Montebello/ Barrow Islands

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 in the Montebello and Barrow islands region.

The Montebello and Barrow islands are located off the Pilbara coast and contain distinctive features not present elsewhere on Australia's north-west coast. The area contains a variety of habitats and supports a wide range of natural communities including coral reefs, rocky and sandy shores, mangroves, limestone pavements with macroalgae, coarse sand and rubble substrates, lagoons and channels. The coral reefs of the area are significant because they represent an important ecological link between the fringing reefs of the Ningaloo Marine Park and the oceanic reefs of the Rowley Shoals Marine Park. The abundance and diversity of coral species on these reefs is high and indicative of overall species diversity which has been described by the Western Australian Museum as among the highest of all tropical marine ecosystems off Western Australia.

The region provides habitat and nesting sites for marine turtles and some reports indicate that a significant proportion of the Western Australian population of hawksbill turtles nest on the Varanus and Montebello islands. This population of hawksbill turtles is the only large population remaining in the entire Indian Ocean. Several species of seabirds also nest on the islands and the largest roseate tern colonies in Western Australian are found in the Montebello Islands. In addition, the area provides one of the stopovers along shore bird migration corridors between Australia and South East Asia. Many species of whales and dolphins have been reported in the area, and dugong feed on seagrass in the shallow waters.

Thousands of years ago when sea levels were lower, Aboriginal people lived on what are now the islands. In 1622 the Montebello Islands were the site of the first European landing on Australian soil following the shipwreck of the *Trial*. Whaling and turtle industries operated in the area for many years and the harvesting of pearl shells has taken place since the late 1800s. During the 1950s, the Montebello Islands were the site of three British nuclear tests. At that time, up to 10,000 Australian and British servicemen worked in the area and adjacent mainland. These tests caused enormous destruction to wildlife and left behind a legacy of twisted metal, ruined bunkers and levels of radioactivity which limit safe access in a few locations.

Today, nobody lives permanently on the islands. However, up to 200 shift workers fly in for a few weeks at a time to operate petroleum production facilities on Barrow and Varanus islands and up to 25 staff live on house boats which service the pearling industry. Lights from these house boats, plus the island bases, and offshore pods and platforms are a reminder that while the area is isolated and appears to be a wilderness, it remains the focus of major industrial activities. Oil and gas production from the Montebello and Barrow islands area make up much of the State's production which was worth $4.8 billion in 1999. A cultured pearling industry also flourishes and commercial fin fishing is a significant industry in the area. Large distances from the mainland towns and harbour facilities preclude access for most recreational boat owners. However, charter boats cater for tourists who want to dive, fish, and sight see. Privately owned yachts visit the area and the channels and lagoons between the islands in the Montebello group provide popular spots for anchoring.

With the mixture of high natural, cultural, commercial and recreational values all within the Montebello/Barrow islands region, there is a potential for degradation of the environment and conflict among users. If human use was to increase, the potential for degradation and conflict might 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 Montebello/Barrow islands marine reserve, either through members of the advisory committee or through public submissions.

Additional information about the Montebello and Barrow islands 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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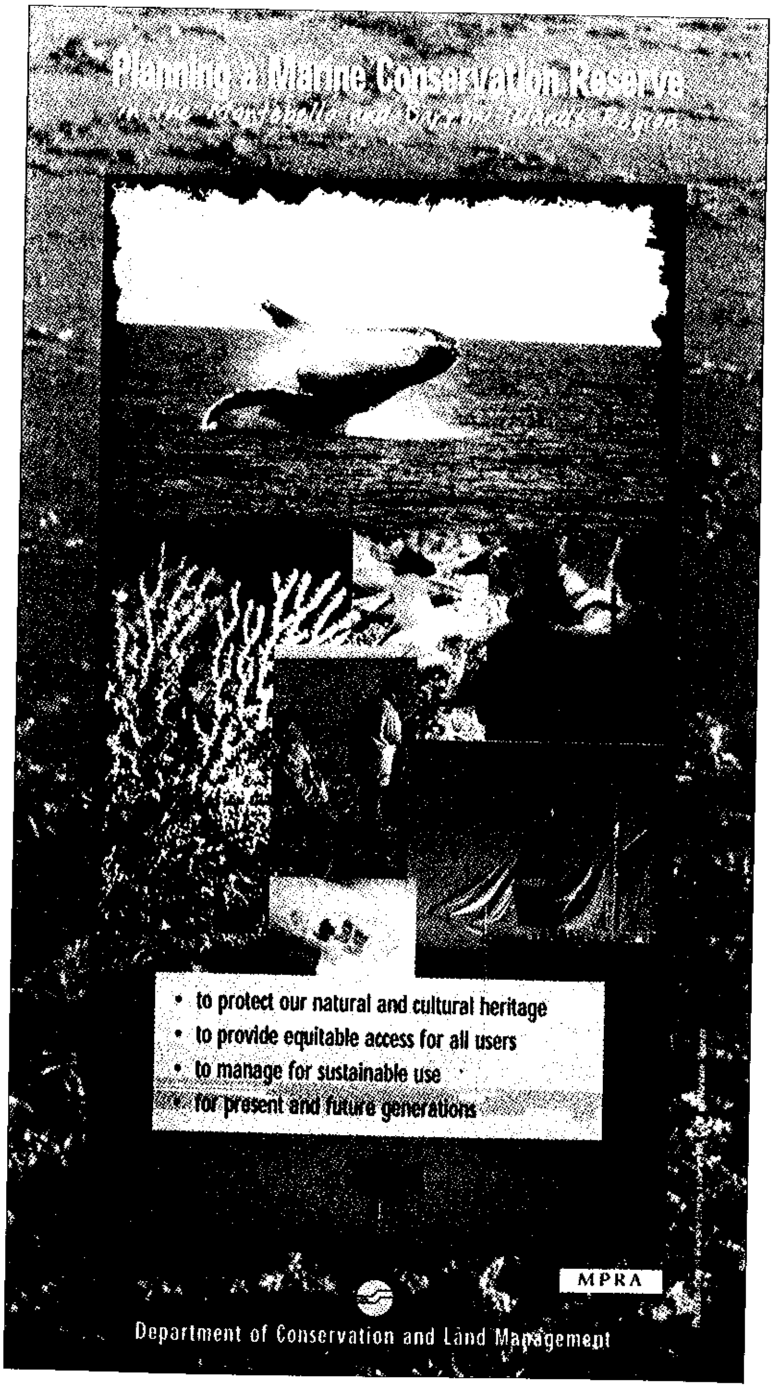

Figure 1. The Montebello and Barrow islands region is valued and used by many Western Australians.

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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. In particular, users 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 mangroves, seagrass meadows and other soft sediment communities, coral reefs, algal-covered rocky reefs and oceanic communities. 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 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 in existence 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 the major coastal ecosystems of Western Australia.

The Montebello/Barrow islands region was identified in the MPRSWG report for its ecologically significant marine and terrestrial flora and fauna. The region is located in the clearer offshore waters of the Pilbara coast and contains distinctive features not present elsewhere on Australia's north-west coast. At the same time, the Montebello/Barrow islands region has a colourful cultural history and is important to Western Australia's economy, supporting major petroleum, pearling and fishing industries.

Apart from involvement in these industries, current levels of human visitation are relatively low. This is due mainly to the remoteness of the islands and the current lack of infrastructure to support tourism. However, the stunning beauty of the region and the presence of extensive coral reefs and wildlife, such as turtles and whales, are likely to attract increasing numbers of visitors in the future.

The natural environment of the Montebello/Barrow islands region supports a diversity of commercial and recreational activities. While the environment has the capacity to sustain a level of human activities without unacceptable levels of degradation, management strategies are required to ensure that current and future human use of the area does not overload the environment and reduce the options for present and future generations. The establishment of a multiple-use marine conservation reserve provides one such management option. Historically, human activities in marine and coastal environments have been managed by a number of separate agencies and with limited involvement from the general community. Marine conservation reserves however, provide a management framework for both government and the community to work together and consider the total impact of all human activities on each other and on the natural environment.

The Western Australian Government is committed to full and open consultation before areas are created as marine conservation reserves and there is a legal requirement for public participation in the planning process. There are two phases of public participation in the planning process for the proposed marine conservation reserve in the Montebello/Barrow islands region. The first phase focuses on a planning 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 both among themselves and with the broader community in a collaborative process to assist CALM in developing advice to Government on the most appropriate 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 and a minimum three-month period is made available for the receipt of written submissions from the public.

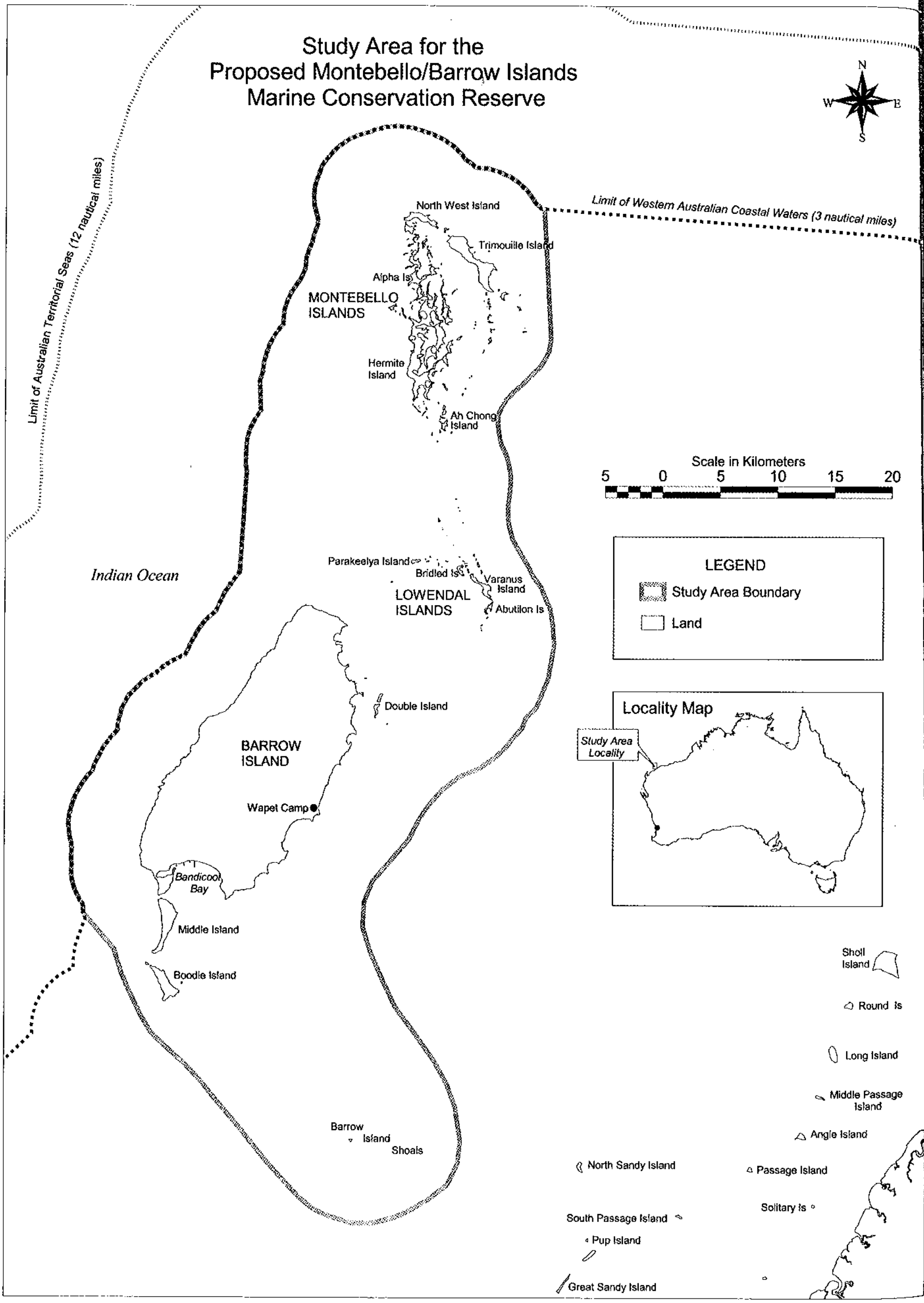

Figure 2. Proposed marine conservation reserve study area including the Montebello, Lowendal and Barrow island groups and the Barrow island shoals.

This regional perspective paper has been written to assist members of the community who have an interest in the Montebello/Barrow islands 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 Montebello/Barrow islands region. Before planning 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 extension 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 is located off the Pilbara coast between latitudes 20.29° S and 21.16° S, and longitudes 115.25° E and 115.64° E. It includes the waters surrounding the Montebello/Barrow islands region, stretching from the State Territorial limit in the west and north, to the 10 m depth contour in the east and south (Figure 2). The islands within the study area are situated to the north of Onslow and to the north west of Karratha, and range in distance off the mainland coast from 50 to 90 kilometres. The study area totals 2,099 square kilometres (km^2), of which 1831 km^2 is marine environment. It encompasses the coastal reefs on the west coast of Barrow Island and the Barrow Island Shoals in the south. The 10 m depth contour roughly corresponds with a submerged limestone platform known as the Montebello, Lowendal and Barrow Island Subtidal Ridge.

PHYSICAL ENVIRONMENT

Geology and geomorphology

The top layers of rock which cover the earth's surface within the study area are predominantly limestone. The limestone was formed from the compressed skeletons of millions of plants and animals which fell to the bottom of the sea during the past 65 million years, during the Tertiary and Quaternary periods. Beneath these 'young' layers of limestone is concealed an ancient and varied history of times when dinosaurs roamed, when extensive ice sheets covered the land, and when Australia was part of the supercontinent, Gondwana. The key events in the geological history of the Montebello/Barrow islands region have taken place during the past 600 million years.

One significant geological development was the formation and accumulation of petroleum deposits. These deposits were formed from the organic remains of terrestrial and marine 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. The area was at higher latitudes and experiencing much colder conditions.

The organically rich deposits were transformed into petroleum products by specific heat and pressure conditions. At that stage, the deposits were buried thousands of metres 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 an impermeable seal formed by domes or faults in the layers of rock. Beneath the study area the impermeable layer is Muderong Shale, formed from fine mud deposits. This lies on top of about 1000 m of porous sandstones and shales that formed from a buried river mouth or delta system. This delta drained from what is now the Exmouth Gulf region about 140 to 70 million years ago when the area would have provided habitat for primitive flowering plants, birds and even some of the last dinosaurs.

It was also during the Jurassic and Cretaceous periods that the great southern supercontinent of Gondwana split apart. This began with the formation of rift valleys that became wider and wider as the continental plates separated and drifted apart. Australia slowly turned to its present orientation and drifted northwards. These massive movements of the earth's crust created cracks and faults within the study area, into which molten igneous rocks were injected, forming structures called dykes. By the end of the Cretaceous period, 65 million years ago, the Australian continent became more stable with less crustal movement.

As the continent drifted north, it eventually made contact with the Indonesian continental plate. The pressure of contact caused the rocks to bend forming folds and faults. A series of folds occurs along the north-west coast of Western Australia including Cape Range, Rough Range and the submerged ridge which forms the backbone on which the Montebello, Lowendal and Barrow islands are located. This submerged ridge extends north from the mainland near Onslow and is called the Montebello, Lowendal and Barrow Island Subtidal Ridge. Today it has a fairly flat top about 10 m below the sea's surface. To the south, it is interrupted by Mary Anne Passage that divides the ridge into northern and southern portions. The study area covers the northern portion.

The ridge comprises an extensive area of subtidal limestone pavement, with numerous shallow banks and three island complexes - Barrow, Lowendals and Montebellos. To the south east and south west, the ridge adjoins habitats that are characteristic of the middle of the continental shelf, having depths of 10 to 20 m and relatively turbid waters. To the west and north east the ridge adjoins steeply sloping habitats with clear waters up to 30 m deep and characteristic of the outer shelf.

The shallow subtidal pavement on top of the ridge is partly covered by dynamic sheets and ribbons of limestone sands of varying thicknesses. The sands are generated both by the continuing erosion of the islands and from the skeletal remains of marine organisms. The sands are moved and dispersed by prevailing tidal currents and by storms and cyclones.

Today, the clearer waters of the shallow ridge support living coral reefs along the north western edge adjacent to the Montebello Islands, along sections of the west side of Barrow Island and in the south eastern corner of the study area. A series of large coral bommies occurs along the eastern edge of the ridge.

The study area has experienced significant changes in sea level through recurring ice ages, the most recent of which took place just 18,000 years ago. At that time, the sea level was 150 m lower than it is today and Aboriginal people lived on the exposed landmass. The subsequent rise of sea level was rapid, reaching a level 1.5 m higher than present day levels 7,000 years ago. At that time many of the islands exposed today would have been submerged or much smaller. The sea level dropped to its present level about 4,500 years ago exposing the islands as we know them today.

The Montebello Islands are dominated by lagoons, channels, intertidal embayments, intertidal shorelines, barrier reefs and shallow limestone platforms exposed to open ocean conditions. The islands are generally irregular with convoluted coastlines forming an estimated total shoreline length of 210 km. The islands lie close to one another, separated by narrow channels and lagoons. They are low lying and, of the 265 distinct islands and islets only 95 are greater than 50 m in length (Figure 3). They are composed of limestone and cross-bedded sandstones that are less than two million years old and are capped in places with sand dunes, some up to 40 m high. Most are characterised by bare rocky terrain fringed with undercut limestone rocky shores and occasional sandy beaches.

The Lowendal Island group contains more than 40 islands, islets and rocky stacks comprising eroded limestone that is less than two million years old. Shorelines are typically steep and the larger islands, including Abutilon, Varanus, Bridled and Parakeelya, have both dunes of white sand and depression deposits of orange sand. The smaller islands comprise low, steep-sided and mostly bare rocky islets and stacks, many exhibiting wave-cut platforms formed during previous interglacial periods.

Barrow is the largest island within the study area and is approximately 25 km long, 10 km wide and 62 m above sea level at its highest point. Its surface is comprised almost entirely of limestone outcrops and deposits overlain by sands. Most of the surface limestone is 26 to 57 million years old though in the centre of the island erosion has exposed older limestone deposits called giralia calcarenite. Much of its coastline has steep undercut limestone rocky shores that connect with intertidal limestone pavements. Its eastern

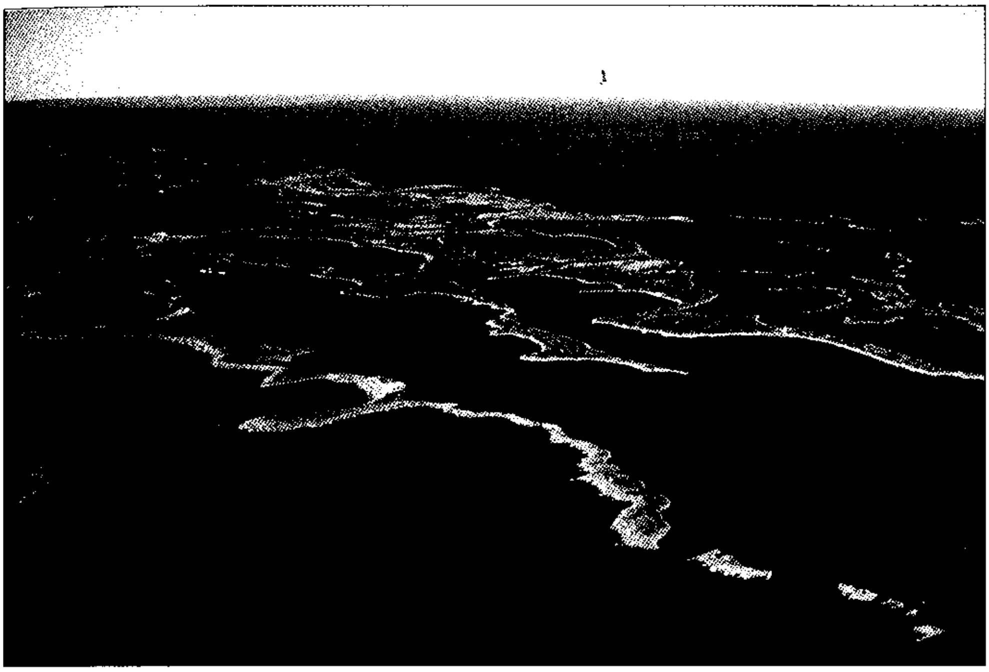

Figure 3. Aerial photo of the Montebello Islands showing their intricate and convoluted shorelines.

intertidal pavements are usually covered with sand or mud but on the more exposed western side, there are wave-cut rock platforms. There are also nine smaller islands in the Barrow Island region, Middle, Boodie, Pasco, Boomerang, Mushroom, Prince, Pelican, and North and South Double Islands.

Drainage and groundwater

Little is known about the freshwater hydrology beneath the islands. Rainfall is low and extremely variable and apart from occasional cyclones, freshwater input is low. There are no major watercourses, swamps or other surface water features on most of the islands. Barrow Island however, has some creeks and claypans that hold water after rain events. It is likely that subsurface mounds of freshwater exist but their volumes, persistence and drainage patterns are unknown.

Any subtle changes to natural drainage or groundwater quality may affect limestone cave ecosystems that support rare cave dwelling animals (see Cave-dwelling fauna section).

