Dampier Archipelago/ Cape Preston

Regional Perspective 2000

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SUMMARY

The Western Australian Government is committed to the establishment of a statewide system of multiple-use marine conservation reserves under the *Conservation and Land Management* (CALM) *Act 1984*. These reserves will both protect the diverse and valuable natural and cultural heritage values of our coastal environment and provide a framework for sustainable management of commercial and recreational activities. One of the areas that has been identified for further consideration as a marine conservation reserve is the Dampier Archipelago to Cape Preston region.

The Dampier Archipelago to Cape Preston region is located in the warm, near-shore waters of the Pilbara coast. Physical environments within the region encompass a cross section of sheltered conditions with turbid waters and fine sediments adjacent to the mainland coast, to exposed conditions and clear waters around the offshore islands and reefs. Because of this diversity of habitats, the area supports many natural communities including mangroves, algal meadows, sandy beaches, submerged soft sediment communities, coral reefs, diverse invertebrate communities, rocky shores and rocky reefs. The area is characterised by a high diversity and abundance of marine plants and animals.

The region provides habitat and nesting sites for marine turtles and is of particular importance to hawksbill turtles. The Western Australian population of hawksbill turtles is the only large population of hawksbills remaining in the entire Indian Ocean and Rosemary Island in the Dampier Archipelago is by far their largest rookery in the State. Several species of seabirds also nest on the islands and the extensive mud flats, intertidal reefs and salt-marshes are used by many species of shore birds during their annual migrations between Australia and south-east Asia. Several whales and dolphins have been reported in the area, and dugong feed on seagrass in the shallow waters.

Aboriginal people have inhabited the Dampier Archipelago, Burrup Peninsula and adjacent coastal areas for thousands of years and their rock engravings make up what could be described as the oldest and finest outdoor art gallery in the world. A vibrant Aboriginal culture remains today and local communities continue to use the region for fishing and hunting.

The Dampier Archipelago was first charted by the Dutch East India Company in 1628 but the earliest recorded European landing was not until 1699 when William Dampier came ashore. Whaling and turtle industries operated in the area for many years and the harvesting of pearl shells has taken place since the late 1800s.

The area remained sparsely populated until 1966 when port facilities were constructed and the region became a focus for industrial development. The Port of Dampier is now the largest in Australia and moves 75 million tonnes of product annually worth 5 to 6 billion dollars. Iron ore from inland mines, salt from local sea-water evaporation ponds and liquefied natural gas and other petroleum products from offshore wells make up the bulk of the exports. The area is currently experiencing a lull in industrial development, but many additional industrial processing projects are in an advanced stage of planning, and heavy industry plus the associated port facilities are set to expand significantly in the near future. A valuable cultured pearling industry also flourishes in the region together with significant commercial fin fishing and prawn trawling industries.

Despite the area being a focus for industrial development, aesthetically, the coastal and island scenery is exceptional. This together with the warm climate, sheltered conditions, abundant wildlife and close proximity to areas of significant Aboriginal and European cultural value, create a highly attractive and popular setting for a wide range of recreational pursuits. Pilbara coastal towns have the highest rate of private vessel ownership anywhere in Australia and charter boats cater for tourists who want to dive, fish, and sight see. Recreational fishing is a very popular activity in the Dampier Archipelago.

With the mixture of high natural, cultural, commercial and recreational values all within the Dampier Archipelago and Cape Preston region, there is a potential for degradation of the environment and conflict among users. With the additional developments which are planned for the near future, the potential for degradation and conflict will also increase. The area is therefore to be considered for reservation both to preserve the marine environment and to put a formal management framework in place to ensure the various uses are managed in an equitable, integrated and sustainable manner.

This document provides a broad regional perspective on the ecological, cultural and socio-economic setting of the region as background information for a community-based advisory committee and for members of the general community who have an interest in the marine environment of the area. The Department of Conservation and Land Management (CALM) encourages readers to contribute to the planning process for the proposed Dampier Archipelago and Cape Preston marine reserve, either through their representatives on the advisory committee or through the public submissions process.

Additional information about the Dampier Archipelago and Cape Preston region and the planning process for marine conservation reserves can be obtained from the primary source documents which are listed under the acknowledgements section in this booklet, or from the following CALM offices:

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Above photo: courtesy Woodside Energy

Figure 1.The Dampier Archipelago/Cape Preston region is valued and used by many Western Australians.

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KEY RESOURCE DOCUMENTS

The information within this document comes from a wide range of sources including published reports, brochures, magazine articles, web sites and personal discussions with experts. Readers are encouraged to refer to the following reports which were used extensively as source documents. Their contribution towards the preparation of this document is gratefully acknowledged:

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INTRODUCTION

The mainland coastline of Western Australia is approximately 21,500 km long and there are 3,424 offshore islands. The adjacent coastal waters support a diverse range of tropical, subtropical and temperate ecosystems such as coral reefs, mangroves, seagrass, algal covered rocky reefs, soft sediment communities and deep open oceans. Recreational use of our marine environment is an integral part of the Australian way of life and 'the beach' is a national icon. Our living and non-living marine resources also support major marine-based industries including tourism, oil and gas, mining, fishing, aquaculture and pearling. These industries represent a significant component of the State's economy providing employment, both directly and indirectly, for many thousands of Western Australians.

The Western Australian Government is committed to the establishment of a statewide system of multiple-use marine conservation reserves under the *Conservation and Land Management* (CALM) *Act 1984* to both protect the diverse and valuable natural heritage values of our coastal environment and to provide a framework for sustainable commercial and recreational use of these resources. A Marine Parks and Reserves Selection Working Group (MPRSWG) was established in 1986 to identify marine areas off the Western Australian coast that were thought to be worthy of consideration for marine reserve status. Their report, *A Representative Marine Reserve System for Western Australia*, was released for public comment in 1994. In addition to the six marine parks and one marine nature reserve already established at that time, the report identified a further 70 areas around the coast which, if reserved, would provide a system of marine conservation reserves representing all of the major coastal ecosystems of Western Australia.

The Dampier Archipelago and Cape Preston regions were identified in the MRSWG report for their significant terrestrial and marine flora and fauna, and because they are subject to increasing human impact. The Dampier Archipelago includes inshore, relatively calm, turbid environments and offshore areas where the conditions are influenced by clearer waters and rougher seas. Because of the variety of environmental conditions, the area supports a wide range of habitat types including mangroves, rocky shores, sand and mud shores, macroalgal or seaweed communities and coral reefs. Within these habitats there is a high diversity of organisms including species of special significance like humpback whales, dugong, migratory birds and marine turtles.

Aboriginal people have lived in the area for many thousands of years. In recent times, human use of the area has escalated with the development of town sites, port facilities and a liquefied natural gas processing facility. Fishing, pearling and tourism industries also operate in the region and the area provides important recreational opportunities for residents who enjoy fishing, boating and diving.

With the mixture of high natural, cultural, commercial and recreational values within the region, there is the potential for degradation of the environment and conflict among users. In addition, proposed developments in the area indicate that the trend is towards further human use of the area, which is likely to increase the potential for both degradation and conflict. The area is therefore to be considered for reservation both to preserve the marine environment and to put a formal management framework in place to ensure the various uses are managed in an equitable, integrated and sustainable manner.

The term 'marine conservation reserve' often raises concern that these areas will exclude many recreational and commercial activities. However, although conservation is the primary objective of marine conservation reserves, recreational and commercial uses are catered for, as long as these activities do not cause unacceptable changes to the environment and can be managed without undue conflict.

The Western Australian Government is committed to full and open consultation before areas are created as marine conservation reserves. The focus of consultation during the first stage of the planning process for the Dampier Archipelago and Cape Preston reserve proposal is a community-based advisory committee. Committee membership is community-based and includes a range of people with knowledge and interest in the proposed area. Working within a broad framework, members contribute technical expertise and exchange ideas among themselves and with the broader community in a collaborative process to assist in developing advice to Government on the most appropriate reserve

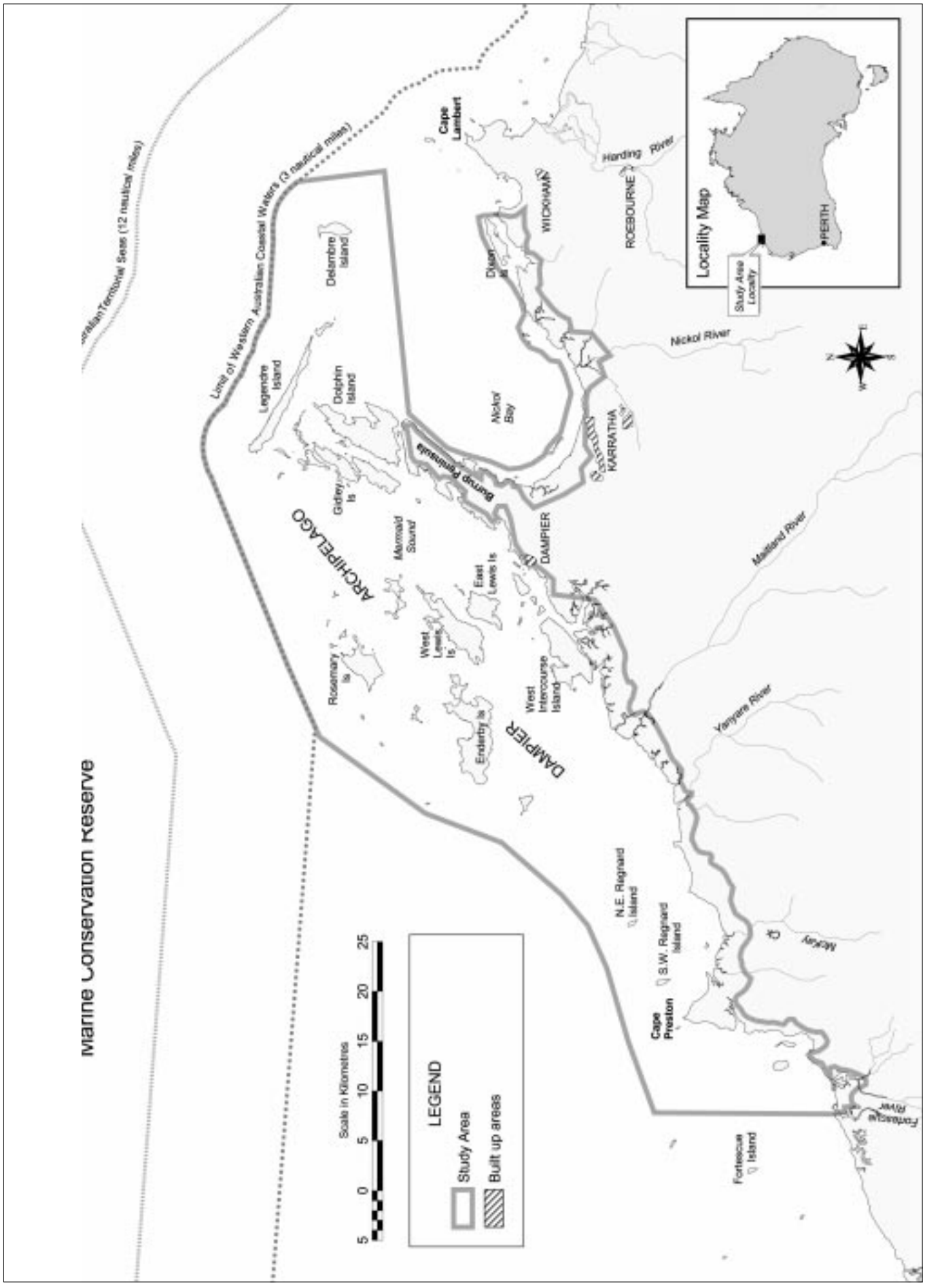

Figure 2. Study area for the proposed Dampier Archipelago/Cape Preston marine conservation reserve.

category, boundaries and management strategies to ensure sustainability. There is a legal requirement for the second phase of public participation in the planning process. During this phase, the draft management plan is published for public comment and a minimum three-month period is made available for the receipt of written submissions from the public.

This regional perspective paper has been written to assist members of the community who have an interest in the Dampier Archipelago/Cape Preston region and would like to participate in the planning process for a marine conservation reserve. It provides an overview of the environmental, cultural, commercial and recreational values within the area and complements a series of booklets and brochures which are associated with the marine conservation reserve planning process.

STUDY AREA

The study area has been defined to guide the community-based advisory committee in its consideration of a marine conservation reserve proposal in the Dampier Archipelago/Cape Preston region. Before the planning process for new marine conservation reserves can begin, Ministerial agreement is needed on the extent of the geographical area the advisory committee can consider. In this instance, the Ministers for the Environment, Fisheries, Minerals and Energy and Resources Development have endorsed the boundaries of the study area. Although these boundaries largely confine the deliberations of the advisory committee, they may not necessarily correspond with the reserve boundaries once the planning process is complete. The extention of a reserve beyond the boundaries of the study area will be considered only if there are very good reasons for doing so.

The study area lies about 1,650 kilometres north of Perth, Western Australia, between 20°20′ to 20°45′ south and 116°25′ to 117° east. The archipelago consists of about 12 major islands and a number of smaller islands, rocks and shoals.

The area is broadly defined as the waters between the Fortescue River mouth to the west, and the Burrup Peninsula to the east. It includes State territorial waters east to Delambre Island and near-shore waters in Nickol Bay east to Dixon Island (Figure 2).

The largest islands in the Dampier Archipelago include Dolphin Island (3,203 ha), Enderby Island (3,290 ha), West Lewis Island (2,144 ha), Legendre Island (1,325 ha), Rosemary Island (1,145 ha) and East Lewis Island (1,050 ha).

The major population centres bordering the study area are: Karratha, with a population of approximately 11,300, and Dampier, with a population of approximately 1,800. Other nearby towns are: Wickham/Port Samson (population 1,973), Roebourne (population 1,213) and Onslow (population 881).

REGIONAL CONTEXT

The marine flora and fauna of Western Australia belong to two biogeographical provinces: a tropical province in the north and a temperate province in the south. Marine plant and animal assemblages of southern Australian waters are characterised by very high levels of endemicity, that is, many species are found nowhere else in the world. The diversity of marine flora and fauna in the north is generally higher and most species are widespread throughout much of the Indo-West Pacific Region which stretches from the east coast of Africa to French Polynesia in the central Pacific, and from Japan to the northern coasts of Australia. Between these two broad biogeographic regions is an overlap zone which, in Western Australia, stretches from Ningaloo Marine Park in the north to the south-west capes in the south. Plant and animal assemblages in this overlap zone combine different proportions of both tropical and southern species.

The Interim Marine and Coastal Regionalisation for Australia (IMCRA) is an ecosystem-based classification for marine and coastal environments. It divides the marine environment of Australia into 60 different biogeographical regions, 18 of which occur in Western Australia. The marine and coastal environments of the Dampier Archipelago/Cape Preston study area lie within the Pilbara near-shore IMCRA bioregion, which stretches from the North West Cape in the west to Cape Keraudren in the east.

The Pilbara near-shore bioregion contains a wide

Figure 3.The Burrup Peninsula and many islands in the Dampier Archipelago are composed of ancient Precambrian rocks.

range of habitats, which support a high diversity and abundance of marine organisms. Of particular note is the high diversity of animals associated with intertidal mud and sand flats, which have fringing mangroves in bays and lagoons. These animals provide an extremely important food source for migratory birds. The mangrove communities are extensive and structurally complex but they are made up of only six species. There are few places in the world where mangrove communities occur in arid conditions and for this reason they are of great scientific importance. The Pilbara near-shore bioregion also encompasses significant fringing coral reefs, which have developed mainly around the more distant offshore islands. In addition, a significant number of the beaches are important turtle nesting sites and some of the islands support large seabird colonies.

The Western Australian Government is committed to establishing a marine reserve system within which all bioregions are represented. In 1994, the Marine Parks and Reserves Selection Working Group recommended that six areas within the Pilbara near-shore bioregion be considered for reservation. From east to west, these areas are: Cowrie Beach and the intertidal waters of Cowrie Creek; the area extending from Delambre Island to Regnard Bay, which encompasses many of the islands in the Dampier Archipelago region; the Cape Preston area; the strip of hinterland from slightly south of James Point to Yammadery Island; an area within Exmouth Gulf which extends from Locker Point to Learmonth; and a small area south of Exmouth. Of these six proposed areas, none are currently marine conservation reserves. The Dampier Archipelago and Cape Preston study area is therefore the first to be given consideration within the Pilbara near-shore bioregion.

The study area is centrally located within the Pilbara near-shore bioregion and includes representative samples of the wide range of both onshore and more exposed habitats that occur throughout the bioregion. The establishment of a marine conservation reserve within the study area will therefore make a significant contribution to the statewide system of representative reserves.

PHYSICAL ENVIRONMENT

Geology and geomorphology

The surface layers of rock within the study area are some of the oldest in the world, formed in Precambrian times when life on Earth was just beginning. The Precambrian rocks were laid down in three stages. Around 3,300 million years ago, volcanoes in the area produced layers of lava. Two hundred million years later, large masses of molten rock were intruded into the lava layers and these cooled slowly forming the large crystals characteristic of granite. Erosion wore down the layers of lava and exposed the granite before the third stage of Precambrian rock formation 2,700 million years ago. During this stage volcanic lava

was deposited on top of the earlier rocks and molten rock intruded into cracks in the older rocks, forming dykes. The lava that filled the dykes cooled quickly, forming small crystals characteristic of dolorite and granophyre rocks. It is the granophyre rock of this period that forms the Burrup Peninsula (Figure 3). In addition, carbonate rocks formed from sediments in shallow seas. These deposits contain fossil stromatolites similar to the living stromatolites, which occur in Shark Bay today.

The north-western boundary of the study area extends into the Carnarvon Basin. Here, thick layers of sediments accumulated between 300 and 70 million years ago. In some locations, these sediments contain petroleum products and there are exploration leases that extend within the study area. The petroleum products within the Carnarvon Basin were formed mainly from the organic remains of plants and animals that lived between 300 and 140 million years ago during the Permian, Triassic and Jurassic periods. At that time, Australia was joined to India, South America, southern Africa and Antarctica and the study area was at higher latitudes, and much colder than it is today. The organic remains that formed the petroleum deposits were most likely of mixed marine and terrestrial origins. The organic marine deposits consisted primarily of single celled plants and animals which lived in the plankton while the terrestrial deposits were most likely Glossopteris fern and other plant assemblages that were widespread during those periods.

The organically-rich deposits were transformed into petroleum products by being subjected to specific heat and pressure conditions. At this stage, the deposits were buried deeply, up to 1,000 m below more recent rocks. Once formed, the fluid and gaseous petroleum products seeped upwards through cracks and pores in the younger rocks. This migration continued until it reached the surface and escaped, or became trapped by impermeable layers formed by domes or faults in the rock. To date, no petroleum products have been found within leases that extend into the study area to the west of Cape Preston and north of Enderby Island.

While the western and north-western edges of the study area are characterised by Carnarvon Basin deposits, it is the Precambrian rocks that form the backbone of most of the study area. These ancient rocks are either exposed at the surface, or are covered by layers of young sediments deposited during the past 65 million years. A major component of this young rock is limestone, made of the compressed skeletons of millions of plants and animals that fell to the bottom of the sea. Varying thicknesses of sand, gravel or mud cover the limestone and Precambrian rocks associated with localised deposition on beaches, coastal deltas, mangrove communities and other features.

The study area has experienced significant changes in sea level through recurring ice ages. The most recent of these occurred about 260,000, 150,000 and just 18,000 years ago. During the

Figure 4. Many of the islands have large rock piles and rocky shores.

most recent ice age, the sea level was 150 m lower than it is today. The rise of sea level since the last ice age was rapid and 7,000 years ago sea level was up to 1.5 m higher than it is today. At that time, many of the islands, which are exposed today, would have been much smaller. Sea level then dropped to its present level just 4,500 to 4,000 years ago exposing the islands as we know them today.

Today, the 12 major islands and 30 smaller islands, rocks and shoals within the Dampier Archipelago represent the peaks of a drowned landmass, which is essentially similar to the present hinterland. The islands range in size from 3,203 ha (Dolphin Island) to small rocky islets of less than 1 ha. The highest, Dolphin Island, rises to 120 m above mean sea level. Many of the islands are composed of Precambrian rocks. Granite occurs at the surface on Dolphin, Tozer and Enderby Islands and granophyre makes up the Burrup Peninsula. In addition volcanic Precambrian rocks underlie the major reefs and shoals in the archipelago. Many of the islands are similar to the present mainland and Burrup Peninsula, with steep and rugged coastal cliffs, large rock piles and rocky shores (Figure 4). Valleys, beaches and coastal sand plains separate the rock piles. However, Legendre Island and the other flatter islands and islets to the north of the archipelago look quite different. They consist primarily of limestone and are low set and lack the rock piles (Figure 5).

The islands and shoals rise above submarine plains that are gently sloping from 5 m deep near the mainland coast to 15 to 20 m deep at the northern margin. The sea floor has extensive limestone pavements and large sheets of shell gravel, sand and muddy sand/gravel.

In addition to the islands, submerged and tidally-submerged hills and ridges rise from the submarine plain. These are rocky reefs, comprised of rock formations and boulder deposits, some of which are colonised by corals and form coral reefs. Shoals often form connections between the islands and coral reefs of the archipelago, and also form on the leeward sides of many islands.

At the northern margin of the submarine plains, the sea floor descends steeply to more than 30 m. These deep open oceanic waters form the inner part of the North West Shelf. In places, the junction between the submarine plains and the deep open waters is delineated by a line of submerged rocky reefs, coral reefs or shoals that locally protrude above the water surface, such as Hamersley Shoal, Legendre Island and Sailfish Reef.

The Burrup Peninsula and Dolphin Island separate Nickol Bay from the Dampier Archipelago. Nickol Bay is a large shallow embayment measuring 35 km by 20 km. The seabed slopes gently from 20 m at the northern margin and becomes intertidal at the south. The shoreline includes mudflats, rocky

Figure 5. Legendre Island to the north of the archipelago is low set and consists primarily of limestone.

shores, limestone pavements, sand beaches and mangrove flats.

The mainland coast between Cape Preston and Cape Lambert is characterised by rocky headlands interspersed with low-lying mudflats and adjoining mangroves. The mangrove communities are generally fringed inshore by salt marshes. Some of the mud flats at Dampier are now used commercially as evaporation ponds for the production of salt. Remnant mangroves are a reminder that these areas used to support extensive mangrove forests. Behind the low-lying coast is a granitic plain that gently rises inland.

Many rivers drain the Pilbara region but most flow only for short periods. Two major rivers drain into the study area: the Maitland River and the Fortescue River. They contribute alluvial deposits at their mouths, which are colonised by mangrove communities. The seabed adjacent to the mainland coast between Cape Preston and the Dampier Archipelago is shallow and gently shelving.

Drainage and groundwater

Groundwater results from rain that has percolated down through soil and cracks in rocks. Geological formations such as sand, sandstone and limestone, which contain useable amounts of water, are called aquifers. Deep aquifers that have been under pressure between relatively impervious layers of rock are called artesian basins. The availability of groundwater depends on how easily water can move through the substrate.

Groundwater in the general Karratha region is of good quality for agricultural stock and is readily available throughout most of the mainland coast. The most significant and exploited groundwater resources are contained within the alluvial aquifers of the coastal plain and valley-fill aquifer of the Fortescue Valley. No significant water resources in the Karratha area have been identified for domestic and industrial uses. As a result of limitations on the supply and quality of water, fresh water is obtained externally from Millstream and the Harding Dam.

Rainfall in the Dampier Archipelago region is unreliable and comes mainly from thunderstorms and cyclones. Rainwater either drains into one of the major rivers or is captured by a number of ephemeral streams and creeks which drain elevated areas. Stream-flow in these creeks is sporadic and brief after heavy rains. Surface run off is relatively efficient due to the hard terrain, and fast-running streams form along the valleys after rainfall. Rocky depressions in the streams can retain water for up to three months after the rains, creating attractive pools. The streams transport high particulate loads, maintaining colluvium fans at the bases of hills where the streams dissipate across coastal plains.

The main rivers within and adjacent to the study area are the Harding, Maitland and Fortescue Rivers. The Fortescue River has a catchment area of about 50,000 km^2 and the Maitland River catchment area, above Miaree Pool, is 2,010 km^2. The Harding River has a catchment above the Harding Dam of 1,068 km^2 and it flows out to sea just east of Cape Lambert. These large catchment areas and heavy rains associated with cyclones result in periodic flooding when large quantities of sediment-laden freshwater are introduced into the coastal marine environment.

Little is known about the hydrology of the Burrup Peninsula area, other than it is part of the Indian Ocean drainage area. There are currently no stock-watering wells or stratigraphic test wells available to assist in determining water-table levels. However, permanent water does occur in several pools in hilly areas and these appear to be fed from ground sources which gain entry along fault lines.

Climate

The climate within the study area is both arid and tropical. It is controlled largely by the seasonal movement of high pressure anti-cyclonic weather systems that migrate from approximately 25° to 30° south in winter, to 35° to 40° south in summer. As a result, there are two broadly defined climatic seasons over north-western Australia; a warm dry 'winter' season from May to September and a hotter and wetter 'summer' season from October to April. However, the region has a low yearly rainfall and is quite arid.

