REVIEW OF RESEARCH AND DATA RELEVANT TO THE MARINE AND TERRESTRIAL ENVIRONMENT OF DAMPIER

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Executive Summary

Over the past 30 years a great deal of effort has been undertaken to describe the marine and terrestrial environments of the Dampier Archipelago. This report describes both the data and information that has been collected, with a focus on the nearshore environments of the Dampier Archipelago and Burrup Peninsula, and where it can be located. In addition, the current level of knowledge of these environments is discussed and possible avenues for future tactical research to fill the major gaps in this knowledge are suggested.

More than 300 documents containing information about Dampier, the Dampier Archipelago and the Burrup Peninsula were reviewed for inclusion in this report. Approximately half of these are discussed within the report itself, while the others can be found in the bibliography. An attempt was made to succinctly include the most relevant or useful studies. Thus some were not included using the criteria that better information could be sourced elsewhere, or that studies were less relevant to this document.

Although every effort was made to include all information available, this review is not exhaustive and cannot include every study carried out in the region. This is because a great deal of work has been undertaken for private industries and can either no longer be located or is access restricted. It should also be noted that any information reviewed was current at the time of publication (February 2006). In addition to this report, a searchable database has been created including all studies that could be located. This can be accessed at the Dampier Port Authority website; http://www.dpa.wa.gov.au/, or directly linked to the Marine and Freshwater Research Laboratory website at; (http://wwwscieng.murdoch.edu.au/centres/mafrl/Dampier/DampierPort.html).
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1.0 Introduction

The Dampier Archipelago lies on the Pilbara coast of northwestern Australia, which is an area of coastline characterised by gently sloping beaches, headlands and numerous small offshore islands (Wells and Walker, 2003). The Archipelago is an inundated land mass consisting of a submerged plain 5-20 m deep, out of which former hills protrude, some reaching above the surface and forming the numerous islands (Semeniuk et al., 1982). The Archipelago is part of the tropical Indo-West Pacific biotic region, which extends across the entire northern coastline of Australia and as such, the marine biota are almost entirely tropical (Wells and Walker, 2003). A number of marine habitats are found in the area, which support a rich diversity of marine life and for some taxa, this richness is unmatched elsewhere in Western Australia. Such diversity may be largely attributed to the complex topography and geology of the region, which provides numerous habitat types. The habitats discussed in this report include coral reefs, seagrass environments, mangrove communities, macroalgal reefs, rocky intertidal shores, intertidal sand and mudflats, and soft-bottom subtidal habitats. The terrestrial environments of the mainland and the Burrup Peninsula will also be briefly discussed.

The Dampier Archipelago is heavily utilised for a number of purposes including port activities, mining and exploration, recreation, commercial fishing and pearling. In addition, it has a rich history of Aboriginal association with the area. Therefore, environmental studies of the area are numerous and have been undertaken for many different purposes, including those for private industry (which are not publicly available). More recently however, due to the recognition that the area may be of importance from a marine biodiversity standpoint, the number of studies of the marine environment has increased. This work has described the habitats and biota of the region and in some cases, knowledge of marine habitats is now quite extensive. However there are still many gaps in the general understanding of some habitats and survey work is still revealing species that are either new to records for the Dampier Archipelago, or in some case new to science.

Thus for a more complete understanding of the marine environment in the region, research undertaken by private industry, government and other sectors, needs to be drawn together and reviewed. This review covers all available, useful information relating to the marine and terrestrial environments of the Dampier Archipelago. Where possible, only studies conducted within the Archipelago are discussed. However, in some instances studies which cover a larger geographic range are also described. The main emphasis of this report is on the inshore waters of the Archipelago, although there is a great deal of information regarding large scale oceanographic processes, sediments, flora and fauna and management issues of the North West Shelf. For a useful and detailed review of studies on the North West Shelf, see Heyward et al. (2000). Jernakoff et al. (1999) also provides a comprehensive bibliography of research conducted on the North West Shelf and Sherwood et al. (1999) provides a less comprehensive, summarised version of Heyward et al (2000). Further to this, CSIRO (2002) outlines the North West Shelf Joint Environment Management Study (NWSJEMS), its aims and objectives as well as an overview of the current level of knowledge. The NWSJEMS was designed to draw together research of the greater North West Shelf area, of which Dampier is a
part, therefore this document will not revisit such information. Additionally, further references regarding the North West Shelf may be sourced at the State Reference Library of Western Australia (1983), which lists relevant material held both at the State Reference Library and Battye Historical Library. Many of these documents are difficult to locate outside of these libraries.

This report will review documents relating to the oceanography, geology, marine habitats, marine biodiversity and terrestrial habitats as well as the uses and social environment of the region. Each section will outline which data and information has been collected and where it can be located. A discussion of the current level of knowledge for each section is provided, identifying the major gaps and suggesting areas in need of more research.

2.0 Online data sources and metadata

A wealth of data exists in databases that while accessible online are, in most instances, restricted in access. The most useful site for information on the Dampier region is the CSIRO CMR Data Trawler site at:


This database accesses all data collected as part of the NWSJEMS and includes biological information, temperature, current meter, conductivity, temperature and depth (CTD), hydrological and shipping data, as well as various models. Data is often available in geographic information systems (GIS) format and all data files have been made compatible with one another so that useful GIS datasets can be created.

The CSIRO Marine Laboratories Information Network (MARLIN) is also a searchable metadatabase that contains data held by the CSIRO Division of Marine Research. It can be accessed at:

www.marine.csiro.au/marlin/

Finally, the Western Australian Museum’s Faunabase is useful for regional searches and can return species lists for amphibians, birds, fishes, mammals and reptiles for a defined area. It is available at:


3.0 Oceanography

The oceanography and climate of the Dampier area has been reviewed by Pearce (2003), which provides a very useful summary of published and unpublished data, describing and discussing both local and large scale oceanographic processes in the region.

3.1 Local and large scale processes

Winds

Raw wind data for the region is available through the Bureau of Meteorology. However, summarised data can be found in Pitt and Mills (1985), including
anemometer data from September 1981 to July 1984 for the Dampier region. For each month, time series plots, percentage occurrence matrices of wind direction, daily time range and wind speed, along with wind roses are presented. Physick (2001) lists the permanent weather stations in the Pilbara/Dampier area, which agency operates them and the type of data they collect, including both surface instruments and upper-air meteorological data. Wind speed, wind direction and radiosonde data (temperature, humidity and wind data) are analysed and discussed for the Dampier region. Additionally, Ford (1985) provides wind roses from Conzinc Island during 1982-1983, with a description of wind patterns for each month during that time.

