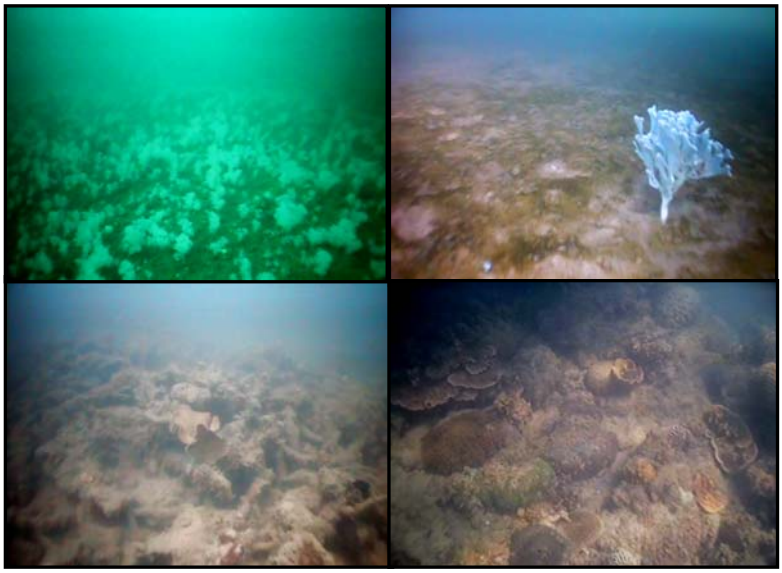
PRELIMINARY RECONNAISSANCE SURVEY OF BENTHIC HABITATS IN THE ANJO PENINSULA AREA, KIMBERLEY BIOREGION, WESTERN AUSTRALIA

Report to the Northern Development Taskforce



Prepared by the Marine Ecosystems Branch

Department of Environment and Conservation

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EXECUTIVE SUMMARY

A preliminary reconnaissance survey of marine benthic habitats has been conducted in the vicinity of the Anjo Peninsula, north-west Kimberley, Western Australia. The overarching aim of this survey was to provide information about benthic habitats around the Anjo Peninsula that could be used by the Northern Development Taskforce (NDT) to inform its appraisal of potential LNG hub sites in the Kimberley. The waters around the Sir Graham Moore Islands, located off the north coast of the Anjo Peninsula, were not surveyed because permission from Traditional Owners to access the area could not be arranged in the time available in the field.

The survey had two operational objectives. The first objective was to ground truth habitats identified from remote sensing data and the second was to determine what benthic habitats occur in deeper or more turbid areas where little is presently known. These objectives were addressed using underwater video to film the benthic environment at sites across an area of interest that had been identified by the NDT. Using the video footage, benthic habitats observed in the survey area were described and broadly classified into eight groups. Based on data collected during the survey as well as remotely sensed images and bathymetric information, a preliminary benthic habitat map has been prepared in a Geographic Information System.

In general, mangrove communities are common along the shores of Napier Broome Bay, including in tidal creek mouths and on elevated intertidal rocky platforms. In the nearshore of Napier Broome Bay, sandstone reefs are common and could be generally classified as algal dominated reefs with the number and diversity of coral colonies present being low, but tending to increase towards the tip of the Peninsula and offshore such as around Louis Island. Broad areas of bare sand and sandy sediments that support patchy sparse to medium density communities of filter feeders also occur in Napier Broome Bay. At the broadest level, the dominant habitat type of sedimentary deeper areas of Napier Broome Bay (>10 m) could be generally classified as fine, bioturbated sediment with occasional sparse density filter feeding communities.

Benthic habitats of the shallow subtidal zone off the west coast of the Anjo Peninsula are mainly reef formations of biogenic and non-biogenic origins that are dominated by macroalgal communities. Abundant live hard coral does occur in places on biogenic and sand stone substrates, but these communities appear to be fairly restricted in their extent and distribution off the north and west coasts of the peninsula. Like Napier Broome Bay, benthic habitats in the deeper areas off the west coast of the Anjo Peninsular are mainly characterised by fine sediments with patchily distributed sparse filter feeder communities. Mangroves occur in patches along the shoreline and also on offshore islands.

If the Anjo Peninsula area is to be considered further as a potential location for a multi-user LNG processing hub, it is strongly recommended that additional work be conducted to ground truth the preliminary benthic habitat map shown in this document and to better understand any temporal variation that may be reflected in the benthic biota of the locality. It will also be important to examine the habitats around the Sir Graham Moore Islands, and other areas in the vicinity of Anjo Peninsula, to evaluate the extent to which benthic habitats and biota which occur in the Anjo Peninsula area are represented at other locations.

BACKGROUND

The Northern Development Taskforce (NDT) was established by the state government to consider issues associated with siting a multi-user LNG production hub to service the Browse Basin natural gas fields located off the Kimberley coast and to coordinate the state's contribution to a joint State Commonwealth assessment of the broader natural values of the Kimberley region of Western Australia (WA).

The NDT is evaluating the relative environmental sensitivities of 11 potential LNG processing hub sites from Gourdon Bay just south of Broome to the Anjo Peninsula in the northwest Kimberley (Figure 1). Two of the sites, one in the vicinity of Cape Voltaire and the other on the Napier Broome Bay side of Anjo Peninsula, were recently added to the NDT's list of potential hub sites at the request of the Kimberley Land Council, which coordinates input from traditional owner groups in the Kimberley.

There is very little information available about the marine environment around the Anjo Peninsula. There are some aerial photographs and satellite images covering the NDT's area of interest that have sufficient water penetration to identify the location and extent of different habitat types based on photo-tones or patterns visible on the seafloor. Although some different habitat types are visible on aerial photography/satellite imagery, it is very difficult to determine what the prominent components of each habitat type are (e.g. differentiate between algal dominated reef and coral dominated reef) without field data from the area of interest. Furthermore, in deeper or turbid areas where it is not possible to see benthic features in aerial or satellite imagery it is not possible to identify the types and distribution of benthic habitats at all. In view of this, the objectives of the present surveys off the Anjo Peninsula were to:

- ground truth habitats identified from remote sensing, and
- determine the different habitats in deeper or more turbid areas where benthic habitats are presently unknown.

This report sets out the findings of a preliminary reconnaissance survey of the marine benthic habitats in the vicinity of the Anjo Peninsula in the north-west Kimberley.

LOCALITY DESCRIPTION

The Anjo Peninsula is a long north-easterly pointing promontory located approximately 650 km north east of Broome and 240 km north-west of Wyndham (Figure 2). The Truscott Airbase is located on the Anjo Peninsula and the community of Kalumburu is located approximately 45 km south-east of the air base. Truscott is currently used by the oil and gas industry as a base for helicopters that fly staff to and from off-shore facilities.

The underlying geological structure of the Anjo Peninsula is King Leopold sandstone (Gellatly and Sofoulis, 1969). Significant areas of the Peninsula are overlain with sandy soils and colluvium, probably a weathering product of the underlying sandstone. There are also localised patches of quartoze/shelly beach sand and coastal silt and muds (Gellatly and Sofoulis, 1969) along the coastal areas of the Peninsula. Brook (1996) also notes the presence of lateritic features on the east facing Anjo Peninsula coast and offshore on Louis Island.