During the winter season, the northern position of the high pressure cells results in a prevailing east-south-easterly offshore flow of relatively cool air (south-east trades) over the north-west coast. These offshore winds are often modified by local breezes. They are enhanced by late night/early morning south-easterly land breezes as the land cools, and are moderated by afternoon north-westerly sea breezes as the land heats. In winter, offshore winds

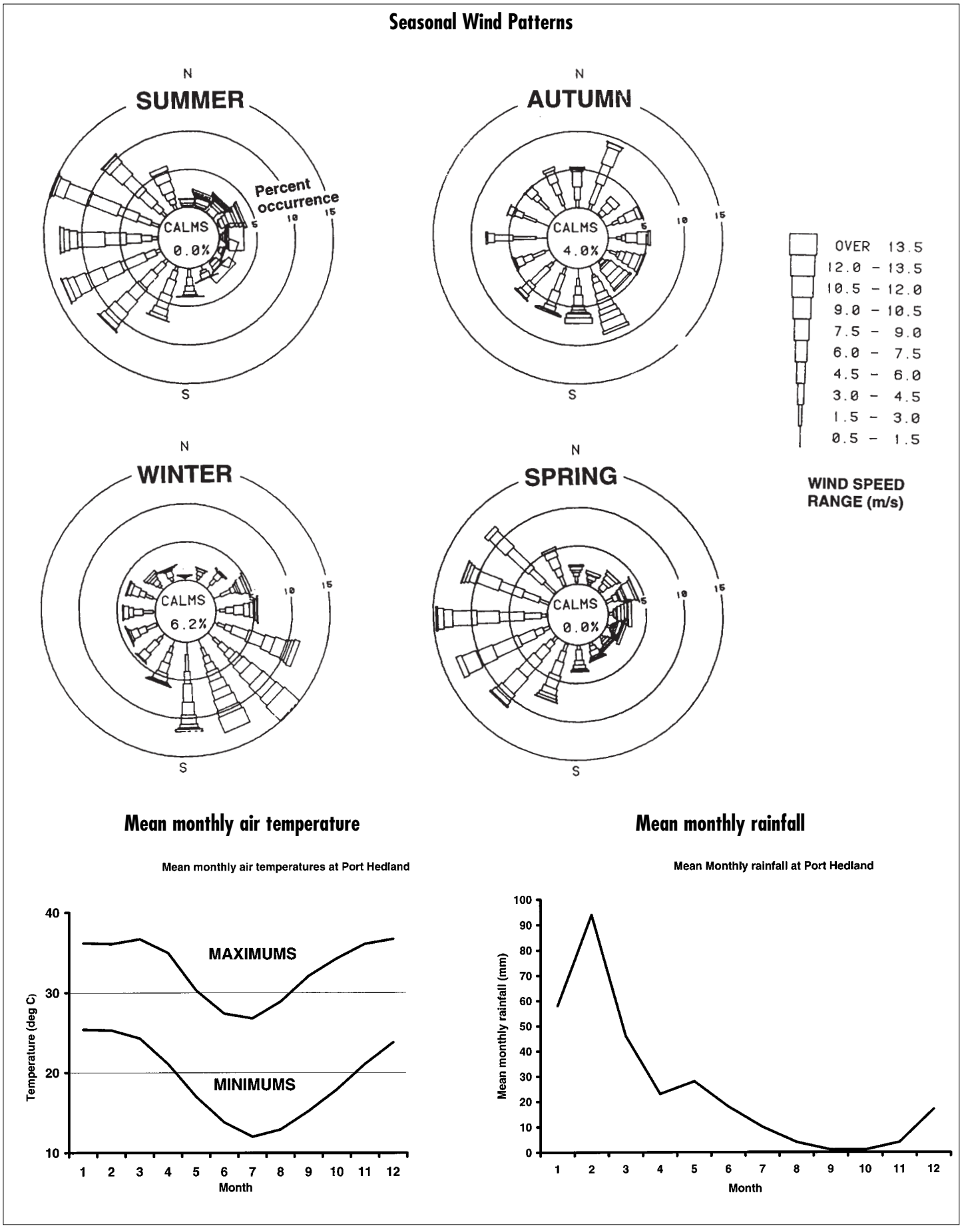

Figure 6. Seasonal wind patterns, mean monthly temperatures and mean monthly rainfall patterns within the arid and tropical Dampier Archipelago to Cape Preston region. Data courtesy Pills & Mills, 1985 and Bureau of Meterorology.

reach speeds of 20 to 30 knots inshore and can occasionally peak at 60 knots offshore (Figure 6).

During summer, the high-pressure cells are further to the south, resulting in warmer winds from the north-west and south-west. There is a pattern of daytime sea breezes and night-time land breezes, with wind speeds typically less than 20 knots.

Winds are at their weakest and most variable during the seasonal changeovers between summer and winter, around April and August, and it is during these periods that the weather is most favourable for recreational activities within the study area.

Cyclones generally form during December to March over the Timor Sea or off the north-west coast and can result in winds up to 300 km/hr. On average, two cyclones cross the coast each year, typically between Onslow and Broome (Figure 7). Cyclones bring destructive winds, heavy rains, storm surges, large waves and cause substantial movement of coastal sediments. Cyclonic waves can damage or dislodge corals and other benthic, or sea-bed-attached, communities. Sediments that are mobilised by cyclonic waves and currents can also smother marine organisms. In addition, infrastructure associated with the port and industries has to be designed to withstand the severe conditions associated with cyclones.

Mean annual rainfall at Karratha (Dampier Salt) is 249 mm, with more than half occurring during the January to March period, but this varies from year to year as a result of cyclones, and extreme downpours are sometimes recorded (Figure 6). The highest recorded rainfall in a 24-hour period in the vicinity of the study area was about 1,000 mm at Whim Creek.

The air temperature at Karratha (Dampier Salt) peaks in January and is at its lowest in July. The mean monthly maximum and minimum temperatures are 35.9°C and 13.4°C, respectively, and the highest and lowest recorded temperatures are 47.1°C and 4.6°, respectively (Figure 6). The relative humidity is highest during the summer months, with average daily humidity for the Dampier/Karratha area ranging from 45 to 64 per cent. Early morning dews can occur during both summer and winter, and these provide an important source of water for fauna. Annual evaporation in the Dampier Archipelago region is about 3,500 mm, far exceeding mean annual rainfall.

The proximity of the study area to the north-west coast results in the unusual exposure of the sea surface to both the relatively cold offshore breezes of the south-east trades in winter and the contrasting warm onshore breezes in summer. As a result, water temperatures in the Dampier

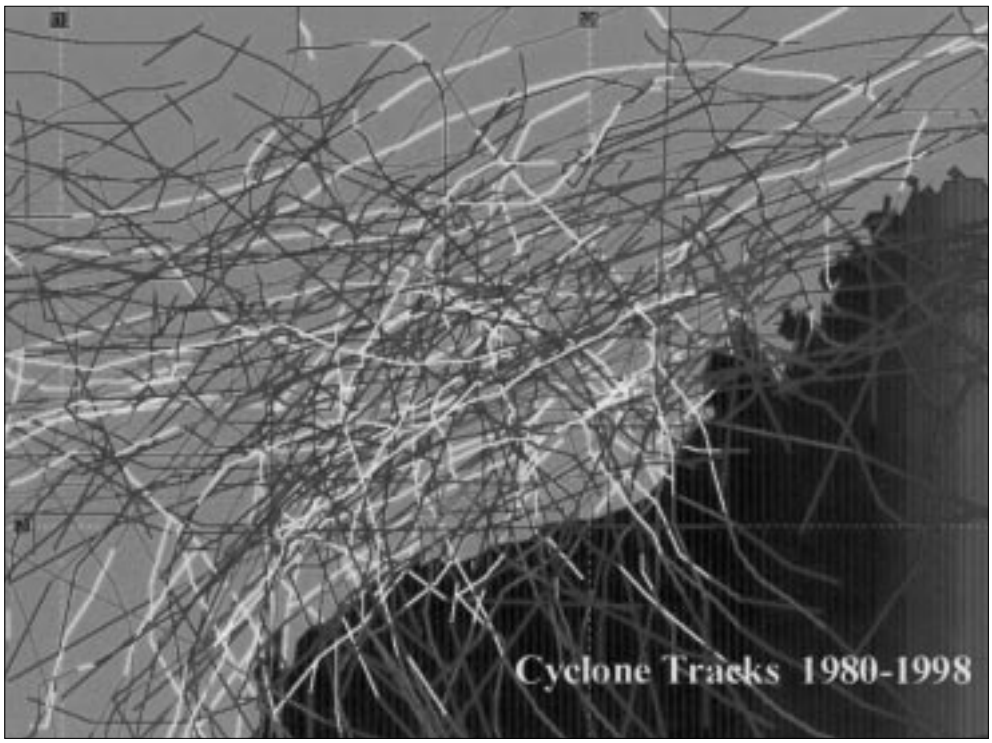

Figure 7. Cyclone tracks in the north-west of Western Australia between 1980 and 1998. Image courtesy Commonwealth Government.

Archipelago display a relatively large annual range compared with other tropical ecosystems, thereby subjecting the local coral reef communities to seasonal temperature fluctuations close to their natural limits of tolerance.

Oceanography

Oceanography is a comprehensive science that incorporates chemical, physical, biological and geographical principles in studying the world's oceans. The biological values of the Dampier Archipelago/Cape Preston region are described in the natural heritage sections of this document, so the focus in this oceanography section is on the chemical and physical attributes of the waters within the study area.

Water level

Tides are caused by the gravitational pulls of the sun and moon on the planet Earth. Because of the orbital motions of the Earth and the moon, the relative locations of the sun, moon and Earth, and therefore the directions of gravitational pull, change with time. When the gravitational pull of the sun and moon complement each other, the tides are referred to as spring tides, which are characterised by large tidal changes. When the gravitational pulls work against one another, the tidal range is much lower and these are referred to as neap tides (Figure 8).

The tides of the Dampier Archipelago region are macrotidal and semi-diurnal, that is, they go through two peaks and two troughs—or highs and lows—per day. They propagate shoreward, or move towards the mainland coast, and amplify across the continental shelf with predicted tides at the coast having a maximum range of 6.3 m, a mean spring range of 5.6 m and mean neap range of 1 m.

Combined meteorological effects such as storm surges, barometric pressure and cyclones can change the water level by considerably more than 1 m. For example, Cyclone Vance in March 1999 caused a surge in water level along the Pilbara coast of almost 4 m above the predicted tidal level. Meteorologically-forced changes in water level are important as they can influence sustained drying of normally submerged benthic communities, which are also subject to the effects of wind and wave turbulence during periods of low water levels.

Waves

There are many sources of energy that create waves in the ocean, including tides and seismic activity, but wind is the primary energy source of ocean waves. In areas where there are high winds or storms, the ocean surface is a jumble of waves of various sizes. To produce large waves, high-speed winds must move in the same direction over an extensive area for a considerable period of time. When the wind abates or when waves move out of a storm system, the waves sort themselves out. Smaller waves interfere with one another, break on the crests of larger waves and dissipate rapidly. What are left are the larger waves, which are known as swell.

Waves on the North West Shelf come from the Southern Ocean (from the south-west), summer monsoonal activity (from the west-north-west) and tropical cyclones. The most persistent swell arrives from the south-south-west before refracting (bending) over the shelf to become more westerly to north-westerly as it approaches the coastline.

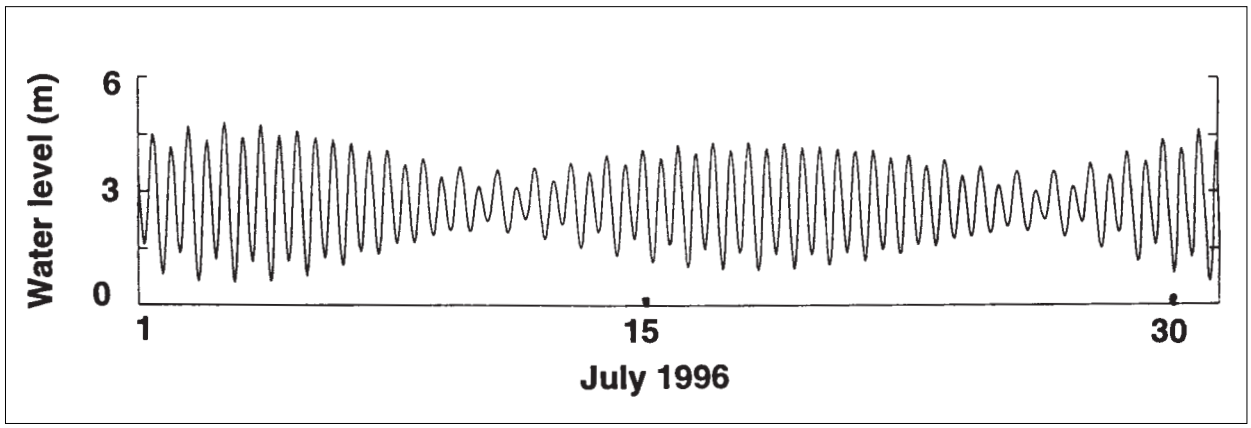

Figure 8. Water levels associated with spring/neap tidal cycles at King Bay. Data provided by Dept. of Transport.

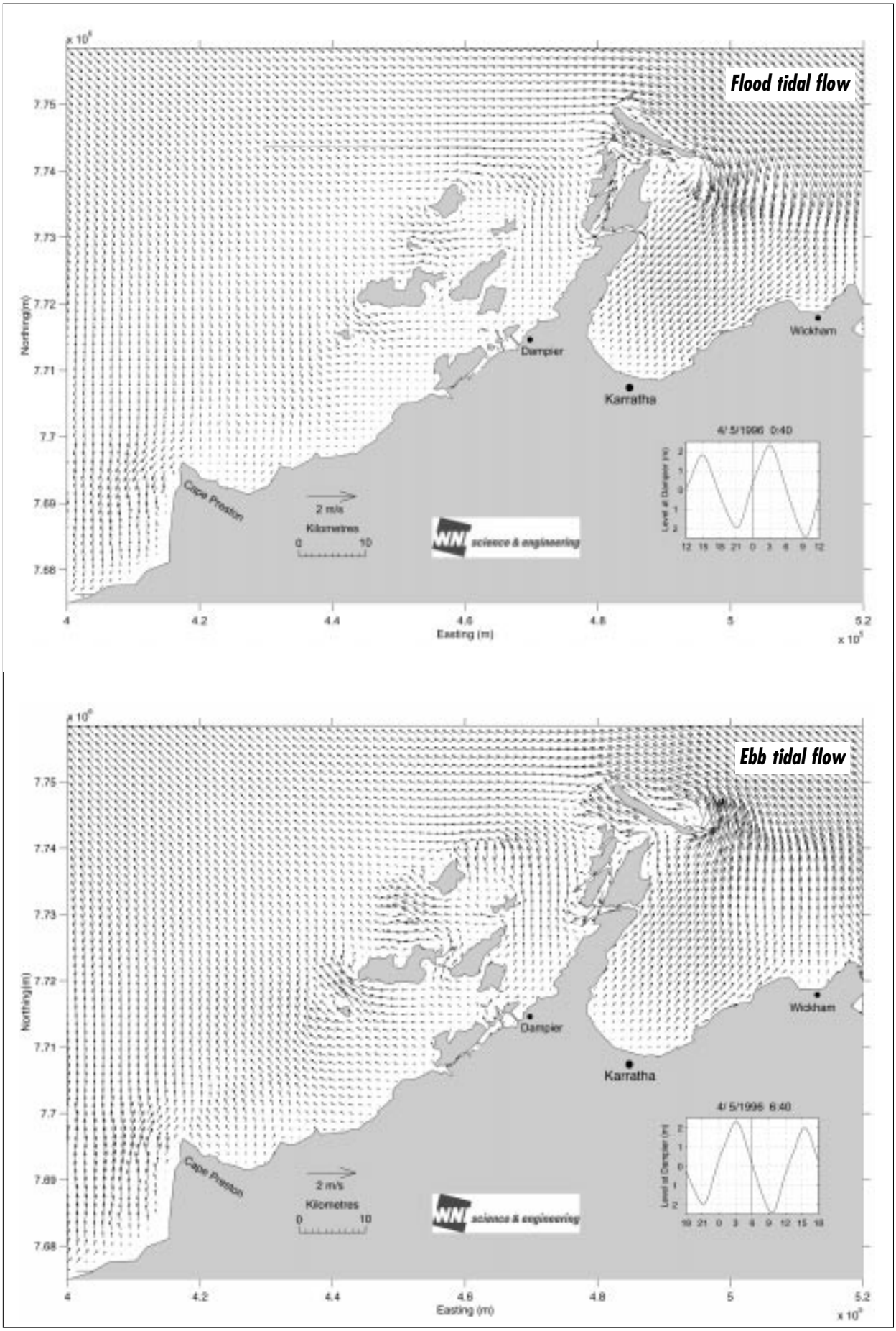

Figure 9. Typical ebb and flood tidal flow patterns generated by winds and spring tides over a 40 day autumn climatic period. Data courtesy CALM and WNI Science and Engineering.

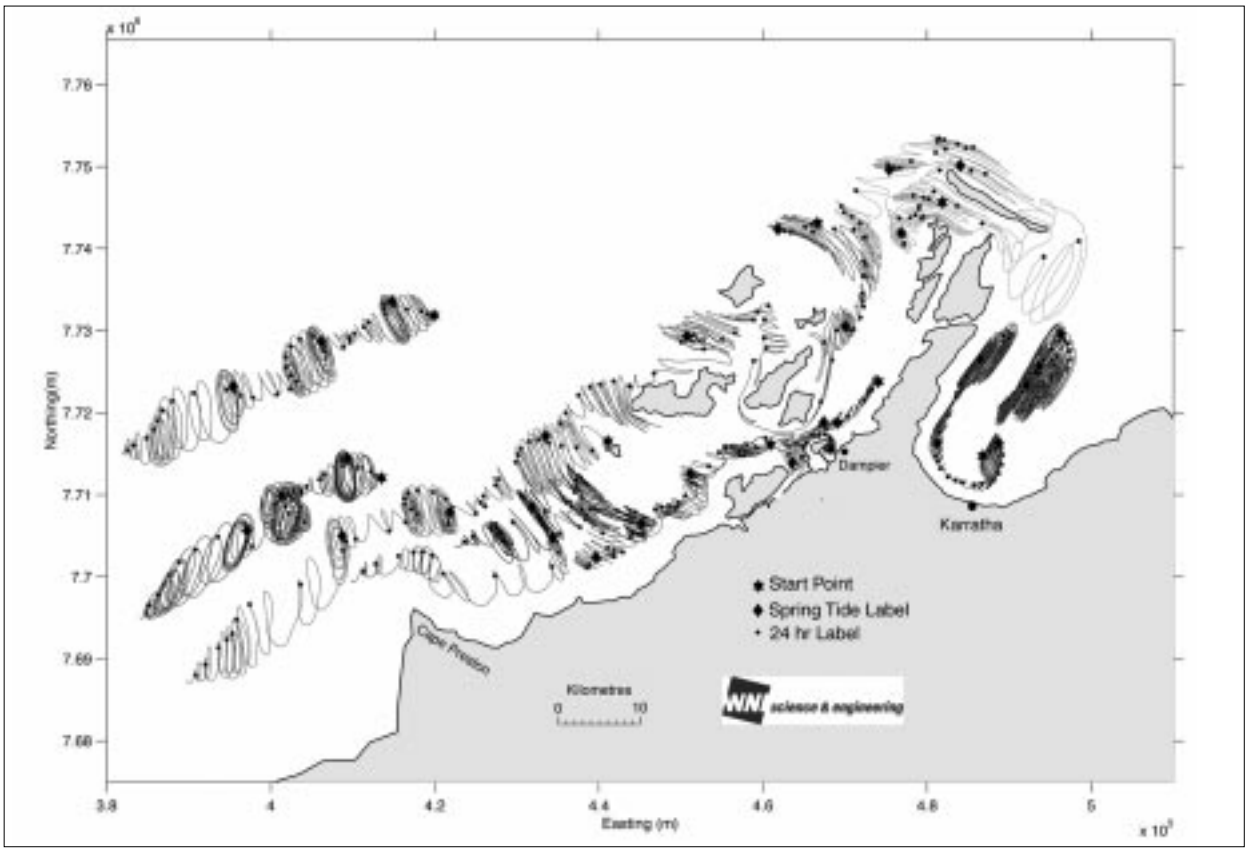

Figure 10. Although water oscillates back and fourth over large distances during spring tide ebb and flow cycles, the net drift is greater during neap tides when wind driven movements have greater influence. Data courtesy CALM and WNI Science and Engineering.

Typical ocean swell heights are about 2 m in winter and 1 m in summer with periods of about 12 to 16 seconds between waves. Winter easterly winds generate 1 to 2 m waves at 6 to 8 second intervals in the open waters offshore from the archipelago. Swell generated in deeper water during storms and cyclones can reach heights well above 5 m, with the theoretical maximum wave height for a strong cyclone estimated to be nearly 20 m.

Oceanic swells can be reduced to less than half of their original size and energy en-route to the inner archipelago region as a result of bottom friction over the shallowing sea-bed, breaking over reefs and blocking by islands and promontories. For example, a 19 m offshore swell during Cyclone Olivia (April 1995) was reduced to about 5 m in the Dampier Archipelago. Wave patterns can influence marine communities by causing spatially variable sedimentation rates and by sorting sediment fractions. Persistent wave action over the offshore reefs of the archipelago transports fine sediment away from these areas, resulting in a relatively clear water column. In contrast, within the inner archipelago, wind and tidal stirring, combined with relatively low throughflow rates, result in local re-suspension of fine sediments, which reduces light penetration through the water column, and may in turn limit the growth of marine plants. The intermediate zone between offshore and near-shore reefs fluctuates in water clarity depending on seasonal variations in wind and wave action.

Currents

Unlike waves, which bring about virtually no net water transport, currents result in mass movement and mixing of ocean waters. It is important to understand current patterns because of their role in transporting and dispersing natural substances, such as dissolved nutrients and the larvae of marine animals. Substances such as oil, toxicants and nutrients from sewage outfalls and aquaculture projects are also dispersed by water currents. In addition, currents are important in the suspension and sorting of sediments and other particulate matter.

Ocean-scale pictures of sea-surface temperatures taken by heat-sensing satellites regularly show the long, narrow Leeuwin Current bringing tropical, warm water south along the west coast of Western Australia, around the south-west capes and then

onwards to south Australia. The Dampier Archipelago/Cape Preston region however resides in the inshore zone of a relatively expansive shelf region. This, along with the presence of islands and reefs, reduces the ability of the Leeuwin Current and other broad scale regional currents to make any significant sustained incursions into the near-shore zone.

Currents in the Dampier Archipelago region are spatially and temporally variable due to the area's complex bathymetry, or sea-bed terrain, and changing tide and wind patterns. Currents are driven principally by tides and wind stress. Records collected from 1981 to 1984 at many sites throughout the archipelago indicate that circulation in the region can be characterised as follows (Figure 9):

- close to the coast, flows are mainly parallel to the shore with speeds ranging from about 5 cm/s (neap tides) to 25 cm/s (spring tides);
- within the archipelago, flows are strongly steered by the bathymetry in and around the islands with speeds ranging typically from 10 to 40 cm/s (neaps and springs, respectively), but with flow concentrations along channels between islands generating currents of up to 80 cm/s;
- currents over the exposed mid-shelf region (20 to 50 m depth) generally run perpendicular to the depth contours with speeds ranging from about 10 to 50 cm/s (neaps and springs, respectively).

An important feature of the water movement is that during a typical ebb/flood cycle, water oscillates back and forth throughout the archipelago. During spring tides the oscillations typically span 5 to 10 km but result in only a small net movement away from any one particular location because water is repeatedly brought back to near its original location on every cycle. During neap tides however, it appears that a relaxation in the influence of strong tidal stirring allows the wind to play a more effective role in moving water, and net movement away from any one location is greater (Figure 10).

Prevailing summer winds from the south and west drive water eastward through Mermaid Straight and between Rosemary and Enderby islands, while water in Mermaid Sound is forced northwards towards the seaward entrance. Easterly and northerly winds induce southward flow into and through Mermaid Sound and drive water westward in between the islands. These winds may occur occasionally as a result of cyclones in summer or during winter wind fields. Net residual transport through the archipelago is thus generally directed towards the north during summer and offshore during winter, in response to the prevailing seasonal wind directions.

Salinity

Salinity measurements taken in and around the archipelago during 1982 and 1983 indicate that the range of salinities is between 35.1 and 37.1 parts per thousand (ppt). The smallest range and lowest salinities (35.1 to 36.1 ppt) occur offshore at the 20 m contour, and the largest range and highest salinities (35.45 to 37.1 ppt) occur inshore within 2 km of the Burrup Peninsula. These salinities are well within the range of salinities typical for reefs where corals flourish. These data are also useful because elevated salinities in a semi-enclosed region of water may reflect a relatively slow flushing time and, when compared to oceanic salinities, can enable salt-budget calculations to be used to estimate the rates at which water is flushed through the area during various times of the year.

Temperature

Water temperatures within the Dampier Archipelago range from about 18 to 31.5°C throughout the year, with minima in July and August and maxima in February and March. The near-shore waters have a greater seasonal temperature range than the offshore waters. Water temperatures can impact coral communities, which may show signs of stress, such as bleaching, during prolonged exposures to either low (<18°C) or high (>32°C) temperatures. The recorded temperature range indicates that corals in the archipelago survive within a temperature regime that is close to their natural tolerance levels. Human activities that result in above-normal changes to water temperatures may therefore cause corals to stress.

Water clarity

Water clarity is influenced by the level of suspended material which is in turn influenced by water movement and sediment type. Clear water contains low levels of suspended material while turbid water contains high levels of fine suspended material which can smother marine organisms and reduce light penetration to marine plants.

Most corals can tolerate deposition rates of less than about 50 g/m^2/day and these rates are rarely exceeded throughout the Dampier Archipelago during normal winter and summer conditions. However, a Department of Environmental Protection study indicates that elevated levels (>250 g/m^2/day), caused by turbidity plumes from an active dredge spoil dumpsite, coincided with significant localised coral deaths during the summer of 1982/83.

Suspended sediment concentrations in the water column are characteristically higher in the relatively shallow near-shore regions of the archipelago compared with deeper sites further offshore. Wind-driven waves are the main reason for sediment re-suspension within the near-shore waters, while offshore sediment re-suspension is mainly caused by ocean swells. Cyclone-induced wave action has been shown to cause relatively high rates of sediment re-suspension throughout the archipelago, with considerable damage to benthic communities and accumulations of calcareous rubble and sands in Mermaid Sound as a result.

Salinity-temperature differences and density currents

Because of heating, cooling and evaporative effects, there are significant salinity and temperature differences between the near-shore and mid-shelf regions throughout the year. The near-shore waters are warmer and saltier than the adjacent mid-shelf waters during summer, while in winter, the near-shore zone is significantly cooler than the offshore zone, even though the direction of the salinity differential remains the same. The lower inshore water temperatures throughout winter are caused by lower air temperatures and relatively cold offshore winds.

As a result of these seasonal salinity-temperature changes, the near-shore waters of the Dampier Archipelago are less dense than the offshore zone in summer but more dense than the offshore zone during winter. Consequently, near-shore and offshore waters show a tendency for two-layer exchange, driven by either the density difference or wind-stress acting at the water surface. Two-layer exchange can be visualised as a buoyant surface flow in one direction under-ridden by a dense bottom flow in the opposite direction. In summer, the near-shore zone of the archipelago is much warmer and therefore less dense than offshore waters, suggesting that it should propagate out as a surface flow. However, in winter the near-shore zone is much colder and therefore more dense than offshore waters, suggesting that it should propagate out as a bottom flow. This type of circulation is significant in semi-enclosed coastal basins elsewhere. However, the existence and influence of such current patterns within the archipelago is yet to be fully explored.

Density gradients within the archipelago could drive gentle cross-shelf circulation at strengths of up to 5 to 10 cm/s, which is equivalent to about 4 to 8 km per day. These speeds are comparable with tidally-driven currents during neap calm conditions and wind-driven currents during weak wind periods.

NATURAL HERITAGE VALUES

Marine habitat

Marine habitats are defined by physical environmental influences, substrate type and dominant marine biota. A comprehensive university study of the region during the 1980s highlighted its diverse physical characteristics and rich range of habitats. The ecological complexities were summarised by defining eight coastal geomorphologic units within the Dampier Archipelago and Table 1 serves to illustrate the complex relationships between these units and the habitat types and animal assemblages which occur there. However, while providing a useful description of coastal ecology, these categories provide a greater level of detail than is required for marine reserve planning.

