RESOURCE ASSESSMENT SUMMARY FOR THE PROPOSED MARINE CONSERVATION RESERVES IN THE PILBARA AND EIGHTY MILE BEACH REGION

Biophysical and socio-economic information to assist in selecting reserve sites and to provide information for the PEMB region marine reserve planning processes.

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INTRODUCTION

The Government of Western Australia is committed to conserving and managing the State's marine environment for current and future generations. A major component of this commitment is the establishment of a network of comprehensive, adequate and representative marine parks and reserves which aim to protect representative and special marine ecosystems and processes and to ensure that human uses of the marine environment are managed in an equitable, integrated and sustainable way (Government of Western Australia, 1998[1]). The Western Australian marine parks and reserves system contributes to the National Representative System of Marine Protected Areas which is a key strategy to preserve Australia's marine biodiversity and assists in meeting obligations under several international conventions and agreements (Australian and New Zealand Environment and Conservation Council, 1998[2]).

On 12 December 2006, Hon Mark McGowan MLA, Minister for the Environment announced the Government's initiative to expand Western Australia's system of marine conservation reserves in the Pilbara and Eighty Mile Beach coasts. The Government has identified six study areas for consideration for reservation for biodiversity conservation and marine turtle protection including Eighty Mile Beach, Cape Keraudren to Spit Point (including Bedout and North Turtle islands), the Depuch region from Cape Thouin and Cape Lambert, Bells Beach at Cape Lambert, the coastline and islands between Fortescue and Cane rivers and the Ashburton River region. A further study area with high biodiversity attributes, the Serrurier island complex, is now also being considered in the project.

The Department of Environment and Conservation (DEC) is coordinating the planning process for marine parks and reserves in the PEMB region which is subject to existing *Conservation and Land Management Act 1984* statutory planning and approvals processes including a commitment to public consultation and concurrence by the Minister for Fisheries and Minister for Resources. DEC is dedicated to extensive assessment, community consultation and management planning before new marine parks and reserves are established. DEC has undertaken this rapid *resource assessment* to provide biophysical and socio-economic information and spatial data for planning the marine parks and reserves. This resource assessment was initiated for the PEMB regions to assist in selecting reserve sites and to provide information for the marine reserve planning processes.

[1] Government of Western Australia. (1998) *New Horizons the Way Ahead in Marine Conservation and Management*, pp 20. Department of Conservation and Land Management. Perth, Western Australia.

[2] Australian and New Zealand Environment and Conservation Council. (1998) *Strategic Plan of Action for the National Representative System of Marine Protected Areas: Public Comment Draft*: ANZECC Task Force on Marine Protected Areas. Environment Australia, Canberra.

1. GEOMORPHOLOGY

1.1 What are the key events in the geological history of the study area (eg history of rock formation, major sea level changes, time of sediment deposition, formation of petroleum/mineral deposits)?

(Semeniuk, 1993) cites six main causative factors contributing to the development of regional-scale coastal types in the Pilbara region:

- o Fluvial construction to develop alluvial fans and delta lands
- o Destruction of deltas to develop barrier coasts and bays
- o Longshore transport away from active deltas
- o Pleistocene limestone barrier ridges formed by Aeolian accumulations along former shorelines
- o Continuing coastal erosion to remove limestone ridges of barrier coasts and to develop scalloped, embayed coasts
- o Outcrops of Precambrian bedrock, forming archipelagos and islands

The Pilbara Quaternary stratigraphy and geomorphology suggests that aridity was intricately involved in sedimentation, geomorphic evolution, and pedogenic and diagenetic alteration of this coastal zone (V & C Semeniuk Research Group, 2000).

1.2 Is the geology/geomorphology of the study area generally uniform, or does the study area consist of distinct coastal zones?

Typical features of the Pilbara coastal system are barrier islands and coastal dune systems, protected tidal embayments/flats, deltas, and coastal limestone formations (LeProvost Semeniuk and Chalmer & Tingay, 1984).

There are six general types of coasts in the Pilbara (in order of most active/accretional, to least active/erosional): active deltas; beach/dune shores; inactive, eroding deltas, and their barriers; limestone barrier coasts; bays associated with eroded limestone barriers; and archipelago/ria coasts. Within each of the regional-scale coastal types there is a multitude of varied large, medium and small scale coastal landforms and sedimentary deposits such as spits, sand mounds an shoals, sand aprons around islands, small alluvial fans and tidal creeks (Semeniuk, 1993).

- o **Active Deltas**: Still in a dominantly accretional phase. Wave dominated, with prevailing winds oblique to the shore, forcing sand away from discharge site (longshore drift). Combined with onshore winds results in buildup of large beach/dune systems.
- o **Beach/Dune shores**: Accreting beaches and dunes.
- o **Inactive eroding deltas, and their barriers**: Some delivery of sediment from rivers, but predominant processes are erosional. Sand eroded from these coasts go to form beach/dune shores. Sandy barriers are often left outside the coastal process zone.
- o **Limestone Barrier Coasts**: Ridge or series of ridges forming a limestone barrier. Erosion is the predominant feature of these coastal types, with the

barrier system effected by sea front erosion, tidal creek erosion and salt crystalisation in high tidal environments. Sedimentation occurs leeward of the barrier as fill in the inter-ridge depressions, and as dune build-ups at the extremities of the barriers.

- **Bays associated with eroded limestone barriers**: eroded limestone barriers, commonly below intertidal levels. Derived from limestone barrier coasts. Features an eroded mud coast exposed to open coastal erosion, extensive hypersaline mud flats, mangrove tidal creeks and outwash alluvial fans.
- **Archipelago/ria coasts**: Formed where Precambrian bedrock outcrops at the shore. Coastal landforms in archipelago/ria coasts range from scattered small islads, to tidally interconnected islands, to large islands with 'ria' coastal morphology. These landforms are formed by the marine inundation of the hilly bedrock topography (Semeniuk, 1993).

At the sub-regional scale, it is appropriate to classify the Onslow-Barrow Island to Fortescue River area into a number of large-scale geomorphic componets including: submarine shelf with numerous emergent islands, cays and submerged rocky reefs; the Barrow Island system; the coastal tract comprising of dunes, barrier islands, tidal flats and embayments; deltas; and the hinterland (Semeniuk, 1993).

The Pilbara coast can be viewed as a coastal plain of alluvial sediments, with a system of nearly continuous stretches of limestone and Holocene dune barriers, behind which are protected embayments, lagoons and tidal flats. This prevalent pattern is disrupted locally by deltas, or by bedrock outcrops (Semeniuk, 1993).

Also see 'Oceanography', section 10.

1.3 What are the rock and sediment types of the coastline of the study area (eg granite, gneiss, limestone) and when were they formed/deposited?

Holocene sedimentary deposits form accumulations of varying size and shape such as veneers, sheets, ribbons, wedges and shoe-strings along the modern coastal zone. Holocene sediments occur as the most seaward accretionary unit in the Pilbara region, forming an accretionary margin to the coastal plain (Semeniuk, 1993).

The conspicuous Pleistocene limestone units in the Pilbara region are ridge-like, forming shore-parallel barriers. Some limestones occur at depth, and are sheet like, as intercalations with Pleistocene red siliciclastic units. The limestone units from shore parallel, near continuous ridges(Semeniuk, 1993).

Three main time-rock units have been recognised in a geomorphology study of the Onslow-Barrow Island area, namely quarternary (Holocene) sediments (comprising shelf sediments, coralline accumulations, coastal sands and tidal flat accumulations); quarternary (Pleistocene) limestone (referred to as the "Coastal Limestone Formation"); and tertiary (Miocene) limestone (referred to as the "Trealla Limestone Formation"). All three time-rock units make contributions as materials and substrates of terrestrial and marine systems (LeProvost Semeniuk and Chalmer & Tingay, 1984).

West of Cape Preston, the coastline falls within the sedimentary Carnarvon Basin with Cainozoic Aeolian and beach rock deposits forming the shore. East of Cape Preston the coastline is near the northern margin of the Pilbara Craton constructed of Archaean metamorphic and igneous rocks. (Rangelands NRM Coordinating Group, 2005)

For much of the region, the shelf consists of gently inclined Pleistocene limestone extending to around 15 metres depth several kilometres offshore. This is broken locally by limestone reefs and small islands. Local biogenic accretion on the shelf results in sheets and mounds of corals, calcareous algae and bioclastic sand and gravel deposits. (Lyne et al., 2006)

The sediment characteristics of the nearshore zone are typically muddy substrates with terrigenous sediments. Deltas produce fluvial sand which covers the delta margin. Offshore substrates are generally more sandy, with a gradual transition in deeper water to finer sands and muds. (Lyne et al., 2006)

The coastal plain and river deposits are underlain by Cenozoic deposits. The coastal plain front the upland ranges forming an extensive ribbon to apron unit descending to sea level. The plain is underlain by a variety of deposits that include gravel, sand and mud sheets, laterised sedimentary deposits, limestone sheets, pedogenic sheets, and calcrete. The river deposits reside in valley tracts and gorges, and are underlain lenses, ribbons and wedges of gravel, sand and mud, laterised sediment and calcrete (V & C Semeniuk Research Group, 2000).

The Quaternary coastal deposits are complex, and are comprised of shoestrings, ribbons, sheets, wedges and lenses of Pleistocene and Holocene sediments and sedimentary rock. The materials include Pleistocene limestones, red sand, red muddy sand, conglomerates, fossil soils, and Holocene, beach sands, dune sands, spit/chenier sands, tidal flat gravel, tidal flat sand, tidal flat mud, high tidal alluvial fan deposits, colluvial gravels and sands, and soils (V & C Semeniuk Research Group, 2000).

1.4 What are the major landforms/habitats of the coastline of the study area?

The lowlands of the Pilbara Coast form a special coastal system in Western Australia in that they are a fluvial plain and coast developed by rivers draining a high relief hinterland in a tropical arid climate. The numerous rivers and creeks with intermittent or infrequent discharge in the arid setting, together with fluvial shoreline accretionary processes, coastal cementation, coastal erosion and ancestral landform architecture have combined during the Quaternary to produce this coastal system (Semeniuk, 1993).

In the Pilbara region, the submarine shelf (termed Rowley Shelf) is generally a plane surface, gently and evenly inclined so that it slopes from tidal at the shoreface to depths of 20m some 20km from shore. This surface is broken locally by upstanding limestone reefs which are randomly located but generally form a NE-trending series of ridges (LeProvost Semeniuk and Chalmer & Tingay, 1984).

The Eighty Mile Beach region consists of coastal areas with almost continuous curving white beaches of siliceous sands and dune systems. The average width of the beach is 100 metres, and it features a drop-off into extensive tidal mudflats. A few small bays support mudflats and mangrove communities, breaking up the sections of white sandy beach. There is no fluvial run-off and wave action is medium. Pastoral leases are adjacent to most of the coastline. (Rangelands NRM Coordinating Group, 2005)

Along the Pilbara coast the land forms consist of barrier islands and associated protected lagoons, embayments and deltas. The coast is either open or partly protected by groups of nearshore, limestone islands. Mangrove and intertidal mudflat communities are prevalent along the Pilbara coast, with occasional beach and rock platform coastal habitats in between. Several large seasonal river estuaries, associated with extensive mangals and salt marsh flats occur in this region (Rangelands NRM Coordinating Group, 2005).

Wide intertidal sand flats occur on the leeward sides of most of the islands, often with the sand forming thin sheets over a rock pavement (Rangelands NRM Coordinating Group, 2005).

The coastline of the Pilbara predominantly consists of systems of barrier islands and associated protected lagoons. The ridges were formed by the accumulation of Aeolian shoreline calcareous sand ridges that are now limestone and form shore parallel barriers. These limestone ridge units are important where they outcrop at or near the shore, as they play a part in determining coastal geomorphology and controlling Holocene sedimentary patterns. (Lyne et al., 2006)

1.5 What are the main processes that currently influence the geology/geomorphology of the study area (eg wave erosion, sediment transport by currents, water level change, cyclone events, biological erosion)?

1.6 Have there been any past, and/or are there any current/potential uses and/or pressures on the geology/geomorphology of the study area (eg coastal development such as groynes, marinas and shipping channels; aquaculture infrastructure)?

1.7 Is there any evidence of environmental impact on the geologic/geomorphic values of the study area? Provide details of the relevant research/monitoring programs.

1.8 What is the current condition of the geology/geomorphology of the study area (good; fair; poor)?

1.9 What strategies are the relevant management authorities utilising/proposing to minimise the environmental impact on geological/geomorphic values (eg monitoring programs)?

2. CLIMATE

2.1 Outline the climate type of the study area (eg Mediterranean climate with cool, wet winters and hot, dry summers)

The climate of the Pilbara coastal region can be described as Tropical Arid (Semeniuk et al. 1978 in (Carr & Livesey, 1996), and 'Hot, humid' (www.bom.gov.au, 2008)

The study area is in the most arid coast of Australia, which is one of only five arid coasts worldwide (V & C Semeniuk Research Group, 2000).

2.2 What are the offshore and localized wind patterns of the study area (eg direction, seasonality, speeds)?

	Maximum Mean Wind Speed 9am			Maximum Mean Wind Speed 3pm		
Location	Month	Wind Speed (km/h)	Prevailing Direction	Month	Wind Speed (km/h)	Prevailing Direction
Onslow	October	15	S	December	21.3	W
Mardie	October	16.8	S	November	30	W
Pardoo	June	14.5	E	January	21.8	N
Mandora	July	18.5	SE	November	22.2	NW
	Minimum Mean Wind Speed 9am			Minimum Mean Wind Speed 3pm		
Location	Month	Wind Speed (km/h)	Prevailing Direction	Month	Wind Speed (km/h)	Prevailing Direction
Onslow	April	10.4	S-SE	June	10.3	N
Mardie	April	12.3	SE	June	16.6	N
Pardoo	February	9.1	Variable	June	11.7	N
Mandora	March	12.3	SE	June	13.3	Variable

Table 1: Wind patterns of selected sites in the PEMB study area. Compiled from www.bom.gov.au, 2008.

2.3 What are the mean maximum temperatures for the hottest months and coldest months?

Location	Hottest Month	Mean Maximum (°C)	Coldest Month	Mean Maximum (°C)
Onslow	January	35.7	July	24.8
Mardie	January	38.1	July	27.7
Cossack	January	36.6	July	24.4
Pardoo	November	36.5	July	27.9
Mandora	March	36.9	July	28.8

Table 2: Mean maximum temperatures in hottest and coldest months for selected locations in the study area. Compiled from www.bom.gov.au, 2008.

2.4 What are the mean minimum temperatures for the hottest months and the coldest months?

Location	Hottest Month	Mean Minimum (°C)	Coldest Month	Mean Minimum (°C)
Onslow	February	24.2	July	11.7
Mardie	February	25.3	July	11.7
Cossack	January	25.8	July	13.3
Pardoo	January	25.9	July	12.9
Mandora	January	25.4	July	12.4

Table 3: Mean Minimum temperatures in hottest and coldest months for selected locations in the study area. Compiled from www.bom.gov.au, 2008.

2.5 What is the average annual precipitation, and detail the seasonal variation of precipitation?

Most of the rainfall occurs from January to April with the driest months being September to December (Johnstone 1990 in (Carr & Livesey, 1996). On average, there are only 16-33 rain days per year (Semeniuk 1983 in (Carr & Livesey, 1996).

Location	Mean Annual Rainfall (mm)	Highest Rainfall Month	Rainfall (mm)	Lowest Rainfall Month (mm)	Rainfall (mm)
Onslow	275.5	February	50.5	October	0.7
Mardie	272.3	February	57.7	October	0.8
Cossack	316.4	March	66.7	October	0.4
Pardoo	316	February	75	October	0.8
Mandora	372.9	February	101.6	October	1

Table 4: Mean annual rainfall at various locations in the study area. Compiled from www.bom.gov.au, 2008.

2.6 What is the average daily and monthly humidity of the study area?

Location	9am High		9am Low		3pm High		3pm Low	
	Month	RH(%)	Month	RH(%)	Month	RH(%)	Month	RH(%)
Onslow	June	64	Oct&Nov	45	February	61	September	50
Mardie	February	59	October	35	February	48	September	28
Roebourne	February	57	October	34	February	44	Sep&Oct	27
Pardoo	February	70	August	36	February	63	August	35
Mandora	February	64	September	32	February	58	August	27

(RH – Relative Humidity)

Table 5: Average humidity of study area sites. Compiled from www.bom.gov.au, 2008.

2.7 Outline any available evaporation data of the study area (eg annual mean, times of highest and lowest occurrence)

Mean daily evaporation:

- Port Hedland Airport: June - 6.4mm, November – 11.4mm
- Broome Airport: June – 6.0mm, November – 9.4mm

(www.bom.gov.au, 2008)

2.8 Do any extreme climatic events occur in the study area (eg cyclones)? If so, what has been the environmental and social impact of these events?

Cyclones during the period December to April generate the strongest winds and highest rainfall experienced along the Pilbara coast (Carr & Livesey, 1996).

Cyclones are a source of major inputs of freshwater and sediment into the coastal zone, this has a considerable impact as the area receives very little runoff at other times. Cyclones can have a major impact on the coastal zone, such as substantial sediment movement and sea floor scouring, however, as they are short lived and generally infrequent, they are unlikely to have a large impact on the biological system as a whole. Cyclones can contribute to spikes in productivity through enrichment of surface layers from enhanced mixing of the water column (NMBP, 2007)??

The effects of cyclones include: marked river discharge of sediment onto the coastal plain, influx of mud as a suspension load into marine waters, flash flooding of creeks, formation of sediment aprons and fans at the junction of the hinterland and the tidal flats, storm surges, defoliation and destruction of mangroves, formation of spits in the coastal zone, and erosion and dispersion of coastal sediment bodies (Semeniuk, 1996).

3. OCEANOGRAPHY

Water level

3.1 What are the tidal patterns and ranges of the study area?

The tidal amplitudes and the tidal currents off the Kimberley coast can be large as 10m and 4 knots respectively (Cresswell & Badcock, 2000).

The average range of spring tides at Port Hedland is 6m. (Prince, 1986).

The tidal currents are predominantly in the cross shelf direction. The strength of the currents and associated tidal ranges increases to the northeast (Condie et al., 2006).

Tides in the Pilbara are semi-diurnal, ranging from 2.7 m in the south, and progressively increasing to c. 8 m in the north (Semeniuk, 1996).

3.2 What is the influence of tides on the hydrodynamics of the study area (eg net water movement, estuary hydrodynamics)?

(Cresswell & Badcock, 2000) argued that if tides mix cold water to the surface then they probably mix nutrients as well. They suggest that stratified shelf waters nearing the banks are mixed by the tides, resulting in cooler surface waters (and warmer bottom waters). This effect is negligent during dry season. They argue that this mixing effect is probably prevalent over a large part of the continental shelf.

Tidal mixing and stratification (of temperature zones) was seen as a key feature of the Kimberley region with some areas as much as 3 degrees cooler. Water property profiles show the most stratification in February near the end of the monsoon and the least during the winter SE trade winds (Cresswell & Badcock, 2000).

Strong barotropic, semi-diurnal tides are seen to dominate the flow over the NWS. The NWS shows the existence of internal waves of semi-diurnal period. Vertical displacements of density interfaces are seen to reach ~30m, nearly half the water depth on the shelf (Holloway, 1983).

3.3 What are the implications of tides on the physical characteristics of the study area (eg influence of tides on coastal geomorphology)?

Coastal processes are driven by tides and rainfall (Mustoe & Edmunds, 2008)??

Climate plays a significant part in the coastal processes and in the generation of sedimentary products through high evaporation rates coupled with the limited rainfall, cyclonic storms, wind, wind waves, and the limited sediment delivery to the coastal zone. This results in a distinctive range of stratigraphic sequences and chemical products. As a result, this arid coast is characterised by a range of features such as construction of arid zone deltas, delta destruction and sediment redistribution during times of sediment depletion, cyclone-induced erosion and sedimentation, mangroves and their associated sedimentary deposits, evolution of coastal groundwater hyper-salinity, formation of salt flats, and precipitation and cementation to form beach rocks, high-tidal crusts and gypsum precipitates (Semeniuk, 1996).

The four main oceanographic factors influencing coastal development are prevailing waves, storm surges, storm waves, and tides (Semeniuk, 1996).

3.4 What are the implications of tides on the biological characteristics of the study area (eg zonation patterns)?

Internal tides draw deeper, cooler waters into the photic zone, stirring up nutrients, consequently increasing primary productivity. The extent of this influence is irresolute. (NMBP, 2007)??

In many parts of the study area productivity levels are strongly influenced by the suspension and re-suspension of sediment due to tidal action. (NMBP, 2007)??

3.5 Are there any other meteorological influences on water level (eg winds, storm surges, barometric pressure and coastally trapped long period waves eg continental shelf waves, tsunamis, cyclone events)?

Storm surges (related to cyclonic activity) can occur during wet season from December to April. It is unclear what the effects on biodiversity are from the literature. There is documentation from the Northern Territory of storm surges creating major ecosystem perturbations in the Gulf of Carpentaria- destruction of seagrass beds, decimation of turtle and dugong populations (Wohling pers. comm.- NT parks and wildlife wrote a paper on this event some years ago).

Periodically, and especially during cyclones, the large rivers in the region discharge freshwater into the coastal zone and bring in mud that is dispersed widely into marine waters. Freshwater also enters the coastal zone from the nearby surrounding hinterland by sheet flooding, numerous small creeks, and via subterranean seepage (Semeniuk, 1983).

Tropical cyclones are a relatively common event over summer on the North West Shelf, with an average of more than two per year. The low pressure associated with the centre of the cyclone generated a local high in sea level. As cyclones move onto the inner shelf, intense currents develop in water trapped against the coast with enhanced mixing to depths of at least 80 m. The most energetic ocean currents occur on the eastern side of a cyclone, where the presence of the cyclone impedes the southwestward propagation of coastally trapped waves. There is a lower incidence of Tropical Cyclones during El Nino years. (Condie et al., 2006)

During the summer period tropical cyclones can generate major short-term fluctuations in current patterns and coastal sea levels and are likely to have significant impacts on sediment distributions and other aspects of the benthic habitat. (Condie et al., 2006)

Waves

3.6 What are the oceanic swell patterns and local sea patterns which affect the study area (eg formation, direction, typical wave height and period as per season)?

The NWS has temperature sections that clearly show internal waves with horizontal wavelengths of approximately 20km. these waves do not appear to propagate far onto the shelf (Holloway, 1983).

3.7 Does the study area have a high, medium or low energy coast?

Wave dominated oceanic system (Semeniuk, 1993).

A study of the Onslow-Barrow Island area notes the coastal and nearshore zone has a variable wave climate with effects produced by combined swell and locally-generated wind waves. Tropical cyclones also occur during the summer (LeProvost Semeniuk and Chalmer & Tingay, 1984).

3.8 How do waves affect the hydrodynamics of the study area? (circulation/flushing/net water movement/re-suspension)?

3.9 What is the effect of geomorphology (eg bathymetry, islands, reefs) on local wave patterns as ocean swells impact on the coastline?

Prevailing onshore winds develops coastal dunes, and influences the construction of coastal sediment bodies by generating wind waves (Semeniuk, 1993). Long period swell originating in the Southern Indian Ocean is refracted by the regional bathymetry to approach the Pilbara Coast mainly from the northerly and north westerly sectors. The swell is then refracted and diffracted by the variable bathymetry and islands of the NW shelf. Land breeze/sea-breeze systems and thunderstorms generate local short-period wind waves which also are an important prevailing feature in the coastal zone (Semeniuk, 1993).

Shores protected by major structures such as peninsulas, or archipelago systems, or shores fronting broad gently shelving sea floors, may be subject only to locally generated wind waves, and consequently tide-dominated coastal landforms become more important (Semeniuk, 1993).

Current patterns are influenced by bathymetry and coastline geometry. Islands and related bathymetric features can cause local acceleration of currents. Tidal motion over bathymetry results in vertical mixing and the formation of relatively deep bottom mixed layers. (Condie et al., 2006)

3.10 What is the interaction between waves and sedimentation processes?

The unifying feature of the Pilbara coast of NW Australia is that it is a sedimentary repository for a range of rivers that drains a high-relief Precambrian rocky hinterland and discharges sediments along a coastal plain which fronts a wave dominated environment in a tropical arid climate (Semeniuk, 1993).

3.11 What are the implications of waves on the physical characteristics of the study area (eg effect of swell on coastal geomorphology)?

Though most tidal ranges in the Pilbara are meso- to macro-tidal and hence the coast may appear to be tide-dominated, regionally the Pilbara coast should be viewed as wave-dominated, because delta-land morphology and the other coastal landforms reflect wave-dominated conditions.

Long period swell, from the Southern Indian Ocean, is refracted by the regional bathymetry to approach the Pilbara coast mainly from northwest and north. The swell is then variably refracted and diffracted by the bathymetry and islands of the Northwest Shelf. Winds generate short period wind waves which also are an important prevailing feature in the coastal zone. Wind waves follow the wind pattern and consequently there is a dominance of waves from northwest through to west, and southeast through to east, depending on the season. As a result of the dominant directions of swell and wind waves, the portions of coastline exposed to the wave trains have coastal features dominated by wave action (e.g. spits, beaches, sand bars, rocky shores) (Semeniuk, 1996).

Tidal processes result in small-scale tide-developed bedforms, such as megaripples and sand waves, but these are superimposed on larger wave-developed coastal features. Large-scale tidal dominated landforms occur only in locations protected from wave action, such as embayments, inlets behind limestone or sand barriers, and within tidal creeks (Semeniuk, 1996).

3.12 What are the implications of waves on the biological characteristics of the study area?

The most recent research (Ivey et al)?? has shown that the NW shelf has a significant internal wave component that at this stage has unknown effects on the ecology of the region.

Currents and tides

3.13 Describe the major regional currents of the study area. Include formation/key forcings, speed, direction and seasonality.

A key characteristic of the oceanography of the North-west Marine Region is the pole-ward flow of the main surface currents. The difference in steric height The Western Australian current system is globally unique as pole-ward current flow is not experienced in the eastern boundary of other oceans. (Holloway, 1983).

The most notable feature was described as being the lack of a well defined spring-neap cycle in either temperature or baroclinic currents particularly given the very pronounced cycle in the barotropic tides (Holloway, 1983).

The dominant current along the Western Australian coastline is the Leeuwin Current (Caputi et al., 1996), which is a flow of warm and low-salinity water from the central Pacific Ocean through the Indonesian Archipelago that is driven by sea-level gradient (Godfrey and Ridgeway 1984; Simpson 1998; Veron and Marsh 1988 in (Gilmour et al., 2006). The current intensifies as a strong flow of warm water to the southwest during the winter months (April to September) when the sea-level gradient is greatest and the wind stress from the south is weakest (Pearse and Creswell 1985 in (Gilmour et al., 2006); (Caputi et al., 1996). The current flows within a relatively stable hydrological environment with little or no upwelling and minimal river runoff. (Godfrey and Ridgway 1985 in (Caputi et al., 1996).

Circulation in the area is influenced by the Indonesian Throughflow and the Leeuwin current which carry warm waters with low salinity in a southwesterly direction from February to June. In the remainder of the year strong SW winds cause intermittent reversals of these currents, leading to weak upwelling onto the shelf. El Nino also causes weakened Indonesian Throughflow (Condie et al., 2006).

The Leeuwin Current has large tropical contributions from the remote equatorial Indian Ocean, via the South Java Current, and also from the Pacific Ocean, via the Indonesian Throughflow. The Eastern Gyral Current augments the poleward flow of the Leeuwin Current (Domingues et al., 2007).

The Leeuwin Current flows adjacent to the Continental Shelf, which is significantly wider along the NW coast, than to the south of NW Cape. This means that it has less effect on nearshore environments in the study area than areas further south (Hutchins, 2004).

There is considerable variation in the Leeuwin current from one year to the next. The latest data from WAMSI's node 6 (Ivey et al)?? has shown a 30% decline in the Leeuwin current speed over the last 30 years.

