of Australia (Geoscience Australia 2011). The locations of the specimen records were visualised using ARCGIS v9, ArcMap v9.3, and the data points were examined to ensure they were within the Project Area. Any outliers were examined and corrected or excluded as appropriate.

Species richness for the nine taxa covered in this project was calculated for each location across the Project Area and visualised on a map. Species richness patterns are highly dependent on sampling effort. The number of collecting events for each location was counted to generate an indicative sample effort. The precise collection date was inconsistently entered in the five source databases (WAM, WAH, AM, QM, MAGNT) creating high variability and error rates. To address this, collecting event was defined by the season (determined from month) and year of collection as these were more consistently captured in the databases.

BIOGEOGRAPHIC AND HABITAT CODING

Biogeographic and habitat codes were assigned to species to provide additional information to resource managers and researchers unfamiliar with the species. Marine species have widely differing geographic distributions, ranging from short range endemics occurring in localised areas to species with a circumglobal distribution. Within its distributional range, a species may be restricted to certain habitat types. The biogeographic ranges and preferred habitats, if known, of the species found in the Project Area were determined from the Australian Faunal Directory (AFD, ABRS 2011), other specialised literature, and personal communications with specialists. Master lists of biogeographic and habitat codes were established (Table 1 and 2 respectively). These codes are included in the species list tables for each taxon group.

OVERALL DATASET

Two hundred and seventeen locations in the Project Area had associated species data, comprising nine offshore atoll locations, one midshelf location (Browse Island) and 207 inshore locations (Appendix 2). Sampling depths were variable with locations either sampled intertidally, subtidally or a combination of both. Some recorded depths were deeper than the specified project depth of 30 m, but were retained in the dataset as the species were known shallow water species. The number of collecting events at a location was also highly variable, ranging from 1 at 101 locations to 168 at Broome. The taxonomic groups recorded at a location were also highly variable. Sixty locations had only a single taxon recorded and eight locations (Ashmore Reef, Broome, Cape Leveque, Clerke Reef, Cockatoo Island, Lacepede Islands, Mermaid Reef and Scott Reef) had representative species from all the main taxonomic groups covered in this study.

The Project established a database exceeding 50,000 registered specimen records housed in five Australian natural science collections (Figure 2, Table 3). Of these records a total of 31,717 records were shallow water species meeting the Project criteria for inclusion in the final dataset (Table 3a). The majority of these (21,759 or 70%) were housed in WAM collections, with MAGNT housing the next most significant proportion (5,462 or 17%). This disparity largely reflects the geographic scope of each institution's collecting responsibilities. Within a taxonomic group, the proportional contribution of each collection to the available data varied and this was largely a function of the available expertise and research interests of scientists at these institutions. For example, there has never been a specialist

