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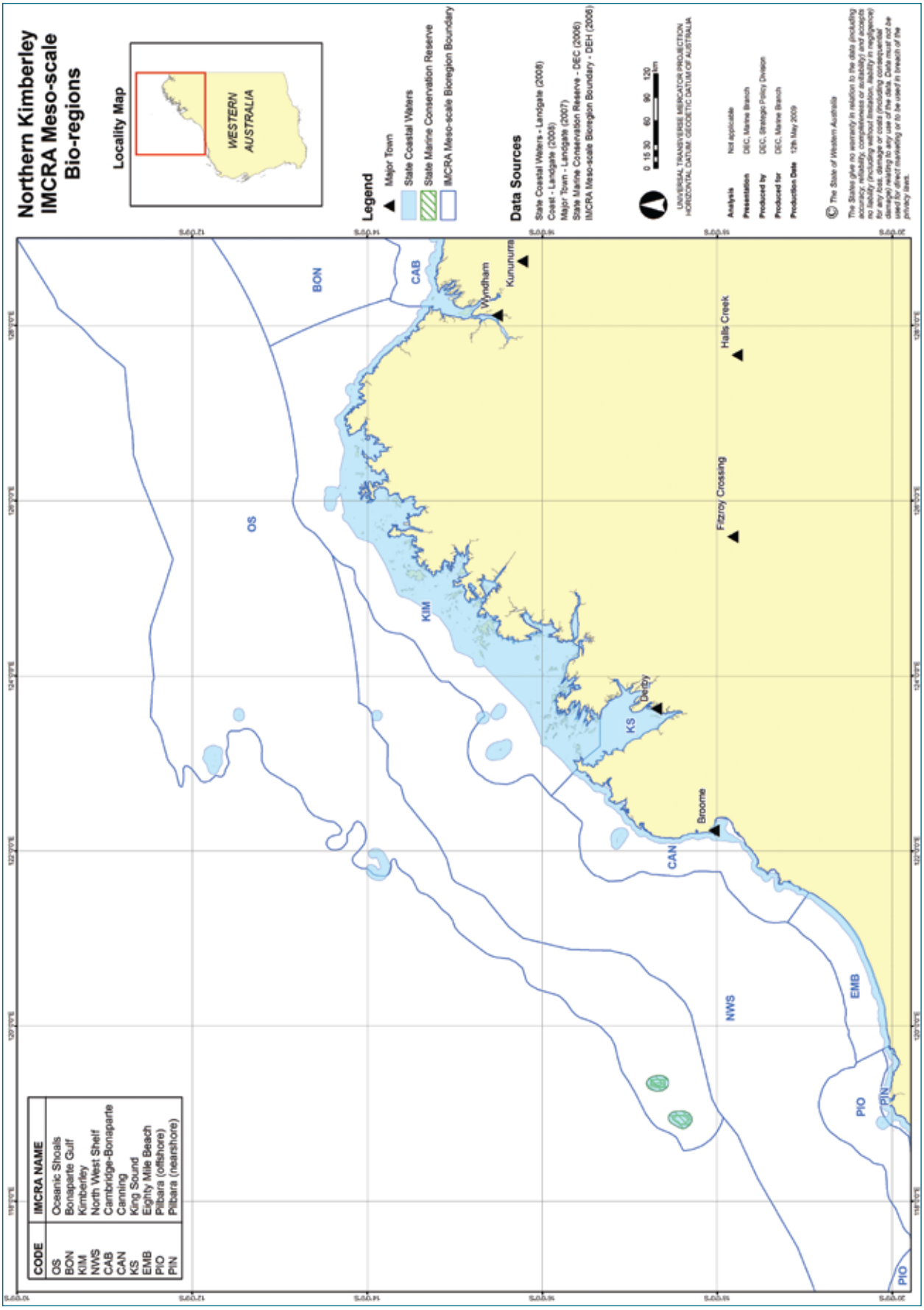
Overview

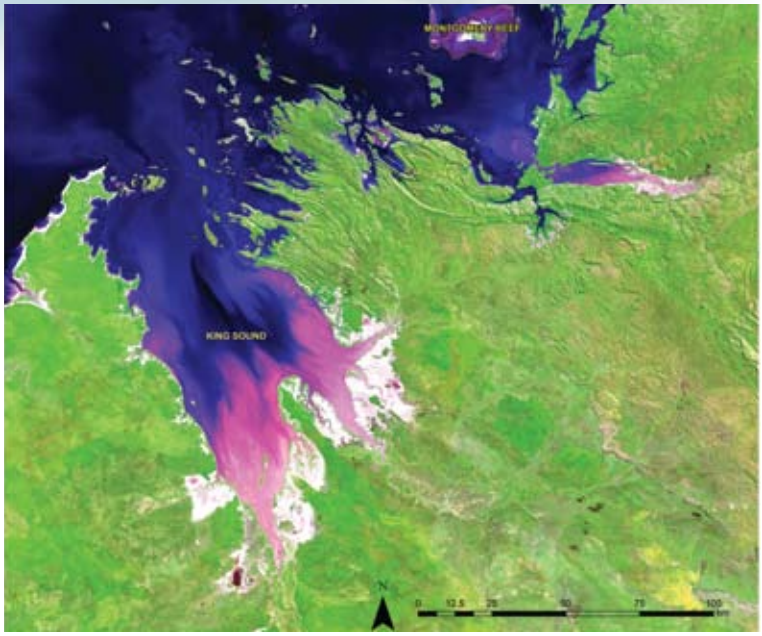
Most of the marine environment in the Kimberley region is internationally recognised as being in very good ecological condition. Halpern *et al.* (2008) in assessing the condition of the world's oceans reported that 41% of the global marine environment has been adversely impacted by humans to a "medium-high to very high" extent and only 3.7% of oceans were rated as "very low impact". Very low impact areas are restricted mainly to the high latitude Arctic and Antarctic polar regions and notably northern Australia including the Kimberley. That most of the world's other coastal tropical marine areas are degraded to varying degrees emphasises the global conservation significance of the tropical marine environment of the Kimberley. However, there are growing human usage pressures in the region that will require sound scientifically-based management if the condition of the marine environment is to be protected (Wood and Mills 2008).