3.14 Describe the local currents of the study area. Include formation/key forcings, speed, direction and seasonality

The primary current is the south-west flowing Leeuwin current (Holloway, 1983). It flows from north to south during the summer/wet season months. Its greatest strength is from February to July, it then moderates around May/June remaining weak through the winter/dry season months until January and sometimes into February (Holloway, 1983). Holloway's research supports previous evidence of a steric (sea level) gradient along the WA coastline and that this gradient persists all year with varying strength.

Holloway's data also suggest that the occasional current reversal to the NE is due to the SW winds that occur between September and March and that counteract the pressure gradient forcing from the steric height gradient. Often these SW winds merely retard the SW currents and are not strong enough to reverse them.

3.15 Outline the formation of eddies and the occurrence of upwelling

Holloway's findings (Holloway, 1983) support the idea that weak upwelling events do occur and result from NE flowing currents, which can occur in both summer and winter months. The winds alone were not regarded as a sufficient indicator of upwelling.

Near-bottom water temps had a different seasonal cycle to surface water with the coldest water in summer and warmest in winter. The intrusions of cold bottom-water appeared as weak upwelling events and were associated with the periods of currents towards the NE.

Mesoscale eddies form from mixed barotropic and baroclinic instability of the Leeuwin Current. As the current strengthens, some of the water spins up from the current as anticyclonic eddies that propagate away from the coast. Wind enhances eddy spin and creates localised upwelling (Waite et al., 2007).

3.16 How do currents influence circulation, mixing and exchange?

The marine waters of the Northwest Shelf fronting the coastal zone generally are well mixed and oceanic, but nearshore waters that have mixed with tidal waters drained from adjoining highly saline salt flats may have salinities of 40-45,000 ppm (Semeniuk, 1996).

Long-termed average sediment fluxes were directed southwest along the shelf and off the shelf. While there were significant uncertainties associated with these fluxes, the results suggested that sediment losses from the shelf exceeded the mean annual river loads by at least a factor of three over the simulation period.

3.17 What is effect of geomorphology (eg bathymetry, islands, reefs) on current patterns?

3.18 What is the interaction between currents and sedimentation processes (eg littoral drift)?

3.19 What are the implications of currents on the physical characteristics of the study area (eg spread of oil spills and other threatening waterborne substances)?

3.20 What are the implications of currents on the biological characteristics of the study area (eg spread of larvae)?

The strength and path of the Leeuwin Current has a major influence on the abundance of many species. Research indicates the larval phase is the stage mainly affected by the current, but not always with the same result. Current strength has a significant positive influence during the larval stage of the Western Rock Lobster (*Panulirus cygnus*). The current has a negative influence during the larval life of the Saucer Scallop (*Amusium balloti*) in Shark Bay. For pelagic finfish species, the current strength has a negative effect on larval survival of pilchards (*Sardinops sagax neopilchardus*) but a positive impact for whitebait (*Hyperlophus vittatus*). Details on the effect of the current on the recruitment of these species can be found in (Caputi et al., 1996).

The Leeuwin Current may transport the propagules of Kimberley fish to the south (Hutchins, 2001).

The life histories and spatial extent of a diverse range of tropical and temperate marine organisms are influenced by the dynamics of the Leeuwin Current system and associated water masses. A high degree of connectivity between populations is also exhibited. (Domingues et al., 2007).

Winds

3.21 What is the influence of winds on the hydrodynamics of the study area (eg net water movement/circulation/flushing)?

The current components consist of an Ekman spiral due to local forcing at the sea surface and a depth-averaged, pressure driven flow, resulting from wind forcing and the constraint of the coastline. The horizontal currents forming the Ekman spiral decay exponentially with depth over a scale depth D, the Ekman depth (Holloway, 1983).

The predominant winds in the area are a seasonal cycle; offshore (SE) in the dry season (May- September) and onshore/longshore (SW) in the build up and wet season (Nov- April)(Holloway, 1983). October tends to be a variable month.

Monsoonal winds in the northern parts of the study area contribute to the mixing of surface waters (NMBP, 2007)??.

3.22 What are the implications of winds on the physical characteristics of the study area (eg water quality)?

Local wind stress was thought to cause only a weak surface current. Long shore current flows were thought to be driven by forcing other than local winds (Holloway, 1983).

See 'Climate' section for details of effects of cyclones on the study area.

3.23 What are the implications of winds on the biological characteristics of the study area (eg spread of larvae)?

Temperature & Salinity

3.24 Where and why do vertical and horizontal temperature and salinity gradients form? Outline the interaction of these gradients with local physical conditions (eg river runoff, winds, currents, tides).

Locker Point – N Kimberly coast study area:

- Mean water temp in the wet period was lower in deep waters (average = 20m) than in shallow waters (average = 10m) (Travers, Newman & Potter, 2006).
- Mean water temp in the dry period was lower in shallow waters (average = 10m) than in deep waters (average = 20m) (Travers, Newman & Potter, 2006).

Pilbara and Kimberly coasts PEMB region mean monthly water temperatures:

- 31.8°-32.4°C October to December
- 17.8°C-21.1°C June to August

Evaporation can form zones of increased salinity at the mouths of rivers in the hot, dry season. These saline plugs can limit the flow of fresh water out of the river/estuary (Alongi, 1990).

3.25 Describe the influence of salinity/temperature gradients on density and describe their role in driving circulation, mixing and exchange.

The marine waters of the Northwest Shelf fronting the coastal zone generally are well mixed and oceanic, but nearshore waters that have mixed with tidal waters drained from adjoining highly saline salt flats may have salinities of 40 45,000 ppm (Semeniuk, 1996).

3.26 What is the impact of temperature and salinity on the marine communities of the study area?

4. ROCKY SHORE COMMUNITIES

4.1 In what IMCRA biogeographical province and biogeographical region(s) does the study area occur, and what are the defining features of the biota and the marine and coastal communities?

4.2 What are the major marine and coastal communities of the study area? For each community, state:

a) distribution and area covered within the study area;

b) structure (eg rock type, sediment type, relief);

c) distribution and diversity of predominant flora and fauna;

d) the occurrence of any species of special conservation status (ie is it listed under the *Wildlife Conservation (Specially Protected Fauan) Notice 1999,* the *Endangered Species Protection Act 1992* and/or the *Threatened Australian Fauna (ANZECC List) 1999*?), rare or endemic species;

e) the influence of the physical environment on structural morphology, and flora and fauna distribution and adaptations;

f) the influence of biological processes on structural morphology, and flora and fauna distribution and adaptations;

g) productivity/food webs/community structure;

h) past, present and potential uses and/or pressures (natural and human-induced); evidence of impact and the relevant research/monitoring programs (if any);

i) current condition/degree of naturalness (eg degraded; healthy); and

j) current/proposed management strategies and future implications.

5. INTERTIDAL SAND AND MUDFLAT COMMUNITIES

5.1 In what IMCRA biogeographical province and biogeographical region(s) does the study area occur, and what are the defining features of the biota and the marine and coastal communities?

5.2 What are the major marine and coastal communities of the study area? For each community, state:

a) distribution and area covered within the study area;

b) structure (eg rock type, sediment type, relief);

Eighty Mile Beach

Eighty Mile Beach is an 150 km long, almost continuous sandy beach with a wide intertidal area interrupted by only a few, small, muddy bays bordered by mangrove trees. The steep upper slope of the beach gives way to intertidal mud and sandflats closer to the shore. At very low tides the maximum width of the flats can be up to 4–5 km (Honkoop et al., 2006).

Conditions at Eighty-mile Beach can be summarised as a tidal-flat system with a reflective upper shore. Coarse sand is deposited high in the intertidal where the incoming waves collide with the backwash resulting in a characteristic step (about 0.5 m) on the lower shore and with a platform of coarse sand above the intertidal slope. The intertidal area is relatively flat and consists mainly of fine sediments except for the area just below the step where sediments consist mainly of medium and coarse sands. (Honkoop et al., 2006).

Generally, the sediment of Eighty-mile Beach is very fine, with 55% of all cores in one study containing more than 50% mud and silt (median grain size <63μ) (Honkoop et al., 2006).

c) distribution and diversity of predominant flora and fauna;

Eighty Mile Beach

Very few species were observed here, crustaceans being the major faunal group (Honkoop et al., 2006).

Omphiura tenuis was found in large numbers on the lower flats. Therefore, the lower part of the intertidal zone can be considered to be an ophiuroid zone (Honkoop et al., 2006).

Sandy beaches are important nesting sites for sea turtles and wedge tailed shearwaters (Rangelands NRM Coordinating Group, 2005).

d) the occurrence of any species of special conservation status (ie is it listed under the *Wildlife Conservation (Specially Protected Fauan) Notice 1999*, the *Endangered Species Protection Act 1992* and/or the *Threatened Australian Fauna (ANZECC List) 1999*?), rare or endemic species;

e) the influence of the physical environment on structural morphology, and flora and fauna distribution and adaptations;

Eighty Mile Beach

Tidal height and median grain size affect the numbers of individuals and species. It appears that the number of bivalves is most influenced by the sediment (Honkoop et al., 2006).

f) **the influence of biological processes on structural morphology, and flora and fauna distribution and adaptations;**

Eighty Mile Beach

Distribution patterns of benthos at Eighty-mile Beach were influenced or determined by other factors than tidal zonation, one possibility being that biotic interactions are more important than the assumed abiotic structuring." (Honkoop et al., 2006)

g) **productivity/food webs/community structure;**

h) **past, present and potential uses and/or pressures (natural and human-induced); evidence of impact and the relevant research/monitoring programs (if any);**

Eighty Mile Beach

Cyclones, such as Vance in 1999, may have a considerable effect on the abiotic environment, and the benthic community takes a significant amount of time to fully recover. (Honkoop et al., 2006)

So far, Eighty Mile Beach has been relatively little impacted by human activities. (Honkoop et al., 2006)

i) **current condition/degree of naturalness (eg degraded; healthy); and**

j) **current/proposed management strategies and future implications.**

6. CORAL REEF COMMUNITIES

6.1 In what IMCRA biogeographical province and biogeographical region(s) does the study area occur, and what are the defining features of the biota and the marine and coastal communities?

6.2 What are the major marine and coastal communities of the study area? For each community, state:

a) distribution and area covered within the study area;

b) structure (eg rock type, sediment type, relief);

Coral communities are found both intertidally and subtidally, on substrates ranging from limestone or igneous rock, to subtidal mud (Simpson 1988 in (Gilmour et al., 2006).

Patch, fringing and platform reefs in less than 30m depth along Kimberly, Canning (Cape Keraudren to Emeriau Point) and Pilbara coasts (to Locker Point) consists mainly of a "living veneer of scleractinian and encrusting coralline red algae, overlying subtidal limestone pavement and igneous rock" (Travers, Newman & Potter, 2006).

Robe

In the area stretching from Passage Islands to Mangrove Islands small submerged coral reefs (bomboras) were scattered throughout (Pendoley & Fitzpatrick, 1999).

c) distribution and diversity of predominant flora and fauna;

There are a large range of habitats and associated coral communities on reefs within the Pilbara. Extreme conditions mean some corals and communities exist at close to their physical limits, particularly at inshore reefs (Gilmour et al., 2006).

On reefs within the Pilbara, at least 223 scleractinian (stony coral) species from 57 genera have been recorded, of which roughly half belong to the families Acroporidae and Faviidae. Many species are thought to be in low abundance and to be widespread among Indo-Pacific reefs (Gilmour et al., 2006).

Communities on offshore reefs tend to have higher coral cover and be dominated by species of *Acropora*, whilst those located around the offshore and inshore divide have moderate cover with a diverse array of species from the families Dendrophylliidae, Poritidae, and Faviidae. The inshore and coastal reefs generally have the lowest cover of corals. Coral diversity is also thought to be lower at inshore reefs, due to extreme conditions such as sedimentation and the growth of macroalgae, and also at the most outer reefs, due to wave energy and the dominance of species like plating *Acropora* (Gilmour et al., 2006).

In addition to the diversity of hard corals, a variety of other organisms are associated with coral reefs in the Pilbara. These include soft corals, ascidians, sponges, hydroids, and anemones (Gilmour et al., 2006).

Robe
Common coral genera include *Porites*, *Turbinaria* and *Goniopora*. Coral bleaching was widespread at the time of survey (April 1998) and approximately 80% of the corals observed in the Mangrove and Mary Anne Island groups exhibiting severe bleaching (Pendoley & Fitzpatrick, 1999).

d) the occurrence of any species of special conservation status (ie is it listed under the *Wildlife Conservation (Specially Protected Fauan) Notice 1999,* the *Endangered Species Protection Act 1992* and/or the *Threatened Australian Fauna (ANZECC List) 1999*?), rare or endemic species;

According to (Gilmour et al., 2006), the extent to which rare or endemic coral species exist within the region is largely unknown.

e) the influence of the physical environment on structural morphology, and flora and fauna distribution and adaptations;

Coral communities along the Pilbara coastline are strongly influenced by regional weather patterns, particularly extended periods of hot weather and acute periods of monsoonal storms and cyclones during summer and early autumn. Associated with these weather patterns, periods of high water temperatures and extreme levels of sedimentation and turbidity are among the most important factors controlling the distribution and abundance of corals (Gilmour et al., 2006).

With respect to coral communities, the Leeuwin current influences the region by affecting water temperatures and the transport of coral larvae, particularly around offshore reefs (Gilmour et al., 2006).

Coral reefs within the Pilbara experience among the most extreme ranges in water temperature recorded around the world, which is related to their relatively shallow depth distribution and the region's climate (Simpson 1988; Vernon and Marsh 1988 in (Gilmour et al., 2006).

Generally within the region, the inshore and coastal reefs are exposed to higher levels of turbidity, sedimentation and temperature ranges, freshwater inundation, and macroalgal growth, particularly during summer. Offshore reefs in comparison have clearer oceanic water, a high cover of coralline algae, and can be exposed to considerable wave energy with storms and cyclones (Gilmour et al., 2006).

f) the influence of biological processes on structural morphology, and flora and fauna distribution and adaptations;

g) productivity/food webs/community structure;

h) past, present and potential uses and/or pressures (natural and human-induced); evidence of impact and the relevant research/monitoring programs (if any);

The Pilbara region is growing rapidly, which will increase the levels of stress to coral reefs from both industrial and recreational use. Dredging and the disposal of dredge spoil, land reclamation, and the discharge of effluents are the key processes associated with industrial developments and port facilities as threats to coral reefs within the Pilbara. Key stressors from these processes include sedimentation, turbidity, and changes in salinity and temperature (Gilmour et al., 2006).

Between approximately two and five tropical cyclones impact coral reefs within the Pilbara during most years (Simpson 1988; Gilmour 2004 in (Gilmour et al., 2006). Impacts from cyclones are largely due to heavy rainfall and freshwater inundation, strong winds, waves, and the re-suspension of sediment. Substantial runoff from the Ashburton, Fortescue and De Grey Rivers can occur following heavy rainfall which can impact locally on coral communities (Gilmour et al., 2006).

Coral reefs within the Dampier Archipelago are recognised as possibly the most affected and at risk. Other examples of existing and approved developments along the coast include ports for the export of iron ore at Cape Preston, Cape Lambert and Port Hedland, and shipping facilities at Onslow for the export of salt. Smaller developments, such as boat harbours, have been established in several towns to support commercial fishing and recreational boating (Gilmour et al., 2006).

Little is known about the cumulative impact of coastal development on coral communities within the region. However, a previous study of an area in the Dampier Archipelago indicated that between 25-35% of habitat that supported coral communities prior to the commencement of development had been directly lost due to anthropogenic impacts (Mscience 2005 in (Gilmour et al., 2006).

The key stressors on coral reefs associated with human activities have been identified as: sedimentation and turbidity (due to mobilised sediments associated with dredging, spoil disposal and land reclamation activities); and changes in salinity and temperature, due to the discharges of wastewater or treatment water (Gilmour et al., 2006). Details on the effects of each of these stressors on corals and coral communities can be found in (Gilmour et al., 2006).

Levels of sedimentation on and around coral reefs vary considerably over different spatial and temporal scales (Gilmour et al., 2006). Spatially, sedimentation is usually highest at inshore reefs and decreases with distance from the shore. Temporally, levels are strongly correlated to weather conditions and the strength of winds, waves, tides and currents. In the Pilbara, rates of sedimentation are generally higher on inshore reefs, and during summer months due to the influence of storms and tides (Forde 1985; Simpson 1988 in (Gilmour et al., 2006).

Like sedimentation, turbidity on and around coral reefs varies over small spatial and temporal scales (Gilmour et al., 2006). Local weather conditions have a strong influence on turbidity, as do the physical characteristics on and around a reef, such as depth, location and the amount of sediment on the substrata. Within the Pilbara, levels of turbidity are highly variable and are driven by local weather conditions (Forde 1985; Simpson 1988; Mscience 2005 in (Gilmour et al., 2006). Turbidity levels are generally higher on inshore reefs, and near the bottom than in surface waters (Gilmour et al., 2006).

Coral reefs within the Pilbara are generally exposed to salinities ranging between 34-38%, with relatively little variation. Communities on shallow reefs adjacent to the major river systems can be affected by freshwater inundation following cyclones. (Gilmour et al., 2006).

Pilbara reefs experience large seasonal ranges in water temperature, however corals probably occur near their upper thermal limit. Exposure to temperature increases of around 2°C above the mean maximum temperatures in summer are likely to cause stress, and potentially bleaching and mortality (Gilmour et al., 2006).

i) current condition/degree of naturalness (eg degraded; healthy); and

A review by (Gilmour et al., 2006) found the following responses were identified as being most useful for detecting responses of increasing impact to corals: photo-physiological stress and decreased photosynthetic nutrition; a change in coral colour; accumulation of sediment on the surfaces of susceptible growth forms; and partial and complete mortality. Levels of impact arising from exposure to the key stressors generally vary according to both the magnitude of change and the duration of exposure.

j) current/proposed management strategies and future implications.

The Marine Ecosystems Branch (formerly of the DoE) commissioned a review of early warning indicators of stress in corals to assist in the protection of corals, coral communities, and dependent ecosystems from the effects of marine infrastructure development and waste discharge in the Pilbara region. Types of indicators that could be used to assess the health or condition of coral reefs range from responses at the individual level to the community (Gilmour et al., 2006).

7. SUBTIDAL SOFT-BOTTOM COMMUNITIES

7.1 In what IMCRA biogeographical province and biogeographical region(s) does the study area occur, and what are the defining features of the biota and the marine and coastal communities?

7.2 What are the major marine and coastal communities of the study area? For each community, state:

a) distribution and area covered within the study area;

NW Cape - Spit Point study area

"Preliminary models of benthic recruitment show that bottom stress has an insignificant effect and that there is no clear connection between current strength and epibenthos cover. The most likely reason is that other factors take its place such as cross-shelf sediment sorting, inshore turbidity and fishing pressure" (Fulton et al., 2006).

"Clear decrease in observed percentage cover of small and large epibenthos as depth increases". Cover is also more variable in shallow waters (Fulton et al., 2006).

b) structure (eg rock type, sediment type, relief);

NW Cape - Spit Point study area

"primarily calcareous sands and fine muds with patchy coverage of reef and sponge beds but with high productivity" (Fulton et al., 2006).

"Biogenic habitats play a large part in structuring the distribution of biological stocks. Epibenthic cover is related to grain size and topography" (Fulton et al., 2006).

Tropical subtidal habitats along the coast are generally low primary producers and are shallow, muddy and turbid (Alongi, 1990).

c) distribution and diversity of predominant flora and fauna;

Pilbara

The sub-tidal areas are populated by burrowing invertebrate species such as worms, crustaceans, gastropods (snails), bivalve molluscs and echinoderms. Macroalgae and algae also inhabit these areas. At some sites, strong tidal currents provide good conditions for filter feeding organisms, such as sponges, corals, sea squirts and molluscs. Algal beds also provide habitat for other molluscs, sea urchins, crustaceans, sea stars and fish (Rangelands NRM Coordinating Group, 2005).

d) the occurrence of any species of special conservation status (ie is it listed under the *Wildlife Conservation (Specially Protected Fauna) Notice 1999*, the *Endangered Species Protection Act 1992* and/or the *Threatened Australian Fauna (ANZECC List) 1999*?), rare or endemic species;

e) **the influence of the physical environment on structural morphology, and flora and fauna distribution and adaptations;**

The distributions and movements of sediments on the North West Shelf have a major influence on the ecosystem, primarily through their effect on primary production and benthic habitat distributions. A high turbidity zone exists in the study area, extending from the coastline to around the 20m isobath. Bottom sediments also show a marked cross shelf zonation, with gravel and sand dominating the inner shelf, and finer sand, silts and clays dominating the less energetic outer shelf (CSIRO & Department of Environment, 2007).

f) **the influence of biological processes on structural morphology, and flora and fauna distribution and adaptations;**

g) **productivity/food webs/community structure;**

h) **past, present and potential uses and/or pressures (natural and human-induced); evidence of impact and the relevant research/monitoring programs (if any);**

NW Cape - Spit Point study area

The greatest impact on benthic habitats are likely to be trawl fishing (other industries are more likely to cause localised impacts) in addition to large scale natural disturbance events (Fulton et al., 2006).

(Fulton et al., 2006) highlighted a general decreasing trend in the proportional coverage of benthos (particularly those >25cm) from 1983-1990. Some recovery was noted after that for large epibenthos (when fishing effort was lower). Recovery of a diminished system can take more than two decades (even locally). Such recovery could be very sensitive to the form of recruitment (or any impediments to recovery). These slow rates of recovery have implications for management in that it may take a number of decades before management goals will be achieved (Fulton et al., 2006).

Findings from an experimental management scheme on the North West Shelf trawl fishery (1986-1991), indicate a considerable time lag after trawling ceases before recovery of large epibenthic organisms is substantial (Sainsbury, Campbell & Whitelaw, 1993).

Demersal trawling reduces benthos density by approximately 15% on each pass through a certain site, although macrobenthos mortality varies according to how the trawl is rigged (Moran & Stephenson, 2000).

i) **current condition/degree of naturalness (eg degraded; healthy); and**

j) **current/proposed management strategies and future implications.**

Trawling for scalefish has been limited to a small area and the level and distribution of the trawling effort has been controlled. Fisheries WA has permitted scalefish trawl fishing only in waters deeper than 50m (Moran & Stephenson, 2000).

8. WETLANDS/RIVERS/ESTUARIES

8.1 What are the size and nature (eg agricultural; urban) of the drainage basins of the study area, and what areas do these systems drain?

8.2 For the major estuaries located within/adjacent to the study area, state:

- **National/International significance (ie listed under the RAMSAR convention (ANCA, 1993), are of national significance (ANCA, 1993), subject to a System 6 recommendation (DCE 1983) and/or are on the register of National Estate);**
- **classification;**
- **basin area (ha);**
- **major drainage systems;**
- **catchment area;**
- **discharge (ML) and time (periodic, seasonal, constant);**
- **surrounding land use;**
- **condition; and**
- **values.**

De Grey River Wetland System
Largest shallow water estuary in northern WA (V & C Semeniuk Research Group, 2000).

8.3 For the major coastal wetlands within/adjacent to the study area, state:

- **National/International significance (ie listed under the RAMSAR convention (ANCA, 1993), are of national significance (ANCA, 1993), subject to a System 6 recommendation (DCE 1983) and/or are on the register of National Estate);**
- **basin area (ha);**
- **condition; and**
- **values.**

De Grey River Wetland System
Listed in the Directory of Important Wetlands
Wetland System contains 4500ha of tidal wetlands including 500ha of tidal mudflats. Also contains 1400ha of mangroves and 2500ha of coastal flats.
Permanent pools support wildlife, fish and waterbirds.
(V & C Semeniuk Research Group, 2000).

Balla Balla mangroves and tidal flats
Part of an area nominated for Register of the National Estate.
Supports extensive mangrove thickets and terrains of algal mat in good condition.
High diversity of bird life.
(V & C Semeniuk Research Group, 2000).

Coastal Site	Significance	Rationale
Ashburton River Delta	National	Arid zone delta, sand dominated with bars, and lagoons
Robe River Delta	International	Facies change in a granule to gravel delta
Fortescue River Delta	International	Gravel delta
Cape Lambert Complex	State Level	Arid zone ria/archipelago
Harding River Delta	State Level	Style of delta in arid setting
Balla Balla coast to Ronsard Island	National	Style of barrier and eroding coast in an arid setting
Yule River Delta	State Level	Style of delta in arid setting
De Grey River Delta	International	Style of delta in arid setting

Table 6: Coastal Wetlands of significance from a Geoheritage perspective adapted from (V & C Semeniuk Research Group, 2000).

Eighty Mile Beach
Key features of the Eighty Mile Beach Ramsar Site
Most important area for waders in northwest Australia.
Critical landfall for southward migrating birds.
Numerous species regularly exceed 1% of the East Asian – Australian Flyway population.
(V & C Semeniuk Research Group, 2000).

8.4 For the major rivers which flow to the coast or to an inlet of the study area, (≥350km2) state:

- **associated estuary (where appropriate);**
- **catchment area (km2);**
- **mean annual flow;**
- **seasonal flow characteristics;**
- **condition; and**
- **values.**

See section 'b' of 'Mangroves' for more information on river and delta systems of the study area.

8.5 What are the characteristics of the groundwater (eg water table level, quality, salinity)?

The shore around Robe and Fortescue and the carbonate islands of the shelf are, or are likely to be, anchialine habitats thus a marine reserve would provide protection of anchialine habitat (Pers. comm.. Bill Humphreys, WA Museum).

Species belonging to ancient freshwater lineages have been recorded from aquifers in the Kimberley and on small continental islands including Barrow Island that has an anchialine system (Humphreys, 2008).

"Unconfined groundwater is contained within underlying sediments of alluvium, colluvium, calcrete, iron goethite as Robe pistolite, and bedrock consisting of dolomite and granite. In confined aquifers, the groundwater is contained between impermeable rock formations such as calcrete, siltstone and claystone." (V & C Semeniuk Research Group, 2000)

Basin	Salinity (mg/L)
Fortescue River	1600
De Grey River	5790-15100
Ashburton/Turee Creek	220-700
Port Headland Coast/Yule River	600
Onslow Coast/Cane River	57-560

Table 7: Salinity of groundwater resources in PEMB. Compiled from (V & C Semeniuk Research Group, 2000).

The coastal zone groundwater is recharged by rainfall, marine waters and hinterland seepage. It is subject to extreme evaporation due to very shallow depths and this can lead to hypersalinity. The array sedimentary units (e.g. tidal flats and sand bars) and stratigraphic types (e.g. delta wedges or limestone ridges) makes the spatial distribution of groundwater types complicated. This results in a range of various water body shapes and chemistries, with salinity varying from fresh to brackish to saline to hypersaline (V & C Semeniuk Research Group, 2000).

8.6 What is the relationship of groundwater with the geological structures of the study area (eg formation of caves)?

9. FINFISH

9.1 species diversity and the relative importance of the faunal group in statewide and regional contexts;

The area from Ningaloo to the West Pilbara islands has the most diverse fish fauna of mainland WA, the richest areas being around Muiron and Serrurier Islands. Diversity reduces significantly to the north east as turbidity increases. The fish fauna in this area is more similar to that at Ningaloo Reef, than the Dampier Archipelago and Monte Bello Islands (Hutchins, 2001).

<u>Locker Point – N Kimberly coast study area</u>
Fish trapping (in both wet and dry seasons, deep and shallow waters, night and day periods) caught 119 species of finfish and 13 species of elasmobranch. The sampling method utilised traps and therefore caught predominately carnivorous fish (Travers, Newman & Potter, 2006).

Regionally, the most common families caught were

- Serranidae (Gropers) – 16 species
- Lutjanidae (Snappers and Sea perches) – 14 species
- Lethrinidae (Emperors) – 9 species
- Carangidae (Trevally) – 9 species (Travers, Newman & Potter, 2006).

Fish composition differs significantly for deep and shallow water habitats between night and day during both the dry and wet seasons. It also differs significantly between locations, except for shallow habitats between Cape Preston and Locker Point and at Emeriau Point (Legrange Bay) (Travers, Newman & Potter, 2006).

Fish composition was influenced more by depth than by day vs night. This difference was greatest in the Pilbara sites than the Kimberly sites. However composition was most influenced by location along the coastline (Travers, Newman & Potter, 2006).

The preference *Lethrinus nebulosus* for the southern locations of the study indicate that it is not well adapted to the particularly turbid waters of the Kimberley (Travers, Newman & Potter, 2006).