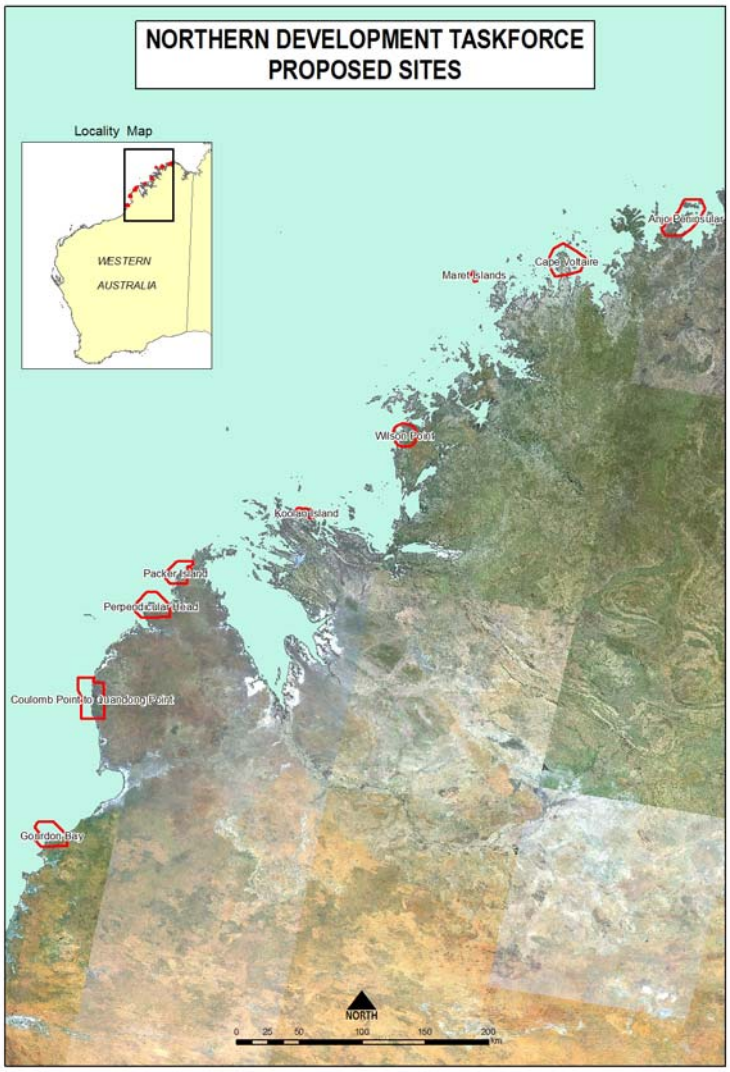

Figure 1: Localities in the Kimberley region that contain the eleven sites being considered by the Northern Development Taskforce as potential locations for a multi-user LNG processing hub.

The area has a monsoonal climate with distinct wet and dry seasons. The annual average rainfall at Kalumburu located approximately 40 km southeast of the Anjo Peninsula is 1220 mm (Bureau of Meteorology, 2008a). The majority of rain (~90%) falls between November and March each year. Rainfall during the remainder of the year is generally light and sporadic. Heavy rainfall is often associated with monsoonal depressions and tropical cyclones. Tropical cyclones George (March 2007) and Ingrid (March 2005, Cat 4, Wind gust at Truscott 174 km/h) passed over, or very close to, the Anjo Peninsula and a number of other tropical cyclones have tracked further offshore since 2000 bringing very heavy rain and strong winds (Bom, 2008b).

The King Edward and Drysdale rivers drain catchments cover approximately 24,000 km^2 (the sub-catchments for the King Edward River and Drysdale River cover ~8400 km^2 and ~15,670 km^2 respectively, DoW, 2008) and these rivers flow into the southern and eastern parts of Napier Broome Bay respectively. Several smaller freshwater creek systems (eg Woppinbie, Dominic and Placid creeks) also drain

directly into Napier Broome Bay (Figure 2). A number of tidal creeks occur around the Bay.

Napier Broome Bay is a large embayment between Anjo Point in the west and Cape Talbot in the east (Figure 2). Within Napier Broome Bay there are smaller embayments. West Bay and Deep Bay are in the southern portions of Napier Broome Bay. Mackenzie Anchorage, to the north of West Bay, is considered to be a potentially suitable location for a deep water port to service any proposed LNG hub facilities on the Anjo Peninsula.

There are several islands (Sir Graham Moore, Scorpion, Louis, Bird and Carronade islands), unnamed rock outcrops and reefs off the eastern and northern coasts of Anjo Peninsula (Figure 2). The north-western side of the Peninsula faces the Eclipse Archipelago and Vansittart Bay. Large portions of the waters off this north-western coastline are uncharted although there are several named (e.g Mary Island) and un-named islands, and submerged and emergent reefs (e.g. the small un-named island and reef system to the north east of Mary Island) shown on the relevant marine navigation charts (Figure 3). No major rivers flow from the southern portion of Anjo Peninsula into Vansittart Bay. The report of the Marine Parks and Reserves Selection Working Group (1994) identifies Vansittart Bay and north-eastern parts of Napier Broome Bay as candidate areas for potential reservation.

Mackenzie Anchorage is between 10 and 14 m deep (Figure 3). A natural deep water channel roughly defined by the 15m bathymetric contour runs seaward in an approximate north-easterly direction from Mackenzie Anchorage. From the point of a small promontory at the northern end of West Bay the 15m contour is approximately 3nM offshore. In general, water depths in the survey area are less than 30m (Figure 3).

The maximum astronomical tidal range in Napier Broome and Vansittart bays is less than 3m. These are some of the smallest tidal ranges in the Kimberley region. By comparison, tidal range at Yampi Sound in the Buccaneer Archipelago can exceed 10 m.

The Anjo Peninsula is near the northern boundary of the Kimberley meso-scale marine bioregion (IMCRA 4.0). The biota of the Kimberley bioregion are typical of the of the Northern Australian region (Interim Marine and Coastal Regionalisation for Australia (IMCRA) Technical Group, 1998). The IMCRA Technical Group (1998) note that mangals are very well developed in the Kimberley Bioregion, especially in bays and mouths of estuaries and these habitats are known to support a diverse fauna. Sand/mud flats are also well developed in some areas seaward of the mangrove zone. Seagrass occurs in the bioregion (Walker, 1995, 1996 & 1997) and some species are likely to be important food resources for dugong populations. IMCRA Technical Group (1998) also suggests that while coral reefs are also known to occur in the Kimberley, they are generally considered to be most well developed around offshore islands.

With the exception of mangroves, for which there is some information about extent and distribution (e.g. Hanley, 1995, Pedretti and Paling, 2001) and ecology in the Kimberley, subtidal marine habitats are poorly known. There is very little information about the marine biological environment of the Anjo Peninsula area. There are some data collected during University of WA and WA Museum surveys from two intertidal sites on Long Island in the Eclipse Archipelago, and intertidal sites on an un-named promontory on the eastern side of the Anjo Peninsula and Lewis Island (Walker *et al*., 1996). As the spatial extent of these surveys was restricted to intertidal zones at a

small number of sites, the application of the information to the NDT's site evaluation process, while providing some useful environmental context, is quite limited.