While there is a growing body of scientific knowledge about the Kimberley marine environment (e.g. Fletcher and Head 2006, Department of the Environment, Water, Heritage and the Arts 2008, Holley and Prince 2008, Wood and Mills 2008), it is relatively small compared with marine areas at similar latitudes off the east coast of Australia (e.g. Great Barrier Reef) where there exists a substantial information base to support management. The limited scientific understanding of the Kimberley marine environment has largely been due to the region's remoteness and the associated high costs of conducting research. As a result, most research has been opportunistic, exploratory or descriptive in nature. Interest in recent years from the petroleum sector in exploiting hydrocarbon reserves in the Browse Basin has provided particular impetus for Government and the private sector to increase scientific understanding of key Kimberley marine systems. This information is needed to inform decision making and support delivery of regional plans and conservation outcomes. In response the WA Government has committed to develop a *Kimberley Science and Conservation Strategy* "to ensure the region's natural and cultural values are protected as the region fulfils its economic potential". In addition, the Western Australian Marine Science Institution (WAMSI) has prepared a report identifying priority marine research to address management issues facing the Kimberley (Wood and Mills 2008).

Figure 1: Interim Marine and Coastal Regionalisation of Australia (Version 4.0) meso-scale bioregions from Eighty Mile Beach to the Western Australia-Northern Territory border.



The Interim Marine and Coastal Regionalisation of Australia (IMCRA Version 4.0) recognises biogeographical boundaries that are primarily based on regional geological characteristics and history, which provide insight into regional ecological patterns. Regionalisation provides a broad-scale classification of different marine areas of the Kimberley coast (Fig. 1). Regional scale drivers of marine communities and their ecology include geological substrate and geological history, oceanographic features including temperature, salinity and ocean currents and circulation patterns (Cresswell and Badcock 2000). Local influences include substrate types, exposure to tidal currents and wave energy, and proximity to river discharges.



Above Colour enhanced satellite image showing extensive turbidity plumes in coastal waters in the King Sound area, southern Kimberley (pink to light blue colour tones). Turbidity plumes in coastal areas of the Kimberley are associated, in part with the discharge of sediment laden freshwater from rivers as well as with significant tidal variation. This image serves to illustrate connectivity between land and marine ecosystems in the Kimberley. The functional significance of terrestrial run-off for the region's marine ecology is largely unknown. Image – DEC and Commonwealth Department of Climate Change).

Ecological processes that link land and sea are also likely to be important and in this respect it is relevant to recognise relationships between terrestrial and marine regionalisation schemes. The Kimberley IMCRA region corresponds broadly to the offshore extent of the Kimberley Basin (Plateau) and North Kimberley IBRA Regions and the Canning IMCRA Region corresponds to the Canning Basin.

While identifying a number of bioregions between Eighty Mile Beach and Cape Londonderry, the IMCRA recognises two broad environments in the region, being the nearshore/coastal and offshore, each with quite different characteristics and values. For the purpose of this paper, the nearshore and offshore environments and their associated IMCRA bioregions are considered separately.

Nearshore and coastal environments (Canning, Kimberley and King Sound IMCRA Bioregions)

Key physical characteristics common to the nearshore and coastal waters of the Canning, Kimberley and King Sound IMCRA meso-scale bioregions (Fig. 1) include turbid waters, low wave energy and a macrotidal regime. Tides are semidiurnal (i.e. two high tides and two low tides each day) with daily amplitude of up to ~11 metres during spring tides and less than ~3 metres during some neap tides, meaning the region experiences some of the largest tides, and correspondingly large degree of water movement, along a coastline adjacent to an open ocean in the world.

Coastal geomorphology and bathymetry are other key influences on the region's marine ecology. The Canning coast from Cape Leveque to Cape Bossut is characterised by beaches between large deeply incised, often barred, embayments with associated lagoons and extensive tidal flats. The offshore bathymetry is gently shelving. In the Kimberley Bioregion, deep coastal valleys were inundated by the sea during past sea level rise events forming the ria type coast with its many gulfs, headlands, cliff-lined shores and archipelagos that now typify this region. There are 2 581 mapped islands between Yampi Sound and the King Edward River estuary. The straight line distance between Yampi Sound and the King Edward River is approximately 400 kilometres whereas the actual length of coastline is about 12 850 kilometres, a ratio of approximately 1:30. Extensive tidal flats have formed in places and these are sometimes associated with the mouths of the numerous rivers that drain sediment-laden freshwater to the coast in the region. Peak river flow is seasonal and generally associated with the northern monsoon. King Sound is a wide gulf with a low relief shoreline and associated intertidal and supratidal flats.

These features, and the semi-diurnal macrotidal regime, mean that the land-sea interface is large and together these features are among the primary controlling factors influencing the productivity and biodiversity of the Kimberley's nearshore marine environment.

Biologically, the nearshore and coastal environments support a diverse array of marine communities including coral reefs, seagrass meadows, mangrove forests and sponge gardens. These communities in turn provide critical habitat, shelter and food resources for specially protected and culturally and commercially important species including marine turtles, cetaceans, dugongs, fish, prawns and birds.

Offshore environments (Northwest Shelf and Oceanic Shoals IMCRA Bioregions)

In contrast to nearshore waters that are under coastal influence, environments offshore are characterised by generally clear waters that are typical of oceanic systems. There are mid-shelf islands (e.g. Browse Island), some embankments and shelf-edge atolls (e.g. south Scott Reef and Clerke and Imperieuse reefs in the Rowley Shoals group) in the bioregions that are under State jurisdiction. The waters around Adele Island are under State jurisdiction, while the island itself is a nature reserve. There are State and Commonwealth managed marine reserves at the Rowley Shoals, three coral atolls west of Broome. The geomorphology of the region's oceanic reefs and banks and offshore islands has been described in considerable detail in Berry (1986). The region's shelf-edge atolls warrant particular mention for their unique formation and structure.

Known key ecologic attributes and values

Ocean currents and circulation

Large-scale oceanography in the region is highly seasonal and a number of ocean processes influence the area. The Holloway Current for instance is a surface layer pole-ward flowing ocean current that brings water from the Banda and Arafura seas southward along the continental shelf in the region at the end of the northwest monsoon. The pole-ward flow of this and other ocean currents in the region is globally unique. Despite this, an understanding of the Holloway Current and the origin of shelf waters throughout the Northwest Marine Region is poor.

River flow to the marine environment is likely to be an important factor influencing the region's marine environment. However, evaluating this influence will depend on a much-improved understanding of the spatial and temporal characteristics of alongshore and cross-shelf water circulation and exchange. Understanding ocean currents and local-scale circulation and exchange patterns, and the influence of these, is important for evidence-based decision making in relation to Environmental Impact Assessment (EIA) of development proposals, planning for biodiversity conservation and sustainable use of marine resources.

Bathymetry

Bathymetry in some areas is well known, however, over vast areas of the region high-resolution contemporary bathymetric data are limited or not available and many areas remain uncharted. Geoscience Australia (GA) have broad-scale data for the region, though bathymetric measurements by the Australian Institute of Marine Science (AIMS) and CSIRO (Fry *et al.* 2008) during benthic habitat surveys in the southern Kimberley in July 2008 indicate that local-scale bathymetry at the survey locations varied from the GA data. The Australian Hydrographic Office (AHO) is currently processing data from contemporary surveys in the northern Kimberley.