Waves

Hamilton (1997) provides descriptions of waves and swell in the port under various weather conditions. For a review of wave conditions in the greater Archipelago, see Forde (1985), who analysed data from waverider buoys near Withnell Bay and Legendre Island (June 1981- March 1982) and reported on the attenuation of wave energy from the outer reefs across Mermaid Sound to the inner reefs. Monthly means of significant wave heights and wave periods, as well as monthly indices of specific wave energy, are presented for both offshore and inshore sites. More detailed information regarding wave conditions in Mermaid Sound and the Archipelago can be found in Steedman (1983) and Steedman (1988).

Currents (water movement)

Mills et al. (1986) summarises current meter data from moored, internally recording current meters throughout the Dampier Archipelago with accompanying anemometer data. Data includes time series plots, progressive vector diagrams, percentage occurrence matrices of current directions and wind speeds, scalar and vector statistics of currents, current roses, current direction histograms and cumulative frequency diagrams of current speeds. Forde (1985) also describes wind driven currents caused by prevailing winds from different directions during different seasons.

Cyclones

Extreme winds caused by the passage of tropical cyclones are a feature of the Archipelago’s climatological environment from around November to April each year (Pearce et al., 2003). Publications by the Bureau of Meteorology (1973a, 1973b) and Lourensz (1977, 1981) provide descriptions of cyclones passing the north west of Australia including their names, tracks and duration, as well as pressure and wind speed values. Ford (1985), discusses the effects of different cyclones (direction, intensity and paths) on wave formation in Dampier.

Tides

Dampier experiences semi-diurnal tides which are described by Forde (1985). This report also discusses how tidal currents contribute to total instantaneous water movement in the region. Tidal currents in different areas of the Archipelago are also described. Mills (1985) discusses the use of a two dimensional, vertically-integrated, finite-difference, numerical hydrodynamic model to investigate the spatial distribution and evolution of water levels and currents related to semi-diurnal tides and tidal currents. Further information on tides and tidal currents can be found in Holloway
(1983) and Easton (1970). These sources cover information from large geographic regions and are not specific to the Dampier Archipelago, although data from Dampier is presented in both cases, including information such as tidal amplitude values, current meter data, harmonic constants from offshore tide gauges and current meter data, and times and heights of high and low tides.

3.2 Biological processes

Literature searches have not found any useful information regarding nutrient transport in the Dampier Archipelago. However, information regarding nutrient transport on the North West Shelf has been collected previous to, and during, the NWSJEMS and can be found in the references mentioned previously for that project.

4.0 Geology

Most privately-funded studies include an overview of the geology and stratigraphy of the Dampier Archipelago, such as Meagher and LeProvost (1979) which describes the historical development of the Archipelago. Kreidwalt (1964) is an excellent source for a detailed account of the stratigraphy of the Dampier area.

4.1 Terrestrial soil type

Kojan (1994) covers the geology of the islands and mainland in the Archipelago and also describes lime sand and limestone resources for the main islands. Copp (2005) provides a basic overview of the geological history of the Dampier Archipelago and Burrup Peninsula with a description of various landforms and formations.

4.2 Marine sediments and substrates

As resource exploration (oil, gas, mining) and industrial activity (shipping) are important components of the economic development of the region, considerable surveying and mapping of the marine sediments in the Dampier Archipelago has been undertaken. Many of these reports are technically detailed and the material contained within them appears most relevant to oil, gas and other resource exploration activities. In addition most are not publicly available. However, the following reports were found to contain information useful in understanding the ecology of the marine and terrestrial environments of the Dampier region, or detail information that may assist with planning future dredging operations.

- Talbot and Creagh (1985) analysed sediment samples from an extensive list of sites around the Dampier Archipelago and present data on the percentage of quartz, aragonite, magnesium with high calcium, clay, feldspars, and total carbonates by site.
- Forde (1985) provides a detailed account of the sediments and their suspension in Mermaid Sound and other locations in the Archipelago. He reports on the organic load of suspended solids derived from seawater samples at different locations and provides accompanying light attenuation coefficients. Data collected from sediment traps and sediment cores are presented, along with contour maps of vertical light attenuation coefficients. Seasonal total sediment load values for Mermaid sound including: organic sediment, CaCO₃ sediment, refractor sediment and percent organic sediment loads are included, along with a discussion of
correlations between suspended sediment load and mean specific wave energy and mean wind speed.

- Kojan (1994) reports on a seafloor sampling survey for Woodside Offshore Petroleum and describes (with maps) the distribution of various marine sediments in the Dampier Archipelago.
- James et al. (2004), also provides a description of the distribution and formation of marine sediments including areas further offshore.
- Geofund (1994a, 1994b) describes port development exploration and includes contoured bathymetry maps of Mermaid Straight, descriptions of the types of marine sediments and their likely ease of dredging. Sediment thickness maps of Holocene calcareous sand in Mermaid Sound are also provided, as well as a discussion of sediment migration. Racal (1994) details the collection of bathymetric data used for mapping in the Geofund reports and provides other useful bathymetric information.

5.0 Marine Habitats

One of the first studies to investigate the marine habitats of the Dampier and Archipelago was Meagher and LeProvost (1979). Previous to this, very little data had been collected - with the exception of the Western Australian Museum. The study assessed the range and distribution of habitats and their associated biotic assemblages. Mermaid Sound was the main area of study along with the coast of the Burrup Peninsula. Ten assemblages were described, based on the dominant or characterising species and the substrate as follows: oyster-barnacle, coral, mollusc-coral, mangal, seagrass, macroscopic algae, mollusc-echinoderm, crustacean-mollusc, embayment fish and pelagic fish-plankton (these assemblages are often referred to in later reports). This report provides a good overview of marine habitats in the Archipelago, describing the assemblages and discussing the general ecology of the area and the factors maintaining the present ecosystem (temperature regime, turbidity, turbulence and nutrients). Semeniu (1982) also provides a useful, although general, review of habitats and associated fauna in the Dampier region.