The spatial variability in the physical and environmental characteristics within the study area is responsible for its high species diversity and abundance. Species counts include six species of seagrass, 193 species of seabirds, 37 species of algae, 229 species of hard coral, approximately 600 fish species, approximately 700 species of molluscs or shells, 126 species of crustaceans and 193 echinoderms (sea urchins, sea stars and their relatives). These records indicate that species numbers within the study area are higher than those in both the Ningaloo Marine Park to the south west and the Montebello and Barrow islands area to the north west. The species numbers within some of these animal groups are likely to be the highest from any area in Western Australia. In addition, it is likely that the numbers of recorded species will increase in most groups as more research is conducted.

Table 1. Seabed plant and animal assemblages and habitats of the Dampier Archipelago/Cape Preston region (adapted from a 1982 study by Semeniuk et al)

Assemblage	Geomorphic unit	Habitat	Tidal range	Biota
Oyster-barnacle	Intertidal rocky shore Intertidal limestone pavement	Cliffed shore Fissured pavement or slope Bouldery shore Limestone cliff Limestone pavement	Intertidal	Encrusting assemblage on hard substrate. Marked zonation of organisms at different heights with an algal slick covering the rocks at the top of intertidal zone, followed by bands of the milky oyster (*Saccostrea* sp.), coral rocky oyster (*S. cucculata*), barnacles (*Tetraclita porosa* & *Chthamalu* sp.), and at the lowest intertidal level are worm-like veritids and an algal turf. A wide range of bivalves, snails, chitons, crabs, polychaete worms, small crustaceans and some small fish are associated with the oysters and barnacles. On the outer islands, the ocean oyster (*Saccostrea commercialis*) replaces the milk and coral rock oysters that occur in Mermaid Sound.
Coral	Subtidal rocky shore Subtidal limestone pavement	Fissured pavement or slope Bouldery shore Limestone pavement	Subtidal to depths of 10 m	Encrusting assemblage on hard substrate. Corals are conspicuous and dominant, with other fauna such as seawhips, anemones, sea stars, sea urchins, sea cucumbers, other echinoderms, crustacean, reef fish, bivalves and gastropods. Sponges occur more abundantly when assemblage is on limestone. Coral reef is associated with almost all the islands in the region, however size, diversity and condition of the reef varies. *Acropora, Favia, Goniopora, Goniastrea, Lobophyllia, Millepora, Pocillopora, Porites, Tubastrea* and *Turbinaria* are some of the corals found in the region.
Mangal	Intertidal flat intertidal rocky shore	Muddy sand flat banks of tidal creeks edges of spits bouldery shore	Mid to high tidal	Mangals incorporate mangroves, shrubs and benthic fauna. Mangal is mainly found on the intertidal flats of embayments. They vary from wide tidal formations (Searipple Passage, King Bay) to a narrow fringing formation. There is an obvious zonation that is the product of various tidal regimes. *Avicennia marina* park and shrub land are formed at about mean sea level. Closed forests of *Rhizophora stylosa* or mixed *Rhizophora*, *Avicennia* and rarer *Bruguiera exaristata*, are usually in the interior sections. Shrublands of *Avicennia* and *Ceriops tagal* occur on the landward edge of the mangal (about high water spring level). In areas where the mangal is located on spits, *Bruguiera* occurs with *Ceriops* and *Avicennia*. Associated fauna include crustaceans (*Uca* spp., *Sesarma* spp., *Macrophthalmus*, shrimps, *Thalassina anomala*, *Epixanthus*, *Scylla serrata*); burrowing worms, gastropods (*Terebralia, Cerithidea, Telescopium, Littorina* and *Nerita*); encrusting organisms (barnacles, bivalves and limpets); gobioid fish and chitons.
Notocallista-echinoderm	Intertidal flat	Sand flat Muddy sand flat	Low tidal	This benthic assemblage is comprised almost entirely of infauna, which includes bivalves (*Notocallista, Anomalocardium, Circe, Fragum, Pinctata, Pinna, Placamen* and *Modiolus*), crustaceans, worms, branchiopods, burrowing anemones, and echinoderms. On the surface of the flats, gastropods (*Natica, Cerithium, Epitonium, Rhinoclavus, Cominella* and *Strombus*) occur. Algae, and Morula and Trochus shells may occur on scattered rocks or larger shells. The sediment is usually highly bioturbated and during inundation at high tide demersal fish feed on the benthos.

Assemblage	Geomorphic unit	Habitat	Tidal range	Biota
Demersal fish--echinoderm -crustacean	Subtidal plain	Muddy sand/gravel sheet	Subtidal tidal	This biotic assemblage inhabits substrates in 5-20 m depth in subtidal embayment plains such as Withnell Bay, King Bay and Mermaid Sound. It is comprised of demersal fish (e.g. flounder, flathead, rays, catfish and eels), echinoderms, polychaete worms, crustacean, bivalves and gastropods.
Donax-crustacean	Intertidal beach	Beach	Mid to low tidal	The *Donax*-crustacean assemblage inhabits exposed beaches in small embayments and tombolo. It supports an infaunal assemblage of mainly *Donax* bivalves and surface gastropods. Zonation occurs and is a function of tidal level. *Scopimera* and *Mictyris* crabs, polychaete worms, surface gastropods *Nassarius dorsata* and *Donax* are found in the mid to low tidal zone. The crab *Matuta* is found in the low tidal zone and *Callapa* crabs are found in the subtidal zone.
Uca-cerithid	Intertidal flat	Salt flat	High tidal	This assemblage includes the burrowing crabs *Uca* sp., *Mictyris* and *Sesarma*, and *Cerithium* gastropods. The salt flats may have a covering of blue-green algae and saltbush may occur on the higher parts of the flat.
Mictyris soldier crab	Intertidal flat	Shoal Sand flat	Low tidal	*Mictyris* soldier crab dominated low tidal sandflats and shoals. Bivalves, echinoderms, branchiopods and the sand bubbler crab *Scopimera* also occur, however to a lesser degree.
Uca-Macrophthalmus	Intertidal flat	Muddy sand flat	Low tidal	The crabs *Uca* spp. and *Macrophthalmus* dominate and to a lesser extent bivalves, echinoderms and worms occur.
Xanthid-sponge	Intertidal limestone pavement	Limestone pavement	Low tidal	This assemblage consists of several species of Xanthids (*Pilumnus, Atergatis*), sponges (encrusting to erect), tubeworms gobioid fish, bivalves (such as *Tridacna* and *Barbantia*), scattered coral and algae.
Ocypode	Intertidal beach	Beach Beach ridge	High tidal	This assemblage is found in the high tidal to supratidal zones of sandy beaches and spits. The ghost crab *Ocypode*, hermit crabs *Coenobita* and amphipods are included in the faunal composition of this assemblage.
Seagrass	Subtidal plain Intertidal flat	Sand/gravel sheet Sand flat	Subtidal Low tidal	Seagrass occurs in the larger bays and sheltered flats of the region. *Halophila ovalis, H. decipiens* and *H. spinulosa* seagrasses occur in sparse density throughout this assemblage with green algae occurring in some shallow areas during winter. Sea urchins, sea cucumbers, molluscs, crabs and demersal fish are locally abundant. Seagrass assemblages are susceptible to changes in density due to seasonal changes in water quality (turbidity, light penetration) and conditions (wave action, temperature).
Algae	Subtidal shoal Subtidal plain Subtidal rocky shore Subtidal limestone pavement	Sand flat Sand/gravel sheet Bouldery shore Fissured pavement	Subtidal	Macroalgae occur on various substrates in the shallow waters of the region and coverage varies with seasonal physiochemical changes and cyclones. Where brown algae occurs, *Dictyopteris* is the most dominant. Articulate corallines are the dominant green algae. Molluscs, echinoderms, corals, crabs and fish also are found in the algal assemblage. Some of the bare limestone pavements are covered with crustose corallines and Jania sp turf. In sheltered embayments such as *Conzinc Bay, Sargasssum, Dictyopteris* and *Pandina* dominate with *Zonaria, Dictyota* and *Turbinaria* in less abundance.

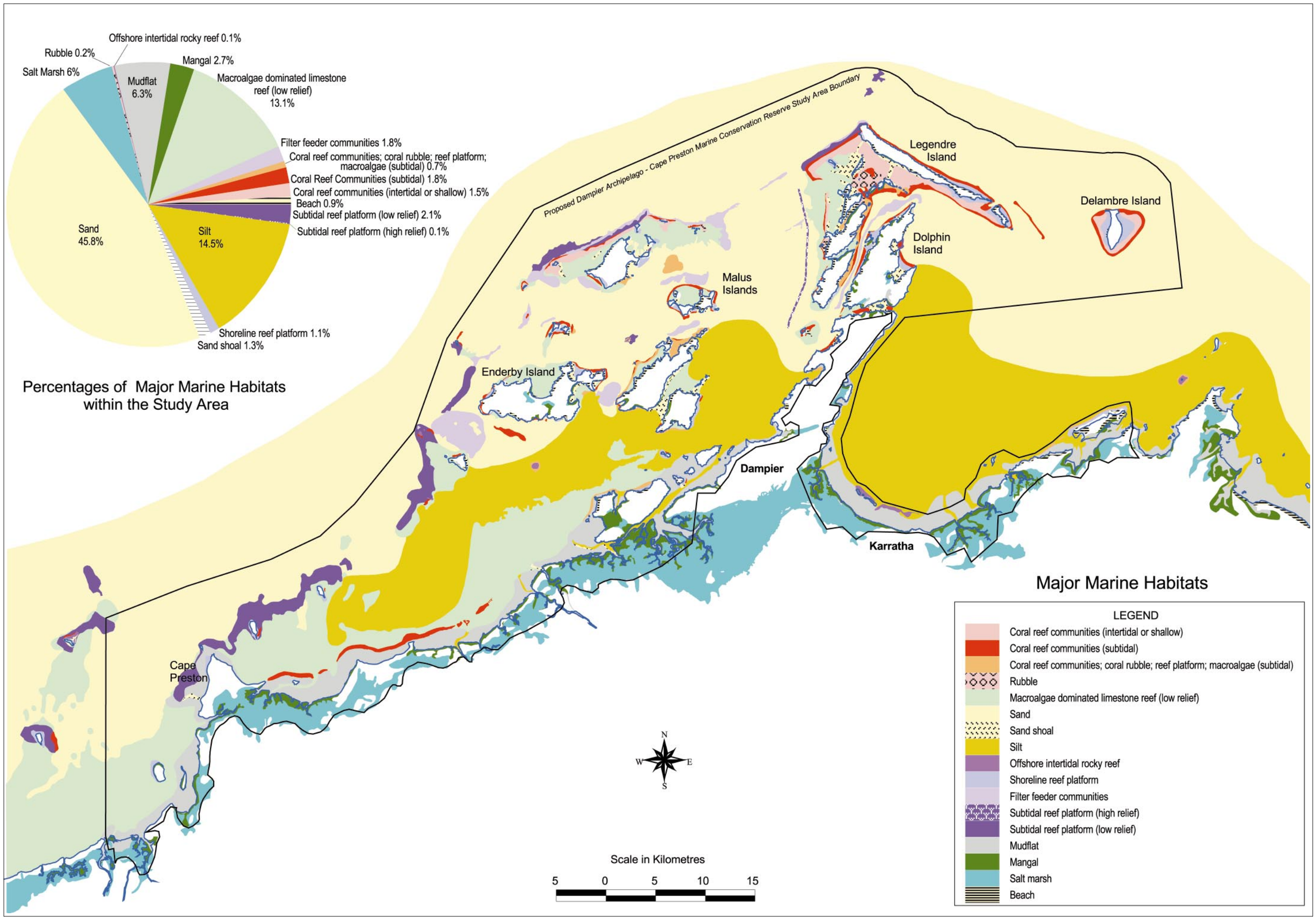

Figure 11. Major marine habitats within the Dampier Archipelago/Cape Preston study area.

While the exact numbers of species within the diverse marine communities have not been determined, there have been several studies to investigate the range and geographical locations of the habitats and assemblages in which they occur. These studies have used a combination of satellite imagery, aerial photography and in-the-field techniques. An amalgamation of data gathered using these techniques has facilitated the development of broad scale habitat maps of the study area (Figure 11). This map provides a useful tool for planning a new marine conservation reserve. However, not every square metre of sea-bed has been surveyed and the separation between habitat types is not always as distinct as the lines on a map would indicate. Also, the distribution of habitat types may vary from time to time. For example, subtidal sand sheets are often mobile and can cover, and later uncover reef platforms.

For the purpose of marine reserve planning, five groups of marine habitats have been defined according to physical environmental influences, substrate type and dominant marine biota. These are:

- rocky shores, shoreline reef platforms and offshore intertidal reefs;
- intertidal mud/sand shoals and beaches;
- mangrove and salt-marsh communities;
- coral communities; and
- subtidal sand/silt/rubble and limestone pavement with macroalgae and seagrass.

Rocky shores, shoreline reef platforms and offshore intertidal reefs

Rocky shores are a dominant feature within the study area covering 42.7 per cent of the island shorelines. The rocky shores vary according to rock type and aspect. The ancient igneous rocks form rubble, boulder or cliff shores (Figure 4). Igneous rubble and boulder shores occur predominantly on the inshore islands. They are either steep or moderately inclined.

The sedimentary limestone rocky shores consist of cliffs, which often have intertidal platforms associated with them. The cliffs are formed by a combination of wave attack, biological erosion, undercutting and rock falls. Marine erosion is also a major contributor in the development of widespread limestone pavements where the limestone has an internally honey-combed structure and the surface is degraded to an irregular or hummocked shape that is covered by a sand/gravel veneer.

Rocky shores are characterised by vertical zonation, with many of the plants and animals that live there restricted to a narrow horizontal band. The large tidal ranges within the study area result in pronounced horizontal zonation. At the top of the intertidal zone, an algal film covers the rocks. Below that is a narrow band of the milky oyster (*Saccostrea* sp.). The coral rocky oyster (*Saccostrea cucculata*) forms a broader band below the milky oyster. Barnacles (*Tetraclita*

Figure 12. Many of the rocky shores within the Dampier Archipelago/Cape Preston study area are associated with intertidal limestone platforms.

porosa and *Chthamalus* sp.) become more abundant below the oyster level. The worm-like vermitids form a zone at the lower level of the intertidal zone where algal turf forms a border. Associated with the oysters and barnacles are a wide range of molluscs such as bivalves, gastropods and chitons as well as crabs and other crustaceans, worms and small fish. Most of these species occur in crevices in the rock and oyster clumps. This zonated intertidal assemblage of marine organisms extends throughout the study area. However, on the outer islands of the archipelago the milk and coral rock oysters are replaced by the ocean oyster (*Saccostrea commercialis*).

The limestone platforms (Figure 12) are inundated for most of the time and during low tide, many of the organisms are protected from desiccation in shallow pools. A wide range of bivalve shells, snails, crabs, worms, and some small fish is found on intertidal limestone platforms and at high tide, larger fish and other marine animals from deeper water come in to feed. In areas of moderate to high wave action, the platforms are covered with an algal turf and are rich with invertebrate life. On some of the more exposed platforms, corals grow on the outer edges. In areas of low wave action, the platforms have less algal turf and are often covered by a layer of sand or mud. The amount and type of sediment present influences the distribution and diversity of species which inhabit the limestone platforms.

Offshore intertidal rocky reefs within the study area also vary according to the rock type. The igneous rocky reefs consist of piles of boulders while the limestone structures have smoother surfaces. Corals, algae and a high diversity of invertebrates characterise these habitats.

The abundance of invertebrate life on rocky shores, intertidal limestone platforms and offshore rocky reefs provides a valuable food source for shore birds. Their use of these habitats remains largely undisturbed, but during peak holiday periods, human visitation has the potential to alienate shore birds from some of the areas which are important for feeding. These habitats are also under pressure from collectors of shells and other organisms, particularly during peak holiday periods on easily accessible shores. In addition, rocky shores are vulnerable to pollution from floating debris and contaminants, and strand-line litter poses a threat to wildlife, which can become entangled.

Intertidal mud/sand shoals and beaches

The sediment size and organic content of beaches varies throughout the study area. It is the sediment size, organic content and the amount of tidal inundation, which determines the distribution of organisms, which live both on the sediment surface and buried within the sediment.

Although most of the island shores within the study area are rocky, sandy beaches extend along 17.3 per cent of their shoreline length (Figure 13). Most of the more exposed beaches are characterised by

Figure 13. Sandy beaches extend along 17.3 per cent of the islands shorelines.

sand with a relatively low organic content. The upper reaches of some of these beaches and the adjoining sand dunes provide nesting sites for sea turtles and wedge tailed shearwaters. In the upper intertidal zone, burrowing ghost crabs (*Ocypode* sp.) are the most conspicuous invertebrates as they scurry over the beach surface and disappear down their burrows. While some invertebrate species live buried within the clean sands of exposed beaches, their diversity is low in comparison with more sheltered conditions.

Sheltered beaches are characterised by fine-grained sands with a high organic content and along sheltered areas of the mainland coast, extensive mudflats occur accounting for over 6.3 per cent of the study area. These areas are covered by a surface film of micro-organisms which provides a rich food source for marine snails, crabs and other organisms. These in turn are predated by larger fish and other organisms, which swim over the area at high tide. Many of the species that live in this habitat are buried in the substrate itself. These include bivalve shells, lampshells or brachiopods, worms, crabs and sea urchins. Because of the burrowing activities and abundance of organisms within the soft intertidal sediments, the sediment is regularly turned over. Many of the estimated 700 mollusc species recorded in the study area can be found in intertidal and shallow subtidal regions.

Sand and mud also occur as a veneer over intertidal limestone platforms in sheltered conditions. Again, a high diversity of organisms is associated with these habitats and species include both those that live on the surface and those that burrow into the substrate. As with the rocky shore habitat the abundance of invertebrate life in intertidal sand and mud substrates provides a valuable food source for shore birds.

The low percentage of sandy beaches, particularly along the mainland coast, results in local residents and tourists seeking recreational use of the island beaches. Currently, the level of human use of sand and mud beaches poses little threat to these habitats. However, uncontrolled shell collecting of volutes, cowries and food species such as oysters and clams, could decimate local populations if these activities are not properly managed. The volutes are considered to be particularly vulnerable because their larvae hatch direct from attached egg masses and do not have a pelagic dispersal stage. Turtle and bird nesting have the potential to attract wildlife tourists. While their rookeries are relatively undisturbed at present, once again this activity is vulnerable to any increase in unmanaged human visitation. Soft substrate shores, such as rocky shores, remain vulnerable to pollution from floating debris and contaminants, and strand-line litter poses a threat to wildlife, which can become entangled.

Figure 14. Exposed mangrove roots provide a substrate for many intertidal invertebrates such as oysters.

Mangrove and salt-marsh communities

Mangroves are a diverse group of largely tropical trees, adapted for life between the tides on sheltered shores, estuaries and tidal creeks. They possess specially-adapted roots for survival in mud, which is inundated by salt water and depleted of oxygen. To cope with low oxygen levels in the mud, the roots of most mangrove species extend above the mud surface (Figure 14). Mangroves need soft substratum in which to anchor their roots.

Six species of mangrove are found in the Dampier Archipelago/Cape Preston region with the two most prevalent being the white mangrove (*Avicennia marina*) and the red mangrove (*Rhizophora stylosa*). The other species present are the club mangrove (*Aegialitis annulata*), the ribbed-fruit orange mangrove (*Bruguiera exaristrata*), the yellow-leaf spurred mangrove (*Ceriops tagal*), and the river mangrove (*Aegiceras cornculatum*). The only Pilbara mangrove species that does not occur in the study area is *Osbornia octodonta*.

Mangroves mostly inhabit intertidal flats in

Figure 15. Six species of mangrove are found in the Dampier Archipelago/Cape Preston.

embayments between mean sea level and high water, though in some locations they occur on steep rocky shores in embayments. In areas exposed to waves, mangrove communities become progressively narrower (one or two trees wide) and finally absent. The most luxuriant mangrove communities occur where a combination of low-energy conditions and sedimentation provide a gently sloping tidal flat. There are extensive mangrove communities within the Dampier Archipelago/Cape Preston region accounting for 2.7 per cent of the study area. Most of these communities are along the mainland coast on the tidal flats at Regnard Bay, the Maitland River mouth, King Bay and Nickol Bay. Over 50 per cent of the mainland shoreline supports mangrove communities. Well-developed communities also occur in some of the sheltered bays on the islands, for example at West Intercourse Island, in Searipple Passage and the southern shores of West Lewis and East Lewis islands. A tidal creek on the southern side of Enderby Island has both well-developed mangroves and clear water. This unusual combination of attributes makes this a valuable and attractive site.

Well-developed mangrove communities display an obvious zonation in response to tide levels salinity and substrate types. In areas where there are spits, *Bruguiera exaristata* occurs with *Ceriops tagal* and *Avicennia marina*. Along shorelines, *Avicennia marina* forms open shrublands at about mean sea level. Interior parts of the mangroves are closed forests of *Rhizophora stylosa* or mixed *Rhizophora*, *Avicennia* and rarer *Bruguiera exaristata*. At the inshore zone of the mangal, at about high-water spring tide level, shrublands of *Avecinnia* with *Ceriops tagal* occur. Salt-marsh communities occur at the landward margin of mangrove communities. They are intertidal plant communities dominated by herbs and low shrubs. The blue-green algal species, *Microcoleus* sp. and *Phormidium* sp. occasionally form mats over salt flats on the landward side of mangroves. Extensive areas of the mainland coast within the study area are characterised by salt-marsh communities and these together with small areas on Enderby Island account for six per cent of the study area.

Mangrove leaves are an important energy source for mangrove ecosystems. When the leaves fall onto the mud below, they become available as a food source for microscopic organisms. These in turn provide a rich source of food for a variety of animals which either feed directly on the decomposing leaves, the microbes or on each other. These animals include snails, worms, crabs, shrimps, fish and birds. A substantial proportion of the fauna are burrowing species and their activities help to oxygenate the muddy substrate. However, the most prominent species occur on the surface and include the large conical snails (*Telescopium telescopium*), gobioid fish or mud skippers and, attached to the tree trunks and exposed roots, oysters of the genus *Saccostrea* and a variety of barnacles.

Mangrove communities provide important nursery areas for juvenile fish and they are also vitally important as prawn nursery areas. In addition, the mangals within the study area are of biogeographic significance as a centre of fiddler crab diversity.

Mangrove communities are affected by natural events such as cyclones and coastal erosion. Of greater concern from a management point of view however, is their vulnerability to human induced change. Some of the mangrove communities within the study area are easily accessible and are favoured locations for fishing and collecting. With the prospect of a significant increase in the residential population in adjacent towns during the next few years, collection and fishing quotas will need to be monitored carefully.

Mangroves are also vulnerable to pollutants, in particular oil, which kills the trees by smothering the aerial roots. Debris, such as plastic bags and ropes may also become entangled among the complex root systems and branches and cause a hazard to wildlife.

Mangroves can be alienated from large areas of suitable substrate if tidal flow rates and directions are altered. This sometimes occurs naturally, but large-scale alienation can also occur as a result of industrial and public works development programs. Smelly, mosquito-ridden mangrove communities have often been undervalued in the past and clearing and reclamation of mangroves is still occurring at an alarming rate overseas. In Australia, there is now a better understanding of the benefits associated with the protection of mangrove communities. These include the availability of nursery areas and habitats for commercial fish, increased inshore productivity, sediment trapping and protection from coastal erosion. Their benefits need to be considered carefully when planning any development that could have a negative impact on mangrove communities.

Coral communities

Vigorous coral growth is dependent on a mutually beneficial, or symbiotic, partnership between single celled plants called zooxanthellae and the coral animals or polyps. The microscopic plants are embedded within the animal tissue where they supply up to 98 per cent of the coral's carbohydrate requirements. The zooxanthellae also take up much of the coral animal's waste products and assist in creating the coral skeleton. Because the plant cells need sunlight, coral reefs grow best in clear shallow waters. They are also limited by temperature, optimum growth occurring between 25° to 29°C and at normal ocean salinity.

Reef-building species are found along the whole coast of Western Australia, but species diversity decreases progressively from north to south. They are conspicuous and dominant in tropical communities where they also provide food, substrate and shelter for prolific and varied marine life including sea stars, sea urchins, crustaceans, bivalve and snail shells, worms and of course fish. Many of the 420 recorded sponge specimens within the study area are found to be most abundant in coral reef and rocky reef habitats.

Coral reef communities occur over four per cent of the study area and records indicate that at least 229 hard coral species occur in the Dampier Archipelago/Cape Preston region. This high diversity of coral species is a reflection of the variety of substrates and oceanographic conditions. Variations in wave exposure, sediment deposition, water clarity, aspect, topography, slope and current all influence the distribution of individual species and the structure of coral communities. Within the study area there is a wide range of conditions from the exposed reefs with high wave action, clear water and low sediment deposition rates, on the seaward coasts of the outer islands, to the sheltered areas with high sediment deposition rates and turbid waters further inshore for example at Withnell Bay. Some coral species, for example *Pavona minuta* and Pocillopora eydouxi, occur only on seaward exposed reefs, *Montipora eurythraea* occurs only in lagoons, some Fungiidae species occur only on sand substrates and some *Caulastrea*, *Ducanopsammia*, *Euphyllia*, *Moseleya* and *Trachyphyllia* species occur only in turbid inshore habitats. The richest coral areas are found on the seaward slopes of Delambre Island, Hamersley Shoal, Sailfish Reef, Kendrew Island and north-west Enderby Island. Live coral cover can also vary greatly from reef to reef, as indicated by contrasting covers of 60 and 10 per cent on Hamersley Shoal and Sailfish Reef, respectively.

Corals of the Dampier Archipelago/Cape Preston region survive within natural temperature regimes that are close to their tolerance levels. Any further elevation in water temperatures related either to

natural fluctuations or greenhouse emissions could cause coral bleaching and death. Any large-scale discharges of industrial cooling water may also have localised affects on coral health.

Coral communities have evolved to compensate and recover from natural disturbances over time. As a result, coral communities may show temporal variation in structure and species composition. Fast growing *Acropora* species can recover from severe damage in a few years while slow growing massive species may take up to 30 years to recover from major damage.

Storms and other natural events periodically affect the coral communities within the study area. Severe storms and cyclones sometimes cause significant coral breakage and damage resulting from suspended sediments. Other causes of mass coral mortality include bleaching and oxygen depletion of the sea-water.

Bleaching occurs when corals become stressed by extreme conditions such as high temperatures and levels of light. When this occurs, they expel the zooxanthellae from their tissues leaving only the colourless animal tissue and the white skeleton beneath. Corals do not always recover from bleaching events and there is some concern that the frequency and magnitude of bleaching events will increase in association with global warming of oceans.