Reliable bathymetric data are fundamental for predictive modelling of water currents and circulation patterns, which in turn are used to inform EIA and understand the degree and extent of ecological linkages between different areas (e.g. larval dispersal). Good bathymetry can also be used as a surrogate to infer habitat types for broad-scale benthic biodiversity mapping where ecological field data are limited.

Coral communities

Coral reefs are well developed in the Kimberley, Northwest Shelf and Oceanic Shoals bioregions in particular and are one of the region's most important marine values. Coral communities are not well developed in the Canning Bioregion, though there are some localised examples off the Dampier Peninsula coast and a biogenic reef structure at the Lacepede Islands (Fry *et al.* 2008, Marine Parks and Reserves Selection Working Group 1994). Development of coral communities in the King Sound Bioregion, particularly in the inner section, is limited due to persistent high water turbidity characteristic of the Sound.

Coral reefs in the region fall into two general, though distinct groups — the fringing reefs around coastal islands and the mainland shore, and large platform reefs, banks and shelf-edge atolls offshore. Cape Leveque

is an approximate demarcation point north and east of which coral communities become well developed in nearshore environments. Preliminary reconnaissance surveys by DEC (unpublished data) and other studies undertaken by the WA Museum and collaborators (Wells *et al*. 1995) and mining companies around islands in the Buccaneer Archipelago indicate that extensive fringing reefs which support high abundance and diversity of coral have developed around many islands and off some mainland shores.

Further east, work by DEC and the LNG industry indicate that fringing and emergent coral reefs are well developed in the Heyward island group, around islands in the Bonaparte Archipelago, and off mainland shores of Cape Voltaire and Cape Bougainville. Surveys by INPEX of Maret, Bethier and Montalivet islands, which were largely restricted to the intertidal zone, have recorded 280 species of coral from at least 55 genera, making the Kimberley Bioregion the most coral-diverse area in WA (INPEX 2008).

Extensive biogenic reef formations have been identified off the west coast of the Anjo Peninsula, but these reefs supported a low cover of live coral at the time they were surveyed (DEC 2008). Further offshore from the Admiralty Gulf, between Cape Voltaire and Cape Bougainville, lies Long Reef which is an emergent biogenic reef of some 150 km^2 rising out of approximately 30 metres of water depth. Long Reef has well developed live coral communities on its periphery.

The WA Museum and collaborators published results of three marine biodiversity surveys in the Kimberley between 1995 and 1997 (Walker 1997, Walker *et al*. 1996, Wells *et al.* 1995). Most survey effort was restricted to the intertidal zone. The survey reports provide accounts of reef geomorphology and include preliminary species lists for some sites visited over the three surveys. Some research has also been conducted at Montgomery Reef which is a biogenic reef of some 300 km^2, located between Camden Sound and Collier Bay.

Aerial photographs and satellite imagery indicate that fringing reef-type formations are very extensive in the Kimberley, however further analysis of the available remote sensing data coupled with targeted field verification are necessary to classify and map the different fringing reefs in the region. Preliminary analysis indicates that the Kimberley contains a fringing coral reef province that will rival the Red Sea in terms of the extent of reefs.

Top Fringing reef, Buccaneer Archipelago Photo – DEC

Above Subtidal coral reef communities are well-developed around some inner and mid-shelf islands and mainland shores. Photo – A. Heyward, Australian Institute of Marine Science

Left An extensive fringing coral reef at low tide, South Maret Island. Photo – DEC

Coral communities have been studied on shelf-edge atolls in the Oceanic Shoals Bioregion which are under WA jurisdiction. Drilling at Scott Reef has shown that geological history of shelf-edge atoll formations is unlike that of coral atolls found in the Pacific Ocean, which have mainly developed on the submerged rims of volcanos. For example, studies of drill cores from Scott Reef indicate that reef formation was initiated in the mid-Miocene period (~15 million years ago) and development has waxed and waned since, partly in response to variation in sea level. There is evidence of biogenically formed reef material approximately 2000 metres below the present sea level (Berry 1986).

A long-term research program is being undertaken by AIMS at Scott Reef, which includes investigations of the effects of tropical cyclones and elevated sea water temperatures (Smith *et al.* in prep.). A benthic habitat map of the Scott Reef system has also been produced (Smith *et al.* 2006). DEC has recently conducted research on the coral and associated communities in the reserve areas at the Rowley Shoals west of Broome (Long and Holmes 2009). These research programs show that the coral communities are diverse and in very good condition. The reefs in the Oceanic Shoals Bioregion probably play an important role as ecological 'stepping stones' that help maintain connectivity between the marine flora and fauna of the Indo-west Pacific and Australian west coast ecosystems. This requires further investigation.

Based on the scale of reef development and the diversity of coral species recorded through limited survey, it is highly likely that further survey will demonstrate that the Kimberley contains a coral reef province of global significance.

Seagrass communities

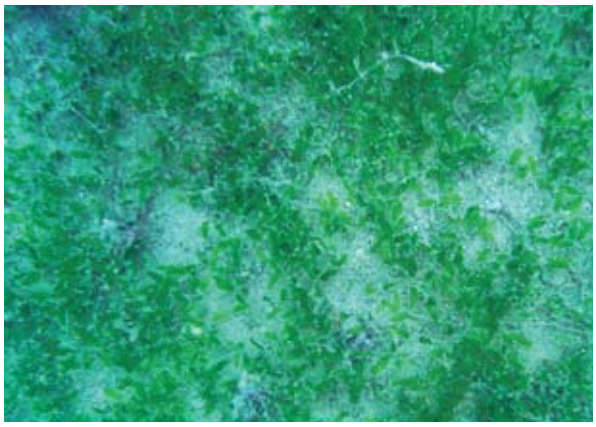
Seagrasses are biologically important for four reasons: 1) as sources of primary production, 2) as habitat for juvenile and adult fauna such as invertebrates and fish, 3) as a food resource, and 4) for their ability to attenuate water movement (waves and currents) and trap sediment.

Western Australia has the highest diversity of seagrass in the world with 25 species represented. Twelve species are known from WA's tropics, including one endemic (*Cymodocea angustata*). Nine species expected to occur in the tropics were collected from intertidal sites in the Kimberley by Walker (1995, 1996 & 1997). Extensive and diverse intertidal seagrass meadows are known from islands in the southern Kimberley, particularly around Sunday Island (Walker 1995, Walker and Prince 1987). It is likely that these meadows would be utilised by a variety of species including prawns and fish as well as specially protected and culturally important species such as turtles and dugong. While some seagrasses were collected from intertidal sites in the central and north Kimberley (Walker 1996 & 1997), these areas were not found to be as species rich and did not support extensive seagrass meadows like those found by Walker (1995) in the southern Kimberley.