More recent work by Bancroft and Sheridan (2000) briefly describes the 16 major marine habitats identified by CALM and used in their broad-scale habitat mapping project. The proportion of each habitat in the study area is reported (which includes the Dampier Archipelago and all its islands, west to Cape Preston and the shore regions of Nickol Bay). The data sets collected by CALM for mapping are described in the appendices, including their formats and any access constraints. Additionally, Bancroft et al. (2000b) lists the location of digital habitat mapping data stored in ArcView (GIS) format, as well as the sites surveyed during mapping, their locations, features and classification for mapping purposes. A general description of sub-tidal habitats in the Archipelago is provided by Morrison (2004), who took video recordings of transects at 45 locations around the region. Percentage cover for various benthic assemblages is provided and much of this data has been converted to GIS format.
5.1 Coral Reefs

**Distribution and diversity**

Extensive coral reefs occur throughout the Dampier Archipelago and they are usually associated with shallow water near islands. A number of studies have examined the variation in coral assemblages and species distribution between inshore and offshore reefs. Meagher and LeProvost (1979) provide a species list for corals divided by inshore, intermediate and seaward corals, as well as the percentage of live coral cover at each study site. Blakeway and Radford (2004) describe the corals of the inshore reefs - of which there are 120 species from 43 genera - which is a significant contribution to biodiversity in the area. They describe five assemblages based on the proportional difference in species composition. They also describe factors controlling the distribution of inshore corals and discuss whether certain assemblages are more tolerant to sedimentation than others. A species list of corals found in the Dampier Harbour is provided. Paling (1986a) analyses coral community data from Dampier, including differences between offshore communities and more protected areas. Veron and Marsh (1988) provide an annotated species list of hermatypic corals from the Dampier Archipelago, along with a description of the climate, oceanography, topography and other factors effecting their distribution. Griffith (2004) includes the most current species list of scleractinian corals from the Dampier Archipelago.

**Environmental factors controlling growth and distribution**

Simpson (1988) provides a detailed overview of the environmental factors controlling distribution and growth of scleractinian corals in Dampier. He also reports on community metabolism which was studied using flow respirometry and chemical and physical measurements. He presents values for gross annual production and respiration, as well as annual net calcification. Additionally, Simpson (1985a) assessed growth rates of *Acropora formosa* for correlation with environmental variables such as temperature, salinity, vertical light attenuation, mean bottom irradiance and sediment load.

**Reproduction**

Simpson (1985b) discusses an observed mass spawning event which did not coincide with spawning events on the Great Barrier Reef, as had been previously assumed. Twenty-seven species of scleractinian corals were seen to release gametes during the event. Environmental data for the week surrounding mass spawning is presented (temperature, salinity, depth, and light). The report discusses possible factors for timing and suggests it may be related to seasonal changes in wind/current patterns, monthly lunar cycles, fortnightly tide cycles and daily tidal/light cycles. Larval distribution and settlement in the Archipelago are also discussed, highlighting the fact that during spawning, buoyant propagules are vulnerable to surface pollutants and other influences. Additionally, Simpson (1988) provides lists of reproductive status by species for corals studied during March (Dampier mass spawn) and November (Great Barrier Reef Mass Spawn). More recent data regarding the Dampier Archipelago coral mass spawning event has been collected by Stoddart and Gilmour (2004) and the reproductive status of inshore corals around the time of the mass spawn is discussed. Other modes of reproduction for inshore corals are also reviewed.


**Stresses and Pressures**

Numerous studies have reported on the stresses and pressures that effect coral growth and survival such as sedimentation, storms and cyclones, and corallivorous species.

**Sedimentation**

Gilmour (2002a) studied sediment deposition injuries in the mushroom coral *Fungia fungites* and reported that injury decreased with polyp size and increased with the amount and duration of sediment exposure. Stoddart and Anstee (2004) reported on a monitoring program undertaken during dredging operations to assess turbidity and suspended sediment load. Coral mortality recorded during monitoring was then discussed in relation to measured sediment loads. The Environmental Protection Agency (EPA, 2003) provides a brief description of the environment in Mermaid Sound and the possible impacts to corals of sedimentation caused by dredging in the area.

Studies have been conducted in the area to discern the effect of sedimentation on reproduction in corals. Gilmour (2002b) focussed on two sites in the Dampier Archipelago (one with a high sediment load) to examine variation in the number of sexual to asexual recruits – asexual budding is related to polyp injury – as this may be a useful indication of the effects of long term exposure to sedimentation. Stoddart and Gilmour (2004) monitored coral to assess the impact of dredging on mass spawning. Gilmour (1999) also studied the influence of high and low levels of sedimentation on fertilisation, post fertilisation embryonic development, larval survival and larval settlement of corals.

**Storms and Cyclones**

Storms and cyclones are influencing factors in the survival and distribution of corals, as physical disturbance caused by waves and swell, as well as freshwater inundation, can lead to coral mortality. Gilmour (2004) discusses the effects of storms on sexual and asexual recruits in mushroom corals in the Dampier Archipelago. Blakeway (2004) analyses 20 years of monitoring data and describes patterns of coral mortality caused by cyclonic freshwater inundation with a discussion of the level of susceptibility of various coral species to such inundation. Forde (1985) provides descriptions of cyclones Trixie, Jane, Lena and Chloe and their effect on coral reefs in the Archipelago.

**Corallivorous species**

The two most well-known corallivorous species in the Dampier Archipelago are *Acantha ster planci* (Crown-of-thorns starfish) and the gastropod *Drupella* sp. Surveys in the 1980s recorded the distribution and abundance of *A. planci* throughout the Dampier Archipelago (Johnson and Stoddart, 1988, Simpson and Grey, 1989). The results of surveys to assess the distribution and abundance of *Drupella* on reefs in the Archipelago are described in Hilliard and Chalmer (1992).

**Monitoring**

Coral reef monitoring data is available from a number of sources, often funded by private industry and may be either short or long term depending on the original
purpose. Useful references include LeProvost, Dames and Moore (1994) which reports on an annual monitoring program for Woodside Offshore Petroleum and details changes in the distribution of coral size classes from 1991 to 1993 as well as the proportion of colonies with partial death, sedimentation rates by site, mean number of colonies per transect, mean cover of colonies per transect, mean number of colonies per transect with partial death and the number of recruits pooled by site. This report, in particular, is very useful, as annual reports after 1994 are less detailed (as it was not considered necessary to continue recording most of the information listed above). LeProvost, Dames and Moore (2000) report on monitoring from 1995 to 1999, which included videographic sampling and discussed changes in percent coral cover during the reporting period. Lastly, Stoddart et al. (2004) detail community change assessed during a 12 month monitoring period encompassing two dredging programs.