METHODS

On 25 August 2008, marine specialists from the Department of Environment and Conservation departed Broome for the Anjo Peninsula on board the 19m charter vessel *Equalizer*. A 5.4 m tender vessel was towed behind the *Equaliser* and this smaller vessel was particularly useful for surveying shallow areas, which could not be safely accessed by the *Equalizer*. The tender also allowed two teams to operate simultaneously, enhancing survey effort and in turn the spatial coverage of the survey that could be achieved in the time available. *Equalizer* arrived at Mackenzie Anchorage on the morning of 29 August 2008.

Upon arrival, members of the survey team met with representatives of the Wunambal Gaambera Uugguu People, traditional owners of sea country around the Anjo Peninsula, at the Garmbemirri base camp. During the meeting, members of the survey team outlined the proposed surveys and described the relationship of the surveys to the NDT's site evaluation process for the Traditional Owners in attendance. Traditional Owners also shared local knowledge of their country with the survey team. It became apparent during discussion that there is more than one native title claim over the NDT survey area and that this would have implications for the geographic coverage of the surveys. The survey team were advised that it would not be appropriate to survey areas off the Sir Graham Moore Islands without first discussing the work and gaining permission from representatives of the claimant group for this island. Unfortunately it was not possible to make the necessary arrangements with the native title claimants in the short time available to conduct field work in the region. Accordingly, the survey was rationalised to exclude the waters immediately surrounding and offshore from Sir Graham Moore Island. Five Wunambal Gaambera Uugguu Rangers accompanied the survey team on board the *Equalizer* during the survey on 29 and 30 August 2008.

Survey design

The surveys consisted of two main components. The first component involved ground truthing habitats that were identified from remote sensing information. The second component involved determining the benthic habitats in deeper or more turbid areas where water penetration was insufficient to identify and resolve the extent and distribution of benthic habitats prior to the survey.

For the ground truthing component of the surveys, a preliminary benthic habitat and shoreline classification map was prepared before commencing the field program. This preliminary map was based on the survey team's initial interpretation of aerial photographs and satellite imagery of the Anjo Peninsula coupled with experience gained from similar surveys undertaken in other parts of the Kimberley. Polygons were created around different shoreline and benthic features that could be reliably interpreted from the available remote sensing information using ArcGIS. Numerous sites were selected, mainly in shallow nearshore areas, where mapped habitat units were ground truthed using underwater video cameras.

In deeper water where pre-field program mapping was not possible, video footage of the benthic habitats was captured at sites identified using available bathymetric data and information on the technical aspects of potential hub sites including their terrestrial and marine infrastructure requirements. In addition, single beam sonar (echosounder) data were examined in real time to identify, and to gain an

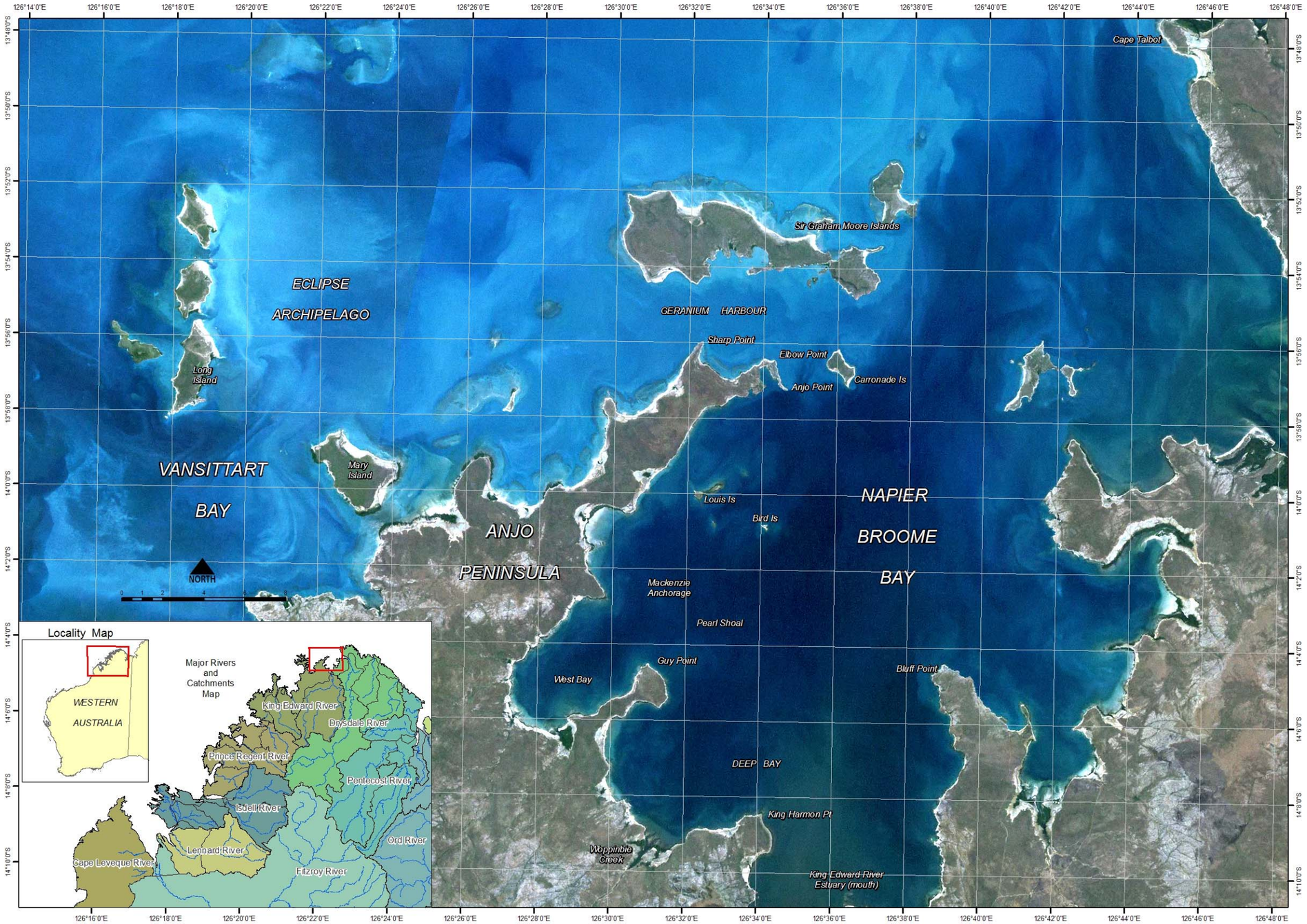

Figure 2: Locality map for the Anjo Peninsula showing key place names overlain on a LandSat image. Sub- catchments of major Kimberley rivers are shown on the insert map.