Sea-water can become depleted of oxygen when the corals undergo mass spawning in March and April. Large quantities of spawn released into the water column have a high oxygen requirement so if water currents do not disperse the spawn, or calm weather prevents mixing of the surface layers, the spawn can reduce the level of dissolved oxygen below that required to sustain marine life. When this occurs, it is not only the corals that perish, but also the multitude of snails, worms, starfish, fish and all the other organisms that live on the reef.

The study area is within the natural ranges of both the crown-of-thorns starfish (*Acanthaster planci*) and the coral eating snail (*Drupella cornus*). When in large numbers, these species can significantly alter coral communities. The living tissue of hard corals is located on the surface of the hard skeletal material and the coral eating starfish and snail remove this surface layer, leaving the white skeleton largely undamaged. The skeletons then become colonised by algae. An apparent increase in the number of *A. planci* was noticed by

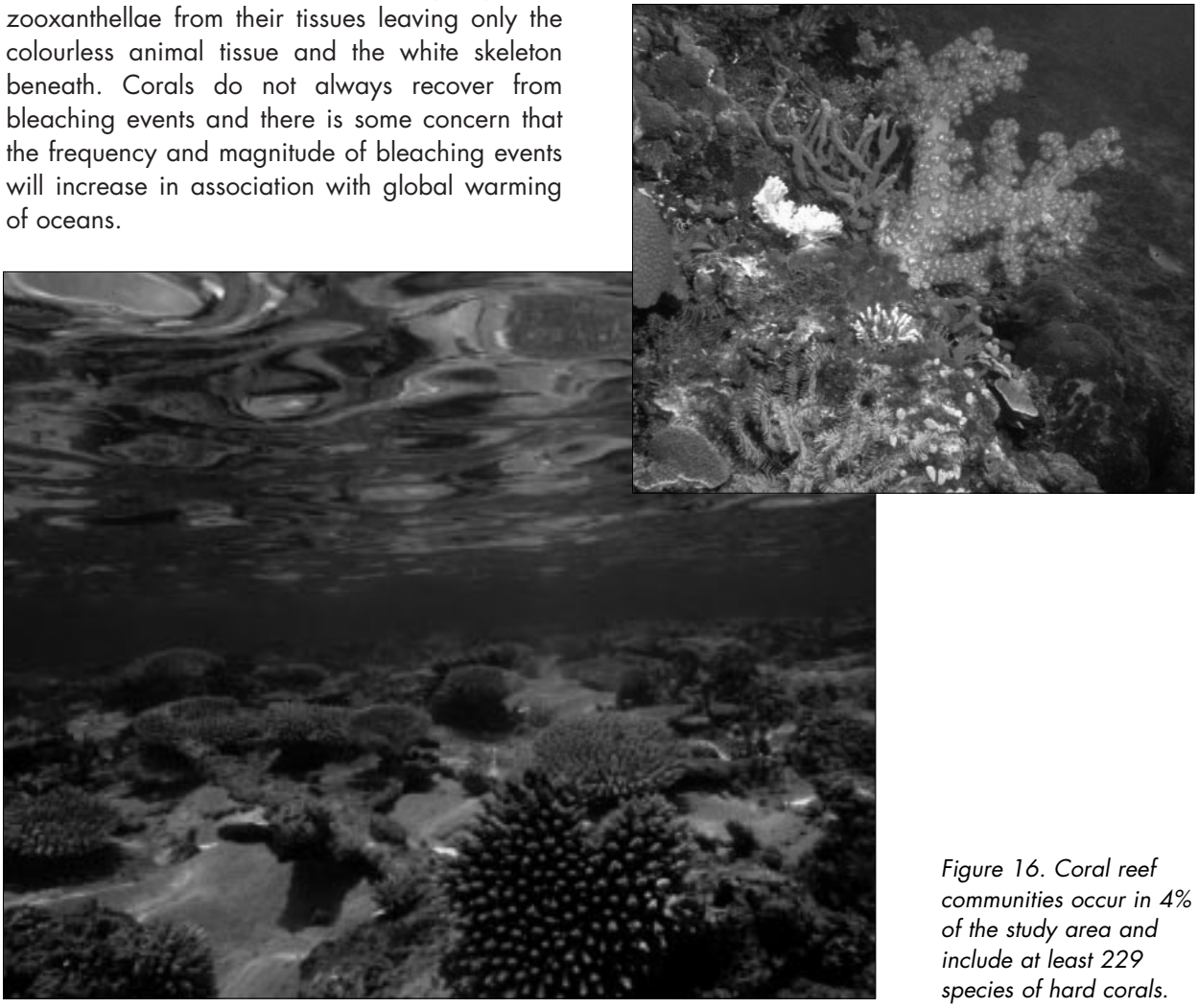

Figure 16. Coral reef communities occur in 4% of the study area and include at least 229 species of hard corals.

researchers on the western side of the Dampier Archipelago in 1983, but significant population densities have not been recorded elsewhere in the study area.

At present, the coral communities within the study area are mainly in good condition, with only limited human disturbance. The coral reefs of the region provide food and protection for an abundance of fish, which are enjoyed by recreational line and spear fishers as well as by divers wishing to observe and appreciate the seascape. However, the potential increase in the size of coastal towns in the area could result in increasing pressure on reef habitats, for example from over fishing and anchor damage, and there is a need both to monitor coral reef health and to educate users to minimise their impact. Within the central Indo-Pacific region, some estimates indicate that up to 70 per cent of all coral reefs have experienced some human induced degradation, so there is a responsibility on Australia to ensure the conservation and good management of its coral reefs.

Subtidal sand/silt/rubble and limestone pavement with macroalgae and seagrass

The islands and shoals of the Dampier Archipelago and Cape Preston region rise above submarine plains. These plains are gently sloping from 5 m deep near the mainland coast to 15 to 20 m deep at the northern margin. The sea floor is characterised by extensive limestone pavements and large sheets of shell gravel, sand and muddy sand/gravel. The sediments that cover the submerged plains are generally of coarser-grained sand and grit in offshore areas while the inshore substrates are characterised by fine-grained silts and mud. The locations and thicknesses of sand sheets and banks vary with time because these mobile sediments are shifted during storm events. The subtidal habitats are also subject to seasonal changes associated with algal cycles of growth and senescence.

This group of subtidal habitats covers the majority of the study area which is 45.8 per cent subtidal sand, 14.5 per cent subtidal silt and 13.1 per cent macroalgal dominated limestone reef. Other habitats within this group include subtidal rocky reef platforms, sand shoals, rubble and filter feeding communities which cover 2.2, 1.3, 0.2 and 1.8 per cent of the study area respectively.

At first glance, some of the subtidal areas of sand and fine rubble look bare. However, a closer look reveals a multitude of burrows built by species that live within the sediment. Some of these burrows, for example those belonging to worms, are quite small, while the predatory mantis shrimp makes significant burrows with adjacent mounds up to 15 cm high. In addition, fish such as flathead, rays and flounder, together with echinoderms, crustaceans, bivalve molluscs and gastropods or sea snails occur on or above the substrate surface.

Large species of algae, or macroalgae dominate the submerged limestone reef habitat and they also grow on stable rubble and boulder surfaces. Macroalgae are important primary producers which means that they capture the energy from sunlight so it is available for other organisms in the natural community. Algae are simple plants that require light to grow and occur at a variety of densities from sparse mainly bare substrate, to dense algal beds.

Brown algae are the most abundant of the major algal groups in the Dampier Archipelago/Cape Preston region, with *Sargassum* sp., *Dictyopteris* sp. and *Padina* sp. being the dominant species. Less prominent brown algal species include *Dictyota* sp., *Zonaria* sp. and Turbinaria sp. Green algae are also present in the region, dominated by the articulate coralline, *Halimeda* sp. The prominent red algal species, include crustose corallines, non-corallines and algal turf (*Jania* sp.).

At some sites, strong tidal currents provide good conditions for filter feeding animals including sponges, coral colonies, sea whips and sea squirts or ascidians. Colonies of filter feeding animals occur interspersed with marine plants but in places the algae are so sparse that the animal filter feeders form the dominant component of the biota. Both the plant and sedentary animal components of the subtidal communities provide an important habitat for bivalve shells, snails, sea urchins, sea stars, crabs and fish. Algal beds also provide important nursery grounds for juvenile fish.

Seagrasses are present on the subtidal soft sediment habitats. Seagrasses are far more advanced plants than algae with a vascular system, flowers and seeds. They do not form extensive meadows within the study area, but occur interspersed among the macroalgae. Six species of seagrass have been recorded in the

study area; *Cymodocea angustata*, *Halophila ovalis*, *Halophila spinulosa*, *Halodule uninervis*, *Thalasssia hemprichii* and *Syringodium isoetifolium*. Seagrasses provide an important food source for turtles and dugong. There are significant seagrass patches between Keast and Legendre islands and between West Intercourse Island and Cape Preston.

The balance between algal and seagrass species has been affected by elevated nutrient levels elsewhere in Australia. Nutrient rich discharges from agriculture, industry and domestic waste can result in excessive algal growth, which then smothers and kills the seagrass leaves. While this is not currently an issue within the study area, aquaculture developments requiring the application of additional nutrients would need to be carefully considered to prevent seagrass degradation. Seagrass and algal beds are also vulnerable to damage from inappropriate mooring designs and careless anchoring. Again, management of these activities would need to be considered if visitation levels increased significantly.

Marine wildlife

Although marine wildlife is dominated by the multitude of molluscs, crustaceans, corals, worms, echinoderms and other invertebrate groups, public attention often focuses on the larger, vertebrate species such as whales, seabirds, turtles and fish. While it is these larger marine species which attract our attention, their conservation and secure future depends on maintaining the health of the whole marine environment including the diverse invertebrate fauna which often goes unnoticed.

Many marine vertebrates migrate vast distances, and some species suffer an insecure population status because of loss of habitat or over-exploitation. Other species support valuable fishing or tourism industries.

Marine mammals

Whales and dolphins

Whales and dolphins, or cetaceans, are some of the most charismatic of all marine wildlife. Like all mammals, they are warm-blooded, breath air and suckle their young. They live permanently at sea, and their streamlined shape, thick layer of insulating fat, efficient swimming and prolonged diving capabilities make them effective ocean-going animals. Cetaceans are also highly social animals that interact with one another and at times with humans.

There are two main types of cetaceans. Toothed whales have teeth and feed on squid, fish and in some cases, on other marine mammals. Baleen whales feed by filtering large volumes of water for planktonic organisms through modified hairs that form sieve plates around the mouth.

There are about 76 species of whales and dolphins in the world's oceans, and 36 are known to visit Western Australian tropical and sub-tropical waters. Of these, eight species of toothed whale including five dolphin species, and four species of baleen whale have been recorded within the Dampier Archipelago/Cape Preston study area (Table 2). However, it is likely that most of the 36 Indian Ocean species occasionally visit the study area.

Despite the exploitation of toothed whales elsewhere in the world, there are limited concerns

Table 2. Whale and dolphin species which have been recorded within the Dampier Archipelago/Cape Preston study area

Whale group	Common name	Scientific name
Baleen whales (suborder Mysticeti)	Minke whale	*Balaenoptera acutostrata*
	Bryde's whale	*Balaenoptera edeni*
	Blue whale	*Balaenoptera musculus*
	Humpback whale	*Megaptera novaeangeliae*
Toothed Whales (suborder Odontoceti)	Killer whale	*Orcinus orca*
	False killer whale	*Pseudorca crassidens*
	Common dolphin	*Delphinus delphis*
	Striped dolphin	*Stenella coeruleoalba*
	Bottlenose dolphin	*Tersiops truncatus*
	Indo-Pacific humpback dolphin	*Sousa chinensis*
	Southern bottlenose whale	*Hyperoodon planifrons*
	Risso's dolphin	*Grampus griseus*

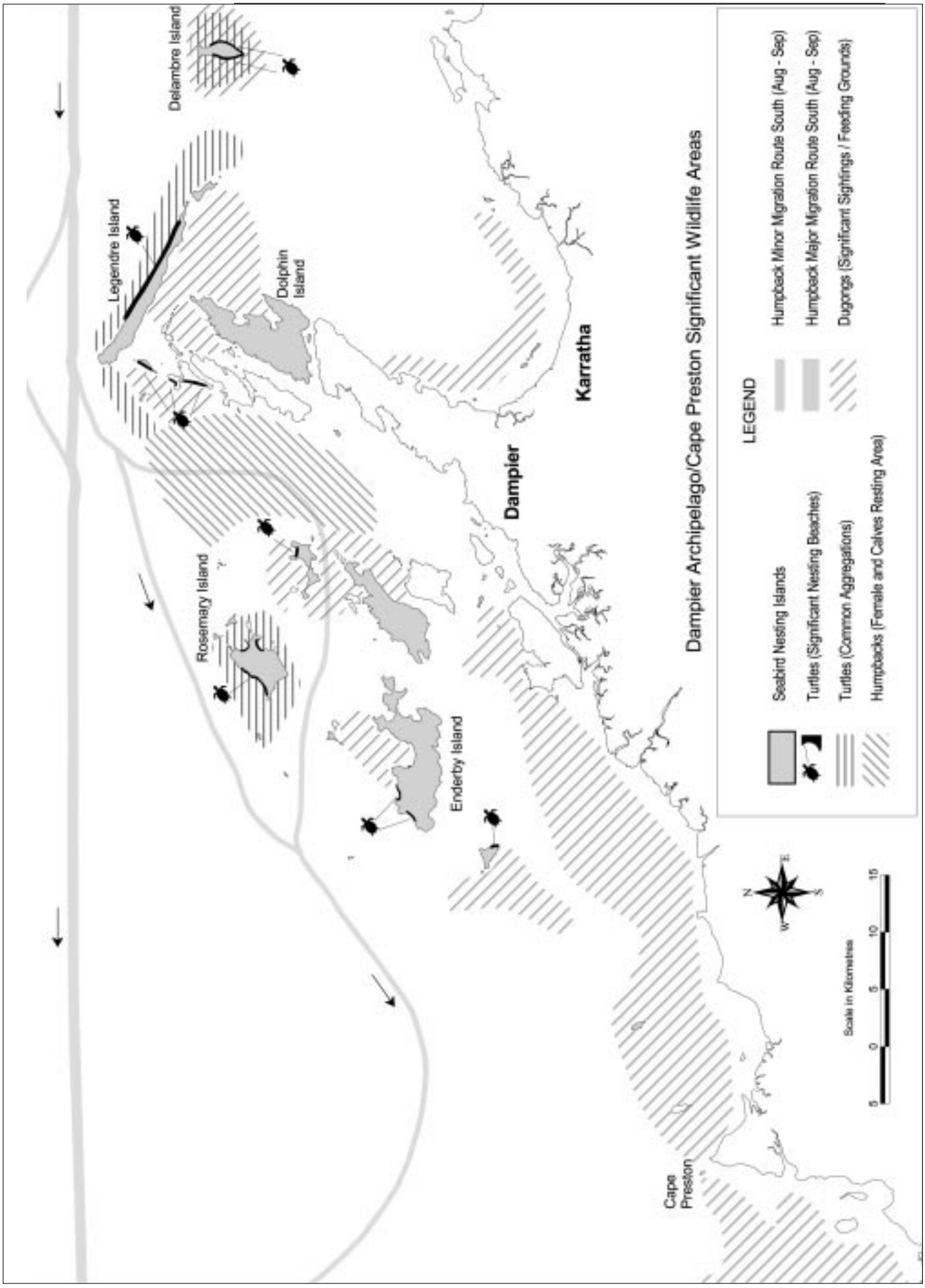

Figure 17. Significant wildlife areas in the Dampier Archipelago/Cape Preston region.

regarding their conservation status in Western Australia. Male killer whales grow to lengths of 9.5 m. Members of this species are known as wolves of the sea because they often hunt together in a coordinated, cooperative way for fish, sea birds, seals and sea lions and other cetaceans, even species much larger than themselves. Killer whales can be trained in captivity but stories of toothed whales befriending people usually concern bottlenose dolphins. This species grows up to 3.9 m and eats a variety of fish and invertebrates. Many people feel an affinity with dolphins and resident populations of bottlenose dolphins support tourism at Shark Bay and other locations along the Western Australian coast, where animals regularly come to the shore or visit boats to interact with humans.

Populations of large whales generally migrate south in summer and north, towards the tropics in winter. This behaviour is driven by the availability of abundant food in the polar seas during the summer months and by the warm, calm tropical waters in winter. The Bryde's whale however, is limited to temperate and subtropical oceans where animals hunt coastal fish. Similarly, although minke whales are more prevalent at high latitudes in summer, some animals are found across their range throughout the year. Humpback whales follow a distinct migratory pathway. During the summer months, they feed in the nutrient-rich waters of Antarctica. They then migrate north to the warm tropical waters off the Pilbara and Kimberley coasts in June and July to give birth and suckle their young. In September, they move south again and mate before returning to their feeding grounds in Antarctica for the summer months. Female humpbacks occasionally give birth within the study area, though the main calving area is further north east, off the Kimberley coast. Adult humpback whales and their young frequent the archipelago on their migration back to their southern feeding grounds in early spring and Mermaid Sound is a significant resting area for females with their calves (Figure 17).

Humpback whales were once the mainstay of the Western Australian whaling industry. Whalers were active in the Dampier Archipelago between 1870 and 1872, with an associated oil processing facility on Malus Island. Continued whaling in the Antarctic feeding grounds has pushed humpback populations to the brink of extinction, and a moratorium on hunting humpback whales currently exists. Humpbacks have special protection under the Western Australian *Wildlife Conservation Act 1950*, where they are described as "*rare or likely to become extinct*". They are listed as "*endangered*" under the *Commonwealth Endangered Species Protection Act 1992*.

Humpback whales are popular among whale watchers for their spectacular behavioural

Figure 18. Individual humpback whales can be identified as they migrate along the Western Australian coast by the colouration on the under surface of their tails. Photo courtesy Mike Osmond.

displays such as pectoral fin slaps, tail slaps and 'breaching', when they leap out of the water. Cetaceans are sometimes disturbed by boating and swimming. In order to protect them from unwanted human company, there are regulations under the Wildlife Conservation Act, which specify appropriate interactions.

Dugong

The other group of marine mammals found in the study area is the Sirenia, represented by one species, the dugong (*Dugong dugon*). Dugong are herbivores which depend primarily on seagrass. They may live for 70 years or more but females do not calve until at least their tenth year. They then produce young every three to seven years after a gestation period of about 13 months. A fully-grown adult dugong weighs around 400 kg and reaches a length of 2 to 3 m.

Dugong occur throughout the tropical and subtropical Indo-West Pacific but they have been reduced to relict populations separated by large areas in which they are extinct, or close to extinction. Within the study area, dugong occur in the shallow, warm waters around the islands, although not in the comparatively large concentrations seen further south in Exmouth Gulf or Shark Bay.

Current knowledge on the size, distribution and migratory habits of dugong populations within the study area is limited. However, dugong have been observed grazing in many of the shallow bays and in areas between the islands. Recreational fishers report regular sightings of dugong at East Lewis Island, Cape Preston, Regnard Bay and Nickol Bay. The shallows west of Keast Island are also known to provide important dugong habitat (Figure 17).

Dugong are vulnerable to injuries from boat propellers and there are large numbers of boats which operate within the study area. Aboriginal and Torres Strait Islander people are allowed to take dugong under the Wildlife Conservation Act. The number of dugong taken by indigenous people is not known.

The dugong is listed under "*other specially protected fauna*" in Schedule 4 of the Wildlife Conservation Act, and although not currently listed under Commonwealth legislation, it is listed internationally by the World Conservation Union (IUCN) as being "vulnerable". A dugong management plan for Western Australia is currently being prepared by CALM.

Birds

Marine birds are often subdivided into seabirds, and waders or shore birds. Ninety-three species of seabirds occur along the Western Australian coast and of these 41 species breed on offshore islands, thereby avoiding introduced ground predators common on the mainland. Many of the islands and rocks in the study area are known breeding grounds for a variety of seabirds and particularly the small islands and islets such as Goodwyn and Keast Islands, and Nelson Rocks provide important undisturbed nesting and refuge sites (Table 3 and Figure 17).

While many of the seabirds are resident in the area throughout the year, their distribution becomes more concentrated around the rookery sites during breeding. For many of the tern species, egg laying starts in mid-December, fledging occurs in March and after breeding the terns disperse. A significant population of wedge-tailed shearwaters breed in the region. In late August, shearwaters return to their burrows and laying occurs for two to three weeks in late October. In late December, the chicks start to hatch and by mid-April they are fledging. Adult wedge-tailed shearwaters are often observed swimming together in dense flocks called rafts.

Western Australia has 57 species of shorebirds of which 15 are resident and the remaining 42 are regular migrants. The vast expanses of arctic tundra are the breeding grounds of dozens of bird species collectively called migratory waders. During June and July, the breeding birds and their young thrive on a protein-rich diet of midge and mosquito larvae, but as the short northern summer draws to an end and the tundra freezes over, the birds are forced to fly south in search of food. Every year from August to October, several million birds wing their way more than 10,000 km from the Siberian icelands to the northern shores of Australia; thousands more journey on to the shallow lakes and estuaries of southern Australia. Many stay until the shortening days of autumn send them back to their breeding grounds in Russia.

Although bird surveys have not been conducted during the migration season, the extensive mudflats, mangroves and rocky intertidal habitats in the study area almost certainly

Table 3 Sea bird nesting sites within the Dampier Archipelago/Cape Preston study area

ISLAND	Australian pelican (*Pelecanus conspicillatus*)	Beach stone-curlew (*Esacus neglectus*)	Brahminy kite (*Haliastur indus*)	Bridled tern (*Sterna anaethetus*)	Caspian tern (*Sterna caspia*)	Crested tern (*Sterna bergii*)	Eastern reef egret (*Egretta sacra*)	Fairy tern (*Sterna nereis*)	Osprey (*Pandion haliaetus*)	Pied oystercatcher (*Haematopus longirostris*)	Roseate tern (*Sterna dougallii*)	Silver gull (*Larus novaehollandiae*)	Sooty oystercatcher (*Haemotopus fuliginosus*)	Striated heron (*Butorides striatus*)	Wedge-tailed shearwater (*Puffinus pacificus*)	White-bellied sea-eagle (*Haliaetus leucogaster*)
Angel Is									•							
Brigadier Is				•											•	•
Cohen Is	•				•		•	•				•	•		•	
Conzinc Is					•		•		•						•	
Delambrie Is									•							
Dolphin Is			•						•							•
Eaglehawk Is					•				•						•	•
East Goodwyn Is									•						•	
Egret Is						•		•								
Elphick Nob				•			•					•			•	•
Enderby Is		•			•		•		•	•						
Fortescue Is									•						•	
Goodwyn (Islet to SW)															•	
Goodwyn Is				•							•	•			•	
Hauy Is									•						•	
Haycock Is				•												
Keast Is	•				•				•			•				•
Kendrew Is				•								•			•	•
Lady Nora (Islet to W)									•							
Lady Nora Is				•	•				•			•			•	
Legendre Is									•							
Malus Is		•	•						•					•	•	•
Mawby Is					•							•				
Nelson Rocks				•		•					•					
North East Regnard Is															•	
Roly Rocks						•										
Rosemary Is				•	•		•		•			•				
Steamboat Is						•			•		•				•	
Walcott Is					•	•			•	•		•	•			
West Lewis Is		•	•						•							

provide important feeding and nesting grounds for waders after their journey from south east Asia.

Many other bird species, while technically neither seabirds nor waders, inhabit marine and coastal environments within the study area. The Australian pelican nests on Keast Island and small birds such as the mangrove robin, the mangrove golden whistler, the white-breasted whistler, the mangrove fantail, the dusky warbler and the mangrove kingfisher all rely on mangrove habitats for food and shelter.

Birds of prey also feed on marine resources and nest on the islands. Sea eagles make large stick nests on the ground and eat both terrestrial and marine prey. Animal remains at their nests within the study area indicate that they eat small mammals, birds, in particular shearwaters, and some fish. Ospreys also build their nests on the ground out of sticks and some are particularly

Figure 19. Many of the islands and rocks within the study area are known breeding grounds for a variety of birds.

large, up to 2 m high. Their diet is almost entirely of marine origin with a preference for fish. Brahminy kites build much smaller stick nests in mangrove trees within the study area.

Seabirds and other ground nesting marine and coastal birds are vulnerable to human disturbance at their rookery and roosting sites. Once the parent birds have been frightened away, the eggs and small chicks fall prey to predators or can be adversely affected by temperature extremes. Some chicks are left alone when they become larger so that both parent birds can forage to satisfy the voracious appetites of their young. These larger chicks are vulnerable to ground predators and the presence of feral ground predators can tip the balance and completely decimate bird rookeries. Both direct human access and potential feral introductions by visitors therefore require careful management if the valuable nesting sites within the study area are to remain sustainable.

Many seabirds feed by flying over and then diving into the water to catch fish. They have learnt that fish congregate under rafts of seaweed and other marine debris. However, oily residues look like rafts on the sea surface and feeding birds tend to dive into them. Oil also coats the surfaces of beaches and mangroves where shore birds feed and these species therefore are also impacted by oil spills. Oil spill contingency planning and the availability of spill combat equipment is essential to minimise the impacts of any spill on birds within the study area.

Many of the migratory marine and coastal bird species which occur within the study area are protected under joint agreements between Australia and the Japanese and Chinese governments.

Marine reptiles

Marine reptiles are well represented in Western Australian waters with 22 species of sea snake, six species of marine turtle and the saltwater crocodile.

Of the six species of marine turtle occurring in Western Australia, five are recorded in the study region: the green (*Chelonia mydas*), loggerhead (*Caretta caretta*), flatback (*Chelonia depressa*), leatherback (*Dermochelys coriacea*) and hawksbill turtles (*Eretmochelys imbricata*). The study area provides important habitat for marine turtles as Australia is one of the few countries in the world still to have relatively large turtle populations.

From August to March, female turtles come ashore to deposit up to 150 eggs in a hole in the sand that they dig with their flippers. The young hatch about seven to nine weeks later, depending on the temperature, and usually leave their sandy nests at night to avoid predation by birds, lizards and crabs. Once in the ocean, the young turtles are under threat from sharks, birds and other

Figure 20. The hawksbill turtle rookery on Rosemary Island is of international significance.

predators, and it is estimated that only five out of 100 reach the open ocean and less than one per clutch survives to breed.

Green turtles are found throughout tropical and subtropical waters but they are heavily exploited in some parts of the world for meat and other products. Large numbers nest within the study area, some migrating from as far away as the Northern Territory, Indonesia and the Gulf of Carpentaria. Green turtle adults are herbivores, feeding on seagrasses and algae while juveniles feed on jellyfish, shellfish, crabs and sponges. The green turtle has major nesting sites on the north-eastern shore of Legendre Island and the north-western beaches of Rosemary Island (Figure 17).