5.2 Seagrasses

Very little information regarding seagrass environments at Dampier has been collected, with the exception of some studies documenting distribution. Walker and Prince (1987) provide a species list of seagrasses at various sites around Western Australia including some from Dampier. Prince (1986) also discusses seagrass distribution in association with dugong distribution. Species information can be found in Huisman and Borowitzka (2003) and Huisman (2004), while distributional data is present in Morrison (2004). Further to this, distribution information can be found in numerous habitat maps such as those produced by CALM (2005).

5.3 Mangroves

Diversity and distribution

Six species of mangroves occur in the Dampier region with most communities distributed along the mainland shore and in sheltered bays on islands. Mangroves are recognised as important primary producers of ecological and economic significance (CALM, 2005). Pedretti and Paling (2000) provide maps and descriptions of many of the mangrove environments in the Dampier region. This report represents the most up-to-date account of mangrove distribution in the region. Johnstone (1990) describes mangroves of the Pilbara and Semeniuk (1993) described mangroves of Western Australia. These are more general references although some specific mangals in Dampier are described in detail. Older studies that describe the distribution of mangroves in Dampier include Gordon (1983), which reports the total area of mangroves in the Archipelago including the islands, this is also divided by dominant species and a discussion of the factors effecting distribution is provided. Gordon (1988), relates distributional control factors and describes changes in tidal exchange with lunar and seasonal cycles, as well as variation in groundwater salinity and soil properties at different locations. Semeniuk and Wurm (1987) provide a detailed description of the mangroves of the Dampier Archipelago, with descriptions of distribution, composition and structure of mangrove assemblages. A classification system based on habitat type is used and maps are provided displaying the habitats, assemblages and mangrove species distribution of selected areas (which are discussed in detail). Discussion of local factors affecting these mangroves including climate, coastal morphology, geomorphology, substrate, stratigraphy and groundwater is also included. Additionally, LeProvost Dames and Moore (2000) describe an annual
monitoring program undertaken for Woodside Offshore Petroleum, which includes surveys of mangroves bordering Mermaid Sound. This report also includes trends in leaf area index from 1994-1999, as well as percent canopy cover and defoliation indices for this period.

**Mangrove fauna**

The fauna associated with Dampier mangroves has been described in a number of documents; however most address specific taxa and no good general description of fauna exists. Hutchings and Rechner (1982) provide a general description of mangrove fauna in Australia, but this is not specific to Dampier, general fauna lists by region are however provided. Blaber *et al.* (1985) and Blaber (1986) are good sources for information regarding fish assemblages in Dampier mangroves. These articles discuss community dynamics of mangrove fish fauna, resident status of species and dietary information on predatory species. Johnstone (1990) provides a list of birds utilising mangroves in the Pilbara, describing their ecology, calls, distribution and breeding habits. More specialised studies of mangrove fauna have been carried out and include: Brearley *et al.* (2003), which investigated molluscan borers in mangroves (a species list is also included); Bartsch (2003a), describes halacarid mite fauna within Dampier mangroves; and Wells and Lalli (2003a) report on the ecology of mud whelks, along with predation, activity patterns and the physical condition of mangrove habitats in the study. Mangroves at Dampier are thought to be of biogeographic significance as a centre for fiddler crab diversity (CALM, 2005). Information regarding fiddler crabs can also be found in George and Jones (1982). Work being undertaken by the Australian Institute of Marine Science (AIMS) on mangroves at Dampier is described in Batterham (2001).

**Mangrove associates**

Paling and McComb (1994) describe cyanobacterial mats found on the saline flats behind mangles at Dampier and their ability to export nitrogen into the environment. Blue-green algal mat distribution and their ability to fix nitrogen are also discussed in Paling (1986b) and Paling *et al.* (1989). Nutrient status, chlorophyll levels, organic carbon content, and nutrient export are described.

**5.4 Macroalgal Reefs**

There is little information available regarding macroalgal reefs in Dampier. The Department of Conservation and Land Management (CALM, 2005) do provide a brief overview of macroalgal communities in the Archipelago including dominant species, and macroalgal reefs are included in habitat maps in this publication. Further distributional information can be found in Morrison (2004), while species information is related in Huisman and Borowitzka (2003) and Huisman (2004).

**5.5 Intertidal (Rocky)**

Meagher and LeProvost (1979) included a number of rocky intertidal shore sites in their early work and consequently the flora, fauna, sedimentology and substrate type for a number of sites around the Archipelago has been recorded. Species lists for fauna are included, as well as habitat maps and stratigraphic sections. Further to this, LeProvost, Semeniuk and Chalmer (1980) discuss a possible biological gradient along
the rocky shores of the Burrup Peninsula. The abundance of various species with height on shore is reported and a species list including subtidal species is provided. Monitoring reports such as LeProvost, Dames and Moore (1994), which describes the densities of seven selected species and the presence/absence of others, and LeProvost, Dames and Moore (2000) which lists the abundance of rocky shore species from 1995-1999, may also be useful.

5.6 Intertidal sand and mudflats

Some work has been undertaken on intertidal sand and mudflat communities, although most of this is concentrated on the Burrup Peninsula. Meagher and LeProvost (1979) describe intertidal habitats and report on the flora, fauna, sedimentology and substrate type at each study site. Species lists for fauna are provided as well as habitat maps and stratigraphic sections. LeProvost, Semeniuk and Chalmer (1980) studied intertidal flats at King Bay and Withnell Bay and their report reviews existing information for these environments and describes the specific physiography, stratigraphy and habitats of the two bays. Species lists of vertebrate and invertebrate fauna are also provided. LeProvost, Semeniuk and Chalmer (1981) discuss identified potential monitoring species, their abundance and distribution and also include information on the use of burrowing organism excavations in monitoring. Kohn (2003b) reports on a census of infaunal and epifaunal macroinvertebrates on an intertidal sand flat on the Burrup Peninsula. A species list for infaunal invertebrates in the top 5 cm of sand, as well as mean densities with varying distances from shore are included.

Studies addressing specific taxa include:

- LeProvost et al. (1982) provides an annotated species list of birds observed utilising the intertidal mud flats of King Bay and describes observed food and feeding habits and the distribution of birds between habitats.
- Blaber et al. (1985) includes a species list of fish inhabiting open shore environments,
- Wells and Lalli (2003b) studied a population of Astropecten sumbawanus (Echinodermata: Asteroidea) and report on their density, tidal distribution and size frequency in Withnell Bay
- Glover et al. (2003) studied the distribution, abundance and foraminiferal diet of the intertidal scaphopod Laevidentalum lubricum on intertidal sandy habitats around the Burrup Peninsula
- Bartsch (2003b) studied mites on sandy beaches in the Dampier Archipelago and described Copidognathus meridianus, which was the most abundant halacarid.