Climate

The climate of the study area is both arid and tropical, with seasonal characteristics mainly controlled by the large high-pressure cells that pass from west to east across the Western Australian coastline. As a result, there are two broadly defined climatic seasons over north-western Australia: a warm 'winter' from May to September and a hot 'summer' from October to April. Most rain falls during October to April when the southern course of high-pressure cells allows the tropical low-pressure rain-bearing depressions into the north-west regions of the State.

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 (Figure 4). 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 reach speeds of 20 to 30 knots near the coast in the vicinity of the Dampier Archipelago and can occasionally peak at 60 knots further offshore over the study area.

During summer, the high-pressure cells are further south, allowing a dominance of westerly to south-westerly winds generated by the interaction of low-pressure monsoonal depressions with the southern high-pressure systems. The summer onshore winds are more constant in direction than in winter. Summer sea breezes reinforce and night-time land breezes moderate the prevailing onshore winds. Coastal wind patterns are characterised by onshore sea breezes during the day and offshore winds at night.

Winds are at their weakest and most variable

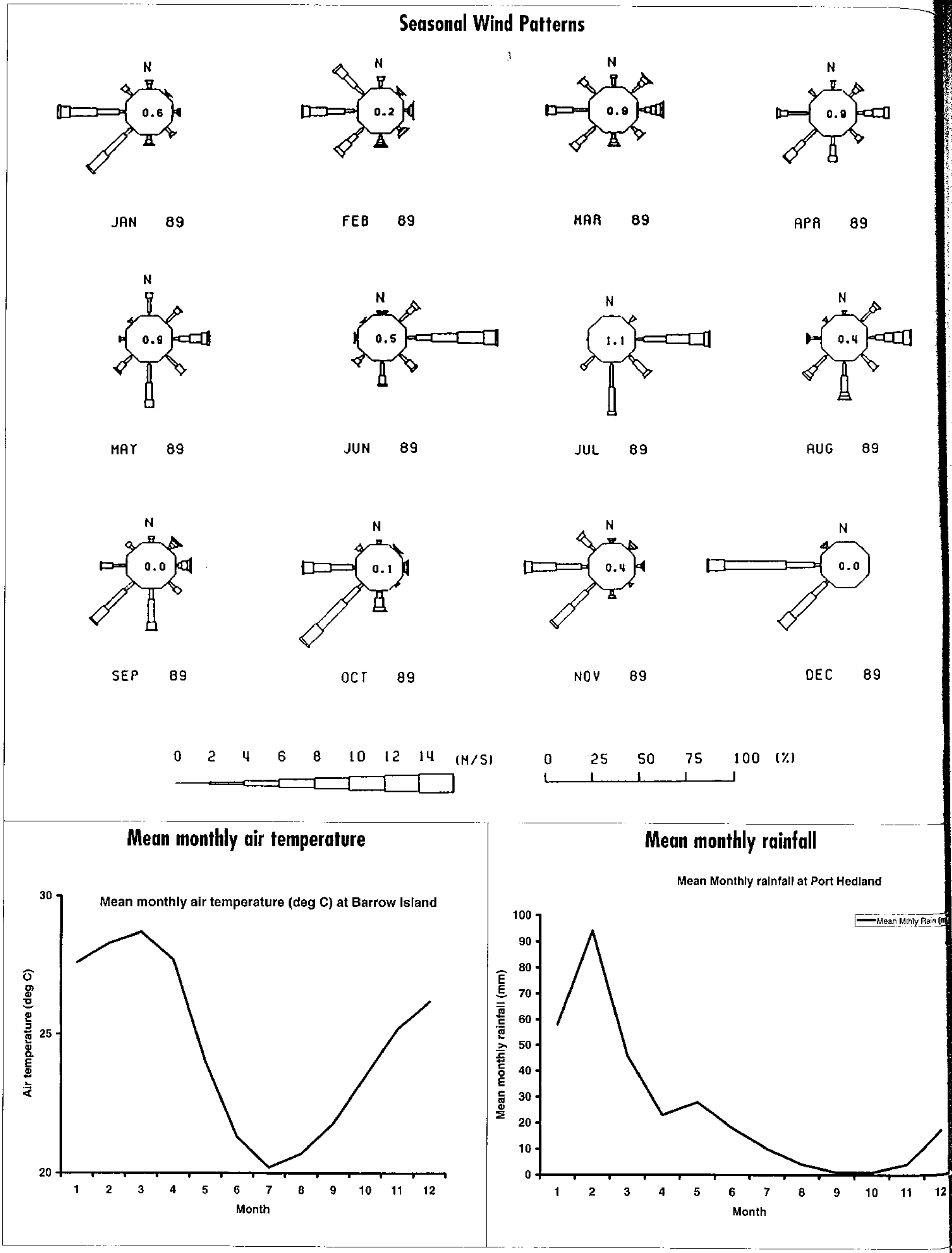

Figure 4. Seasonal wind patterns, mean monthly temperatures and mean monthly rainfall patterns along the arid and tropical Pilbara coast. Data courtesy Buchan and Stroud, WNI Science and Engineering and Bureau of Meteorology.

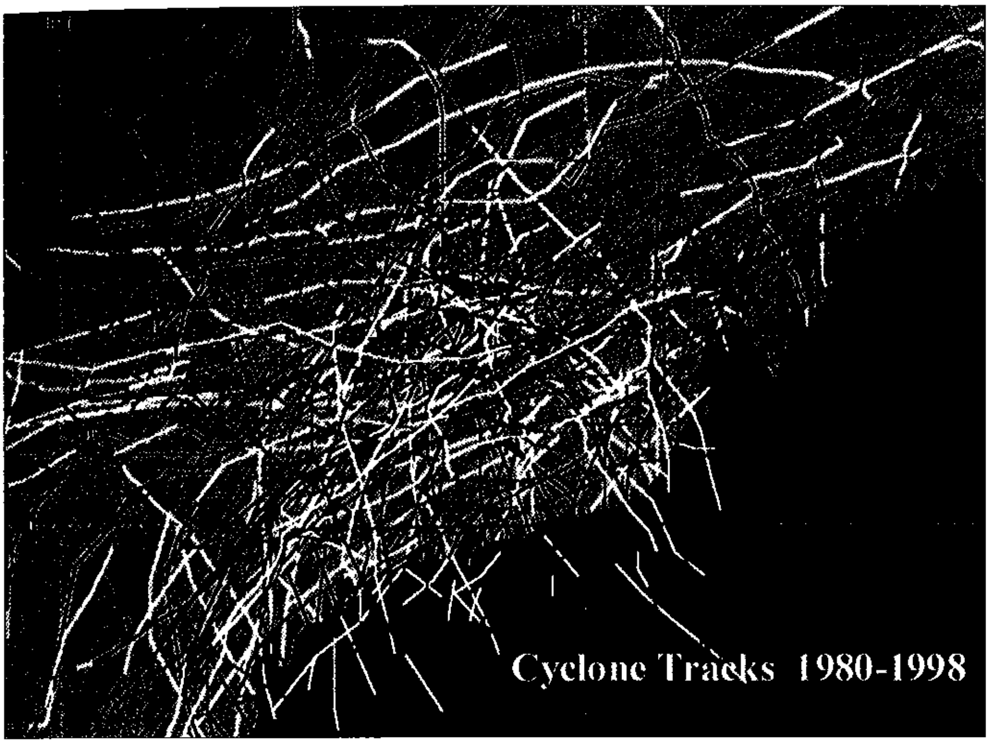

Figure 5. Cyclone tracks in the north-west of Western Australia between 1980 and 1998. Image courtesy Commonwealth Government.

during the seasonal changeovers between summer and winter, around April and August, and it is then that the weather is most favourable for recreational activities in the area. Winds typically blow from the south-west to the south-east during these periods.

Extreme winds during cyclones can exceed 150 knots. On average, about two or three cyclones occur within 350 km of the islands each summer. Fewer cyclones approach within the closer radius of 220 km and records indicate that between 1977 to 1996, 23 cyclones passed within this distance of the islands (Figure 5). Cyclones bring destructive winds, heavy rains, large surges in coastal water levels, large and violent waves, strong currents and substantial movements in coastal sediments. Cyclones are important ecologically because the waves they generate can damage corals and other benthic, or sea-bed-attached, communities. They may also re-suspend and transport sediments, which scour and smother marine organisms or lead to uncharacteristic transport patterns of larvae and other biological material. Cyclone events also influence the design and location of infrastructure associated with the petroleum, pearling and tourist industries.

Mean annual rainfall at the Harriet Oilfield near Varanus Island is about 330 mm, with more than half occurring during the January to March period (Figure 4). Rainfall varies from year to year, depending on the number of rain-bearing systems that pass close to the area. There are no evaporation data for the islands, but annual rates are likely to be similar to those at Dampier, about 3,000 mm, which far exceeds rainfall.

Air temperatures at the islands are generally more moderate than the adjacent mainland, and range between 34.2 °C and 24.8 °C in summer, and between 25.2 °C and 17.1 °C in winter (Figure 4).

The mildest and most conducive conditions for tourism and recreational activities occur during winter and spring. Climatic forces are important when considering the design of infrastructure and properly assessed contingency plans need to be in place to protect not only life and property, but also the environment.

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 Montebello/Barrow islands region are described in the natural history section of this document so the focus in this oceanography section is on the chemical and physical attributes of the waters within the study area.

Studies of the regional oceanography of the North

West Shelf have been motivated mainly by the need to calculate engineering design parameters for offshore structures such as rigs and platforms and for risk analyses associated with contamination events such as oil spills. These studies have focussed on tides, internal waves, wind-driven circulation and tropical cyclones. A broad understanding of the physical and chemical attributes however, are best described by considering all of the main components of water movement and water quality.

Water level

Tides are caused by the gravitational pulls of both the sun and the moon on our 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 pulls of the sun and moon complement one another, the tides are referred to as spring tides, which are characterised by large tidal ranges. When the gravitational pulls from the sun and moon counter, or work against one another, the tidal range is much lower and they are referred to as neap tides (Figure 6).

The tides of the Montebello/Barrow islands region are 'semi-diurnal', that is, they go through two peaks and two troughs—or highs and lows—per day with a predicted water level range of about 3.3 m during spring tides and about 0.75 m during neap tides.

Combined meteorological effects such as winds and barometric pressure change water levels in excess of predicted tides. Changes of 0.5 m are common, with cyclones capable of causing water level changes well in excess of 1 m. For example, Cyclone Vance, in March 1999, caused a surge in water level of almost 4 m above the predicted tidal level along the Pilbara coast.

The large tidal ranges have a major influence on the distribution of marine and coastal organisms. Large areas of intertidal substrates are exposed for long periods during low tides and only those species, which can withstand sustained drying or can move to the shelter of deeper water in rock pools or offshore, can inhabit these areas. Even below low tide levels, organisms which are continually submerged are influenced by waves and wind-induced mixing in conditions of very shallow water at low tides.

Waves

There are many sources of energy which 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. Waves of short wavelength 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 swell (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 shallowing continental shelf approaching the coastline from the west-south-west.

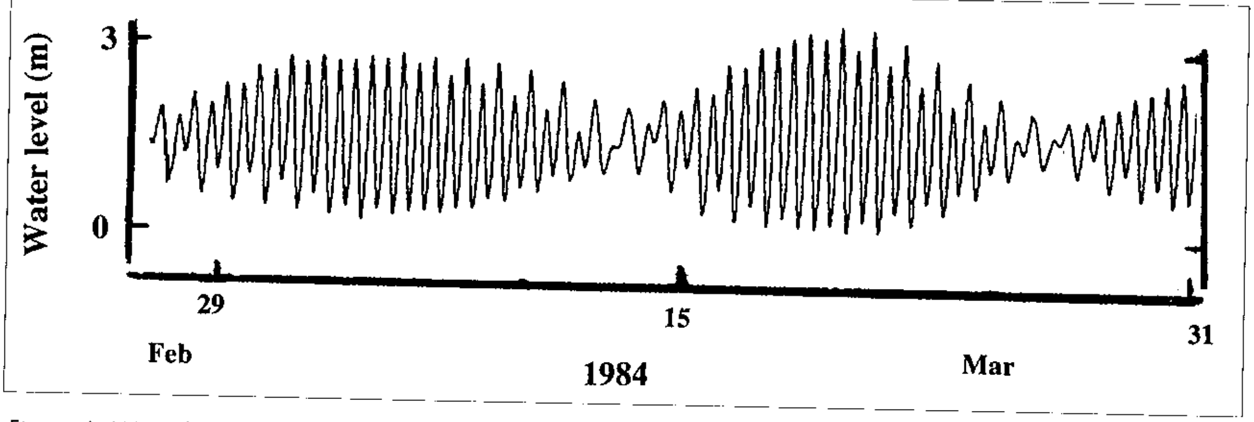

Figure 6. Water level variation showing typical spring and neap cycles recorded at the north-eastern end of Barrow Island. Data courtesy Buchan and Stroud.

Typical ocean swells are about 2 m high in winter and 1 m in summer with periods of about 12 to 16 seconds between waves. However, the swells experience significant loss of size and energy en route to the coastal zone as a result of bottom friction over the shallowing sea-bed, breaking over reefs and blocking by islands and promontories. Oceanic swells can be reduced to less than half of their original size due to these factors. Computer modelling predicts that a 3 m offshore swell from the west-south-west will arrive at the Montebello/Barrow islands region with a height of about 2 m and with a direction from the west-north-west. Swell waves 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.

Winter easterlies generate 1 to 2 m waves with frequencies of 6 to 8 seconds in the open waters off the mainland coastline. They become fully developed over the mid-shelf, just offshore from the Dampier Archipelago, and influence the sea conditions in the study area.

Internal waves occur below the sea surface and are generated by sub-sea impulses of water such as changing tides or underwater seismic activity. They travel between horizontal layers of water of differing density—a warm layer residing on a cold layer or fresher water residing on sea water of higher salinity. Internal waves approaching shallow areas steepen and break underwater just as surface waves do when they approach the shore.

Both the movement of waves over the sea-bed and the breaking of waves in shallow water, releases energy. The distribution of marine organisms reflects their adaptations to withstand these high-energy zones along, for example, coral reef crests and exposed rocky shores. The varying sizes and energy levels of waves caused by topographic effects, such as shallowing sea-bed, islands, or reefs, can also influence the ecology of marine communities by causing sedimentation rates to vary from place to place and by sorting or separating out sedimentary particles of different sizes. During storm events, when energy levels are higher than usual, wave action can cause significant direct damage to fragile ecosystems such as coral reefs. They may also damage benthic communities by re-suspending large amounts of fine sediment. This in turn can smother organisms and reduce light penetration which may inhibit the growth of marine plants.

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 (Figure 7). The Montebello/Barrow islands region is located in an area considered to be the headwaters of the Leeuwin Current. This relatively narrow coastal current which is usually less than 50 km wide south of the North West Cape, moves southwards transporting substances such as eggs and larvae from reef habitats to more southerly destinations. This suggests that the Montebello/Barrow islands region may be an important source for recruits of tropical species along the west coast, particularly for Ningaloo Marine Park. Similarly, the study area is hydrodynamically and potentially biologically connected to other marine ecosystems to the north, by flows such as the Leeuwin Current and the Indonesian Throughflow. It is therefore likely that the Rowley Shoals Marine Park is a source of recruits for tropical marine species within the study area. There is still much to be learnt about the role of regional currents in moving water over the mid-near continental shelf. They are however, undoubtedly significant in a regional context as they transport living organisms to and from the study area and assist in the recruitment process for fauna such as fish and corals in the Montebello/Barrow islands.

Also at the regional scale, internal tides moving below the sea surface towards and up onto the shelf may transport deep ocean nutrients up towards the surface. This manner of introducing nutrients onto the shelf, where they can be moved to shallower water habitats by wind and tide, is a feature of oceanography that is poorly understood

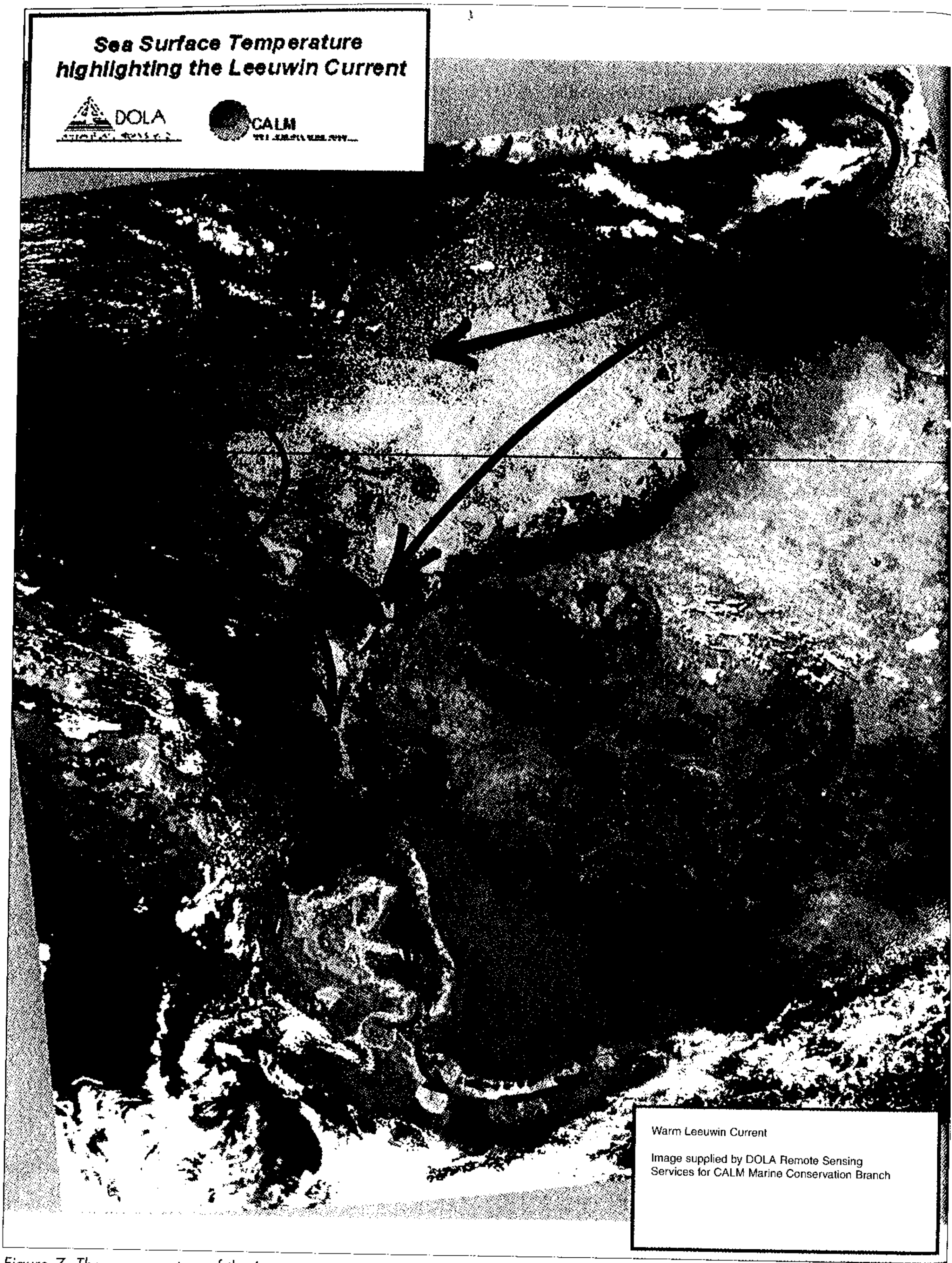

Figure 7. The warm waters of the Leeuwin current transport the eggs and larvae of some tropical species south along the Western Australian coast. Photo courtesy NOAA, CALM and DOLA.

at present. However, this phenomenon is potentially important to the overall ecology of the region and is the focus of current research.

Tidal water movements within the study area also generate strong current flows. The direction of these broad-scale flow patterns is influenced by the shape of the sea-bed and island coastlines. Tidal flows which are funnelled between the islands produce much stronger localised currents than the less constricted shelf areas surrounding the islands. Spring tides can produce currents of up to 4 knots in the shallow channels of the Montebello Islands, while south of Barrow Island, currents have been recorded to reach speeds of about 1 to 1.5 knots during spring, and about 0.2 to 0.5 knots during neap tides. Strong tidal flows also cause eddying and re-circulation in the lee of islands. These swirls can lift material up from the bottom leading to sediment re-suspension. They can also trap larvae close to the shore. The results of water movement model simulations of wind and tide-driven circulation patterns are illustrated in Figure 8.

An important feature of tidally-driven water circulation within the study area is the tendency for water to oscillate rapidly back and forth over ebb/flood tidal cycles. However, water does not return to exactly the same spot at the end of each tidal cycle. There is instead a net drift away from any one particular location. So even though current speeds may be high and water is moved over large distances, the actual flushing or exchange of original water from a particular area, may be relatively poor. During spring tides, the effect of wind-driven flushing is usually dominated by tidal circulation and water returns to nearly the same spot, with net drift typically less than about 3 km per day. However, when tides are weak such as during neap tides, the wind plays a more important role in flushing water through the region and enhances the net draft away from a site (Figure 9).