Loggerhead turtles are found in tropical and temperate waters worldwide and while their meat is not prized, they have suffered from significant disturbance to nesting beaches elsewhere. There is concern that their populations are declining in Australia possibly because animals are drowning in trawl nets. The number of nesting loggerheads within the study area is lower than that of green turtles. Loggerhead turtles migrate from their feeding grounds in the Northern Territory, Shark Bay, the Gulf of Carpenteria and Indonesia to breed within the study area. The Dampier Archipelago contains the northern-most known nesting beaches for loggerhead turtles in Western Australia.

Hawksbill turtles are found worldwide in tropical and warm temperate waters (Figure 20). The hawksbill has a beautiful carapace that is prized in some areas and globally this species has experienced significant population declines. The Western Australian population is the only large population of hawksbill turtles remaining in the entire Indian Ocean and research to date indicates that Rosemary Island is the main focus for nesting in this State. The hawksbill nesting beaches on Rosemary Island are therefore of great value not only at a State level but also internationally. None of the hawksbill turtles that have been tagged within the study area has been recaptured so there is little information about their migratory behaviours but it is believed that they migrate large distances from their rookeries within the study area, like the greens and loggerheads. The hawksbill turtle uses its beak to feed on sponges, seagrasses, algae, soft corals, shellfish and sea squirts.

The flatback turtle is not widely distributed and occurs mainly in the tropical waters of northern Australia with low numbers recorded in Indonesia and Papua New Guinea. The flatback breeds only in Australia and flatbacks which were tagged within the study area, have been recovered from the Northern Territory, the Kimberley coast and Exmouth. They inhabit the soft bottom sea-beds of sand and mud and feed on soft corals, jellyfish, sea cucumbers and sea pens. Rosemary, Delambre and Malus Islands are significant flatback turtle nesting sites (Figure 17).

Leatherback turtles are the largest species of marine turtle. They grow to a length of 1.6 m and weigh up to 500 kg. Only a small proportion of the world's leatherback population is observed in Australia, and there have been few sightings recorded within the study area. The study area is not used as a rookery by this species, which migrates mainly to the east coast of Malaysia and Indonesia to breed. Leatherback turtles are heavily exploited mainly by taking eggs from rookery beaches.

Nesting turtles can be disturbed by people wishing to observe their nesting behaviours. While visitation levels are currently low, any significant increase in tourism within the study area would need careful management. A code of practice has been adopted to minimise disturbance at some of Western Australia's other turtle rookeries and a State marine turtle management plan is currently being prepared by CALM.

Hatchlings are attracted to lights, particularly in the blue range of the spectrum. This can cause them to perish in areas where electric lights, on land or offshore facilities, lure them off-course so that they fail to reach the open ocean. The impacts of any development with lighting therefore need to be given careful consideration. Aboriginal people have traditionally hunted turtles.

The threatened conservation status of sea turtles has been recognised in wildlife legislation. All four species which nest within the study area are included in a National Action Plan prepared by the Commonwealth and State governments. Green, leatherback and hawksbill turtles are listed as "*vulnerable*" under the Commonwealth Endangered Species Protection Act and the loggerhead is listed as "*endangered*" also under the Act. Under Western Australian legislation, green and hawksbill turtles currently have no special status but are listed among the priority species that are kept under review. Both species have been recommended for inclusion on the 'threatened' list. However, the loggerhead and the leatherback turtles are listed as "*fauna that is rare or is likely to become extinct*" under Schedule 1 of the *Wildlife Conservation (Specially Protected Fauna) Notice 1999* under the Western Australian Wildlife Conservation Act. The flatback turtle is not listed under either Commonwealth or State legislation.

Of the 22 Western Australian species of sea snakes, at least 11 are believed to occur within the study area. The longest is the bar-bellied snake (*Hydrophis elegans*) which grows up to 2 m long. Despite the large size and deadly venom of many sea snake species, they are generally placid animals and do not pose a serious threat to swimmers and divers.

Saltwater crocodiles (*Crocodylus porosus*) were historically found in the archipelago and were commercially harvested from around 1945 until 1971. During that time, they were hunted to extinction between Onslow and Broome, but their populations have since started to recover. Recently, saltwater crocodiles have been recorded as far south as Exmouth Gulf and they are occasionally observed swimming great distances out to sea. Saltwater crocodiles require freshwater rivers and lagoons in which to breed, so although there have been a few saltwater crocodile sightings within the study area, it is outside their breeding range.

The saltwater crocodile is afforded special protection as "*other specially protected fauna*" under 1992 amendments to Schedule 4 of the Wildlife Conservation Act.

Fish

Approximately 600 fish species have been recorded in the Dampier Archipelago/Cape Preston region. None of these is endemic (locally unique) to the region and all can be found in adjacent waters. The fish fauna of the study area is part of a tropical inshore fauna that stretches from Shark Bay to Queensland. It has a prominent component of coral reef species and many species that inhabit mangroves.

The fish fauna supports both recreational and commercial fishing within the study area. Recreational line and spear fishers target reef fish such as coral trout (*Plectropomus* sp.), tusk fish (*Choerodon* sp.) and rock cod (*Cephalopholis* sp.). Game fishing is another popular recreational pursuit, concentrating on deepwater pelagic species such as marlin (*Makaira* sp.), sailfish (*Istiophorus* sp.), Spanish mackerel (*Scomberomorus* sp.), golden trevally (*Gnathanodon* sp.) and turrum (*Caranx* sp.).

The diverse fish fauna also helps to support a recreational diving industry by providing participants with close encounters with some

colourful and large animals. The manta ray (*Manta birostris*) and potato cod (*Epinephelus tukula*) inhabit the study area.

Fish stocks are managed by Fisheries Western Australia through a wide range of management tools, including, size and bag limits, gear restrictions, licences and closed seasons. Five species of fish are totally protected under Western Australian fisheries legislation and two of these occur within the study area. The potato cod (*Epinephelus tukula*) grows up to 1.4 m long and is often inquisitive, approaching recreational divers. Another fully protected fish is the whale shark (*Rhincodon typus*) which is the largest fish in the world. A whale shark has been recorded off Cape Preston but large seasonal aggregations do not occur within the study area as they do at Ningaloo where they support a flourishing tourist industry.

Coastal Terrestrial Biota

The terrestrial habitats of the shorelines and islands of the Dampier Archipelago/Cape Preston region provide important breeding sites for turtles and seabirds and also support many terrestrial organisms and reptiles. Biogeographical studies have found more than 288 plant species from 60 families to occur in the region. The different plant species characteristically occur in different areas and the four main groups of plants, or plant assemblages, are rocky outcrops, sandplain shrubland, flats and drainage lines.

Rocky outcrop assemblages consist of very sparse vegetative cover which includes small stands of trees, such as rock kurrajongs (*Brachychiton acuminatum*), native figs (*Ficus platypoda, Ficus virens*), shrubs, such as *Hakea suberea* and *Grevillea pyramidalis*, and a range of grasses including spinifex or *Triodia* sp.

The sandplain shrubland is dominated by the native wattles *Acacia bivenosa* and *A. coriacea*, over a moderate cover of spinifex grasses (*Spinifex longifolius, Triodia* sp.) and other low-lying vegetation including *Myoporum accuminatum* and *Acanthocarpus preissi*. Some of the larger islands support diverse eucalypt communities.

The flatlands are areas of alluvial soils which flood or are waterlogged after rain. These areas are covered with moderate to dense grasses and the occasional shrub. Drainage lines along the rocky slopes on the islands support open bushland communities of *Eucalyptus microtheca, E. terminalis*, and *E. patellaris*, sparse shrubland of the yellow-flowering cassias (*Cassia* sp.), and dense *Triodia angusta* spinifex.

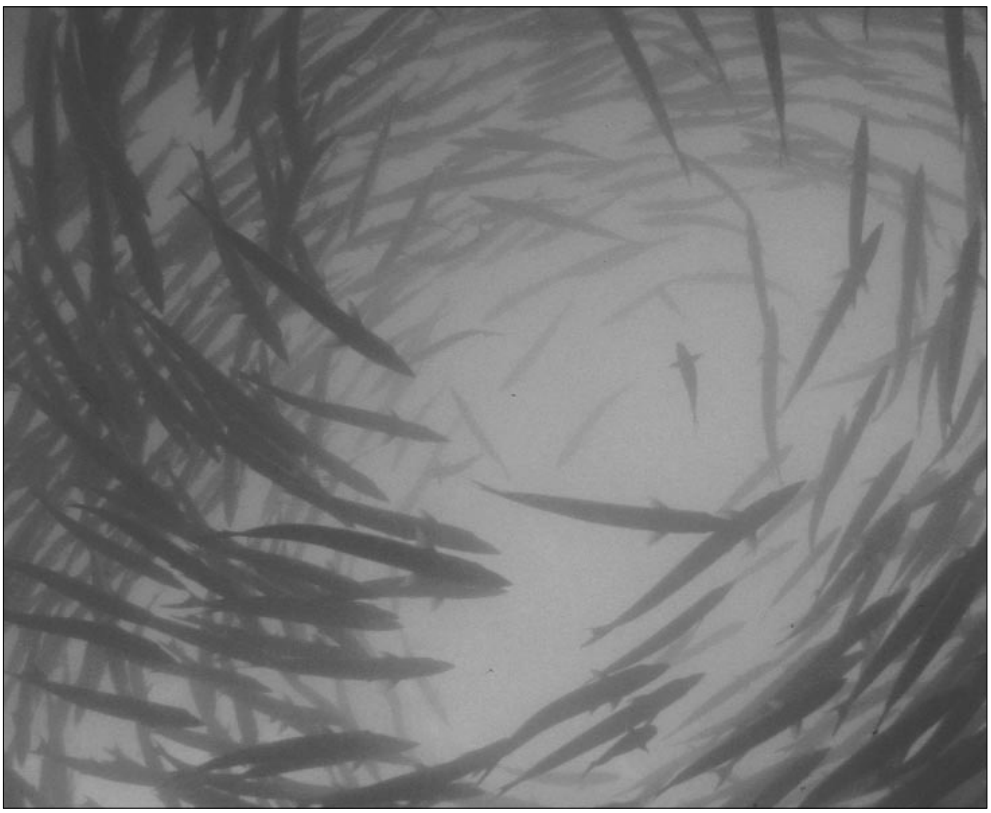

Figure 21. Approximately 600 fish species have been recorded in the Dampier Archipelago/Cape Preston region.

Table 4. Terrestrial mammals within the Dampier Archipelago and adjacent mainland coast to Cape Preston

Groups of mammals	Common name	Scientific name
Monotremes	Echidna	*Tachyglossus aculeatus*
Marsupials	Little red antechinus	*Dasykaluta rosamondae*
	Northern quoll	*Dasyurus hallucatus*
	Pilbara ningaui	*Ningaui timealeyi*
	Common planigale	*Planigale maculata*
	Euro	*Macropus robustus*
	Rothschild's rock-wallaby	*Petrogale rothschild*
Native rodents	Water rat	*Hydromys chrysogaster*
	Delicate mouse	*Pseudomys delicatulus*
	Sandy Island mouse	*Pseudomys hermannsbergensis*
	Pale field-rat	*Rattus tunneyi*
	Common rock cat	*Zyzomys argurus*
Bats	Little red flying fox	*Pteropus scapulatus*
	Common sheath-tailed bat	*Taphozous georgianus*
	Finlayson's eptesicus	*Eptesicus finlaysoni*
	Lesser long-eared bat	*Nyctophilus geoffroyi*
Introduced mammals	House mouse	*Mus musculus*
	Black rat	*Rattus rattus*
	Domestic dog	*Canis familiaris*
	Red fox	*Vulpes vulpes*
	Feral cat	*Felis catus*

Weeds that are established on many of the islands include buffel grass (*Cenchrus ciliaris*), kapok (*Aerva javanica*) and prickly pear (*Opuntia stricta*). There are also tamarisk trees which have been planted to provide shade on West Lewis and Rosemary Islands.

Twenty-one terrestrial mammal species have been recorded in the Burrup Peninsula area, comprising one monotreme (echidna), six marsupials, four native rodents, four bats and six introduced mammals (Table 4). In addition, the characteristic mound-like dwellings of the pebble mound mouse (*Pseudomys chapmani*) can still be found throughout the region though the animals themselves are believed to be locally extinct.

Approximately 50 species of terrestrial reptile inhabit the study area. These include 16 snakes, of which the Pilbara olive python (*Morelia olivacea barroni*) is specified as "*rare or is likely to become extinct*" in the *Wildlife Conservation (Specially Protected Fauna) Notice 1998* of the Wildlife Conservation Act. The remaining reptile species comprise nine geckos, four legless lizards, four dragon lizards, five goanna lizards and 12 skink lizards. Two species of frogs are also found in the area.

Major threats to these terrestrial inhabitants are industrial land use and fire. Fire on the arid islands of the Dampier Archipelago can be devastating for wildlife, but fortunately they are infrequent.

Figure 22. Coastal terrestrial biota includes 21 species of mammals.

HUMAN USAGE

Cultural history

Aboriginal heritage

The pre-history of Aboriginal habitation in the area dates back 20,000 years, well before the rising sea levels flooded the valleys and separated the islands of the archipelago.

The Dampier Archipelago, Burrup Peninsula and adjacent coastal areas were once home to Aboriginal people known as the Yaburrara or 'island' people. According to Aboriginal elders in the region today, the Yaburrara people originally numbered 100 to 120 but their numbers declined following the introduction of diseases such as smallpox and exploitation of their food and water sources. It is also likely that they, and members of other Aboriginal groups, were exploited for labour by whalers and pearlers, and there were violent confrontations with European settlers, climaxing in the Flying Foam massacre of 1868. Some reports suggest that the Yaburrara people had all died by the 1930s or 1940s and others suggest that they died in the 1950s or 1960s. The Yaburrara people used rafts for transport between the islands and their midden sites (Figure 23) and fish traps are testimony to their extensive use of marine life for food. Little is known about their language, which may have been a northern linguistic division of the Ngaluma, a neighbouring community, or it may have been a separate language altogether.

Some of the islands in the western archipelago were visited by the Mardudhunera people, who lived on the mainland near Nickol Bay. Remnant Aboriginal campsites in the area contain indigenous shell middens, artefacts and rock art. The Burrup Peninsula, adjacent to the study area, contains hundreds of thousands of Aboriginal rock engravings, providing a rich collection of Aboriginal rock art and some of the earliest examples of art that exists in Australia. The peninsula's indigenous archaeological features include engravings, mythological and ceremonial sites, graves, rock shelters, artefact quarries, factories, burials and middens. The Burrup Peninsula has been described as "the world's oldest and most spectacular outdoor art gallery".

There are many sites of important historical Aboriginal significance in the area, such as the Flying Foam Massacre site and the Climbing Man site on the Burrup Peninsula. Aboriginal sites are protected under the *Aboriginal Heritage Act 1972*.

There is still a strong Aboriginal identity in the region with individuals and families retaining strong ties to particular sites and land locations. The Ngaluma and Injibandi communities are based in Roebourne and some families have custodianship of the study area. Current Aboriginal usage in the area includes limited hunting of turtle and dugong. There are several

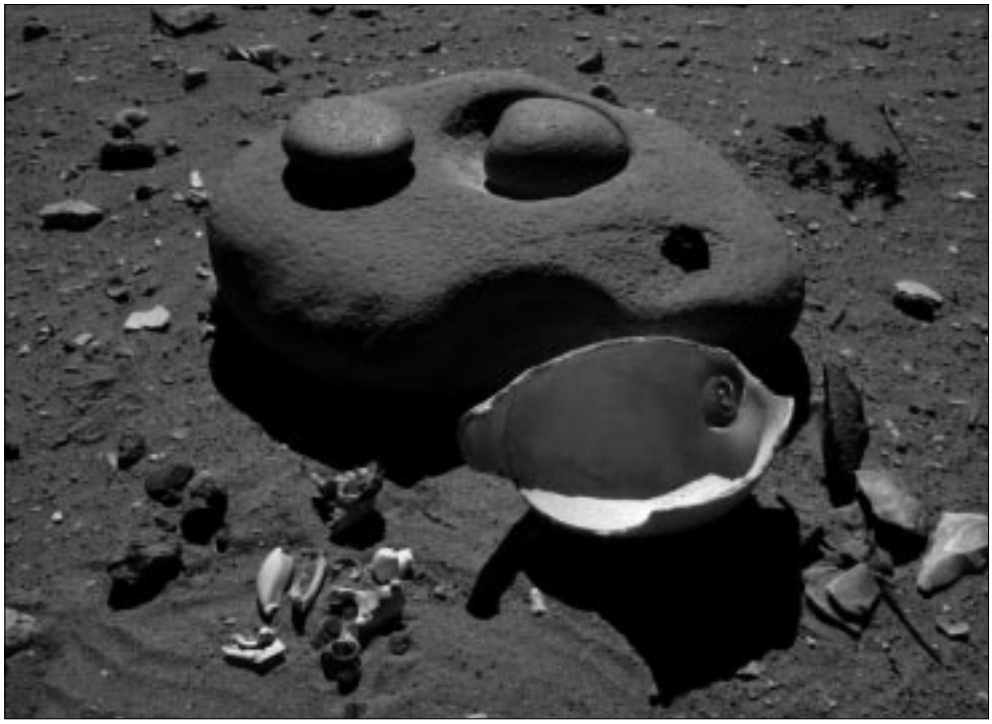

Figure 23. Midden sites indicate that the Yaburrara Aboriginal people made extensive use of marinelife for food.

Figure 24. A whaling station was established on Malus Island to process humpback whales. Photo courtesy Mr Johnson.

native title claims over parts of the waters and islands of the Dampier Archipelago/Cape Preston region (see Native title section).

European and maritime history

European ships may have ventured into Pilbara waters from as early as 1618 and the Dampier Archipelago was first charted in 1628 for the Dutch East India Company.

The earliest recorded European landing in the archipelago was in 1699, when William Dampier used the protected waters of what he named Rosemary Island as an anchorage for the vessel *Roebuck*. It is now agreed that the island, which bears this name today, is not the one originally named by Dampier. Instead, it is thought that Dampier landed on what is now known as Malus Island, which was named by Nicholas Baudin in 1801.

While the earliest recorded landing was not until 1699, it is likely that survivors from the English East India Company ship, the *Trial* (also known as the Tryal) landed in 1622. The Trial became the first known shipwreck in Australian waters when it struck what are now known as Trial Rocks nine nautical miles north-west of the Montebello Islands. Of the 139 people on board, there was room for just 46 on board the small boats and it was these men who most likely came ashore within the study area in search of water before setting off for Jakarta.

In 1772, St. Allouarn noted Rosemary Island while sailing from the North West Cape to Timor, but no landing was made.

Nicholas Baudin sailed the islands of the archipelago in 1801 aboard the *Geographe* and named them, as a group, Dampier's Archipelago. Legendre, Hauy and Delambre Islands were also named during this visit. Rosemary Island, as it appears on today's charts, is situated approximately 4 km to the north-west of Malus Island, and was so-named by Baudin during this same expedition.

Lieutenant Philip Parker King made a more detailed investigation of the Dampier Archipelago during his 1818 voyage of the north-west coast aboard the *Mermaid*. During this visit Enderby, Gidley, the Lewis islands and the Intercourse islands were named, as was Nickol Bay to the east of the archipelago.

In 1851, Lieutenant F.B. Helpman visited the archipelago in search of guano deposits. He made special mention of "…numerous fresh native foot marks on the beach…" and "… three graves lying side by side" on Enderby Island. These gravesites have been located and are believed to be the graves of early whalers. A whaling station was established on Malus Island to process humpback whales (Figure 24). In 1879 Pemberton Walcott made mention of these same gravesites whilst he was searching for survivors of the "*Rosette*". However, he also documented seeing five gravesites which have yet to be

Figure 25. A Catalina flying boat was wrecked near Enderby Island during World War II.

documented by the Western Australian Museum.

The pearling industry flourished in the region during the nineteenth century with Cossack, Flying Foam Passage and Dolphin Island used as the main bases for the pearling fleet. Many pearling luggers were wrecked in the Dampier Archipelago during this period and towards the end of the century, the industry moved to Broome leaving relics of their operations in Black Hawke Bay on Gidley Island, where pearling boats were careened and repaired.

The commercial fishing industry was established during the late 1800s. In addition to the harvesting of oysters and longline fishing for finfish, turtles and their eggs were commercially harvested until 1936.

Following the invasion of Singapore by the Japanese during World War II, the 30-tonne yacht *Sedjatra* was wrecked off the north-west tip of Enderby Island as it fled from Indonesia en-route to Fremantle. During this same period, a PBY 5 Catalina flying boat sank on the eastern side of Enderby Island. This seaplane belonged to the 10th Air Wing of the United States Navy and operated out of Perth, Geraldton and Exmouth. The remains of this craft can still be seen on the shores of Enderby Island (Figure 25).

Much more recently, during Cyclone Orson in 1989, a dredging barge moored off West Lewis Island broke its moorings and was wrecked on Eaglehawk Island. This large wreck has become a landmark within the study area.

The first Europeans to explore the inland Pilbara region landed at Hearson Cove, on the Burrup Peninsula, in 1861. This party, under the leadership of F.T. Gregory, travelled aboard the *Dolphin* from Fremantle to determine the potential of the north west for agriculture. Gregory named Dolphin Island after his ship. He also named other features after members of his expedition party, such as Cape Lambert, and Pemberton, Walcott and Dixon islands. F.T. Gregory recommended that the land would be suitable for pastoral purposes. He also noted the abundance of iron ore. The first settlers to the region established a pastoral industry in the 1860s and this remained the local economic mainstay until the 1960s. Remains of pastoral buildings and stockyards are visible on West Lewis Island.

Large deposits of iron ore were first mined in the region during the 1960s, and major industrial development began with Hamersley Iron Pty Ltd's iron ore stockpiling and ship loading facilities at Parker Point in 1966. The industry prospered and resulted in the establishment of the towns of

Dampier and Karratha. The Karratha townsite was excised from Karratha Station pastoral lease in 1968.

The 1960s also saw the founding of the offshore oil and gas industry. In the late 1970s, the North West Shelf Gas Project developed a liquefied natural gas (LNG) production plant and export wharf. The North Rankin A production platform was constructed and located 130 km north-north-west of Dampier. This facility was connected to the onshore site by pipeline. Natural gas from the region has been supplied to homes and industry since 1984 and LNG has been exported to Japan since 1989.

Salt production in the region began with the establishment of Dampier Salt's activities at Dampier in 1972.

ADMINISTRATIVE SETTING

State, Commonwealth and international frameworks

In 1994, the Minister for the Environment released a report entitled *A Representative Marine Reserve System for Western Australia*. This report identifies 70 areas in the coastal waters of Western Australia worthy of consideration for marine reservation under the CALM Act. In the same year, the Government of Western Australia released a document, New Horizons in Marine Management, which provided a policy framework for management of the marine conservation reserves system in Western Australia, and foreshadowed legislative changes to the CALM Act with regard to marine conservation and management. These legislative changes came into effect in August 1997 and established:

- the Marine Parks and Reserves Authority (MPRA) which is a vesting, policy and Ministerial advisory body;
- the Marine Parks and Reserves Scientific Advisory Committee;
- a revised consultation process for the establishment of marine conservation reserves; and
- clear guidelines for commercial activities in marine conservation reserves.

The roles and responsibilities of State Government agencies within marine conservation reserves are also defined and these are summarised in Table 5.

Table 5. The roles and responsibilities of State Government agencies within Western Australian marine conservation reserves

Agency	Roles and responsibilities
Marine Parks and Reserves Authority	• Vesting body for marine conservation reserves • Provides policy advice to the Minister for the Environment • Audits management plan implementation by CALM
Marine Parks and Reserves Scientific Advisory Committee	• Provides advice to the Minister for the Environment • Provides advice to the Marine Parks and Reserves Authority
Department of Conservation and Land Management (CALM)	• Manages marine conservation reserves, including (a) preparation of management plans (b) implementation of management plans (c) coordination with other agencies (d implementation of education and monitoring programs (e) management of flora, fauna and nature-based tourism, and (f) lead role in enforcement (non-fisheries issues) • Manages use of adjacent land/island conservation reserves
Fisheries Western Australia	• Manages and regulates commercial and reacreational fishing, aquaculture and pearling in marine conservation reserves
Department of Transport	• Regulates boating activities, boat launching facilities, jetties, navigational aides and the safety of coastal marine traffic under the *Marine Act 1983* • Gazettes areas designated for moorings in consultation with CALM • Chairs and supports the State Coordinating Committee that provides the mechanism to coordinate the management of marine pollution incidents
Department of Environmental Protection	• Assesses development proposals as required under the *Environmental Protection Act 1986* on behalf of the EPA • Regulates waste discharge to the environment
Environmental Protection Authority (EPA)	• Provides advice to the Minister for the Environment on the impact of development proposals
WA Maritime Museum	• Protection of pre-1900 shipwrecks and artefacts under the *Marine Archaeology Act 1973*. Shipwrecks more than 75-years old are declared and protected under the Commonwealth *Historic Shipwrecks Act 1976*

If established, a marine conservation reserve within the study area would become part of the National Representative System of Marine Protected Areas (NRSMPA). The NRSMPA is being developed cooperatively by the Commonwealth, State and Northern Territory agencies responsible for conservation, protection and management of the marine environment. The primary goal of the NRSMPA is to establish and manage a comprehensive, adequate and representative system of marine protected areas to contribute to the long-term ecological viability of marine and estuarine systems, to maintain ecological processes and systems and to protect Australia's biological diversity. The development of an NRSMPA helps fulfil Australia's international responsibilities and obligations as a signatory to the Convention on Biological Diversity. It also provides a means of meeting obligations under the Convention on Migratory Species and bilateral agreements with Japan and China, concerning migratory birds. In addition, it supports the World Conservation Union (IUCN) World Commission of Protected Areas program of promoting the establishment and management of a global representative system of marine protected areas.

At a national level, the conservation of marine biodiversity, maintenance of ecological processes and the sustainable use of marine resources are addressed in an *Intergovernmental Agreement on the Environment*. This is implemented through actions developed under national strategies such as the *National Strategy for Ecologically Sustainable Development, National Strategy for the Conservation of Australia's Biological Diversity, National Oceans Policy* and the *Strategic Plan of Action for the National Representative System of Marine Protected Areas.*

Local government

The study area lies within the Shire of Roebourne, which covers an area of 15,196 km^2. The population of the Shire of Roebourne is about 15,000, though numbers fluctuate greatly depending on local employment associated with large industrial construction projects. The Shire's five major townsites are: Karratha, Dampier, Roebourne, Wickham and Point Samson. Dampier is on the coast, adjacent to the study area. The townsite and port facilities were established in 1966 by Hamersley Iron Pty Ltd to provide housing for its workforce, and to service its mining operations at Tom Price. Dampier is administered by the Shire of Roebourne but remains within the Hamersley Iron Special Agreement lease and the company still has input into issues affecting the town. A home ownership scheme is currently in progress and private ownership should increase as a result of the area's attractive coastal outlook and broadening of economic activity.

The seven major industries within the Shire of Roebourne are pastoralism, mining, processing, commercial fishing, pearling and aquaculture, tourism and shipping.