Until recently, most of what is known about seagrass in the region was based on collections of individual voucher specimens from sites in the intertidal zone (Prince 1986, Walker 1995, 1996 & 1997, Walker and Prince 1987) and there was very little known about the subtidal communities.

Dugong feeding in the vicinity of James Price Point (Prince 1986) suggested the presence of seagrass in that area, but this was not verified until recent benthic habitat surveys by DEC and CSIRO/AIMS between November 2007 and December 2008. These surveys found seasonally-abundant subtidal seagrass communities patchily distributed across large areas along the Dampier Peninsula from the lower intertidal and out to a depth of approximately 20 metres. Maps showing subtidal seagrass cover and distribution have been produced from a

Below Seagrass in the Kimberley is an important food resource for dugong and turtles; **left:** Intertidal seagrass, Maret Islands; **right:** Dense subtidal *Halophila* meadow, Dampier Peninsula. Photos – DEC



single but very comprehensive dry season survey in the southern Kimberley (Fry *et al.* 2008, see Fig. 2). Subtidal seagrass patches and meadows appear to be well developed in areas where sediments were relatively fine and stable such as in inter-reefal areas and between/among patches of filter-feeder communities. These subtidal meadows were first observed during surveys undertaken by DEC in November 2007. At this time, meadows were well developed and biomass was high. Repeat surveys of some locations where seagrass was found in November 2007 were undertaken in April 2008 but no seagrass was recorded. Seagrass had re-established in these areas by June 2008 and surveys by DEC in December 2008 found prolific seed production in *Halophila* sp, suggesting that recruitment from seed may be a very important process for sustaining these seagrass communities. Community monitoring co-ordinated by the Global Seagrass-Watch program is being carried out to map seagrass communities in intertidal areas of Roebuck Bay (McKenzie 2007).

Apart from localities on the Dampier Peninsula mentioned above, there are no maps of intertidal seagrass habitats and very limited information about the extent and distribution of subtidal seagrass habitats in the region. Furthermore, little is known about the ecological role and importance of seagrass communities in the region or the key processes that sustain them.

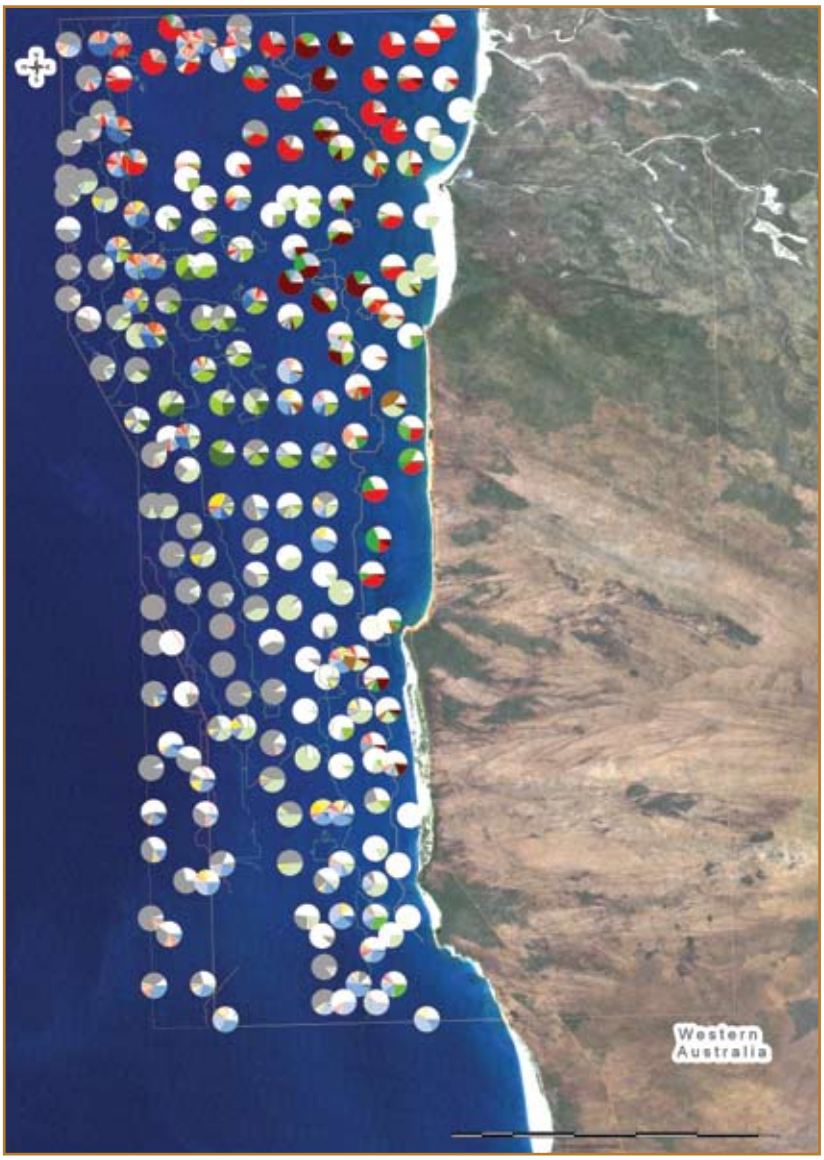


Figure 2: Pie charts showing the relative proportions of different benthic habitat types recorded during benthic habitat surveys of the area between Quondong and Coulomb Points on the Dampier Peninsula, north of Broome in June 2008. Each pie chart shows data for a 500 m long underwater video transect (source: Fry *et al.* 2008).

Data Sources

Benthic habitats – video survey conducted during June 2008 as part of a collaborative project between CSIRO Marine and Atmospheric Research, the Australian Institute of Marine Science (AIMS WA) and the Department of Environment and Conservation (WA). Funded by the Northern Development Taskforce.

Bathymetry – Contours (5, 10, 15, 17 and 20 metre) derived by AIMS based on height datum, AHO Broome Predicted (4.55m above MSL).

Imagery – Australian Greenhouse Office Landsat Mosaic 2005.

Basemap – Geoscience Australia 250K Series Version 3.

Datum – Geodetic Datum Australia 1994 (GDA94).