5.7 Sub-tidal soft bottom

Meagher and LeProvost (1979) describe the range of sub-tidal habitats and biota, and nearshore sub-tidal substrates. Additionally, the range of organisms in these habitats and any spatial variation in the distribution and abundance of species is discussed. LeProvost, Semeniuk and Chalmer (1980) describe deep subtidal plains in Dampier and species lists with abundances for benthic fauna from various sampling stations
near the Burrup Peninsula are included. Meagher and LeProvost (1979) report on the sediment size variation across Mermaid Sound and list fish species captured in trawls. Species lists are also provided for macrobenthic surveys. LeProvost et al. (1985) briefly describe the sedimentology, bathymetry, water quality and habitats of the seafloor of Mermaid Sound, of which a considerable proportion is sand and silt. They provide geomorphic unit descriptions, distributions and describe their relationship to physiographic units. They also compare benthic infauna records for Mermaid Sound from previous studies.

6.0 Terrestrial Environment

The terrestrial environment of the Dampier Archipelago, in particular the vegetation and flora has been well studied. Most work however has been restricted to the Burrup Peninsula and some of the larger islands.

6.1 Vegetation and flora of the Burrup Peninsula

Blackwell and Carla (1979) give an overview of the topography and geology of the Burrup Peninsula and Dolphin Island. They provide thorough descriptions of the vegetation, including plant associations and communities which are grouped by habitat and structure. They list 310 plant species, 23 of which are either range restricted or poorly known species. Additionally, the effect of temperature, season, rainfall, winds, evaporation, humidity and dew in controlling the distribution of plants in the area is discussed.

More recently, a major study by Trudgen and Griffin (2001) and Trudgen (2002) was undertaken to survey the flora and vegetation of the Burrup Peninsula, Dolphin Island, Angel Island and Gidley Island. Included in the reports are descriptions of the plants surveyed and their habitats, as well as of floristic groups, which are defined in detail. Additionally, the presence of geographically restricted, rare and newly identified plants in the area are discussed. The project also involved vegetation mapping of the Burrup Peninsula at a 1:5000 scale, entry of all plant species into a central database and statistical analysis of results. Welker (2002c) reviewed the statistical analysis of Trudgen and Griffin (2001) for the purpose of providing advice on areas of the Peninsula that may require special consideration in development planning. This report also provides useful reviews of other studies in the area including Beard (1975), Blackwell and Carla (1979), SKM (2001b) and Trudgen (2002). URS (2003a) discusses the regional significance of the Burrup Peninsula and the conservation significance of vegetation in their study area near Withnell Bay. A map of the distribution of vegetation units in Withnell East industrial area is also provided. URS (2003b) provides a hydrological assessment of the proposed GTL methanol plant site at the Burrup Peninsula. Several studies were undertaken of the flora and vegetation of the Burrup Peninsula in the vicinity of the proposed Burrup service corridors. Although these studies cover only a very specific area, they are quite detailed and useful (Bennett, 2002b, Bennett, 2002a, Welker, 2002b, Welker, 2002a). Sinclair, Knight Merz (2001b, 2001a) also contains useful information regarding the vegetation of the Burrup Peninsula.
6.2 Vegetation and flora of areas other than the Burrup Peninsula

Beard (1975) describes the geology and soils of the Pilbara region with relevance to vegetation. Descriptions of plant formations and communities are included. Long (1988) provides flora lists for Enderby, Rosemary, Malus, West Lewis, East Lewis, Eaglehawk, Angel and Delambre Islands. Species are listed by association for all islands studied. Associations included are: littoral, beach, sandplain, run-on, drainline, rocky slope and rock outcrop. Descriptions and notes are provided for new species, species needing re-identification and unidentifiable species.

6.3 Terrestrial fauna

Most terrestrial fauna surveys in the Dampier Archipelago have been undertaken for the purpose of gaining information regarding areas for possible development, and thus cover only small geographic ranges. Alternatively, they were designed to target specific species or genus for studies of population genetics or morphological diversity. However, the following are documents that may be useful for a review of terrestrial fauna in Dampier:

- Morris (1990) provides species lists and distributional information for birds, terrestrial mammals, amphibians and reptiles in the Archipelago.
- Burbidge and Prince (1972) provide species lists for fauna from Dolphin, Angel, Gidley, Legendre, West Lewis, Enderby and Rosemary Islands. Faunal lists include mammals, land birds, seabirds and waders, reptiles and amphibians.
- Tingay (1979) studied the vertebrate fauna of Burrup Peninsula and selected islands, making records of amphibians, reptiles, birds and mammals. The distribution of species surveyed is discussed. Habitats are ranked in terms of diversity and uniqueness of species.
- Sinclair, Knight Merz (2001a) describes the terrestrial fauna of Burrup Peninsula including rare and priority fauna and non-marine molluscan fauna.
- Johnson et al. (2004) discusses several endemic species of Rhagada (Gastropoda: Pulmonata) living on islands within the Archipelago. It describes the genetics of the species within the Dampier Archipelago from an evolutionary standpoint.
- BIOSTAT (2002) reports on a faunal assessment of the proposed Burrup Peninsula service corridors and includes a list of birds named under international migratory bird agreements as well as other significant bird species, describing their habitats and conservation status. It also addresses mammals and herpofauna at the site, their habitats, significance and status. Terrestrial vertebrate species lists are provided. Information from this report can also be found in summarised form in Bennett (2002a).

6.4 The Fortescue River

The Fortescue River is the largest in the vicinity of Dampier. An overview of the hydrology of northern Australian rivers (including the Fortescue) is given by Dames et al. (1979). Flow duration (days/year) for different flow ranges (m³ s⁻¹) are presented. Kay et al. (1999) reports the distribution of macroinvertebrate families in north-west Australian rivers including the Fortescue.
7.0 Marine Biodiversity

Many studies have been undertaken to explore biodiversity in the Dampier Archipelago. One of the main bodies of work representing this exploration is Jones (2004b), which resulted from a partnership between the Western Australian Museum and Woodside Energy Ltd. GIS spatial datasets were collected as part of this project and include video transects and GPS locations of sampling stations with accompanying species lists and metadata. These are available from the Western Australian Museum upon request. The following sections will review the current level of understanding of marine biodiversity in the Dampier Archipelago.