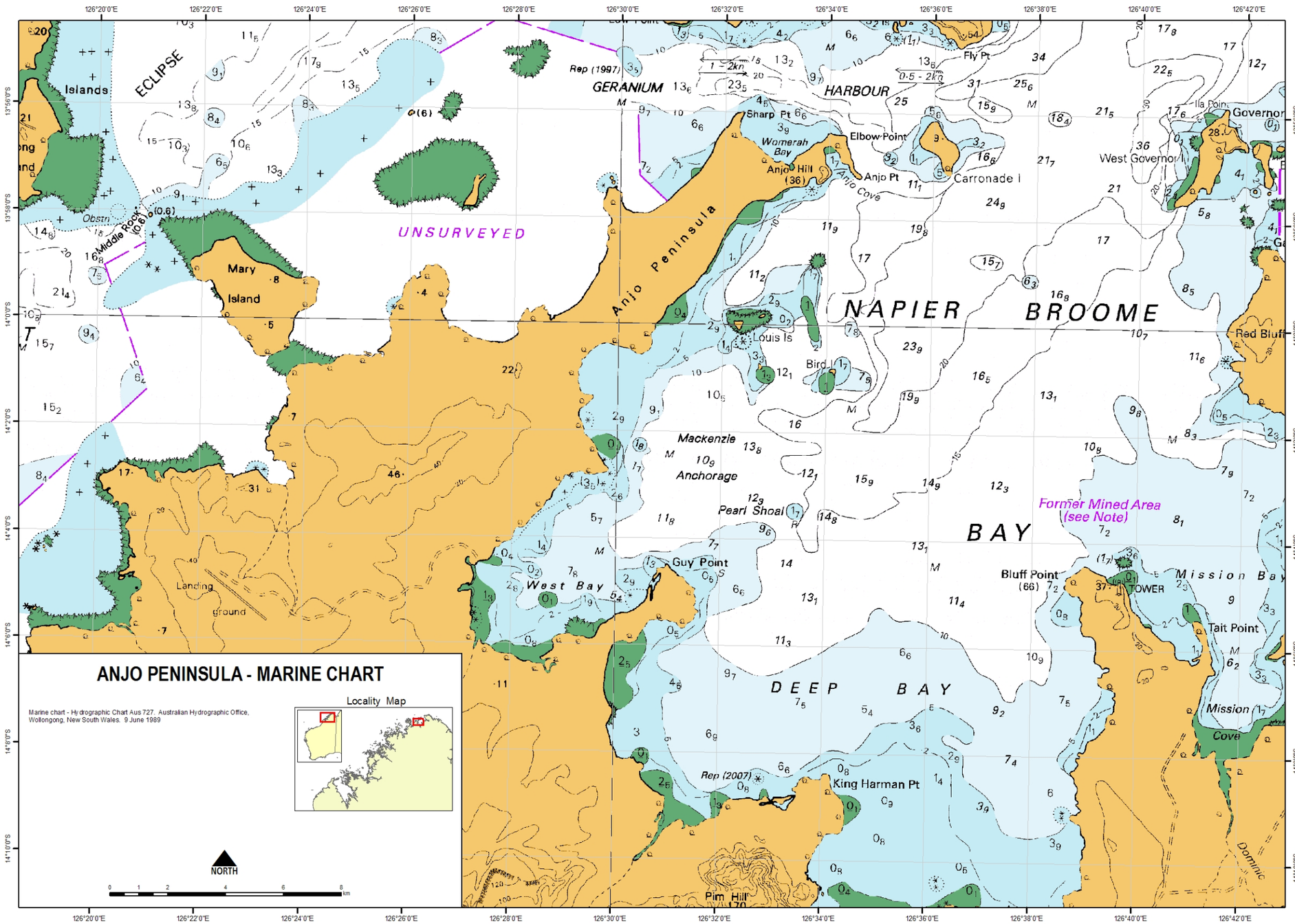

Figure 3: Extract from the hydrographic chart for the Anjo Peninsula area. Water depths are in meters.

appreciation of the relative extent of areas with obvious epibenthic biota and areas where no biohabitat was evident. Footage was captured in deeper waters of embayments, on raised bathymetric features (e.g. charted shoals) and in areas where the seabed was obscured by turbidity in the available remote sensing images. A map showing the general location of each survey site is show in Figure 4.

At each site a Deep Blue Pro underwater video camera was lowered over the side of the survey vessel until it was just above the seabed. Once in this position, the camera was moved over the seabed by allowing the survey vessel to drift with tidal currents. If current speeds were too low for the camera to move over the seabed, then the camera was towed by the survey vessel at a slow speed (e.g. 1-2 knots). Video footage was captured direct to DVD in the field using a Sony DVD burner (VRD-MC3 DVD recorder) customised to run on 12V power.

Video footage was geo-referenced, meaning that geographic position data (and water depth) was captured in real time and written to DVDs simultaneously with video footage. GeoStamp® Audio: GPS to audio encoders (Intuitive Circuits) were used on both survey vessels to convert geographic position data from navigation equipment to an audio signal that could then be written to an audio track on the DVDs. Position data were acquired using a Garmin GPS/echo sounder (Model: GPSMAP 450/450s) on the 5m tender and a Furuno GPS (Navigator GP150) on the larger vessel. Both GPS systems operated in the WGS84 (World Geodetic System 1984) datum and the time reference was Western Standard Time.

While the video footage was being captured at each site, members of the survey team made notes on pre-prepared maps recording geographic position and information about the most prominent benthic features observed on the screen in real-time. General observations of shore line features and fauna were also recorded on the maps.

RESULTS

A total of 82 sites were visited during the survey and video footage of the benthic environment was collected at 44 of these sites. At the remaining 38 sites, observations of fauna (e.g. marine mammals, birds) and the benthic communities were made and recorded on maps of the survey area while in the field.

Napier Broome Bay, West

(including West Bay, Deep Bay and Mackenzie Anchorage)

Although tidal amplitude in Napier Broome Bay is small relative to other areas in the Kimberley, water clarity was generally quite poor during the survey, in some places making it difficult to capture clear images of the seabed. Underwater visibility was generally less than 0.5 m in deeper waters (approx >7 m, increasing to 2-3 m in shallow protected inshore waters.

Extended sections of coast on the western side of Napier Broome Bay are fringed by a narrow mangal, which is occasionally interrupted by sandy beaches, rocky coastline and mangrove-lined tidal creeks. There are more extensive stands of mangroves at the southern end of West Bay and also southeast of Guy Point where Woppinbie Creek and the King Edward River discharge into Deep Bay. Mangroves also occur in the intertidal zone around islands (e.g. Louis Island, Bird Island) and small rock outcrops that protrude above the water surface off the east coast of the

Anjo Peninsula. The narrow bands of fringing mangroves on the Anjo Peninsula appear to be growing among rocks along the shoreline, while the larger more dense stands associated with tidal creeks and estuaries appear to be growing in more sandy and muddy substrates, typical of the intertidal in these types of systems.

Immediately offshore from the rocky and mangrove-lined shores and then seaward to approximately the 5 m bathymetric contour, rocky reefs and sand banks are the predominant benthic habitats. At the time of the survey, areas of the shallow sandy habitat were colonised in places by microalgal films and/or were highly bioturbated, suggesting these areas support an abundant sediment-dwelling fauna. In some places, there were few obvious indicators of biota living in, or on, sandy substrates.

An extensive (probably intertidal) sand bar has formed across the mouth of Woppinbie Creek. The benthos immediately over this sand bar was not surveyed using underwater video because it was considered unsafe to access the shallow bar on a falling tide. A dugong was observed offshore from the sand bar and Traditional Owners informed the survey team that they regularly hunt dugong in the area offshore from, and within, the Woppinbie Creek. Despite the presence of dugong and previous reports of seagrass from Napier Broome Bay (Walker, 1996), no seagrass (which is the main food resource for dugong) was observed in any of the areas surveyed. Given that dugong are know to occur in southern portions of Napier Broome Bay (sometimes in considerable numbers according to Traditional Owners), it is likely that seagrass would occur in, and near to, Woppinbie Creek. There are several possible reasons why seagrass was not observed during the present survey. For example, it is possible that seagrass was present in the area but not at the specific sites surveyed, or that species which do occur in the area may display marked seasonality in their local abundance. Temporal variation in the abundance of seagrass has been observed previously at locations in the southern Kimberley (e.g. DEC unpublished data, Fry *et al*. 2008), however the timing and determinants of the observed changes in abundance are unknown. A possibility is that the time of the year when this survey was conducted may have been coincident with a period of natural seagrass senescence.