Legend

No Biohabitat
Bioturbated
Alcyonarian Garden Sparse
Alcyonarian Garden Medium
Alcyonarian Garden Dense
Whip Garden Sparse
Whip Garden Medium
Whip Garden Dense
Gorgonian Garden Sparse
Gorgonian Garden Medium
Gorgonian Garden Dense
Sponge Garden Sparse
Sponge Garden Medium
Sponge Garden Dense
Hard Coral Garden Sparse
Hard Coral Garden Medium
Hard Coral Garden Dense
Live Reef Corals
Algae Turf / Microphyto
Algae red / green mix
Algae Halimeda
Algae Sargassum
Algae other brown
Seagrass Sparse
Seagrass Dense
Bivalve Shell Beds

Filter-feeder communities

Filter-feeders are invertebrate animals that feed by filtering small particles from seawater, typically by passing the water over a specialized filtering structure. Examples of filter-feeders are sponges, soft and whip corals and sea squirts. Filter-feeder communities are aggregations dominated by these animals growing together on consolidated seabed and some of the most well-developed communities have been found elsewhere in WA in waters deeper than 40 metres (e.g. off Ningaloo Reef).

Recent dry season underwater video surveys by AIMS and CSIRO (Fry *et al.* 2008) indicate that filter-feeder communities are a prominent component of the subtidal benthic environment off the Dampier Peninsula and Gourdon Bay, south of Broome (Canning Bioregion) in water depths as shallow as 10 metres. These communities are patchily distributed and vary in terms of their spatial extent, diversity and cover but generally appear to be associated with stable hard substrates overlain by sand veneers in areas of gently shelving bathymetry. Abundance and species diversity appear to be high in places, however very little is known about the species represented in these communities or their ecology. A preliminary assessment by local experts indicates that many of the taxa present may be undescribed and hence likely to be new to science (J. Fromont, pers. comm.).

Surveys by DEC in the Kimberley Bioregion revealed that filter-feeder communities occur in the areas associated with fringing biogenic reefs. In these areas, filter-feeder communities tend to occur where the substratum is hard and steeply sloping, and/or where light availability is limiting for hard corals. A generally repeating pattern that has been observed around fringing coral reefs is that benthic cover gradually shifts from a predominance of hard corals to filter-feeders with increasing water depth. Preliminary observations suggest that the transition from corals to a predominance of filter feeders tends to occur at water depths of approximately 10 metres (below estimated mean sea level), which is much shallower than in other tropical areas in WA (e.g. Ningaloo Reef). Communities also appear to be well developed down steeply sloping reef fronts and in deep sandy basins and subtidal reef platforms off island and mainland shores to depths of at least 35 metres.

Below Diverse communities of filter feeding invertebrates have been observed on low-relief subtidal reef pavements in the Kimberley.
Photos – A. Heyward, Australian Institute of Marine Science

From underwater video footage collected during recent surveys in the Kimberley, there is often an abundance of small fin fishes and some large demersal fishes (e.g. snappers and gropers) associated with filter-feeder communities. This observation is supported by data from Ningaloo Reef and suggests that filter-feeder communities in the Kimberley provide important habitat for fish populations.

With the exception of work off the Dampier Peninsula, little is known about the extent and distribution of filter-feeder communities in the Kimberley and research is needed to test the broader transferability of observations about the apparent association between fringing reef and filter-feeder communities. Species composition and diversity of subtidal filter-feeder communities, and the seasonal and/or inter-annual variation in the structure of these communities in the region are unknown, as is the ecology of filter-feeder communities including the key processes that sustain them.

Intertidal systems

Very large tidal amplitudes in combination with the extensive and complex coastline produce very extensive, ecologically diverse and highly productive intertidal areas with environments ranging from vertical cliffed coasts to wide expanses of mudflats, sand banks, coral (addressed earlier) and algal reef flats, mangrove forests and beaches.

The gently shelving nearshore bathymetry of the Canning Bioregion produces areas of extensive mudflats and sand banks. Sand/mud flats may be kilometers wide in some places, providing habitat for diverse assemblages of burrowing and crawling invertebrates. Seagrasses are also often present and are a critical food resource for dugong.

The intertidal benthos has been studied at only a few locations in the region. Roebuck Bay and Eighty Mile Beach in the Canning Bioregion have received most attention. Both areas are Ramsar-listed wetlands primarily because of the seasonally high numbers of migratory birds they support (including species listed under the Japan-Australia Migratory Birds Agreement (JAMBA) and the China-Australia Migratory Birds Agreement (CAMBA)). For example, in terms of total numbers of birds utilising the area as a migratory terminus or stop-over site, Eighty Mile Beach is one of the most important non-breeding and migratory stop-over areas in the East Asian – Australasian Flyway for use by migrant shorebirds (CALM 2003). The rich intertidal invertebrate communities recorded from these locations provide an important food resource for the seasonally abundant bird populations (Piersma *et al.* 1999 & 2006). While Roebuck Bay and Eighty Mile Beach studies have identified abundant and diverse intertidal faunas, similar research has not been undertaken at other sites so it is not known whether these are typical of tidal flats across the Kimberley.

Surveys of intertidal habitats at three locations in the Canning Bioregion (Gourdon Bay, Perpendicular Head and Packer Island) have recently been undertaken for the Government's Northern Development Taskforce (WA Museum 2008). The surveys revealed the study areas to be broadly representative of the Canning Bioregion in terms of diversity and assemblages of biota, with each having examples of all or most of the habitat types present in the bioregion. The relative importance of habitats and communities varies between locations, though in the absence of broader regional studies it is not possible to make informed appraisals of the significance of individual sites. Waples (2007) notes that some research has also been conducted at other sites in the King Sound and Cambridge–Bonaparte Bioregions but the majority of intertidal studies have focussed on mangroves.

Mangrove communities are important for providing a source of nutrients to surrounding waters, for fauna habitat and as a buffer against wave action to reduce erosion and maintain coastline stability. Mangroves are very well developed in the Kimberley and from a global perspective, these mangrove ecosystems are considered to be relatively pristine (IUCN Working Group on Mangrove Ecosystems 1981) having not been subject to broad-scale deforestation and fragmentation due to coastal development. Mangrove systems also provide a nursery and breeding area for various fish stocks (Loneragan *et al.* 2002) and it is considered that these systems are important for sustaining some major fishing industries. A better understanding of the marine ecology of Kimberley's mangrove systems is warranted.

Pendretti and Paling (2000) developed a database of mangrove sites along the WA coast and made assessments, based on information available at the time, of each site against the Australian Heritage Commission's Register of National Estate Criteria. A database is available on the internet and DEC has recently refined the associated spatial data, however, there is a need to validate its accuracy and to ensure it remains current. Fine scale and accurate mapping of mangroves would provide a valuable record of mangrove areas so that changes and trends, driven by both natural (e.g. cyclones) and anthropogenic influences (e.g. oil spills, climate change effects), may be detected and assessed. In terms of species diversity, 19 of the 41 species of mangrove which occur in Australia are represented in the Kimberley but there are no species unique to the region. (E. Paling, Murdoch University, pers. comm.). From a marine ecological perspective, there are at present large gaps in basic knowledge such as mangrove habitat assemblages and their extent and distribution, soil types, faunal species including fish, and roles and contributions of exported nutrients to marine productivity.