Tenure

The seaward limit of the State territorial sea is three nautical miles from the terrestrial sea baseline. In the Dampier Archipelago/Cape Preston region, the baseline varies in relation to different geographical features to encompass offshore reefs and islands. As a result, much of the terrestrial sea baseline is more than three nautical miles from the mainland coastline. The State territorial sea line is shown in Figure 2.

Twenty five of the islands within the study area are vested as nature reserves with the National Parks and Nature Conservation Authority (NPNCA) under the CALM Act. Another two islands and a portion of a third island are 5(g) reserves for conservation and recreation and are also vested in the NPNCA. Land tenure and vestings in the Dampier Archipelago and Cape Preston region are summarised in Table 6 and Figure 26.

Nature reserves are for the purpose of wildlife and landscape conservation, scientific study and preservation of natural features. These are areas in which wildlife values may not be commercially exploited and where no recreation that damages natural ecosystems is allowed. Nature reserves within the study area extend to the low water mark and can be classified as either A, B or C Class. The tenure of A Class reserves can be changed only by agreement of both Houses of the Western Australian Parliament. The Governor of Western Australia can change the tenure of B Class reserves without the approval of Parliament, however the Minister for Lands must report the reasons for any change to Parliament. The tenure of a C Class reserve can be changed by the Governor without reference to Parliament, as long as any changes are published in the Government Gazette.

The purpose of 5(g) reserves is normally related to recreation, and the conservation of wildlife and

Table 6. Land tenure and vesting in the Dampier Archipelago and Cape Preston region

Reserve	Class	Name	Tenure	Purpose	Vesting	Comment
380	C	Landing Rock Well	Non-CALM Act - general	Public purpose	Unvested	
1766	C		Non-CALM Act - general	Public purpose	Unvested	
30948	C		Non-CALM Act - general	Airport	Shire of Roebourne W.P.L. and Minister for Land	Approval required (21 years)
33831	B	Great Sandy Island Nature Reserve	Nature reserve	Conservation of flora and fauna	NPNCA	Gazetted to Low Water Mark
34944	B	Dolphin Island Nature Reserve	Nature reserve	Conservation of flora and fauna	NPNCA	Gazetted to Low Water Mark and forms part of Dampier Archipelago reserve system
36907	C	East Lewis Island, Boiler Rock	5(g) reserve	Conservation and recreation	NPNCA	Forms part of Dampier Archipelago Reserve system
36909	C	West Lewis and Whittaker Islands	5(g) reserve	Conservation and recreation	NPNCA	Gazetted to Low Water Mark and forms part of Dampier Archipelago reserve system
36910	C	Malus Island	5(g) reserve	Conservation and recreation	NPNCA	Gazetted to Low Water Mark and forms part of Dampier Archipelago reserve system
36913	C	Angel, Brigadier, Conzinc, Delambre, Eaglehawk, Egret Gidley, Goodwyn, Hauy, Keast, Kendrew, Lady Nora, Malus, Mawby, Tozer, and Wilcox islands, and Bare, Collier, Millers and Nelson Rocks, and Elphick Nob	Nature reserve	Conservation of flora and fauna	NPNCA	Gazetted to Low Water Mark and forms part of Dampier Archipelago reserve system
36915	A	Enderby and Rosemary islands	Nature reserve	Conservation of flora and fauna	NPNCA	Gazetted to Low Water Mark and forms part of Dampier Archipelago reserve system
36991	C		Non-CALM Act - general	Water supply and pipeline	Corporation Water	
39161	C		Non-CALM Act - general	Quarry	Minister for Works	
39202	C	Cohen Island	Nature reserve	Conservation of flora and fauna	NPNCA	Gazetted to Low Water Mark and forms part of Dampier Archipelago reserve system
39777	C		Non-CALM Act - general	Natural gas pipeline purposes	Dbngp Land Access Minister	

Reserve	Class	Name	Tenure	Purpose	Vesting	Comment
40457	C		Non-CALM Act - general	Air traffic control tower	Airservices Aust	
40877	C		Non-CALM Act - general	Marine navigation aid	AMSA	
40896	C		Non-CALM Act - general	Radio communication	Minister for Mines	
41012	C		Non-CALM Act - general	Natural gas pipeline purposes	Dbngp Land Access Minister	
41636	C		Non-CALM Act - general	Port purposes	Dampier Port Authority	
423111	C		Non-CALM Act - general	Service corridor	Dbngp Land Access Minister	
42820	C	Legendre Island	Non-CALM Act - general	Future industrial purposes	Minister for Resource Development	
43195	C		Non-CALM Act - general	Archaeological site	WA Museum	
43303	C		Non-CALM Act - general	Marine aid to navigation	AMSA	
44922	C		Non-CALM Act - general	Recreation and drainage	Shire of Roebourne W.P.L. and Minister for Land	Approval required (21 years)
3114/464			Special lease	CL1976/55	Hamersley Iron Pty Ltd	
3114/1027			Special lease	CL 1984/453	Chininara Pty Ltd	
3116/464			Special lease	CL 1976/55	Hamersley Iron Pty Ltd	
3116/716		Mt Welcome Pastoral	Special lease	CL 1976/335	Mt Welcome Pastoral Company Pty Ltd	
3116/3468			Special lease	CL 1966/712	Hamersley Iron Pty Ltd	HWM
3116/3469		East Intercourse, Channel & Tidepole islands	Special lease	CL 1966/713	Hamersley Iron Pty Ltd	
3116/3471		(channel)	Special lease	CL 1966/715	Hamersley Iron Pty Ltd	
3116/3806		(channel)	Special lease	CL 1969/13	Hamersley Iron Pty Ltd	
3116/3807		(Parker Point, Ship Rock)	Special lease	CL 1970/39	Hamersley Iron Pty Ltd	
3116/3907			Special lease	CL 1969/14	Hamersley Iron Pty Ltd	HWM
3116/4596			Special lease	CL 1969/15	Hamersley Iron Pty Ltd	
3116/4598		(Channel Reef)	Special lease	CL 1974/75	Hamersley Iron Pty Ltd	
3116/4600			Special lease	CL 1974/76	Hamersley Iron Pty Ltd	
3116/4976		Mistaken and East Mid Intercourse islands	Special lease	CL 1978/42	Dampier Salt Pty Ltd	
3116/4984			Special lease	CL 1975/144	Hamersley Iron Pty Ltd	
3116/5503		(channel)	Special lease	CL 1974/93	Hamersley Iron Pty Ltd	
3116/5552			Special lease	CL 1979/318	Hamersley Iron Pty Ltd	HWM
3116/6702		(Courtenay)	Special lease	CL 1979/146	Hamersley Iron Pty Ltd	
3116/7842			Special lease	CL 1984/161	Hamersley Iron Pty Ltd	
3116/7936			Special lease	CL 1985/263	BHP Petroleum Pty Ltd	HWM
3116/8870			Special lease	CL 1985/26	Hamersley Iron Pty Ltd	
3116/9124			Special lease	CL 1985/265	BP Petroleum Pty Ltd	LWM
3116/9125			Special lease	CL 1989/1822	BP Petroleum Pty Ltd	
3116/9126			Special lease	CL 1985/266	BP Petroleum Pty Ltd	
3116/9127		Mt Wongama	Special lease	CL 1985/267	BP Petroleum Pty Ltd	
3116/9129			Special lease	CL 1985/269	BP Petroleum Pty Ltd	
3116/9130			Special lease	CL 1985/270	BP Petroleum Pty Ltd	
3116/11281			Special lease	CL 1994/434	AUUA - Carotene Ltd	

Reserve	Class	Name	Tenure	Purpose	Vesting	Comment
3116/11311		Special lease	CL 1994/527		North West Game Fishing Club Inc	
	Vacant Crown land	Bezout Island			not vested	
	Vacant Crown land	Dixon Island			not vested	
	Vacant Crown land	East Mid Intercourse Island			not vested	
	Vacant Crown land	Haycock Island			not vested	
	Vacant Crown land	Intercourse Island			not vested	
	Vacant Crown land	Pemberton Island			not vested	
	Vacant Crown land	Roly Rocks			not vested	
	Vacant Crown land	Walcott Island			not vested	
	Vacant Crown land	West Intercourse Island			not vested	
	Vacant Crown land	West Mid Intercourse Island			not vested	
CT 1022/255			Freehold land		AMSA	

historical features. This reserve classification is often used to give an area a temporary reserve classification pending the completion of studies to support a more appropriate permanent classification. Tenure extends to the low water mark and while the class of a 5(g) reserve is determined on a case by case basis, they are usually given B or C Class status.

Native title

Native title, or the traditional ownership of land and waters by Aboriginal people and Torres Strait Islanders, may be found to exist if it has not already been extinguished, or where the native title claimants have maintained their connection over the land.

In the West Pilbara region, there are many Aboriginal people who claim traditional associations with the local land and sea areas and there are currently four Native title claims lodged with the National Native Title Tribunal. These claims encompass some or all of the study area (Figure 27) and they are currently awaiting mediation in the Federal Court.

The claims have been made by:

- Ngaluma/Injibandi people for an area of 24,430 km^2;
- Kurama people for an area of 15,760 km^2;
- Yaburrara / Mardudhunera people for an area of 13,940 km^2; and
- Wong-goo-tt-oo people for an area of 20,240 km^2.

All applications lay claim to coastal waters within the study area, three with expansive coverage and one with minor coverage.

Infrastructure and facilities

Ports

Dampier Port is managed by the Dampier Port Authority, which is a statutory authority established under the *Port Authorities Act 1999*. Port operations are carried out by the private sector with the Authority providing strategic management in line with its functions under the Act. It is the job of the Port Authority to manage the Port safely and efficiently and to control, manage, maintain and develop the Port in a manner that both serves existing trade and attracts additional trade. It is also a function of the Dampier Port Authority to protect and enhance the environment of the Port.

The port boundaries encompass Mermaid Sound and include waters to the north which are used for anchorage of large vessels. The port also includes the waters between Enderby Island to the north

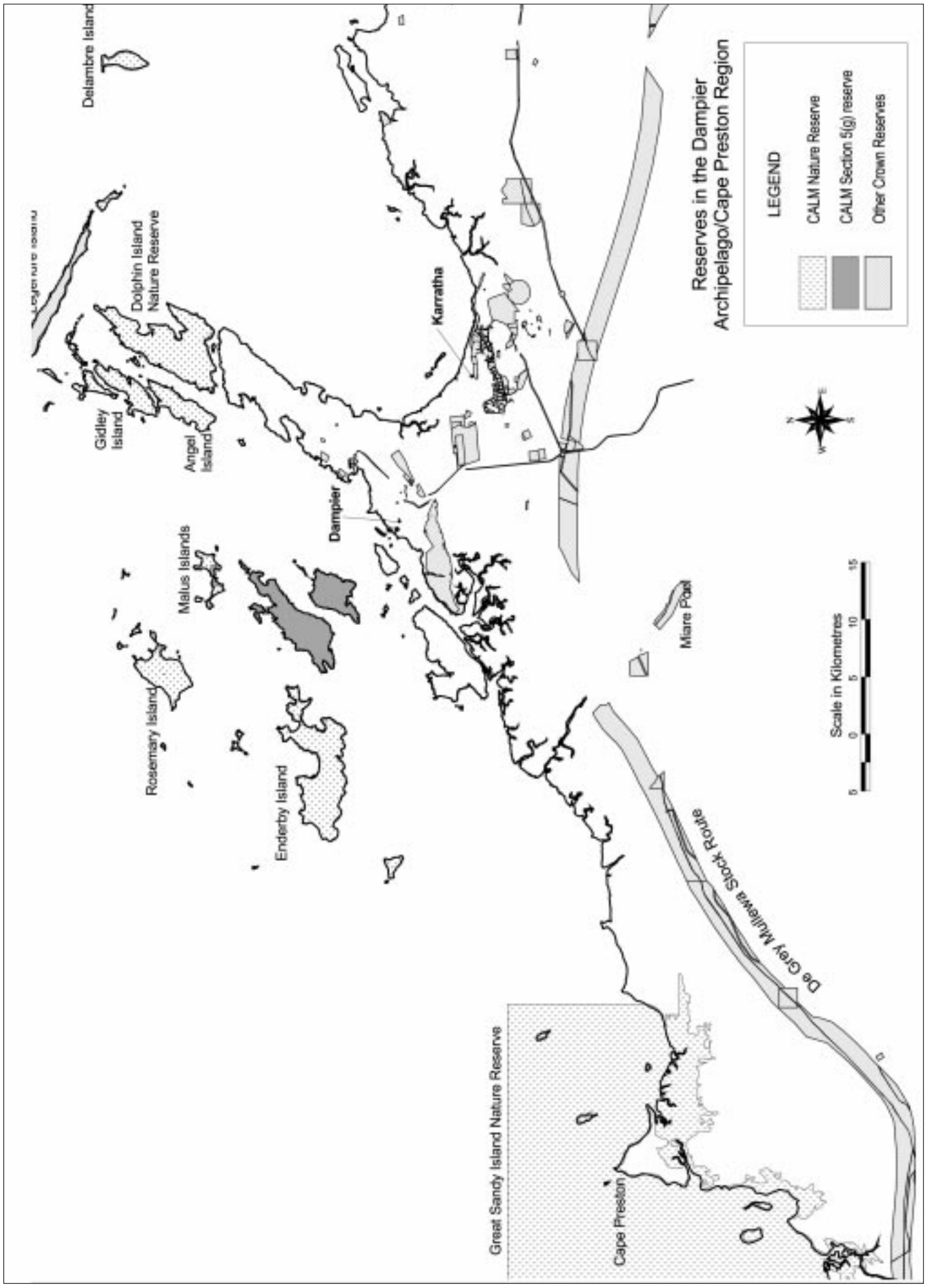

Figure 26. CALM and other reserves in the Dampier Archipelago to Cape Preston region.

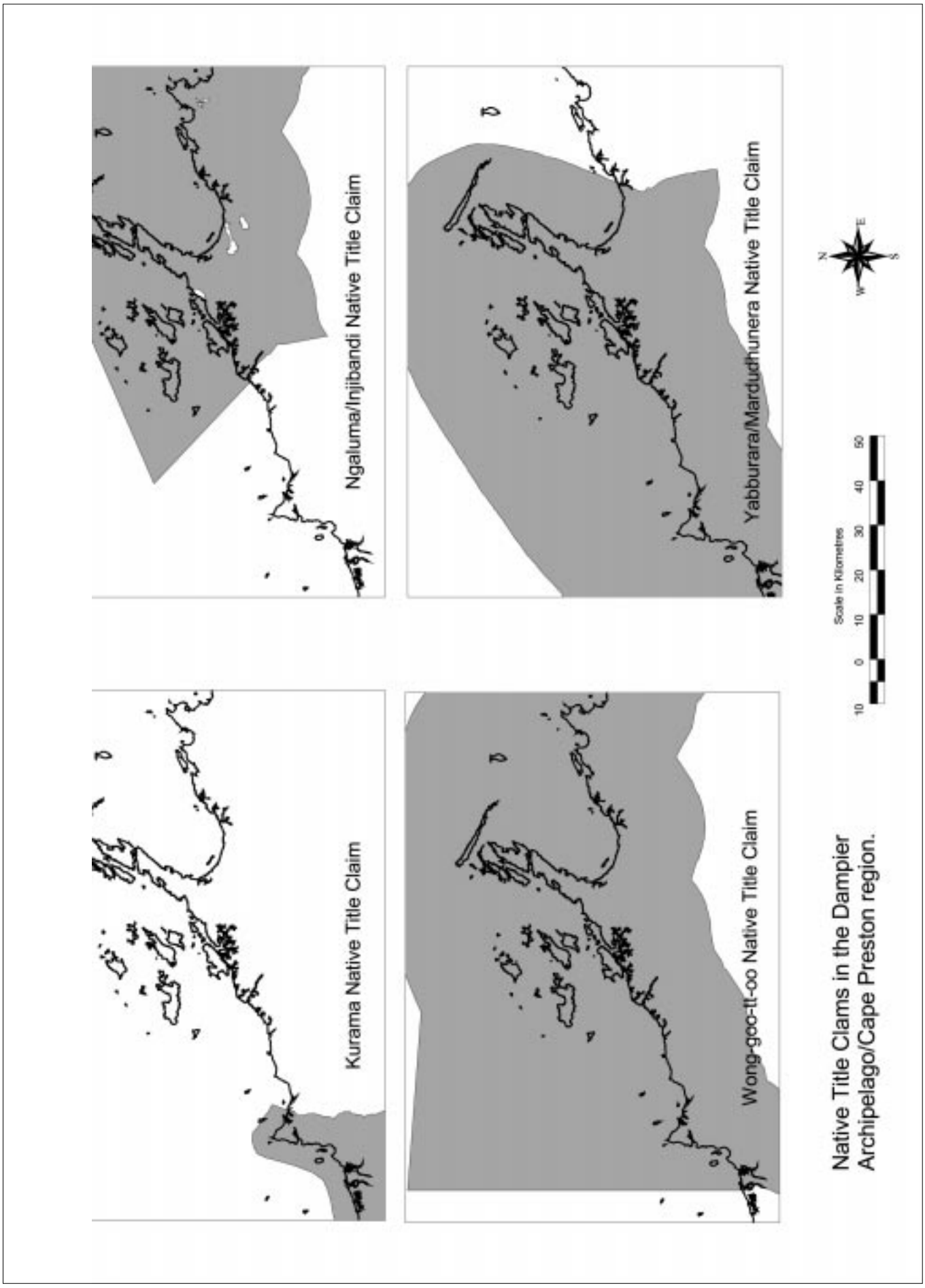

Figure 27. Native title claims in the Dampier Archipelago/Cape Preston region in July 2000.

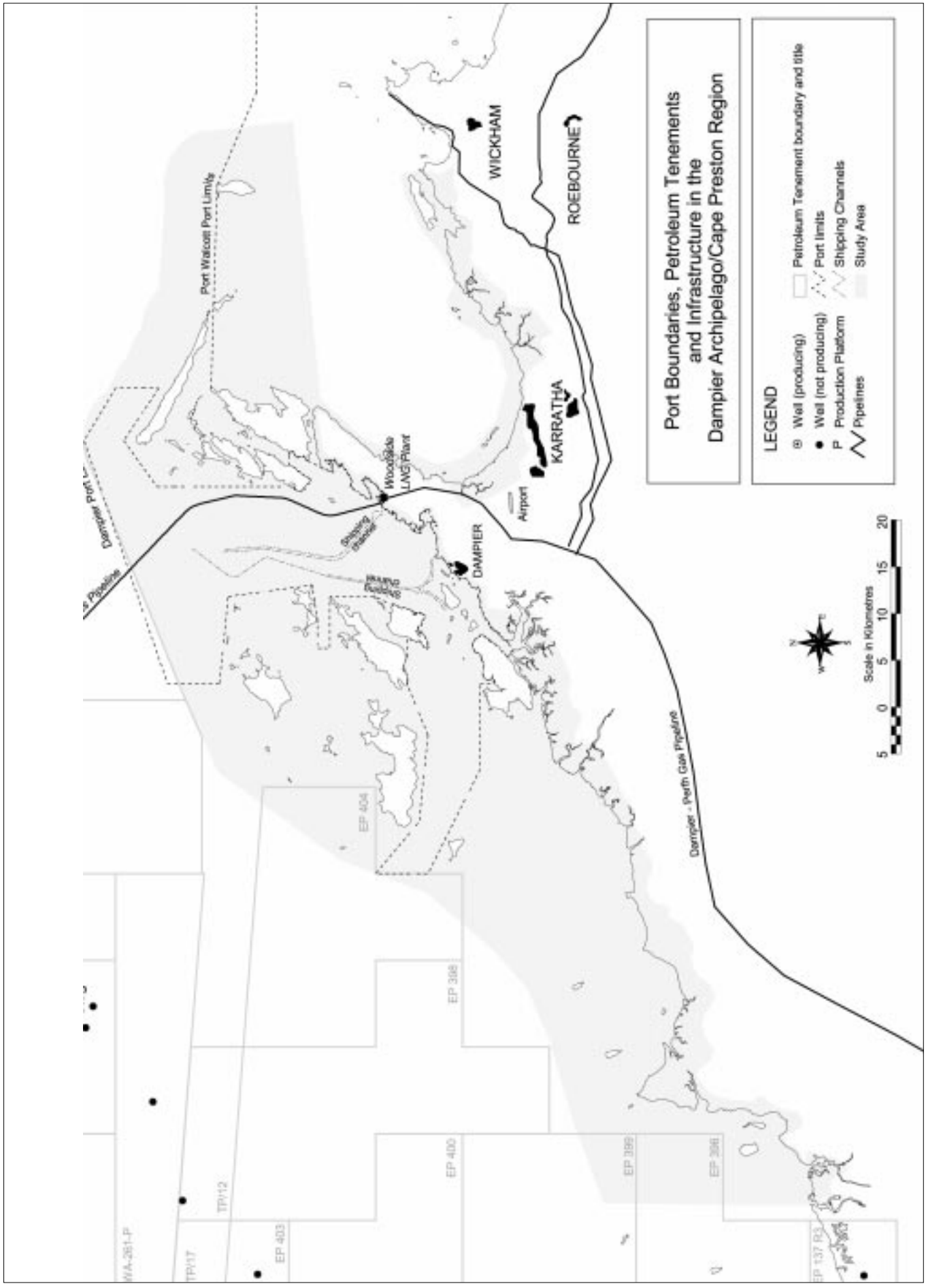

Figure 28. Port boundaries, petroleum tenements and infrastructure in the Dampier Archipelago/Cape Preston region.

and Eaglehawk and Low islands to south to accommodate future development proposals (Figure 28).

Dampier Port is the largest port in Australia and moves 75 million tonnes of product each year which is worth five to six billion dollars or 20 per cent of the State's export earnings. Trade forecasts indicate that the Port will be exporting 94,300,000 tonnes by the year 2004/05, which is a 25 per cent increase. This figure does not incorporate any new projects. Nearly all of this cargo is the result of the operations of just three companies, which use their own private wharfs.

By 1966, a port and townsite had been constructed to service the iron ore export requirements of Hamersley Iron Pty. Limited. Their first wharf at Parker Point was initially designated to accept vessels of up to 60,000 dead weight tonnes (DWT) and this required the dredging of a 13 m channel. Since that time, Hamersley Iron has continually upgraded their facilities and today Hamersley Iron operates three wharves; Parker Point ore wharf, the East Intercourse Island wharf and a service wharf from which general cargo and petroleum products are handled. The Parker Point ore wharf accepts vessels up to 180,000 DWT and has a departure channel which is 15.5 m deep. The East Intercourse Island ore wharf has accepted vessels of up to 320,000 DWT. The departure channel for this wharf has been dredged to 15.35 m but by working the tides, maximum draughts of some 18.5 m can be achieved. The largest shipment to date is 235,453 tonnes.

Dampier Salt commenced operations during 1972. Salt is produced by solar evaporation in crystallisation ponds and six million tonnes is exported annually. The bulk of the salt goes to the petrochemical industry in vessels of up to 70,000 DWT. Dampier Salt operates a wharf at Mistaken Island.

In 1980 Woodside Energy and their joint venture owners decided on the Burrup Peninsula as the site for their onshore liquefied natural gas (LNG) production plant and export wharf (Figure 29). The offshore petroleum production platforms were connected by pipeline to the onshore site and the total project is estimated to have cost some $12 billion. A fleet of dedicated 130,000 cubic metre LNG carriers transport 6,000,000 tonnes per annum to Japan. Additionally, some 3,500,000 tonnes of condensate is shipped to various markets elsewhere in the world. Woodside Energy now operates three facilities at Withnell Bay: the loading terminal that handles tankers of capacity up to 150,000 DWT and LNG carriers; a second loading jetty, which is designed to handle liquefied petroleum gas (LPG) vessels and condensate tankers; and the King Bay Supply Base, which handles all supply and construction vessels associated with Woodside's North West Shelf project. Actual export tonnages for 1998/99, with estimates for 1999/00

Figure 29. Woodside Energy's liquefied natural gas production plant and export wharf on the Burrup Peninsula. Photo courtesy Woodside Energy.

in brackets are: LNG 7,958,099 (7,500,000); LPG 869,000 (650,000) and condensate 4,385,747 (4,7000,000).

In addition to these private company wharves, the Dampier Port Authority manages a public wharf which is located near to Phillip Point. Seven berths are available at this facility and the largest will accept vessels up to 25,000 tonnes.

A causeway between East Intercourse Island and the mainland coast has created a sheltered harbour adjacent to the township of Dampier called Hampton Harbour. Hampton Harbour is located within the boundaries of Dampier Port and the Port Authority therefore maintains overall responsibility for safety issues in this area. However, the Hampton Harbour Boat and Sailing Club, Department of Transport and the Shire of Roebourne are responsible for infrastructure such as jetties, refuelling facilities and boat ramps within the harbour. Hamersley Iron holds a lease over the sea-bed of Hampton Harbour.

A small marina facility exists at the eastern end of Hampton Harbour. This marina was built 25 years ago to berth the port service vessels such as dredges, tugs and oil spill equipment. Today it is run by the Hampton Harbour Boat and Sailing Club, with approximately 33 pens for recreational yachts and other vessels. There are also many moorings within Hampton Harbour for both commercial and recreational vessels and additional tug pens are located on the eastern side of East Intercourse Island and King Bay.

Mermaid Marine is a privately-owned company that operates a supply base at King Bay. The company currently has land and jetty facilities which cater for tugs, supply and support vessels which service offshore petroleum projects. Commencing this year they will be upgrading their facilities to include boat pens and a slipway.

There are two other shipping facilities in close proximity to the study area. Port Walcott is located at Cape Lambert and services the Robe River Iron Ore operation. Structures at this port facility extend out to sea for 2.8 km and cater for vessels with a capacity up to 320,000 tonnes. Port Walcott is managed by the Department of Transport and the current port boundaries extend within the marine reserve study area. However, the port boundaries are likely to be altered during the next few years. A small coastal harbour at John's Creek, near Point Samson, is managed by the Department of Transport and caters for fishing, prawning and recreational craft. The demands on this facility are likely to expand as a result of increases in local population and tourist numbers, and growth in commercial fishing and aquaculture.

Environmental considerations associated with shipping operations and facilities

The operation of large vessels in shallow confined waters inevitably poses some risks for the marine and coastal environments. Strategies to minimise environmental risks include incident response planning and the adoption of cautious operational procedures. For example, it is compulsory that all vessels entering Port Dampier have a pilot on board, unless they are less than 150 tonnes or the master has current pilotage exemption qualifications.

Ballast water poses a risk to marine communities within the study area. Large empty vessels fill their holds with sea-water to maintain stability while steaming between ports. This water is pumped out before a new cargo is loaded but sea-water from distant ports can contain exotic marine organisms and when ballast water is discharged within the study area it has the potential to introduce foreign organisms into the local environment. There are several introduced marine pests within Australian waters already. Some of these are aggressively competitive and dominate areas where they have become established. Others cause millions of dollars worth of damage to aquaculture industries and submerged superstructures.