Along with the sandy habitats described above, rocky reefs are common along the east coast of the Anjo Peninsula in waters less than 5 m deep. In general, the substratum of these reefs is sandstone along the peninsula or what appears to be a matrix of dead coral and rubble around the islands and reefs offshore of the eastern shoreline of the peninsula. The rocky sandstone substrates tended to grade to scattered rocks and then sand with distance from the shore. Most subtidal areas of rocky reef are covered by macroalgae, which often included a canopy of *Sargassum* spp. The cover of macroalgae sometimes made it difficult to determine reef substrates and when very dense, it almost totally obscured the underlying reefs.

The most visually prominent biota associated with most of the rocky reef areas surveyed were marine macroalgae (often *Sargassum* but sometimes including mixtures of other brown, green and red macroalgae), although filter feeders (such as sponges, seawhips and soft corals) and small hard coral colonies were also observed. While biogenic reef substrates that support dense live hard coral cover were not observed in Napier Broome Bay, small hard corals were patchily abundant among macroalgae and other reef biota at one site in particular (e.g. S13 59.133", E126 31.826").

Biohabitats at sites close to the north-eastern shore of Carronade Island, which is off shore from the northern tip of the Anjo Peninsula, were quite different to those observed at other sites in the survey area. Benthic habitat at these sites was

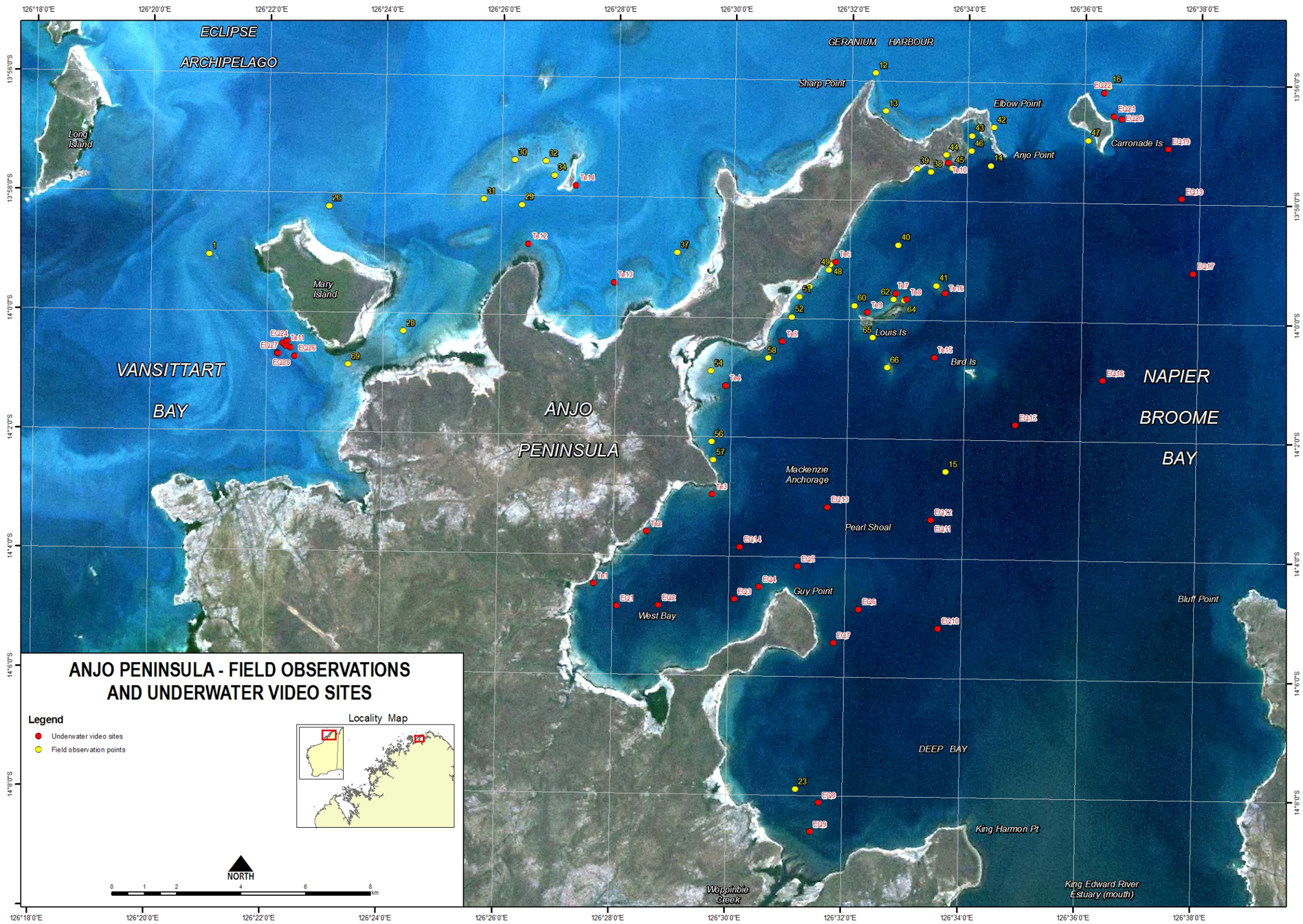

Figure 4: Location of sites where underwater video has been captures and points where general observations of the environment were made by the survey team.

characterised by what appears to be sandstone rocks and angular boulders that support medium to dense cover of mostly small hard coral colonies from a number of different genera. Sessile filter feeders were also observed on the rocky substrate, though these organisms were generally in low abundance relative to hard coral cover. Significant numbers of demersal fish were also observed in the rocky habitats off Carronade Island. Similar to sites in shallow nearshore areas in Napier Broome Bay, benthic habitats in water less than 5 m deep off the south western shore of Carronade Island were generally composed of rocky reefs among sand with macroalgae (mainly *Sargassum* along with a mixture of other brown, green and red macroalgae).

Further offshore from the zones where sand and rocky reefs predominate and where water depths are generally greater than 5 m, a number of sites were surveyed along a line running in an approximately north-easterly direction from the West Bay through Mackenzie Anchorage and out to Anjo Point (Figure 4). Bioturbated fine sands, mud and silty substrates were common at most sites in waters deeper than ~10-12 m. Water clarity was particularly poor at sites in Deep Bay, near the mouth of the King Edward River, presumably due to resuspension and transport of fine sediments by wind-waves and tidal currents. Video data from these areas confirms that fine mud and silty sediments are very easily resuspended when disturbed, particularly in deeper waters (>10m). At Pearl Shoal, sandy substrates were colonised by sparse to medium density filter feeder communities that were patchily distributed among bare/bioturbated sands along the video track. Sandy substrates with patches of mainly sparse density filter feeder communities were observed at sites between 5 and 10 m deep in West Bay and off Guy Point. Patches of high density filter feeders were observed, but they were generally small and isolated. Sandy sediments colonised by a microalgal film and turf algae were observed at a site surveyed west of Guy Point. At the eastern-most site surveyed in Napier Broome Bay, fine sands supported very dense patches of soft coral communities. These communities were distributed among areas of mostly bare fine sediments and the patches of soft corals were generally only about 5 - 10 m across and may indicate the presence of hard substrate under a veneer of fine sediment. Fine sediment habitats that support variable densities of filter feeders appear to extend west from Napier Broome Bay and into the deeper waters of Geranium Harbour, the body of water that separates the Anjo Peninsula from Sir Graham Moore Island.