Lateral spreading due to mixing processes will complement wind and tide-driven flows and also be important in flushing eggs, larvae, sediments and contaminants. Over short periods, a cluster of eggs or larvae may be spread significantly by lateral mixing processes such as turbulent swirls and wave-induced mixing. This is a topic of the oceanography of the region that warrants further investigation.

The capacity of marine ecosystems to regenerate after damage is influenced by the dispersion of water-borne planktonic larvae. Communities with species that have long-lived larval dispersal stages may depend on 'upstream' sources for their recruitment. Most corals and many fish and crustacean species fall into this category and the long-term sustainability of a local reef community, such as that on Biggada Reef, may depend in part on planktonic larvae that originate in the Montebello Islands or the Rowley Shoals. It follows that ecosystem management of marine communities requires a sound knowledge of oceanographic processes.

Strong tidal currents also influence recreational potential within the study area. Navigation in fast flowing channels can be hazardous and caution is required when diving and participating in other water sports.

Temperature

Sea-surface temperatures around the islands range from about 20°C in winter to about 30°C in summer, with temperatures up to 33°C occurring in the shallowest areas.

Temperature is generally constant throughout the water column, due to tidal stirring that prevents the formation of any significant layering in temperature. However, under certain conditions, water may cool to form cold and therefore dense water pools in lagoons. Cold water can sink to the bottom of depressions creating vertically layered conditions where the bottom layers of water are trapped. The same can apply to salinity stratification, as described below. Poor flushing due to vertical stratification over sustained periods may cause temperature stress to bottom dwelling communities. There is also the potential for pollutants to accumulate within the trapped waters at the bottom of depressions. Poor flushing due to vertical stratification needs to be considered when assessing development proposals that would increase nutrient levels in the water.

Corals can show signs of stress, such as bleaching, during prolonged exposure to low (<18°C) or high (>32°C) water temperatures. Prolonged exposure to direct sunlight, high temperatures and desiccation (drying) can cause significant stress to corals in intertidal zones. Such conditions may occur during daytime low spring tides, when there is the greatest threat of mortality due to drying or de-oxygenation in pools. The known temperature climate of the Montebello/Barrow islands region indicates that corals in the area survive within a

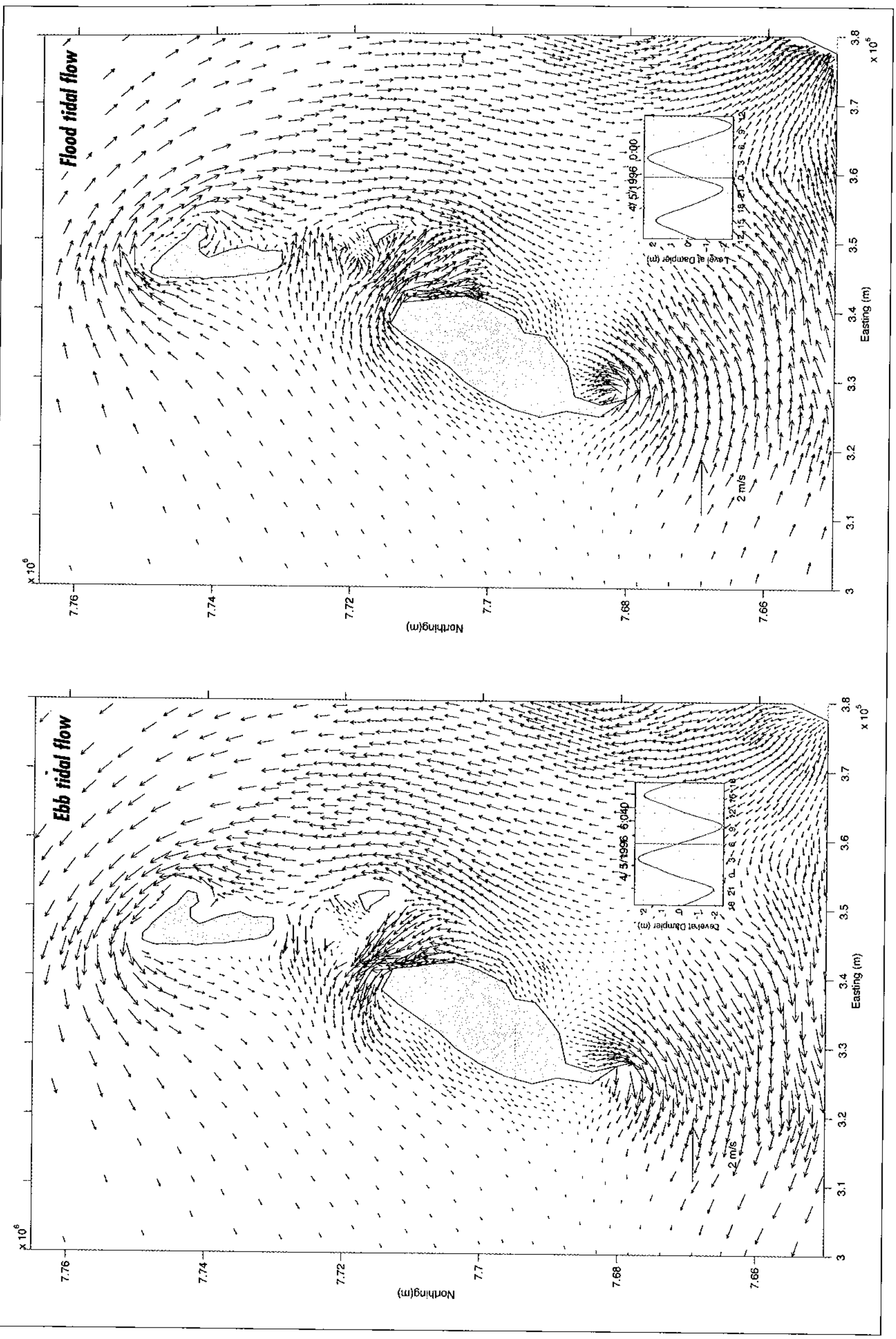

Figure 8. Typical ebb and flood flow patterns generated by winds and spring tides over a typical 40 day Autumn climatic period. Data courtesy CALM and WNI Science and Engineering.

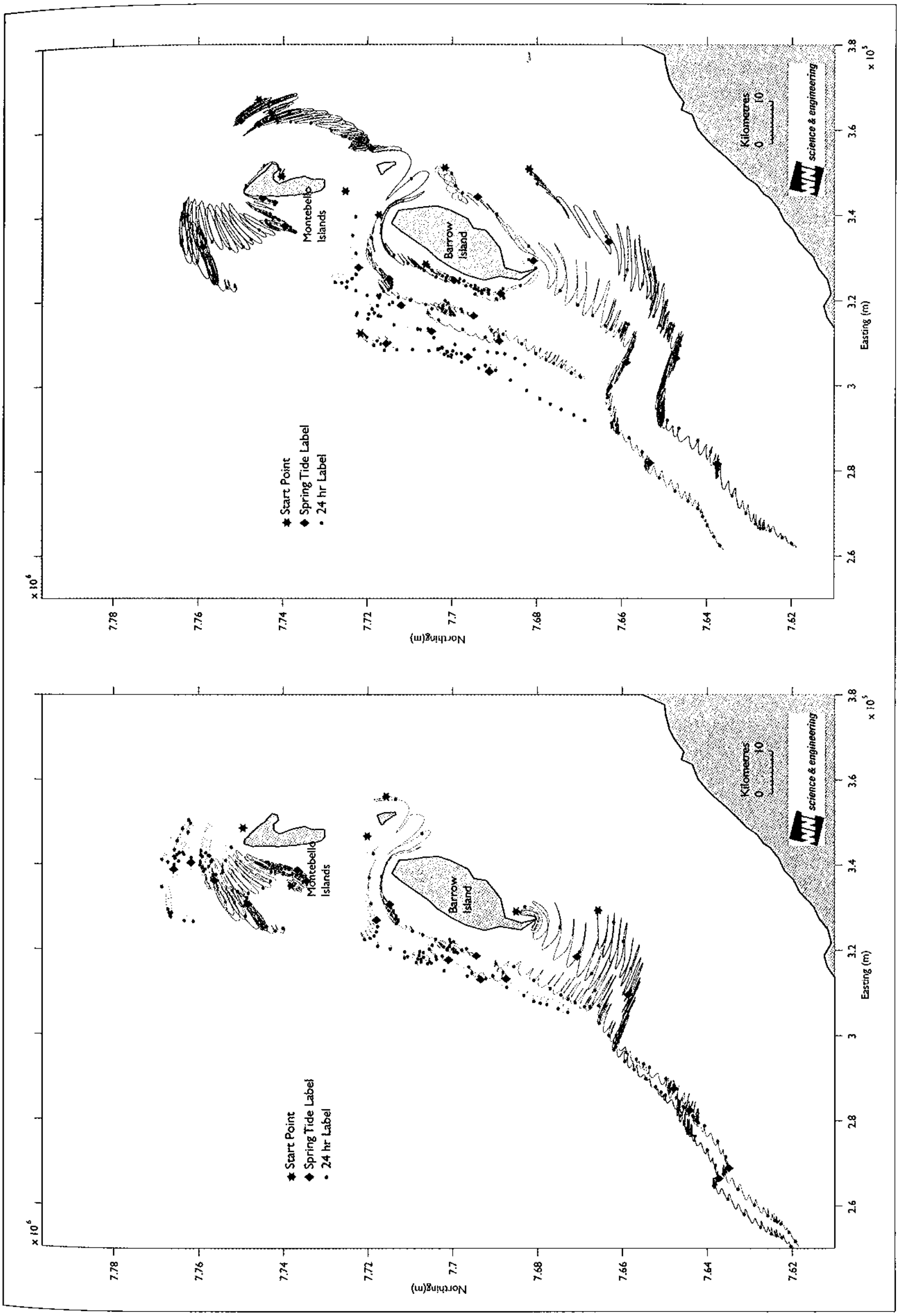

Figure 9. Although water oscillates back and forth over large distances during spring tide ebb and flow cycles, the net drift is greater during neap tides when wind-driven movements have greater influence. Data courtesy WNI Science and Engineering.

temperature range close to their natural tolerances. Human activities that result in above-normal changes to water temperatures may therefore cause corals to stress.

Natural broad-scale mortality of marine organisms as a result of oxygen depletion occurred in 1991at Dugong Reef to the south-east of Barrow Island. This occurred when a dense slick of coral spawn depleted the dissolved oxygen in the surrounding water. The oceanographic conditions at the time were characterised by a sustained period on weak circulation, consequent poor flushing and elevated temperatures. More recently, scientists from Sydney University have published a report on broad-scale coral bleaching which is believed to have been caused by a combination of global warming and natural increases in water temperatures during El Nino events.

Salinity

Studies indicate that salinity is generally constant throughout the water column around the islands, again due to the action of vigorous tidal stirring that prevents significant salinity layering from forming. The presence of moderate to strong winds also assist vertical mixing. However, water may evaporate to form hypersaline pools (high salt concentrations) in sheltered lagoons among the islands. Dense hypersaline water can occasionally sink to the bottom of deep depressions, creating vertically layered conditions. The ecological consequences of this on plants and animals are similar to those described above for temperature stratification.

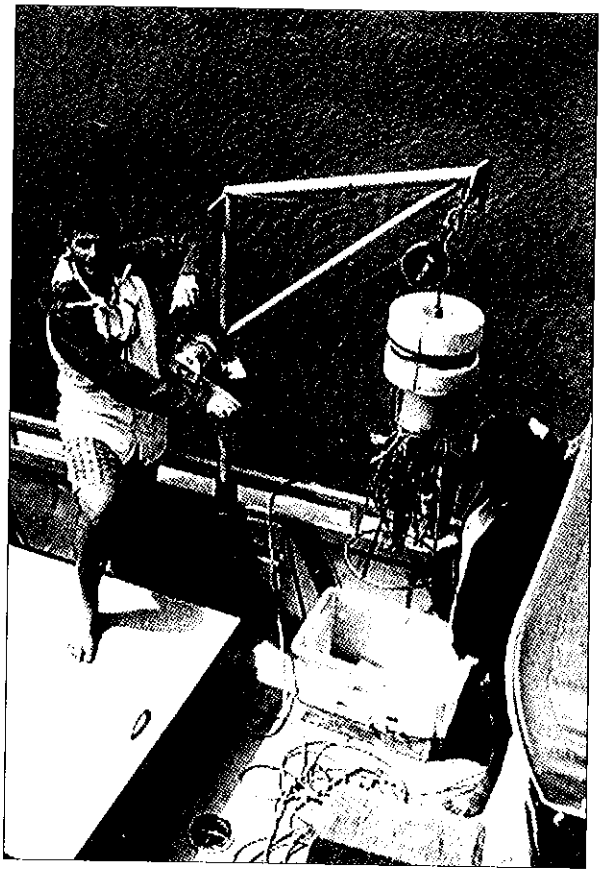

Figure 10. Deployment of water temperature and current measuring probes.

Horizontal density gradients, formed when areas of water have patches with different temperatures and/or salinities, may drive water circulation. Under these conditions, dense waters and buoyant waters flow in interleaving patterns.

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.

The central chain of broken reefs within the Montebello Islands is dissected by channels which connect the eastern and western lagoons allowing direct throughflow. The channel beds are of coarse sand and rubble substrates, created by strong currents that prevent sustained settling of fine materials. Because of energetic flows and mixing in these channels there is little opportunity for fine sediments to accumulate and turbidity is relatively low.

The lagoons and intertidal embayments that flank the central chain of the Montebello Islands are subject to weaker currents. Because flushing is limited in these lagoons fine sediments are not carried away and the areas are characterised by fine, sandy substrates and turbid water. The water is also relatively turbid between the top of the central chain and North West and Primrose islands to the north and north-west.

The western barrier reef protects the inner portions of the Montebello Islands and acts as an effective breakwater to the strong swells of the open ocean. It is broken along its length by several deep channels, which allow strong throughflow with the adjoining lagoon. The shallow open ocean habitats to the west of the Montebello Islands are subjected to relatively high wave and current action, creating extensive areas of exposed limestone pavement and reef, interspersed with patches of sand overlaying the pavement. Turbidity is relatively low compared with the lagoons and channels.

South of the Montebello Islands, water clarity decreases towards the eastern side of Barrow Island and also towards the mainland Pilbara coast reflecting the fine sedimentary content of coastal freshwater discharges.

Currently, there are few data available from which to characterise the water clarity of the study area. Because of the importance of the light climate to the ecology of benthic communities in the region, further studies to detail accurately the characteristics of the turbidity are warranted.

NATURAL HERITAGE VALUES

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) divides the marine environment of Australia into 60 different biogeographical regions, 18 of which occur in Western Australia. The Montebello/Barrow islands region lies within the Pilbara Offshore bioregion, which covers the waters seaward of the 10 m contour between North West Cape and Cape Keraurdren. This region is characterised by a series of limestone islands on a section of coast where the continental shelf is wide. The fringing coral reefs of the region are characteristically extensive and species-rich and the burrowing invertebrate fauna of the island sand flat habitats are also diverse and abundant. The Pilbara Offshore bioregion also contains a low diversity of mangroves which occur in small, species-poor mangrove communities and as scattered mangrove trees on the sheltered sides of islands. Although the majority of species present within the Pilbara Offshore bioregion area are widespread throughout the Indo-West Pacific, there is a significant number of species that are found nowhere else.

The Western Australian Government is committed to establishing a reserves system within which all bioregions are represented. There are currently no marine conservation reserves within the Pilbara Offshore bioregion. In 1994, the Marine Parks and Reserves Selection Working Group recommended that the following Pilbara Offshore areas be given consideration: the waters around the Murion Islands, and around Serrurier and Bessieres Islands in the south west; around the Montebello and Barrow Islands, and to the north east, around Bedout and North Turtle islands. A marine conservation reserve within the Montebello and Barrow islands study area would be the first to represent the special habitats and biota of the Pilbara Offshore bioregion, and because of its extensive size and central location within the bioregion, the study area is well placed to represent the habitats and species of the whole Pilbara Offshore bioregion.

High diversities of marine animals have been recorded within the region. During a 1993 survey of the Montebello area by the Western Australian Museum, 457 fish species, 635 mollusc, 85 crustacean (crabs, crayfish, shrimps and kin), 170 echinoderm (seastars, sea cucumbers, sea urchins and kin) and 150 coral species were recorded. These figures for fish and mollusc species are similar to those recorded within Ningaloo Marine Park. However, the number of echinoderms is significantly higher and the number of coral species is significantly lower than within Ningaloo Marine Park. The wide range of habitat types within the Dampier Archipelago on the adjacent mainland coast results in species numbers which are generally higher than those within the study area with records of 229 species of hard corals, 600 species of fish, 700 species of molluscs and 193 species of echinoderms. It is likely however, that as the amount of research within the study area increases, the numbers of species recorded will also increase.

Marine habitats

There have been several studies to determine the types and geographical locations of marine habitats within the study area. A combination of mapping techniques has been used including satellite imagery, aerial photography, diver observations and underwater remote video cameras. The habitat map presented in Figure 11 is an amalgamation of data that were gathered using these techniques. 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 sub-tidal sand sheets are often mobile and can cover reef platforms and algal beds from time to time.

Marine habitats are defined by physical environmental influences, substrate type and dominant marine biota. For the purpose of planning a marine conservation reserve, the main groups of marine habitats within the study area can be described as:

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

Rocky shores, shoreline reef platforms and intertidal limestone platforms

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.

The island shores within the study area are predominantly rocky limestone shores (Figure 12). Physical, chemical and biological processes often erode limestone faster in a horizontal direction than in a vertical direction and horizontal rock platforms commonly develop between tide levels. At the shoreward limit of the platform, a characteristic 'notch' is eroded, undercutting the rock face. Most of the limestone cliffs are low from just one to a few metres above high water level. In contrast, the cliffs on the west coast of southern Barrow Island, are 30 m high.

In the upper intertidal zone, the undercut may have a zone of rock oysters (*Saccostrea cucullata*) with further characteristic vertical zonation of invertebrates such as *Leptograspus* crabs, molluscs and barnacles.

Beneath the majority of the undercut cliffs, an

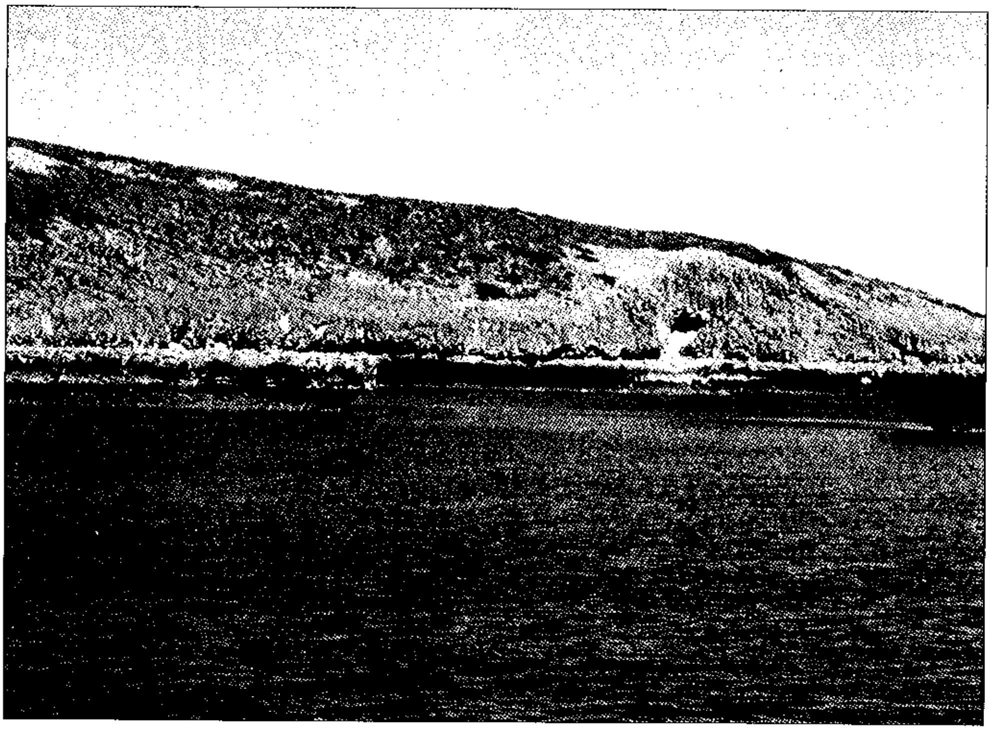

Figure 12. Undercut limestone rocky shores surround most of the islands within the study area.