The Australian Quarantine and Inspection Service (AQIS) has developed voluntary guidelines for the handling and treatment of ballast water on ships entering Australian waters. These guidelines recommend the chemical treatment and exchange of ballast water in deep offshore waters but because the guidelines are voluntary, they cannot be enforced. The Dampier Port Authority also encourages ship's masters to safeguard against contamination through ballast water discharge by requesting:

- every effort be made to ensure that ballast water is clean and free from suspended sediment and turbidity on loading;
- sediment not be disposed of in Australian waters; and
- a sample of ballast tank sediment be provided for analysis.

Despite the guidelines and requests from the Port Authority and major companies which operate in the area, there are many reports of 'dirty' ballast water discharge and this environmental threat remains of major concern.

Adverse weather conditions also pose a threat to safe shipping in shallow enclosed waters. There are a number of cyclone moorings in Hampton Harbour and Hamersley Iron has cyclone moorings south of West Lewis Island. Cyclone moorings have also been constructed in Flying Foam Passage and Mermaid Strait. Port procedures require all medium to large vessels (including local vessels) to finish loading and go out to sea in the event of a cyclone.

Various hazardous chemicals are carried in Australian waters, with the potential for accidents resulting from spills or fires. Ammonium nitrate is perhaps the most hazardous material currently transported though petroleum products are also volatile. New development proposals may result in other hazardous materials being transported through the Port. Vessels carrying dangerous goods currently anchor in an area north of Hamersley Shoal. The storage and transportation of hazardous materials is controlled by the Departments of Transport and Minerals and Energy.

There is an oil spill contingency plan for Dampier Port, and some $2 million worth of oil spill combat equipment is kept in storage. This equipment gives the Port the capacity to respond to large spills, equivalent to 1,000 tonnes of oil or greater. In addition to the equipment which is stored locally, equipment can be brought in from Fremantle and interstate in the event of an emergency. The Port Authority has recently spent $30,000 on oil spill response training. As part of the training program, an international mock oil spill exercise was staged in Dampier Port during June 2000. This training results in a high level of preparedness.

Tributyl tin (TBT) is used on ships hulls to prevent fowling by encrusting organisms. It is one of the most toxic substances introduced into the marine environment. It continually sloughs off the hull surface and is usually found in the water column and sediment in the vicinity of shipping operations. TBT is such a toxic substance that the recommended water quality guideline for TBT in Australian marine waters is just 2 mg TBT/l, equivalent to just two grams of TBT in a billion litres of sea-water. Measurements of TBT levels taken by Curtin University in 1997 indicated that concentrations at sites associated with commercial shipping activities were several times higher than the recommended concentration for protection of aquatic ecosystems. Growth deformities in nearby marine snails associated with TBT contamination were also detected.

Dredging requires Department of Environmental Protection approval because it increases water turbidity and can smother marine organisms. To maintain Port operations, there is a requirement for two shipping channels, one of which is maintained by Woodside Energy and the other by Hamersley Iron. The channel maintained by Woodside Energy was initially dredged in 1987 with some remedial dredging undertaken in 1990. Total spoil from the initial dredging operations was approximately seven million cubic metres, some of which was dumped in a spoil ground to the east of the channel in Mermaid Sound, and the rest was dumped ashore. The shipping channel maintained by Hamersley Iron was initially dredged in 1965, with subsequent dredging performed approximately every two years until 1991 and then again in 1998. The spoil ground for this channel is located on the eastern side of East Lewis Island. Applications for additional spoil grounds are currently being considered.

The construction of wharves and causeways can result in significant changes to water flow. Such changes may reduce the flushing rates in enclosed areas, which can cause changes to the temperature, salinity and dissolved oxygen conditions experienced by marine organisms. Changes to water flow patterns are also likely to impact recruitment and dispersal of marine propagules and the dissipation of noxious substances.

Boat ramps

Small dinghies can be launched from sheltered shorelines wherever vehicle access is possible and tides permit (Figure 30). Several undeveloped launching sites are used regularly by boat owners at Back Beach in Nickol Bay, Cleaverville Creek, Cowrie Cove, Withnell Bay, Yowrie Creek, Maitland River, Forty Mile Beach, King Bay Fishing Club, Hearson's Cove and the Fortescue River. However, the high tidal range in the region often limits the use of these facilities to high tide conditions.

Sealed boat ramps have been constructed within

Figure 30. Small dinghies can be launched from sheltered shorelines wherever vehicle access is possible and tides permit.

Hampton Harbour. One of these ramps is located at the Hampton Harbour Boat and Sailing Club, and three other sealed ramps are located side by side about 1 km to the east. These ramps can be used in all but the very lowest tides.

Shacks

There are 34 shacks within the Dampier Archipelago (Figure 31). Thirty three are licensed by CALM to the Dampier Archipelago Recreational Dwellers Association Inc. (DARDA) and one is leased from the Department of Land Administration (DOLA). All shacks within the Dampier Archipelago are situated in conservation and recreation (5g) reserves and the owners have CALM licences which specify the types of structures which are permitted and ensure that they are maintained and have minimal visual impact. The shacks provide an accommodation base for many recreational users. King Bay Fishing Club has a shack on Malus Island and the Norwest Game Fishing Club has a shack on Rosemary Island, which is leased from (DOLA). In addition, fishers camp on Steamboat, Sholl, Fortescue and North East Regnard islands during fishing trips. No facilities such as water or toilets are provided on the islands.

CALM has two research stations in the Dampier Archipelago, one on Enderby Island and one on Rosemary Island. These stations are used by research groups and volunteers carrying out work on CALM projects.

There are also two shorebases used by the pearling/aquaculture industry on Dolphin and West Lewis islands. The use of these facilities is managed through licences issued under the CALM Act.

Figure 31. There are 34 shacks within the Dampier Archipelago.

Roads

There are no sealed roads on the islands of the archipelago. However, there is a substantial track from the Norwest Game Fishing Club Shack to an old airstrip on Rosemary Island. Along the adjacent coast, residents and visitors have created many four-wheel-drive tracks providing access to fishing and camping sites. These tracks have the potential to cause environmental damage, particularly if their use increases. A sealed road provides access to Forty Mile Beach.

The North West Coastal Highway is a major route for industrial and private transport connecting the Dampier region with Perth and Port Hedland.

Airports

Karratha airport is the only licensed airport close to the study area. There are unlicensed airports at Roebourne and Wickham.

Sewerage

Hamersley Iron Pty Ltd has a wastewater treatment plant located at Dampier. This plant has a 50-metre sewerage outfall pipe into Hampton Harbour. The treatment plant was designed and licensed to treat a maximum volume of 600 cubic metres per day of sewage. However, the daily discharge rate may not be the full licensed amount as some wastewater is used to water parks and gardens. The wastewater treatment plant is designed to treat wastewater to a secondary standard prior to discharge. Wastewater passes through an Imhoff tank, trickling filter and clarifier, prior to discharge. Three monthly surveys must be conducted by Hamersley Iron to test the water quality near the discharge pipeline and every six months, surveys are carried out to monitor the levels of heavy metals. These data are submitted to the Department of Environmental Protection. The Shire of Roebourne also monitors water quality in the area. Both Dampier and Karratha are also serviced by deep sewerage. The effluent is treated in oxidation ponds and reticulated to various irrigation uses. Surplus effluent treated in this manner is disposed of in evaporation ponds.

Commercial activities

Commercial fishing

Commercial fishing makes an important contribution to the regional economy. Currently, the major commercial fishing activities in the Dampier Archipelago/Cape Preston region are prawn and finfish trawling, trapping and wet lining.

Commercial fishing vessels operate out of the ports of Dampier, Onslow and Point Samson, the latter primarily supporting the finfish fishery. There is also a finfish processing facility located at Point Samson.

Prawn trawling is generally restricted to inshore areas of the coast. There are two prawn fisheries within the Dampier Archipelago/Cape Preston region. The Onslow Prawn Managed Fishery extends from south of Dampier to Onslow. The major trawling grounds associated with this fishery lie north of Enderby Island, west of West Lewis Island and around islands near Onslow. The Onslow Prawn Managed Fishery currently comprises 31 licensed vessels, 12 of which are also licensed to fish in the Exmouth Gulf Prawn Fishery and 12 are also licensed to fish in the Nickol Bay Prawn Managed Fishery. The Onslow Prawn Managed Fishery has an estimated annual value of $1.2 to 1.4 million. Catch figures for 1995/6, 1996/7 and 1997/8 are given in Table 7.

The Nickol Bay Prawn Managed Fishery extends east from Dampier to longitude 120° E which is east of Port Hedland. The Nickol Bay Prawn Managed Fishery has 14 licensed vessels, 12 of

Table 7. Catch information for the Onslow Prawn Managed Fishery (OPMF) and the Nickol Bay Prawn Managed Fishery (NBPMF)

Fishery	Year	King prawn (t)	Tiger prawn (t)	Endeavour prawn (t)	Banana prawn (t)	Total penaeids (t)
OPMF	1995-96	34.0	42.0	15.0	6.0	97.0
OPMF	1996-97	51.8	8.8	6.8	27.0	94.4
OPMF	1997-98	19.0	5.0	5.0	91.0	120.0
NBPMF	1995-96	25.0	19.0	2.0	109.0	115.0
NBPMF	1996-97	34.4	4.3	2.7	122.2	163.6
NBPMF	1997-98	20.0	4.0	<1.0	212.0	237.0

Figure 32. The major commercial fishing activities in the Dampier Archipelago/Cape Preston region are prawn and fin fish trawling, trapping and wet lining.

which are also licensed to operate in the Onslow Prawn Managed Fishery. The Nickol Bay Prawn Managed Fishery operates over trawling areas covering most of Nickol Bay, with an estimated annual catch value of $1.6 to 2 million. Catch figures for 1995/6,1996/7 and 1997/98 are given in Table 7.

The Pilbara finfish industry involves trawl, line and trap fishing, with its boundaries stretching from west of Onslow (114°09'36" E) to east of Port Hedland (120°00'00" E). The industry has an estimated annual value of $10.3 million and an approximate annual catch of 3,000 to 3,400 tonnes.

The Pilbara Trawl Interim Managed Fishery currently involves 11 licensed fishing boats. The amount of time during which a boat may fish is determined in accordance with the number of time/gear units associated with the relevant licence. Currently, the total level of effort available in the fishery is 21,096 trawl hours. The waters of the study area are currently closed to fin fish trawling.

The Pilbara Trap Managed Fishery currently involves six licensed boats. This fishery targets demersal scalefish such as snapper, grouper, emperor and jobfish species. Waters landward of a line generally following the 30 m isobath are closed to trapping. The only areas within the study area that are open to trap fishing are the deep waters offshore between Legendre and Rosemary islands.

Commercial line fishing is permitted throughout the study area. Line fishing vessels use droplines, longlines and handlines and target similar species to those caught in the trap fishery.

The North Coast Shark Fishery currently has eight operators and seven have access to the waters of the study area. This fishery stretches from Onslow (114°06' E) to the Northern Territory border and has an annual catch of approximately 200 to 250 tonnes which is worth about $0.6 million. Fishers use hook and line techniques; either drop lines, which are set vertically through the water column or long lines which are set horizontally. They target a wide range of species including black tips, spot tailed, hammerhead, milk sharks and a variety of whalers. The focus of the fishery is on small edible specimens and the meat is sold mainly to the local market.

Trawling for Beche-de-mer (trepang or sea cucumbers) is not permitted in Western Australia, but there are currently seven licences authorising collection by hand. Collectors wade in shallow water or use hookah diving equipment to locate mainly three species: the sand fish (*Holothuria scabra*), the black teat fish (*Holothruia nobilis*) and the white teat fish (*Holothuria fuscogilva*). In 1998, 345 tonnes of product were taken, primarily from the Kimberley and exported to Asian markets where it is considered a delicacy.

The tropical rock lobster fishery is closed between Cape Lambert and Cape Preston, out to the 200 m isobath. Commercial fishers therefore do not have

access to the study area for this activity. Fisheries Western Australia has issued four commercial mud crab licences. However, there is a closure to commercial mud crabbing between Cape Preston and the Jones River.

Fisheries Western Australia has issued 32 commercial shell collecting and 13 aquarium fish collecting licences. These collectors have access to waters throughout the State and periodically operate within the study area.

Commercial fishing in Western Australia is managed under the Fish Resources Management Act, by Fisheries Western Australia. A range of management techniques is used including limitations on fishing gear, closed areas, limits to the number of licences issued and the monitoring of catch and stock levels.

In line with the State Government's multiple-use policy, commercial fishing is provided for in marine conservation reserves. Government policy relating to commercial fishing in marine conservation reserves can be summarised as follows:

- commercial fishing will be provided for in marine management areas and in certain zones in marine parks;
- commercial fishing will not be permitted in sanctuary, recreation and certain special purpose zones of marine parks;
- no fishing will be permitted in marine nature reserves;
- commercial fishing in marine conservation reserves will continue to be managed by Fisheries Western Australia;
- the Minister for the Environment requires the consent of the Minister for Fisheries before creating any marine conservation reserve or management zone within a marine park or marine management area;
- if the commercial value of an authorisation is apparently diminished by the establishment of a marine nature reserve or exclusion zone in a marine park, then the holder of the authorisation will be eligible to apply for compensation.

Pearling and aquaculture

Pearling began in Western Australia in the 1850s, when natural pearls were found at Shark Bay, and later at Nickol Bay. At that time, pearlers mainly collected the mother of pearl, which is the shiny layer inside the shell, and counted themselves lucky if they found a pearl inside the shell as well. In the 1890s, an industry pioneer, G. S. Streeter, tried to 'culture' a pearl, that is, create it artificially. However, the State Government feared this might undermine the mother of pearl industry and banned artificial pearl cultivation.

By 1910 almost 3,500 people were fishing for shell to harvest mother of pearl. This was an

Figure 33. The cultured pearling industry is worth about $182 million a year in Western Australia.

industry fraught with danger with many divers being lost through the 'bends' after spending too many hours underwater. Others fell victim to shark attacks or drowned during storms and cyclones. Many Japanese and Aboriginal divers were exploited by the early pearlers, who often abused or did not pay their workers.

The manufacture of plastics heralded the demise of the mother of pearl industry. By World War 1 the price of mother of pearl shell had plummeted and by 1940 the industry had almost collapsed. However, in the 1950s the ban on cultured pearl production was lifted and the industry regained its former strength. Today it is worth around $180 million a year.

Pearls develop when a nucleus, such as a piece of grit, finds its way inside a shell. To stop the irritation, the oyster lays down lustrous coatings of nacre, a form of calcium carbonate, around the fragment. Cultured pearls are created when an irritant, usually a piece of Mississippi mussel shell, is placed into the flesh of the oyster. Shape, colour, size, and lustre determine how much a pearl is worth. Oysters that grow closer to the equator produce duller pearls than those produced at higher latitudes and for this reason, sites within the study area are some of the best in the world for the growth of high quality pearls.

Today, the pearling industry refers generally to the culturing of pearls in certain species of oysters, which are either collected from the wild or grown in hatcheries. Oyster shells are seeded with irritant fragments and then replaced on the seabed in panels. During this phase of the process, the panels are turned regularly to aid the formation of round pearls. After a few months the panels of oysters are taken to farms, and hung from long ropes, which are located in areas of high tidal movement where microscopic planktonic food is abundant. They stay in these grow-out areas for about two years, by which time the pearls have grown to a harvestable size and quality. While the pearls are growing, the oyster shells become encrusted with sedentary marine organisms, which have to be scraped off at regular intervals. Most of the pearls, which are grown within the study area are sold to Japan, but some go to the United States, Hong Kong and Europe.

Leases for cultivating the oyster *Pinctada maxima* in State waters are issued under the *Pearling Act 1990*. However, licences for the cultivation of other pearl oyster species; *Pteria penguin, Pinctada margarifera*, and *Pinctada albina*, are issued under the Fish Resources Management Act and from a technical point of view are therefore considered as "aquaculture" rather than pearling.

There are three existing or proposed pearling leases and three existing or proposed aquaculture licences for the culture of pearls within the Dampier Archipelago/Cape Preston region (Figure 34). To support pearling activities, shore-based buildings and other structures have been permitted on Dolphin and West Lewis islands.

As with all human activities, pearling and aquaculture have the potential to impact the natural environment and the granting of licences and leases is just one form of control over this industry. Additional management strategies include quotas and size limits on the collection of wild oysters. The entire industry has an annual quota of 572 units, where one unit is generally equivalent to 1,000 shells. However, in the year 2000, each quota unit is equivalent to 1,100 shells. Wild oysters can only be gathered when they reach the minimum size of 120 mm. The optimum size of oysters is between 120 and 160 mm. If the oysters are greater than 160 mm, they are left as breeding stock. There are also restrictions on breeding pearl oysters for hatchery production. Production of baby oysters or spat is controlled by licence. The original allocation was for 20,000 spat to each licensee plus an extra 10,000 to a licensee who already had a hatchery. The quota is also transferable and so a licensee may hold much more than 20,000 spat if they can secure a quota from another licence.

Distances between pearl oyster farms and holding or grow-out areas are controlled carefully. Disease can be transmitted from one oyster to another, so if farms are close together, diseases may be transported through the movement of water.

The study area has the potential to support other forms of aquaculture. Land-based aquaculture has been slow to develop in the region with the only licences issued to date being for the production of algae (*Dunaliella salina*) associated with the solar salt fields at Karratha and red claw crayfish (*Cherax quadricarinatus*) production near Karratha Airport.

The production of algae (*Dunaliella salina*) occurs in Nickol Bay, about 2 km from Karratha.

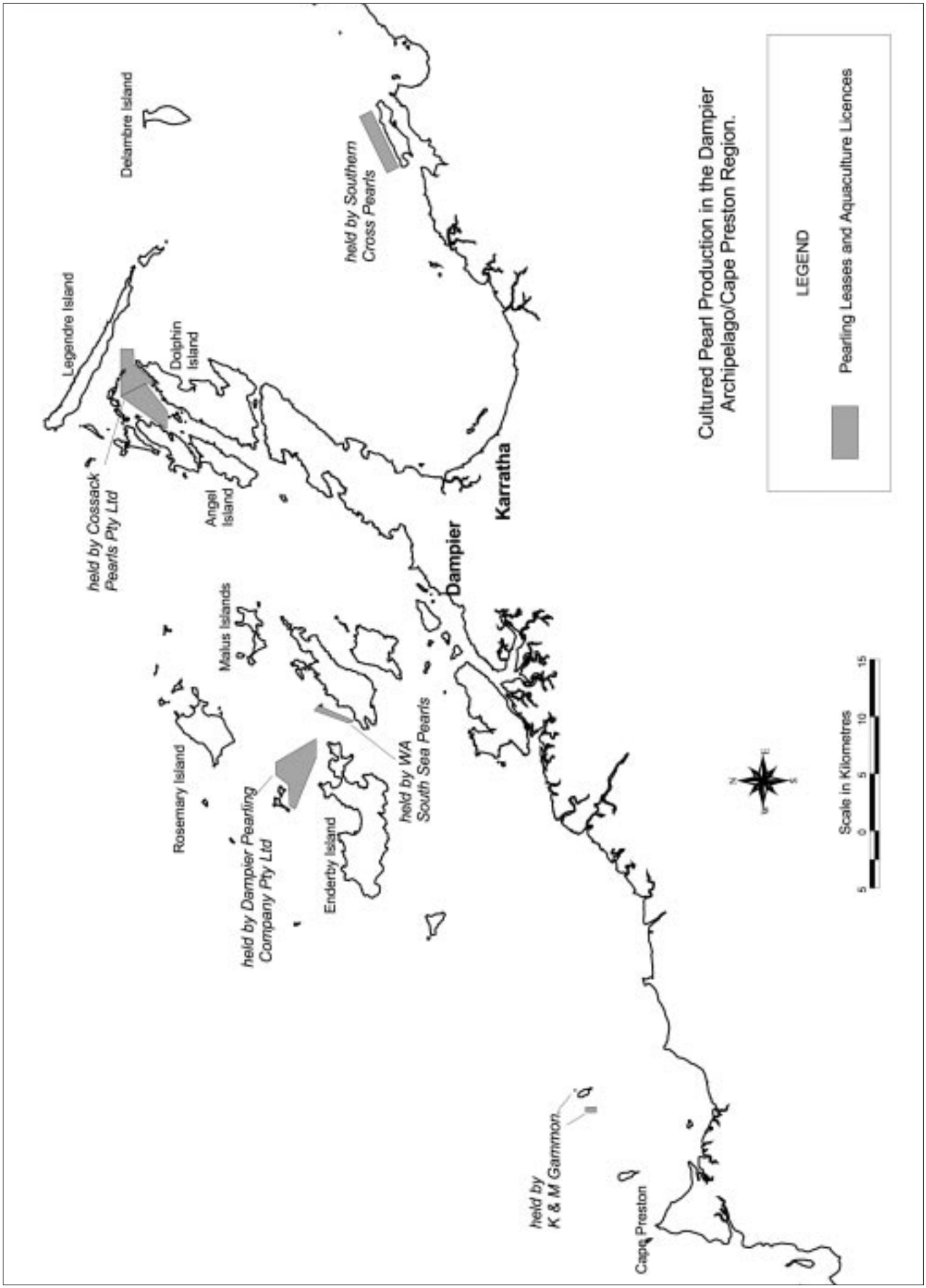

Figure 34. Existing and proposed pearling leases and aquaculture licence areas within the Dampier Archipelago/Cape Preston region.

Currently the production area is 304 ha, with an application for an additional 604 ha. The algal culture is grown in ponds that are about 200 to 400 mm deep. The algae are grown for their beta carotene component which is used in a variety of products including pet food, human dietary supplements and food colourings.

Environmental concerns associated with pearling and other forms of aquaculture include the potential for grow-out panels and cages to shade benthic flora and fauna. All plants require light to grow and any reduction in light will cause a reduction in productivity. In cases of severe light depletion an area may become unsuitable for plant growth altogether. Shell grow-out panels, aquaculture cages and the associated ropes and markers all have the potential to entangle marine wildlife and if these structures break loose during storms, they can litter the water column and nearby beaches, causing a further hazard to wildlife. Lights associated with pearling and aquaculture industry facilities can attract and disorientate birds and turtles and prevent hatchlings from reaching the open ocean. In addition, vessels servicing pearling and aquaculture facilities have the potential to transport feral animals and weeds onto the islands.

When cultured marine organisms and the species on which they feed are brought into the study area from elsewhere, they have the potential to carry diseases and not only affect the industry but also to infect local wild populations. The addition of nutrients into the marine environment also has the potential to affect natural populations, and some aquaculture activities require the addition of nutrient rich food substances. Additional nutrients stimulate plant growth, and algae can smother other forms of marine life when nutrient levels are artificially raised. The location of aquaculture facilities which involve the addition of nutrients in well-flushed areas reduces the risk of nutrient build up. The nutrient loading (additional phosphorous and nitrogen) associated with effluent from the beta-carotene facility in Nickol Bay is considered negligible.

Public access to pearl grow-out areas is stipulated in the lease conditions, though it is usually restricted to protect the public from entanglement and to maintain pearl farm security. Access must however be maintained through and within the site at all times for legitimate uses and all sites must be marked and lit to ensure navigational safety. The development of pearl oyster farms is restricted by natural factors such as tidal ranges, water quality and oceanic swells. They therefore cannot always be located in places where other users do not wish to go and the study area provides some of the best conditions for pearling in the State. The planning process for a marine conservation reserve provides an opportunity for all user groups to establish solutions to conflicts over resource sharing and issues of access in the marine environment.

In line with the State Government's multiple-use policy, pearling and aquaculture are provided for in marine conservation reserves. The State Government's policy on pearling and aquaculture in marine conservation reserves can be summarised as follows:

- Aquaculture and pearling will be provided for in marine management areas and in certain zones in marine parks.
- Fishing, aquaculture and pearling in marine conservation reserves will continue to be managed under fisheries legislation.
- Existing authorisations for aquaculture and pearling will continue to be valid if the area to which they apply becomes a marine conservation reserve. If an area becomes a marine nature reserve, or, for example, a sanctuary zone in a marine park, the authorisation will continue until its expiry date.
- If the commercial value of an authorisation is apparently diminished by the establishment of a marine nature reserve or exclusion zone in a marine park, then the holder of the authorisation will be eligible to apply for compensation.
- The Minister for the Environment requires the consent of the Minister for Fisheries before creating any marine conservation reserve or management zone within a marine park or marine management area.

Tourism

Tourism is a major industry in Western Australia, valued at $2.1 billion in 1993/94, and accounting for 4.8 per cent of Western Australia's gross State product. Of this, $1.8 billion was attributable to the domestic market.

A Western Australian Tourism Commission survey in 1996 estimated the value of tourism in the Pilbara region at $59.5 million. Total tourist

Figure 35. Charter boats operating out of Dampier take tourists round the Dampier Archipelago.

numbers to Karratha and Dampier have not been quantified, but numbers for the entire Shire of Roebourne were estimated at 58,700 during 1993/94. The Karratha Tourist Bureau estimated that almost 543,000 tourists used its services in 1999, a conservative estimate of the total number of tourists to the region. Almost half of the visitors to the Pilbara, 48 per cent, were from elsewhere in Western Australia, 41 per cent came from interstate and 11 per cent were from overseas.

The study area offers a wide variety of attractions and therefore has significant tourism potential. The natural rugged beauty, attractive underwater scenery and both the variety and abundance of native fauna, including large marine wildlife, provide valuable experiences for visitors who enjoy the natural environment and wildlife viewing. The study area also offers a range of recreational opportunities for those who enjoy the outdoors. These include diving, fishing, boating, camping and four wheel driving. The large-scale industrial developments also attract interest and visitor lookouts and tours have been developed to cater for this market. A well-appointed visitor centre has been built overlooking the liquid natural gas processing plant at Withnell Bay. This centre houses a display, which explains the petroleum industry's activities in the area. Tourism is also generated through interest in cultural heritage and history. The Aboriginal rock art on the Burrup Peninsula and living culture within the local communities together with European historical buildings at Cossack and Roebourne all enrich the tourist experience.

The great potential for tourism within the Dampier Archipelago/Cape Preston region is illustrated by its identification as a Pilbara *Priority Tourism Destination Area* in the Western Australian Tourism Commission's, Western Australian Tourism Strategy. The high eco-tourism potential of the region has also been identified in the Pilbara Development Commission's *Pilbara Gascoyne Offshore Islands Ecotourism Management Strategy*.

To cater for the tourism market within the study area, there are currently five tourism-based charter boat companies operating out of Dampier and these provide fishing, diving, snorkelling, swimming and island tours (Figure 35). Charter fishing is becoming increasingly popular and companies based in the study area are establishing a local eco-tourism charter association. There is presently one helicopter operator and one fixed-wing aircraft operator providing scenic tours over the study area. The Western Australian Tourism Commission expects the number of visitors to the study area to continue to increase and this is particularly likely if the profile of the area is raised as a result of the declaration of a marine conservation reserve. If this does occur, the number of tour operators will also increase. In light of this fact, CALM is currently negotiating with proponents for island-based, low-key tourism accommodation.