Little is known about the ecology and biodiversity significance of rocky intertidal shores. Rapid one-off surveys have been conducted at numerous intertidal sites in the Kimberley by the WA Museum and collaborators during voyages through the region in the mid-1990's (Walker 1997, Walker *et al.* 1996, Wells *et al.* 1995). The survey reports provide accounts of intertidal invertebrate, macroalgal and seagrass diversity. Surveys of the intertidal zone have been conducted for petroleum industry proponents, but the results of these surveys are not published.

Above The Kimberley coast provides calving and resting habitat for Humpback whales. Photo – C. Jenner, Centre for Whale Research.

Whales and dolphins

A number of cetacean (whale and dolphin) species are known to occur in the Kimberley region including humpback whales, the snubfin dolphin as well as several other species of delphinid. These species are important because of their iconic status and public appeal and also for their conservation value. Humpback whales are specially protected species in WA due to their threatened status.

Information about humpback whale utilization of the region has increased considerably since the mid-1990s. The Kimberley is the northern migration destination and calving ground for the largest population of humpback whales in the world. Since cessation of whaling for humpback whales off WA's coast and in the Southern Ocean, the 'Group IV' population (i.e. the one which migrates along the WA coast to the Kimberley) has increased by 10% per annum and in 2007 was estimated to comprise some 20 000 animals. On the basis of data collected over a 10 year period, there is an important humpback whale calving and resting area between the Lacepede Islands – Beagle Bay in the south and Camden Sound in the north (Fig. 3). While some cows will calve and rest outside this area, most whales outside the area are migrating animals. The northern migration peaks in July but occurs through July to September. The southern migration peaks for cows with calves at the end of September. Other whale species observed inshore and offshore in the region include pygmy blue whales, false killer whales, pygmy killer whales and blue whales.

There are populations of snubfin dolphin, recently identified as taxonomically unique to Australia, found in coastal waters of the north (Beasley *et al.* 2005). This species has received limited attention, but a research program is currently underway by Deakin University to examine the distribution, abundance and general ecology of the species in the Kimberley. Other dolphin species known from the region include the Indo-Pacific bottlenose dolphin and Indo-Pacific humpback dolphin, striped dolphin and spinner dolphin. A number of other species may also be present. Greater survey effort would be required to confirm this.

Dugong

In Australia, dugongs occur in northern waters from Shark Bay to the Kimberley and across the top end to Torres Strait and down the Queensland coast to Moreton Bay. The dugong is an air-breathing herbivorous marine mammal that relies primarily on seagrasses for food. Its reliance on large meadows of seagrass in shallow waters close to land has resulted in a significant decline in numbers throughout much of its Indo-Pacific range as a result of human activity and natural events. The dugong is considered vulnerable under international conventions and is afforded special protection under the Wildlife Conservation Act in WA. Dugong are widely known from the region and have strong cultural significance for coastal indigenous people of the Kimberley.

Prince (1986) and Walker and Prince (1987) provide accounts of knowledge about dugong and dugong habitat for northern WA. A contemporary review of relevant literature by Holley and Prince (2008) found a lack of quantitative data on dugong abundance and distribution in the Kimberley. This is mainly due to the region's remoteness and lack of dedicated survey effort. The large tidal variation and water turbidity make standard aerial survey methods difficult to implement and the data difficult to interpret. To address the paucity of information, satellite tracking of dugongs has been trialed by Edith Cowan University and DEC, in collaboration with the Bardi Aboriginal rangers. This work has provided some insight into habitat utilisation and preferences of these animals. An individual animal tagged in Pender Bay moved southwards over a distance of approximately 100 kilometres to an area off James Price Point, which is known to support extensive subtidal seagrass communities. Dugong feeding has also been observed in both subtidal and intertidal seagrass communities.

Kimberley dugong populations have been traditionally harvested by indigenous people, who have good local knowledge of dugong distribution at certain times of the year. The North Australia Indigenous Land and Sea Management Alliance (NAILSMA), in partnership with the Kimberley Land Council (KLC), have commenced research into the dugong population and sustainable harvest in the region.

More information will be required to conserve and manage dugong populations in the Kimberley. For example quantitative data on dugong abundance and distribution in the Kimberley are needed. Presently little is known of seasonal movement patterns and important feeding or breeding areas. Although there is an indigenous cultural understanding of dugong distribution at certain times of the year, there are gaps in knowledge for other times and uncertainty regarding dugong density due to fluctuations in numbers of animals seen and hunted from year to year. Population structure and degree of connectivity between populations are unknown.