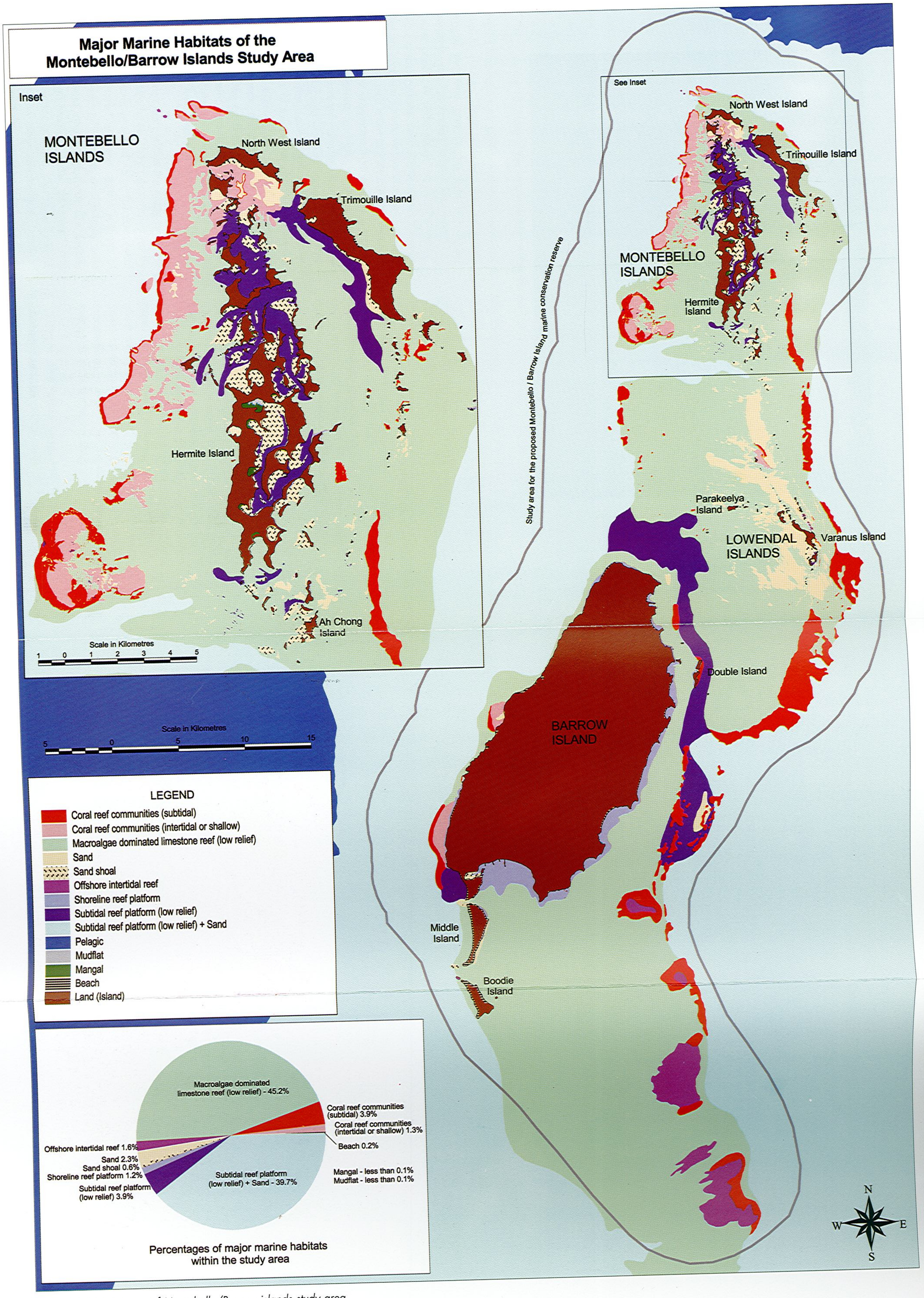

Figure 11. Habitat map of Montebello/Barrow islands study area.

Figure 13. Many of the sandy beaches within the study area are used by nesting sea turtles.

intertidal limestone rock platform extends seaward for up to 100 m. These platforms are inundated much of the time and during low tide many organisms are protected from desiccation in shallow pools. A wide range of bivalve shells, snails, crabs, worms and some small fish are found on intertidal limestone platforms and at high tide, larger fish and other marine animals come in to feed on these organisms from deeper water. 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 such as the east coasts of Barrow, the Lowendals, and the Montebello Islands, the platforms have less algal turf and are often covered by a layer of mud or sand. The amount and type of sediment present influences the distribution and diversity of species that inhabit the limestone platforms.

Offshore intertidal reefs within the study area are also limestone structures. They are surrounded by coral reef communities and form the low relief platforms associated with the central sections of offshore coral reefs in the south on the study area (Figure 11). These offshore habitats are usually exposed to high energy water movement and consequently support hard coralline algae, macroalgal turf and other macroalgae. Intertidal gastropods and other invertebrates are also present on these offshore intertidal reefs.

The abundance of invertebrate life on rocky shores provides a valuable food source for shore birds. Their use of this habitat remains largely undisturbed, as human visitation within the study area is currently low. However, if human usage patterns were to change significantly, the accessibility of rocky shores to collectors would place them under greater pressure. While direct human impact is low, these habitats are vulnerable to pollution from floating debris and contaminants, and a significant strandline litter problem poses a threat to wildlife, which can become entangled.

Intertidal mud/sand shoals and beaches

Although the majority of the coastline within the study area is rocky, beaches occur along approximately 47 per cent of the coast in the Barrow Island complex, 12 per cent of the Lowendal Island complex and 10 per cent of the Montebello Island complex (Figure 13). Many of the sandy beaches within the study area are used by sea turtles and a few beaches provide nesting sites for wedge-tailed shearwaters. The burrowing ghost crab (*Ocypode* sp.) is the most conspicuous invertebrate and a species of marine snail (*Amoria macandrewi*, a member of the attractive volutidae family), is endemic to the study area.

Most of the more exposed beaches are characterised by sand with a relatively low organic content. While some invertebrate species live buried within these sediments, their diversity is low in comparison to more sheltered conditions.

Sheltered beaches between rocky headlands and along the narrow channels between islands are inundated at high tide, but at low tide, fine-grained sands are exposed. The beaches shelve gently and large expanses of intertidal sands are exposed at low tide. These areas are covered with a surface film of microorganisms, a rich food source for marine snails, crabs and other organisms. These in turn are eaten by larger animals including fish that swim over the area at high tide. Many of the species, which live in this habitat, are buried in the substrate itself. These include bivalve shells, lampshells or brachiopods, worms, crabs and sea urchins. Their burrowing activities regularly turn over the sediment.

Extensive sand and mud flats also occur over intertidal limestone platforms in sheltered conditions. Again, these habitats support a high diversity of organisms including species that live on the surface and those that burrow into the substrate.

The abundance of invertebrate life on intertidal sand and mud substrates provides a valuable food source for shore birds. Current levels of human use provide no threat to this activity. Turtle nesting also remains undisturbed, though this activity is vulnerable to any increase in unmanaged human visitation. Soft substrate shores, like rocky shores, remain vulnerable to pollution from floating debris and contaminants, and strandline litter such as twine poses a threat to wildlife.

Mangrove communities

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

Six species of mangroves have been recorded in the Montebello/Barrow islands region. They are the white mangrove (*Avicennia marina*), ribbed-fruit orange mangrove (*Bruguiera exaristata*), yellow-leaf spurred mangrove (*Ceriops tagal*), red mangrove (*Rhizophora stylosa*), club mangrove (*Aegialitis annulata*) and river mangrove (*Aegiceras corniculatum*).

Figure 14. Mangroves possess special roots, stems and leaves. They are adapted for survival in mud which is inundated by salt water and depleted of oxygen.

Small mangrove communities occur in the protected bays of all three island groups. They range in size from isolated mangrove trees (usually *A. marina*) to multi-species mangrove stands. Mangrove communities occur along approximately 4.4 per cent of the Montebello Islands shoreline and along approximately 5.3 per cent of the Barrow Islands shoreline. The largest mangrove community in the study area is found at the end of Stephenson Channel on Hermite Island. This community covers 15 ha, with some trees up to 5 m high. Stunted mangrove trees are found in narrow fringing strips along the shores of embayments such as on the east coast of Barrow Island. In the Lowendal group, less than 0.1 per cent of the coastline is inhabited by mangroves, but *Avicennia* trees occur on the west side of Varanus Island and on Bridled Island there are pockets of mixed *Avicennia* and *Rhizophora* communities.

Because of the arid climate, none of the mangrove communities within the study area is influenced by freshwater run-off. However, the mangrove communities with mixed species are characterised by a distinctive pattern of zonation associated with their tolerance to seawater inundation. In these communities, shrublands of *A. marina* occur on the landward edge, usually around high water spring level, while at greater depths, where there is more frequent inundation by high tides, closed forests of either *R. stylosa*, or a mixture of *A. marina*, *R. stylosa* and sometimes B. exaristata occur.

Mangrove leaves are an important energy source for mangrove ecosystems. When the leaves fall onto the mud, they become a food source for microscopic organisms. These in turn provide 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 and fish. The most prominent species 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. Many organisms live within the muddy substrate and the most conspicuous borrows are those of the mud crab (*Scylla serrata*). Mangrove communities also provide valuable nurseries for juvenile fish.

Mangrove communities are affected by natural events such as cyclones and coastal erosion. Of greater concern is their vulnerability to pollution, particularly oil pollution 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 cause a hazard to wildlife. Mangrove communities are used by recreational fishers in search of mud crabs.

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°C and 29°C and at normal ocean salinity.

Reef-building coral species are found along much of the Western Australian coast 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

Figure 15. Coral reefs provide homes for many other plant and animal species.

marine life including sponges, seastars, sea urchins, crustaceans, bivalve and snail shells, worms and fish.

Coral communities occur throughout the study area and together, the shallow intertidal and subtidal reef communities cover about 7 per cent of the marine substrate (Figure 15). The best developed coral communities are on a fringing reef to the west and south-west of the Montebello Islands, Biggada Reef on the west side of Barrow Island, and along the eastern edge of the subtidal ridge on isolated bommies and more extensive patch reefs. The coral species diversity and community structure vary with the different environmental conditions such as exposure to wave action, currents and water clarity. For example, plate corals of the genus *Acropora* spp. are dominant on the western reefs, while slow growing *Porites* spp. and favids are dominant on bommies to the east of the study area. Delicate branching coral species occur in sheltered lagoonal locations. Very high percentages of live coral cover have been recorded at South West Reef. However, coral communities in lagoonal areas with higher turbidity typically have much lower live coral cover.

Although knowledge of coral abundance and diversity within the study area is incomplete, research indicates relatively high diversities with 54 genera and 150 species already recorded in the waters around the Montebello Islands and 38 genera and 117 species of hard corals recorded at Biggada Reef alone. Most corals are found in moderately clear water conditions, but five genera occur in turbid inshore waters. No doubt as further research is undertaken, the number of recorded coral species will increase to narrow the apparent discrepancy between the species richness within the study area and the 300 coral species recorded in the Ningaloo Marine Park.

Surveys of patch reefs between Varanus Island and the Montebello Islands have revealed some 41 genera and 127 species to date. Many of the patch reefs are comprised of both living and dead corals, and are frequently derived from and/or composed of a number of large *Porites* spp. colonies, with smaller areas of diverse coral communities on or around the base of each patch reef. The species-richness of the patch reefs range between 34 to 63 species at each survey site but the community structures are similar at most sites.

Coral communities are affected by storms and other natural events. Severe storms and cyclones sometimes cause significant coral breakage and further damage results from suspended sediments. Other causes of mass coral mortality include bleaching and oxygen depletion of the seawater. Bleaching occurs when corals become stressed by extreme conditions such as high temperatures and light. Under these conditions, corals expel the zooxanthellae from their tissues leaving only the colourless animal tissue and the white skeleton beneath. Corals sometimes recover from bleaching events, but there is concern that the frequency and magnitude of these episodes will increase with global ocean warming.

Seawater can become depleted of oxygen when the corals undergo mass spawning in March and April. Large quantities of spawn released into the water column (Figure 16) 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 levels of dissolved oxygen below what is required to sustain marine life. When this occurs, it is not only the corals that perish but also a multitude of snails, worms, starfish, fish and other organisms as well. A significant deoxygenation event associated with mass coral spawning occurred at Dugong Reef in 1991.

Coral communities can 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.

The study area is within the natural ranges of both the crown-of-thorns starfish (*Acanthaster planci*) and the coral eating snail (*Drupella cornus*). Significant numbers of these species have been recorded on the western and eastern sides of the Montebello Islands. 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 and during severe population outbreaks, whole coral reef communities can be significantly altered.

Whether the outbreaks of crown-of-thorns and *Drupella* snails are induced by humans or are part

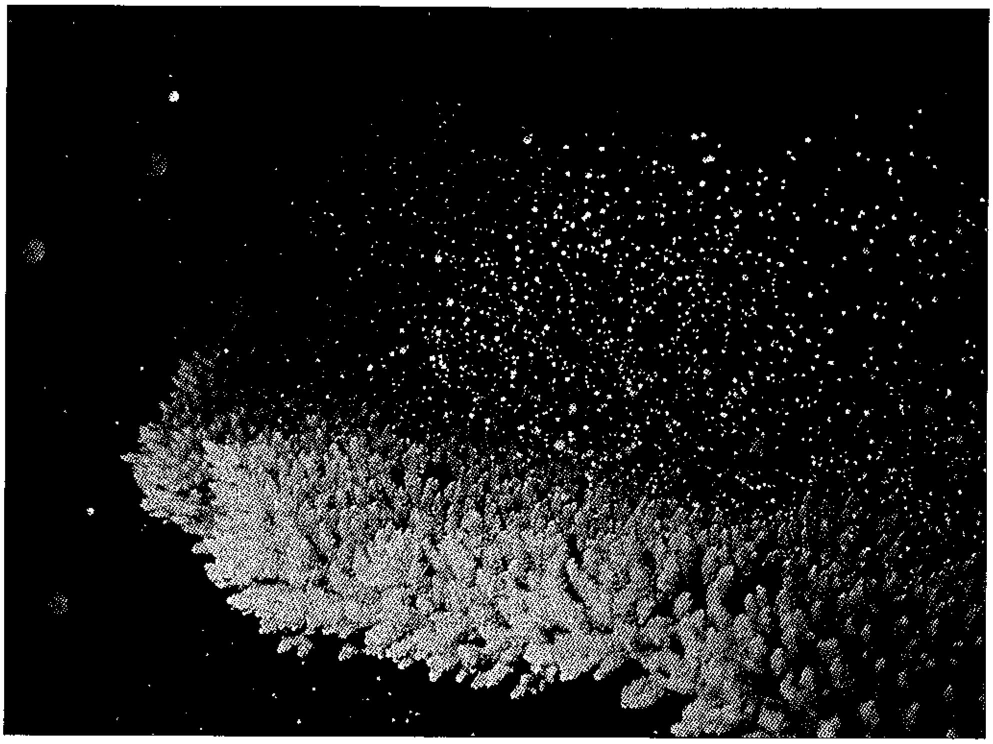

Figure 16. Corals undergo mass spawning in March and April.

of a natural cycle remains under debate. However, despite these outbreaks, the coral communities within the study area are in good condition with very little evidence of human disturbance. They are an important ecological value of the study area and are a major attraction for visitors.

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 great 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

This group of habitats covers the most extensive area under consideration (Figure 11). The flat topped limestone ridge forms the base on which these subtidal habitats occur. Most of this limestone ridge is in exposed conditions but the lagoonal sites within the island groups experience sheltered conditions. In some places, the limestone rock is exposed on the sea-bed. In other locations, the limestone is covered by sand or rubble deposits. The exact locations and thicknesses of sand sheets and banks can vary as these mobile sediments are shifted during storms. The habitats are also subject to seasonal changes associated with algal cycles of growth and senescence. These habitats occur at depths between 5 to 10 m.

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, such as those belonging to worms, are quite small, while others, like that of the predatory mantis shrimp, are significant with adjacent mounds up to 15 cm high. Fish, such as flathead, rays and flounder, together with echinoderms, crustaceans, bivalve molluscs and gastropods or sea snails also occur on or above the substrate surface.

Large species of algae, or macroalgae, grow on areas of limestone pavement and on stable rubble surfaces. Algae are simple plants that require light to grow and occur at a variety of densities from sparse to dense algal beds. Brown algae from the genera *Sargassum*, *Turbinaria*, and *Pandina* are the most dominant types. Green algae from the genera *Caulerpa* and *Cladophora* are also quite common. At some sites, strong tidal currents provide good conditions for filter feeding animals including sponges, coral colonies, sea whips and sea squirts or ascidians. These are found among the algal plants and together they provide important habitat for bivalve shells, snails, sea urchins, sea stars, crabs and fish, and nursery grounds for the juveniles of other fish species.

Seagrasses are also present on the subtidal limestone ridge habitats. They do not form extensive meadows but rather 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*. In the deeper waters over the edge of the limestone ridge, seagrass distribution is unknown. However, *Halophila spinulosa* has been recorded to depths of 20 m. The most extensive areas of seagrass within the study area are located around the Lowendal Islands. Seagrasses provide an important food source for turtles and dugong.

The balance between algal and seagrass species has been affected by elevated nutrient levels elsewhere in Australia. Nutrient-rich discharges from agriculture and industry have resulted in excessive algal growth that 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. Management of these activities would need to be considered if human 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 often these larger marine species which attract our attention, their conservation and secure future depends on maintaining the health of the whole marine environment, and the maintenance of biological processes requires the protection of 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, 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. Seven species of toothed whale and three species of baleen whales have been recorded in the Montebello/Barrow islands region (Table 1) but 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 regarding their conservation status in Western Australia. Sperm whales are the largest toothed whales in the world and adult males may reach a length of 20.5m. Killer whales, refered to as 'wolves of the sea', often hunt together cooperatively for

Table 1. Whale species sighted within the study area

Whale group	Common name	Scientific name
Baleen whales (Suborder Mysticeti)	Minke whale	*Balaenoptera acutostrata*
	Bryde's whale	*Balaenoptera edeni*
	Humpback whale	*Megaptera novaeangeliae*
Toothed whales (Suborder Odontoceti)	Sperm whale	*Physeter macrocephalus*
	Short-finned pilot whale	*Globicephala macrorhynchus*
	Killer whale	*Orcinus orca*
	False killer whale	*Pseudorca crassidens*
	Common dolphin	*Delphinus delphis*
	Striped dolphin	*Stenella coeruleoalba*
	Bottlenose dolphin	*Tersiops truncatus*

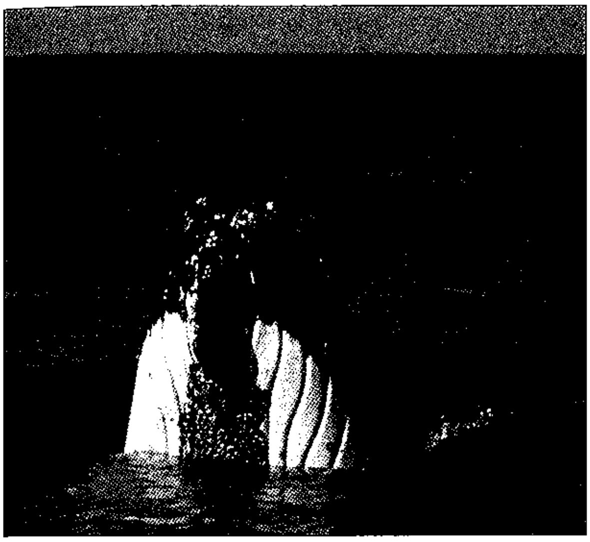

Figure 17. Humpback whales feed in the nutrient rich waters of Antarctica, then migrate north to the warm tropical waters off the Pilbara and Kimberley coasts in June and July. Photo courtesy Doug Coughran.

fish, sea birds, dugong and other cetaceans, even species much larger than themselves.

Bottlenose dolphins grow up to 3.9 m and eat 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 and interact with humans.

Populations of large baleen whales generally migrate south at the onset of the austral summer and back towards the tropics in winter, to take advantage of both the availability of abundant food in the antarctic seas during the summer months and the warm, calm tropical waters during winter. The Bryde's whale however is limited to temperate and subtropical oceans where it hunts coastal fish. Minke whales are more prevalent at high latitudes in summer. However, some animals are found across their range throughout the year. Humpback whales (Figure 17) follow a distinct migratory pathway. During the summer months, they feed in the nutrient-rich waters of Antarctica, 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. During this migration, humpbacks swim past the west and north coasts of Barrow Island and the Montebello Islands. They sometimes give birth within the study area, though the main calving area is further east off the Kimberley coast. An area of sheltered water to the west of Trimouille Island in the Montebello group is used as a resting area for female humpback whales and their young calves (Figure 18).

Humpback whales were once the mainstay of the Western Australian whaling industry and continued whaling in their Antarctic feeding grounds has pushed their populations to the brink of extinction. 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 displays such as pectoral fin slaps, tail slaps and 'breaching', which is when they leap out of the water. Cetaceans are sometimes disturbed by boating and swimming so to protect them from unwelcome human company, there are regulations under the *Wildlife Conservation (Close Season Notice for Marine Mammals) Notice 1998*, 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, depend primarily on seagrass, and may live for 70 years or more. 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 up 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 and over the submerged limestone ridge (Figure 18) although not in the comparatively large or dense concentrations seen further south in Exmouth Gulf or Shark Bay. Current knowledge on the size, distribution and migratory habits of dugong populations in the region is limited. However, the seagrass beds around the Lowendal Islands are thought to provide a valuable food source for these animals.