Nature-based tourism has the potential to make a major contribution to protecting the State's unique ecosystems, especially in coastal environments. Providing high quality experiences of the natural environment will foster greater understanding of the environment. However, unless carefully managed, increased visitation to the region also has the potential to cause environmental damage.

Many visitors to the study area enjoy wildlife observation. Whales, dugong, dolphins, turtles, birds and whale sharks are fully protected and it is an offence to disturb any of these animals. To prevent disturbance, and for visitors' safety, human interactions with wildlife are controlled through codes of conduct. Visitors are required to maintain a minimum distance between themselves and the animals. There are also maximum boat speeds within the vicinity of some animals. Nesting turtles are particularly vulnerable to disturbance and visitors are required to keep still, quiet, and minimise lighting near nesting females. Sea and shorebirds use the islands and shores within the study area during migrations and for nesting, but they are easily disturbed by noise and the presence of people. Visitor access therefore needs to be carefully managed to avoid disturbance.

Careless anchoring and mooring can cause physical damage to benthic communities, in particular corals. Appropriate anchoring practices may need to be the focus of an education program as usage increases. Trampling of vegetation and coral plus over-fishing and over-collecting of shells and other species can also cause localised environmental damage.

State Government policy recognises the relationship between the marine conservation reserve system and the tourism industry. Appropriate tourism development will be encouraged to maximise the opportunity for visitors to enjoy marine conservation reserves while ensuring such development does not adversely affect the conservation values or conflict with other uses. Commercial tourism activities within marine conservation reserves require a licence.

Mining

The Pilbara mining industry accounted for 51.2 per cent of Western Australia's mineral production in 1997/98, making it the State's major mineral producing region. Dampier is a major exporting base for the State's minerals, oil and gas.

There are major oil and gas exploration and production sites within 60 km of Karratha and the western boundary of the study area includes sections of three petroleum leases (Figure 28).

Salt production is a major industry in the Dampier area. Dampier Salt Pty. Ltd. holds a 15,000-hectare lease in which evaporation ponds have been constructed. Salt is extracted from sea-water by a simple process which relies on natural evaporation. The hot, dry climate increases the salinity of ponded sea-water to a level at which salt crystals are formed and drop out of solution. The hypersaline wastewater, called bitterns, is then disposed of and the salt crystals are dried and scooped up by bulldozers.

The Dampier Salt operation produces 3.7 million tonnes of salt per year which is worth $60 million. Fifty per cent of the salt produced in Dampier is exported to Japan and the rest goes to south east Asia, Europe, America and a small amount is exported to Africa. Salt from Dampier is used in the production of glass, chlorine and caustic soda. It is also used to de-ice roads during northern hemisphere winters and of course it is used as table salt.

The initial construction of evaporation ponds altered natural water flow and alienated the area for mangroves. The company now monitors the volume and density of bitterns which is discharged and there is also an aerial surveillance and on-site monitoring program of the nearby marine and coastal environments both in the mangroves to the west of the salt operations and on the eastern side of the Burrup Peninsula in Nickol Bay.

Processing

A fish processing factory is located at Port Samson. It is at this facility that fish are frozen in preparation for transport.

Secondary processing of minerals and petroleum adds value to the basic raw materials. The establishment of Woodside Energy's liquid natural gas facility south of Withnell Bay on the Burrup Peninsula is one of the largest processing projects in the region.

There is currently a lull in development in the Dampier area. However, additional industrial areas are now in advanced planning (Figure 36). The Maitland Estate will comprise a mainland industrial site of approximately 4,500 hectares with

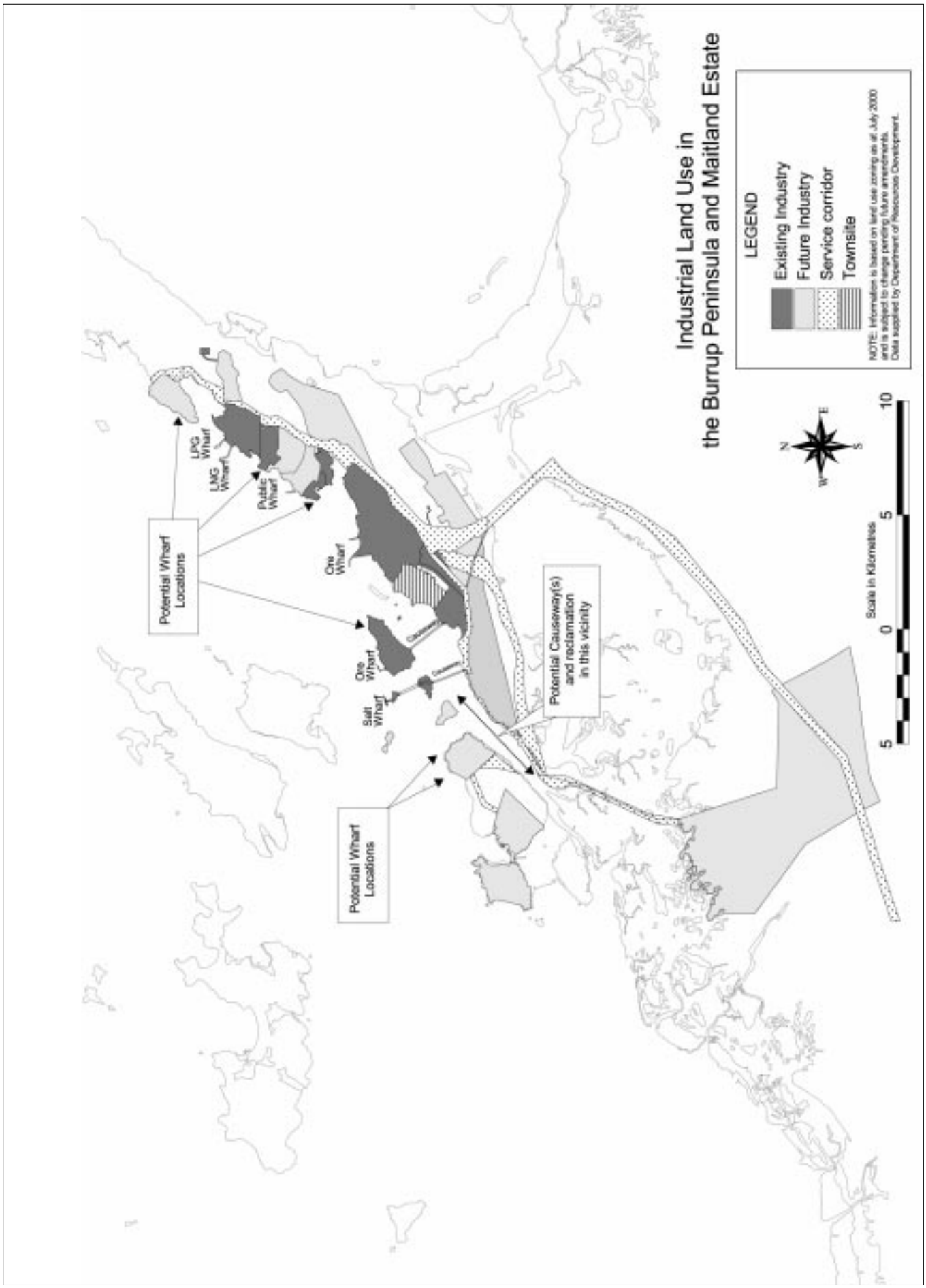

Figure 36. Proposed industrial development in the Maitland Estate, West Intercourse islands and south-west Burrup showing additional port facility requirements.

additional sites on West Intercourse Island, West Mid Intercourse Island and the south-west Burrup. Corridors and causeways crossing tidal channels between the islands and mainland sites would need to be constructed to service these facilities.

Industries that are likely to locate in these estates are those that will further process local and regional raw materials such as iron, salt and gas, and may include:

- petroleum (gas) processing into products such as liquid natural gas, methanol, ammonium nitrate/urea and synthetic oils;
- salt processing into caustic soda and ethylene dichloride;
- downstream processing of iron ore into products such as hot briquetted iron and steel;
- power-intensive industries producing ferro manganese, silicon-manganese, manganese sulphate, ferro-silicon, chrome and nickel alloys.

Several potential iron ore processing, base metals processing, LNG, petrochemicl and chemical companies have and are continuing to look at sites in the Dampier/Karratha area.

In addition, a range of support industries is expected to establish to service the major resource processing projects. Examples include fabrication workshops, industrial machinery hire companies, laboratories and fuel distribution depots.

Expansion of processing and other industrial facilities has implications for management of the adjacent waters. These include increased shipping activity and the need for additional port infrastructure. Processing facilities may also result in changes to water quality through the introduction of contaminants and changes to water temperatures.

Pastoral/agriculture

Three pastoral leases border the study area. Karratha Station is leased to Hamersley Iron. Mt Welcome Station is leased to the Mt Welcome Pastoral Company and Mardie Station is leased to Chininara Pty Ltd. These stations are used predominantly for cattle and sheep farming and the leases remain current until 2015.

Recreational activities

The waters and islands of the study area provide opportunities for land and sea-based recreational pursuits. The climate is conducive to outdoor activities between April and November and even the scorching temperatures of summer are moderated by sea breezes. Local boat ownership is very high and recreational fishing is popular, as are diving, snorkelling, surface water sports and wildlife viewing.

Recreational fishing

In Western Australia, recreational fishing is enjoyed by about 30 per cent of the population across all groups over 16 years—about 600,000 people. The Pilbara region has the highest rate of boat ownership per capita anywhere in Australia and consequently local residents have good access to local recreational fishing sites within the study area. Several different methods of recreational fishing are used including line fishing, netting and spearfishing.

Line fishing can be further divided. Game fishers target very large species such as marlin and sailfish in deeper offshore waters. Sport fishers troll for smaller pelagic species such as tuna and mackerel. General line fishers target mainly coral trout, spangled emperor, black snapper, and trevally and shore based line fishers target bream and trevally. The areas which are accessed by recreational line fishers depend on the tides and prevailing weather conditions. The distribution of recreational line fishing activity is illustrated in Figure 38. Fishers target coral and subtidal rocky reefs offshore and make use of the artificial habitat

Figure 37. About 600,000 Western Australians enjoy recreational fishing and it is one of the most popular activities within the Dampier Archipelago/Cape Preston study area.

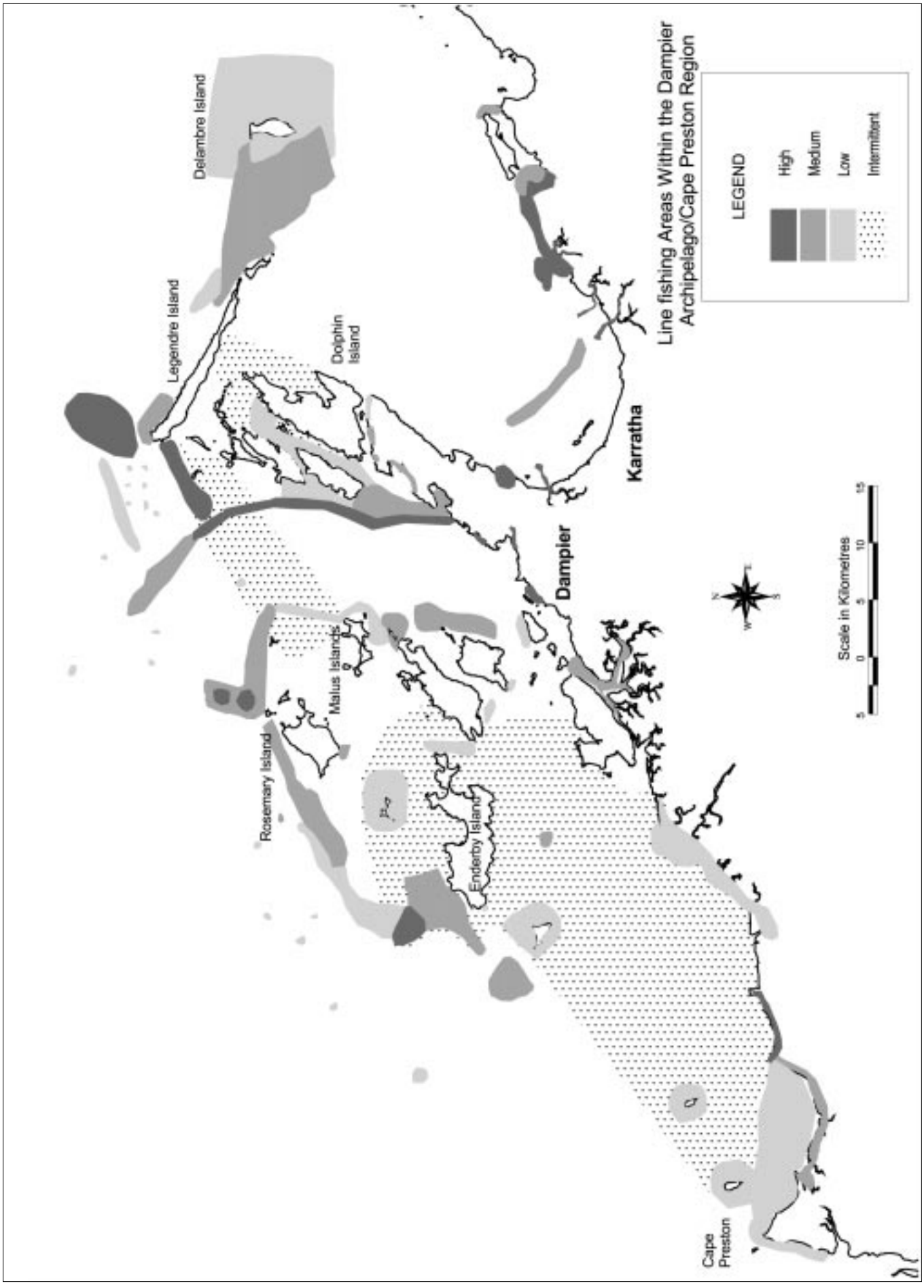

Figure 38. The distribution of line fishing activity within the Dampier Archipelago/Cape Preston region.

created by the North Rankin A Gas Pipeline in Mermaid Sound. Sites close to boat launching access are also used extensively. The recreational line fishery is managed by Fisheries Western Australia through a system of size restrictions and bag limits.

Netting in the study area is mainly a shore based activity. Haul and cast nets are allowed in some areas, but there is a prohibition on set netting north of Beadon Creek near Onslow. Fisheries Western Australia requires recreational netters to obtain a recreational netting licence. The recreation net fishery is also managed through a system of size and bag limits, forbidden catch species, gear restrictions and closed areas.

Spearfishing is carried out while SCUBA diving or snorkelling. Spearfishers operate mainly in the clearer waters offshore where they target coral trout, snapper and cod species. Size and bag limits apply to spearfishing. Divers also take the tropical ornate rock lobster by hand or by loop but the spearing of lobster is not permitted. There is no closed season for this species of lobster, but size and bag limits apply and other catch and processing restrictions are in place.

Certain species of fish are completely protected under Western Australian fisheries legislation. Of these, the potato cod, hump head maori wrasse and whale shark occur within the study area. In addition, all large specimens of rock cod species (over 1,200 mm) must be returned undamaged to the water.

Crabbing for mud and blue manna crabs is a popular activity in the study area. Mud crabs are mainly caught near mangroves and the blue manna crabs are caught mainly in Nickol Bay. Recreational crabbing is managed by controlling the catch method and implementing size restrictions and bag limits. Spawning females are protected.

Recreational prawning in the region is controlled through the method of catch and through the implementation of bag limits.

Cleaverville Beach is a popular fishing and camping location. Forty Mile Beach is another popular camping, swimming and fishing location.

Fisheries Western Australia is responsible for the conservation and development of the State's fish resources, and will shortly prepare a Regional Recreational Fishing Strategy for the Pilbara and Kimberley. This planning process will aim to protect the future quality of recreational fishing throughout the Pilbara and Kimberley. A community-based consultative committee will be established to have input into the development of the strategy, which will provide a blueprint for the long-term management of recreational fishing in the north west.

Fisheries Western Australia is introducing licensing and management arrangements for the Aquatic Charter Industry throughout Western Australia. Two new types of licence are to be introduced: Fishing Tour Operators Licences; and Aquatic Eco-Tourism Operators Licences. These operations are to be managed under recreational fishing rules. However, region specific charter management arrangements are likely to be developed in accordance with Regional Recreational Fishing Strategies.

Boating

Boating is a popular recreational activity in Western Australia, with 57,000 private vessels registered with the Department of Transport. Coastal towns of the Pilbara have the highest rate of boat ownership per capita in Australia. The study area offers excellent boating opportunities given the good shelter afforded by the islands and bays. Combined with ideal weather and sea conditions for much of the time, recreational boating is an extremely popular recreational activity with residents and tourists (Figure 39).

The Departments of Transport is responsible for all boating regulations including licensing, safety standards, marker buoys, moorings and jetties. However, mooring controls can be delegated to other agencies. The Department of Transport registration figures for 1998 show that in Dampier and Karratha alone, there were nearly 1,200 registered vessels with 98 per cent being less than 9 m in length and nearly 50 per cent being open vessels under 5 m in length.

Small boats can be launched at many locations where vehicle access is possible and formed boat ramps are located in Hampton Harbour. For more information about boat ramps, refer to the boat ramp section of infrastructure and facilities earlier in this document.

The Department of Transport has designated areas where boating is restricted within Hampton

Figure 39. Coastal towns of the Pilbara have the highest rate of boat ownership per capita in Australia.

Harbour. An area prohibiting boat access has been declared adjacent to the beach to protect swimmers and further off shore in the harbour, an eight knot speed limit applies. Access in waters surrounding wharves is also restricted (Figure 40).

Boating can result in environmental damage as a result of careless anchoring and mooring on fragile communities, in particular corals. The discharge of toilet waste and rubbish from small vessels, as well as fuel spills during refuelling, also have the potential to degrade the environment in some locations.

Swimming and diving

Beaches around the islands within the study area face in all directions so there is just about always a beach somewhere which is sheltered. Calm, relatively clear water in a warm to hot climate provides the ideal combination of conditions for swimming. Hearson Cove is a perhaps the most popular swimming beach on the mainland, but just about all sandy beaches in the archipelago and on the Burrup Peninsula are used recreationally. The Department of Transport has designated a no swimming area in close proximity to the public boat ramps in Hampton Harbour.

An estimated 15,000 SCUBA divers are trained in Western Australia each year. Many come from overseas and a significant number remain for diving holidays after training. The study area offers a variety of unspoilt coral reefs and other attractive marine habitats with a variety of large marine mammals, turtles and other charismatic wildlife. Fast tidal currents however, can make diving and snorkelling dangerous for inexperienced people.

Large numbers of divers can degrade the environment through careless anchoring, the direct breakage of fragile structures like corals and the excessive collection of trophies and momentos. As diving and snorkelling become more popular with the projected population growth associated with proposed developments, monitoring of dive sites and education programs to minimise environmental damage will become essential.

Surface water sports

Sailing is a popular recreational activity in the sheltered waters of the archipelago and there are two sailing clubs. Hampton Harbour Boat and Sailing Club members race in Hampton Harbour on a regular basis and members of the Wickham Yacht Club conduct an annual race out and around Delambre Island. In addition, the camp school at Dampier conducts sailing expeditions into the Dampier Archipelago for school children. Strong tidal currents require participants to be cautious.

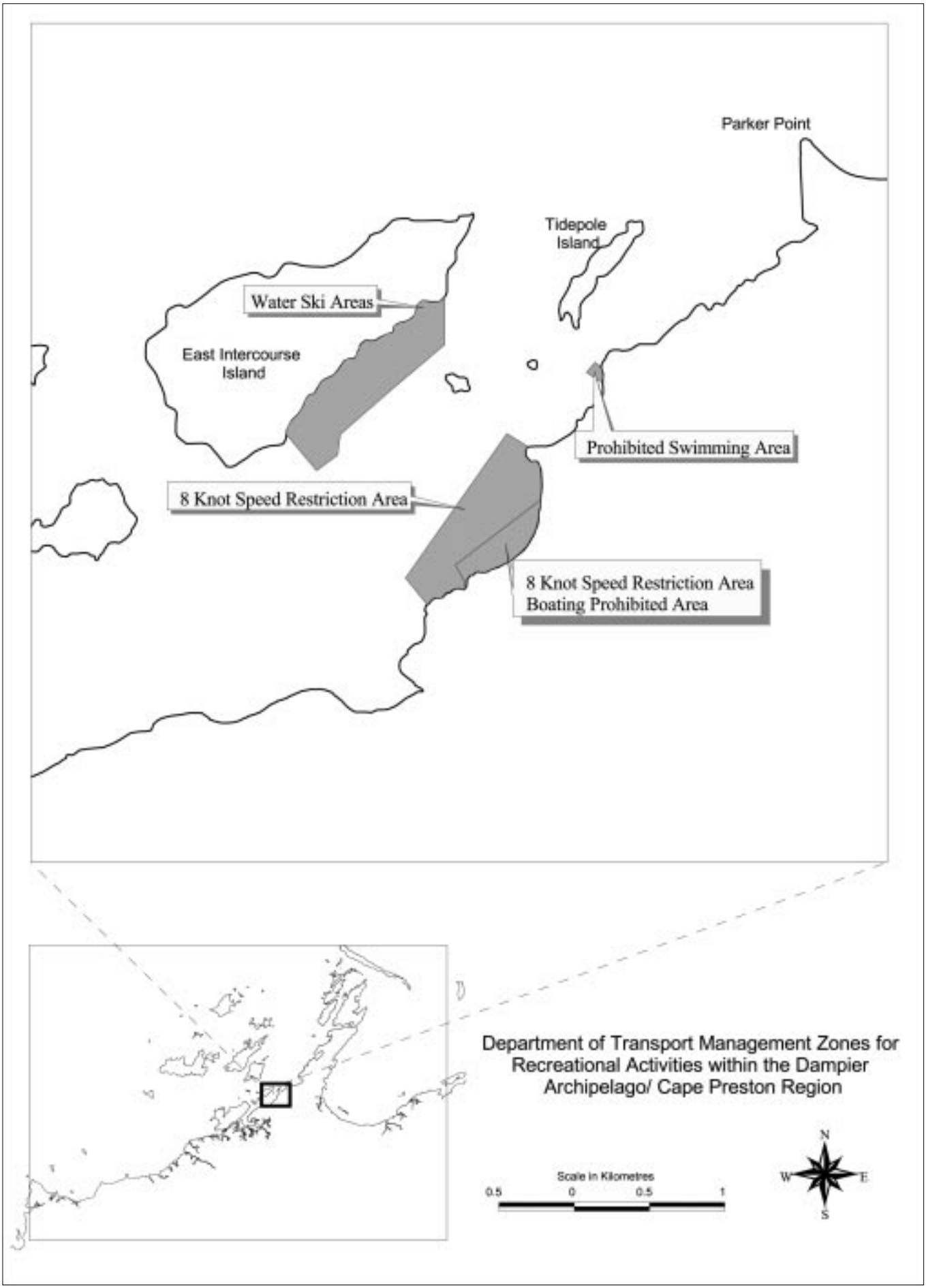

Figure 40. Department of Transport management zones for recreational activities within the Dampier Archipelago/Cape Preston study area.

Water skiing is undertaken occasionally throughout the study area where calm conditions prevail. In addition, the Department of Transport has designated a water skiing area along the south-eastern edge of East Intercourse Island. Jetskiing and the use of kneeboards and "biscuits" also occasionally takes place throughout the Dampier Archipelago with speed and access restrictions in the harbour and around wharves applying.

The calm waters also provide good conditions for sea kayaking and a small number of people venture throughout the archipelago. Strong tidal currents however, make this a dangerous activity for inexperienced people.

Windsurfing is popular within Hampton Harbour and occasionally people go further afield within the archipelago. There is a surf break on the northern end of Angel Island but there are few other surf breaks within the study area.

Coastal land-based activities

The islands of the archipelago, the Burrup Peninsula and adjoining Pilbara coast offers a wide range of land-based recreational opportunities including walking, camping, photography, picnicking, the study of Aboriginal art and nature study. There are 34 privately-owned shacks on islands of the archipelago and these, together with conventional tents provide accommodation for campers. Campers along the mainland coast often use caravans. Cleaverville Beach is a popular fishing and camping location and Forty Mile Beach is another popular camping, swimming and fishing location.

All the shacks within the Dampier Archipelago are situated in recreation reserves. In addition, fishers camp on Steamboat, Sholl, Fortescue and North East Regnard islands during fishing trips.

EDUCATIONAL VALUES

Many of the attractions discussed in the tourism industry section of this document are valuable as educational resources. In fact, nature-based tourism often provides an educational experience and educational groups could be considered as a specialist sector of the tourism market. The study area offers educators a wide range of natural and cultural resources which provide 'hands on' experiences for students undertaking courses in geology, coastal geomorphology, marine and terrestrial biology, Aboriginal culture, European history and industry. Protected sheltered waters also provide opportunities for less academic courses in water sports and other marine skills.

Figure 41. Swimming and diving are popular recreational activities in the Dampier Archipelago/ Cape Preston region.

Karratha has primary and secondary schools and there is also a TAFE college. Dampier, Roebourne and Wickham all have primary schools and Wickham has a secondary school. Secondary school children from other towns either have to commute to Karratha or board further afield. In addition, groups from other schools visit the area because of its educational resources. The majority of these visiting school groups are based at the Dampier Camp School where dormitory accommodation, catering and limited classroom facilities are available. The Pilbara Camp school runs educational programs which are primarily designed for school groups between years seven and 10. The students participate in a variety of outdoor activities and marine studies are sometimes included in the program.

COMMUNITY INVOLVEMENT

The marine environment of this State is owned by all Western Australians. Unlike the land where usage rights are defined by titles and boundaries, the sea is not private property but a common asset available to all users. While the freedom of open

access is cherished by most Western Australians, experience elsewhere clearly demonstrates that increasing levels of human usage lead to conflict among users, and eventually to environmental degradation.

The establishment of a marine reserve in the Dampier Archipelago/Cape Preston area will provide a framework to ensure environmental protection, maintain human usage at a sustainable level and minimise conflict among users. The planning process to establish a marine reserve relies heavily on community input. Local knowledge and experience of the area and the representation and mutual understanding of all interests, are essential ingredients in achieving the best outcome to protect the environment and accommodate the widest range of uses.

As facilitator of the planning process, CALM urges readers to become involved, either through their representatives on the Advisory Committee or through the public submission process.

For further information about the Dampier Archipelago/Cape Lambert area and the marine reserve planning process, contact the following CALM offices:
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Phone: (08) 9143 1488

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Fremantle, 6160
Phone: (08) 9432 5100