Vansittart Bay

Pre-field program interpretation of remote sensing information was that much of the west-facing coast of the Anjo Peninsula was fringed by live coral reefs. Benthic habitats at the sites visited in Vansittart Bay were generally contrary to these initial expectations. While reefal substrates were dominant features, they generally did not support abundant live hard coral. Dead coral reef platforms and coral rubble was observed in a number of locations where live fringing coral reef was anticipated.

Reef substrates varied along the surveyed stretch of coast off the west coast of the Anjo Peninsula. Reefs were of biogenic (mainly dead coral and coral rubble) and non-biogenic (e.g. sandstone) origins, with veneers of sand in places.

The biohabitats also varied considerably. In general, areas where dead coral and coral rubble were the predominant substrates, macroalgae and turf algal communities occurred. Similar to sites in Napier Broome Bay, the cover of macroalgae on reefs varied from occasional individual plants to dense cover of

canopy-forming species (e.g. *Sargassum*) and communities of mixed macroalgal (e.g. *Padina* sp., *Lobophora* sp. *Turbinaria* sp. and *Dictyota* sp.) and turf species.

Off the western side of Mary Island, live hard coral was generally associated with *Porites* coral colonies (<10 m across). These coral 'bombies' occurred in the subtidal zone near to the edge of biogenic reef platforms, which themselves would have most likely once supported live coral. Corals from a range of genera were observed growing on the *Porites* colonies surveyed. Significant numbers of demersal fish from a number of different genera were also associated with the coral bombies.

Areas around the un-named island east of Mary Island were visited. Sites in shallow waters shown on the hydrographic chart around this un-named island (Aus 727, AHO 1989) were generally characterised by sand, however there were some notable exceptions. The northern shoreline supported a dense mangrove stand on intertidal sandstone rocky reef and the shallow subtidal areas north and north-east of the island contained large sandstone rocks on a largely sandy seabed. The subtidal rocks were dominated by macroalgal communities, including *Sargassum* sp. that often formed a canopy. Occasional coral bombies and filter feeders were noted at three sites in this area; two sites south of the sand bar and one to the east, closer to the un-named island. A site dominated by a well-developed coral reef with abundant live coral cover was surveyed off the south eastern shore of the un-named island. This was the only true extant biogenic coral reef supporting a high abundance of live coral surveyed in the vicinity of the Anjo Peninsula during the field program. Although not visited, the north-west of the sand bar appeared to have the characteristics of a coral reef.

The north-western coast of the Anjo Peninsula (east of Mary Island) consisted of sections of sandy beach that are occasionally interrupted by tidal creek mouths, mangrove stands and low sandstone rock headlands that extended out into the shallows. The subtidal sandstone rocks were generally covered with macroalgal communities similar to Napier Broome Bay but without the tall *Sargassum* canopy. Much of the shore line was also paralleled by what appears to be a largely dead fringing coral reef formation. This biogenic reef formation was only shallow (1-3 m) with an outer seaward edge located between approximately 400 m to 1.6 km offshore. Inshore of this graded to a lagoon of mainly rubble and sand. The most prominent benthic biota on this reef were macroalgae, but sparse hard coral colonies and filter feeders were also observed.

Seagrass was not observed at any of the Vansittart Bay sites during this reconnaissance survey.

OVERALL DESCRIPTION AND PRELIMINARY MAPPING OF BENTHIC HABITATS

The data collected during the present survey were combined with the available remote sensing and bathymetric information and then professional judgement was applied to create a preliminary benthic habitat map for the survey area (Figure 5). Mangrove mapping was also augmented with spatial data collected for, and provided to, the NDT by ENV Australia. Key features of preliminary benthic habitat map are outlined below. Representative examples of the different benthic habitat categories are also shown in Appendix 1.

Assumptions have been made to create the preliminary benthic habitat map. These assumptions primarily relate to the placement of the polygon boundaries that spatially define the extent and distribution of different benthic habitats within the survey area. For habitat types such as mangroves and some reefs in shallow or relatively clear water that can be distinguished from remote sensing information, polygon boundaries were created using data collected from this survey in conjunction with aerial photography, Land Sat images and Spot satellite imagery contained in Google Earth. In deep or turbid water, boundaries have been created based on observations made during this survey and the assumption that water depth is a major driver of habitat type and distribution. Accordingly, where remote sensing information is not sufficiently resolute to spatially define habitats, survey data and observations, and bathymetric contours (where they have been created, noting large parts of the survey area are unsurveyed for water depth; see Hydrographic chart Aus 727) have considered together as the main discriminators of different benthic habitat types.

Mangrove communities are common along the shores of Napier Broome Bay. They often occur in narrow bands along rocky shorelines (Figure 5 and Appendix 1). In places the narrow banding of the mangal presented difficulties for spatially defining mangrove communities at the scale of the preliminary benthic habitat map. Hence the narrow bands of mangroves shown on Figure 5 are to be considered indicative until such time that higher resolution mapping is undertaken. In addition to the narrow fringing mangals, there are also other more dense stands of mangroves associated with tidal creek mouths and elevated intertidal rocky platforms such as around Louis Island.

From the information collected during this survey, rocky reefs that occur amongst sand are likely to be distributed broadly across intertidal and shallow subtidal zones in Napier Broome Bay (Figure 5). The extent to which these reefs are stable, or are exposed or buried over intra- and inter-annual timescales, is not known, but it is likely there would be cycles or pulses of sand inundation and erosion in the survey area. Intertidal rocks often lack a predominant macroalgal cover, however, turf algae occur on rocks in the low intertidal zone that are exposed during some parts the tidal cycle. In the subtidal zone, rocky reefs support mixed macroalgal and invertebrate communities, which in many places are dominated by a canopy of *Sargassum* (Appendix 1). As such, the nearshore subtidal reefs of Napier Broome Bay could be generally classified as algal dominated reefs with the number and diversity of coral colonies present being low, but tending to increase towards the tip of the Peninsula and in offshore shallows such as around Louis Island.

There are also broad areas of bare sand and sandy sediments that support patchy sparse to medium density communities of filter feeders. In Napier Broome Bay, it is considered that the latter habitat type is likely to occur between areas of shallow bare sand and the more sedimentary environments that appear typical of waters generally deeper than approximately 10 m.

Overall, based on the available information and knowledge of river flows it is considered that a large portion of the deeper areas of Napier Broome Bay are characterised by fine sediments that are bioturbated and support patches of filter feeder communities. Within these fine sediment habitats, filter feeders are patchily distributed and, where they occur, they are generally at sparse densities. As such, at the broadest level the dominant habitat type of the deeper waters could be generally classified as fine, bioturbated sediment with occasional sparse density filter feeding communities.