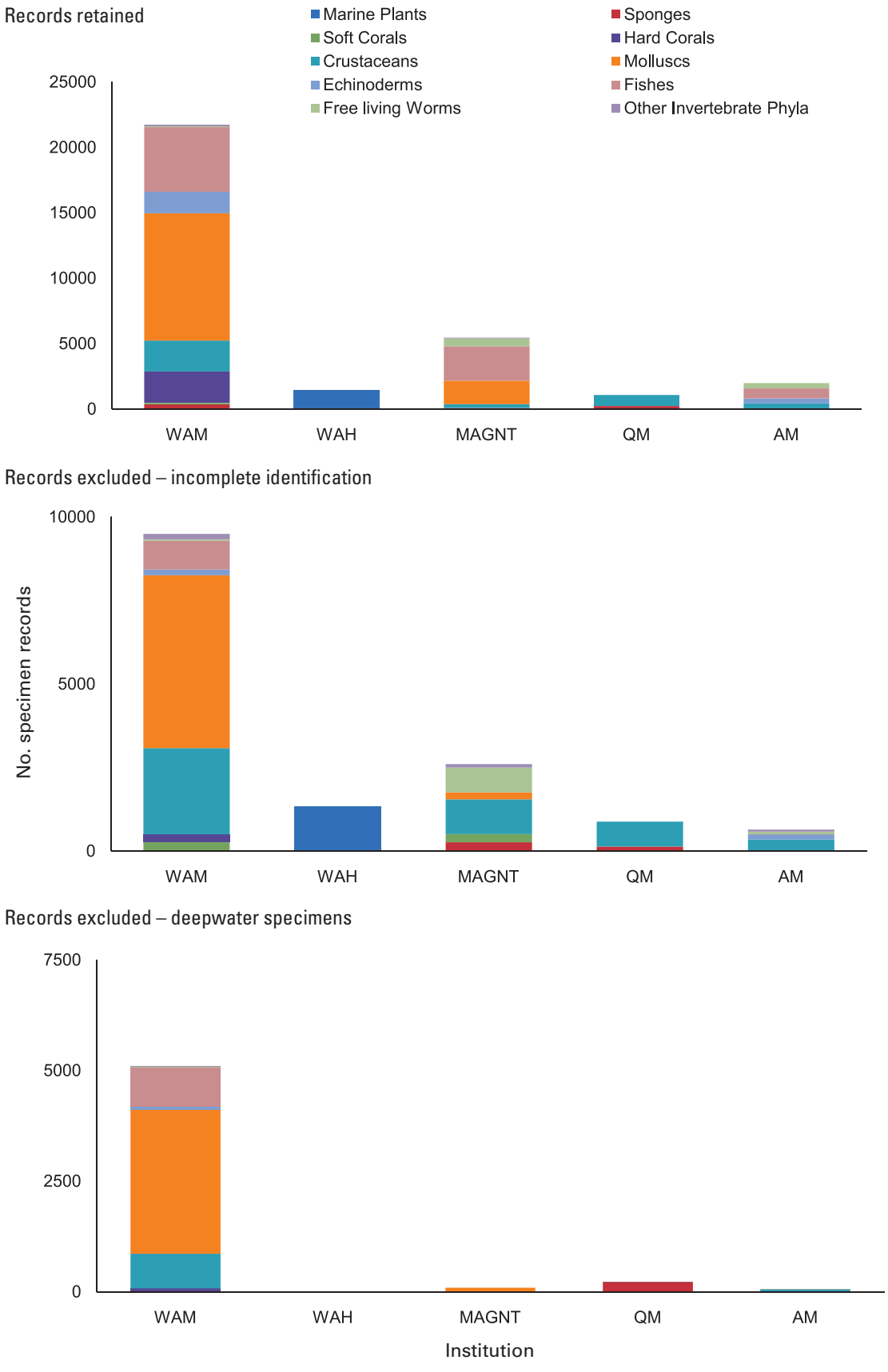

FIGURE 2 Number of registered specimen records per taxonomic group and data source.

TABLE 1 Biogeographic Codes assigned to taxa in the Project Area.

Code	Definition
WA	Western Australian endemic. Currently known from WA waters, often only from the type locality; may be a northern Australian endemic with more collecting effort.
NA	Northern Australian endemic. Found in tropical Australian waters.
SA	Southern Australian endemic. Found in temperate Australian waters and presence in the Kimberley region is the northern extent of its range.
A	Australian endemic. Found in tropical and temperate Australian waters.
IA	Indo-Australian. Found in Australian and Indonesian waters, may extend to the Philippines and Japan.
IO	Indian Ocean. Restricted to the Indian Ocean.
IWP	Indo-West Pacific. Found in the Red Sea, Indian and western Pacific Oceans.
IP	Indo-Pacific. Found in the Red Sea, Indian and Pacific Oceans.
WP	West Pacific. Found in the western Pacific, presence in the Kimberley region indicates occurrence in the south eastern Indian Ocean.
T	Tropicopolitan. Found in all tropical oceans.
C	Circumglobal. Found in all oceans in both tropical and temperate waters.

TABLE 2 Habitat Codes assigned to taxa in the Project Area.

Code	Description
^{i}	Intertidal zone.
^{s}	Subtidal zone.
H	Associated with hard substrates (e.g. rock, coral, rubble).
S	Associated with soft substrates (e.g. sand, mud).
P	Pelagic and found in the water column; includes nektonic and planktonic species.
E	Estuarine or brackish waters.
M	Mangroves.
SG	Seagrass meadows.
EZ	Epizoic. External association with a species of animal.
EP	Epiphytic. External association with a species of marine plant.
EnZ	Endozoic. Living within another animal.
EnP	Endophytic. Living within a marine plant.
A	Amphibious. Living along the land/water interface, e.g. mudskippers.
U	Habitat of the species is unknown.

working on marine worms in Western Australia and this is reflected in the size of the collection (71 records or 7%). Most of the data on Kimberley polychaetes are housed at either the MAGNT (588 or 56%) or the AM (417 or 39%), where there are polychaete experts. The WAH houses all the marine flora records represented in the Project Area.

14,969 shallow water specimen records were excluded from the dataset as the species were either incompletely identified, or the identification was a recently revised species (Table 3b). Re-examination of these specimens is required to verify species identity and this was beyond the scope of the current project. Fishes and corals had a low proportion of records excluded from the final dataset as most of the specimens were identified to species. By comparison, some of the marine invertebrate groups had a high proportion of records excluded as much of the collection has not been identified to species. For example, a large number of molluscs and crustaceans were excluded;

TABLE 3 Number of registered specimen records per taxonomic group and data source.

a) No. of specimen records retained in project data set.

Taxa Group	WAM	WAH	MAGNT	QM	AM	Total
Marine Plants	0	1,430	0	0	0	1,430
Sponges	365	0	60	238	2	665
Soft Corals	109	0	29	0	2	140
Hard Corals	2,412	0	5	0	6	2,423
Polychaetes	45	0	588	0	413	1,046
Crustaceans	2,358	0	274	835	426	3,893
Molluscs	9,743	0	1,808	0	0	11,551
Echinoderms	1,639	0	0	0	375	2,014
Fishes	4,944	0	2,627	0	765	8,336
Other Marine Invertebrates	154	0	71	0	4	229
Total	**21,769**	**1,430**	**5,462**	**1,073**	**1,993**	**31,727**

b) No. of specimen records excluded due to incomplete identification.

Taxa Group	WAM	WAH	MAGNT	QM	AM	Total
Marine Plants	0	1,343	0	0	0	1,343
Sponges	0	0	265	132	9	406
Soft Corals	261	0	244	0	0	505
Hard Corals	243	0	0	0	0	243
Polychaetes	35	0	697	0	80	812
Crustaceans	2,576	0	1,038	750	336	4,700
Molluscs	5,175	0	208	0	0	5,383
Echinoderms	169	0	0	0	156	325
Fishes	868	0	7	0	3	878
Other Marine Invertebrates	162	0	143	0	59	364
Total	**9,489**	**1,343**	**2,602**	**882**	**643**	**14,959**

c) No. of deepwater specimen records.