Although found throughout the study region, the preference of *Lethrinus* sp. 3 for Cape Preston and Locker Point "probably reflects a preference of this species for protected waters" (Travers, Newman & Potter, 2006).

Lethrinus laticaudis, as a major species that typifies assemblages, spends its early life in seagrass beds and mangroves and moves offshore as it becomes an adult (Travers, Newman & Potter, 2006).

Cape Keraudren

Trapping at Cape Keraudren in shallow waters showed that *Lethrinus* sp. 3 (69.5%), *Lutjanus carponotatus* (9.5%) and *Lethrinus laticaudis* (5.6%) were the most abundant species. These species typify the fish assemblages in shallow water for this location (Travers, Newman & Potter, 2006).

Robe

Species	Cape Preston Deep (%)	Cape Preston Shallow (%)
Lethrinus sp. 3 NW endemic blue spot emperor	45.7	47.5
Lutjanus carponotatus Stripey snapper	9	14.9
Lethrinus laticaudis Grass emperor	(4.3)	9.2
Abalistes stellatus Starry triggerfish	8.3	(1.7)
Lutjanus sebae Red emperor	5.6	(0.1)
Lutijanus russelli Moses seaperch	(1.1)	6.1
Lethrinus lentjan Red spot emperor	(0.8)	5.2

Table 8: The most common species caught in a survey from Cape Preston. From (Travers, Newman & Potter, 2006).

Overall (combined comparison between site, season and time) the typifying species (based on relative abundance) for the fish assemblages at Cape Preston are *Lethrinus* sp. 3, *Lutjanus carponotatus*, *Lethrinus laticaudis* and *Abalistes stellatus* (Travers, Newman & Potter, 2006).

- In shallow waters (combined season and time) the major typifying species are *Lethrinus* sp. 3, *Lutjanus carponotatus*, *Lethrinus laticaudis*
- In deep waters (combined season and time) the major typifying species are *Lethrinus* sp. 3, *Abalistes stellatus*, *Lutjanus carponotatus*, *Lutjanus sebae*

Samples collected during the day versus during the night at Cape Preston showed limited overlap (in both seasons).

Differences between deep and shallow sites in Cape Preston and Locker Point assemblages are likely to reflect the distances between the deep and shallow sites and the differences in the water temps (the difference was greatest in these two locations) (Travers, Newman & Potter, 2006).

Ashburton River

The most common species were (greater than 5% of total catch):

Species	Locker Point Deep (%)	Locker Point Shallow (%)
Lethrinus sp. 3 NW endemic blue spot emperor	31.1	51.8
Lutjanus carponotatus Stripey snapper	(2.7)	11.1
Lethrinus laticaudis Grass emperor	Not present	11.5
Lethrinus genivattatus Threadfin emperor	9.3	(2.3)
Pentapodus emeryii Purple threadfin bream	5.1	(0.1)
Lethrinus nebulosus Spangled emperor	13.8	(1.9)
Lethrinus atkinsoni Yellow-tail emperor	15.8	(0.1)

Table 9: The most common species caught in a survey from Locker Point. From (Travers, Newman & Potter, 2006).

Overall (combined comparison between site, season and time) the typifying species (based on relative abundance) for the fish assemblages at Locker Point are *Lethrinus* sp. 3, *Lutjanus carponotatus*, *Lethrinus nebulosus* (Travers, Newman & Potter, 2006).

- In shallow waters (combined season and time) the major typifying species are *Lethrinus* sp. 3, *Lutjanus carponotatus*, *Lethrinus laticaudis*
- In deep waters (combined season and time) the major typifying species are *Lethrinus atkinsoni*, *Lethrinus* sp. 3, *Lethrinus nebulosus*

Western Australia has 1855 recorded species of fish. Of these 19.5% are endemic to Australia while 7.7% are endemic to WA. The majority of WA endemics are found in the temperate waters of the mid and lower west coasts (Perth region had the highest number with 78 species). As latitude decreases and one moves closer to the Indo-pacific region, endemicity decreases. However, (Fox & Beckley, 2005) noted that there was a slight increase from the Kimberley coast to North West Cape.

Its worth noting that (Fox & Beckley, 2005)in their paper stated, "the marine protected areas in the north west will provide some protection to this species rich location but protection for WA and Australian endemics is scant".

In the Kimberley/PEMB region species composition of fish assemblages were influenced by habitat type, season, region and the extent of tidal action and turbidity. Differences between compositions in the extreme wet and dry were attributable to emigrations and immigrations of large numbers of particular species at certain times.

Although species composition was strongly influenced by latitudinal position it appears that the correlation between location and species composition is stronger at the regional and local level.

The number of species was significantly influenced by season. The data indicates that spawning aggregations begin to occur in the early wet peaking in the late wet. Mangrove habitats tended to peak earlier (early wet) and the least number of species were present in the late dry for both mangrove and bare sand habitats (Pember et al., 2003).

Surveys undertaken in intertidal pools resulted in 82 species and 38 families. 19 of the 82 species were of commercial and recreational importance with a further 5 species important only from a recreational perspective. Most abundant species:

- *Ambassis vachelli* (glass perch)
- *Craterocephalus pauciradiatus* (silverside)
- *Atherinomorus lacunosus* (hardyhead silverside)
- *Lutjanus russelli* (Moses snapper)

Moses snapper is very important to commercial and recreational fishing in the PEMB and Kimberley.

In studies of the Pilbara and Kimberley coasts, juvenile fish represented up to almost 90% of species caught in nearshore, shallow waters. Less than half of these species were caught as adults, thus it was suggested that as these species approach adulthood they emigrate to deeper waters where they spawn.
(Pember et al., 2003).

Fish fauna in Pilbara and Kimberley nearshore, shallow waters was dominated by small species; in particular:

- Engraulids (anchovies)
- Atherinids (hardyheads)
- Clupids (herrings)

These small species were regarded as fundamental to maintaining the commercial and/or recreational fish stock in these waters as they constitute the prey of predatory fish-the target of both commercial and recreational fishermen. This is particularly the case for threadfin salmons, estuary rockcod, Malabar grouper and mangrove jack. (Pember et al., 2003)

The progressive change in the fish fauna south along EMB paralleled the progressive shift that occurred in the degree of exposure to tidal action and thus the turbidity of the water, with conditions being least extreme to the north and most extreme at the southern end of EMB. This suggests that the strong environmental variation between sites is in part responsible for differences in fish fauna. It also suggests that the influence of tidal action and other associated environmental effects exerts a greater influence on ichthyofaunal compositions than those that are associated with latitude (Pember et al., 2003).

Fish fauna in near shore shallow waters in the dry and wet periods at EMB differed markedly. The differences were largely attributable to greater numbers of *Arius* (catfishes) and *Engraulids* (anchovies) in the wet and *Escualosa thoracata* (sardines) and *Valamugil cunnesius* (mullets) in the dry (Pember et al., 2003).

EMB had greater variation in fish fauna in comparison to other areas of the Pilbara/Kimberley. It is unclear why EMB has greater variation than other areas where there are similar marked differences in environmental conditions and fish fauna (Pember et al., 2003).

Most abundant species sampled:

- Blue spot emperor (*Lethrinus hutchinsi*)
- Stripey snapper (*Lutjanus carponotatus*)
- Grass emperor (*Lethrinus laticaudus*)

(Travers, Newman & Potter, 2003).

Species composition in shallow and deep water, in total was 352 species/194 genera/82 families. Overall the most speciose families were: Carangidae (trevally/queenfish), Serranids (cods), Bothidae (flounders), Lutjanids (snappers), Tetraodontidae (puffers). The most speciose families over reefs: Serranidae (cods), Lutjanidae (snappers), Lethrinidae (emperors), Carangidae (trevally/queenfish) (during both day and night). The most speciose families over soft substrate: Carangidae (trevally/queenfish), Bothidae (flounders), Tetraodontidae (puffers), Mullidae (goatfish), Leiognathidae (ponyfish) (Travers, Newman & Potter, 2003).

Species assemblages, as would be expected changed with latitude. The distribution of samples on the ordination plots indicated that in deeper water there was a 'faunal' break between Cape Voltaire and Hall Point in the north and all of the more southern locations. The wet and dry and associated extreme weather patterns are probable influences on fish assemblages and species composition. Similarly, major ecosystem perturbations such as cyclones can have a major effect on fish assemblages and species composition. (Travers, Newman & Potter, 2003)

Benthic habitat structure has a significant influence on the fish community structure (Fulton et al., 2006).

9.2 size of population(s), including size of any genetically distinct populations (if known), and details of most recent survey(s);

Genetic data is deficient at present.

9.3 Species which are rare, endemic and/or of special conservation status (ie is it listed under the Wildlife Conservation (Specially Protected Fauna) Notice 1999, the Endangered Species Protection Act 1992 and/or the Threatened Australian Fauna (ANZECC List) 1999?);

Family	Sub-family	Genus	Species	C'mon Name	Status (IUCN)
Labridae		Choerodon	shoenleinii	blackspot tuskfish	NT: near thrtned
Serranidae	Epinephelinae	Epinephelus	coioidies	Estuary cod cod/rockcod	NT near thrtned
Serranidae	Epinephelinae	Epinephelus	malabaricus	Estuary cod cod/rockcod	NT near thrtned

Table 10: IUCN listed finfish species from the PEMB region.

Some species found in the study area endemic to WA are:

- *Lethrinus hutchinsi* (Blue Spotted Emperor)
- *Pempheris spp.* (Bullseye)
- *Kyphosus cornelii* (Western Buffalo Bream)
- *Chaetodon assarius* (Western Butterflyfish)
- *Anampses lennardi* (Blue and Yellow Wrasse)
- *Choeridon cauteroma* (Bluespotted Tuskfish)
- *Coris auricularis* (Western King Wrasse)
- *Halichoeres brownfieldi* (Brownfield's Wrasse)
- *Suezichthyes cyanolaemus* (Bluethroat Rainbow Wrasse)

(Hutchins, 2001).

9.4 If special, rare or endemic, state:

- **biogeographical and local distribution;**
- **seasonality of occurrence; and**
- **behavioural patterns (eg migration, breeding, nesting);**

See fish database for details on ecology of above species.

Plectropomus maculatus (coral trout) was caught in all of the sampling locations and is an iconic target species for both recreational and commercial fishers. The lengths of the individuals of this species caught in the samples lay to either side of the minimum legal length (MLL). This indicates that the legislation preventing commercial fishing in water depths less than 30m is protecting substantial numbers of both the smaller and larger individuals of this species from capture by commercial fishers. The researchers believed that although this species was targeted by recreational fishermen in shallow waters, individuals less that the MLL are more likely to survive release in shallower waters than deep (Pember et al., 2003; Travers, Newman & Potter, 2003).

9.5 past, present and potential uses and/or pressures (natural and human-induced); evidence of impact and the relevant research/monitoring programs (if any); and

Commercial and particularly recreational fishing is on the increase in the region (Newman, Skepper & Williamson, 2003). The region from Karratha to Broome has more access points for recreational fishers than from Onslow to Karratha (Newman, Skepper & Williamson, 2003).

The finfish species landed by shore based fishers tended to be associated with open beaches and mangrove creek systems. Species landed by boat-based fishers tend to be associated with reefs as well as mangrove creek systems (Newman, Skepper & Williamson, 2003).

Researchers recognised that both recreational and commercial fishing is increasing along the NW coast of WA, thus a need for better baseline data and to clearly understand the distribution and relative abundance of fish fauna in the region (Pember et al., 2003).

While threats to fish resources in the past have focused on the problems of over-fishing, more recently concern has shifted to the destruction of habitats required to support fish resources. This concern has generally focused on the effects of fishing itself on the marine habitat (Sainsbury, Campbell & Whitelaw, 1993).

Following trawling activities on the North West Shelf (by Japanese, Taiwanese and to a lesser extent domestic trawl operators) for more than 20 years, a major change within the species composition of fish catch was observed, although the total catch rate of the trawl fishery remained relatively constant. The demersal habitat of the region was also known to have altered during this period. More specifically, the quantity of epibenthic fauna (mostly sponges, alcyonarians, and gorgonians) declined considerably since the early development of the trawl fishery (Sainsbury, Campbell & Whitelaw, 1993).

Results from an experimental management scheme on the North West Shelf trawl fishery (1986-1991) indicate the composition of the multi-species fish community is at least partially dependent and that historical changes in relative abundance and species composition in the region are at least partly due to the damage of the epibenthic habitat by the demersal trawling gear (Sainsbury, Campbell & Whitelaw, 1993).

9.6 past/current/proposed management strategies (eg codes of practice, monitoring programs).

(Sainsbury, Campbell & Whitelaw, 1993) advocates the use of an 'adaptive' management approach in fisheries research to provide active feedback between management action and empirical learning.

10. CETACEANS

10.1. Species diversity and the relative importance of the faunal group in statewide and regional contexts;

10.2. Size of population(s), including size of any genetically distinct populations (if known), and details of most recent survey(s);

In the Locker Point – De Grey River mouth area (above 20m isobath) there is a small population of about 1500. These are believed to be predominately *Tursiops* sp (bottlenose), with some *Sousa* sp (humpbacked). The aerial survey did not find the Irrawaddy (*Orcaella brevirostris*). These dolphin estimates lie within the range of values obtained similarly for a wide range of other Australian localities (Prince, Lawler & Marsh, 2001).

(Jenner & Jenner, 1994) indicate that the size of the Humpback Whale group IV breeding stock population is estimated at 3878. Group IV is one of five feeding areas in Antarctic waters, this particular group migrates up and down the WA coast to calf in the Kimberley (Jenner, Jenner & McCabe, 2001).

10.3. Species which are rare, endemic and/or of special conservation status (ie is it listed under the Wildlife Conservation (Specially Protected Fauna) Notice 1999, the Endangered Species Protection Act 1992 and/or the Threatened Australian Fauna (ANZECC List) 1999?);

Some recent genetic studies in the NT (2007 unpublished) have shown that the Irrawaddy Dolphin is in fact genetically distinct from its SE Asian counterpart. Thus, Australia has its first endemic dolphin (pers. Comm.. Palmer 2007). If Irrawaddy are found in the region it would be of significance.

10.4. If special, rare or endemic, state:
- **biogeographical and local distribution;**
- **seasonality of occurrence; and**
- **behavioural patterns (eg migration, breeding, nesting);**

The migratory paths of humpback whales along the Western Australian coast lie within the continental shelf boundary or 200m bathymetry. Near the Exmouth peninsula, the north and southbound migratory paths occur within 9nm of the coast. The northern migratory path is separate from the southern migratory path at the Dampier Archipelago (Jenner, Jenner & McCabe, 2001).

North and southbound whales were encountered in equal numbers near the 30m depth contour offshore from Eighty Mile Beach (Jenner, Jenner & McCabe, 2001)

The peak of the northern Humpback whale migration could be expected to pass through the study area in late July-early August, while the southern migration passes in September (Jenner, Jenner & McCabe, 2001).

Whales are seldom reported from the area between Barrow Island and the mainland, possibly due to the extensive shoals and strong currents found there. (Jenner, Jenner & McCabe, 2001)

10.5. Past, present and potential uses and/or pressures (natural and human-induced); evidence of impact and the relevant research/monitoring programs (if any); and

10.6. Past/current/proposed management strategies (eg codes of practice, monitoring programs).

11. DUGONG

11.1. Species diversity and the relative importance of the faunal group in statewide and regional contexts;

Critical connectivity across Shark Bay to the Pilbara Coast region at least is indicated in April 2000 survey and there is no obvious biologically significant boundary separating the coastal waters within Exmouth Gulf, and out to the offshore islands, from those of remainder of the Pilbara coast (Prince, Lawler & Marsh, 2001).

Considering the sighting data across all survey periods (1977-2000), the general consistency of the sighting locations supports the view that the Pilbara coastal and offshore waters does include some very important focal dugong habitat (Bowman Bishaw Gorham, 1995; Prince, Lawler & Marsh, 2001).

As charismatic megafauna, the dugong is an 'umbrella species' for the conservation of tropical coastal environments throughout much of the Indo-West Pacific. The dugong is thus of particular conservation significance globally, nationally and regionally (Marsh et al., 1999).

The coastal area from Port Hedland to Onslow and associated offshore islands are of major significance to the dugong. (Prince, 1986)

11.2. Size of population(s), including size of any genetically distinct populations (if known), and details of most recent survey(s);

Results from an April 2000 survey between Locker Point and De Gray River mouth show a relatively small but widely distributed population of more than 2000 predominately adult individuals. This is considered likely to be near the minimum for this area due to extended disturbance resulting from severe Category 5 cyclones between 1995 and 2005. For example, dugongs are likely to have migrated south to Shark Bay from Exmouth Gulf due to habitat disturbance and loss as a result of Cyclone Vince, with surveys of Shark Bay supporting this statement. The serial substantial disturbance from cyclones will adversely impact and influence seagrass availability and hence dugong location (Prince, Lawler & Marsh, 2001).

Aerial surveys along the West Australian coast indicated significant numbers of dugongs on the Pilbara coast, however no systematic surveys have been conducted along the Kimberley coast (The North Australian Indigenous Land and Sea Management Alliance & Smyth, 2006).

11.3. Species which are rare, endemic and/or of special conservation status (ie is it listed under the Wildlife Conservation (Specially Protected Fauna) Notice 1999, the Endangered Species Protection Act 1992 and/or the Threatened Australian Fauna (ANZECC List) 1999?);

On the IUCN Red List, dugongs are listed as vulnerable to extinction. They are also listed in Appendix I of the *Convention on International Trade in Endangered Species* (CITES) and in Appendix 2 of the *Convention for the*

Conservation of Migratory Species of Wild Animals (CMS). At a national level, dugongs are listed as a Migratory Species and a Marine Species (both EPBC Act) as well as a Protected Species (GBRMP Act). In Western Australia, dugongs are listed as *Specially Protected Fauna* (The North Australian Indigenous Land and Sea Management Alliance & Smyth, 2006).

Despite the lack of data on dugong populations and mortality, it has been suggested that "dugongs are probably the most endangered marine mammal, if not one of the most endangered large mammals, in the Western Indian Ocean region" (Cockcroft 1995, p. 8 in (Preen, 1998).

11.4. If special, rare or endemic, state:

- **biogeographical and local distribution;**
- **seasonality of occurrence; and**
- **behavioural patterns (eg migration, breeding, nesting);**

Robe

Between Middle and North Mangrove Island is a broad shallow limestone platform which supports a dense meadow of *Halodule* mixed with *Halophila* and *Cymodocea* growing on a thin veneer of soft sediments. Although no animals were seen, the seagrass meadows were characterised by dugong scars (Pendoley & Fitzpatrick, 1999).

Dugongs have a long life, low reproductive rate and a long interval between generations. Research indicates that females do not bear their first calf until they are at least 6 years old and may not commence breeding until they are up to 17 years old. The delay in onset of breeding may be linked to the availability of seagrass - when dugongs do not have enough to eat they delay breeding. Pregnancy lasts for between 13 and 15 months, and usually only one calf results from each pregnancy. The time between pregnancies varies between two and a half years and seven years. Dugongs breed in August and September. Calves are born in shallow waters and suckle for 18 months. (The North Australian Indigenous Land and Sea Management Alliance & Smyth, 2006).

Along the Pilbara coast, dugongs have been recorded as using tidal creeks and inlets within mangals and sometimes venturing into mangrove communities during high tide (Carr & Livesey, 1996).

Population simulations indicate that even with the most optimistic combinations of life-history parameters, a dugong population is unlikely to increase more than 5% per year. This makes the dugong vulnerable to over-exploitation (Marsh et al., 1999).

Dugongs are seagrass specialists and have a preference for species of the genera *Halophila* and *Halodule* (Marsh et al., 1999). The specialised dietary requirements of the dugong suggest that only certain seagrass meadows may be suitable as dugong habitat (Preen 1995b in (Marsh et al., 1999). Areas that support sizeable dugong numbers may have the capacity to provide better 'quality' food than areas that support few or no dugongs (Aragones and Marsh 1999 in (Marsh et al., 1999).

Major concentrations of dugongs tend to occur in wide shallow protected bays, wide shallow mangrove channels and in lee of large, inshore islands (Heinsohn et al. 1979 in (Marsh et al., 1999). They are also observed in deeper offshore waters. There is evidence that dugongs use specialised habitats for various activities, such as shallow waters on tidal sandbanks and estuaries for calving (Marsh et al., 1999).

At least some dugongs undertake long-distance movements whilst daily movements depend on tidal amplitude (Marsh et al., 1999). It has been suggested that dugongs have modified their behaviour in response to hunting from powered craft, as hunters switch off their engines on their final approach toward the animal. (Prince, 1986)

11.5. Past, present and potential uses and/or pressures (natural and human-induced); evidence of impact and the relevant research/monitoring programs (if any); and

Dugongs are particularly vulnerable to a range of human impacts, including vessel strikes, harvesting for food and other products, entanglement in fishing lines and nets, and habitat damage from trawling or build-up of silt caused by mining, poor catchment management or coastal development (The North Australian Indigenous Land and Sea Management Alliance & Smyth, 2006).

In his study, (Berson, 2004) examined three threatening processes – entanglement in nets; habitat loss and degradation; and Indigenous harvest. Of these, habitat loss and degradation was considered to have the greatest potential effect on a dugong population.

On the Kimberley coast, large Aboriginal communities have a tradition of using marine resources, including dugongs. Twelve dugongs were reported to have been taken by the One Arm Point Community in 1998. Dugong tusks are highly prized among Kimberley people, and in the past they were traded to be used as cigarette holders and other artefacts (The North Australian Indigenous Land and Sea Management Alliance & Smyth, 2006).

Indigenous harvest of dugongs (and turtles) was by hand only until European settlement when spear and harpoon techniques were introduced. Dugongs are still taken on a seasonal basis (March-April to August-September) in the area, where local annual catch was around 50-80 animals in 1984 (Prince, 1986).

There are concerns that a population of dugongs will decline if more than about 2% of adult females in a population is killed each year (The North Australian Indigenous Land and Sea Management Alliance & Smyth, 2006).

Dugongs are vulnerable to anthropogenic influences because of their life history and their dependence on seagrasses that are restricted to coastal habitats, which often come under pressure from human activities (Marsh et al., 1999).

Halophilia ovalis, a preferred food species of dugongs, appears to be particularly sensitive to light reduction (Marsh et al., 1999).

Accidental entangling in gill and mesh nets set by commercial fishers is considered a major, but largely unquantified cause of dugong mortality. The relationship between tides, bottom topography, turbidity and netting patterns needs investigation. In relatively shallow bays with large tidal fluctuations and high turbidity, seagrass meadows are largely intertidal. In such circumstances, dugongs and netters are all forced to use intertidal areas on the high tide, increasing the chances that dugongs will be caught (Marsh et al., 1999).

11.6. Past/current/proposed management strategies (eg codes of practice, monitoring programs).

Dugongs in Western Australia are protected and managed under international (Convention on Migratory Species, Convention on the International Trade in Endangered Species, Convention on Biodiversity), Commonwealth (Environment Protection and Biodiversity Conservation Act 1999) and State (Wildlife Conservation Act 1950, Wildlife Conservation [Close Season for Marine Mammals] Notice 1998) legislation. This legislation provides various mechanisms for the recognition of indigenous people's right to hunt dugong for subsistence and other non-commercial cultural purposes. Section 211 of the *Native Title Act 1993 & 1998* also protects native title holders' non-commercial hunting rights (The North Australian Indigenous Land and Sea Management Alliance & Smyth, 2006).

The Kimberley Land Council (KLC) has established a Land and Sea Management Unit to undertake projects for looking after land and sea country, including marine resource management. The unit works with Traditional Owners to look after, manage and take control of traditional country, and has partnerships with community organisations, industry, government agencies and local government (The North Australian Indigenous Land and Sea Management Alliance & Smyth, 2006).

Other relevant Australian Government management strategies for dugongs include: The NAILSMA Dugong and Marine Turtle Project; Sustainable Harvest of Marine Turtles and Dugongs in Australia – A National Partnership Approach; Threat Abatement Plan for Marine Debris; closing areas of inshore seagrass habitat to trawling; Bioregional Marine Planning; and a Code of Conduct for dugong and marine turtle tourism. There are also a number of specific initiatives to protect and manage dugongs in Western Australia including the Jurabi Turtle Centre north-west of Exmouth (The North Australian Indigenous Land and Sea Management Alliance & Smyth, 2006).

(Berson, 2004) found that management efforts in protecting and increasing dugong numbers are best directed toward decreasing the mortality of adult females. A system of marine reserves is one method that has the potential to decrease mortality and protect the seagrass beds. Such reserves must also include management of the adjacent coastline to ensure full protection of the seagrass. At the same time, the rights of local Indigenous communities must be taken into consideration. Management through the declaration of Indigenous Protected Areas appears to be an attractive option, for both Indigenous peoples and government conservation agencies.

The long-term survival of dugongs relies on the establishment of an adequate network of protected areas where impacts of human activities can be minimised. According to (Preen, 1998), dugong sanctuaries need to be located at areas of current or historical dugong importance and need to be large enough to accommodate the large home ranges of dugongs (50-200km^2). They should be located at intervals of approximately 200km, so genetic exchange between populations can be maintained. To accommodate natural catastrophes such as cyclones, dugong sanctuaries should include some redundancy. Within dugong sanctuaries, it is advised that most forms of mesh netting should be banned, while hunting should be prohibited or regulated.

According to (Marsh et al., 1999), the challenge is to develop integrated dugong conservation strategies involving all stakeholders. Such strategies must contribute to maintaining numbers at present or higher levels and to facilitate the recovery of depleted populations, which providing for the sustainable, traditional use of dugongs by indigenous communities.

Factors to consider in the establishment of dugong sanctuaries and protected areas include adequate size (to incorporate home ranges), quality of habitat, control of netting, control of mining, local support and appropriate enforcement. Additional factors to be considered include the seasonal movement of dugongs in the higher latitude parts of their range, the need to protect movement corridors and the maximum spacing that will still allow gene flow between sanctuaries (Marsh et al., 1999).

Long term effectiveness of sanctuaries and protected areas will depend on whether high-quality dugong habitat can be maintained. This will depend on the capacity to control land-based inputs. For instance, areas where human impacts other than fishing are low are more likely to be effective than areas targeted for industrial development (Marsh et al., 1999).

12. CRUSTACEANS

12.1. Species diversity and the relative importance of the faunal group in statewide and regional contexts;

Crab diversity in the Pilbara coast is high for Australia and includes several species endemic to the North West. The Pilbara mangal crab group is particularly rich in with many species present (Carr & Livesey, 1996).

The North West region is of biogeographic significance as a centre of Fiddler Crab diversity in Australia. North-west Australia has been a major region of speciation for the genus *Uca* and may be the region where the genus *Uca* evolved and radiated from (Davie 1985 in (Carr & Livesey, 1996).

Australia has a phylogenetically diverse and species rich stygofauna which occurs over a wide range of both substrates and water quality (Humphreys, 2008).

Groundwater systems have been recognised as dynamic systems and it is apparent that Australia contains stygofauna of global significance (Humphreys, 2008). The only regional survey of stygofauna in Australia has been conducted in the Pilbara where c. 350 species have been recorded (Department of Environment and Conservation Pilbara Stygofauna Survey, S. Halse pers comm. in (Humphreys, 2008)).

Anchialine ecosystems occur in salinity-stratified coastal aquifers affected by marine tides but with no surface connection with the sea. These systems are noted for their relict faunas and their high species richness. At least ten new families of crustaceans have been described from anchialine systems in the last two decades and they support an anchialine-endemic class in Remipedia. Cape Range has the only example of a remipede-type anchialine community known outside the north Atlantic and elements of this fauna also occur on Barrow Island and on the Pilbara coast (Robe and Fortescue River deltas) (Humphreys, 2008).