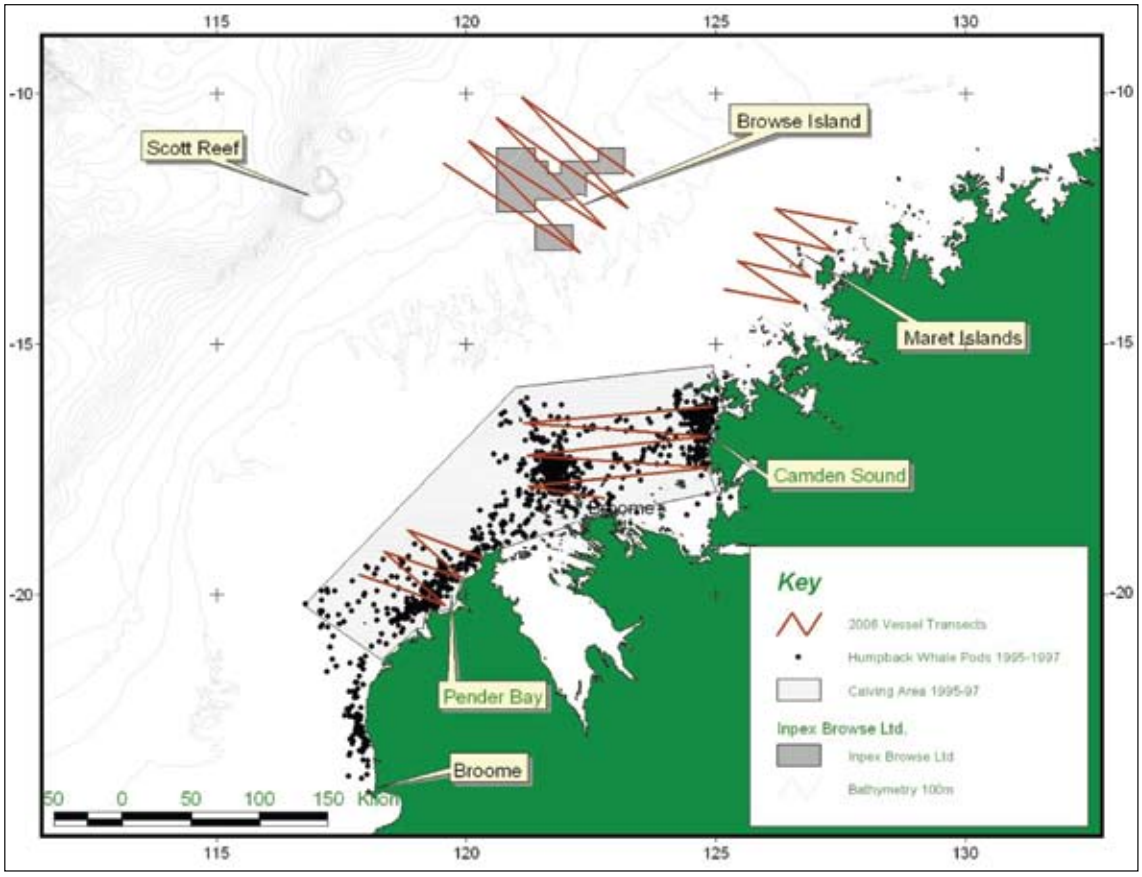


Figure 3: Locations of humpback whale pod sightings, vessel-based survey transects and approximate boundaries of the high density humpback whale calving and resting area in the southern Kimberley (source: Jenner and Jenner 2008).

Marine turtles

Six species of marine turtle occur in the Kimberley and all are listed as specially protected species under WA and Commonwealth legislation (Waples 2007). There are coastal beaches and offshore islands in the region that support marine turtle rookeries. Confirmation of this is provided by data from aerial surveys by INPEX covering much of the west Kimberley coast and islands which show some levels of nesting on nearly all islands supporting suitable beach habitat. Moderate density nesting activity was observed on Albert, Lamarck and Prudhoe islands and the highest density nesting activity was noted on the Lacepede Islands, Cassini Island, Maret Islands and East and West Montalivet Islands (INPEX 2008). The *State of the Fisheries Report* (Fletcher and Santoro 2007) discusses interaction between commercial fishing activities and protected species including marine turtles and describes management actions being taken to avoid or minimise impacts.

With the exception of unpublished work by INPEX on the Maret Islands and knowledge of the importance of the Lacepede Islands as nesting and inter-nesting habitat for green turtles (R. Prince, pers. comm., Waples 2007), little is known about population structure of turtles that utilise habitats in the Kimberley or the affinities these populations may have with other populations. Data gathered from long-term but intermittent tagging of sea turtles at a variety of rookeries on the north coast of WA, including the Kimberley region, are currently being analysed and prepared for publication by DEC scientists. There is a current study on the nesting activities of flatback turtles at Cape Dommett that has identified seasonal nesting patterns. Conservation Volunteers Australia (CVA) commenced a community-based turtle monitoring program on Cable Beach in 2006 and the first report on that program was published late in 2008 (McFarlane 2008). CVA has also recently commenced a turtle monitoring program near the Eco Beach resort south of Broome (G. McFarlane, pers. comm.).

Turtles tagged at Barrow Island (flatback turtles) and off east Java (green turtles) have been tracked from their respective tagging sites to waters off the Dampier Peninsula (seaturtle.org). This finding highlights the potential regional significance of the Kimberley and provides an insight into the relevant spatial scales that need to be considered when developing conservation and management plans for these species.

Seabirds

The region is important for seabirds and migratory shorebirds and a large variety and number of these species are present in the Kimberley on a seasonal basis. There are a number of recognised sites where migratory birds congregate, feed and breed in the Kimberley. The national and international importance of Roebuck Bay for migratory birds is recognized through listing of birds that visit these sites under agreements such as JAMBA and CAMBA and this area has been a focal point for a considerable amount of research attention (see Piersma *et al.* 2006).

An appraisal of field notes held by the WA Museum has provided some indication of the marine-related avifauna of the Kimberley region (R. Johnston, pers. comm.). The notes indicate that there are some important small islands for breeding seabirds in Napier Broome Bay in the far north Kimberley, to the north of Cape Voltaire in the Institut Islands and also in Admiralty Gulf. There are no breeding seabirds, and few shorebirds or northern hemisphere migrants known from the Maret Islands and this is likely to be the case for most of the islands with poorly developed mangal or other suitable foraging or nesting habitat (e.g. intertidal sand/mud flats and beaches/dunes). The significance of the Camden Sound area to seabirds is unknown and no important seabird sites are known on or around Koolan Island. These islands hold little habitat for waders and little mangal. Further south along the Dampier Peninsula, the intertidal flats and mangal around Packer Island are noted as important areas for both shorebirds and mangrove birds. The Lacepede Islands to the southwest have very important seabird rookeries. Intertidal areas on the adjacent mainland shore are thought to be well utilized by waders and terns but there are few records from this area.

The blocks of mangal at Cape Bossut are important bird areas and are at the southern extent of Kimberley mangal. Ramsar-listed wetlands occur at Roebuck Bay to the north and Eighty Mile Beach to the south of Cape Bossut.

Fish

A large diversity of fishes are known from the region, including endemics. Areas with high habitat diversity are presumed to support high fish diversity (B. Molony Department of Fisheries, pers. comm.). Most research on marine fish in the Kimberley region has been undertaken by the Department of Fisheries and is biased towards commercial species. The WA Museum has also gathered data on marine fish species and studies by AIMS of offshore reef communities have included investigations of fish species.

Creek systems, mangroves and rivers, and ocean beaches provide habitat, and hence fishing opportunities, for a variety of species including barramundi, tropical emperors, mangrove jack, trevallies, sooty grunter, threadfin, mud crabs and cods (Fletcher and Santoro 2007). Offshore islands, coral reef systems and continental shelf waters support species of recreational and commercial interest, including saddle-tail snapper and red emperor, cods, coral and coronation trout, sharks, trevally, tuskfish, tunas, mackerels and billfish. Wild pearl oysters, which are collected and then seeded for pearl production, are obtained from fishing grounds primarily off the Eighty Mile Beach, with smaller catches being taken around the Lacepede Islands. A detailed account of commercial and recreational fisheries that operate in the region is provided in the *State of the Fisheries Report 2006/07* (Fletcher and Santoro 2007) and Newman *et al.* (2003) make recommendations for priority research to inform fisheries management.