7.1 Molluscs

Considerable work has been undertaken on the taxonomy, distribution and ecological significance of marine molluscs. Slack-Smith and Bryce (2004) recorded 695 species of mollusces during intertidal and sub-tidal surveys and found the greatest diversity in subtidal habitats. Species lists are presented including habitat information. Glover and Taylor (2004) recorded 422 specie of macromolluse, including 227 species of gastropod, 188 species of bivalve, four scaphopod species and three chiton species. Results of community analysis are presented and shallow, muddy, inshore waters were noted for their high diversity and abundance of suspension-feeding bivalves. This report indicated that sub-tidal molluscan fauna is the least well known for the region. Meagher and LeProvost (1979) provide a species list of mollusces encountered during survey work which is divided by habitat (encrusting, cryptic, infaunal) and assemblage (oyster-barnacle, coral, algae).

Other studies that targeted specific genera or species include Britton and Morton (2003); which discusses intertidal chitons at Dampier, including their distribution, taxonomy, ecology and biogeography; Hickman (2003) discusses two species of trochoidean gastropod endemic to tropical and subtropical Australian sandy shores and includes a discussion of complex dissipative macrotidal beach habitats, which are poorly known worldwide; and Kohn (2003a, 2003a) describes the biology, habitats, distribution and general ecology of the genus Conus on the shores of Dampier.

7.2 Algae

A taxonomic account of the marine benthic flora of the Dampier Archipelago is presented in Huisman and Borowitzka (2003), while Huisman (2004) provides a checklist of marine benthic flora. At the time of publication, Huisman (2004) stated that the checklist was ‘temporary’ and that there was still a lack of understanding regarding marine benthic flora for the region. Further information can be found in Meagher and LeProvost (1979) who examined the floral characteristics of marine benthic algal communities and reports percentage cover of plants in benthos, percentage of leafy vs. encrusting species, percentage of plants from the various taxonomic divisions in each sample and more. Creagh (1985) reviewed literature regarding the blue-green algae of the genus Trichodesmium and included information about blooms in Dampier.
7.3 Sponges
Fromont (2004) studied the biodiversity (distribution and habitats) of sponges in the Dampier Archipelago. Previous to this, only 14 species of sponge had been recorded for the area. Fromont (2003) places the taxonomic and biogeographical affinities of the sponge fauna in the context of other regions. Sponge data can also be found in Salotti et al. (2004). As a result of these three studies, 275 species of sponge have now been recorded, indicating high species richness for the region.

7.4 Coelenterates (soft corals, sea fans, anemones)
A preliminary list of coelenterates collected during dredge surveys is provided by Salotti et al. (2004); however, many had not yet been identified to species at the time of publication.

7.5 Fish
Hutchins (2004) presents the most up to date list of fish species for the area. Listing 650 species of shallow water fish (< 30 m) including: coral reef fauna (465 species), mangrove fauna (116 species), soft bottom inhabitants (106 species) and pelagics (67 species). Hutchins (2003) includes fish to 45 m depth. Meagher and LeProvost (1979) provide a reef fish species list consisting of existing museum records and new findings from their study. The list is divided by habitat (Archipelago, Burrup Peninsula reefs, embayments and the Mermaid Sound seafloor). Fish were studied in detail for spatial variation between embayments, seasonal variation in distribution and abundance, and the use of nursery habitats by juveniles. In addition, they report on the gut content analysis of fish caught in the shallow flats of Withnell Bay. Species lists for embayment fish are also provided and are listed by site along with accompanying abundance and biomass data. Fox and Beckley (2005) report 1012 species of neritic fish from the Damper Archipelago which, when compared to other areas, indicates the region is a species richness ‘hotspot’.

7.6 Crustaceans
Diving and dredging surveys by Hewitt (2004) resulted in the identification or 381 crustacean taxa, bringing the total to 426 for the area, including 361 species of Decapoda. The surveys resulted in 120 new species recorded for the Dampier Archipelago, 14 species not previously recorded in Western Australia, five species new to Australia and three species new to science. Species diversity was found to be greatest in intertidal and shallow subtidal habitats around islands and lowest in subtidal waters between islands. Species lists are also provided. From survey work, Peart (2004) identified 68 species of amphipod from 21 families in the Dampier Archipelago. Ten of those families were new records for Western Australia, suggesting there are probably many gaps in our current knowledge of amphipod diversity. Jones (2004a) reports 49 species of littoral and shallow water barnacle as being currently recorded for Western Australia. Barnacle distribution is discussed, noting that species richness is highest in intertidal waters and very low in deeper areas. A checklist of species is provided. For further information on barnacles in Dampier see Jones (2003).
7.7 Corals
A significant amount of work has been completed on corals in the Dampier Archipelago and most of this has been presented previously in the marine habitats section. Griffith (2004) provides the most up-to-date species list of scleractinian corals, which includes 229 species from 57 genera, 14 of which were new records from that study. This high number of species places the Dampier Archipelago second only to Ashmore reef in terms of coral species diversity. Although older, Vernon and Marsh (1988) provides a very useful annotated species list of corals from the area.

7.8 Plankton
Meagher and LeProvost (1979) provide tables of biomass and density by phylum for zooplankton. No other studies of plankton specific to the Dampier Archipelago have been found, although more data exists for the greater North West Shelf from the NWSJEMS.

7.9 Echinoderms
Diving and dredge surveys that included more than 170 sites throughout the Dampier Archipelago by Marsh and Morrison (2004) brought the total number of recorded species of echinoderms to 286. This is extremely rich for echinodermata fauna and is currently unmatched by other parts of Western Australia. Possible reasons for this are discussed. Considerable differences were seen in the echinoderm fauna across different areas of the Archipelago. A species list is provided which includes the number of individuals caught at different depths.

7.10 Large mobile marine fauna
Because of their conservation value, cetaceans, turtles and seabirds are addressed separately below, although information on them is scarce in some cases. Msicience (2005) lists endangered and vulnerable species known to occur in the Dampier Archipelago as classified by the Environmental Protection Biodiversity Conservation Act 1999 and the World Conservation Union 2004 Red List of Threatened Species.