12.2. Size of population(s), including size of any genetically distinct populations (if known), and details of most recent survey(s);

12.3. Species which are rare, endemic and/or of special conservation status (ie is it listed under the Wildlife Conservation (Specially Protected Fauna) Notice 1999, the Endangered Species Protection Act 1992 and/or the Threatened Australian Fauna (ANZECC List) 1999?);

12.4. If special, rare or endemic, state:

- **biogeographical and local distribution;**
- **seasonality of occurrence; and**
- **behavioural patterns (eg migration, breeding, nesting);**

12.5. Past, present and potential uses and/or pressures (natural and human-induced);

evidence of impact and the relevant research/monitoring programs (if any); and

The mud crab (*Scylla serrata*) is a large edible species that is socially and economically significant. It is a popular recreational fishing crab and is caught extensively throughout the Pilbara. This species has been noted as being under pressure from recreational fishing (Hergerl 1982 in (Carr & Livesey, 1996).

12.6. Past/current/proposed management strategies (eg codes of practice, monitoring programs).

13. ELASMOBRANCHS

13.1. Species diversity and the relative importance of the faunal group in statewide and regional contexts;

Eighteen elasmobranch species were collected in the PEMB region (Pember et al., 2003; Travers, Newman & Potter, 2003). One of the most important typifying species from bare sand samples at Cape Keraudren was the chondrichthyan *Pristis zijsron* (green sawfish) an IUCN red listed (CR) species and WA Threatened species. A larger number of chondrichthyans were also found in the late wet season at Cape Keraudren. *Pristis zijsron-* was caught only as juveniles but over bare sand

The majority of elasmobranchs in the samples were young juveniles. This data suggests that the nearshore shallow waters at Cape Keraudren play an important nursery role for chondrichthyans in the late wet season.

Data indicated that certain species of elasmobranch use nearshore waters only as nursery areas: Negaprion acutidens (lemon shark) were caught solely as juveniles, predominately in mangroves. The lemon shark is IUCN listed as vulnerable.

Carcharhinus cautus (nervous shark) is a nearshore resident and was relatively abundant in samples but mainly in mangroves rather than bare sand. This species is listed as also IUCN listed data deficient.

The sandbar shark is found within the region. There appears to be only one population in WA with considerable spatial separation between adults and juveniles. Adults and sub-adults are more abundant north of 26 deg (Shark Bay) with the juveniles found predominately in waters further south (McAuley et al., 2007).

The remote coastline of North Western Australia is likely to support the healthiest populations in Australian waters (Giles et al., 2006).

13.2. Size of population(s), including size of any genetically distinct populations (if known), and details of most recent survey(s);

There appears to be a paucity of data on elasmobranchs in the region.

The sandbar shark is could be genetically distinct from the east coast population due to the smaller size of adults at maturity. More research required (McAuley et al., 2007).

Species which are rare, endemic and/or of special conservation status (ie is it listed under the Wildlife Conservation (Specially Protected Fauna) Notice 1999, the Endangered Species Protection Act 1992 and/or the Threatened Australian Fauna (ANZECC List) 1999?);

Family	**Genus**	**Species**	**C'mon Name**	**Status (IUCN)**
Charcharinidae	*Carcharhinus*	*cautus*	nervous shark	DD:data deficient
Charcharinidae	*Negaprion*	*acutidens*	sickle fish lemon shark	V:vulnerable
Charcharinidae	*Carcharhinus*	*limbatus*	blacktip shark	LR/nt:lower risk near threatened
Charcharinidae	*Carcharhinus*	*plumbeus*	Sandbar shark	LR/nt:lower risk near threatened
Pristidae	*Pristis*	*zijsron*	green sawfish/longcomb sawfish	CR:critically endangered
Pristidae	*Pristis*	*clavata*	dwarf sawfish	CR:critically endangered

Table 11: IUCN listed elasmobranch species in the PEMB region.

Three shark species in the region are listed under the *Environment Protection and Biodiversity Conservation Act 1999*. The white shark (*Carcharodon carcharias*), grey nurse shark (*Carcharias taurus*) and whale shark (*Rhincodon typus*) are all listed as Vulnerable, while the white shark and whale shark are also listed as Migratory. All three species are listed on Appendix II of the *Convention on International Trade in Endangered Species* (CITES). The white shark and the whale shark are listed on Appendices I and II of the *Convention of Migratory Species of Wild Animals* (CMS) (Brewer et al., 2007).

Carcharhinus tilstoni (Australian Blacktip Shark), a commercially caught species in the region, is endemic to Australia (Shark Advisory Group, 2000).

All four *Pristis* species are listed under the IUCN Red List of Threatened Species as Endangered globally, due to their vulnerability to overfishing (Stevens, West & McLoughlin, 2000). *P. zijsron* is on the FAO International Plan of Action for Sharks (Stevens, West & McLoughlin, 2000).

The Grey Nurse Shark was protected in Western Australian waters in 1999, under the Wildlife Conservation Act (1950). It is listed as 'Vulnerable' on the IUCN Red List and also under the EPBC Act (2001) (Chidlow, Gaughan & McAuley, 2006).

13.3. If special, rare or endemic, state:

- **biogeographical and local distribution;**
- **seasonality of occurrence; and**
- **behavioural patterns (eg migration, breeding, nesting);**

The increased number of elasmobranchs during the wet and strong onshore winds parallels the findings elsewhere in Australia (Blaber, Young & Dunning, 1985; Pember et al., 2003; Travers, Newman & Potter, 2003)

This data suggests a predator-prey relationship between the abovementioned finfish and elasmobranchs.

There are no known aggregation sites for grey nurse sharks in the region, though some potentially suitable sites have been recorded around Exmouth and the North West Cape (Brewer et al., 2007).

There are no known aggregation sites for white sharks in the region, and this species is likely to be found south of North West Cape only, probably only in low densities (Brewer et al., 2007).

Ningaloo Reef is the main aggregation site for whale sharks (Brewer et al., 2007).

Pristis zijsron (Green Sawfish)
The current distribution is severely reduced due to fishing pressure and coastal habitat changes due to development. *Pristis zijsron* is distributed on the north coast of WA, as far south as Shark Bay. It has been recorded in inshore coastal environments, as well as estuaries and river mouths in slightly reduced salinities, but it does not penetrate into freshwater. Northern Australia may be the last region where significant populations remain (Stevens, Pillans & Salini, 2005).

There is a distinct lack of data on the biology of *Pristis* spp with important parameters such as age and size at maturity, reproductive periodicity and lifespan being largely unknown (Stevens, Pillans & Salini, 2005).

P. zijsron occupies a relatively small area of available habitat, concentrated in a narrow strip of water close to the shoreline. Their apparent preference for these shallow inshore waters as pupping grounds increases the likelihood of their interaction with inshore gillnets (Stevens, Pillans & Salini, 2005).

Importantly, *P. zijsron* are not an ambush predator but actively pursue schools of baitfish and prawns. Data from the individual tracked in Port Musgrave (Peverell and Pillans, 2004 in (Stevens, Pillans & Salini, 2005), showed that it moved continuously throughout the track and did not rest on the bottom. This behaviour makes *P. zijsron* even more vulnerable to capture in gillnets as animals are more likely to encounter fishing gear if they are moving around an area as apposed to being inactive for long periods (Stevens, Pillans & Salini, 2005).

Grey Nurse Shark (*Carcharias taurus*)
Very low rate of intrinsic population growth, due to its biennial reproductive cycle that produces only two pups per litter. Their ability to sustain fishing pressure is consequently low, and this has caused populations to seriously decline (Chidlow, Gaughan & McAuley, 2006).

Grey Nurse Sharks may not be restricted to particular localities or habitats and are though to occur all around the Australian mainland coast, across most of the continental shelf (Chidlow, Gaughan & McAuley, 2006).

13.4. Past, present and potential uses and/or pressures (natural and human-induced); evidence of impact and the relevant research/monitoring programs (if any); and

Sandbar sharks are targeted by demersal gillnet and longline shark fisheries, as well as being a by-catch of other fisheries including trawl and recreational fisheries. Between 1995 and 2004, reported landings by target fisheries more than quadrupled to 413 tonnes live weight, in addition to an unknown quantity taken as by-catch. Differences between size at maturity between males and females occurs, this could effect stock management depending on the reason for the difference (unknown at present). Longline is the main method of catching the species (north of 26 deg). (McAuley et al., 2007).

For Grey nurse and white sharks, the greatest threat in the region come from commercial fishing activities (Brewer et al., 2007). These sharks are particularly susceptible to fishing pressure, as they are generally slow growing, reach sexual maturity at a late age and produce few young per litter.

Whale sharks are vulnerable to over-exploitation by fishing due to their slow growth; delayed, infrequent reproduction; and widespread distribution in small, highly mobile populations. They have limited interaction with fisheries in the region, and the greatest threat to this species is associated with fishing pressure outside Australian waters (Brewer et al., 2007).

The main interaction between commercial fisheries and protected sharks in the North-West Marine Region is through unintentional by-catch (Brewer et al., 2007). None of the species listed under the EPBC Act are targeted by commercial fisheries in the region. Most of the protected sharks caught as by-catch are returned to the sea alive, but release after capture is likely to be associated with increased mortality (Stevens et al. 2000 in (Brewer et al., 2007).

Sharks are thought to be major target species for Illegal, Unreported and Unregulated (IUU) fishers in the region. Demand are prices for shark products, such as fins and jaws, are relatively high. Most IUU fishing activity in the region comes from Indonesia, and increased dramatically between 2001 and 2006, but this activity has decreased in recent times (Brewer et al., 2007).

Foreign fishing incursions now occur within sight of the Australian coast and it is possible that *P. zijsron* from Australian waters are caught by illegal Indonesian fishers (Stevens, Pillans & Salini, 2005).

The seasonal aggregation of whale sharks at Ningaloo Reef has generated a significant tourism industry which have the potential to negatively impact on whale shark behaviour, habitats and ecology (Brewer et al., 2007). However, whale shark tourism activities are reported to be well managed and are not thought to have a major impact.

Collisions between shipping vessels and whale sharks have been recorded occasionally (Brewer et al., 2007).

Deterioration or destruction of important seasonal coral reef habitat and feeding areas by coral bleaching events, climate change or other disturbances may pose a threat to the survival of whale sharks (Brewer et al., 2007).

The toothed rostrum of sawfish makes them highly susceptible to capture in all fisheries that utilise nets. Gill net and trawl fisheries operate throughout the range of *P. zijsron* and pose the greatest threat to this species (Stevens, Pillans & Salini, 2005).

Habitat degradation, pollution and overfishing are still impacting on sawfish populations (Stevens, Pillans & Salini, 2005).

"The majority of sawfish captured by inshore gill net fishers operating along the Eighty Mile Beach, area are released alive according to Rory McAuley (Fisheries WA, personal communication). It is uncertain whether this occurs when observers are not present." (Stevens, Pillans & Salini, 2005)

Grey Nurse Sharks have never been subjected to targeted fishing in Western Australia (Chidlow, Gaughan & McAuley, 2006).

13.5. Past/current/proposed management strategies (eg codes of practice, monitoring programs).

Recovery plans are in place for the three protected shark species found in the region (Brewer et al., 2007).

14. ECHINODERMS

14.1 Species diversity and the relative importance of the faunal group in statewide and regional contexts;

14.2 Size of population(s), including size of any genetically distinct populations (if known), and details of most recent survey(s);

14.3 Species which are rare, endemic and/or of special conservation status (ie is it listed under the *Wildlife Conservation (Specially Protected Fauna) Notice 1999,* the *Endangered Species Protection Act 1992* and/or the *Threatened Australian Fauna (ANZECC List) 1999?*);

14.4 If special, rare or endemic, state:

- **biogeographical and local distribution;**
- **seasonality of occurrence; and**
- **behavioural patterns (eg migration, breeding, nesting);**

14.5 Past, present and potential uses and/or pressures (natural and human-induced); evidence of impact and the relevant research/monitoring programs (if any); and

14.6 Past/current/proposed management strategies (eg codes of practice, monitoring programs).

15. TURTLES

15.1 Species diversity and the relative importance of the faunal group in statewide and regional contexts;

Western Australia has some of the largest and most important nesting turtle populations in the world (Department of Environment and Conservation, 2008). Four of the world's seven species of sea turtles nest on the islands and coastline of the North West Shelf Region, namely Hawksbill turtles (*Eretmochelys imbricata*), Green turtles (*Chelonia mydas*), Loggerhead turtles (*Caretta caretta*) and Flatback turtles (*Natador depressus*) (Prince 1994 in (Pendoley & Fitzpatrick, 1999).

The majority of turtles in the NW Cape – De Gray River mouth area are expected to be green turtles with smaller populations of Flatback, Hawksbill and Loggerheads. Olive Ridley are not thought to be present but Leatherbacks are known from these coastal waters (Prince, Lawler & Marsh, 2001).

15.2 Size of population(s), including size of any genetically distinct populations (if known), and details of most recent survey(s);

An average of 20,000 female Green turtles is estimated to nest in Western Australia each year (http://www.deh.gov.au/coasts/species/turtles/ in (The North Australian Indigenous Land and Sea Management Alliance & Smyth, 2006). This population is the largest in the indo-pacific region (Department of Environment and Conservation, 2008).

The population of nesting Loggerhead turtles in Western Australia is estimated at 3 000 females. This is the largest population of nesting Loggerheads in Australia. The Western Australian populations of Hawksbill, Flatback, Green and Loggerhead turtles are amongst the largest in the world, this is significant considering their conservation status (Department of Environment and Conservation, 2008).

Researchers estimate an average of 1,000 to 2,000 Hawksbill turtles nesting in Western Australia each year (http://www.deh.gov.au/coasts/species/turtles/ in (The North Australian Indigenous Land and Sea Management Alliance & Smyth, 2006).

In the Locker Point to De Grey River area, estimated mixed species population of 49 000 of predominately adult Chelonid turtles within the 20m isobath. This lies in the mid-range of densities for Australian tropical waters (using similar survey technique). However this estimate is conservative as large numbers of turtles were present in deeper waters beyond the 20m isobath and small to medium sized turtle are less easily detected than adults. Observations made on April 2000 survey over waters deeper than 20m suggest that turtles were generally as common just outside the 20m isobath as they were just inside the 20m isobath, so using the 20m isobath as a cut off point is not valid for turtles. (Prince, Lawler & Marsh, 2001).

Genetic studies on Australian Green and Hawksbill turtles have shown that the WA and Qld populations are genetically distinct (Broderick *et. al.* 1994, Norman *et. al.* 1994 in (Pendoley, 2005)).

Within WA there are no significant genetic differences between rookeries, suggesting that the interbreeding unit for WA Green and Hawksbill turtles are spread over the state, supporting the hypothesis that Hawksbills undertake long distance migrations in the same manner as greens (Broderick *et. al.* 1994 and Fitzsimmons *et. al.* 1996 in (Pendoley, 2005)).

15.3 Species which are rare, endemic and/or of special conservation status (ie is it listed under the *Wildlife Conservation (Specially Protected Fauna) Notice 1999*, the *Endangered Species Protection Act 1992* and/or the *Threatened Australian Fauna (ANZECC List) 1999?*);

Based on the ongoing threats and recorded declines in numbers, marine turtles are generally listed as endangered, threatened or vulnerable by Australian and international conservation agencies (The North Australian Indigenous Land and Sea Management Alliance & Smyth, 2006).

In Western Australia waters, the conservation status of all marine turtle species is rare, or likely to become extinct (The North Australian Indigenous Land and Sea Management Alliance & Smyth, 2006).

Nationally, the Loggerhead is listed as endangered while the Flatback, Green, Leatherback and Hawksbill are listed as vulnerable (Department of Environment, Water Resources and the Arts 2008, www.environment.gov.au accessed 11/6/08).

On the IUCN Red List, Green and Loggerhead turtles are listed as endangered, Hawksbill and Leatherback turtles are listed as critically endangered, while Flatback turtles are listed as data deficient. The vulnerability of marine turtles is also recognised by their listing under international agreements such as the *Convention on International Trade in Endangered Species* (CITES, all species listed on Appendix I) and *Convention for the Conservation of Migratory Species of Wild Animals* (CMS, all species listed on Appendices I and II except the Flatback turtle, listed on Appendix II only). Australia is also a signatory to the *Memorandum of Understanding on the Conservation and Management of Marine Turtles and Their Habitats of the Indian Ocean and South-east Asia* (IOSEA MoU) (Department of Environment and Conservation, 2008).

Marine turtles are considered to be declining globally, despite successful conservation efforts in many countries, including Australia (Environment Australia & Marine Turtle Recovery Team (Australia), 2003).

15.4 If special, rare or endemic, state:

- **biogeographical and local distribution;**
- **seasonality of occurrence; and**
- **behavioural patterns (eg migration, breeding, nesting);**

Biogeographical distributions

Typical habitats of marine turtles in Western Australia are benthic and pelagic zones of coastal waters, open ocean, intertidal areas and foredunes of the coast from Shark Bay to the Northern Territory border. Subtidal and intertidal coral reefs, rocky shores, seagrass meadows, mangroves, sandy shores mud flats, estuaries and coastal waters are important areas for foraging (Department of Environment and Conservation, 2008).

Very high density aggregations were observed in specific locations, however turtles overall were relatively abundant across the whole study area and overall turtles appeared quite abundant and well distributed throughout the entire visible depth of the water column. This indicates that populations are not reflecting any response to the environmental disruption of soft bottom communities resulting from cyclones (unlike dugongs) (Prince, Lawler & Marsh, 2001).

Given the reef and limestone nature of the benthos in the study area (Onslow-De Grey River) is more conducive to algal communities, it is reasonable to assume that the majority of the Green turtle population are algal feeders. These communities are much less likely to be affected by cyclones and where macroalgae is dislodged by cyclones are remains adrift, this may continue to provide a food source long after detachment (Prince, Lawler & Marsh, 2001).

According to (Environment Australia & Marine Turtle Recovery Team (Australia), 2003)), most significant rookeries in Western Australia are on island nature reserves.

Local distributions

Aerial surveys of beaches between Onslow and Port Hedland highlight the importance of inshore islands for marine turtle populations, including many of the islands in the Great Sandy Islands Nature Reserve and Middle Mangrove Island. Large numbers of tracks were observed on certain mainland beaches between Karratha and Port Hedland, namely Bells beach, Munda (Cowrie and Victory beaches) and Cemetery Beach. No mainland nesting sites were observed between Karratha and Onslow during this particular study (Kregor, Stanley & Liddelow, 2005).

Eighty Mile Beach

Satellite tagging work for a Green turtle from Barrow Island revealed that a foraging area exists at northern EMB (Cape Jaubert is close to northern boundary of area), however it is predominately in offshore waters (Pendoley, 2005).

Cape Keraudren

Turtles were particularly abundant during the April 2000 survey over reef and shallow water areas at North Turtle Island (Prince, Lawler & Marsh, 2001).

De Grey River and offshore islands

The De Grey River area – "I can confirm that the De Grey and the islands off the river mouth are important foraging grounds for Green, Hawksbill and Flatback turtles from Barrow Island (green and flatback) and Varanus Island (hawksbill), and judging from the recent tracking work done from NW Cape it is also an important area for Loggerhead foraging. While our data set is fairly small at the moment it is the only place that I have found so many species using at the same time and so is VERY important." Personal comment, Kellie Pendoley.

A Flatback turtle satellite tagged at Barrow Island migrated to a foraging area between the bay south of Spit Point and Little Turtle Island. Approximately 2/3 of the points recorded are within the study area (Pendoley from www.seaturtle.org, accessed 11/06/08).

5 turtles satellite tagged (3 Barrow Is Greens and 2 Varanus Is Hawksbills) use the De Grey and offshore areas as foraging areas. One identified foraging area east of De Grey (near Cartaminie Point) is approximately half within the study area and half outside the study area. Most of the foraging area around North Turtle Island (one Green, one Hawksbill) is within the study area (Pendoley, 2005).

Mundabullanga

Turtles were particularly abundant during the April 2000 survey over reef and shallow water areas inshore near Cape Cossigny (Prince, Lawler & Marsh, 2001).

A Flatback turtle satellite tagged from this nesting beach in 2006 spent approximately 3.5 months in the area (internesting habitat?) before reappearing 9 months later in the Kimberley. The main internesting area was both inshore and offshore waters east of Cape Thouin to the edge of the study area. A second turtle tagged from the same beach spent 2 months in the area, but her internesting habitat was larger, extending from Cowrie Beach to the De Grey River (Pendoley from www.seaturtle.org, accessed 11/06/08). Turtles using this rookery do not travel as far to their internesting habitat as those on Barrow Is (*pers. comm.* K. Pendoley 17/6/2008).

The rookery supports around 4000 nesting females and is more important than Barrow since it is only one beach (as opposed to Barrow's multiple beaches) and is a single species rookery (*pers. comm.* K. Pendoley 17/6/2008).

Satellite information from tagged turtles indicate that all foraging areas are to the north of Munda (*pers. comm.* K. Pendoley 17/6/2008).

Cowrie Creek, near the mouth of the Yule River, is a significant turtle breeding area (Department of Transport & Pilbara Development Commission, 1997).

Robe

This is a priority area for turtle conservation, some key sites include:

- Mary Anne Group – these are perched lagoons important for adult hawksbills;
- Long Is – I have seen hundreds of juvenile turtles here, likely due to the protection offered by shallow water (very shallow, few metres at best)

(*pers. comm.* K. Pendoley 17/6/2008).

Aggregations of male green turtles are known to occur on the Mangrove Islands, north east of Onslow, prior to the nesting season, however the purpose of these aggregations is not known (Pendoley Environmental 2005 in (Brewer et al., 2007)). This aggregation is important as access to male turtles is very limited (*pers. comm.* K. Pendoley 17/6/2008).

- Specifically, this aggregation occurred on a broad shallow limestone platform between Middle and North Mangrove Island. In shallow water (40cm) in excess of 10 individuals within a 50m radius were observed with most animals resting or feeding. Most animals were mature male turtles (Pendoley & Fitzpatrick, 1999).
- Another area of high turtle density was amongst the mangroves on the northern coast of North Mangrove Island. Most animals were sheltering or feeding under the mangrove canopy in water around 50cm deep. "One large female Green turtle raised her head clear of the water to eat the mangrove (*Avicennia marina*) leaves".

Turtles were particularly abundant during the April 2000 survey over reef and shallow water areas near North Sandy Island (Prince, Lawler & Marsh, 2001).

Turtles were particularly abundant during the April 2000 survey over reef and shallow water areas near south mangrove Is (Prince, Lawler & Marsh, 2001).

Satellite tagging of Flatback turtles from Barrow Island show that some travel to coastal areas as part of their internesting habitat. Specific locations for individual turtles include coastal inshore waters from Robe River to Weld Island and the areas adjacent to the South Passage Island, Cowrie Island, Solitary Island and east of North Sandy Island (Pendoley from www.seaturtle.org, accessed 11/06/08).

Foraging areas identified for 2 hawksbills tagged at Varanus are throughout the Mary Island Group and adjacent to and SE of Great Sandy Island. The approximate size of these two foraging areas are very different, with the Mary Anne Group is about 628 km^2 while the GSI area is about 160km^2. Although these sites were only 65-85 km/2 days swim from their nesting ground they did not travel to this feeding ground during nesting (Pendoley, 2005).

Foraging areas identified for two Hawksbills tagged at Rosemary Island are adjacent to and NW of Scholl Island and south of Fortescue/west of Mardi Islands. These foraging areas are about the same size (160km^2 and 232km^2) (Pendoley, 2005).

The most important Hawksbill foraging ground identified by the study are the extensive and diverse coral, macroalgal and limestone reef assemblages that occur in this area (Tap 1998 in (Pendoley, 2005)).

Flatbacks nest on the back beach at Onslow (outside of study area) but significant because beach was much more rubbly than the species normally found on – likely that Flatbacks therefore nest in Great Sandy Islands NR (*pers. comm.* K. Pendoley 17/6/2008).

The islands between Dampier and Exmouth Gulf are important non-breeding habitats for Leatherback turtles and important nesting locations for Hawksbills (Department of Environment and Conservation, 2008)

Serrurier Islands

Turtles were particularly abundant during the April 2000 survey over reef and shallow water areas at Serrurier Islands (Prince, Lawler & Marsh, 2001).

During a 4 day survey of the island in 2007, nesting success of Green turtles was determined. Day 1 had 23% success (# false crawls vs # nests), day 2 had 26% success, day 3 had 32% success and day 4 had 29% success. Successful nests were located predominately on the eastern side of the island (central and southern part of this coast), however nesting occurred along most of the coastline. No nests were observed on the south-western 'spur' of the island (Mau & Balcazar, 2007)

Locker Point to Rocky Point

No turtle tracks were seen in the study area during a single aerial survey conducted in January 2007, however 4 fresh tracks (from the previous night) were seen adjacent to the study area between the Ashburton River and Entrance Point and 7 tracks on Locker Island (Mau & Balcazar, 2007).

On a single survey at Locker Island in January 2007, 6 nests were observed and were a combination of new nests and old nests. The nests were made by Loggerhead, Flatback and Hawksbill turtles and were found predominately on the southern side of the island, with 2 on the central east coast of the island. Turtle track characterisation suggestion that the south-eastern section of the island is used by Flatbacks (Mau & Balcazar, 2007).

One Green turtle tagged at Barrow Island (of only two) headed south and was operating prematurely near Locker Island (Pendoley, 2005).

Wind is a significant influence for aerial track counts in this area, since it is likely to obscure tracks within a relatively short time frame (*pers. comm.* K. Pendoley 17/6/2008).

Behavioural patterns & migration routes

Satellite tagging of Green and Hawksbill turtles tagged at Barrow, Varanus, Rosemary and Sandy Islands all showed that animals remain close to their nesting beaches during internesting and do not disperse to other locations during this period (Pendoley, 2005). Green turtles move up to 5km and Hawksbills up to 10km from nesting beaches. Flatbacks however do move much further during the internesting period, and satellite tagging show they will travel to the mainland from Barrow Is. Turtles using the Munda rookery do not travel as far between nesting beach and internesting habitat as Barrow Is turtles (Pendoley 2008 at www.seaturtle.org, *pers. comm.* K. Pendoley 17/6/2008).

The Pilbara Green, Hawksbill and Flatback turtles will often follow the depth contours during their migration from nesting to foraging. Flatbacks are more closely link to depth contours than green or hawksbills (*pers. comm.* K. Pendoley 17/6/2008).

- Green and hawksbill turtles leaving Barrow and Varanus Islands primarily travelled within the 30m isobar and no deeper than the 50m isobar. For example Migration routes of 3 Green and 3 Hawksbill turtles from Barrow and Varanus Islands showed that these turtles tracked along the 20m isobath to McLennan Bank and Dampier Archipelago. A further 3 Barrow Island Green turtles tracked further offshore, 2 within the 50m isobath but didn't turn towards the coast until well past the Archipelago and 1 turtle further offshore again. Of these 9 animals, seven of these animals then travelled inside the 30m isobar to a foraging area of De Grey River, one stopped transmitting and the other continued to a foraging area at EMB (Pendoley, 2005).
- Two Gawksbill turtles tagged at Rosemay Island travelled SW to the their foraging areas in the Robe study area (Scholl Island vicinity), one turtle following the 10m isobar the other the 15m isobar (Pendoley, 2005).

Turtles that migrated north to feeding grounds, appeared to use the Dampier Archipelago as a navigation marker for their migration along the coast. They possibly use other areas of the coast to navigate as well as using the protection of the shallow near shore waters (Pendoley, 2005).

The Pilbara Green and Hawksbill turtles did not appear to pause along the migration route to feed or graze, rather swam directly there (Pendoley, 2005).

Both Green and Loggerhead turtles are known to inhabit mangrove creeks and waterways and utilise mangrove food (Milward, 1982 in (Carr & Livesey, 1996). Juvenile marine turtles feed on a range of plant and animal food within mangals.

Male Flatbacks have been seen off the west 'coast' of the Monte Bello Islands (one of few times males have ever been seen). Should similar topography be found elsewhere you might also find aggregations of male Flatbacks (*pers. comm.* K. Pendoley 17/6/2008).

Unlike other species of marine turtle, Flatbacks forage in the local area instead of dispersing into the open ocean (Department of Environment and Conservation, 2008).

Each species are generally found in different depth ranges and eat different foods:

- Flatbacks are generally found in 30-40m depth range and eat foods like sea pens (soft bottom species);
- Hawskbills are generally found in the 0-20m depth range and are sponge eaters;
- Greens are generally found in 0-10m depth range and eat macroalgae (not much seagrass in the region);

- Loggerhead – not well known by Kelly but have been known to eat pearl shell;
- Olive Ridley – have been caught in trawl nets in Nikol Bay, eating sponges.