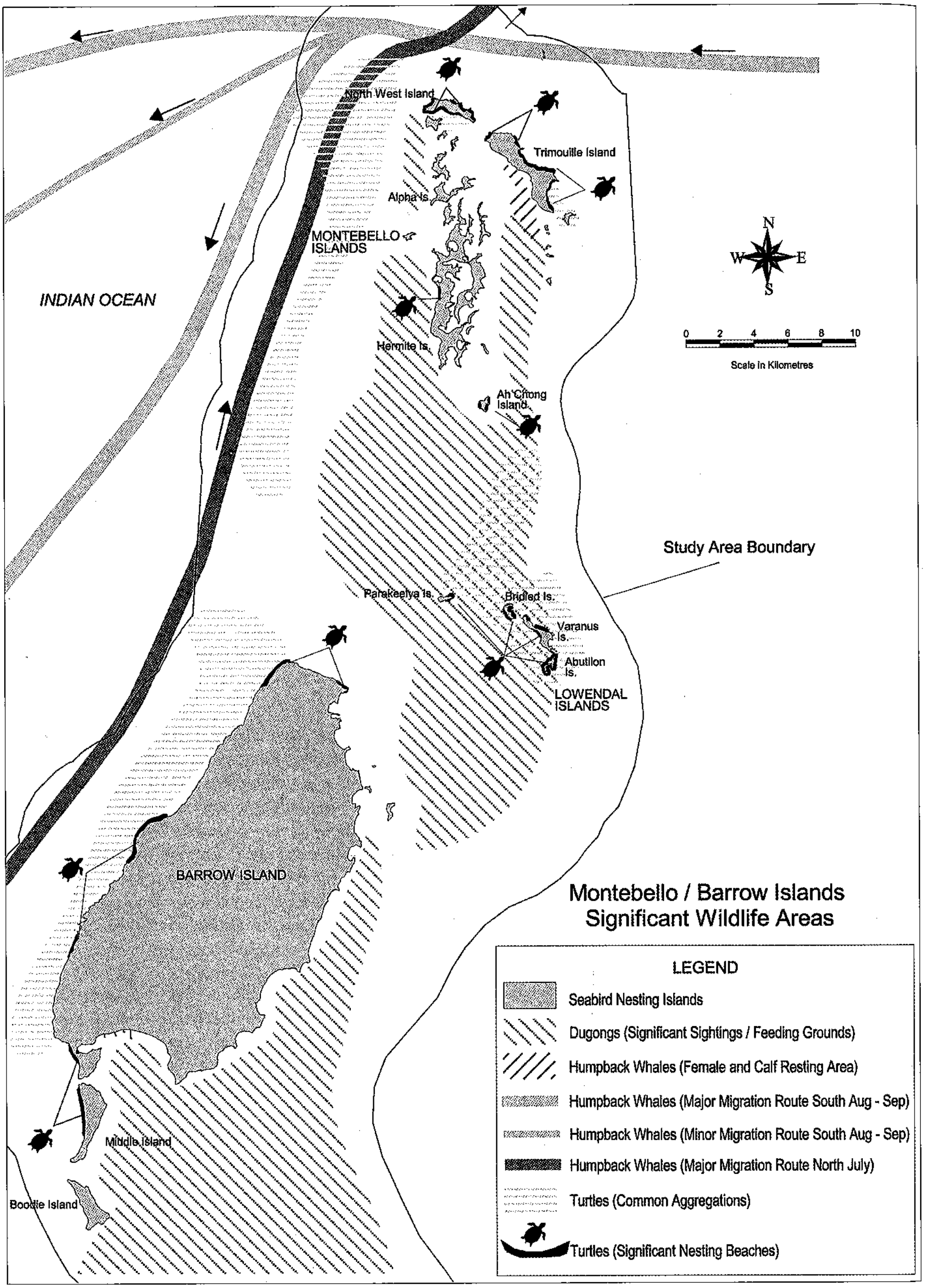

Figure 18. Wildlife distribution and patterns of use within the Montebello/Barrow island study area.

Elsewhere, dugong are hunted by indigenous people and their vulnerability to injuries from boat propellers causes concern in areas of high boat usage. The dugong is listed as *"other specially protected fauna"* under Schedule 4 (other specially protected fauna) of the Western Australian 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.

Birds

Marine birds can be 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 Montebello/Barrow islands region are known breeding grounds for a variety of seabirds. A total of 15 seabird species is known to nest on these islands and the distribution of their rookeries is listed in Table 2 and shown in Figure 18.

Wedge-tailed shearwaters, crested terns, bridled terns and roseate terns have large nesting populations on North West Shelf islands. The population of shearwaters in the region is estimated to be around 100,000 breeding pairs. In July and August, shearwaters return to their breeding islands to clean out their burrows and laying occurs during 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 have been observed offshore from their colonies, in dense flocks, called 'rafts'.

At the change of season, particularly in March, the waters to the west of the Montebello Islands are used by many migrating sea birds. Some of these are listed in Table 3.

Large nesting colonies of crested terns of up to 5,000 pairs occur in the Montebello Islands (Figure 19). They nest during late summer and winter. A significant number of pairs of lesser crested terns has been observed interspersed among nesting crested terns on Bedout Island. Larger numbers (about 700 pairs) have been recorded breeding with crested terns on Beacon Island, part of the Lowendal group.

Figure 19. Crested terns and many other seabird species nest on islands in the Montebello/Barrow islands region. Photo courtesy Terry Goodlich.

Bridled tern colonies occur on many of the islands and rocks of the Lowendal group and southern Montebello Islands. Bridled Island has a large colony of around 4,000 breeding pairs, but the total population in the region could be around 15,000 to 20,000 breeding pairs. The bridled terns of north-west Western Australia are migratory, wintering in the northern Indo-Pacific. Egg laying starts in mid December, fledging occurs in March and after the breeding period, the terns start their winter migration in May.

The largest roseate tern colonies recorded anywhere in Western Australia are found in the Montebello Islands. Colonies of up to 4,000 pairs nest in winter and large flocks can be found in the island group all year round. They also nest on the Lowendal islands. In addition, large flocks of fairy terns feed in the local waters which probably indicates significant breeding populations of this species too.

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.

Table 2. The distribution of nesting seabirds in the Montebello/Barrow islands region

	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 cormorant *(Phalacrocorax varius)*	Pied oystercatcher *(Haematopus longirostris)*	Roseate tern *(Sterna dougallii)*	Silver gull *(Larus novaehollandiae)*	Sooty oystercatcher *(Haemotopus fuliginosus)*	Wedge-tailed shearwater *(Puffinus pacificus)*	White-bellied sea-eagle *(Haliaetus leucogaster)*
20 30 92 S 115 31 64 E															
Abutilon Island			•									•			
Ah Chong Island				•				•						•	
Ah Chong - 1st islet to NW				•											
Ah Chong - islet to SSW								•							
Alpha Island				•				•						•	
Barrow Island		•				•		•		•					
Birthday Island														•	
Black Rock															
Bluebell - 2nd islet to N								•							
Bluebell - islet to N				•				•							
Bluebell - islet to NW					•										
Bluebell - islet to S				•										•	
Bluebell - islet to W								•							
Bloodwood Island						•		•							
Boodie Island				•		•		•				•		•	•
Boomoorang Island								•					•		
Bridled Island			•						•			•		•	
Bridled Island - 2nd island to NE									•						
Brooke Island												•		•	•
Buttercup						•		•							
Campbell Island								•							
Carnation - island to SW					•			•				•			
Carnation - islet to S								•							
Carnation - islet to W									•						
Crocus Island		•													
Crocus - islet to E								•							
De Delion Island			•									•			•
Dahlia Island			•								•				
Dahlia - islet to W											•				
Daisy Island					•			•							
Dandelion Island				•							•				
Delta Island															
Double Island						•		•		•			•	•	•
Epsilon Island					•										
Fairy Tern Island				•			•	•							
Flag Island				•	•								•	•	
Flag - islets to S											•				
Foxglove Island				•				•							
Gannet Island											•				
Gannet - islet to N											•				
Gardenia Island				•				•				•		•	
Gossypium			•					•						•	
Hermite Island								•							•
Hermite - islet to S				•											
Hermite - islet to W															

	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 cormorant *(Phalacrocorax varius)*	Pied oystercatcher *(Haematopus longirostris)*	Roseate tern *(Sterna dougallii)*	Silver gull *(Larus novaehollandiae)*	Sooty oystercatcher *(Haematopus fuliginosus)*	Wedge-tailed shearwater *(Puffinus pacificus)*	White-bellied sea-eagle *(Haliaetus leucogaster)*
Hibbertia Island				•			•								
Hollyhock Island								•		•					
Howe Island															
Ivy Island				•				•							
Ivy - islet to ESE											•				
Jonquil Island															
Kincup Island														•	
Marigold Island															
Melaleuca Island															
Middle Island	•	•		•			•	•		•		•	•	•	
North Double Island						•		•						•	
North West Island								•							•
Overhaning Rock															
Pansy Island			•											•	
Parakeelya Island			•									•		•	
Pasco Island															•
Primrose - islet to NE				•											
Primrose - islet to N								•							
Renewal Island				•				•		•		•			
Rose Island															
South East Island			•									•		•	•
South Double Island	•					•		•						•	
Spar Island															
Trimouille Island	•			•				•							•
Tringa Rock															
Varanus Island	•		•	•	•				•	•	•			•	

NB: Shaded rows indicate either lack of information or absence of nesting birds.

Table 3. Some migratory sea birds using the Montebello/Barrow island study area

Common name	Scientific name	Migration information
Streaked shearwater	*Calonectris leucomelas*	From Japan
Hutton's shearwater	*Puffinus huttoni*	From New Zealand
Bulwer's petrel	*Bulweria bulwerii*	From the tropical northern Pacific
Wilson's storm petrel	*Oceanites oceanicus*	In passage from the Timor Sea to the Antarctic
White-faced storm petrel	*Pelagodroma marina*	From south-western islands of Western Australia to the Arabian Sea
Bridled terns	*Sterna anaethetus*	From south-western islands of Western Australia
Brown noddies	*Anous stolidus*	From the Abrolhos Islands

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 and 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.

No bird surveys have been undertaken in the study area during the spring and autumn months which are the peak periods for sighting migratory waders elsewhere along the Kimberley and Pilbara coasts. However, casual observations indicate that the study area is an important resource for a variety of migratory bird species that rest in the area and feed on the buried worms, bivalves and other animals in the sand and mud flats.

One of the resident waders found within the study area is the beach stone curlew (*Esacus magnirostris*). This species is of interest because of its uncertain conservation status, and the independent ornithological organisation, Birds Australia, regards it as 'vulnerable'. There are many resident pairs of beach stone curlews within the study area all year round.
Many of the sea and shore birds within the study area are covered by international treaties with Japan and China, and Australia therefore has an international obligation to protect these species.

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 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.

Marine reptiles

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

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 predators, and it is estimated that only five out of 100 reach the open ocean and only one or two survive to breed.

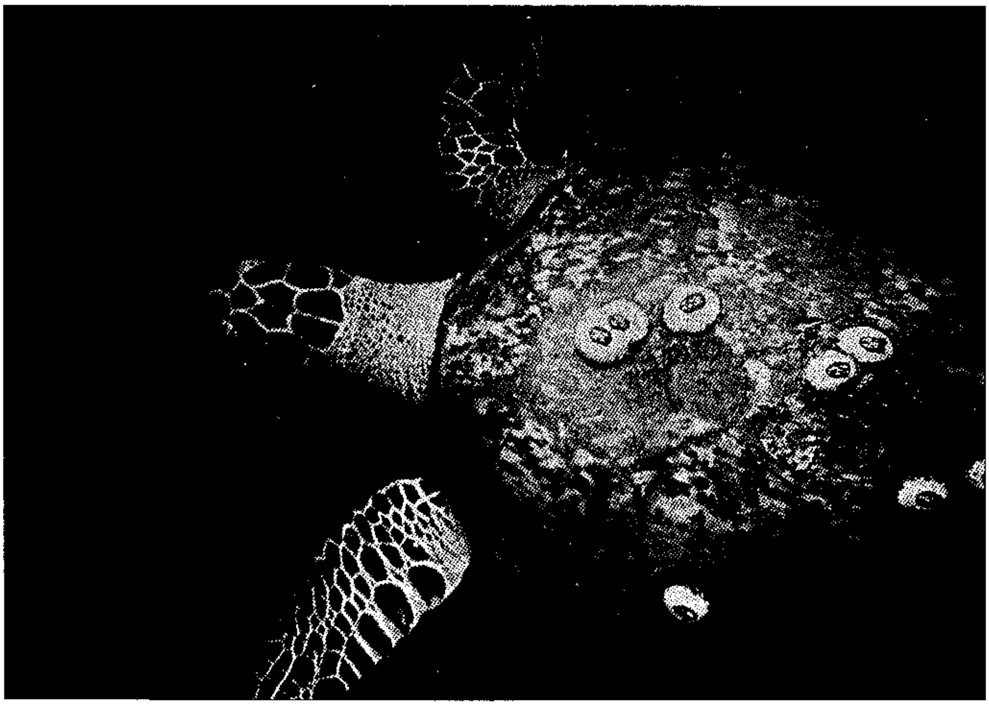

Figure 20. The study area provides an important habitat for marine turtles.

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

Green turtles are found throughout tropical and subtropical waters but are heavily exploited in many 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.

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. There is concern that their populations are declining in Australia too, possibly because they are drowning in trawl nets. The number of nesting loggerheads within the study area is lower than that of green turtles and the Montebello/Barrow islands region is the northern limit of their Western Australian breeding range. Loggerhead turtles migrate from their feeding grounds in the Northern Territory, Shark Bay, the Gulf of Carpentaria and Indonesia to breed within the study area. They feed on shellfish, crabs, sea urchins and jellyfish.

Hawksbill turtles are found worldwide in tropical and warm temperate waters. 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 the species remaining in the entire Indian Ocean. None of the tagged hawksbill turtles 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.

Flatback turtles occur mainly in the tropical waters of northern Australia with low numbers recorded in Indonesia and Papua New Guinea. They breed only in Australia and nesting females tagged in 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.

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, with only a few nesting in Western Australia. 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.

It is likely that nearly all of the sandy beaches within the study area are used for nesting but the major nesting sites occur on Middle and Boodie islands, the west coast of Barrow Island, the four largest islands in the Lowendal group and on Ah Chong, Trimouille and North West islands of the Montebello Islands group. Favoured beaches are those that face away from the island groups towards the open ocean rather than those facing the intricate channel systems (Figure 18).

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 busy rookeries and a State marine turtle management plan is currently being prepared by CALM. There are also concerns that lights used at petroleum and pearling industry facilities within the study area can disorientate turtles. Fortunately, turtles appear less sensitive to the yellow/red end of the colour spectrum, so the impact of gas flares is low. However, fluorescent and other lights attract hatchling turtles which then fail to go out to sea. Consequently, many of the lights used at petroleum industry facilities have yellow filters or are screened from the coast. Where possible, low vapour pressure sodium lights are used, because they produce hardly any light at the blue/green end of the spectrum.

The uncertain conservation status of sea turtles has been recognised in wildlife legislation. All five

Figure 21. A total of 457 species of fish has been recorded within the study area. Photo courtesy Fisheries WA.

species of marine turtle that occur within the study area are included in a Draft Recovery Plan prepared by the Commonwealth Government. Green, hawksbill and leatherback turtles are listed as *"vulnerable"* under the Commonwealth *Endangered Species Protection Act 1992* and the loggerhead is listed as *"endangered"*. Under Western Australian legislation, green and hawksbill turtles are not afforded any special status but are listed among the priority species to be kept under review. Loggerhead and leatherback turtles are listed as *"specially protected fauna"* under Schedule 1 (rare or likely to become extinct) of the Western Australian Wildlife Conservation Act. The flatback turtle is not listed under Commonwealth legislation or State legislation but is treated as *"rare or insufficiently known"* in the Draft Recovery Plan.

Of the 22 Western Australian species of sea snakes, 11 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*) have been recorded as far south as Exmouth Gulf and they are occasionally observed swimming for great distances out to sea. Saltwater crocodiles require areas of freshwater in which to breed and while it is possible that they may occasionally visit the study area, it is generally outside their range.

Fish

A 1993 Western Australian Museum survey of the Montebello Islands reported a total of 457 fish species belonging to 76 families. Most of the species have relatively wide distributions throughout the Indo-West Pacific region but a small number of species are found only in the north-west region. Two of the fish species listed, *Doryrhamphus multiannulatis* and *Phoxocampus belcheri*, from the pipefish family Sygnathidae, represent new records for Australia.

Nearly all of the fish species listed have either eggs or larvae that are dispersed in the water column so it is possible that the majority of juveniles found in the study area come from elsewhere, such as the Dampier Archipelago, Rowley Shoals and outer reefs upstream in the Leeuwin Current. Similarly, the eggs and larvae produced within the study area may be of importance for recruitment in areas further west and south.

Some of the fish species found within the study area are important to commercial and recreational fishers. These include sharks, north-west snapper (*Lethrinus* spp.), Spanish mackerel (*Scoberomorus* spp.), red emperor (*Lutjanus sebae*), coral trout (*Plectropomus* spp.), sea perch (*Lutjanus* spp.), golden trevally (*Gnathanodon speciocus*) and cod (*Epinephelus* spp. and *Cephalopholis* spp.).

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 some of these occur within the study area. The potato cod (*Epinephelus tukula*) grows up to 1.4 m long and is often inquisitive, approaching delighted recreational divers. The hump head maori wrasse (*Cheilinus undulatus*) can grow up to 2.3 m long and also occurs within the study area. Another fully protected fish is the whale shark (*Rhincodon typus*) which is the largest fish in the world. In a recent survey of the Great Sandy Island Nature Reserve, a whale shark was recorded off Cape Preston and it is likely that they also visit the study area but have not been encountered.

Island Biota

Although the landscape of the Montebello Islands is dominated by spinifex (*Triodia* spp.) there are more than 100 different kinds of plants which have adapted to live in the harsh dry and hot conditions on these islands. The native island animals however have not prospered so well.

In the late nineteenth century, pearlers camping on the islands were probably responsible for introducing both cats (*Felis catus*) and the black rat (*Rattus rattus*). These introduced animals subsequently caused extensive damage to native wildlife. Not even the atomic tests on the Montebello Islands in the 1950s eliminated the feral cats and rats from these islands but served instead to demonstrate their resilience and surprisingly, the resilience of many of the other plant and animal species. Cats and rats have only recently been eradicated following an intensive and prolonged program by CALM scientists.

Biological surveys of land fauna were made prior to the introduction of the cat and the black rat, and both before and after the atomic explosions. The golden bandicoot disappeared from Hermite Island prior to 1912, and the spectacled hare-wallaby disappeared between 1912 and 1950. Some bird species, such as the crimson chat and rufous whistler also disappeared before the atomic explosions, and again the cat and rat are likely culprits. The spinifex bird and the black and white wren were last recorded on the Montebellos in 1950 and it is likely that the extensive fire that followed the atomic explosions, together with predators rendered the area unsuitable for these predominantly grassland birds. Burrowing fauna, such as reptiles (and rats) that were underground at the time of the atomic testing, were able to survive its effects. The Hermite Island worm lizard (*Aprasia rostrata rostrata*) has been recorded only once, in 1952, and is listed as "*threatened*" under Western Australian legislation.

When the eradication of cats and rats on Hermite Island is scientifically confirmed, reintroductions of

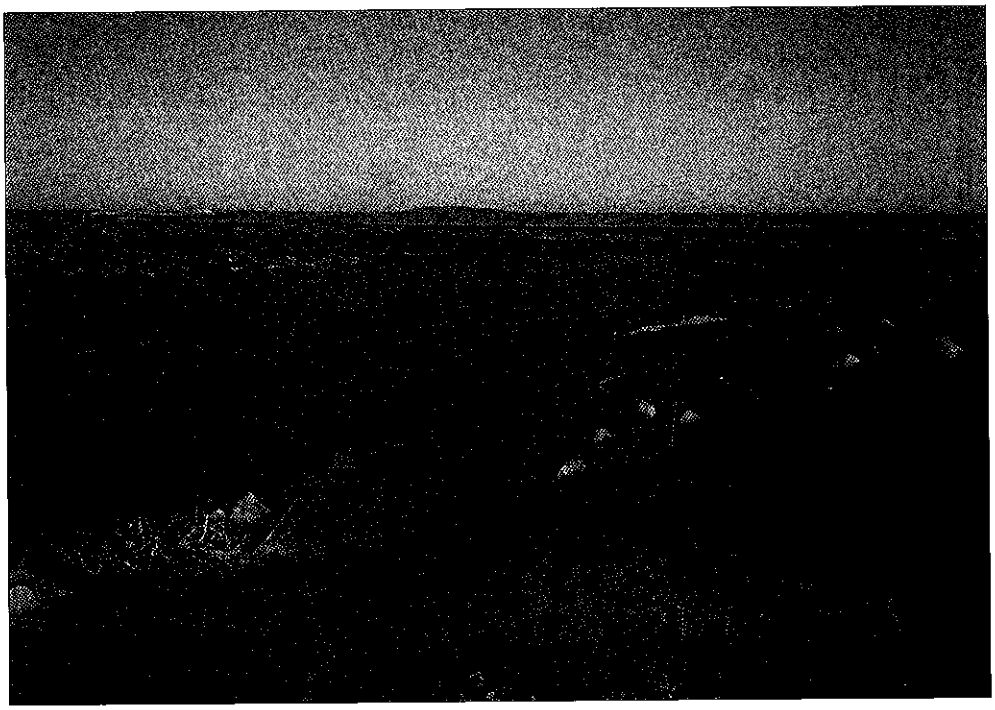

Figure 22. More than 300 species of plants grow in the harsh, dry and hot conditions of the Montebello, Lowendal and Barrow islands.

the golden bandicoot and spectacled hare-wallaby will be undertaken. One reintroduction that appears to have taken place naturally is that of the native water rat (*Hydromys chrysogaster*). This large rat has a body length of 30 cm plus a tail length of 30 cm and it weighs up to 1 kg. Water rats have webbed feet and are very good swimmers so it is likely that they swam to the Montebello Islands from Barrow Island. They live by scavenging along the seashores. However, they have not been recorded for several years.