Whales
The Department of Conservation and Land Management (CALM, 2005) lists eight species of toothed whale, including five species of dolphin and four species of baleen whale that have been recorded in the Dampier Archipelago. A brief discussion of their conservation and management is provided. Jenner and Jenner (1991) detail humpback whale (Megaptera novaeangliae) observations in the Archipelago during the 1991 season, in which 218 whales were observed. A discussion of the whales’ locations, direction of migration, age classes and intra-season resightings are included, as well as population estimates. See also Jenner and Jenner (1994) for further population estimates including data from other years of study. Descriptions of humpback whale migratory paths and timing of migrations can be found in Jenner et al. (2001). Bannister et al. (1996) describes all whale species occurring in Australia, including the blue whale (Balaenoptera musculus) and the humpback whale which have both been sited near Dampier. Descriptions include a biological overview, taxonomic status, survival status, distribution, migration patterns and habitat.
Bancroft et al. (2000a) contains appendices that describe the datasets available through CALM which describe humpback whale migration routes.

**Turtles**
The Department of Conservation and Land Management (CALM, 2005) lists five species of turtle as being recorded for Dampier. A list of the sites used for nesting and breeding is also included. Bancroft et al. (2000a) describe the datasets compiled by CALM that show turtle nesting beaches and common aggregation sites, while Bowman, Bishaw and Gorman (1994) include maps of turtle nesting beaches.

**Dugongs**
Very little information is available about the use of the Archipelago by dugongs. However, Prince (1986) discusses sightings from aerial surveys conducted in 1984. Bancroft et al. (2000a) describes the datasets collected by CALM revealing the locations of sightings and feeding grounds.

**Sea birds**
Sixteen species of seabird have been recorded utilising the Dampier Archipelago, CALM (2005) describes the areas within the Archipelago that are important for breeding, nesting and refuge. Storr (1984) describes birds of the Pilbara including their distribution and whether they are permanent or migratory. Bowman, Bishaw and Gorman (1994) provide maps of seabird nesting locations.

**8.0 Users, uses and the social environment**

**8.1 Uses**
Morris (1990) provides an overview of the uses of the Dampier Archipelago including recreational, research, aquaculture, mining and industry. Aboriginal and European heritage are also discussed along with a history of land use since 1860. Driscoll (1996) also provides a summary of the main uses along with the issues arising from them.

**Fishing and pearling**
The 2005 State of the Fisheries report (Penn et al., 2005) outlines the commercial and recreational fisheries in the area, their boundaries, management and catch statistics. The Department of Conservation and Land Management (CALM, 2005) provides maps of commercial fishing locations within the Archipelago and a brief discussion of recreational fishing activities with maps highlighting the intensity of fishing at different sites. Fraser (1996) gives an overview of pearling and pearl oyster aquaculture operations including lease holding maps and a list of public concerns regarding these operations.

**Recreation**
The Department of Conservation and Land Management (CALM, 2005) provides descriptions of the recreational activities commonly undertaken in the Archipelago and provides maps highlighting common locations for various pursuits.
8.2 Social environment

URS (2003a) describes the social environment of the Pilbara region including economic development and population characteristics. Recreational and heritage values, register of natural estates and conservation values are also discussed. Sinclair Knight Merz (SKM, 2001b) describes the social environment of the Pilbara including population characteristics, community infrastructure and economic development of the various shires, including Roebourne, of which Dampier is a part.

8.3 Aboriginal and European heritage

The Dampier Archipelago has a rich history of Aboriginal and European habitation and numerous studies have investigated heritage sites in the area. While a great deal of data has been recorded on the location and nature of heritage sites, much of this was recorded before exact location techniques (i.e. GPS) and it appears that many sites have not been re-located. The Department of Conservation and Land Management (CALM, 2005) provides a brief overview of Aboriginal heritage in the region with maps showing the locations of identified Aboriginal heritage sites and native title claims. Vinnicombe (1987) includes detailed descriptions of the archaeology of the Burrup Peninsula with descriptions and locations of historical sites with artefacts i.e. engravings, grindings and shelters. The Western Australian Museum (n.d.) is an unpublished report detailing the results of a survey for Aboriginal sites in the Dampier Archipelago which focused on Withnell Bay, Noname Point, Searipple Passage and the construction workforce camp near Hearson Cave. Aboriginal sites are divided into the following categories: rock engravings, shell middens, stone artefact quarries and factories, habitation sites, stone arrangements and burials. An anthropological survey by Australia Interaction Consultants involving consultation with the Yaburarra, the Mardudhenera, the Nagarluma and the Injibandi people regarding aboriginal heritage sites in the area is included; a further appendix refers to consultation with the Wong-goo-tt-o people.

9.0 Current level of knowledge

This section outlines the current level of knowledge for the various areas reviewed in this document focusing on gaps in our understanding. It is not realistic, within the confines of this document, to discuss all specific knowledge gaps relating to all sections. Instead a general description is presented of areas requiring further research to enhance understanding of the marine and terrestrial environments of Dampier.

9.1 Marine Habitats

In general, the marine habitats of the Dampier Archipelago have been described and their distribution has been documented in numerous publications. A solid understanding of the ecology of these habitats and their relationships to other habitats in the area is however less well known.
Coral reefs
Considerable work has been undertaken on coral reefs in the Archipelago, describing the distribution of coral species and differences in species richness and diversity in the area. An annual mass spawning event has been seen in March/April in Dampier, with suggestions of a second smaller event in spring. Adverse environmental and anthropogenic stresses at key times such as this may decrease the changes of larval survival and settlement. Although work on the mass spawning event has been done there are still some questions as to which species take part and more work has been concentrated on the inner, rather than outer, reef. Other modes of reproduction have been less well studied and may need to be addressed.

Seagrasses
Seagrasses have not been well studied in Dampier and little information exists outside of general benthic habitat studies, mapping projects and benthic floral taxonomic accounts. The importance of seagrass beds to marine fauna has not been studied and there is virtually no information available as to the species utilising seagrass beds. The importance of seagrass beds in sediment stabilisation, nutrient uptake, as nurseries for juvenile fish and crustacean species and other benefits to the environment of the presence of seagrass has been well established in other areas, but not in Dampier. A study of Dampier Harbour seagrasses conducted through the University of Western Australia as a student project in 2005/6 will provide some data on these issues.

Mangroves
Mangrove diversity and distribution and the factors affecting them have been well documented for the region. Mangrove fauna has been fairly well described for birds, fish and other specific groups. General descriptions of mangrove fauna found in Dampier are however not available. Some understanding is available on the relationship of mangrove communities with other habitats, including nutrient transport and diel changes in fish distribution between habitats.