  (*pers. comm.* K. Pendoley 17/6/2008).

Site-specific rookery/nesting information

Green

- There are Green turtle nesting sites on the North West shelf of Western Australia at the Lacepede Islands, sites north of Broome, and Barrow and the Monte Bello Islands to the south. Green turtles nesting along the Western Australian coast migrate from feeding grounds in Indonesia, western Cape York Peninsula, Northern Territory and Western Australia (The North Australian Indigenous Land and Sea Management Alliance & Smyth, 2006).
- The large population of nesting Green turtles on (Gorgon influenced) Barrow Island is a major part of the Northwest Shelf genetic stock. This stock is one of the few remaining very large populations of breeding Green turtles worldwide (Limpus, 2006).
- Serrurier Island is a major nesting area for green turtles and may also be a feeding ground for this species (Pendoley Environmental 2005 in (Brewer et al., 2007). It also has some minor Loggerhead and Hawksbill activity on the west coast (Mau & Balcazar, 2007).
- The Passage Islands and Eighty Mile Beach, along with Serrurier Island, are known as important nesting sites for Green Turtles in Western Australia (Department of Environment and Conservation, 2008).

Flatback

- The main nesting sites for Flatback turtles in Western Australia are in the Kimberley Region and along the North-west Shelf, namely at Cape Drommit, Lacrosse Island, Barrow Island and Cape Thouin. In the Pilbara region most nesting takes place during the summer, and in the Kimberley nesting occurs in the middle of the year (The North Australian Indigenous Land and Sea Management Alliance & Smyth, 2006).
- The nesting population of Flatback turtles on the eastern beaches of (Gorgon influenced) Barrow Island is a major part of the Pilbara Coast genetic stock. The Pilbara stock could account for more than 30% of the total breeding population of Flatbacks (Limpus, 2006).
- Information available for the Flatback turtle suggests the species is relatively widespread from the southern Pilbara coast northwards and it appears to be relatively abundant as a nesting species. The more common pattern of nesting appears to be widely dispersed use by smaller numbers of turtles of a range of mainland and offshore island beaches. There is an important mainland rookery located near Cape Thouin, while less intensive nesting has been observed elsewhere in the Port Headland district (also EA 2003 in (Brewer et al., 2007). Some mainland nesting locations reported in the Onslow district may be used by Flatbacks. The Flatback may nest alone, or in mixed species groups (Prince, 1994).

- Critical nesting and internesting habitat for Flatback turtles has been identified at Mundabullangana Beach (also EA 2003 in (Brewer et al., 2007). This is a denser rookery than that located on Barrow Island. The Barrow Island rookeries are spread over multiple beaches and are mixed species. So even though around the same number of turtles nest on Barrow as at Munda (approx. 4000), I believe the Munda rookery is more important. It is also a single species rookery (*pers. comm.* K. Pendoley 17/6/2008).
- As well as the offshore islands, there is a known turtle nesting area used by Green turtles at Cowrie Creek on the mainland Pilbara coast. This area is a small sandy beach immediately adjacent to mangals (Carr & Livesey, 1996).
- Flatback turtle rookeries exist at Mundabullangana Station, Port Headland (Cemetery Beach/Pretty Pool Beach), Eighty Mile Beach, the Onslow coast, Bells Beach, and the islands between Dampier and Exmouth Gulf (Department of Environment and Conservation, 2008).

Hawksbill

- Hawksbill turtle nesting takes place all year round (mainly between October and January) in Western Australia (The North Australian Indigenous Land and Sea Management Alliance & Smyth, 2006).

The three species of turtles show distinct spatial and temporal nesting characteristics (through study in Barrow-Montebello-Lowendal area):

- Green turtles favour larger, high energy beaches with deep sand and an open foreshore approach.
- Flatback turtles, which are more susceptible to mechanical damage due to low keratin levels in the shells, were hound in highest numbers of narrow, low energy beaches that may or may not have an obstructed foreshore approach (Pendoley, 2005).
- Hawksbills had the densest nesting on small, rubbly, shallow sand beached characterised by coral reef habitat in the foreshore zone. The concentration of hawksbills on these beaches may also be a factor of the shallow sand depth precluding Green and Flatbacks from using these beaches. Hawksbills also appear to use the larger, deeper sand beaches favoured by Green and Flatbacks, however the higher density of tracks by other species probably obscures the less dense Hawksbill tracks.

The nesting season for each species varies:

- Greens commence nesting in November, peak in January and February, with limited data suggesting a decline in March.
- Flatbacks appear to nest over a relatively short 2 month period in December and January (86% of the mean number of tracks were counted in these months).
- Hawkbills commence nesting in September, peaking between October and December and ending in January (Pendoley, 2005).
- Loggerheads nest from December to March, but generally south of the study area (Department of Environment and Conservation, 2008).

General reproductive and life cycle

The location of post-hatchling (ie. between leaving the rookery beach and returning to coastal foraging areas) foraging areas are different for each species. Green and Hawksbills head offshore into oceanic areas and are not generally seen in coastal waters until 10-15 years (dinner plate size). Although little is known about the location of Flatback post-hatchlings it is thought they remain in nearshore waters. For example, carcasses of post-hatchling Flatbacks have been found in sea eagles nests (sea eagles only forage up to 10km out to sea). A post-hatchling Flatback has also been found swallowed by a Cobia (bottom dwelling fish) offshore from Barrow Island. We do know they are found deeper than expected – 10-20m (*pers. comm.* K. Pendoley 17/6/2008).

All species of marine turtles have the same general life cycle. They grow slowly and take decades to reach sexual maturity. As immature turtles, they may drift on ocean currents for many years or live for years in the one place before maturing and making a long breeding migration of up to 3000 km from the feeding ground to a nesting beach. At an unknown age male and female turtles migrate to a nesting area located in the region of their birth. Both male and female turtles mate with a number of partners. The females store sperm in their bodies to fertilise the three to seven clutches of eggs that are laid during the season (The North Australian Indigenous Land and Sea Management Alliance & Smyth, 2006).

Mating generally takes place offshore a month or two prior to the turtle's first nesting attempt for the season, which is usually in summer. Male turtles generally return to their foraging areas once the females commence their fortnightly trips to the beach to lay eggs. When ready, females emerge from the sea and dig out a body pit then excavate a vertical egg chamber. For most turtles, digging the nest takes about 45 minutes. Another 10 to 20 minutes are then spent laying the clutch of leathery-shelled eggs. Each clutch contains about 120 eggs, ranging in size from the golf ball-sized egg of the Hawksbill to the billiard ball-sized egg of the Flatback. After the nesting season, females return to their distant foraging areas and may not nest again for two to eight years (The North Australian Indigenous Land and Sea Management Alliance & Smyth, 2006).

The temperature of the nest during incubation determines the sex of hatchlings. Warm, dark sand produces mostly females. Eggs laid in cool, white sand result mostly in males and generally take longer to hatch. After about 7-12 weeks the eggs hatch, usually emerging as a group at night. To find the sea, hatchlings orient towards the brightest direction and use the topography of the surrounding horizon line. Once in the sea, hatchlings use a combination of cues to orient themselves to deeper offshore areas. Crossing the beach and swimming away is believed to imprint the hatchlings with the cues necessary to find their way back when they are ready to breed. Once in the ocean, hatchlings are believed to enter regions where ocean currents meet. There they associate with floating seaweed mats and other flotsam caught up in ocean currents. Here they feed on tiny sea animals. These young turtles are rarely seen again until their shell length is 20-40 cm, which may be five or ten years after hatching. At this time, the young, free-swimming turtles migrate back to inshore foraging areas. They remain in these areas until they are ready to breed and the cycle begins again (The North Australian Indigenous Land and Sea Management Alliance & Smyth, 2006).

Marine turtles take up to 30-50 years to mature. Adults do not breed every year. Life history characteristics make turtles vulnerable to a range of influences that can affect the integrity of wild populations (Environment Australia & Marine Turtle Recovery Team (Australia), 2003). Recovery of a small decline in population can take 150 years, assuming no further mortality (Limpus, 2006).

15.5 Past, present and potential uses and/or pressures (natural and human-induced); evidence of impact and the relevant research/monitoring programs (if any); and

Marine turtles are subjected to numerous natural pressures, particularly while developing in their eggs, as hatchlings and as free-swimming juveniles. However, human activities are currently causing severe population declines and may lead to species extinctions if not addressed. Human threats are well documented and include: direct fisheries pressure and bycatch, oil spills and marine debris, shark nets, boat strikes, noise (seismic testing) and light pollution, dredging, vehicles and recreational activities on nesting beaches, predation by feral animals, habitat changes from coastal development, unsustainable harvest, and diseases (Department of Environment and Conservation, 2008; The North Australian Indigenous Land and Sea Management Alliance & Smyth, 2006).

Capture locations from trawlers indicate that Flatbacks feed in turbid, shallow inshore waters N of latitude 25°S in depths from less than 10 m to depths of over 40 m (Robins 1995 from Department of Environment, Water Resources and the Arts http://www.environment.gov.au/cgi-bin/sprat/public/publicspecies.pl?taxon_id=59257 accessed 11/6/08). Because of this they are also at risk from dredging (Pendoley, 2005).

Turtles have been caught as bycatch in some of the fisheries that exist in the region. The Onslow and Nickol Bay Prawn fisheries have low impact on turtles as they use Turtle Exclusion Devices (TEDs) in their nets, reducing turtle capture. The Pilbara Demersal Finfish (Trawl) fishery has a moderate impact, although it is monitored and most turtles captured are released alive. Recreational fishers have been known to catch turtles (mainly when using nets), but generally return them to the water (Department of Environment and Conservation, 2008).

A commercial Green Turtle fishery operated off the western Pilbara coast in the 1960's and early 70's under provisions of the then existing State Fisheries legislation (Kennett, 1997).

Light pollution has been identified as a factor affecting successful marine turtle nesting. Some examples of problem light sources are oil production and processing plants, coastal and island development, and boats. Lighting from industrial complexes affects Flatback, Green and Hawksbill turtles from the North West Shelf (Environment Australia & Marine Turtle Recovery Team (Australia), 2003). Light influence can reduce the success of nesting and inhibit orientation (Department of Environment and Conservation, 2008), and can repel nesting turtles from brightly illuminated beaches, leading to reduced adult nesting population (Limpus, 2002; Limpus, 2006).

Results from lighting experiments on nesting turtles in the Barrow-Montebello-Lowendal Islands suggest that Flatback turtles are at the greatest risk of exposure (42% of population) followed by hawksbills (12% of population). No Green turtle rookeries currently are within 1.5km of industrial lighting (Pendoley, 2005).

Concern has been expressed about the potential impact on turtles through light disturbance and entanglement in equipment used in pearl farming and aquaculture. No available evidence exists to suggest any mortality due to pearl farming and aquaculture but a precautionary principle is appropriate (Environment Australia & Marine Turtle Recovery Team (Australia), 2003).

On the North West Shelf, Loggerhead, Green and Flatback turtle populations have been identified as being affected by tourism and recreational activities. Mainland nesting sites are affected by vehicle damage (Environment Australia & Marine Turtle Recovery Team (Australia), 2003). Tyre ruts from vehicles can trap and disorient turtles and compress eggs in nests (Limpus, 2006). This has been observed at Cleaverville Creek, Pretty Pool, Eighty Mile Beach and Wickham beaches (Department of Environment and Conservation, 2008).

Introduced and native species are known to prey upon marine turtle eggs. Predation by the European Red Fox has been identified as a key threatening process for mainland nesting sites (loggerhead and green turtles) in Western Australia (Environment Australia & Marine Turtle Recovery Team (Australia), 2003).

Results from a study of fox predation activity (2003/04 turtle nesting season) along beaches within Jurabi Coastal Park on the North West Cape indicate cause for concern for the sustainability of turtle nesting populations. All three turtle species (green, loggerhead and hawksbill) nesting along the coastal strip were predated upon. Most predation experienced was to emergent phase nests, although incubating nests in the later stages of development were also totally or partially destroyed (McKinna-Jones, 2005).

Silver gulls prey on turtle juveniles and eggs, and their influence can be increased through human impacts such as providing food, which increases gull numbers, and the provision of light to enable constant hunting (Department of Environment and Conservation, 2008).

Insufficient information is available to make an accurate assessment of the Western Australian Loggerhead population, however researchers have expressed concern about the long term stability of this population. This is because the Western Australian population faces similar threatening processes to those in eastern Australia (The North Australian Indigenous Land and Sea Management Alliance & Smyth, 2006).

Turtles are taken legally under the *Wildlife Conservation Act 1950* by persons of Aboriginal descent, and illegally by fishermen from Taiwan, Papua New Guinea and Indonesia (Department of Environment and Conservation, 2008). Researchers have expressed concern that unsustainable levels of egg harvesting by indigenous people may result in a decline in Flatback turtle numbers (The North Australian Indigenous Land and Sea Management Alliance & Smyth, 2006).

Popular turtle nesting sites can attract tourist visitors. If tourism is uncontrolled the disturbances to turtles can be significant (Department of Environment and Conservation, 2008).

Turtles can be injured or killed by ingesting or becoming entangled in marine debris. Plastics comprises up to 90% of marine debris on northern beaches of Australia. Oils spills and bitterns from salt production can also be detrimental to turtle health (Department of Environment and Conservation, 2008).

The effects of climate change can alter nest temperatures, determining the sex of the turtles and, in some cases, leading to mortality (Department of Environment and Conservation, 2008).

Low frequency sounds and vibrations can affect marine turtles, generally causing them to move away from the disturbance. Siesmic testing, generators, machiney and vehicle movements can cause such disturbances (Department of Environment and Conservation, 2008; Limpus, 2006)

The proposed Gorgon Gas project is likely to contribute to a significant reduction in nesting Flatback turtle population on Barrow Island within 20 to 30 years (Limpus, 2006). This highlights the importance of enhancing turtle stocks by protecting other areas of important habitat.

15.6 Past/current/proposed management strategies (eg codes of practice, monitoring programs).

Marine turtle conservation measures currently conducted in Western Australia include: tagging; beach track monitoring; satellite tracking; aerial surveys; vehicle and vessel based surveys; nesting studies; advice on development proposals; pest control; vehicle beach closures; track rationalisation; education; interpretive centres; signage; guide training; managed tours; indigenous and community group training; research projects; recovery of stranded, dead and injured turtles; gazettal of new marine reserves; preparation of recovery plans and investigations into illegal harvest of turtles and eggs (Department of Environment and Conservation, 2008).

Marine turtles in Western Australia are protected and managed under international (Convention on Migratory Species, Memorandum of Understanding on the Conservation and Management of Marine Turtles and their Habitats of Indian Ocean South East Asia (IOSEA), Convention on the International Trade in Endangered Species, Convention on Biodiversity), Commonwealth (Environment Protection and Biodiversity Conservation Act

1999) and State (Wildlife Conservation Act 1950, Wildlife Conservation [Close Season for Marine Mammals] Notice 1998) legislation. This legislation provides various mechanisms for the recognition of indigenous people's right to hunt dugong for subsistence and other non-commercial cultural purposes. Section 211 of the *Native Title Act 1993 & 1998* also protects native title holders' non-commercial hunting rights (The North Australian Indigenous Land and Sea Management Alliance & Smyth, 2006).

Loggerhead and Leatherback turtles are listed as threatened species under the Western Australian *Wildlife Conservation Act 1950*. All other species are protected as native fauna. Provision is made in this Act for the take by indigenous people (Environment Australia & Marine Turtle Recovery Team (Australia), 2003).

Other relevant Australian Government management strategies for marine turtles include: The NAILSMA Dugong and Marine Turtle Project; A Recovery Plan for Marine Turtles; Sustainable Harvest of Marine Turtles and Dugongs in Australia – A National Partnership Approach; Threat Abatement Plan for Marine Debris; the compulsory use of Turtle Exclusion Devices (TEDs); closing areas of inshore seagrass habitat to trawling; Bioregional Marine Planning; and a Code of Conduct for dugong and marine turtle tourism (The North Australian Indigenous Land and Sea Management Alliance & Smyth, 2006).

The Recovery Plan for Marine Turtles in Australia adopts a threat-based approach to manage sources of mortality. The overall objective is: "to reduce detrimental impacts on Australian populations of marine turtles and hence promote their recovery in the wild" (Environment Australia & Marine Turtle Recovery Team (Australia), 2003). In the absence of historical data, recovery targets cannot generally be established. Specific objectives have the principal aims of reducing or managing factors that cause mortality in marine turtles, and seeking information that will assist in making judgements about the security of turtle populations in Australia. Management and research actions are directed at improving the conservation status of species to the extent that they no longer need to be listed as endangered or vulnerable (Environment Australia & Marine Turtle Recovery Team (Australia), 2003).

(Limpus, 2002) states that marine turtle nesting on the mainland beaches is not well represented in the current conservation reserve system. He highlights Mundabullangana Station and Eighty Mile Beach as areas within pastoral leases that could be better protected.

The Kimberley Land Council (KLC) has established a Land and Sea Management Unit to undertake projects for looking after land and sea country, including marine resource management. The unit works with Traditional Owners to look after, manage and take control of traditional country, and has partnerships with community organisations, industry, government agencies and local government. The Gnulli Working Group, representing the Traditional Owners of the Northwest Cape area near Exmouth, was involved in the development of the Jurabi Turtle Centre which opened in March 2004. The interpretive centre is located in the Jurabi Coastal Park, which is a breeding ground for Green, Loggerhead and Hawksbill turtles (The North Australian Indigenous Land and Sea Management Alliance & Smyth, 2006).

There are also a number of initiatives and programs to protect and manage turtles in Western Australia including the Jurabi Turtle Centre north-west of Exmouth and the West Australian Marine Turtle Program, operational since 1985. Research and monitoring activities include: long-term monitoring of most major rookeries; migration studies; estimates of inshore numbers at feeding grounds; management of oil field lighting and seismic activities; diseases in marine turtles; development of interaction with indigenous groups in monitoring programs; and the salvage of Leatherback and other turtles entangled in crayfish pot floatlines in summer (The North Australian Indigenous Land and Sea Management Alliance & Smyth, 2006).

To reduce the impact from light pollution on turtle nesting areas, it is recommended that lighting should be excluded from beaches and areas behind beaches that are known major nesting sites. A buffer zone of no development, providing darkness without light alteration of light horizons, is the preferred management option (Limpus, 2002).

Indigenous hunting of turtles has traditionally been managed through customary law. Recent technological improvements and the disruption of culture however, have affected this management. (Environment Australia & Marine Turtle Recovery Team (Australia), 2003) points out that cooperative management agreements (between indigenous communities and management agencies) can both ensure sustainability and provide for community aspirations.

The deployment of wire cage traps employed by CALM to control fox predation of turtle nests at Jurabi Coastal Park (North West Cape) during the 2003/2004 turtle nesting season proved ineffective. The use of 1080 (sodium fluoroacetate) poison dry meat baits deployed at Bateman Bay in the southern region of Ningaloo Marine Park had more success. To assess the future effectiveness of fox control measures, some form of monitoring is recommended (McKinna-Jones, 2005). The broad scale baiting of foxes in areas adjacent to mainland turtle nesting beaches will substantially reduce egg loss to foxes (Limpus, 2002).

Identify critical major nesting, internesting, courtship and foraging areas that can be included into planned minimal disturbance areas (Limpus, 2002).

16. INVERTEBRATES

16.1 Species diversity and the relative importance of the faunal group in statewide and regional contexts;

Little knowledge exists of sponge communities between Exmouth Gulf and Cape Preston. (NMBP, 2007)?? Relatively little survey work has been done on sponges and problems often exist in the classification to species level due to unresolved taxonomic issues (Hooper, Kennedy & Quinn, 2002).

Assessment of Australia-wide sponge populations shows that the NW Shelf of WA (including adjacent coastal areas such as Dampier Archipelago and Montebello Islands) are one of three regions in Australia with over 600 species (Hooper, Kennedy & Quinn, 2002).

16.2 Size of population(s), including size of any genetically distinct populations (if known), and details of most recent survey(s);

16.3 Species which are rare, endemic and/or of special conservation status (ie is it listed under the *Wildlife Conservation (Specially Protected Fauna) Notice 1999,* the *Endangered Species Protection Act 1992* and/or the *Threatened Australian Fauna (ANZECC List) 1999?*);

In a sample of the Onslow to Cape Keraudren area (including offshore waters) there were 344 spp, 127 of which were endemic (37%). There were 129 genera in the same region with 6 endemic genera (5%) (Hooper, Kennedy & Quinn, 2002).

16.4 If special, rare or endemic, state:

- **biogeographical and local distribution;**
- **seasonality of occurrence; and**
- **behavioural patterns (eg migration, breeding, nesting);**

At the small scale, species of sponges living within all reef communities and at all depths contain the greatest proportion of endemic taxa. An even greater diversity of species are found in the smaller, cryptic habitats (e.g. sciaphilous, encrusting, plaque-forming taxa), although this fauna has barely been sampled. Consequently nutrient levels and other factors may only account for small-scale gradients in cross-shelf distributions whereas other factors such as local recruitment and connectivity and local geomorphology have an equal or probably greater importance in biodiversity gradients (Hooper, Kennedy & Quinn, 2002).

At the larger scale (e.g. Onslow to Cape Keraudren scale), biogeographic and environmental influences (especially sediments and tidal regimes) are more prominent than latitude in effecting endemism, richness and taxonomic relationships between fauna (Hooper, Kennedy & Quinn, 2002).

16.5 Past, present and potential uses and/or pressures (natural and human-induced);

evidence of impact and the relevant research/monitoring programs (if any); and

Trawling activities caused damage to what was formerly a considerable sponge community (NMBP, 2007)??

16.6 Past/current/proposed management strategies (eg codes of practice, monitoring programs).

17. MOLLUSCS

17.1 Species diversity and the relative importance of the faunal group in statewide and regional contexts;

17.2 Size of population(s), including size of any genetically distinct populations (if known), and details of most recent survey(s);

17.3 Species which are rare, endemic and/or of special conservation status (ie is it listed under the *Wildlife Conservation (Specially Protected Fauna) Notice 1999,* the *Endangered Species Protection Act 1992* and/or the *Threatened Australian Fauna (ANZECC List) 1999?*);

17.4 If special, rare or endemic, state:

- **biogeographical and local distribution;**
- **seasonality of occurrence; and**
- **behavioural patterns (eg migration, breeding, nesting);**

17.5 Past, present and potential uses and/or pressures (natural and human-induced); evidence of impact and the relevant research/monitoring programs (if any); and

17.6 Past/current/proposed management strategies (eg codes of practice, monitoring programs).

18. SEABIRDS AND SHOREBIRDS

18.1 Species diversity and the relative importance of the faunal group in statewide and regional contexts;

Bedout Island (located within the Cape Keraudren to Spit Point study area) is recognised as a site of significance for nesting seabirds. The Masked Booby, Broown Booby, Lesser Frigate-bird, Lesser Crested Tern and Common Noddy have breeding colonies on the island (Burbidge, 1989). The island has been identified as the most southerly recorded breeding station in Western Australia of the Lesser Frigatebird and of the Masked and Brown Booby. However, because of the difficulty of access, it has rarely been visited by ornithologists (Bush & Lodge, 1977).

The avifauna of the Pilbara mangals is extremely diverse. Mangrove communities of northern and north-western Australia have been found to support the richest mangrove bird fauna in the world. In the Pilbara mangal areas there are 8 mangrove species and a total of 11 bird species associated with mangals (Johnstone, 1990 in (Carr & Livesey, 1996).

18.2 Size of population(s), including size of any genetically distinct populations (if known), and details of most recent survey(s);

North Turtle Island

Species breeding (Fuller & Burbidge, 1998b):

- Pied Cormorant (*Phalacrocorax varius*) - colony of 1500 in 1975 breeding pairs, colony of 700 nests in 1982, colony of 500 nests in 1984.
- Australian Pelican (*Pelecanus conspicillatus*) – three colonies in 1975, two active and one abandoned; 600 nests in the central island in 1981; two colonies, one abandoned with 300 fresh eggs, one with 600-700 nest in 1982; 500 chicks in 1984.
- Caspian Tern (*Terna caspia*) – one abandoned egg in 1975.
- White-bellied Sea Eagle (*Haliaeetus leucogaster*) – pair nest on the island taking seabirds for food.

Species recorded (Fuller & Burbidge, 1998b):

Brown Booby	*Sula leucogaster*
Lesser Frigatebird	*Fregata ariel*
Eastern Reef Egret	*Egretta sacra*
Sooty Oystercatcher	*Haematopus fuliginosus*
Silver Gull	*Larus novaehollandiae*
Gull-billed Tern	*Sterna nilotica*
Crested Tern	*Sterna bergii*
Roseate Tern	*Sterna dougallii*
Fairy Tern	*Sterna nereis*

Bedout Island

Species breeding (Bush & Lodge, 1977; Fuller & Burbidge, 1998a):

- Masked Booby (*Sula dactylatra*) - 300 birds in October 1949, 400 pairs and c. 400 nesting pairs in May 1972, 177 nests and 235 birds in May 1978, 300 to 400 birds and 50 nests still in use on 25 September 1981, 120 occupied nests on 5 June 1982, and 178 nests on 5 June 1984. Most nesting on bare ground NW of the lighthouse.
- Brown Booby (*Sula leucogaster*) – the most common bird on the island. About 5 500 occupied nests were estimated 1982 and 11200 on 5 June 1984. Other estimates are: 5 000 in May 1972, 1 000 in May 1975, 600-700 in May 1978, and about 600 chicks and 400 to 500 birds sitting on eggs on 25 September 1981. Nests were located on the beach, as well as amongst the *Spinifex* clumps.
- Lesser Frigatebird (*Fregata ariel*) – 2290 and 1113 occupied nests were counted on 1982 and 1984. Estimates and counts by other visitors were: c. 2000 pairs in May 1972, c. 900 nesting pairs in May 1975, 300 nests in May 1978 and 700-800 old nests and 40 to 45 large chicks on September 1981.
- Silver Gull (*Larus novaehollandiae*) – single nest with egg in June 1981 with 300-400 birds present. June 1982 a few dead chicks with 20-30 birds. June 1984 c. 200 birds. Thought to be autumn breeder.
- Lesser Crested Tern (*Sterna bengalensis*) – one pair breeding in 1972, two pairs in 1975.
- Crested Tern (*Sterna bergii*) – 300 pairs in May 1972, and c. 200 nesting pairs in May 1975. About 400 birds were present on September 1981 and c. 600 on June 1982, with one non-flying chick. Apparently an autumn-winter breeder.
- White-bellied Sea Eagle (*Haliaeetus leucogaster*) – pair nest on the island taking seabirds for food.
- Roseate Tern (*Sterna dougallii*), Sooty Tern (*Sterna fuscata*) and Common Noddy (*Anous stolidus*) all have early or incidental reports of breeding.

Species recorded (Fuller & Burbidge, 1998a):

Pied Cormorant	*Phalacrocorax varius*
Australian Pelican	*Pelecanus conspicillatus*
Eastern Reef Egret	*Egretta sacra*
Caspian Tern	*Sterna caspia*
Bridled Tern	*Sterna anaethetus*

Eighty Mile Beach

Species	Flyway Population	Australian Population	EMB Population	EMB % of Flyway Pop.	EMB % of Aust. Pop.
Red-capped Plover	95,000	Unknown	9,600	10.1	N/A
Red Knot	255,000	153,000	80,700	31.6	52.7
Grey-tailed Tattler	48,000	36,000	8,500	17.7	23.6
Curlew Sandpiper	255,000	188,000	60,000	23.5	31.9
Large Sand Plover	99,000	74,000	30,400	30.7	41.1
Terek Sandpiper	36,000	18,000	6,100	16.9	33.9
Great Knot	319,000	Unknown	160,000	50.2	N/A
Greenshank	40,000	20,000	2,440	6.1	12.2
Grey Plover	16,000	12,000	1,650	10.3	13.8
Oriental Plover	44,000	40,000	18,400	41.8	46.0
Sharp-tailed Sandpiper	166,000	Unknown	25,000	15.1	N/A
Red-necked Stint	471,000	353,000	60,000	12.7	17.0
Bar Tailed Godwit	330,000	165,000	34,300	10.4	20.8
Ruddy Turnstone	28,000	14,000	740	2.6	5.3
Eastern Curlew	21,000	19,000	480	2.3	2.5
Pacific Golden Plover(N)	90,000	9,000	440	0.5	4.9
Whimbrel (N)	40,000	10,000	180	0.5	1.8
Marsh Sandpiper(N)	90,000	9,000	140	0.2	1.6
Sanderling (N)	11,000	8,000	100	0.9	1.3

(N) – Area is only of National Importance for these species.