Due to the considerable spatial heterogeneity of reef substrates off the west coast of the Anjo Peninsula, limited bathymetric data and difficulties using the available remote sensing that arose from the unexpected finding that extensive areas were coral rubble and dead coral, it was considered that the classification of substrate types and biohabitats should only occur at a coarse level. As a result, almost all reefal areas off the west side of the Anjo Peninsula have been placed in the same habitat category (Reefs biogenic and non-biogenic, with sand veneers and coral rubble). There are only a few exceptions to this where notional boundaries for areas of sand and live coral reefs were created.

DISCUSSION

In view of the relatively small tidal range in the survey area and that the survey was conducted on neap tides, water clarity was expected to be higher than other areas in the Kimberley. Contrary to this expectation, water clarity was quite poor during the survey. This is likely to be due in part to the large area of fine, easily disturbed sediment observed in the deep areas of Napier Broome Bay. These fine sediments are probably transported to the Bay from the extensive catchments of the Drysdale and King Edward rivers during periods of high volume flow associated with the monsoon season and tropical cyclones in the Kimberley (~December to March). Tidal water currents and waves generated by wind and tropical storms are likely to be the main forcing agents responsible for resuspending fine sediments under natural conditions.

Although tidal amplitude is relatively small in the Anjo Peninsula area, it is possible that relatively high local tidal current velocities could be influenced by water movement driven by tidal regimes from either side of the local area. For example, spring tidal ranges in the vicinity of Jar Island (in the southern part of Vansittart Bay ~40 km south-west of Anjo Point) and Wyndham (~240 km to the east of the Anjo Peninsula) average about 2.9 m and 8 m respectively. The timing of tides also varies significantly along the north Kimberley coast and this also influences the magnitude of tidal currents. It would appear that the Anjo Peninsula area is an amphidromic point for tides in the far north-west of WA and it is possible that although local vertical movement in water height is relatively small, gravity currents driven by tidal water height variation either side of the Anjo Peninsula are still significant and where tidal water flow is constrained by narrow passages currents may accelerate, sometimes forming tidal races.

Patches of filter feeder communities are present throughout the survey area on what appear to be soft mobile sediments. This suggests that, in places, stable substrates probably underlie veneers of soft sediment. In view of this, inputs of sediments from river catchments to the marine environment may have implications for the abundance, distribution and structure of filter feeder communities, but there is insufficient information to gauge this at present. Determining whether there are relationships between filter feeder communities and sediment transport and accretion processes is a science question that warrants investigation. Similarly, the extent of any seasonality and interannual variability in these distributions could only be resolved through further investigation.

The types of algae present on rocky substrates provide an insight into whether reefs are intertidal or subtidal. Reefs covered by dense canopy-forming brown macroalgae are likely to be subtidal because macroalgae are likely to have a low tolerance to

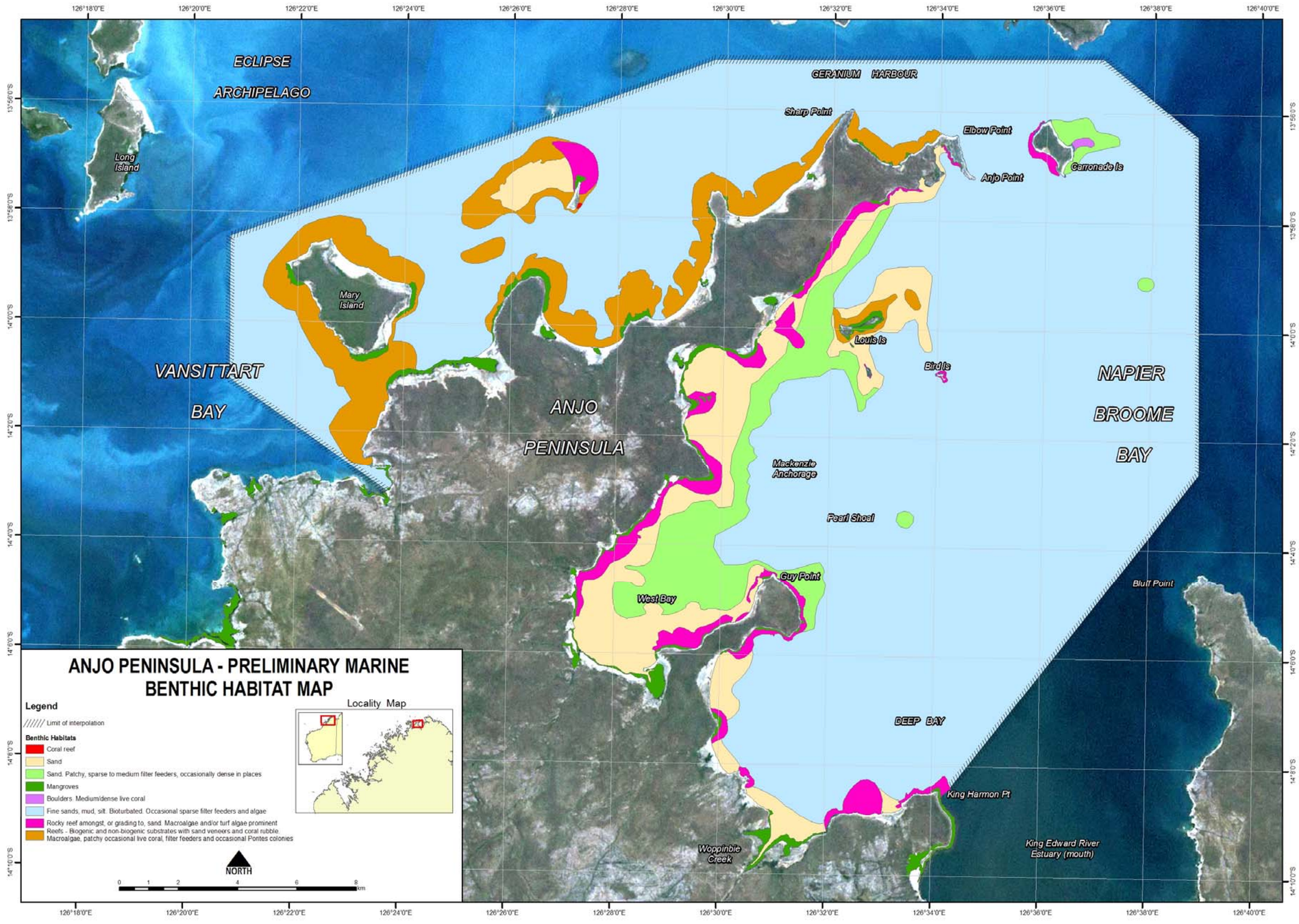

Figure 5: Preliminary marine benthic habitat map of the Anjo Peninsula area.

high air and water temperatures and desiccation that would be experienced during low tides or periods when the reefs are expose to air. It is postulated that a tendency towards a prominence of small turf algae or little obvious algal cover on reefs would suggest that reefs of this type are more likely to be exposed to air at some times during the tidal cycle.

It is important to note that the abundance of canopy-forming macroalgae such as *Sargassum* spp. varies naturally over time on Australian tropical reefs (Vuki and Price, 1994, Rogers, 1997). When a dense macroalgal canopy forms, it can obscure understorey organisms including smaller macroalgae, sessile invertebrates and coral when the habitat is viewed from above such as when using a video camera. As canopies senesce understorey communities are revealed and this may potentially alter the classification of the habitat type. Accordingly, surveys conducted at other times of the year or in other years may reveal temporal variation in the abundance of the canopy-forming macroalgae observed during this program and also lead to a modification of how the macroalgal-dominated habitats are broadly described.