Taxa Group	WAM	WAH	MAGNT	QM	AM	Total
Marine Plants	0	0	0	0	0	0
Sponges	1	0	6	227	2	236
Soft Corals	9	0	0	0	0	9
Hard Corals	69	0	0	0	0	69
Polychaetes	0	0	0	0	0	0
Crustaceans	783	0	0	1	56	840
Molluscs	3,259	0	87	0	1	3,347
Echinoderms	74	0	0	0	0	74
Fishes	889	0	0	0	0	889
Other Marine Invertebrates	7	0	0	0	0	7
Total	**5,091**	**0**	**93**	**228**	**59**	**5,471**
Grand Total	**36,349**	**2,773**	**8,157**	**2,183**	**2,695**	**52,157**

this was frequently due to some families being very well known and described, while others are virtually unidentified. Sessile invertebrates have large numbers of specimens excluded as these were only identified to phylum, e.g. sponges and soft corals. This reflects the current state of knowledge of these taxa and indicates where work is needed.

We limited our project to shallow water species for reasons specified in the methods above. However, there were 5,471 deep water specimen records (Table 3c) in the Project Area databases. At least two major expeditions have undertaken sampling from the deeper (30–200 m) shelf waters in the region, the *Soela* (1979–1984) and the *Southern Surveyor* (2007). Deep water species and communities differ from those in shallow water and these records would provide additional information about the ecology of the Kimberley region.

TAXONOMIC PAPERS

This paper is the second in a series on historical natural science data of marine taxa in the Kimberley and provides a general introduction, an outline of the methods used and defines the parameters of the dataset. It will be followed by a number of papers giving a more detailed summary of each taxonomic group. Papers on current surveys (2009–2014) of targeted taxa being undertaken in the Project Area will be published separately.

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APPENDIX 1 Summary of locations and taxonomic groups covered in the published and unpublished reports.

References: a) Berry (1986); b) Wells (1989); c) Johnstone (1990); d) Morgan (1992); e) Berry (1993); f) Wells et al. (1995); g) Walker et al. (1996); h) Bryce et al. (1997); i) Walker (1997); j) Russell et al. (2005); k) Willan (2005); l) Bryce (2009); m) Brown & Skewes (2005).

*Sahul Shelf reports were not WAM surveys and the collecting effort in days and number of stations is unclear or not directly comparable, so not included in the totals.
**Fish only. [OA] Offshore atolls.

Reef/Island	Year Sampled	Sampling Days	# Intertidal Stations	# Subtidal Stations	Marine Plants	Polychaetes	Sponges	Hard & Soft Corals	Molluscs	Crustaceans	Echinoderms	Fishes
Admiral Bay	1973–1982		1		c							
Admiral Island	1994	1	1		f	f			f	f		f
Admiralty Gulf	1973–1982[c]		3		c							
Albert Islands	1988	1	1						b	b		
Ashmore Reef[OA]	1986[e], 1972–1998[i,*], 1970–1997[k,*]	9[e]	6[e]	14[e]				e	e,k	e	e	e,j
Augustus Island	1988	1	1						b			
Bathurst Island	1988	1	1						b			
Baudin Island	1988	1	1						b			
Beagle Bay	1997	5	1	2			h		h			h
Beagle Reef	1991	1	1	1		d		d	d	d	d	d
Bedford Island	1994	1	1		f	f			f	f		f
Bernouilli Island	1988	1	1						b	b		
Berthier Island	1988[b], 1996[i]	2	2		i			i	i	b,i		i
Broome	1973–1982		2		c							
Caffarelli Island	1994	1	1		f	f			f	f		f
Cambridge Gulf	1995[g], 1973–1982[c]	3[g]	9		g,c				g	g		g
Camden Sound	1996	1	1		i				i	i		
Cape Bertholet	1973–1982		1		c							
Cape Bossut	1973–1982		1		c							
Cape Jaubert	1973–1982		1		c							

Reef/Island	Year Sampled	Sampling Days	# Intertidal Stations	# Subtidal Stations	Marine Plants	Polychaetes	Sponges	Hard & Soft Corals	Molluscs	Crustaceans	Echinoderms	Fishes
Cape Londonderry	1995	1	1	1	g				g	g		g
Cape Talbot	1995	2	3	1	g				g	g		g
Careening Bay	1988[b], 1973–1982[c]	1[b]	2		c				b	b		
Cartier Island[OA]	1986[e], 1972–98[j,*], 1970–1997[k,*]	2[e]	1[e]	3[e]				e	e,k	e	e	e,j
Cassini Island	1988[b], 1991[d], 1996[i]	5	3	3	d,i	d		d,i	b,d,i	b,d,i	d	d,i
Chambers Island	1988	1	1						b	b		
Champagny Island	1988	1	1						b			
Churchill Reef	1991[d], 1996[i]	3	1	2		d		i	d,i	d,i	d	d,i
Clerke Reef[OA]	1982[a], 1983[a,**]	20	6	28				a	a		a	a
Cockatoo Island	1991	1	1						d	d	d	
Colbert Island	1996	1	1		i			i	i	i		i
Condillac Island	1988[b], 1991[d]	2	2	1		d			b,d	b,d	d	
Corneille Island	1988	1	1						b	b		
Coronation Island	1988[b], 1973–1982[c]	1[b]	2		c				b	b		
Cygnet Bay	1973–1982		1		c							
De Freycinet Island	1996	1		1				i	i	i		i
Derby	1973–1982		1		c							
Descartes Island	1988	1	1							b		
Drysdale River	1995	1	1		g				g	g		
Entrance Island	1988	1	1	1					b	b		
Etisus Island	1988	1	1							b		
Fenelon Island	1988	2	1	1					b	b		
Freshwater Bay	1995	1	1		g				g	g		g
Gagg Island	1994	1	1	1	f				f	f		f
Gibbings Reefs	1996	1		1	i			i	i	i		i
Gregory Island	1994	1	1		f	f			f	f		f