Table 12: Populations of species at Eighty Mile Beach, an area of International and National Importance for Shorebirds, compiled from (Watkins, 1993).

18.3 Species which are rare, endemic and/or of special conservation status (ie is it listed under the *Wildlife Conservation (Specially Protected Fauna) Notice 1999,* the *Endangered Species Protection Act 1992* and/or the *Threatened Australian Fauna (ANZECC List) 1999?*);

Following birds are listed in JAMBA: Caspian Tern, Masked Booby, Lesser Frigatebird, Common Noddy and Bridled Tern.

Following birds are listed in CAMBA: Caspian Tern, White-bellied Sea Eagle, Lesser Frigatebird, Eastern Reef Egret, Common Noddy, Bridled Tern and Lesser Crested Tern.

The Eastern Curlew is considered to be a species of "special concern" (Watkins, 1993).

The Pilbara Mangrove Kingfisher (*Halcyon chloris pilbara*) is an endemic sub species to the Pilbara region. They are confined to mangals containing *Avicennia* forest or woodlands as this is the only mangrove species large enough to contain nesting hollows (Carr & Livesey, 1996).

Gaps in the distribution of the Striated Heron (Mangrove Heron) have resulted in the evolution of a unique Pilbara form, the sub species *Ardeola striatus regersi* (Carr & Livesey, 1996).

18.4 If special, rare or endemic, state:

- **biogeographical and local distribution;**
- **seasonality of occurrence; and**
- **behavioural patterns (eg migration, breeding, nesting);**

Nesting behaviour of the Fairy Tern makes it especially susceptible to disturbance. If a colony is approached, the parent birds will swoop, and will not sit on the nest while people are nearby (Burbidge & Fuller, 1987).

For Wedge-tailed Shearwaters, egg laying on the North West Shelf takes place at the end of October and beginning of November (Dunlop et al., 2002).

In a study of Wedge-tailed Shearwaters in the North West Shelf Region, findings indicate the oceanographic factors operating on a regional scale accounted for much of the variation in breeding success (Dunlop et al., 2002).

"The Eastern Curlew is the largest of the shorebirds that migrate to Australia. It occurs in greatest numbers on the coastal mudflats of eastern and north-western Australia (Lane 1987 in (Watkins, 1993). Birds arrive at sites in eastern Australia from late August and numbers are relatively stable between November and February. Departure occurs from late February to March" (Watkins, 1993).

18.5 Past, present and potential uses and/or pressures (natural and human-induced); evidence of impact and the relevant research/monitoring programs (if any); and

Potential risks to the integrity and maintenance of shorebird populations include: uncontrolled use of recreational or 4x4 vehicles on the beach (especially at high tide); Reckless use of hovercraft, aircraft, airboats or recreational toys close to groups of shorebirds, pollution from vehicle residues; pollution from food scraps and packaging residue; unlawful shooting or trapping; uncontrolled dogs, pets and stock on the beach; disturbance from camping; uncontrolled fishing on tidal flats (tablefish, shellfish and infauna invertebrates); and any other activity that might impact on the bird's ability to survive their migration flights (Pearson, Piersma & Hickey, 2005).

Since most seabirds nest on the ground they are highly susceptible to predation from foxes, cats, dogs and rats, while rabbits also disturb nesting burrows. The value of undisturbed islands (off the WA coast) to the persistence of seabird populations has been recognised (Burbidge & Fuller, 1987).

<u>Turtle Island</u>

Island is seldom visited and there would be little disturbance to the nesting pelicans most seasons (Fuller & Burbidge, 1998b).

Bedout Island

Abbott' suggested that the numbers of breeding Masked Booby, Brown Booby and Least Frigatebird on Bedout Island showed a marked decline between 1972 and 1978, attributing this to a decline in productivity of the waters around the island. Our data from June 1981 show that the decline had been reversed for both booby species, but not for the lesser frigatebird (Fuller & Burbidge, 1998a).

18.6 Past/current/proposed management strategies (eg codes of practice, monitoring programs).

19. MANGROVES

19.1 Species diversity (give details of most recent survey) and relative importance in statewide and regional contexts;

Sector	Assessment
Ashburton River Delta	N
Yardie Landing, Mangrove Islands	I,B,H
Robe River Delta	I,H
Fortescue River Delta	I,B,H
Cape Preston Area	I,B,H
Cossack to Harding Delta	N,B
Sherlock Bay Sector	R
Ronsard Island area	I,H
Yule River Delta	N,B,H
De Grey River Delta	N,B,H

I- Good examples of internationally significant, or unique tracts of coasts with, mangrove formations.
N- Good examples of 1 of 6 coastal types in relatively undisturbed states
R- Regionally/state-wide significant (significance is determined by meeting 1 of 5 criteria)
B- Unusual biodiversity or occurrence of uncommon species (e.g. geographic limits)
H- Explicitly exhibit mangrove/habitat relationships

Table 13: Status of PEMB mangroves. Modified from (Semeniuk, 1997) and (V & C Semeniuk Research Group, 2000)

Eight mangrove species occur in the Pilbara region, though not all of these may be found in the PEMB study area (Semeniuk *et al.*, 1978; Kenneally, 1982; Wells, 1982; Semeniuk, 1983; Johnstone, 1990; Semeniuk, 1993 in (Pedretti & Paling, 2001). These include: *Avicennia marina*, *Aegialitis annulata*, *Aegiceras corniculatum*, *Rhizophora stylosa*, *Ceriops tagal*, *Osbornia octodonta*, *Bruguiera exaristata*, *Exoecaria agallocha*.

Although the Pilbara region supports a relatively small number of mangrove species, the area is of major importance for many animal groups. The mangals of the Pilbara are distributed along the coast in an almost linear belt, hence forming an interconnected habitat through which fauna can move (Carr & Livesey, 1996).

Pilbara mangals provide a habitat for species not found elsewhere in the region and a high number of species are at or near the ends of their natural range within the Pilbara mangals (Carr & Livesey, 1996).

Pilbara mangals have national importance as being an excellent example of tropical arid coast mangroves. Having large areas of relatively undisturbed mangals also provides the opportunity to conduct valuable baseline studies into the ecology of mangroves (Carr & Livesey, 1996).

The Pilbara mangroves are internationally significant in terms of the mangrove bird fauna they support and also in terms of their limited levels of disturbance (Carr & Livesey, 1996).

Within the study area, two key mangal sites identified as having particular importance for the ongoing biological processes were De Grey River Mouth and Butcher Inlet (Carr & Livesey, 1996).

The high productivity of Pilbara mangal results in fauna from different areas utilising its resources (Semeniuk 1978 in (Carr & Livesey, 1996).

Bat communities are particularly rich in Pilbara mangals as they are one of the only closed forest habitat types available. In a study conducted by McKenzie and Start (1989), a total of 9 species were recorded from a potential pool of 15 in the region. Two of the species sampled are at the end of their range within the Pilbara mangroves. The Arnhem Land Long-eared Bat (*Nyctophilus arnhemensis*) is restricted to mangal in the Pilbara. Pilbara mangroves are also a particularly important habitat for flying foxes (Carr & Livesey, 1996).

The avifauna of the Pilbara mangals is extremely diverse. Mangrove communities of northern and north-western Australia have been found to support the richest mangrove bird fauna in the world. The number of bird species recorded as living in Pilbara mangals is 11 permanently and 15 temporally (Johnstone, 1990 in (Carr & Livesey, 1996).

It appears a permanent population of saltwater crocodiles has become established in mangals at Cape Keraudren (MPRWG, 1994 in (Carr & Livesey, 1996). Further sightings have been reported at the mouth and lower reaches of the De Grey River. It was initially thought the saltwater crocodile was not a permanent resident of the Pilbara coast and further research on its status in the region may be warranted (Carr & Livesey, 1996).

The White-bellied Mangrove Snake inhabits estuaries and mangal areas in northern Australia. It has been recorded in the Pilbara from Port Hedland to Nickol Bay and it reaches the end of its range in the Pilbara mangroves at Nickol Bay (Storr et al. 1986 in (Carr & Livesey, 1996). It is not found south of the Pilbara due to lack of suitable habitat.

The sea snakes are the largest group of snakes that inhabit Pilbara mangrove areas with at least 6 species recorded, including 3 species endemic to WA (Carr & Livesey, 1996).

A study by (Blaber, Young & Dunning, 1985) of the fish fauna of mangrove creeks and inlets in the Dampier region revealed Pilbara mangals were important as a nursery for inshore fish species rather than offshore species. This is in contrast to other mangrove systems around the world that are highly important as nursery areas for many offshore species as well as inshore species (Carr & Livesey, 1996).

The range of structural habitat types in Pilbara mangals is large and in places there is a greater diversity of habitats than in the south-west Kimberley region. This can be attributed to the large numbers of rivers and the more structurally diverse coastline (Johnstone 1990 in (Carr & Livesey, 1996).

The mangroves along the Pilbara coastline are the largest single unit of relatively undisturbed tropical arid zone mangrove habitats in the world (Environmental Protection Authority, 2001).

The Pilbara mangals are structurally complex, but with fewer species than those of the Kimberley, due to the semi-arid climate. There are few places in the world where mangals occur in arid conditions, and for this reason they are of international scientific importance (Rangelands NRM Coordinating Group, 2005). This habitat has a high ecological value for region, pertaining to productivity for feeding grounds and fish nurseries, and for scientific reasons of heritage, research, education and preservation of biodiversity (Environmental Protection Authority, 2001); (Semeniuk, 1997).

19.2 Biogeographical and local distribution and endemism;

All of the mangrove species within the Pilbara region belong to the Indo-Pacific group of mangrove species that is found within the Indian and Pacific Ocean regions. Within this large group, the Pilbara species are part of the Indo-masalian sub-group, the most species rich region of mangroves in the world (Semeniuk 1994 in (Carr & Livesey, 1996).

The Pilbara region does not contain any mangrove species that are geographically restricted and all Pilbara mangroves are common within the Indo-Pacific region. The mangroves of the Pilbara coast are a continuation of species that are found across northern Australian and into the Kimberley and Pilbara regions (Carr & Livesey, 1996).

The Eighty Mile Beach region is the northern boundary of Pilbara mangrove distribution. It is almost devoid of mangroves due to the lack of sheltered coastal habitats. The exceptions are at Mandora Station where two small tidal creeks contain mangroves. After about a 120km gap mangroves then extend without major breaks from Cape Keraudren at the southern end of Eighty Mile Beach throughout the study area (Carr & Livesey, 1996).

"There are few places in the world where mangals occur in arid conditions. In this regard, the mangals are of great scientific importance" (Semeniuk, 1993). The whole mangrove system of the region is considered important in order to maintain nutrient cycles and productivity of the coastal zone" (Department of Environment, 2006).

Robe

Mangrove Islands supported dense stands of flowering *Rhizophora stylosa* and fruiting *Avicennia marina* (Pendoley & Fitzpatrick, 1999).

Yardie Landing, Yammadery Island and the Mangrove Islands are designated as 'regionally significant' (Environmental Protection Authority, 2001):
The area is significant as the mangrove assemblages are in a limestone setting that is regionally to globally distinct. The limestone barrier that trends from Yardie Landing to Yammadery Island protects an extensive and rich mangrove system to leeward that are developed on mudflats and tidal creek networks. The

three offshore islands contain a range of variable and important mangrove habitats: limestone pavements, limestone cliffs, beaches, local sand sits and mud flats. The dominant mangroves in the system are *Avicennia marina* and *Rhizophora stylosa* which occur is most of the commonly occurring habitats. The full range of habitats at the small scale result in some diversity of vegetation with 6 species of mangrove locally occurring in areas where there are spits, point bars or beaches (*Aegialitis annulata*, *Aegiceras corniculatum*, *Avicennia marina*, *Bruguiera exaristata*, *Ceriops tagal*, and *Rhizophora stylosa*) (Semeniuk, 1997); (V & C Semeniuk Research Group, 2000).

Robe River Delta is designated as 'regionally significant' (Environmental Protection Authority, 2001):
The main mangrove habitats are in the tidal creek networks and here leeward of the barriers, are developed extensive and thick formations. It contains the following habitats: gravel and sand ridges and associated swales, local mud flats, tidal creeks and tributaries and abandoned tributaries. The delta is large inactive, but is important regionally in that it exhibits a type of delta in the Pilbara region and exhibits the progressive break-up of the seaward barrier by tidal creeks in a west to east direction. Dominant species are *Avicennia marina* and to a lesser extent *Rhizophora stylosa* and occur in most of the common habitats (Semeniuk, 1997); (V & C Semeniuk Research Group, 2000).

Fortescue River Delta is designated as 'regionally significant' (Environmental Protection Authority, 2001):
Second of the three largest Pilbara delta systems and is a gravel-dominated fronted by a series of limestone and gravel barriers that are locally breached by tidal creeks. This system is more active that the Robe River delta and more gravel dominated to the northwest. Main mangrove habitats are in the tidal creek networks of which there are regionally significant areas.

Coonga Tidal Creek area has the following habitats: seafront gravel flats, high-tidal sand plain, associated swales, local mud flats and tidal creeks. The tidal creek incising the largely inactive delta is an erosional feature. It is important as a type of delta in the Pilbara. Mangrove formation is not large and regionally extensive. Dominated by *Avicennia marina* and to a lesser extent *Rhizophora stylosa*. Locally at the edge of the san plain and in the tidal creek deposits there is development of *Aegialitis annulata*, *Aegicera conrinulatus* and *Ceriops tagal* (Semeniuk, 1997); (V & C Semeniuk Research Group, 2000).

At the Fortescue River mouth there area series of gravel ridges, associated inter-ridge swales and tidal creek networks. There is an important and unusual associated of gravel fans, inter-ridge swales, gravel ridges, tidal creeks and gravel flats each with its own mangrove assemblage. The assemblages are not large and regionally extensive. Dominant species are *Avicennia marina* and to lesser extent *Rhizophora stylosa* and *Ceriops tagal*. Also occurring locally in the system is *Aegialitis annulata*, *Aegiceras corniculatum* and *Bruguiera exaristata* (Semeniuk, 1997); (V & C Semeniuk Research Group, 2000).

Edward Creek outlet system is sourced ultimately on a tributary system of the Fortescue River where it abuts Precambrian bedrocks of the Cape Preston complex. The tidal creek network contains unusual assemblage of mangrove species including *Aegialitis annulata*, *Aegiceras corniculatum*, *Avicennia marina*, *Bruguiera exaristata*, *Ceriops tagal*, and *Rhizophora stylosa*. Formation is not large or regionally extensive (Semeniuk, 1997); (V & C Semeniuk Research Group, 2000).

Cape Thouin to Cape Lambert

Cossack to Harding Delta complex is designated as 'regionally significant' (Environmental Protection Authority, 2001):

This is a deltaic system juxtaposed against the rocky structure of the archipelago/ria coast of the Cape Preston structure. It is the most southern occurrence of *Osbornia octodonta* in the southern hemisphere. The shelter afforded by Cape Lambert has created an unusual delta for the Harding River, which has a sand and mud delta that is bordered to its east by limestone barriers and sand ridges where the coast becomes more exposed. The habitats include mud flats, tidal creeks, spits, cheniers, tributaries and abandoned tributaries. The dominant mangroves are *Avicennia marina* and *Rhizophora stylosa* which for extensive formations. Other species include *Aegialitis annulata*, *Aegiceras corniculatum*, *Bruguiera exaristata* and *Ceriops tagal* (Semeniuk, 1997); (V & C Semeniuk Research Group, 2000).

Sherlock Bay Sector is designated as 'regionally significant' (Environmental Protection Authority, 2001):

Area is the eroding seafront of the Little Sherlock River delta which is fronted by a series of limestone and sand barriers that are locally breached by tidal creeks. Main habitats are in the tidal creek networks and leeward of the barriers are developed extensive and thick mangrove formations. Habitats include limestone and sand ridges and associated swales, mud flats and tidal creeks. Area exhibits progressive breakup of seaward barriers by tidal creeks. Dominant species are *Avicennia marina* and to a lesser extent *Rhizophora stylosa* (Semeniuk, 1997); (V & C Semeniuk Research Group, 2000).

Ronsard Island area is designated as 'regionally significant' (Environmental Protection Authority, 2001):

The eroding seafront of the Peewah River delta is a large muddy tidal flat complex protected in part by Ronsard Island. The sector is comprised of muddy tidal flats and cheniers, locally breached by tidal creeks and contains extensive mangrove formations fronting the tidal flats and residing in the tidal creek networks. It is one of the best locations in the Pilbara for the development of cheniers through time on the muddy tidal flats. Dominant species are *Avicennia marina* and to a lesser extent *Rhizophora stylosa*. Locally are also *Aegialitis annulata*, *Aegiceras corniculatum*, *Bruguiera exaristata* and *Ceriop tagal* (Semeniuk, 1997); (V & C Semeniuk Research Group, 2000).

Cape Keraudren

Cape Keraudren supports a low closed forest of *Rhizophora stylosa*, with a low understory of *Aegialitis annulata* growing in the more seaward zone. *Avicennia marina* as well as scattered trees of *Osbornia octodonta*, *Bruguiera exaristata* and shrubs of *Aegialitis annulata* occur on the more landward areas along the main creek. *Ceriops tagal* and *Rhizophora stylosa* abut the samphire and mudflats (Department of the Environment and Water Resources, 2007)??.

De Grey River Delta is designated as 'regionally significant' (Environmental Protection Authority, 2001):
It is an active sand and mud delta and contains a range of habitats such as sand ridges and associated swales, barred lagoons, mud flats, tidal creeks, spits, cheniers, tributaties and abandoned tributaries. Dominant species are *Avicennia marina* and *Rhizophora stylosa* which occur in most habitats. Full range of habitats at the small scale result in some diversity of vegetation with 7 species occurring locally in areas where there are spits, point bars or beaches (*Aegialitis annulata*, *Aegiceras corniculatum*, *Avicennia marina*, *Bruguiera exaristata*, *Ceriops tagal*, and *Rhizophora stylosa*). Also important regionally as is the most southern location of *Exoecaria agallocha* (Semeniuk, 1997); (V & C Semeniuk Research Group, 2000).

Ashburton River Delta
One of the three largest deltas in the Pilbara.

Sand and mud delta with a range of habitats such as sand ridges and associated swales, barred lagoons, mud flats, tidal creeks, spits, cheiners, tributaries and abandoned tributaries.

Dominant mangroves are *Avicennia marina* and *Rhizophora stylosa*.

The delta is active and exhibits a history of dynamic channel changes and readjustment of tidal landforms (V & C Semeniuk Research Group, 2000).

Cape Preston Area
The most southern ria-shore/archipelago type of mangrove habitats.

Mud flats, tidal creeks, rocky shores, high-tidal alluvial fans, high-tidal colluvial slopes, and spits.

Extensive mangroves exist behind the structure of the cape (V & C Semeniuk Research Group, 2000).

Yule River Delta
Comprises a range of habitats such as sand ridges and associated swales, barred lagoons, mud flats, tidal creeks, spits, cheniers, tributaries and abandoned tributaries.

Mangroves in tidal creeks are extensive. Delta is largely inactive.

Dominant mangrove species are *Avicennia marina* and *Rhizophora stylosa*.

The southern-most occurrence of *Excoecaria agallocha* is at the De Grey River Delta, and the southern-most occurrence of *Osbornia octodonta* is at Cossack (V & C Semeniuk Research Group, 2000).

19.3 Past, present and potential uses and/or pressures (natural and human-induced); evidence of impact and the relevant research/monitoring programs (if any);

To date clearing of mangroves in Australia has been confined to small areas of the mangal-dominated coastline (Bridgewater & Cresswell, 1999).

Mangal is threatened by many human activities, including the filling and draining of coastal wetland systems, the development of port infrastructure, invasion of alien species and pollution. Other more insidious threats arise from a lack of coordination between jurisdictions involved in managing mangal, lack of awareness of the continuum nature between river catchments and the open sea, overfishing reducing particular species (especially larval stages), and lack of management-orientated research effort on mangroves (Bridgewater & Cresswell, 1999).

19.4 Current condition;

In comparison to global exploitation and destruction, the majority of mangrove ecosystems in Western Australia are relatively pristine (IUCN Working Group on Mangrove Ecosystems, 1981; Saenger *et al.*, 1983) in (Pedretti & Paling, 2001).

Despite the prevalence of threats, it appears unlikely that in Australia, any species of mangrove, or species associated with mangal, has become extinct, or is considered endangered (Bridgewater & Cresswell, 1999).

19.5 Management strategies currently used and/or proposed (eg moorings policies, monitoring programs).

The Convention on Biological Diversity has recognised the importance of mangrove (and saltmarsh) ecosystems in its work on coastal and marine ecosystems, through the Jakarta Mandate (Bridgewater & Cresswell, 1999).

Pilbara mangals receive very little active management (Carr & Livesey, 1996). The Department of Fisheries regulates the fishing industry, some of which occurs within mangal areas, or is dependent upon mangroves for their role as nursery areas, particularly for prawn species.

A study by (Carr & Livesey, 1996) highlighted that existing conservation reserves failed to adequately represent mangrove communities across the Pilbara region.

20. SEAGRASS

20.1 Species diversity (give details of most recent survey) and relative importance in statewide and regional contexts;

Macroalgae are thought to be of relative importance as habitat and also as a secondary food source for large herbivores (e.g. dugong) in the area (Fulton et al., 2006).

The northwest Australian coastline lies between the two most diverse seagrass floras ever recorded (Walker & Prince, 1987).

Six species of seagrasses occur in the Pilbara (Rangelands NRM Coordinating Group, 2005).

Seagrass meadows are the nursery grounds for many commercial and non-commercial fish and crustacean species, including juvenile tiger and endeavour prawns. These meadows provide protection form predators and food such as epiphytes and detrital matter (Kirkman, 1997).

Seagrasses are food source for dugongs and green turtles (Kirkman, 1997).

Detrital wrack is an important food source for shore communities (Kirkman, 1997).

Species found along the NW coast: *Cymodocea angustata, Halophila ovalis, Halophila sinulosa, Halophila ovata, Syringodium isoetifolium, Thalassia hemprichii* and *Thalassodendron ciliatum.*

Seagrass is critical for dugong and fish habitat and important for sustaining fish populations (NMBP, 2007)??

20.2 Biogeographical and local distribution and endemism;

Halophila ovalis was common throughout entire Pilbara/Kimberley study area. It has a very wide ecological tolerance and reproductive parts are often observed. It has a high turnover rate and is important for dugong grazing (Walker & Prince, 1987).

Thalassia hemprichii was widespread in reef associated habitats. The species is very common around coral rubble with *Halophila ovalis* or *Halodule uninervis.* It accumulates sediment on raised reefs, as well as at depth.

Halophila decipiens has hairy leaves and glabrous sheath and is frequently mixed with *Halophila ovalis* on rock with a thin sediment veneer or in pools. It is generally a species of deeper water.

Cymodocea angustata is endemic to NW Australia and occurs on all sediment types from fine muds to coarse gravels to occasionally on rocks. It frequently grows with *Halophila ovalis, Halodule uninervis* and *Syringodium isoetifolium.*

Commonly occurring at 2-3m depth, however was never found emersed but in intertidal pools on raised reef areas.

Halodule uninervis is a very common species and was found in a wide range of habitats from MTL to 30m depth and on fine mud to shell grit. It develops a rhizome mat and can trap sediment and is frequently mixed with *Halophila ovalis* and forms a preferred food source for dugongs.

Syringodium isoetifolium is found either at the edges of the canopy of larger seagrass species or brown algae (*Dictyopteris, Sargassum*), or in rock pools with a sediment veneer, from LWN to 10 m depth.

Thalassodendron ciliatum grows directly on rock or coarse shell frit, particularly in areas subject to fast currents. It carries an extensive epiphyte population, resembling that of *Amphibolis*. It was never found emersed but in intertidal pools on raised reef areas.

Halphila ovata was only found intertidally or in the shallow subtidal waters and is apparently relatively resistant to desiccation, freshwater run-off and high temperatures. It generally occurred in mixed populations with *Halophila ovalis* and *Halodule uninervis*.

Halophila spinulosa is commonly found at 8-15m (can be up to 45m depth) in course sediments in areas away from direct tidal streams, but in shallower waters in areas of rapid tidal movement it occurs either in patches between larger species or as sparse populations (Walker & Prince, 1987).

	Cape Keraudren	**Robe**			**Serrurier Island**	
Species	Bedout Island	North Sandy Island	Beagle Island	West Island	Bessieres Island	Serrurier Island
Halophila ovalis	✓	✓	✓	✓	✓	
Thalassia hemprichii		✓	✓		✓	
Halophila decipiens		✓		✓	✓	
Cymodocea angustata		✓	✓	✓		✓
Halodule uninervis		✓	✓	✓		
Syringodium isoetifolium		✓	✓	✓	✓	
Thalassodendron ciliatum		✓	✓			
Halophila ovata				✓		
Halophila spinulosa						✓

Table 14: Distribution of seagrasses in Pilbara locations. Created from information in (Walker & Prince, 1987).

In the area extending from the Passage Islands to the Mangrove Islands, the shallow sediments often supported seagrass meadows. The most common species were *Halophila spinosa, H. ovalis, H. ovata, H. minor*, *Halodule* and *Cymodocea* (Pendoley & Fitzpatrick, 1999).

Between Middle and North Mangrove Island is a broad shallow limestone platform which supports a dense meadow of *Halodule* mixed with *Halophila* and *Cymodocea* growing on a thin veneer of soft sediments. Large numbers of male turtles were seen (which is unusual) as well as feeding scars of dugong (Pendoley & Fitzpatrick, 1999).

20.3 Past, present and potential uses and/or pressures (natural and human-induced); evidence of impact and the relevant research/monitoring programs (if any);

Seagrass beds can be lost or degraded through natural processes such as 'wasting disease' (a parasitic fungus) or extreme natural weather events such as cyclones and floods (Berson, 2004). Other natural pressures come from flooding, other diseases, and exposure to high temperature (Kirkman, 1997).

Most seagrass losses are through anthropogenic impacts, either directly through mining, trawling and boat propeller scarring, or lost through the effects of disturbances such as dredging, inland and coastal clearing, and land reclamation (Berson, 2004). These activities increase sedimentation and turbidity which, in turn, lead to degradation through smothering and lack of light (Marsh et al., 1999); (Berson, 2004); (Kirkman, 1997).

Other threats include herbicide runoff, and sewage, detergents, heavy metals, hypersaline water from desalination plants and other waste products (Marsh et al., 1999).

Halophilia ovalis, a preferred food species of dugongs, appears to be particularly sensitive to light reduction (Marsh et al., 1999).

Nutrients that cause eutrophication come from a number of sources, including; sewage outfalls, septic tank overflows, over fertilising of agricultural lands and effluent from industry (Kirkman, 1997).

Localities that provide shelter and water conditions ideal for seagrasses are often the target for port developments and at the downstream end of severely affected catchments Lee Long and Coles 1997 in (Marsh et al., 1999).

Dredging is a major factor in the decline of seagrass. It not only causes direct loss, but can also affect seagrass meadows by causing sediment plumes, and also deepening the seabed past the euphotic zone, making it impossible for re-colonisation (Kirkman, 1997).

The construction of groynes, sea walls and other coastal developments can cause sediment accretion, leading to seagrass decline (Kirkman, 1997).

Boat users can have an impact on seagrasses, particularly in shallow areas, such as tidal flats. Boat propellers can cut up seagrasses and the tracks they leave can become channels for ingoing and outgoing tides, slowing any rehabilitation processes. Moorings and anchors can produce circular scours in seagrass meadows (Kirkman, 1997).

Recovery and re-colonisation can take more than 10 years for tropical seagrass species (Kirkman, 1997).