Protected sawfish utilize or pass through a range of nearshore habitats, including in the vicinity of rivers and open sandy beach habitats, but are unlikely to be common around offshore islands (B. Molony Department of Fisheries, pers. comm.). Speartooth shark and the northern river shark which are listed under the *Environment Protection and Biodiversity Conservation Act 1999* as 'critically endangered' and 'endangered', respectively, are also known from the region.

Management Issues

While human impacts on the Kimberley region's marine environment are generally very low relative to almost all of the world's marine ecosystems (Halpern *et al.* 2008) and relative to the mainland, significant management issues exist and will continue to emerge as development pressure increases. An overarching context for delivery of management, targeted science and conservation outcomes for the Kimberley encompasses principles of sustainable development, regional marine planning, implementation of a comprehensive, adequate and representative (CAR) system of marine protected areas (MPAs) and recognition of the strong interaction between land and sea in the region. Some important management issues can be addressed immediately on the basis of existing knowledge and some will require further work, including scientific research and survey designed to inform management options (see Wood and Mills 2008).

At the broadest level there are two key management issues relevant to the Kimberley: 1) biodiversity conservation and 2) environmental impact assessment (EIA) of development proposals.

Biodiversity conservation

Protection of the Kimberley breeding population of humpback whales has emerged as a key issue for decision making in relation to LNG development proposals and also the broader community. As discussed above, data on migration patterns and habitat utilisation in the southern Kimberley by humpback whales are sufficient to define approximate boundaries of a high density calving and resting area for this species that range from near the Lacepede Islands in the south to Camden Sound in the north. In view of this, it is possible to define important areas of habitat in the southern Kimberley that are under the State's jurisdiction and put in place a management framework to protect critical stages of the life histories of humpback whales in the region.

The considerable volume of research that has been conducted on migratory birds and their utilisation of intertidal flats in Roebuck Bay as foraging habitat, which point to the importance of the Roebuck Bay area

for populations of migratory birds including specially protected species and species listed under international agreements (CAMBA, JAMBA), also is sufficient to define and put in place a management framework to protect the area's values.

Further research is required to better understand the regional significance of the Kimberley for other specially protected marine fauna such as turtles and dugong. In particular, quantification of dugong and marine turtle harvest by traditional hunters is required to ensure such harvest is sustainable.

In the terrestrial environment, management of livestock and fire are key issues for the Kimberley (see Part B below). Managing these threatening processes will, among other things, help in controlling soil loss from Kimberley catchments. Heavy wet season rainfall (often associated with tropical cyclones) erodes soils, particularly in areas of catchments disturbed by stock and inappropriate fire regimes. Large volumes of eroded soil make their way into rivers that drain to the Kimberley coast. While little is known about the actual volumes of sediment transported into the marine environment from river catchments, or the ecological consequences of this sediment (if any) for marine communities, it is clear from case studies such as the Great Barrier Reef that managing elevated terrestrial sediment input to coastal environments is one of the most critical issues for the conservation of inshore reefs. The management of these issues can not be divorced from climate change effects that are predicted to include more frequent and intense storms, which as mentioned above strongly influence sediment inputs to the marine environment from terrestrial catchments. Nevertheless, actions in the river catchments to manage erosion and improve *in situ* soil retention will have positive consequences for coastal marine ecosystems.

A Marine Science Case for the Kimberley-Browse region has been prepared, after extensive consultation with stakeholders, for WAMSI (Wood and Mills 2008). This document identifies planning and management issues that require science inputs and sets out, at a high level, priority areas for research and a proposal for undertaking science in the region to address the identified planning and management issues. The WAMSI Marine Science Case is the logical platform from which to identify science needs and priorities.

Planning for, and environmental impact assessment of, development proposals

The Kimberley region is facing significant development growth in future years, particularly in the petroleum, aquaculture and marine-based tourism sectors. These activities will need to be carefully planned and managed for the long term environmental, economic, social and cultural good.

The WA and Commonwealth Governments have been working together on the selection and assessment of a preferred location for on-shore processing of LNG from natural gas reserves in the Browse Basin. The preferred site for an LNG precinct has been announced as being in the vicinity of James Price Point on the Dampier Peninsula. A proposal for that site will undergo EIA under State and Commonwealth legislation, before being considered for approval. The EIA will require a wide suite of tactical marine scientific studies to inform decision making that will follow. These studies will contribute to increased understanding of the ecological values and key sustaining processes that operate in the region.

Until the Government implemented the strategic site selection process for an LNG processing precinct in the Kimberley, planning for large-scale development was proponent-driven. In the case of smaller scale development/activities including pearling, aquaculture and marine tourism, proponents are still largely responsible for selecting the sites for their activities in the Kimberley. This approach inevitably leads to conflict between uses as the intensity and diversity of use increases. This highlights the need for integrated marine planning at the region scale. Regional marine planning in advance of the projected growth in development proposals over the short to medium term is likely to deliver ecological and other benefits for the region, by identifying important areas to be included in marine conservation reserves and areas that may be suitable for development. Informed regional marine planning should ideally be underpinned by targeted strategic science.

Attachment 4: References cited in this document

Part A: Marine references

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Protecting the Kimberley

A synthesis of scientific knowledge to support conservation management in the Kimberley region of Western Australia

Part A: Marine environments: R.J. Masini, C.B. Sim and C.J. Simpson

Part B: Terrestrial environments: N.L. McKenzie, A.N. Start, A.A. Burbidge, K.F. Kenneally and N.D. Burrows

May 2009

Department of
Environment and Conservation

Our environment, our future

The State Government has made a commitment to develop an integrated Kimberley Science and Conservation Strategy to ensure the region's natural and cultural values are protected as its economic potential is fulfilled.

This synthesis has been prepared by the Department of Environment and Conservation as a starting point to summarise scientific knowledge relevant to biodiversity conservation in the Kimberley region. It is acknowledged that this document is not yet a comprehensive summary, particularly in respect of research conducted by other organisations and research that is unpublished.

Further information will be added during the course of stakeholder consultation and people are welcome to forward details of scientific knowledge about the region to Kimberley.Strategy@dec.wa.gov.au.

Department of
Environment and Conservation
Our environment, our future

Front cover
Cone Bay, Yampi Peninsula, showing a tidal river with mud flats, fringing mangroves and dissected mainland sandstone.
Back cover
(top row) Comb-crested jacana, golden-backed tree rat and green tree frog.
Photos – Jiri Lochman/Lochman Transparencies
(below) The kurrajong (*Brachychiton xanthophyllus*) is a deciduous tree restricted to patches of monsoon vine thicket in the north Kimberley and is gazetted as a Priority 4 species for conservation.
Photo – Kevin Kenneally