Reef/Island	Year Sampled	Sampling Days	# Intertidal Stations	# Subtidal Stations	Marine Plants	Polychaetes	Sponges	Hard & Soft Corals	Molluscs	Crustaceans	Echinoderms	Fishes
Hale Island	1991	1		1		d		d	d	d	d	d
Hall Point	1988	1	1						b	b		
Hedley Island	1996	1	1		i			i	i	i		i
Heritage Reef	1991[d], 1996[i]	2		2	i	d		d,i	d,i	d,i	d	d,i
Hibernia Reef[OA]	1972–1998[j,*], 1970-1997[k,*]	-	-	-					k			j
Hunter River	1988[b], 1973-1982[c]	1[b]	2		c				b	b		
Irvine Island	1988[b], 1994[f]	2	2		f	b			b,f	b,f		f
Jackson Island	1988	1	1						b	b		
Jamieson Reef	1996	1		1	i			i	i	i		i
Jar Island	1995	1	1	1					g	g		g
Jones Island	1991[d], 1995[g]	2	2			d		d	d,g	d,g	d	d,g
Jungulu Island	1988	1	1						b	b		
Jussieu Island	1996	1		1	i			i	i	i		i
Keraudren Island	1988	1		1					b	b		
King Edward River	1995	1	1		g				g	g		g
King George River	1991[d], 1995[g]	2	2		g	d		d	d,g	d,g	d	d,g
Kingfisher Island	1994	1	1		f				f	f		f
Kuri Bay	1991	1	1			d		d	d	d	d	d
Lacepede Islands	1991	1	1			d			d	d	d	d
Lafontaine Island	1988	1	1						b	b		
Lagrange Bay	1973–1982		1		c							
Lamarck Island	1988[b], 1996[i]	2	2	1	i			i	i	b,i		i
Langgi	1988	1	1						b	b		
Lauangi Island	1988	1	1						b			
Leonie Island	1994	2	1		f	f			f	f		f
Lesueur Island	1991	1	1			d		d	d	d	d	d

Reef/Island	Year Sampled	Sampling Days	# Intertidal Stations	# Subtidal Stations	Marine Plants	Polychaetes	Sponges	Hard & Soft Corals	Molluscs	Crustaceans	Echinoderms	Fishes
Long Island	1995	2	2		g				g	g		g
Long Reef	1988[b], 1991[d]	3	1	3		d		d	b, d	b, d	b,d	d
Lord Island	1991[d], 1994[f]	2	2		d,f	d		d,f	d,f	d,f	d	d,f
Louis Islands	1995	1	1	1	g				g	g		g
Lucas Island	1988	1	1						b	b		
Mackenzie Anchorage	1995	1	1		g				g	g		g
Macleay Island	1994[f], 1996[i]	3	4	1	i	f		i	f,i	f,i		f
Maret Islands	1988[b], 1996[i]	2	2		i			i	b,i	i		i
Mermaid Island	1991[d], 1994[f]	2	2		d,f	d		d,f	d,f	d,f	d	d,f
Mermaid Reef[OA]	1982[a], 1983[a,**], 2006[l]	10	2	19	l		l	a,l	a,l	a,l	a,l	a,l
Mictyis Island	1988	1	1							b		
Montalivet Islands	1988[b], 1991[d], 1996[i]	3	2	1	i	d			b,d,i	b,d,i	d	d,i
Montgomery Reef	1994[f], 1996[i]	2	4		f,i	f		i	f,i	f,i		f,i
Museum's Island	1988	1	1						b			
Napier Broome Bay	1991[d], 1973–1982[c]	1[d]	2	1	c			d	d	d	d	
Okenia Island	1988	1		1					b	b		
Packer Island	1973–1982		1		c							
Parry Harbour	1991	1	1	1		d		d	d	d	d	d
Point Torment	1973–1982		1		c							
Powerful Island	1991	1	1			d		d	d	d	d	d
Prince Regent River	1973–1982		1		c							
Prudhoe Islands	1996	1	1		i			i	i	i		i
Pyrene Island	1988	1	1						b	b		
Quoy Island	1988	1	1						b	b		
Raft Point	1988	1	1						b			
Reveley Island	1995	1	1		g				g	g		g