20.4 Current condition;

20.5 Management strategies currently used and/or proposed (eg moorings policies, monitoring programs).

To date, the approach to seagrass protection has largely been through marine parks and fishing industry closures to prevent structural damage to seagrass beds through trawling. There have been few attempts to protect seagrass beds from adverse impacts on ecosystem processes associated with land use (Marsh et al., 1999).

21. MACROALGAE

21.1 Species diversity (give details of most recent survey) and relative importance in statewide and regional contexts;

21.2 Biogeographical and local distribution and endemism;

Robe
In the area extending from Passage Islands to Mangrove Islands, the hard substrates were dominated by macroalgae. The subtidal and intertidal zones were dominated by *Sargassum*, *Padina* and *Dictyota* (Pendoley & Fitzpatrick, 1999).

21.3 Past, present and potential uses and/or pressures (natural and human-induced); evidence of impact and the relevant research/monitoring programs (if any);

21.4 Current condition;

21.5 Management strategies currently used and/or proposed (eg moorings policies, monitoring programs).

22. CYANOBACTERIA

22.1 Species diversity (give details of most recent survey) and relative importance in statewide and regional contexts;

22.2 Biogeographical and local distribution and endemism;

22.3 Past, present and potential uses and/or pressures (natural and human-induced); evidence of impact and the relevant research/monitoring programs (if any);

22.4 Current condition; and

22.5 Management strategies currently used and/or proposed (eg moorings policies, monitoring programs).

23. CORALS

23.1 Species diversity and the relative importance of the faunal group in statewide and regional contexts;

23.2 Size of population(s), including size of any genetically distinct populations (if known), and details of most recent survey(s);

23.3 Species which are rare, endemic and/or of special conservation status (ie is it listed under the *Wildlife Conservation (Specially Protected Fauna) Notice 1999,* the *Endangered Species Protection Act 1992* and/or the *Threatened Australian Fauna (ANZECC List) 1999?*);

23.4 If special, rare or endemic, state:

- **biogeographical and local distribution;**
- **seasonality of occurrence; and**
- **behavioural patterns (eg migration, breeding, nesting);**

23.5 Past, present and potential uses and/or pressures (natural and human-induced); evidence of impact and the relevant research/monitoring programs (if any); and

23.6 Past/current/proposed management strategies (eg codes of practice, monitoring programs).

24. WATER QUALITY

24.1 How does flushing/exchange influence the water quality of the study area?

24.2 What are the natural turbidity levels of the study area? Include rates of deposition and the effects of local conditions (eg wind, swell, riverine input).

The near-shore marine waters of the region are relatively turbid, being subject to disturbance from strong tidal flows and to episodic runoff from adjacent rivers. The mid to outer continental shelf waters are generally clear (Department of Environment, 2006).

24.3 What are the patterns of sediment re-suspension in the study area? Include rates and the effects of local conditions (eg wind, swell).

24.4 What are the natural nutrient levels of the study area?

24.5 Have there been any past, and/or are there any current/potential uses and/or pressures (ie nutrient/toxic/pathogenic contaminant inputs) on the water quality of the study area. Provide details of these inputs (source, type and level).

The predominant contaminant of concern in ports is the antifouling ingredient tributyltin (Fandry et al., 2006).

24.6 Is there any evidence of environmental impact (eg the occurrence of algal blooms; enhanced epiphyte growth)? Provide the details of the relevant research/monitoring programs.

24.7 According to water and sediment quality survey data and to the occurrence of historical and current input of nutrient, toxic and pathogenic contaminants, what is the current water and sediment quality of the study area (high, medium or low)?

Water
The results of a study by (Wenziker et al., 2006) indicate that the coastal waters of the North West Shelf are generally of very high quality. The concentrations of metals were low by world standards, with localised elevations of some metals adjacent to industrial centres and ports.

Sediment
Concentrations of metals in Pilbara coastal sediments are low and are generally within the range of concentrations measured in sediments around Australia. Concentrations along the coast are variable with no specific trends except in the sediments of the Ashburton River Mouth which was found to contain high concentrations of a number of metals in association with the fine muddy sediments. These sediments were very high in aluminium and iron concentration which suggests high clay content (Department of Environment and Conservation, 2006).

24.8 What strategies are the relevant management authorities utilising/proposing to minimise the environmental impact on the water quality of the study area (eg water quality monitoring programs)?

The Environmental Protection Authority (EPA) has developed a State Government endorsed environmental quality management framework for implementing the *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (ANZECC & ARMCANZ, 2000) in Western Australia. This Environmental Quality Management Framework (EQMF) is being applied to manage activities that can affect the quality of marine ecosystems (Fandry et al., 2006; Wenziker et al., 2006).

The Department of Environment (DoE) is currently establishing environmental values and environmental quality objectives for the North West Shelf through a Natural Heritage Trust funded program; *Community derived marine quality objectives for the North West Shelf* (Wenziker et al., 2006).

25. TENURE

25.1 Which shires/local government authorities are responsible for the administration of the area? What are the major townsites of each shire?

Town of Port Hedland – Port Hedland
Shire of Roebourne - Karratha
Shire of Ashburton – Onslow (Paraburdoo & Tom Price)
Shire of East Pilbara – (Marble Bar & Newman)
(Department of Local Government and Regional Development & Pilbara Development Commission, 2006)

25.2 What is the population and growth rate of each shire?

Pilbara population was 39 282 with a growth rate of 0.1% in 2005 (Department of Local Government and Regional Development & Pilbara Development Commission, 2001).

Pilbara Coastal Town Population:

Port Hedland – 11 344
Karratha – 11 325
Wickham/Point Samson – 1973
Dampier – 1810
Roebourne – 1213
Onslow – 881
(Department of Transport & Pilbara Development Commission, 1997)

25.3 Outline any illegal or formalised squatter development in the area (time of development, users of the shacks, recognisable communities, facilities such as water and toilets).

25.4 What are the details of any existing leases held by squatters (annual cost, date of expiry)?

25.5 Does the shire/s have a squatter removal program (provide details)?

25.6 What is the past, present and predicted future land development in the study area (eg proposed town sites, resort developments)?

25.7 Is there any current use of the area for military purposes?

25.8 Are there any other existing leases on land, seabed or waters of the area (eg for industrial purposes)? Do these leases permit input into the administration of the area?

25.9 How is the territorial sea baseline determined in the identification of the seaward limit of state territorial seas?

25.10 Obtain datasets of the:

- **Limits of Australian Territorial seas and Western Australian State Waters;**

- **Boundaries of the local government authorities;**
- **major towns;**
- **tenure and vestings in or adjoining the study area (eg Department reserve, shire reserve, residential area, pastoral lease, freehold land); and**
- **existing conservation areas (eg Fish Habitat Protection Areas).**

26. INFRASTRUCTURE AND FACILITIES

Coastal access

26.1 Do roads/tracks provide access to all sections of the coast?

26.2 What is the nature of the authorisation of the airports/landing strips?

26.3 Are there any plans to develop additional infrastructure and/or expand existing infrastructure?

26.4 Have there been any past, and/or are there any current/potential environmental impacts of infrastructure in the study area? Provide details of the relevant research/monitoring programs.

26.5 What strategies are the relevant management authorities and/or involved companies utilising/proposing to minimise the environmental impact of infrastructure on the marine and coastal environment (eg monitoring programs to determine environmental impact)?

Shipping and boating

26.6 What are the management authorities of the ports in the study area?

26.7 What is the number of vessels calling at each port each year, and where are the majority from?

26.8 What is the type and quantity of cargo exported/imported? Identify the importance of each port in relation to cargo exported and imported on a local scale and a state-wide scale (as a percentage of total exports and imports).

Ship loading capacity of 58 million tonnes per annum at Port Walcott. Expansion underway to 80 million tonnes per annum (Rio Tinto Iron Ore, 2008)??

26.9 What is the total value of trade through the port?

26.10 What are the trade forecasts for the port?

26.11 Provide the details of any shipping/boating channels. Who is responsible for maintaining the channels, and provide details of the associated dredging programs (eg where is the spoil dumped and how often)?

26.12 Provide the details of any public and private wharfs (eg maximum draughts).

26.13 Provide details of moorings and management of the harbours of the study area.

26.14 Provide details of the holding capacity and management of the marina facilities in the study area.

26.15 Are there any plans to develop additional shipping/boating infrastructure and/or expand existing infrastructure?

26.16 Have there been any past, and/or are there any current/potential environmental impacts of shipping/boating in the study area? Provide details of the relevant research/monitoring programs.

An important emerging issue for the North Coast bioregion is that of biosecurity. In 2006/07, Fisheries officers based in Karratha and Broome will be undertaking biofouling inspections of vessels coming into state waters for introduced marine pests such as the Asian green mussel (Department of Fisheries, 2007).

"The Port of Dampier and surrounding areas such as Cape Lambert have seen greatly increased international vessel movement. Further planned expansions to Cape Lambert and Cape Preston will see additional dredging vessels engaged to carry out the work. Dredging vessels involved in the port expansions are considered to be high risk for the introduction of marine pests such as Asian green mussels and black striped mussel" (Department of Fisheries, 2007).

26.17 What strategies are the relevant management authorities utilising/proposing to minimise the environmental impact of shipping/boating?

<u>Sewage</u>

26.18 Provide details of any wastewater treatment plants located in the study area, including the type of treatment (primary or secondary), location, details of outfall pipes and the maximum volume of sewage that each is licensed to treat per day.

26.19 Is the study area serviced by deep sewage?

26.20 Are there any plans to develop additional sewage facilities and/or expand existing facilities?

26.21 What are the controls on the discharge of sewage by boats in the study area?

26.22 Have there been any past, and/or are there any current/potential environmental impacts of sewage treatment and disposal in the study area? Provide details of the relevant research/monitoring programs.

26.23 What strategies are the relevant management authorities utilising/proposing to minimise the environmental impact of sewage treatment and disposal?

- **Obtain datasets of the infrastructure of the study area, including:**
- **major townsites and areas covered by the town planning schemes;**
- **major highways and sealed roads;**
- **railways; and**
- **airports and landing strips.**
- **Obtain navigation charts and/or datasets of:**
- **gazetted ports;**
- **location of the major shipping routes and channels; and**
- **other maritime infrastructure (eg public and private boat ramps, major beach launching sites, moorings, groynes, lighthouses, fish aggregating devices, jetties and navigation markers).**

27. TOURISM

27.1 Identify the major tourism industries that operate in the study area (eg fishing, diving, wildlife observation). Identify:

(a) number of tourism-based charter boat companies;

(b) mode of operation (eg with respect to season, constraints);

Dive tours and Whale watching tours are conducted from April to October in the Pilbara. Charter activities in the Kimberley include; bottom, game and sport fishing, dive tours, whale watching, 4WD and dinghy safaris and tour guided camps (Tour Operators Fishing Working Group (TOFWG), 1998).

(c) number of participants and significance;

There are 29 charter operators in the Exmouth-Port Hedland Region, with 18 being mobile (ie. based in another region). There are 33 charter operators in the EMB-Derby region, with20 of those being mobile operators (Tour Operators Fishing Working Group (TOFWG), 1998).

(d) economic value and significance;

(e) market (domestic and/or overseas);

(f) past trend, current status and predicted future trend; and

(g) past/current/potential environmental impacts in the study area, providing details of the relevant research/monitoring programs.

Some charter boat operators also hold commercial fishing licences (LFB), which makes it difficult to determine whether they are engaging in fishing or tourism activities at any particular time, and also to enforce recreational bag limits (Tour Operators Fishing Working Group (TOFWG), 1998).

Environmental impacts involving aquatic charters include; rubbish, sewerage, habitat damage (anchors, tracks, camps, exhaust fumes, fuel and oil), feeding of wildlife (Tour Operators Fishing Working Group (TOFWG), 1998).

27.2 What are the major tourist attractions of the study area?

27.3 What are the requirements of tourism industries in the study area (eg high water quality)?

Some tourism experiences rely on pristine, uncrowded environments (Tour Operators Fishing Working Group (TOFWG), 1998).

27.4 What strategies are the relevant management authorities utilising/proposing to minimise the environmental impact of tourism (eg codes of conduct). Obtain datasets of the location and intensity of tourism activities in the study area.

28. MINING AND PETROLEUM

28.1 Identify the major mining and petroleum industries (exploration and production) that currently operate in the study area. For each industry, identify:

- **(a) details of leases (eg size and duration);**
- **(b) processes involved;**
- **(c) tonnes of product per annum (including waste product and pollutants) and significance;**
- **(d) economic value and significance;**
- **(e) markets;**
- **(f) uses of the products;**
- **(g) past trend, current status and predicted future trend (ie identify any potential deposits, any expansions, new proposals or new interests); and**
- **(h) past/current/potential environmental impacts in the study area, providing details of the relevant research/monitoring programs.**

Petroleum

The North West Shelf is Australia's major oil and gas producer. As at June 1994, six North West Shelf gas fields had been developed with estimated resources of 170 billion cubic metres (bcm), with 8 fields with reserves of 250 bcm undeveloped, and 600bcm identified in another 5 fields (Department of Transport & Pilbara Development Commission, 1997).

The NWS petroleum industry was worth $3 100 million in 1994. Oil and condensate production is between 250 000 and 300 000 barrels per day. LNG production is 7.5 million tonnes per annum (Department of Transport & Pilbara Development Commission, 1997).

Iron Ore

Iron Ore worth $2 612 million in 1994 (Department of Transport & Pilbara Development Commission, 1997).

Gold

Worth $225m p/a (Department of Transport & Pilbara Development Commission, 1997).

Salt

Worth $103m p/a (Department of Transport & Pilbara Development Commission, 1997)

28.2 Outline the history of exploration and mining in the study area.

28.3 Are there any operations in the study area which are covered by State Agreement Acts?

28.4 Are there any operations in the study area which are required to have an Environmental Management Plan? If so, what are the obligations with respect to operations and lease duration?

28.5 What are the requirements of mining and petroleum industries in the study area?

28.6 What strategies are the relevant management authorities and/or involved companies utilising/proposing to minimise the environmental impact of mining and petroleum (eg waste disposal guidelines, oil spill management plans, exploration permits, production and pipeline licences).

- **Obtain datasets of:**
- **exploration and production facilities and associated infrastructure (eg pipelines); and**
- **exploration and mining leases/permits etc**

29. NON-EXTRACTIVE RECREATIONAL ACTIVITIES

29.1 Identify the major non-extractive recreational activities in the study area and state the:
- **number of participants per season; and**
- **economic value and significance in an international/national/regional/local context.**

NB: Activities should be divided into the following general categories:
- **boating (launches/dinghies, yachts, skiboats, hovercrafting, jetskiing);**
- **beach use (swimming, sunbathing, snorkelling);**
- **scuba-diving**
- **surface water sports – surfing, sea kayaking e.t.c; and**
- **coastal land based activities - camping, picnicing, walking, cycling, photography, nature appreciation e.t.c.**

There is a high level of coastal island activities in the Pilbara, such as camping, 4WD, rock climbing, fishing, turtle and whale watching, walking and shell collecting. Marine-based activities found throughout the Pilbara include diving, snorkelling, swimming, sailing, boating and various other water sports (eg skiing, jet skiing) (Rangelands NRM Coordinating Group, 2005).

Informal camping is popular in the Pilbara, evidenced by the popularity of locations such as the De Grey River, Fortescue River Mouth and 40 Mile Beach (Department of Transport & Pilbara Development Commission, 1997)

Cowrie Creek at the mouth of the Yule River is a popular recreation area and is also a significant turtle breeding ground (Department of Transport & Pilbara Development Commission, 1997).

Local community

29.2 What are the annual recreational events which occur in the study area (eg sporting classics)?

Broome Sailfish Tournament and Dampier Classic are state and national fishing competitions held in the region (Pilbara/Kimberley Recreational Fishing Working Group, 2004).

29.3 What has been the past trend, and what is the current status and predicted future trend for non-extractive recreational activities in the study area?

29.4 Have there been any past, and/or are there any current/potential environmental impacts of non-extractive recreational activities in the study area? Provide details of the relevant research/monitoring programs.

29.5 What factors have been shown to or appear to influence patterns of recreational activity throughout the study area (eg geomorphology such as sandy beach or surf break, currents, season/holiday periods, presence of marine hazards such as crocodiles, proximity to population centres)?

High levels of human use are generally localised in areas of predominantly sand flats, beaches and dune areas along the Pilbara coastline and islands (eg

Cleaverville Beach, Ashburton river mouth) (Rangelands NRM Coordinating Group, 2005).

29.6 What are the requirements of the non-extractive recreational activities in the study area?

29.7 What strategies are the relevant management authorities utilising to minimise the environmental impact of non-extractive recreational activities (eg speed restrictions, restricted access, monitoring)?

- **Obtain datasets of:**
- **the location and intensity of the major non-extractive recreational activities (eg scuba-diving; shore-based activities); and**
- **designated recreational special use zones (eg jet ski zones) and campsites.**

30.EDUCATION

30.1 What has been the past and what is the current/potential use of the study area for education purposes?

30.2 What has been the past and what is the current/potential use of the study area for scientific research purposes?

30.3 Are there any existing community monitoring programs in the study area?

30.4 What are the requirements of the education use of the study area?

31. CULTURAL HISTORY

Aboriginal

31.1 Outline the historical occupation of the study area by Aboriginal groups.

Early expeditions considered Depuch Island was not constantly inhabited by Aborigines, but suggested it was visited by mainland natives (Ride et al., 1964).

31.2 What sacred/significant sites have been registered with the Aboriginal Affairs Department under the *Aboriginal Heritage Act 1972*? What is the significance of these sites in a regional context?

Depuch Island is recognised as being outstanding as a site for Aboriginal art. The combination of well finished and well preserved engravings is known nowhere else in the Pilbara and possibly nowhere else in Australia. The engravings have certain unique features, making their preservation of "considerable anthropological importance". Assemblages of significant engravings include: Hunters Pool and the adjoining cliffs; Watering Valley above the 100ft contour line; Anchor Hill; and Jane Creek (Ride et al., 1964).

31.3 What was the historical Aboriginal use of the study area and its resources? Outline any evidence of Aboriginal occupation and use of the study area (eg rock paintings, shell middens)?

Mangroves were important for aboriginal people who previously lived in the Pilbara, providing both food resources and raw materials. Common mangrove species were used for making harpoons, fish traps and fishing platforms, boomerangs, shields, ornamentation, dyes, insect repellent and firewood. Aboriginal children are recorded as gathering edible fruits within the mangal (Kenneally 1982 in (Carr & Livesey, 1996).

A large number of shell midden sites contain evidence of aboriginal use of Pilbara mangal and nearby mudflat areas (Reynolds 1989 in (Carr & Livesey, 1996). Shellfish were an important resource to aboriginal people in the Pilbara. The majority of these would have been collected from mangal areas.

Depuch Island is regarded as an important site of native rock art. Engravings have a very high proportion of anthropomorphic figures showing enlarged genitalia, and scenes of copulation are common (Ride et al., 1964).

31.4 What is the current use of the study area by Aboriginal groups (eg subsistence uses, commercial uses)?

(Prince, 1985) notes the West Kimberley area is a focal point for continued exploitation of dugong and turtles and other marine life by the local Aboriginal people. At the time of writing, anecdotal evidence suggested changes in the availability of dugongs over the previous 10 to 15 years.

Coastal indigenous communities from the study area are known to harvest turtle eggs and flatback turtles for their meat. Turtles have cultural, spiritual and economic (subsistence) importance to indigenous people (Environment Australia & Marine Turtle Recovery Team (Australia), 2003).

31.5 Are there any applications on the Register of Native Title Claims under the *Native Title Act 1993* which refer to waters and/or adjoining land of the study area? Who have these been made by (provide contact details) and to what extent of an area do they apply? At what stage of the process are these Native Title applications (eg have they been accepted for mediation by the National Native Title Tribunal?)

Maritime

31.6 Outline the significant aspects of the maritime history and European settlement of the study area (eg the naming and charting of localities, the first inhabitants) and any remaining evidence of this history.

31.7 Outline the historical commercial activities (eg whaling, sealing, pearling).

31.8 Are there any sites gazetted by the WA Maritime Museum in the study area (eg shipwrecks/historical remains) governed by the *Heritage of Western Australia Act* 1990 or on the register of the National Trust?

The following heritage places fall adjacent to the study areas (Eighty Mile Beach):

- P305 Wallal Downs Station Group, Wallal Downs Road, Pardoo; and
- P14197 Cattle Dip – Wallal Station, Great Northern Highway, Pardoo.

P305 has been entered into the Register of Heritage Places on an interim basis. In WA, places included on the Register of Heritage Places are given legal protection under the Heritage of Western Australia Act 1990. Register of a place is official recognition by the community of its cultural significance to the heritage of WA. Places are entered on the advice of the Heritage Council and the Minister for Heritage. Development controls apply under the Heritage of Western Australia Act 1990 and conservation incentives are available to owners. Should development or subdivision be proposed for a registered place, it would need to be referred to the Heritage Council for approval and advice. The Act requires that any development matter pertaining to a place adjacent, behind or across the road from a registered place be referred to the Heritage Council as a development application.

P305 has also been identified on the Shire of Broome's Municipal Inventory. Local Governments maintain a Municipal Inventory as required by the Heritage of Western Australia Act 19910, which is a lsit of places considered by the local community to have heritage value. Local Governments have the ability to protect heritage places by including them in Town Planning Schemes, which would mean the impact of developments or change would be considered before those changes would be allowed to occur.

P14197 is situated within the P305 precinct and as a result has the same protection under the Heritage Act and is also identified on the Shires Municipal Inventory.
(Information provided by letter from the Heritage Council of WA 3 April 2008.)

Military

31.9 Outline the history of any significant military activities relevant to the study area.

31.10 Is there any evidence/remains of historical military activities?

31.11 Have any sites of historic significance been declared?

32. FISHING

Commercial fishing

32.1 Identify the major commercial fisheries that operate in the study area (eg finfish, rock lobster, prawns). For each industry, identify:

a) number of licensed and actual operators in the study area;
b) species targeted as per season;
c) predominant techniques (eg potting, trawling, demersal gillnet and longline);
d) tonnes of product per annum and significance;
e) economic value and significance;
f) markets;
g) past trend, current status and predicted future trend; and past/current/potential environmental impacts in the study area, providing details of the relevant research/monitoring programs.

The main commercial fisheries in the north coast bioregion [i.e. from North West Cape to the Northern Territory boarder] are the Pilbara Fish Trawl Fishery and Pilbara and Northern Demersal Trap Fisheries which target tropical finfish, particularly high value snappers, emperors and cods. Typical annual catch for these fisheries is about 3000 tonnes and an estimated fishery value of $12 million annually makes this the most valuable finfish sector in Western Australia (Department of Fisheries, 2007). Several small, limited-entry prawn trawl fisheries producing 700 tonnes annually and valued at about $10 million annually also operate in the north coast bioregion (Department of Fisheries, 2007). There are also significant fisheries for Spanish mackerel, barramundi/threadfin salmon and shark and a developing blue swimmer crab fishery as well as a number of wetline activities including offshore demersal line fishing and near-shore beach seining and gillnetting.

The commercial fisheries that can operate within the study areas (i.e. the licence area falls within the study area) include:

- Exmouth Gulf Prawn Managed Fishery.
- Onslow Prawn Managed Fishery.
- Nickol Bay Prawn Managed Fishery.
- Northern Demersal Scalefish Fishery.
- Mackerel Managed Fishery.
- Pearl Oyster Managed Fishery.
- Bech-de-mer Fishery.
- Wetline Fishing (with fishing boat licences under s43 order).
- Aquaculture (including pearling of Pinctada maxima and other aquaculture ventures).
- Marine Aquarium Fish Managed Fishery.
- Specimen Shell Managed Fishery.
- North Coast Blue Swimmer Crab Fishery.

Other commercial fisheries that operate within the Pilbara region but outside the study areas (i.e. offshore or adjacent to study areas) include:

- Pilbara Fish Trawl (Interim) Managed Fishery and Pilbara Trap Managed Fishery together referred to as the Pilbara Demersal Finfish Fisheries.

- Kimberley Gillnet and Barramundi Managed Fishery.
- WA North Coast Shark Fishery and the Joint Authority Northern Shark Fishery together referred to as the Northern Shark Fisheries.

Prawn fishing on the north coast of Australia has a history of over-fishing, high mortality of turtles and using methods that capture large quantities of bycatch and damage benthic habitats (DEH, 2003).

Exmouth Gulf Prawn Managed Fishery

The potential trawl area for the Exmouth Gulf Prawn Managed Fishery extends north to Serrurier Island and the Muiron Islands however the main area of fishing is not within the study areas.

There are 16 boat licences in the Exmouth Gulf Prawn Managed Fishery, however only 12 boats operated during the 2006 season as a result of changes in gear configuration (Department of Fisheries, 2007).

The Exmouth Gulf Prawn Managed Fishery targets western king prawns (*Penaeus latisulcatus*), brown tiger prawns (*Penaeus esculentus*), endeavour prawns (*Metapanaeus spp.*) and banana prawns (*Penaeus merguiensis*) (Department of Fisheries, 2007); (Kangas et al., 2006).

Fishing is undertaken using otter trawls and the total allocation of net headrope for this fishery is 240 fathoms, however gear configuration (i.e. net and board sizes) permitted within this total allocation are under review with vessels operating for the past few seasons under an exemption allowing the use of four smaller nets (quad gear) rather than the standard two 7.5 fathom nets (Department of Fisheries, 2006). In 2006, 229 fathoms of net headrope was used by 12 boats (Department of Fisheries, 2007). The nominal effort for the 2006 season was 21,184 hours (Department of Fisheries, 2007). The yearly cycle of operation for the fishery changes year-by-year with opening and closing dates varying depending on environmental conditions, moon phases and the results of fishery-independent surveys that predict tiger prawn recruitment (Department of Fisheries, 2006). Other management arrangements include by-catch reduction devices are fully implemented.

Total catch of major penaeids for the 2006 season were 899 tonnes, comprising 442 tonnes of king prawns, 258 tonnes of tiger prawns and 199 tonnes of endeavour prawns (Department of Fisheries, 2007). Recorded landings of by-product included 32 tonnes of coral prawns, 18 tonnes of blue swimmer crab (*Portunus pelagicus*), 10 tonnes of squid, 2 tonnes of bugs (*Thenus orientalis*) and 1.5 tonnes of cuttlefish (Department of Fisheries, 2007).

The estimated annual value to fishers for the year 2006 is $10 million (Department of Fisheries, 2007). Estimated employment for 2006 was 37 skippers and crew and additional processing and support staff are also located in Exmouth Gulf and Fremantle (Department of Fisheries, 2007). Within the Exmouth area the fishery is one of the major regional employers and contributes to the economic viability of Exmouth (Department of Fisheries, 2007).

Onslow Prawn Managed Fishery
The Onslow Prawn Managed Fishery extends along the coast and out to deep water of the North West Shelf from Serrurier Island to the Dampier Archipelago. Several study areas overlap the potential fishing areas, in particular there will likely be trawl activity within the Great Sandy Island NR study area.

A total of 31 boats fished during the 2006 season with different licence classes allowing them to trawl in specific zones (Department of Fisheries, 2007).

The Onslow Prawn Managed Fishery targets western king prawns, brown tiger prawns, endeavour prawns and banana prawns using otter trawl (Department of Fisheries, 2006).

There is a total allowable effort arrangement whereby all boats have an equal allocation of headrope length (16 fathoms) for all areas operating as twin or quad rigged otter trawls (Department of Fisheries, 2007). The fishery has different opening and closing dates within each season as well as seasonal and area closures to protect smaller prawns and allow access to various target species at appropriate times (Department of Fisheries, 2007). Other management measures include by-catch reduction devices are fully implemented.

The total catch of major penaeids for the 2006 season were 54 tonnes, including 5 tonnes of king prawns, 39 tonnes of tiger prawns, 2 tonnes of endeavour prawns 8 tonnes of banana prawns (Department of Fisheries, 2007). This season's catch was lower than the target range for this fishery (60 - 180 tonnes). Recorded catch of by-product species included 2 tonnes of bugs, 1 tonne of blue swimmer crabs and less than 1 tonne each of squid, cuttlefish and mixed finfish species (Department of Fisheries, 2007).