In 1998, 30 mala (rufus hare-wallaby, *Lagorchestes hirsutus*—central Australian subspecies) were translocated to Trimouille Island. This species is *"critically endangered"* and reintroductions to the Tanami Desert have failed mainly due to predation by feral cats. Monitoring in June 1999 indicated that the translocation to Trimouille Island was successful and that the animals were breeding. The Shark Bay mouse (djoongani—*Pseudomys fieldi*) was translocated to North West Island in May 1999. Monitoring in September 1999 indicated that the population was faring well.

Rats were introduced to Barrow Island in the 1890s and were eradicated in 1991. The house mouse was also introduced to the island and has since been eradicated. Today the island supports a rich flora and fauna that has been relatively undisturbed by introduced animals and atomic bombs. In fact the high diversity of small and medium sized marsupials that survive on Barrow Island provides a glimpse of what the adjacent Australian mainland was like before the introduction of foxes, cats and other introduced animals that have drastically damaged our ecosystems.

Like the Montebello Islands, Barrow Island is mainly covered in spinifex (*Triodia* spp.) but there are also fig, wattle, *Erythrina* and eucalypt trees. Some of the eucalypts grow to 3 m tall and one small clump of *Eucalyptus xerothemica* reaches 4 m tall. Barrow Island has a total of about 300 species of plants and 13 species of land mammals, 78 birds, 43 reptiles and two frogs with additional species expected to be found as more research is carried out.

The wildlife on Barrow Island can only be preserved in the absence of introduced plants and animals. The current petroleum lease prohibits public landing on the island so it is unlikely that introductions will be carried ashore by tourists. The movement of goods and personnel onto the island associated with petroleum activities is subject to stringent hygiene conditions which include fumigating, sealing and labelling goods and placing baits and flour trays in transport barges to look for the footprints of unwanted stowaways. Staff are trained to remove all seed materials from their clothing before coming onto the island and to keep a look out for foreign weeds or animals that may have been accidentally transported from the mainland.

Nearby Middle, Boodie and Double Islands are spinifex covered and support significant colonies of Caspian terns and wedge-tailed shearwaters. Boodie Island provides significant breeding and nesting grounds for nine species of marine birds. Boodie Island is also home to the boodie (*Bettongia lesueur*) and Middle Island supports a population of golden bandicoots.

The burrowing bettong or boodie (*Bettongia lesueur*), the Barrow Island spectacled hare-wallaby (*Lagorchestes conspicillatus conspicillatus*) and the Barrow Island euro (*Macropus robustus isabellinus*) are listed under Schedule 1 as being *"rare or likely to become extinct"* under the Western Australian Wildlife Conservation Act. The Barrow Island black and white fairy wren (Malurus leucopterus leucopterus) is also listed under Schedule 1 of the Act as *"fauna that is rare or is likely to become extinct"*.

The Lowendal Island group supports 78 species of plants, 39 bird species and 13 reptiles. No terrestrial mammals or amphibians have been recorded.

Cave-dwelling fauna

Extensive cave systems exist beneath both Barrow and Varanus islands and there may be other systems yet to be discovered on other islands within the study area. Below a certain depth, these caves are flooded. Both freshwater mounds and seawater wedges flood the caves and brackish water is formed where the two water sources mix. The life in these cave systems and similar systems beneath Cape Range on the North West Cape have been the focus of Western Australian Museum studies for several years.

Most natural ecosystems rely on green plants to convert the energy from sunlight into carbohydrate material that can then be consumed by other organisms. Some of the energy that drives the cave ecosystems undoubtedly comes from plant material washed down sinkholes from surface plant material above. However, some of the energy comes from special sulphur bacteria that use the energy from chemical processes that take place in total darkness. These are called chemoautotrophic bacteria.

The energy from plant debris and chemoautotrophic bacteria support a surprising diversity of animals adapted to live in caves and which have very limited distributions. Two of these are crustaceans, the Barrow Island Liagoceradocus (*Liagoceradocus subthalassicus*) and the Barrow Island Bogidomma (*Bogidomma australis*) which are listed under Schedule 1 as *"rare or likely to become extinct"* under the Western Australian Wildlife Conservation Act. So far research has focussed on caves at Cape Range where 34 animal species have been recorded including several found nowhere else in the world. Two of these are fish; the blind gudgeon (*Milyeringa veritas*) and a blind eel (*Ophisternon candidum*) which are listed as *"rare or likely to become extinct"* under the Act. It is likely that the caves within the study area have equal conservation value so any activities that might alter the conditions, particularly in the brackish interfacial zone within the cave systems, need to be given careful consideration.

Other crustaceans that have been recorded in the study area that are listed as *"rare or likely to become extinct"* under the Act are; *Nedsia fragilis, Nedsia humphreysi, Nedsia hurlberti, Nedsia macrosculptilis, Nedsia straskraba, Nedsia urifimbriata* and also the Barrow Island millipede (*Speleostrophus nesiotes*).

HUMAN USAGE

Cultural history

Aboriginal history

Recent research has produced archaeological evidence that confirms Aboriginal occupation of the Montebello Islands from about 30,000 years ago until the most recent sea level rises about 7,500 years ago. Aboriginal artefacts, such as stone items, and associated terrestrial and marine animal remains have been recovered from shallow sedimentary deposits in several small caves on Campbell Island, in the central part of the Montebello Islands chain and on Barrow Island. A total of 13 sacred or significant sites has been identified on these islands.

The results of Montebello cave excavations suggest that the diets of indigenous inhabitants comprised mainly terrestrial species, although marine snails, bivalves and fish were also eaten. The remains of terrestrial animals in cave sediments confirm that there used to be a much greater variety of native species. The marine species contained in the sedimentary deposits indicate, as elsewhere in northern Australia, that animals from mangrove communities make up a significant dietary component.

During the period of Aboriginal occupation, the Montebello and Barrow islands were part of one large island separated from the mainland by a

Figure 23. The wreck of the Trial was the first known shipwreck in Western Australia. Photo courtesy WA Maritime Museum.

narrow channel only a few kilometres wide. Occupation ceased after the last rise of sea level, which further isolated the islands, rendering them beyond the reach of Aboriginal people. There is no evidence of Aboriginal habitation immediately prior to or during the European contact period.

Maritime history

In 1622, the English East India Company ship the *Trial* (also known as the *Tryal*) en route to Batavia, became the first known shipwreck on Australian shores when it struck what are now known as Tryal Rocks, nine nautical miles (nm) north west of the Montebello Islands (Figure 23). Ten men left the stricken vessel in a small skiff and a further 36 boarded the long boat leaving 93 to die when the ship broke up and sank. The two small boats landed on the Montebello Islands where the survivors searched for water before setting off for Batavia, finally arriving one month later. The Trial wreck site is protected by the Commonwealth *Historic Shipwrecks Act 1976* and also has National Estate status. While the Tryal Rocks lie just outside the study area, there are a number of other uncharted wrecks believed to be lying within the study area including pearling luggers lost over the years during cyclones.

Figure 24. Turtle harvesting within the study area began in the 1870s and continued until 1973. Photo courtesy Col Limpus, QLD Dept of Environmental Heritage.

The *Wild Wave*, a wooden brig under the command of Captain Fothergill, was wrecked in 1872 while carrying a load of sandalwood, mining equipment and 27 passengers, including the captain's wife and children. All passengers and crew of 15 Malays reached shore safely on the Montebellos, 8 nm to the east. The captain and a passenger set out in a small boat to find help and came across the *Mary Ann* in Flying Foam Passage near Dampier. This vessel was dispatched to rescue the remaining passengers and crew.

An unidentified boat was lost in 1893, and in 1905, the *Marietta* was scuttled. Little is known about this vessel, but it is likely that she was a pearling lugger that had reached the end of her working life. In the late nineteenth century other luggers may also have been lost in the area during cyclones.

The French explorer Baudin named the Montebello Islands in 1803 to commemorate the French victory at the battle of Montebello in northern Italy, over the Austrian army in 1800.

In 1818 Lieutenant Phillip Parker King conducted a British hydrographic survey throughout the study area in the *Beagle*. King named Barrow Island after John Barrow, second secretary of the British Admiralty. The *Beagle* revisited the area in 1840 under Captain John Clements Wickham to make observations of the fauna of Barrow Island and John Hart Stokes chartered the Montebellos and Tryal rocks. Naturalists did not visit the area again until 1900, when J.T. Tunney collected birds and mammals on behalf of the Western Australian Museum.

The natural resources within the study area have been harvested for many years. American and British whalers are believed to have worked in the region as early as the late 18th century. Turtle fishing leases were first granted in the 1870s. Turtles continued to be taken commercially until 1973, when concern over the decline of green turtle populations led to the cancellation of licences (Figure 24).

Between 1902 and 1913 a pearling lease was held over waters around the Montebello Islands by Mr Thomas Haynes. North Delta Island, previously named Campbell Island was reserved for the 'Water Pearling Industry' and remnants of Haynes' buildings and other structures can still be seen there. An experimental pearl farming pen was

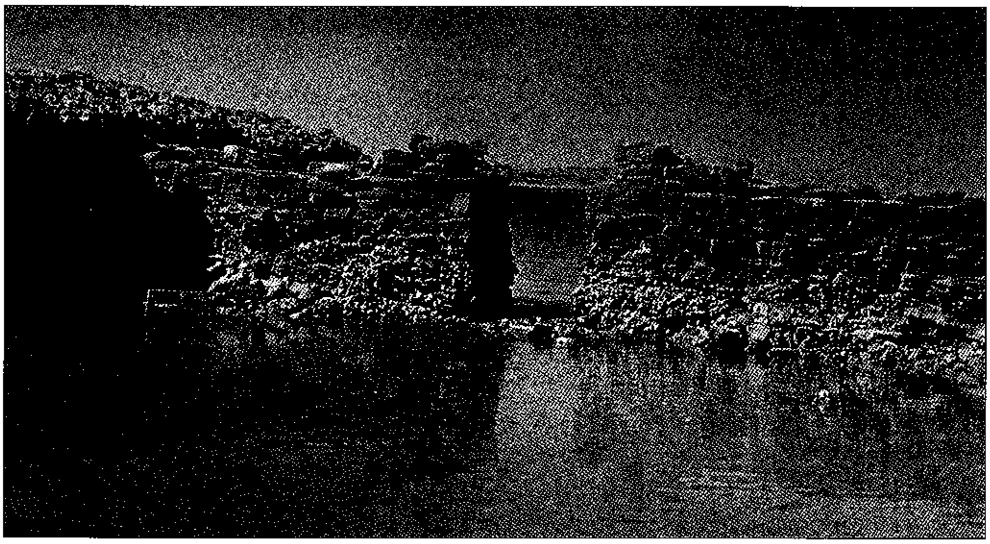

Figure 25. An experimental pearl farming pen was established in Faraday Passage in 1906. Photo courtesy WA Maritime Museum.

established in Faraday Passage in 1906 and later, in the 1970s, the lagoon was modified for pearl culture experiments (Figure 25). In 1986 a pearling lease was granted to Morgan and Co. at the Montebello Islands and a short time later to Cossack Pearls at the Lowendal Islands.

Military history

In 1952 and 1956, a total of three British nuclear weapon tests were conducted at the Montebello Islands (Figure 26). The 1952 operation, called Operation Hurricane, saw a 25 kiloton device exploded inside the hull of the *HMS Plym*, a frigate which was anchored in 40 feet of water, 400 yards offshore from Trimouille Island. The explosion left a saucer shaped crater on the sea-bed, 20 feet deep and 1,000 feet across. In 1956 during Operation Mosaic, two more devices were exploded, one on Trimouille Island and the other on Alpha Island. The 15 kiloton bomb on Trimouille was exploded at the top of a 31m tower. The bomb, which was detonated on Alpha Island, was originally stated to be a 60 kiloton device. However, recent access to documentation confirms that it was 98 kiloton, making it the largest nuclear weapon tested in Australia.

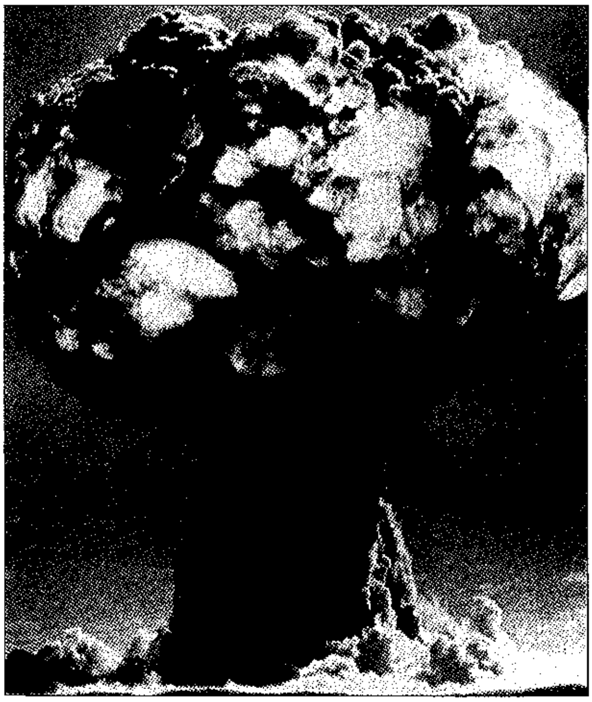

Figure 26. During the 1950s the Montebello Islands were used to test three nuclear bombs. Photo courtesy Department of Defence.

At the height of the military operation, more than 5,000 servicemen were based on and around the islands with a further 5,000 supporting the operations on the mainland. Surviving ex-servicemen describe the area as being destroyed after the tests. The islands were levelled or cropped, with no surviving vegetation left. Eyewitness accounts say that the bodies of thousands of marine turtles were washed up on the beaches.

Remains of the military activities during the 1950s include scrap steel, disused roadways and the foundations of former British operational headquarters on the south of Hermite Island. Continuing radiation hazards limit the recommended length of time people can remain safely on parts of Trimouille and Alpha islands. Limited investigation of the *HMS Plym* site has been undertaken by the Maritime Museum of Western Australia and the site is considered to be of historic significance.

Current Administration 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* which identified 70 areas in the coastal waters of Western Australia worthy of consideration for marine reservation under the Conservation and Land Management 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), a vesting and Ministerial advisory body;
- the Marine Parks and Reserves Scientific Advisory Committee;
- revised statutory consultative protocols for the establishment of marine reserves; and
- clear guidelines for commercial activities in marine reserves.

The roles and responsibilities of State Government agencies within marine conservation reserves are also defined and these are summarised in Table 4.

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 to protect Australia's biological diversity. The development of a NRSMPA helps fulfil Australia's international responsibilities and obligations as a signatory to the Convention on Biological Diversity. It also helps to provide a means of meeting obligations under the Convention on Migratory Species and to fulfil responsibilities under bilateral agreements for migratory birds with Japan and China. In addition, it supports the World Conservation

Table 4. 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*

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*, the *National Strategy for the Conservation of Australia's Biological Diversity*, the *National Oceans Policy* and the *Strategic Plan of Action for the National Representative System of Marine Protected Areas.*

Local government authority

Two shire councils are responsible for land in the study area, but local government has no jurisdiction over marine waters. The Montebello Islands lie within the municipality of the Shire of Roebourne, and the Lowendal and Barrow Islands are within the Shire of Ashburton. The local government authorities are responsible for health and some building matters on the islands. No land-based infrastructure of relevance to the Shire of Roebourne currently exists on the Montebello Islands. However, the Shire of Ashburton conducts inspections twice a year on Barrow and the Lowendal islands where petroleum companies have constructed several buildings. Both councils take an interest in environmental issues concerning the islands, commenting on environmental matters and working cooperatively with other management agencies.

Port areas and shipping routes

There are two crude oil loading terminals in the study area; at Varanus and Barrow islands. The crude oil loading terminals for Varanus and Barrow Islands are located about 4 and 10 km offshore, respectively. Tankers are moored near the end of submarine pipelines for loading. The Varanus Island port covers a circular area, centred at the end of the submarine pipeline and with a radius of 3.2 nm. The Barrow Island port covers a hemispherical area centred at the pipeline landfall, and has a radius of 7 nm extending from the northern-most point of the island at Cape Dupuy to almost the south-western tip of the island (Figure 27).

Ships travelling round the north-western tip of the study area pass between the Montebello Islands and Tryal Rocks. The southern end of Stephenson Passage, adjacent to Hermite Island, is used to shelter from cyclones. There are three moorings presently at this site.

Tenure

Within the Montebello/Barrow islands region there are two conservation parks and four island nature reserves. They are the two sections of the Montebello Islands Conservation Park, the Barrow Island Nature Reserve, the Lowendal Islands Nature Reserve, Middle, Boodie and Double Islands Nature Reserve and the Great Sandy Island Nature Reserve (Figure 28). These parks and reserves are vested in the National Parks and Nature Conservation Authority (NPNCA).

The Montebello Islands Conservation Park comprises more than 100 islands, islets and rocks of the Montebello archipelago. The islands, covering 1,446 ha, are reserved as A Class conservation park (reserve Nº. 42196) to the high water mark, with the area between the high and low water marks being a C Class conservation park (reserve Nº. 42197).

The Barrow Island Nature Reserve is an A Class nature reserve (Nº. 11648). It covers the land above the low water mark and has an area of approximately 23,483 ha. Barrow Island was reserved for conservation in 1908 following a faunal survey that highlighted its diversity in1900. The Lowendal Islands Nature Reserve is a C Class nature reserve (Nº. 33502) which extends to high water mark and comprises 40 islands, islets and rocks with an area of 445 ha.

Middle, Boodie, Pascoe, Boomerang and Double Islands make up a C Class nature reserve (Nº. 38728) which covers all the land above the low water mark and has an area of approximately 588 ha.

The Great Sandy Island Nature Reserve is a Class B nature reserve (Nº. 33831) comprising all of the islands and sand cays between the delta of the Fortescue River, approximately 40 km south-west of Dampier, and Gnoorea Point, approximately 50 km north-east of Onslow. The reserve is vested in the NPNCA and managed by CALM to conserve flora and fauna. The reserve extends to the low water mark in all areas and includes one of the sand cays known as the Barrow Islands Shoals, which is located within the study area.

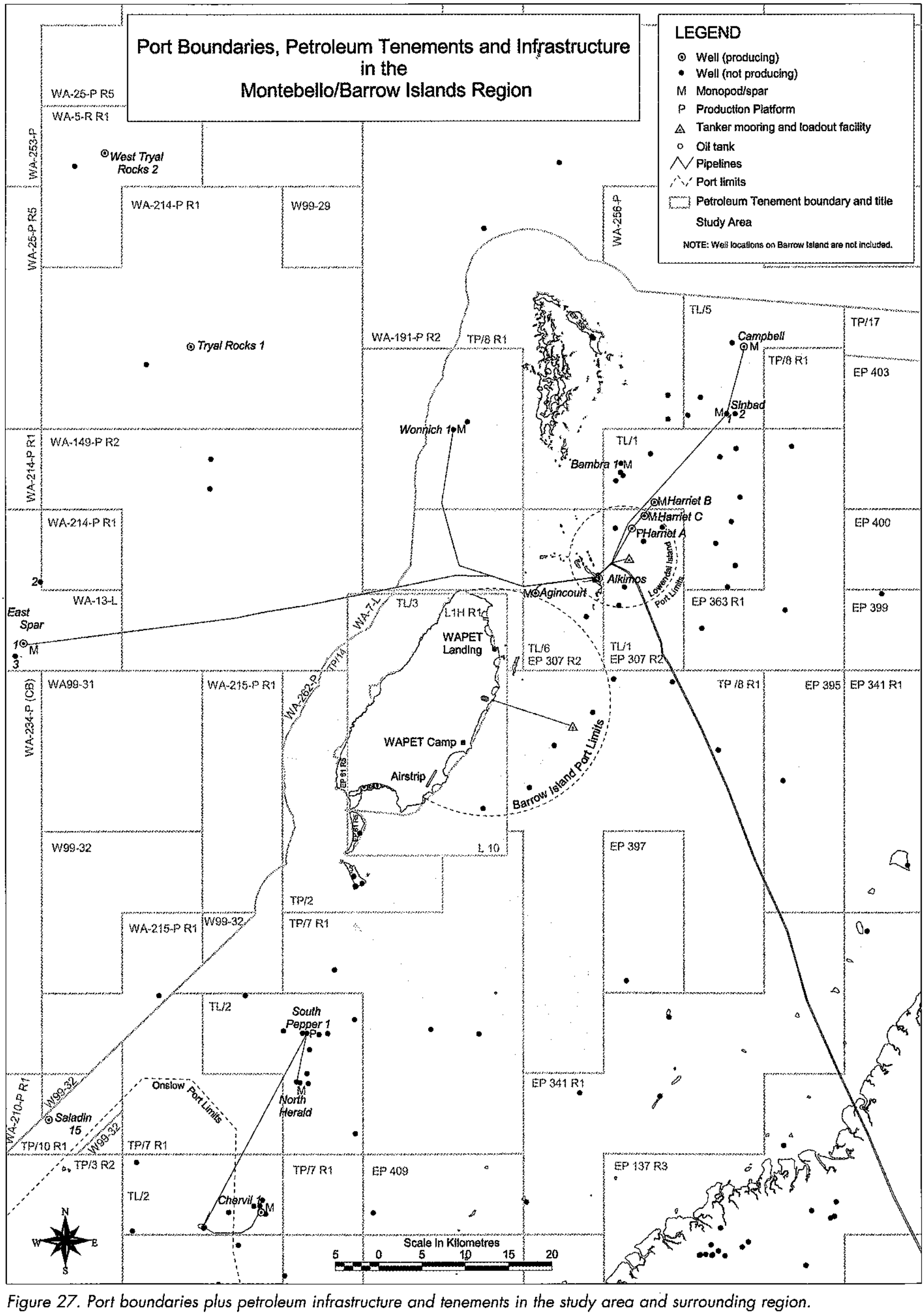

Figure 27. Port boundaries plus petroleum infrastructure and tenements in the study area and surrounding region.