Reef/Island	Year Sampled	Sampling Days	# Intertidal Stations	# Subtidal Stations	Marine Plants	Polychaetes	Sponges	Hard & Soft Corals	Molluscs	Crustaceans	Echinoderms	Fishes
Robroy Reefs	1988[b], 1991[d], 1996[i]	3	1	3	i	d		d,i	b,d,i	b,d,i	d	d,i
Scorpion Island	1991	2	1		d	d		d	d	d	d	d
Scott Reef[OA]	1982[a], 2006[l]	18	16	38	l		l	a,l	a,l	a,l	a,l	a,l
Seringapatam Reef[OA]	1982[a], 2006[l]	4	2	5	l		l	a,l	a,l	a,l	a,l	a,l
Shirley Island	1988	1	1						b	b		
Slate Islands	1988[b], 1996[i]	2	2		i				b,i	b,i		i
Solem Islands	1991	1		1		d		d	d	d	d	d
Sunday Island	1991[d], 1994[f]	5	3	3	d,f	d,f		d	d,f	d,f	d	d,f
Talbot Bay	1994	1	1		f				f	f		f
Tallon Island	1994	1	2		f	f			f	f		f
Trent River	1973–1982		1		c							
Trochus Island	1988	1	1						b	b		
Turbin Island	1988	1	1						b			
Vansittart Bay	1991	1		1					d	d		d
West Governor Island	1995	1	1						g	g		g
Whirlpool Pass	1994	1	1		f				f	f		f
White Island	1996	1	1		i			i	i	i		i
Wildcat Reefs	1988[b], 1996[i]	2	1	2	i			i	b,i	i		i
Willie Creek	1973–1982		1		c							
Woodward Island	1991	1	1	1	d			d	d	d	d	d
Yankawingarri Island	1991	1		1	d			d	d	d	d	d

APPENDIX 2 Summary of locations with species data in the Kimberley Project Area.

Location is the nearest geographic location (offshore atoll[OA], midshelf[MS], remaining sites are along the coast). Mean decimal latitude and longitude is given for the nearest location. Depth range of the specimen records for that location (a dash only indicates that no depth was recorded and usually corresponds to an intertidal station). Number of collecting events for that location.

*Imprecise locality/depth data - all species were retained as they were known to occur in shallow waters of the Project Area.

Location	Latitude (Decimal Degrees)	Longitude (Decimal Degrees)	Depth Range (m)	No. Collecting Events	Marine Plants	Polychaetes	Crustaceans	Other Marine Invertebrates	Fishes	Hard & Soft Corals	Echinoderms	Molluscs	Sponges
Adele Island	-15.49707	123.15976	0–24	5	□		□	□	□	□	□	□	
Admiral Bay	-18.84163	121.61041	-	1	□							□	
Admiral Island	-16.06425	123.39232	0	2	□	□	□		□		□	□	
Admiralty Gulf	-14.26457	125.92240	0–40*	7		□	□		□		□	□	
Albert Islands	-14.51904	124.92559	0	5	□	□	□		□		□	□	
Allora Island	-16.40000	123.15000	-	1	□								
Ashmore Reef[OA]	-12.22469	123.01342	0–30	23	□	□	□	□	□	□	□	□	□
Augustus Island	-15.39967	124.57206	<1	7	□					□	□	□	
Bathurst Island	-16.02917	123.54028	0	1								□	
Baudin Island	-14.12861	125.60443	0	1								□	
Beagle Bay	-16.91552	122.49213	0–15	10	□		□	□	□	□	□	□	□
Beagle Reef	-15.35000	123.53331	0–12	1		□	□		□	□	□	□	
Bedford Island	-16.14178	123.31799	0	3	□	□	□	□	□	□	□	□	
Berkeley River	-14.33748	127.76670	-	3			□					□	
Bernouilli Island	-15.02083	124.80395	0	2		□	□					□	
Berthier Island	-14.49767	124.99590	<1	3	□		□		□	□		□	
Bigge Island	-14.53488	125.12821	0	5	□		□		□		□	□	
Bird Island	-14.01660	126.56670	-	0			□						

Location	Latitude (Decimal Degrees)	Longitude (Decimal Degrees)	Depth Range (m)	No. Collecting Events	Marine Plants	Polychaetes	Crustaceans	Other Marine Invertebrates	Fishes	Hard & Soft Corals	Echinoderms	Molluscs	Sponges
Bonaparte Archipelago	-14.00000	126.00000	12–60*	1					□				
Boomerang Bay	-14.53300	125.11680	-	1						□			
Boongaree Island	-15.08009	125.18426	-	2	□								
Borda Island	-14.23330	126.03330	-	1					□				
Brecknock Island	-15.43330	124.59443	0	1					□			□	
Broome	-17.97570	122.23610	0–30	143	□	□	□	□	□	□	□	□	□
Browse Island[MS]	-14.10472	123.54259	-	3	□		□		□			□	
Buccaneer Archipelago	-16.08330	123.41670	-	0								□	
Buffon Island	-14.91897	124.71381	0–20	2		□	□		□		□	□	
Caffarelli Island	-16.03665	123.28665	<1	1	□	□	□		□		□	□	
Cambridge Gulf	-15.01630	128.18019	0–3	8	□		□		□	□	□	□	
Camden Sound	-15.54621	124.48663	0–5	8	□		□		□	□	□	□	
Cape Bernier	-14.00000	127.46667	-	1	□								
Cape Bertholet	-17.26250	122.17500	-	1	□								
Cape Boileau	-17.66660	122.21670	0–2	3					□				
Cape Bossut	-18.67830	121.63471	0–30	10	□		□		□		□	□	
Cape Bougainville	-13.98334	126.15255	0–3	1	□		□						
Cape Domett	-14.80417	128.17209	0	3	□		□		□			□	
Cape Dussejour	-14.73333	128.18333	-	1	□								
Cape Frezier	-18.86660	121.60000	-	1							□		
Cape Jaubert	-18.94047	121.55237	0–10	2	□		□	□			□	□	
Cape Latouche Treville	-17.58111	121.94701	0–18	1									□
Cape Leveque	-16.40726	122.91059	0–12	17	□	□	□	□	□	□	□	□	□