The finding that subtidal reefs off the west coast of the Anjo Peninsula did not support abundant living hard coral was unexpected. While it appears that the reef formations themselves are most likely of biogenic origin, an event or series of events has resulted in considerable mortality of hard corals in this area. It is not possible to determine what would have caused the coral mortality or when this may have occurred, however there are a number of possibilities. The Anjo Peninsula is within a region that experiences severe monsoonal storms and tropical cyclones. Large ocean swells and significant inputs of freshwater to the marine environment are often associated with these extreme meteorological events. Different corals have different tolerances to the effects of physical disturbance from waves and freshwater inundation. In the shallower areas at least it appears that there have been impacts to most coral groups at reef sites immediately off the west coast if the Anjo Peninsula and Mary Island. Abundant living coral cover was largely restricted to associations with large subtidal *Porites* colonies and patches of reef offshore from the mainland towards the Eclipse Archipelago (e.g. off the un-named west coast island). It is also possible that elevated seawater temperature effects or disease may have been responsible for the observed impacts. Given the remote location and small local population it is highly unlikely that the observed impacts would have been directly associated with human activity in the area. These biogenic reefs may contain valuable Holocene environmental records.

This present survey is a preliminary reconnaissance of the benthic habitats present in the vicinity of Anjo Peninsula. The results, including the preliminary benthic habitat map, are not definitive in terms of the full suite of different benthic habitats that may be present or their spatial distributions. It is also important to recognise that the marked seasonality of the Kimberley region is also likely to be reflected as temporal variation in the abundance and distribution of marine biota. The issue of seasonality is not addressed with a single, short field program at one time of year.

It should also be noted that shipping navigation channels to service export facilities in the vicinity of Mackenzie Anchorage would need to pass by the Sir Graham Moore islands which were not surveyed during this field program. The benthic and coastal habitats of the islands and waters would need to be considered with assistance from the relevant native title claimant group(s).

If the Anjo Peninsula area is to be considered further as a potential location for a multi-user LNG processing hub, it is strongly recommended that additional work be conducted to ground truth the preliminary benthic habitat map shown in this

document and to better understand any temporal variation that may be reflected in the benthic biota of the locality. It will also be important to examine other areas in the vicinity of Anjo Peninsula to evaluate the extent to which benthic habitats and biota which occur in the Anjo Peninsula area may be represented at other locations.

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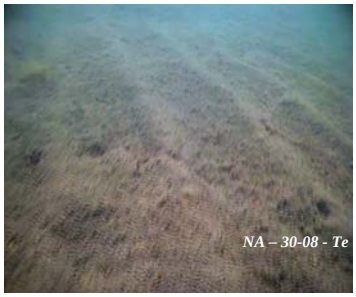
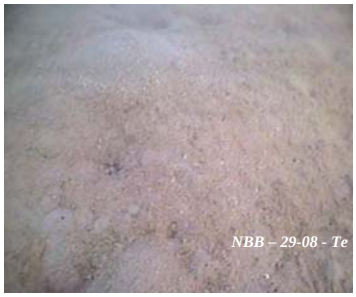
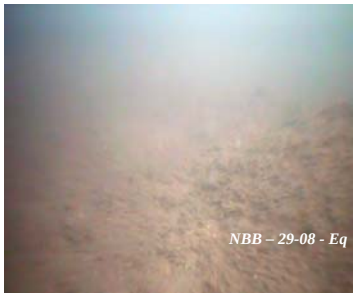
Appendix 1

Images showing representative examples of marine benthic habitats around the Anjo Peninsula

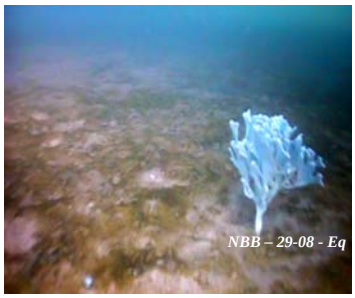
Sand

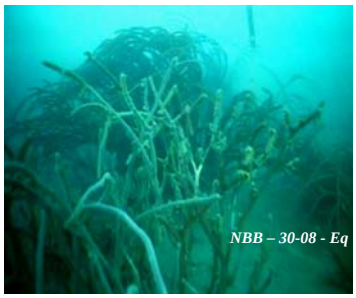




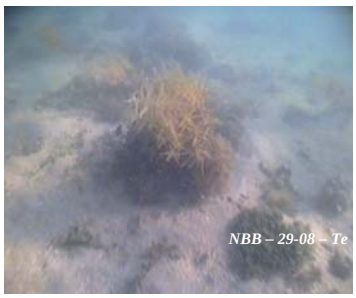


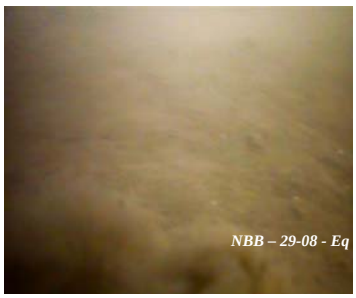
Sand. Patchy, sparse to medium filter feeders





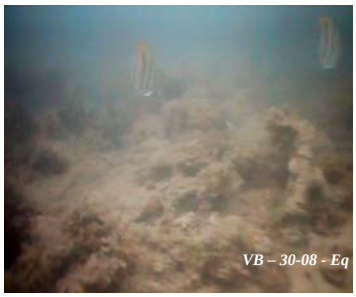
Fine sands, mud, silt. Bioturbated. Occasional sparse filter feeders and algae

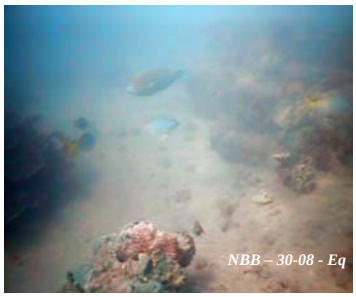




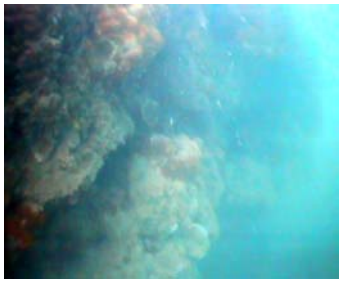
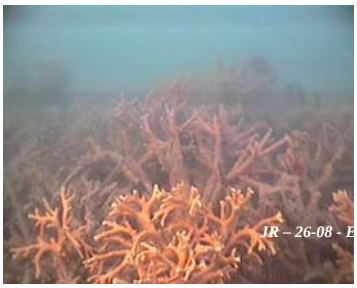
Rocky reef amongst sand. Macroalgae and turf algae prominent. Note hard coral colonies among the macroalgal community.

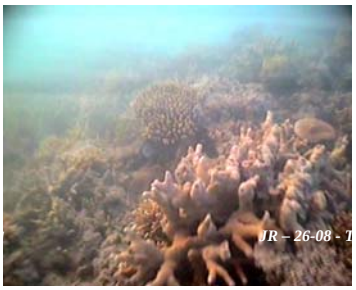
Reefs – biogenic and non-biogenic substrates with sand veneers and coral rubble. Macroalgae, patchy live coral, filter feeders and occasional *Porites* spp. colonies.





Coral reef



Boulders, medium/dense live coral