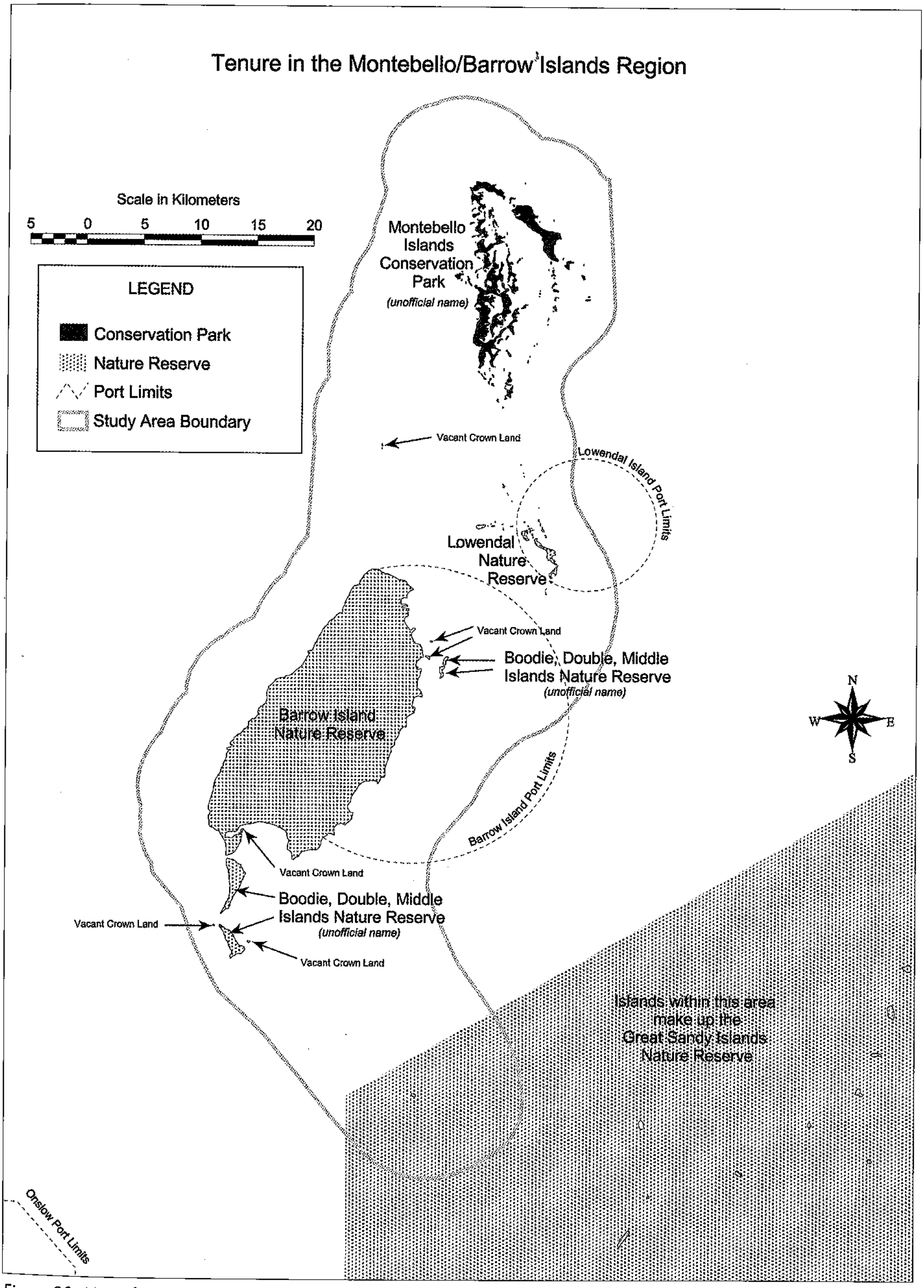

Figure 28. Map of tenure within the study area and surrounding region.

Table 5. Tenure within the Montebello/Barrow islands study area

Reserve	Class	Name	Tenure	Purpose	Vesting authority	Comment
11648	A	Barrow Island	Nature Reserve	Conservation of flora and fauna	NPNCA	Gazetted to LWM
33902	C	Lowendal Islands (which include Abutilon, Bridled, Parakeelya and Varanus islands, and Overhanging Rock)	Nature Reserve	Conservation of flora and fauna	NPNCA	Gazetted to LWM; CALM Lease 902/100 granted to Bond Corp and others over portion of the reserve
38728	C	Boodie, Double and Middle islands	Nature Reserve	Conservation of flora and fauna	NPNCA	Gazetted to LWM
40828	C		Non-CALM Act - general	Marine navigation aid	AMSA	
41080	C		Non-CALM Act - general	Marine navigation aid	AMSA	
42196	A	Montebello Islands (which includes Ah Chong, Alpha, Buttercup, Bluebell, Brooke, Campbell, Carnation, Crocus, Daisy, Dandelion, Delta, Epsilon, Flag, Foxglove, Gannet, Gardenia, Hermite, Hollyhock, Howe, Ivy, Jonquil, Karangi, Kincup, Marigold, Northwest, Pansy, Primrose, Rose, South East and Trimouille islands)	Conservation Park	Conservation Park	NPNCA	Gazetted to HWM; includes all islands and rocks; excludes 40828 and 41080; CALM Lease granted to Woodside Offshore Petroleum Pty Ltd over portions of Trimouille Island
42197	C	Montebello Islands (which includes Ah Chong, Alpha, Buttercup, Bluebell, Brooke, Campbell, Carnation, Crocus, Daisy, Dandelion, Delta, Epsilon, Flag, Foxglove, Gannet, Gardenia, Hermite, Hollyhock, Howe, Ivy, Jonquil, Karangi, Kincup, Marigold, Northwest, Pansy, Primrose, Rose, South East, and Trimouille islands)	Conservation Park	Conservation Park	NPNCA	Includes all islands and rocks; legal area gazetted is indeterminable; between HWM and LWM
	Vacant Crown land	Mushroom Island			Not vested	
	Vacant Crown land	Prince Island			Not vested	
	Vacant Crown land	Boomerang Island			Not vested	
	Vacant Crown land	Pasco Island			Not vested	

Closer to the mainland, there are several island nature reserves including the Airlie Island, Little Rocky Island, Thevenard Island and Weld Island Nature Reserves. Land tenure in the Montebello/Barrow islands region is summarised in Table 5.

Native title

There are no native title claims lodged with the National Native Title Tribunal which cover land or waters within the study area.

Commercial Activities

The petroleum industry

Western Australia's petroleum industry began more than 40 years ago and today, annual State production exceeds 100 million barrels of oil and condensate (one barrel is 159 litres), 65 million barrels of liquefied gas and more than 23,000 million cubic metres of gas. In 1999 the industry was valued at $4.8 billion per annum, making it the State's most valuable commodity. It employs 2,500 people directly with an estimated

17,000 employed by companies servicing the industry.

The Pilbara region is the State's most productive petroleum area with 99.3 per cent of its oil and 92.2 per cent of its gas production. All Pilbara production is offshore with the exception of one small mainland project.

Oil was discovered on Barrow Island in 1964, and brought into production in 1966. However, interest in the region remained low until the early 1980s when fields were discovered south of Barrow. The Harriet fields off Varanus Island in the Lowendal Islands were developed in 1983 and the gas fields of Campbell, Sinbad and Rosette were subsequently brought into production.

There are two major petroleum projects within the study area, the Barrow Island Project operated by Chevron Australia Pty. Ltd., and the Harriet and East Spar projects on Varanus Island, operated by Apache Energy (Figure 27). More than 307 million barrels of oil have been produced from fields in the area between 1966 and 1996.

The Barrow Island Project is the State's largest oil-producing project (34 per cent of total State production) and some gas is produced as well (two per cent of total State production). There are 451 production wells on the island, which also supports infrastructure including accommodation, an airport, five 200,000-barrel oil storage tanks, plus separation and compression facilities.

Although Barrow is a nature reserve, Chevron Australia's lease covers virtually the whole island and the company is responsible for ensuring that operations do not negatively impact on the island's conservation values. The oil field has an estimated production life of a further 25 years.

The Harriet and East Spar projects produce gas, condensate and oil. The project comprises the Harriet, Agincourt, Campbell, Tanami, Sinbad, Rosette, East Spar and Wonnich fields, all of which are linked to the Varanus facilities. The two projects produce approximately six per cent of the State's oil production and 25 per cent of domestic gas production. Condensate and oil are sold to the domestic and international markets, while gas is sold to the domestic market. Liquid products are loaded onto tankers offshore and natural gas is piped from the island to link into the Goldfields and Dampier to Perth Gas Pipelines. Apache

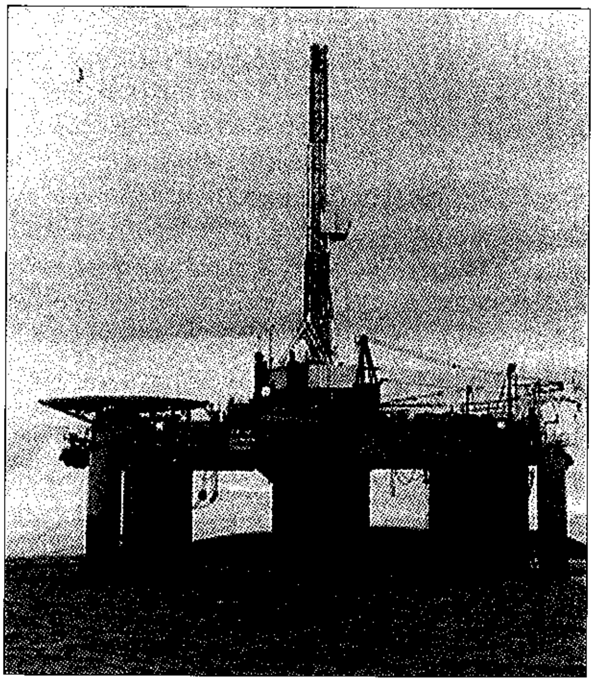

Figure 29. In 1999 the petroleum industry was valued at $4.8 billion per annum, making it the State's most valuable commodity.

Energy uses approximately 0.4 km^2 of Varanus Island for industrial facilities. Gas, condensate and oil are produced from 11 wells, seven located on platforms or monopods to the north east of the island, two onshore and two at sub-sea buoys. Liquids are stored in three 250,000-barrel tanks on the island before transfer via a submarine pipeline to the offshore terminal (Figure 27).

Other petroleum finds within the study area yet to be developed include the Ulidia, Pascoe, Gorgon and Bambra discoveries, and the presence of east-west faults with the potential to trap oil and gas make the area highly prospective.

The Department of Minerals and Energy is responsible for managing petroleum activities and administering the relevant Acts. Petroleum operations on land are controlled through the *Petroleum Act 1967*. On the water, operations are controlled though the *Petroleum (Submerged Lands) Act 1982*. Both Acts provide for the issue of exploration permits (seismic and drilling) and production licences. With the exception of a few small blocks, exploration permits or production leases cover the entire study area.

The *Petroleum Pipelines Act 1969* governs the construction, operation and maintenance of petroleum pipelines. Companies are required to obtain a Pipeline Licence to construct a pipeline. Apache Energy's Harriet and East Spar projects have the most extensive submarine pipeline system. These pipes transport oil from the Agincourt and Harriet A, B and C platforms and gas and condensate from the Campbell, Sinbad and Wonnich monopods to production and storage facilities on Varanus Island. Condensate and oil are delivered via a 4 km long submarine pipeline to the load-out terminal, while gas is transported along a 90 km long pipeline to the mainland for connection to the Dampier to Perth gas pipeline.

The State Government's policy on petroleum exploration and development in marine conservation reserves is summarised below.

- Petroleum drilling and production will be prohibited in marine nature reserves, both sanctuary and recreation zones of marine parks, and in those special purpose zones of marine parks where such activity would be incompatible with the conservation purpose of the zone.
- Petroleum drilling and production will be permitted in parts of general use and special purpose zones of marine parks subject to assessment through the *Environmental Protection Act 1986*.
- Petroleum drilling and production can be undertaken in marine management areas subject to assessment through the *Environmental Protection Act*.
- Seismic surveys may be permitted in marine parks and marine management areas subject to environmental impact assessment processes agreed by the Environmental Protection Authority in consultation with CALM and Fisheries Western Australia.
- The Minister for the Environment requires the consent of the Minister for Mines before creating any marine conservation reserve or management zone within a marine park or marine management area.

All Western Australian marine conservation reserves are limited to a depth of 200 m below the sea-bed. This enables directional drilling as part of petroleum exploration and production activities below the 200 m limit while preserving the integrity of the reserves.

Environmental issues

As with all human activities, the petroleum industry has the potential to impact the natural environment, and perhaps the scenario of greatest concern to the public is the unlikely event of an oil spill or shipping accident. Fortunately, the oil produced within the study area is a light crude which evaporates quickly in the tropical temperatures and strong breezes. However, engine oils that could leak from damaged vessels are heavy, evaporate slowly and have the potential to cause significant environmental damage.

All petroleum companies that operate within the study area have comprehensive oil spill contingency plans, which include oceanographic models to predict the drift of spilt materials. The companies also stockpile equipment for combating oil spills with additional equipment being available at Fremantle and elsewhere. In addition, regular exercises and practice drills are conducted to ensure that the equipment functions and staff are adequately trained to cope with an oil spill emergency.

Seismic surveys to investigate underground geological formations and prospective drilling locations use a pulse of energy directed down into the rock layers. Explosives were once used to create the pulse but this method caused significant environmental damage so today, air guns are used. The environmental impacts of air guns are not well understood but research is currently being undertaken to investigate the effects on a wide range of marine animals including whales and turtles.

During drilling, the drills require lubricant fluids to reduce friction. Petroleum companies within the study area use water based fluids where possible and avoid the more toxic oil and synthetic based fluids except for particularly difficult rock formations. The tailings, or cuttings brought to the surface during drilling are covered in drilling lubricants and can smother plants and animals growing on the surrounding sea-bed. In very sensitive locations, companies sometimes re-inject the cuttings into the drill hole to minimise environmental damage. This technique, called annular re-injection was carried out at an exploration well near Dugong Reef within the study area.

When oil is pumped to the surface, water and gas are contained in the mixture. This mixture is pumped into a tank and placed under pressure to separate the three components. The water goes to a storage tank where further oil is skimmed off. The remaining water still contains low levels of petroleum and sometimes heavy metals. WAPET produces 60,000 to 70,000 barrels of water and 13,000 to 14,000 barrels of oil per day indicating that about 80 per cent of the day's production is water. The production water on Barrow Island has been re-injected into the ground to a depth of about 160 m but now the company is about to implement a new system of deep re-injection to about 1,000 m. Until recently, the production water on Varanus Island was discharged into shallow water bores, but it too is now re-injected deep into the ground. Production water from offshore wells within the study area is discharged into the ocean and is monitored and managed by the Department of Environmental Protection.

Many facilities are lit up at night and there are concerns that birds and turtles can become disorientated by artificial lights. Fledging shearwaters are drawn to lights on the horizon and some are lost each year around flares, particularly on Thevenard Island. Fortunately, the gas flares have limited impact on turtles, which appear relatively insensitive to the yellow/red end of the colour spectrum, but fluorescent and other white lights attract hatchlings which then fail to go out to sea. Today, research is continuing, but in the interim many of the lights used at petroleum industry facilities have yellow filters or are screened from the coast and low vapour pressure sodium lights are used where possible.

While not directly related to the petroleum industry, shipping also poses a potential risk to the environment through the pumping of bilges. Large empty vessels fill their holds with ballast seawater to maintain stability at sea. This is pumped out before a new cargo is loaded thereby transporting significant volumes of seawater between ports. Seawater 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. All tankers visiting Chevron Australia's marine terminals in the Pilbara are informed of the guidelines and the company collates statistics on the source and volume of ballast water discharged at the Barrow Island facility. This information is provided in Table 6. Vessels entering the Varanus Island loading terminal discharge roughly 9,000 tonnes of ballast water a month. These tankers are also requested to comply with the AQIS guidelines.

Tributyl tin (TBT) is used on ships hulls to prevent fouling by encrusting organisms. It continually sloughs off the hull surface and is one of the most toxic substances introduced into the marine environment. TBT is usually found in the water column and sediment in the vicinity of shipping operations. However, there is no monitoring of TBT levels near the Varanus or Barrow loading facilities.

Commercial fishing

The Pilbara demersal finfish fisheries target red emperor, rankin cod, scarlet perch, red snapper, jobfish, spangled emperor, blue spot emperor, flagfish and threadfin bream. The greatest finfish catch throughout the Pilbara is taken by the trawl fishery. However, the study area is located within a trawling exclusion area and is therefore not currently used by this fishery. Two other commercial techniques are used to catch demersal

Table 6. The source, volume and treatment of ballast water discharged at the Barrow Island facility

Number of ships	Origin	Ballast treatment	Volume discharged (tonnes)
1	Overseas	Ballast exchange at sea	31,000
2	Overseas	Ballast exchange at sea (flow through method)	22,726
2	Overseas	Ballast not treated	36,760
13	Australian ports	Ballast not treated	263,359

finfish within the study area: fish trapping and line fishing.

The Pilbara Trap Managed Fishery, established in 1992, lies north of 21° 44′ south latitude and between 114° 9′36″ east longitude and 120° east longitude between the 200 and 30 m depth contours. The number of licences was reduced from 12 to six in 1996. In 1997, the total number of traps which could be used in the fishery was restricted to 78. In that year, the catch was 234 tonnes worth $1.4 million, with red emperor having made up the greatest proportion of the catch. At the commencement of the year 2000 licensing period, a new system of effort regulation based on the allocation of time/gear units was introduced. A time gear unit is equal to one fish trap used for a given time period (currently one day). For the year 2000, 5,867 trap days were allocated (Figure 30).

Line fishing is unrestricted throughout the study area and in 1997, 49 commercial line fishers operated in this fishery. Issues associated with unrestricted access by commercial line fishers to the Pilbara are discussed in a paper (Fisheries Management Paper 111) that considers management options to address these concerns. In 1997, the line fishing catch was 109 tonnes worth $0.7 million and the species that made up the greatest proportion of the catch was jobfish.

Some of the commercial line fishers also troll for the valuable Spanish mackerel in waters of 20 m and more. In 1997, trolling off the Pilbara coast landed 152 tonnes of pelagic fish worth $1.1 million.

The North Coast Shark Fishery has access to the study area and in 1997, landed approximately 250 tonnes worth an estimated $240,000. There are currently eight licensed operators within this fishery, seven of which have access to the study area. They use hook and line techniques; either drop lines which are set vertically, or long lines which are set horizontally through the water column. 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.

Zones 2 and 3 of the Onslow Prawn Managed Fishery fall within the Montebello/Barrow islands region. There are 31 operators licensed for the region: 12 can only fish in zone 2; 12 can only fish in zone 3, and seven have access to both zone 2 and 3. However, prawn trawling is generally restricted to inshore areas near to the mainland coast so operators do not currently use the study area.

Figure 30. The Pilbara Trap Managed Fishery is worth about $1.4 million per annum. Photo courtesy Fisheries WA.

There are four commercial fishers with mud crab licences. However, there is a closure to commercial mud crabbing west of Yardi River near Coolgra Point and this line excludes the south-western portion of the study area. Although the rest of the study area is open for commercial mud crabbing, it is hardly used at all by commercial operators because of its distance from mainland facilities.

There is a closed area for tropical rock lobsters between Onslow and Cape Preston that includes the Montebello Islands. However, the fishery has access to waters west of Barrow Island.

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 (*Holothuria nobilis*) and the white teat fish (*Holothuria fuscogilva*). In 1998, the Beche-de-mer fishery landed 345 tonnes wet weight of product, most of which was taken in the Kimberley. The product is exported to Asian markets where it is considered a delicacy.