Location	Latitude (Decimal Degrees)	Longitude (Decimal Degrees)	Depth Range (m)	No. Collecting Events	Marine Plants	Polychaetes	Crustaceans	Other Marine Invertebrates	Fishes	Hard & Soft Corals	Echinoderms	Molluscs	Sponges
Cape Londonderry	-13.76169	126.92691	<1	3	□		□		□			□	
Cape Talbot	-13.75961	126.77191	0	1	□		□		□			□	
Cape Villaret	-18.30833	122.08833	-	1		□					□		
Cape Voltaire	-14.26083	125.58987	-	2	□					□	□	□	
Careening Bay	-15.10048	125.02444	0	5	□	□	□	□	□	□	□	□	
Carlia Island	-14.36667	125.98333	-	0	□								
Carronade Island	-13.93330	126.60000	-	1								□	
Cartier Island[OA]	-12.52797	123.55047	0–32	11	□	□	□		□	□	□	□	□
Cascade Bay	-16.00940	123.63330	-	2			□						
Cassini Island	-13.93935	125.62679	0–30	10	□	□	□	□	□	□	□	□	
Chambers Island	-16.26479	123.52640	0	1			□					□	
Champagny Island	-15.27935	124.06157	6–10	5	□				□			□	□
Churchill Reef	-15.51221	123.28551	0–23	2	□	□	□		□	□	□	□	
Clerke Reef[OA]	-17.30090	119.34962	0–35*	14	□	□	□	□	□	□	□	□	□
Cockatoo Island	-16.09227	123.59561	0–20	14	□	□	□		□	□	□	□	□
Colbert Island	-14.84407	124.70706	0–15	5	□		□		□	□		□	□
Collier Bay	-16.18330	124.32083	-	1			□			□		□	
Condillac Island	-14.10186	125.55166	0–20	5		□	□			□	□	□	
Cone Bay	-16.48330	123.51670	2–3	0									□
Corneille Island	-14.18720	125.73612	0	2		□	□		□		□	□	
Coronation Island	-14.98442	124.88955	0	4	□	□	□					□	
Coulomb Point	-17.39340	122.13533	0–14	7			□		□		□	□	
Cygnet Bay	-16.53751	123.01527	0–20	6	□		□		□		□	□	

Location	Latitude (Decimal Degrees)	Longitude (Decimal Degrees)	Depth Range (m)	No. Collecting Events	Marine Plants	Polychaetes	Crustaceans	Other Marine Invertebrates	Fishes	Hard & Soft Corals	Echinoderms	Molluscs	Sponges
Dampierland	-17.45577	122.20281	11–23	1			□						
Darcy Island	-15.33333	124.38333	-	0	□								
De Freycinet Island	-14.98832	124.53832	5–32	2	□		□		□	□		□	
Derby	-17.32932	123.66716	0	27	□	□	□		□	□	□	□	
Descartes Island	-14.17477	125.66876	0	1		□	□						
Don Island	-14.26800	125.31470	0–8	1			□						
Doubtful Bay	-16.07913	124.44582	0	1								□	
Drysdale River	-13.96667	126.85000	0	1	□		□					□	
Eclipse Shoals	-16.91575	122.33305	0–12	1									□
Entrance Island	-15.30851	124.63706	0–5	2		□	□				□	□	
Etisus Island	-15.24440	124.42221	0	2			□						
False Cape Bossut	-18.59444	121.70000	-	3	□						□		
Fenelon Island	-14.11899	125.67169	0–20	3		□	□		□		□	□	□
Freshwater Bay	-14.00748	126.28838	0	2	□		□		□	□		□	
Freshwater Cove	-15.80972	124.40639	-	1	□								
Gagg Island	-16.18634	123.45304	5–10	1	□		□		□			□	
George Water	-15.82494	124.64314	0	2		□				□		□	□
Gibbings Island	-16.15500	123.50833	0–10	1									□
Gibbings Reefs	-15.94166	123.77500	5–22	5	□		□		□	□		□	
Gourdon Bay	-18.42473	121.79712	0–30	4					□		□	□	□
Green Island	-15.33333	124.70000	-	1									□
Gregory Island	-16.31567	123.31276	<1	2	□	□	□		□	□		□	
Grey Island	-15.07332	124.94526	0	1			□					□	