The estimated annual value to fishers for the year 2006 was $0.65 million (Department of Fisheries, 2007).

Nickol Bay Prawn Managed Fishery
The Nickol Bay Prawn Managed Fishery extends along the coast and out into deep water of the North West Shelf from the Dampier Archipelago to east of Cape Keraudren. Two study areas overlap the potential fishing area, the 'Cape Keraudren to Spit Point' and 'Cape Lambert to Cape Thouin' study areas.

A total of 14 boats were licensed to fish during the 2006 season with only 11 boats fishing during the season (Department of Fisheries, 2007).

The Nickol Bay Prawn Managed Fishery targets banana prawns, western king prawns, brown tiger prawns and endeavour prawns using otter trawl (Department of Fisheries, 2006).

There is a total allowable effort arrangement whereby all boats have an equal allocation of headrope length (16 fathoms) for all areas operating as twin or quad rigged otter trawls (Department of Fisheries, 2007). The fishery has different season dates allowing access to target species at appropriate times. In addition, by-catch reduction devices are fully implemented.

The total catch of major penaeids for the 2006 season was 394 tonnes, comprising 366 tonnes of banana prawns, 2 tonnes of king prawns, 25 tonnes of tiger prawns and less than 1 tonne of endeavour prawns (Department of Fisheries, 2007). The recorded catch of by-product species in 2006 included 3 tonnes of blue swimmer crabs and less than 1 tonne of bugs, coral prawns, squid and mixed finfish species (Department of Fisheries, 2007).

The estimated annual value to fishers for the year 2006 was $3.7 million (Department of Fisheries, 2007).

The export value of the Exmouth, Onslow and Nickol Bay prawn fisheries combined is around $90 million with 80% of product being exported with the rest being sold on the local or interstate markets. (Kangas et al., 2006)

Northern Demersal Scalefish Fishery

The Northern Demersal Scalefish Fishery operates in the Kimberley region with Area 1 (inshore) covering part of Eighty Mile Beach to the east of 120°E longitude (Pilbara/Kimberley Recreational Fishing Working Group, 2004).

The Northern Demersal Scalefish Fishery is managed with annual fishing effort quotas, supplementary gear controls and area quotas (Department of Fisheries, 2007).

Tropical snappers (*Lutjanidae*), emperors (*Lethrinidae*) and groupers (or cod) (*Serranidae*) dominate the landed catch in this fishery (Department of Fisheries, 2006); (Looby, 1997); (Pilbara/Kimberley Recreational Fishing Working Group, 2004) although Nemipterids (eg. Threadfin Bream) are more abundant in the area (Looby, 1997).

Major species are: Red Emperor (*Lutjanus sebae*) and Goldband Snapper (*Pristipomoides multidens*). (Pilbara/Kimberley Recreational Fishing Working Group, 2004)

Permitted means of operation within the fishery include handline, dropline and fish traps (Department of Fisheries, 2007).

Commercial landings during the 2006 season were 801 tonnes (Department of Fisheries, 2007). The fishery principally targets red emperor and goldband snapper with a number of species of snapper, emperors and cods comprising the remainder of the catch (Department of Fisheries, 2007). In 2006, the catches of red emperor, goldband snapper and cod/grouper complex either exceeded the trigger point of a 20 % increase in catch, or were close to the trigger point despite a reduction in effort from 2005 (Department of Fisheries, 2007). The increasing trend in catch for these species has triggered the requirement for an updated stock assessment review that is currently in progress (Department of Fisheries, 2007).

Estimated value to fishers for the year 2006 was $4.6 million (Department of Fisheries, 2007).

Mackerel Managed Fishery
The Mackerel Managed Fishery operates between Geraldton and the WA/NT border, with the largest catches taken off the Kimberley and Pilbara coasts (Department of Fisheries, 2007). The main targeted species is Spanish mackerel (*Scomberomorus commerson*), however the fishery includes the taking of all species of the general *Scomberomorus, Grammatorcynus* and *Acanthocybium* (Department of Fisheries, 2007). WA fishers have expanded their participation in the fishery since 1980 and total landings of Spanish mackerel have ranged from 98 t (in 1980) to 468 t (in 2002). Spanish mackerel (*Scomberomorus commerson*) is considered fully exploited and Grey mackerel (*Scomberomorus semifasciatus*) is considered under-exploited (Department of the Environment and Heritage, 2004).

Mackerel are usually taken by trolling close to the surface in coastal areas around reefs, shoals and headlands, with jigs also use to capture grey mackerel (Department of Fisheries, 2007).

Spanish mackerel is usually captured at or near the surface in coastal areas around reefs, headlands and shoals. The main fishing method is by trolling baits and lures, with up to seven lines trolled at a time. Baits and lures drifted or cast from an anchored or drifting boat are also used to target Spanish mackerel and incidental catches may occur when using handlines and droplines (Department of the Environment and Heritage, 2004).

Management of the fishery includes limitations on the number of permits authorising a person to fish in the fishery and the type of gear that can be used, as well as a closed season (Department of Fisheries, 2007).

The number of permits issued in the Pilbara was 16, of which 7 had the required amount of individual transferable quota to operate in the fishery. In 2006, the number of participants in the Pilbara was 7 with some transfer of quota occurring amongst stakeholders (Department of Fisheries, 2007).

From 1 August 2004 the following fishing seasons apply:
• Area 1 (Kimberley) - 1 June to 30 November
• Area 2 (Pilbara) - 1 April to 30 September (Department of the Environment and Heritage, 2004).

In 2006 commercial landings for the whole fishery was 261 tonnes of Spanish mackerel, 17 tonnes of grey mackerel and 13 tonnes of other mackerel (Department of Fisheries, 2007). In the Pilbara, 48.2 tonnes of Spanish mackerel were landed in 2006 (Department of Fisheries, 2007).

Fishing for Spanish mackerel uses specialised trolling lines to target the schooling fish and involves limited discarding. Species occasionally caught and generally discarded include billfish, pike, barracuda, shark, mackerel tuna, queenfish and trevally (Department of Fisheries, 2007); (Department of the

Environment and Heritage, 2004). Species retained as Byproduct include School mackerel (*Scomberomorus queenslandicus*), Shark mackerel *(Grammatorcynus bicarinatus),* Wahoo (*Acanthocybium solandri*), Cobia (*Rachycentron canadum*), Bonito (*Sarda australis*), Yellowfin Tuna (*Thunnus albacares*), Longtail Tuna (*Thunnus tonggol*) and Skipjack Tuna (*Katsuwonus pelamis*), Dolphinfish (*Coryphaena hippurus*), smaller sharks, trevally and occasional reef fish (Department of the Environment and Heritage, 2004).

In 2001 for example, species other than Spanish and Grey mackerel comprised only 3.5% of the total trolling catch (Department of the Environment and Heritage, 2004).

Most mackerel is sold on the domestic market (except those caught from the Gascoyne-West Coast region, which is exported, mainly to Taiwan) (Department of the Environment and Heritage, 2004).

The estimated annual value to fishers for 2006 was $2.5 million for Spanish mackerel and $154,000 for other mackerel (Department of Fisheries, 2007).

The WAMF is not known to interact with any protected, endangered or threatened species (green, hawksbill and loggerhead turtles and grey nurse, great white and whale sharks) and there are no threatened ecological communities in the area of the fishery (Department of the Environment and Heritage, 2004).

There is little known of tropic interactions generally and DEH recommends that DFWA give priority to research on this issue, particularly in relation to removal of Spanish mackerel from reef ecosystems (Department of the Environment and Heritage, 2004).

Pearl Oyster Managed Fishery

The WA pearling industry is comprised of three components: the collection of wild pearl oysters *Pinctada maxima* (silver lipped pearl oyster); the production of hatchery-reared pearl oysters; and grow-out of pearls on pearl farms. The former is dealt with in this section and the two later components are dealt with in the 'aquaculture and pearling' section below.

Fishing for wild pearl oyster is undertaken by 6-8 divers which are attached to large outrigger booms on a trawler-style vessel and towed slowly over pearling beds, harvesting legal-sized oysters by hand (Department of Fisheries, 2007). Fishing can occur all year, but is generally between March and July, when visibility is best (Environment Australia, 2003). The maximum depth of harvest is 30m (pers. Comm. Brett McCallum, Pearl Producers Association), while the average depth is 12-13m (Department of Fisheries, 2007).

The fishery is divided into four zones, with zones 1, 2 and 3 overlapping the Pilbara/Eighty Mile Beach study areas. The main fishing areas are Eighty Mile Beach, Port Hedland and Exmouth Gulf (Department of Fisheries, 2007). Quota limits are set for the take of wild pearl oyster shells and also set for hatchery reared pearl oysters (Department of Fisheries, 2007). There are 572 wild-stock quota units and 350 hatchery quota units allocated amongst 17 pearling licensees

(Department of Fisheries, 2007). The value of a hatchery quota unit is 1,000 shell and the value of wild-stock quota units varies depending on status of wild stocks but is usually also about 1,000 shell per unit (e.g. in 2006, wild stock quota units were valued at 1,100 shell in zone 2 and 1,000 shell in zone 1 and 3) (Department of Fisheries, 2007). Wild stocks are reviewed each year by the Department of Fisheries in liaison with the Pearling Industry Advisory Committee (Department of Fisheries, 2007). There is a minimum legal size of 120mm shell length and maximum legal sizes and area specific total allowable catch have been set where appropriate (Department of Fisheries, 2007).

Pinctada maxima (silver lipped pearl oyster) between 120-174mm DVM (Dorso-Ventral Measurement) are targeted by the commercial fishery and are referred to as 'culture shell'. Animals below 120mm DVM are known as 'chicken shell', while those with DVM above 175mm are referred to a 'Mother-Of-Pearl' (MOP) (Hart & Friedman, 2004).

In 2006, the number of wild-caught pearl oyster was 538,882 oysters and the total allowable catch for the fishery was 592,500 oysters (Department of Fisheries, 2007).

Total effort in all zones was 13,684 dive hours with zones 2/3 comprising 11,992 dive hours (Department of Fisheries, 2007). There were 8 vessels involved in wild harvest of this fishery in 2006 (Environment Australia, 2003).

Annual harvest quantities have significantly reduced since the fishery commenced from 1,000-1,500 tonnes in the 1930s (targeting MOP), to about 250 tonnes for culture size shells in the 1960-70s. This reduction in harvest levels has persisted for approximately thirty years. Catch rate information indicates that the overall abundance of the pearl oysters is increasing (Environment Australia, 2003).

The estimated annual value to fishers for the year 2006 was $122 million (Department of Fisheries, 2007).

The WA pearling industry generates $160-200 million per year (Hart & Friedman, 2004). It is the second highest grossing fishery in WA (Environment Australia, 2003). 90-95% of product is exported (Environment Australia, 2003).

In 2000, 88% of total catch was taken from the Eighty Mile Beach area (Environment Australia, 2003).

There is no bycatch and very little impact on other species from this fishery due to the extremely selective harvesting method of diving, and the license restriction that fishers are only allowed to take *P. maxima* (Environment Australia, 2003). "EA (Environment Australia) is satisfied that the fishery is conducted in a manner that minimises the impact of fishing operations on the ecosystem generally." (Environment Australia, 2003)

<u>Beche-de-mer Fishery</u>

The beche-de-mer fishery operates from Exmouth Gulf to the NT border. It is a hand-harvest fishery, with animals caught principally by diving and a smaller amount by wading (Department of Fisheries, 2007). There are six target species caught commercially in WA, however 99% of the catch is Sandfish (*Holothuria scabra*) (Department of Fisheries, 2007).

The fishery is managed through input controls including limited entry, maximum number of divers, species-dependent minimum legal size limits and gear restrictions (Department of Fisheries, 2007). Access is limited to six operators holding a fishing boat licence endorsement to take Beche-de-mer (Department of Fisheries, 2007). The maximum number of divers (per endorsed fishing boat licence) allowed to dive for Beche-de-mer at any one time is four with a maximum number of crew (6) allowed on the vessel (Department of Fisheries, 2007). The minimum size for Sandfish is 16cm (Department of Fisheries, 2007).

In 2006, the total Beche-de-mer catch was 156 tonnes live weight, which is the lowest level of catch since the fishery began in 1995 (Department of Fisheries, 2007). Three licensed vessels fished for Beche-de-mer in 2006, which is half of the potential number of vessels endorsed to fish (Department of Fisheries, 2007).

In 2006, the estimated annual value to fishers was $448,000 (Department of Fisheries, 2007).

Marine Aquarium Fish Managed Fishery

The Marine Aquarium Fish Managed Fishery targets more than 250 species of fish as well as coral, algae, live rock, live sand and invertebrate (Department of Fisheries, 2007). The fishery is active in waters from Esperance to Broome with popular areas being around Dampier, Exmouth, Perth and Albany (Department of Fisheries, 2007).

Primarily a dive based industry fishers use hand-held nets and dive from vessels of up to 8m in length (Department of Fisheries, 2007). Catch is relatively low due to special constraints of the industry including handling requirements of live fish, heavy weather dependency and human constraints associated with diving (Department of Fisheries, 2007). These factors limit the fishing effort, the depth of water and the distance offshore where collection occurs (Department of Fisheries, 2007).

The fishery is managed through input controls such as limited entry to the fisher and permanent closed areas (Department of Fisheries, 2007).

There are 13 licenses in the fishery in most years all licenses are used, however in 2006, 11 licences were operated (Department of Fisheries, 2007).

In 2006, commercial landings were 28,203 fish (Department of Fisheries, 2007). Fishing effort was an average of 806 days fished (Department of Fisheries, 2007).

Specimen Shell Managed Fishery

The Specimen Shell Managed Fishery is based on the collection of individual shells for the purposes of display, collection, cataloguing, classification and sale (Department of Fisheries, 2007). This fishery does not include the collection of dead shells above high water mark by collectors operating under the authority of a commercial fishing license (Department of Fisheries, 2007). Up to 550 different shellfish species are collected by hand by divers operating in shallow waters, particularly in Perth, Bunbury, Albany and Port Hedland (although the fishery covers all of WA) (Department of Fisheries, 2007).

The fishery is managed through input controls such as limited entry, gear restrictions and permanent closed areas (Department of Fisheries, 2007).

There are 32 licenses in the fishery though many are inactive of fished only rarely (Department of Fisheries, 2007). Only 6 of these licences are regularly active (Department of Fisheries, 2007). A maximum of 2 divers is allowed in the water per licence at any one time and specimens may only be collected by hand (Department of Fisheries, 2007).

Commercial landings in 2006 were 19,074 shells (Department of Fisheries, 2007). In 2006, 1027 days were fished (Department of Fisheries, 2007).

North Coast Blue Swimmer Crab Fishery

Crabbing for blue swimmer crab (*Portunus pelagicus*) in the north of WA is centred largely on the inshore waters from Onslow through to Port Heldand, with most commercial and recreational acticity occurring in and around Nickol Bay (Department of Fisheries, 2007).

Dedicated blue swimmer crab fishers use purpose-designed 'hourglass' traps while the Pilbara trawl fisheries target prawns, but also retain crabs as a by-product (Department of Fisheries, 2007). Majority of recreational fishers use drop nets with a small portion using scoop nets or diving for crabs (Department of Fisheries, 2007).

One dedicated commercial crab fisher is endorsed to operate two 200-trap allocations between approximately Onslow to Port Hedland from high water mark out to the 200m isobath (Department of Fisheries, 2007). The other fisher is endorsed to use a maximum of 200 traps, with boundaries that mirror those of the first endorsement other than waters of Nickol Bay (Department of Fisheries, 2007). Other fishers as part of the Onslow Prawn Managed Fishery and Nickol Bay Prawn Managed Fishery also fish for crabs.

The fishery is managed through regulation of vessel and trap numbers as well as retainable species and associated minimum size limits, gear specifications and seasonal and daily time restrictions (Department of Fisheries, 2007). The legal minimum sizes range of 135mm carapace width in the Pilbara fisheries is set well above the size at sexual maturity (Department of Fisheries, 2007).

The total commercial catch of blue swimmer crabs in the North Coast bioregion is during the 05/06 year was 55 tonnes (Department of Fisheries, 2007), comprising 53 tonnes from the dedicated fishers and 2.6 tonnes from the Pilbara trawl fishers (Department of Fisheries, 2007). By-catch is negligible as the pots are purpose made and fish that are infrequently captured are released (Department of Fisheries, 2007).

The estimated annual value to fishers for the year 2005/06 was $0.25 million (Department of Fisheries, 2007).

32.2 Provide details of any processing facilities, including location, products processed, quantity of product, markets and economic value.

32.3 What are the requirements of commercial fishing in the study area (eg high water quality)?

Mangrove areas are vitally important as prawn nursery areas and thus the ongoing viability of the industry (Carr & Livesey, 1996).

32.4 What strategies is DoF utilising/proposing to minimise the environmental impact of commercial fishing (eg management plans, quotas, gear reductions, licence buy-back, closed seasons, closed areas, designated fishing zones, bag and size limits)?

See section above for details of each fishery.

Fisheries and Marine Officers working out of two district officers at Karratha and Broome (located 800 km apart by road) deliver compliance and community education services across the region. In 2006, these two district offices maintained a permanent staff of nine officers, supplemented by a 2-officer mobile patrol during peak winter months (Department of Fisheries, 2007). Extended remote patrols, lasting up to 2 weeks at a time are conducted across the Pilbara and Kimberley region (Department of Fisheries, 2007). In 2006, a total of 4,527 officer houses of active compliance patrol time for the Pilbara and Kimberley (Department of Fisheries, 2007).

Extensive fisheries closures over coastal and most offshore waters have been introduced to manage finfish trawling by Australian vessels (Department of Fisheries, 2006).

Aquaculture and pearling

32.5 Identify the major aquaculture and pearling industries that operate in the study area. For each industry, identify:

- **(a) number of current licenses/leases and details (eg duration) and number of applications for licenses;**
- **(b) species targeted;**
- **(c) mode of operation (eg with respect to season, physical requirements, source of juveniles);**
- **(d) tonnes of product per annum and significance;**
- **(e) economic value and significance;**
- **(f) markets;**
- **(g) past trend, current status and predicted future trend; and past/current/potential environmental impacts in the study area, providing details of the relevant research/monitoring programs.**

Aquaculture development in the region is dominated by pearling of *Pinctada maxima* obtained from fishing groups primarily off Eighty Mile Beach and smaller catches taken around the Lacepede Islands, near Port Hedland and off Onslow and Exmouth Gulf (Department of Fisheries, 2006). See 'Pearl Oyster Fishery' section above.

Hatcheries operate at Broome and King Sound to supplement wild caught oyster and pearl farm sites are located mainly along the Kimberley coast, particularly in Bucanneer Archipelago, in Roebuck Bay near Broome and at the Montebello Islands (Department of Fisheries, 2006).

There are 91 leases in the Western Australian pearl oyster fishery, shared between 16 pearling companies (licences). The lease area covers an area of 192.84 square nautical miles. The fishery has a total quota of 572 units, where one quota unit equates to 1000 pearl oysters (Pilbara/Kimberley Recreational Fishing Working Group, 2004).

A fish farm located in Cone Bay (in the Kimberley region) is currently producing barramundi and there are several indigenous aquaculture projects in the region targeting aquaculture of barramundi, cherabin and rock oysters (Department of Fisheries, 2007).

32.6 What are the requirements of aquaculture/pearling industries in the study area (eg high water quality)?

Unpolluted coastal waters and lack of population pressures are favourable for aquaculture industry, however the lack of relatively sheltered areas and infrastructure reduces this potential (Department of Transport & Pilbara Development Commission, 1997)

32.7 What strategies is DoF utilising/proposing to minimise the environmental impact of aquaculture and pearling (eg size limits, quota system, minimum distance between farms)?

Recreational fishing

32.8 Summarise DoF recreational fishing survey information if available.

"The total recreational catch of all finfish species for the region was estimated at 383 tonnes (95%CI: 331 – 435). This was approximately one sixth of the commercial catch of 2,442 tonnes taken in the region during 2000." (Williamson, Sumner & Malseed, 2006)

"The total annual recreational fishing effort for the Pilbara region was estimated to be 201,000 fisher days (95%CI: 193,000 – 210,000). This comprised 109,000 fisher days by boats launched from public ramps, 26,000 fisher days by boats launched from beaches and 67,000 days by shore-based fishers." (Williamson, Sumner & Malseed, 2006)

32.9 How many participants are involved in recreational fishing as per season and/or on an annual basis, and what is the recreational fishing effort? What is the significance of these values in an international/national/regional/local context?

Recreational fishing in the region is continually increasing with a distinct seasonal peak in winter when the local population as well as visitors from Perth and interstate visit the area. Main areas visited include Onslow, Dampier Archipelago and Broome sections of the coastline (Department of Fisheries, 2006).

"The estimated total annual recreational fishing effort for the Pilbara region was 201,000 fisher days (95%CI: 193,000 – 210,000). The fishing effort was highest in the more accessible areas such as Dampier, Karratha, Port Hedland, Broome and Onslow." (Williamson, Sumner & Malseed, 2006)
The winter months, or 'dry season' (April through to October), is the most popular season for recreational fishing in the Pilbara and Kimberley (Williamson, Sumner & Malseed, 2006);(Pilbara/Kimberley Recreational Fishing Working Group, 2004).
"An estimated 6.5 per cent of the State's recreational fishers fished marine waters in the Pilbara/Kimberley during 1998/99, while a further 1.6 per cent fished in freshwater in the region." (Pilbara/Kimberley Recreational Fishing Working Group, 2004)
Recreational fishing participation has increased from 287,000 in 1987 to 598,819 in 2003 (Pilbara/Kimberley Recreational Fishing Working Group, 2004).

32.10 What is the origin of the recreational fishers (eg Perth metropolitan area, local coastal communities etc)?

"The largest proportions of recreational fishers launching boats from public ramps were residents of the Pilbara region itself. Residents from other regional areas of the state, the Perth metropolitan area and other states also fished in the region. No overseas residents were interviewed." (Williamson, Sumner & Malseed, 2006)

32.11 What are the predominant fishing techniques used (eg shore or boat angling, net fishing, spearfishing, pots)?

The high tidal range means that much of the recreational fishing activity in the region is boat-based with beach fishing limited to periods of flood tides and high water (Department of Fisheries, 2006).

"Overall, recreational fishers in the region spent more days boat-based fishing than shore-based fishing." (Williamson, Sumner & Malseed, 2006)

32.12 What is the level of boat ownership of the study area?

"During the 12-month survey, 3,085 boat crews were interviewed at public boat ramps when they returned from their fishing trip." (Williamson, Sumner & Malseed, 2006)

"Broome boat ownership rate is third highest in Western Australia and very few of those boats are regularly used for activities other than fishing." (Rangelands NRM Coordinating Group, 2005). Approximately 2000 recreational vessels are registered in the Pilbara region (Looby, 1997).

In the Pilbara area, there are 13 charter vessels, five of which have commercial fishing boat licences and target demersal scalefish (Looby, 1997).

It is estimated that 1 in 4 households in the Dampier/Karratha area owns a boat (Department of Transport & Pilbara Development Commission, 1997).

32.13 What is the total catch by species?

Creek systems, mangroves and rivers and ocean beaches provide shore and small boat fishing for species such as barramundi, tropical emperors, mangrove jack, trevallies, sooty grunter, threadfin, mudcrabs and cods, while offshore islands, coral reef systems and continental shelf waters provide highly prized species such as saddletail snapper and red emperor, cods, coral and coronation trout, sharks, trevally, tuskfish, tunas, mackerels and billfish (Department of Fisheries, 2006).

"The most common species kept by all recreational fishers in the Pilbara region were (in order of estimated number kept rounded to nearest 100) blue swimmer crabs (71,600), mullet species (21,500), stripey seaperch (21,300), green mud crabs (19,200), blue-lined emperor (18,700), spangled emperor (16,400), threadfin salmon species (15,600), Queensland school and Australian spotted mackerel (8,900), western yellowfin bream (8,700), blackspot tuskfish (8,400) and golden trevally (8,300)." (Williamson, Sumner & Malseed, 2006)

Species	Kept	Released	Estimated kept weight (tonnes) Using average weight from Operators	Estimated kept weight (tonnes) Using length/weight relationship
Emperor, spangled	2,510	451	7	6
Seaperch, stripey	1,773	4,613	1	1
Bream, fingermark	1,632	2,722	4	#
Mangrove Jack	1,588	2,239	3	2
Barramundi	1,566	6,129	8	7
Seaperch, saddle-tailed	1,485	589	4	3
Emperor, blue-lined	1,474	1,006	3	2
Mackerel, narrow-barred Spanish	1,281	570	14	13
Emperor, red	1,015	526	4	4
Chinaman fish	1,001	52	4	5

Table 15: Catch information from 63 tour operators for top ten species caught in Pilbara/Kimberley in 2002 (Pilbara/Kimberley Recreational Fishing Working Group, 2004).

The National Recreational and Indigenous Fishing Survey conducted in 2000/2001, estimates that between 306 and 413 t2 of mackerel (Spanish, Grey, School, Shark and "other" mackerels and Wahoo) were taken by recreational fishers in WA in that year (Henry & Lyle, 2003).

32.14 What is the economic significance of recreational fishing in an international/national/regional/local context?

In 1995/6, direct expenditure on recreational fishing activities was estimated at $299 million in WA. Combined with indirect impact, the total was $569 million and an estimated 7 000 full time jobs (Pilbara/Kimberley Recreational Fishing Working Group, 2004).

32.15 What has been the past trend, and what is the current status and predicted future trend for recreational fishing in the study area?

"Recreational fishing is one of the most popular leisure activities in Western Australia. A survey estimated that 533,000 persons participated in recreational fishing at least once a year. According to this survey, the Pilbara region of the North Coast bioregion was utilised by 27,000 (five percent) recreational fishers each year." (Williamson, Sumner & Malseed, 2006)

32.16 Have there been any past, and/or are there any current/potential environmental impacts of recreational fishing in the study area (eg threats to the sustainability of local fish stocks)? Provide details of the relevant research/monitoring programs.

Little information is available on the impact of recreational fishing pressure has on fish stocks in Pilbara mangals, though anecdotal evidence suggests that over-fishing has depleted stocks in popular fishing locations near the major coastal towns (Carr & Livesey, 1996).

32.17 What factors have been shown or appear to influence patterns of recreational fishing activity throughout the study area (eg geomorphology such as sandy beach, season/holiday periods, presence of marine hazards such as crocodiles)?

32.18 What are the requirements of recreational fishing in the study area (eg maintenance of target species habitat)?

Pilbara mangrove creeks and inlets are important sites for recreational fishing. Fishing within mangrove creeks is one of the main reasons why people visit mangal areas in the Pilbara (Carr & Livesey, 1996).

32.19 What strategies is DoF utilising to minimise the environmental impact of recreational fishing (eg closed seasons, closed areas, bag and size limits).

- "There was a very high level of compliance with the fishing regulations. Only five percent of boats launched from public ramps, three percent of boats launched from the beaches and one percent of shore-based fishers interviewed kept undersize fish. Very few fishers exceeded the bag limits. Most fishers had a reasonable knowledge of the fishing regulations and knew the bag (67%) and size (67%) limits for the species they were targeting or the predominant species they had caught." (Williamson, Sumner & Malseed, 2006)

- "The Recreational Fisheries Program of the Department of Fisheries has a strategic plan to conduct creel surveys of recreational fishing in each of the four bioregions within the state on a rotating bioregion-by-bioregion basis (Penn *et al.*, 2003). To record and monitor changes in recreational catch and fishing effort an integrated approach where all bioregions are to be surveyed on a regular basis (about once every five to six years) was proposed." (Williamson, Sumner & Malseed, 2006)

- Controls on recreational fishing in the region include; minimum and maximum size limits, bag limits, boat limits, gear restrictions, seasonal closures and licensing for some species (Pilbara/Kimberley Recreational Fishing Working Group, 2004).

- Education strategies such as the use of brochures and publications, school programs, TV and radio advertising and community based education programs are use to promote conservation and environmental awareness in recreational fishing. An example of this is the Volunteer Fisheries Liaison Officer (VFLO) program, which involves fishers educating each other at popular fishing sites. This program was established in 1992 (Pilbara/Kimberley Recreational Fishing Working Group, 2004).

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