Macroalgal reefs
Very little work has been conducted on macroalgal reef environments at Dampier. Nearly all information regarding the taxonomy of benthic floral species can be found in only two references. Additionally little information is available regarding the fauna that inhabit these reefs. There is also no information regarding the importance of such habitats for primary production and their position in the general ecology of the area.

Intertidal (rocky)
There have been several useful studies of the rocky intertidal shores at Dampier; however nearly all of these address only a few specific sites along the Burrup Peninsula. Surveys indicate that rocky intertidal shores support a large range of invertebrate organisms and may therefore be important for preserving biological diversity.
Intertidal sand and mudflats
Several studies have addressed sand and mudflat environments although many of these were concentrated on the Burrup Peninsula. These habitats have been reported to be of high importance from a biodiversity standpoint, due the high species richness found in the infauna, suggesting further study of infaunal organisms may be required. Surface films of micro-algae may be an important food source for invertebrates which in turn may support larger fish and shore birds which feed in these areas on high tide.

Sub-tidal soft bottom
Sub-tidal soft bottom habitats are the least well studied environments at Dampier. Physical characteristics such as sediment size distribution are well known, however the biotic components are not. Such habitats make up a large proportion of the benthic environment yet the fauna (particularly infauna) inhabiting these areas are not well described.

9.2 Terrestrial environments
The vegetation and flora of the Burrup Peninsula and some of the major islands can be considered well known. With the exception of searches for rare or priority species in specific areas prior to development activities, further work may not be required.

9.3 Marine Biodiversity
Although the Woodside/Western Australian Museum (WAM, Jones, 2004b) partnership project enhanced our understanding of marine biodiversity of the Dampier Archipelago, many groups are still less well known from a taxonomic point of view. Fish and corals are the most well described groups for the region; however new species were recorded from both these groups during the Woodside/WAM surveys. Marine flora is also well described; however at the time of publication of the Woodside/WAM surveys several species were still unidentified. Considerable work has been completed on mollusc taxonomy in the region, yet sub-tidal molluscan fauna still requires attention. Few studies have addressed sponge taxonomy and distribution in the region. Considering the Dampier Archipelago may be of significance in regards to sponge diversity, further work in this area may be needed. Very little information is available regarding the coelenterates of the Dampier Archipelago. The Woodside/WAM surveys provided a preliminary species list that is limited and further work is needed. One hundred and twenty new species of crustacean were recorded for Dampier during the Woodside/WAM surveys, while this greatly increased the level of knowledge regarding crustacean taxonomy, several groups are likely to be poorly described, for example the amphipods. Although considerable work on the echinodermata of the Dampier Archipelago has been conducted through WAM, this group has very high species diversity in comparison to other regions and therefore probably warrants further study. Information regarding plankton in the Archipelago is altogether scarce. However, plankton studies that aim to understand changes in distribution and the role of plankton as a food source to other organisms may be more beneficial than taxonomic studies. Lastly, considering their high conservation value, large mobile marine fauna such as cetaceans, turtles, dugongs and seabirds are not well understood in terms of their distribution, habitat usage patterns and habitat requirements. More information is required in these areas to better
understand the effects of anthropogenic activities on the ability of such animals to continue to utilise the region for resting, breeding and nesting, in the case of migratory animals, and general daily activities in the case of permanent residents.

9.4 Users, uses and the social environment

The social environment of the region is fairly well understood. The economic development and population characteristics of Dampier have been studied and reported in several sources. The various users and uses of the Archipelago have also been reported including the issues and concerns of the general public regarding those uses. The Dampier Archipelago (including the Burrup Peninsula) is an important area for Aboriginal heritage sites. Although considerable effort has been exerted in locating and documenting such sites, many of the earlier records can no longer be used to locate described sites. Therefore survey work undertaken without the use of GPS may need to be repeated.

10.0 Suggestions for future tactical research

In some areas there appear to be large gaps in our knowledge of the Dampier marine environment. It should also be highlighted that, although a great deal of work has been undertaken in studying the marine environment, a great deal of the information collected is held in reports that are neither easily located nor generally accessible. For this reason and others, it is not uncommon for studies to expend resources gathering previously collected data, rather than on areas that may add to our understanding of the region. It was the purpose of this document to review as much of the information that has been previously collected as possible and provide guidance to direct future research. The following is a list of suggestions for future research in areas that are most in need of study to enhance the general understanding of the marine environment at Dampier. This list is not exhaustive and no attempt has been made to suggest avenues to fill all mentioned gaps.

- Introduced marine pests – considering the high risk level of the area due to shipping activities, surveys for marine pests are lacking. Thorough surveys for introduced marine pests currently in the area should be undertaken and programs to monitor introduced pests put in place.
- Sub-tidal soft bottom habitats – such habitats are the least well studied at Dampier. Considering the potential impacts to these habitats of dredging and spoil disposal, further work should be undertaken. The sediments of these habitats have been generally well studied; however, the fauna has not, particularly the infauna. Further understanding of the species inhabiting these environments and their importance to the ecology of the area should be established
- Cetaceans and dugongs – shipping and development activities are likely to interfere with the activities of large marine fauna such as whales, dolphins and dugongs. Dugongs are the least well studied in the area. Their population characteristics, activity patterns and habitat requirements should be better established. The effect of shipping and port activities on the movements of migratory cetaceans also requires further attention.
- Coral reproduction – the various modes of reproduction for different species and the timing of reproductive events (other than the mass spawning event) needs to
be firmly established to avoid engaging in activities that may potentially affect coral larvae during times of reproduction.

- Seagrasses – species lists of the fauna inhabiting seagrasses should be more firmly established, as well as the importance of these habitats to such species. The impact of anthropogenic activities on seagrasses in Dampier has not been well established. The effects of sedimentation and increased nutrient input, for example, might be better understood.

- Macroalgal reefs – faunal studies are required to establish species lists of animals utilising such habitats.

- Intertidal biodiversity – as the intertidal zone (including the rocky intertidal as well as sand and mudflats) is considered to be of importance from a biodiversity standpoint, further work should be undertaken to better establish the diversity of organisms in these habitats, their abundance, biomass and distribution.

- Coelenterates – very little work has been completed in describing this group of organisms and even less in describing their distribution, abundance or any other aspects of their biology or ecology - this should be addressed.
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