Location	Latitude (Decimal Degrees)	Longitude (Decimal Degrees)	Depth Range (m)	No. Collecting Events	Marine Plants	Polychaetes	Crustaceans	Other Marine Invertebrates	Fishes	Hard & Soft Corals	Echinoderms	Molluscs	Sponges
Grey Shoal	-17.39000	122.02500	12–15	1									□
Hale Island	-14.36663	125.41669	3–12	1		□	□		□	□	□		
Hall Point	-15.67915	124.37919	0	2			□						
Hedley Island	-14.92619	124.65429	<1	1	□		□		□	□			
Heritage Reef	-14.24354	125.15063	0–27	2	□	□	□		□	□	□	□	□
Heywood Island	-15.24999	124.35554	-	2		□	□					□	
Hibernia Reef[OA]	-11.92797	123.46186	0–30	4		□			□			□	□
Hidden Island	-16.23722	123.47324	-	2	□								
Hunter River	-15.03331	125.41666	0	1		□	□						
Imperieuse Reef[OA]	-17.57095	118.93123	0–50*	6	□				□			□	
Ingram Shoals	-14.11660	125.26670	20–21	1					□				
Iredale Island	-14.90277	124.68332	0–22	1			□					□	
Irvine Island	-16.06999	123.55417	0	4	□	□	□		□			□	
Jackson Island	-15.93077	123.72605	0	8	□	□	□		□			□	
James Price Point	-17.47943	122.14527	0–7	5	□				□	□	□	□	
Jamieson Reef	-14.04514	125.35285	12–24	2	□		□		□	□		□	□
Jar Island	-14.14101	126.24287	0	2	□		□		□		□	□	
Jones Island	-13.73949	126.35175	0	3	□	□	□	□	□	□	□	□	
Joseph Bonaparte Gulf	-14.32598	128.21198	5–25	2			□					□	
Jungulu Island	-15.27900	124.42382	0–5	2		□	□					□	
Jussieu Island	-14.71335	124.98204	12–32	1	□		□		□	□		□	
Kalumburu	-14.21332	126.61966	1–2	5			□		□		□	□	
Katers Island	-14.44470	125.51670	-	1			□						

Location	Latitude (Decimal Degrees)	Longitude (Decimal Degrees)	Depth Range (m)	No. Collecting Events	Marine Plants	Polychaetes	Crustaceans	Other Marine Invertebrates	Fishes	Hard & Soft Corals	Echinoderms	Molluscs	Sponges
Kathleen Island	-16.06660	123.55000	0–20	1					□				
Keraudren Island	-14.93887	124.66110	-	2			□		□				
King Edward River	-14.21667	126.58332	0	2	□		□		□			□	
King George River	-14.00803	127.33300	0–25	6	□	□	□		□			□	
King Sound	-16.62738	123.38888	0–10	10	□		□		□	□	□	□	□
Kingfisher Island	-16.15561	123.97521	0	5	□		□		□		□	□	
Koolan Island	-16.13496	123.74915	0–20	9		□	□	□	□	□		□	
Kuri Bay	-15.47389	124.51000	0	7		□	□	□	□	□	□	□	
Lacepede Islands	-16.86275	122.14051	0–10	12	□	□	□	□	□	□	□	□	□
Lacrosse Island	-14.74906	128.30120	0–10	1	□		□		□		□		
Lafontaine Island	-14.17022	125.78621	0–24	1		□	□					□	
Lagrange Bay	-18.59443	121.74999	0–30	6	□		□				□	□	
Lagrange Island	-14.20000	125.76670	-	1								□	
Lamarck Island	-14.77649	125.01766	0–24	2	□		□		□			□	
Langey Crossing	-17.66660	123.56400	-	1					□				
Langgi	-15.75474	124.39818	0	4			□				□	□	
Lauangi Island	-14.18017	125.66669	0	1								□	
Lawley River	-14.68332	125.95833	0–2	1			□		□				
Leonie Island	-16.40964	123.05753	0–2	3	□	□	□		□		□	□	
Lesueur Island	-13.80000	127.25000	<1	1		□	□	□	□	□	□	□	
Long Island	-14.09338	126.19910	<1	2	□		□		□			□	
Long Reef	-13.88209	125.77734	0–25	5		□	□		□	□	□	□	
Lord Island	-16.15860	123.46530	0	2	□	□	□	□	□	□	□	□	

Location	Latitude (Decimal Degrees)	Longitude (Decimal Degrees)	Depth Range (m)	No. Collecting Events	Marine Plants	Polychaetes	Crustaceans	Other Marine Invertebrates	Fishes	Hard & Soft Corals	Echinoderms	Molluscs	Sponges
Lord Mayor Shoal	-16.31200	122.36400	0–21	1									□
Louis Islands	-14.01621	126.53277	0	1	□		□		□		□		
Lucas Island	-15.20493	124.49241	2–30	1		□	□		□		□	□	
Mackenzie Anchorage	-14.04390	126.50479	0	1	□		□		□				
Macleay Island	-15.94149	123.69954	0–30	6	□		□		□	□	□	□	
Malcolm Island	-14.44280	125.90716	0	1			□			□		□	
Maret Islands	-14.42312	124.99916	0	8	□	□	□		□			□	
Mary Island	-14.00000	126.40000	-	1							□		
Medusa Banks	-14.65195	128.33742	9–20	2			□		□	□			
Mermaid Island	-16.40738	123.35000	<1	2	□		□		□	□	□	□	
Mermaid Reef[OA]	-16.97004	119.62539	0–30	13	□	□	□	□	□	□	□	□	□
Mictyis Island	-15.21740	124.78610	0	2			□						
Mission Bay	-14.06667	126.68333	0	0		□							
Mitchell River	-14.61130	125.65475	0–12	2			□		□		□	□	
Montague Sound	-14.33330	125.55830	15–15	2			□	□					
Montalivet Islands	-14.28557	125.28107	0–26	10	□	□	□		□		□	□	
Montesquieu Island	-14.10000	125.73300	-	1					□				
Montgomery Island	-15.95000	124.20000	-	1								□	
Montgomery Reef	-15.93170	124.20136	0	10	□	□	□	□	□	□	□	□	
Myrmidon Ledge	-14.84442	128.19308	0	1	□				□				
Napier Broome Bay	-14.05931	126.62001	0–23	13	□	□	□		□	□	□	□	
Naturalists Island	-15.01246	125.30418	-	2	□		□			□			
Ngalaguru Island	-15.91660	124.35000	-	1								□	