Commercial boats operating in Commonwealth-managed fisheries such as tuna longliners, can access the waters of the study area but are currently not active in the region.

Fisheries Western Australia has issued 32 commercial shell collecting and 13 aquarium fish collecting licences in Western Australia although only a few of the operators fish commercially full time. This industry tends to focus on the mainland coast where access is easier. However, the endemic marine gastropod *Amoria macandrewi* is targeted in the study area but actual numbers taken are not known.

Commercial fishing in Western Australia is managed under the *Fish Resources Management Act 1994* 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. The Government's policy on commercial fishing in marine conservation reserves is summarised below:

- 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 within 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; and
- 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

Pearling began in Western Australia in the 1850s when natural pearl oysters were found in Shark Bay and later at Nickol Bay near Karratha. At that time, pearlers collected the mother of pearl, the shiny layer inside the shell, and counted themselves lucky if they found a pearl. In the 1890s, 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 in the Broome area. This was an industry thwart with danger and many divers were exploited and lost their lives.

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 pearl cultivation was lifted and the industry regained its former strength. Today it is worth around $180 million a year.

Pearling is the production of pearls from particular species of oysters, which are either collected from the wild or grown in hatcheries. Shells are seeded, then allowed to recover for several months before being transported to farms to grow out for several years. During the grow-out period the shells are tended very carefully to create beautiful pearls.

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 layers of a lustrous coating called nacre around the fragment. Nacre is a form of calcium carbonate. 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 close to the equator tend to produce duller pearls than those produced at higher latitudes. This is one of the reasons why sites within the study area are some of the best in the world for the production of high quality pearls.

There are approximately 60,000 shells at the Montebello Islands pearl farm alone and large numbers are also held at the Lowendal pearl farm. Juveniles are brought from Carnarvon, as there are no hatcheries within the study area. After seeding, the oysters are replaced on the sea-bed

Figure 31. Pearl shells need to be tended regularly while the pearls are growing.

in panels, which are turned regularly to aid the formation of round pearls. A few months later, the panels of oysters are suspended from long ropes in the water column to grow out. The panels are placed in areas of high tidal movement, where microscopic planktonic food is abundant. They stay in the grow-out area for about two years, by which time the pearls have grown to a reasonable size and quality. During this period, the shells become encrusted with sedentary marine organisms which have to be scraped off at regular intervals. Most of the pearls produced within the study area are sold to Japan, but some go to the United States, Hong Kong and Europe (Figure 31). Two companies hold pearling leases within the study area. Morgan & Co Pty Ltd operates in 16 sites covering approximately 1,230 ha within the Montebello Islands area. This lease will remain current for three years while the proposed marine conservation reserve is being planned. Cossack Pearls Pty Ltd holds a 1,231 ha, 21 year lease to the west of the Lowendal Islands (Figure 32).

Leases for cultivating Pinctada maxima in State waters are issued under the *Pearling Act 1990*. Licences for cultivating other pearl oyster species, *Pteria penguin*, *Pinctada margarifera*, and *Pinctada albina* are issued under the Fish Resources Management Act and are considered as aquaculture rather than pearling.

As with other human activities, pearling has the potential to impact the natural environment and the granting of licences is just one form of control over the 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. In the year 2000, the unit size within the study area is to increase to 1,100 shells. Wild oysters can only be gathered when they reach the minimum size of 120 mm. The optimum size for harvesting oysters is between 120 and 160 mm. If the oysters are greater than 160 mm, they are left to form breeding stocks. There are also restrictions on breeding pearl oysters for hatchery production. Production of baby oysters or spat is controlled, with a limit of 20,000 spat per licence.

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

Other concerns associated with pearling include the potential for grow-out panels to shade benthic flora and fauna. All plants require light to grow and any reduction in light will cause a reduction in productivity to the extent that severe light depletion will result in an area becoming unsuitable for plant growth. Shell grow-out panels and the associated ropes and markers have the potential to entangle marine wildlife and if they break loose during storms they can litter the water column and nearby beaches causing a further hazard to wildlife. Lights associated with pearling industry facilities can attract and disorientate birds and turtles and for hatchling turtles this has the potential to prevent them from reaching the open ocean. In addition, although the majority of facilities are located on house boats and pontoons, there is demand for shore-based facilities for seeding and storage of equipment. This demand may place pressure on adjacent reserves and vessels servicing island pearling facilities have the potential to transport and reintroduce feral animals onto the islands.

Public access to pearl grow-out areas is stipulated in the lease conditions, though some areas may be 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 conditions such as tidal ranges, water

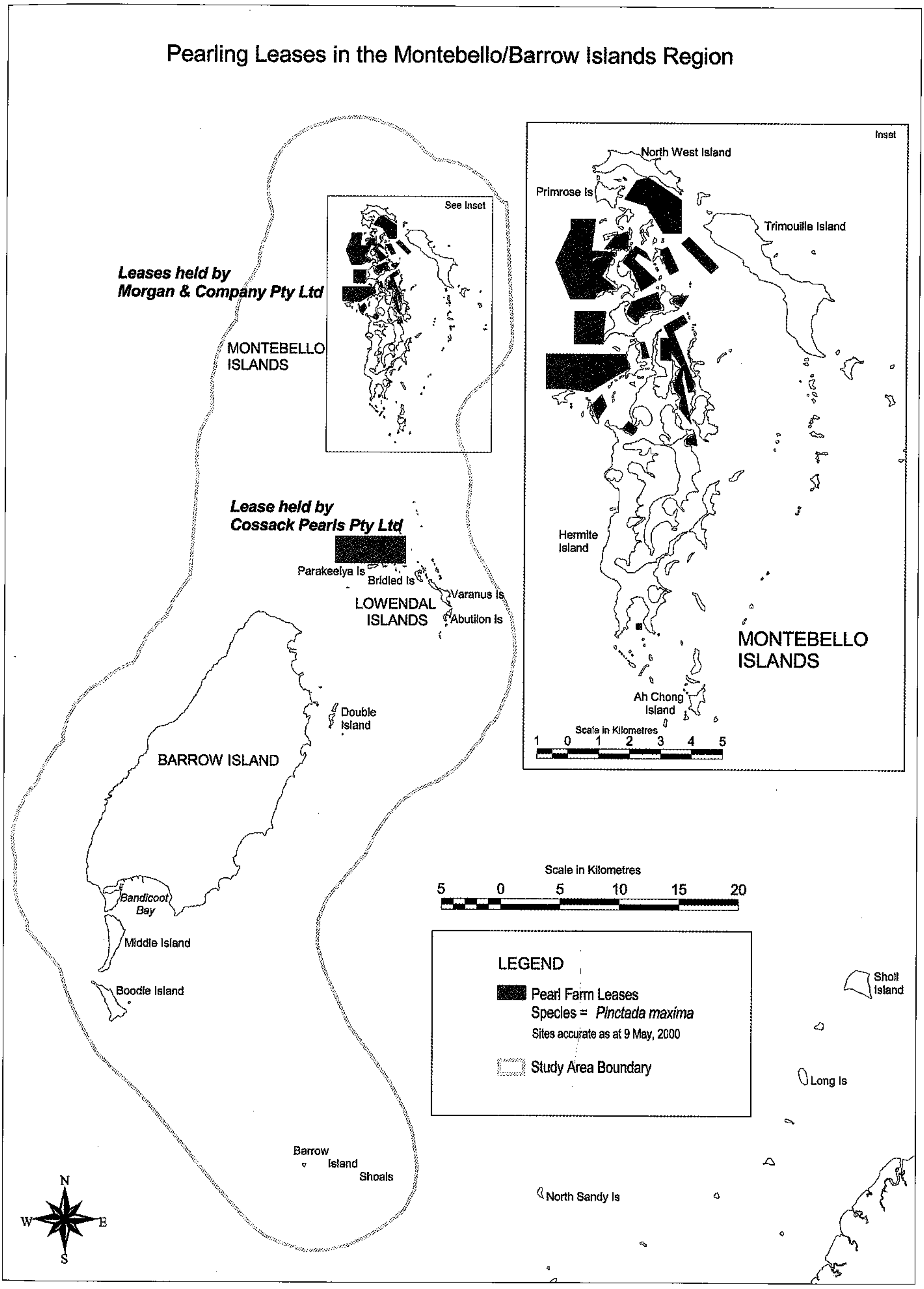

Figure 32. Map of pearling leases within the Montebello/Barrow islands study area.

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 negotiate solutions to conflicts over resource sharing and issues of access in the marine environment.

The State Government's policy on aquaculture and pearling in marine conservation reserves is summarised below:

- 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 and recreation

The study area offers a range of possibilities for recreation and tourism. The climate is pleasantly warm and sunny in winter, while breezes in summer temper the hot temperatures experienced on the mainland. Stunning island scenery is complemented by blue seas and productive coral reefs that support prized table fish. Although the area was damaged by the atomic tests and currently supports major petroleum and aquaculture industries, it still has an untamed beauty which is sought by many people. This wilderness supports a wealth of charismatic species including whales, dolphins, dugong, turtles and birds that delight tourists and have the potential to support nature-based tourism.

Recreational boating, diving, fishing, collecting and wildlife observation all occur within the study area, but remain at low levels. The area's isolation from major mainland centres prohibits all but a few private boat owners from venturing out so far. In addition the atomic tests in the 1950s have left some areas of the Montebello Islands unsafe to visit for more than a few hours, while access to other islands is restricted.

Petroleum leases prohibit public access on Barrow Island and Varanus Island of the Lowendal group. The other Lowendal Islands are gazetted as nature reserves, and while camping is prohibited, public access for day visits is allowed. Currently, there is no potential on the Barrow and Lowendal islands for tourism development. However, the accommodation facilities for company staff could be converted for tourists when petroleum production on Barrow Island ceases. The Montebello Islands are gazetted as a conservation park, but there is no management plan at present. On the completion of a management plan, opportunities for ecotourism activities and low key wilderness accommodation on the Montebello Islands may be made available.

Very few of Western Australia's 600,000 recreational fishers visit the study area. The few who do target spangled emperor, red emperor, Spanish mackerel, coral trout, mangrove jacks and trevally. Visitors also take mud crabs, oysters, squid and other edible organisms.

Recreational fishing is managed by Fisheries Western Australia through a variety of management

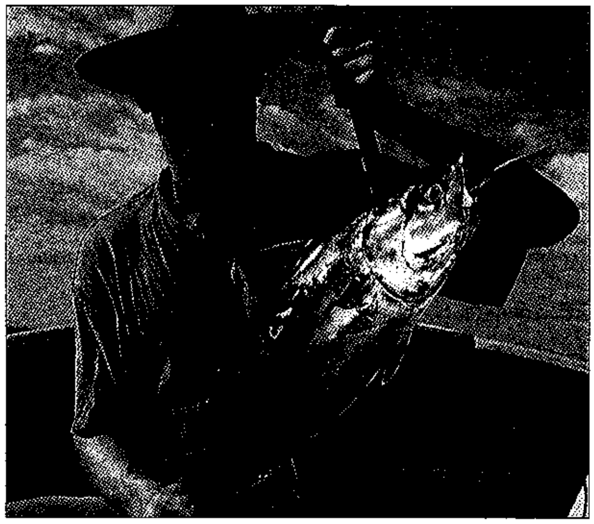

Figure 33. Recreational fishing is enjoyed by 600,000 Western Australians but only small numbers fish within the Montebello/Barrow islands study area. Photo courtesy Fisheries WA.

tools to limit catch levels within sustainable levels. Bag and size limits apply to most species of fish and a license is required to take crayfish. Potato cod, whale sharks and hump headed maori wrasse are fully protected and large specimens of all cod species must be returned undamaged to the water.

Fisheries Western Australia has commenced work on a Regional Recreational Fishing strategy for the whole North West Shelf region. This study will review the sizes and status of fish resources and identify human activities that threaten them. Management strategies will be reviewed to ensure that fishing pressure remains within sustainable limits. A significant component of this study will involve community input and in 2001, a consultative committee will be established.

In line with the State Government's multiple-use policy, recreational fishing will be provided for in marine conservation reserves. Recreational fishing will not be permitted in marine nature reserves or in sanctuary and certain special purpose zones in marine parks. However, access will be maintained in marine management areas plus general use zones, recreation zones and some special purpose zones within marine parks. Recreational fishing in marine conservation reserves will continue to be managed under fisheries legislation.

Boating is a popular recreational activity in Western Australia, with a total of 57,000 private vessels registered with the Department of Transport. Pilbara coastal towns have the highest rate of boat ownership per capita in Western Australia. Despite the large number of private vessels on the adjacent mainland coast it is estimated that only about 50 yachts and 30 other vessels visit the study area each year for recreational activities which include fishing, diving and wildlife viewing.

If boating increases in the future, disposal of effluent and other rubbish, plus the misuse of anchors and moorings in sensitive habitats have the potential to impact the marine environment.
The Department of Transport is responsible for all boating regulations including licensing, safety standards, marker buoys, moorings and jetties. This management responsibility remains with the Department of Transport within marine conservation reserves. However, mooring controls can be delegated to other agencies.

An estimated 15,000 SCUBA divers train in Western Australia each year (Figure 34). Many

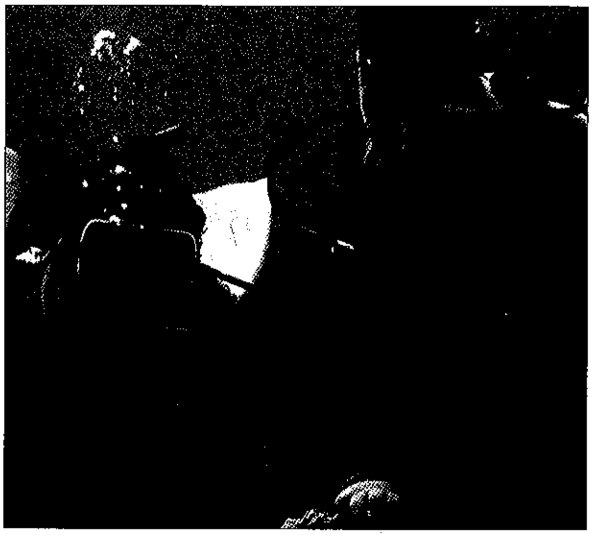

Figure 34. Stunning underwater scenery and a profusion of marine wildlife provides excellent opportunities for diving and snorkelling.

come from overseas and a significant number remain for diving vacations after training. Beautiful corals and other underwater scenery together with the variety and profusion of large marine wildlife attract divers and snorkellers to the study area but the absence of public flights and accommodation in the study area keep their numbers low.

There is currently very little use of the study area for surface water sports. Surfing, sea kayaking and wind surfing could take place around the islands, though fast tidal currents would make these activities dangerous for inexperienced visitors.

Many visitors to the study area enjoy wildlife observation. Whales, dolphins, dugong, 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 interaction during wildlife viewing is 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 and the use of flash cameras near whale sharks requires a licence. Nesting birds and turtles are particularly vulnerable to disturbance and visitors are required to keep quiet, keep still and minimise lighting near nesting turtles.

In addition to the marine wildlife that already attracts visitors, the elimination of feral cats and rats and the reintroduction of native animals that are rare on the mainland has the potential to attract more wildlife viewers to the region.

Tourism in the whole Pilbara region was estimated to be worth $59.5 million in 1996 and visitation figures indicate that this amount would have increased. Staff accommodation on Barrow Island may be converted to tourist facilities when petroleum production ceases, but current options for overnight tourist accommodation are limited to visiting charter vessels, camping ashore, and one small houseboat in Claret Cove, Hermite Island.

The wide variety of wildlife and the wild, natural appearance of the land and seascapes within the study area have the potential to support nature-based tourism. The high nature-based tourism potential was identified in the Pilbara Development Commission's ecotourism management strategy for the Pilbara and Gascoyne offshore islands. Providing high quality experiences for visitors could make a major contribution towards protecting the State's unique ecosystems, especially in coastal environments, by fostering a greater understanding of nature.

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

Community involvment

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 is a common asset available to all users. While most Western Australians cherish the freedom of open access, 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 Montebello/Barrow Islands area will provide a framework to ensure environmental protection, maintain human usage at a sustainable level and minimise conflict among users. The planning process for the establishment of a marine reserve relies heavily on community input. Access to 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 via their representatives on the Advisory Committee or through the public submission process.

For further information about the Montebellos/ Barrow islands and the marine reserve planning process, contact the following CALM offices:

Mardie Road
Karratha Industrial Estate
Karratha 6714

Phone (08) 9143 1488
47 Henry Street
Fremantle 6160
Phone (08) 9432 5100

Figure 35. Charter vessels bring tourists to the study area to enjoy the scenery and wildlife as well as to fish, dive and explore the islands.

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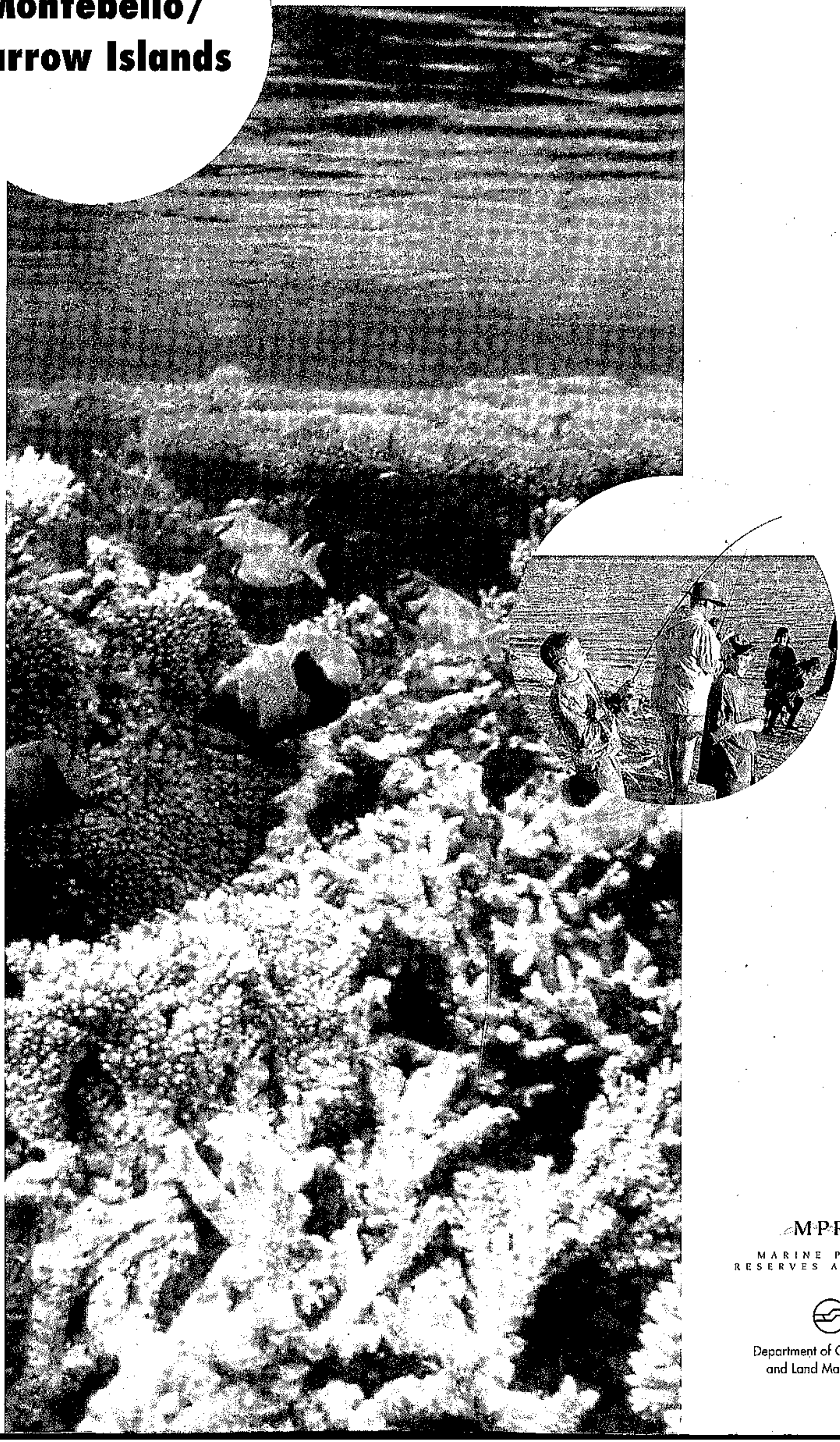
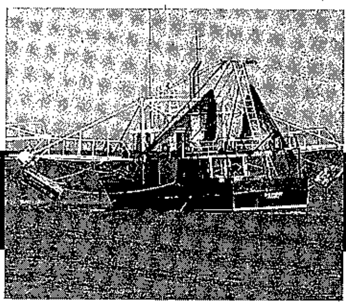
Regional Perspective

Montebello/ Barrow Islands



MPRA
MARINE PARKS & RESERVES AUTHORITY

Department of Conservation and Land Management



MARINE PARKS AND RESERVES AUTHORITY

For more information contact:

Marine Parks and Reserves Authority
Department of Conservation and Land Management
Hackett Drive
Crawley WA 6009
Ph: (08) 9442 0300 Fax: (08) 9386 1578

Marine Conservation Branch
Department of Conservation and Land Management
47 Henry Street
Fremantle WA 6160
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