Location	Latitude (Decimal Degrees)	Longitude (Decimal Degrees)	Depth Range (m)	No. Collecting Events	Marine Plants	Polychaetes	Crustaceans	Other Marine Invertebrates	Fishes	Hard & Soft Corals	Echinoderms	Molluscs	Sponges
Okenia Island	-15.21667	124.46668	3–4	1			□					□	
One Arm Point	-16.43959	123.06824	0	36	□			□		□	□	□	
Osborne Islands	-14.34229	125.97209	0	4	□		□		□	□		□	
Packer Island	-16.56434	122.77316	15–23	2	□		□					□	□
Parry Harbour	-13.96987	126.08002	0–12	4		□	□	□	□	□	□	□	
Pender Bay	-16.73653	122.66410	0–25	7			□		□		□	□	□
Point Torment	-17.03217	123.58367	-	0			□						
Port George IV	-15.33541	124.65790	0–6	2		□	□			□			
Port Warrender	-14.52651	125.84677	0–6	12		□	□		□	□	□	□	
Powerful Island	-16.08331	123.44091	<1	1			□		□	□	□	□	
Prince Frederick Harbour	-15.04112	125.29547	0	7	□		□		□	□	□	□	
Prince Regent River	-15.45033	125.12973	0–4	3	□				□		□	□	
Prudhoe Islands	-14.39739	125.26593	0–11	3	□	□	□		□	□		□	
Pyrene Island	-15.25693	124.40361	0	2			□					□	
Quondong Point	-17.55017	122.14116	0–14	8	□	□	□		□		□	□	□
Quoy Island	-14.42190	125.23971	0	1			□						
Reveley Island	-14.36700	127.83056	<1	1	□		□		□			□	
Robroy Reefs	-14.42578	124.88580	0–31	3	□	□	□		□	□	□	□	
Roebuck Bay	-18.18084	122.35820	-	1			□						
Rogers Strait	-15.44165	124.61670	<1	1			□	□		□		□	
Rowley Shoals	-17.35749	119.30365	20–28	5			□		□	□		□	
Salural Island	-16.38333	123.12194	-	2	□								
Scorpion Island	-13.86664	126.60000	<1	2	□	□	□		□	□	□	□	

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Scott Reef[OA]	-14.04645	121.83603	0–37*	23	□	□	□	□	□	□	□	□	□
Seringapatam Reef[OA]	-13.65903	122.04328	0–28	11	□		□	□	□	□	□	□	□
Sheep Island	-15.35830	124.60835	0	1						□	□		
Shirley Island	-16.28070	123.43279	0	1		□	□				□	□	
Sir Graham Moore Island	-13.89836	126.57143	-	2	□							□	
Slate Islands	-15.53381	124.41026	0	4	□	□	□		□			□	
Solem Islands	-14.18886	125.63331	0–18	1			□		□	□	□	□	
Steep Island	-16.06660	124.46670	0–12	1						□			
Stokes Bay	-16.90000	123.90000	-	0					□				
Storr Island	-15.84165	124.63330	0	1							□		
Suffern Island	-14.53833	124.92500	0–7	0						□			
Sunday Island	-16.42605	123.18445	0–36*	16	□	□	□	□	□	□	□	□	
Talbot Bay	-16.20669	123.85671	0	1	□		□		□			□	
Talboys Rock	-17.18500	122.01800	0–12	1									□
Tallon Island	-16.40615	123.13272	0	1	□	□	□		□		□		
Tangier Shoals	-17.02107	122.25362	14–15	1									□
Thais Island	-14.96360	125.15830	0	1			□						
Tranquil Bay	-13.93333	127.30000	-	0		□							
Trent River	-16.56667	123.11667	-	0	□								
Trochus Island	-14.48623	125.48127	0	1			□					□	
Troughton Island	-13.75003	126.17181	0	11	□		□		□	□	□	□	
Turbin Island	-14.47500	124.99333	1–7	0						□			
Valentine Island	-17.08330	123.31670	13–13	1			□						

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Vansittart Bay	-14.00164	126.54874	0–16	9	□	□	□		□	□	□	□	□
Wailgwin Island	-15.54283	124.28801	0	3		□	□			□	□		
Walcott Inlet	-16.38165	124.59100	-	1			□						
Walsh Point	-14.56357	125.84848	0–4	2	□				□	□	□		
West Governor Island	-13.94565	126.63725	<1	2	□		□		□		□	□	
West Island	-16.85000	122.11670	-	1								□	
Whirlpool Pass	-16.26460	123.49872	0	1	□		□		□		□	□	
White Island	-15.07349	124.53301	0–2	1	□		□		□	□		□	
Wildcat Reefs	-15.28347	124.16276	0–23	4	□	□	□		□	□		□	
Willie Creek	-17.76360	122.21371	-	3	□	□							
Woodward Island	-14.85111	124.71669	0–20	1	□		□		□	□	□	□	
Wyndham	-15.46387	128.12179	0–2	12	□		□		□	□		□	
Yampi Sound	-16.12889	123.65115	<1	20	□		□		□	□	□	□	
Yankawingarri Island	-14.15000	125.65000	0–14	1	□	□	□		□	□	□	□	
York Sound	-14.88332	125.05000	0–30	1			□		□			□	