An eco-narrative of Joseph Bonaparte Gulf Marine Park – North marine region

Marine Park Eco-narrative Series

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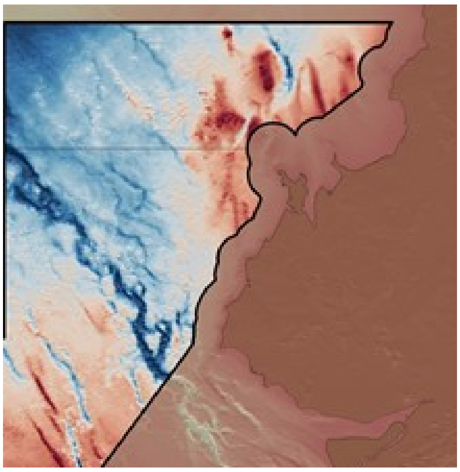
Project D1 – National data collation, synthesis and visualisation to support sustainable use, management and monitoring of marine assets

25 February 2019

Milestone 17 - Research Plan v4 (2018)
Final report on ecologically important features of selected Australian Marine Parks



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Preferred Citation

Galaiduk, R., Huang, Z., Miller, K., Nanson, R., Przeslawski, R., Nichol, S. (2018). An eco-narrative of Joseph Bonaparte Gulf Marine Park: North-west marine region. Report to the National Environmental Science Program, Marine Biodiversity Hub. 21 pp.

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Acknowledgement

This work was undertaken for the Marine Biodiversity Hub, a collaborative partnership supported through funding from the Australian Government's National Environmental Science Program (NESP). NESP Marine Biodiversity Hub partners include the University of Tasmania; CSIRO, Geoscience Australia, Australian Institute of Marine Science, Museum Victoria, Charles Darwin University, the University of Western Australia, Integrated Marine Observing System, NSW Office of Environment and Heritage, NSW Department of Primary Industries.

Important Disclaimer

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EXECUTIVE SUMMARY

This report is one in a series of eco-narrative documents that synthesise our existing knowledge of individual Australian Marine Parks. This series is a product of the National Environmental Science Program Marine Biodiversity Hub Project D1, which seeks to collate, synthesise and visualise biophysical data within the parks. These documents are intended to enable managers and practitioners to rapidly ascertain the ecological characteristics of each park, and to highlight knowledge gaps for future research focus.

Joseph Bonaparte Gulf Marine Park is representative of the broad inner continental shelf of tropical northern Australia that is influenced by seasonal river inflow, strong tidal currents and regular cyclones. This combination produces a dynamic oceanographic setting within the marine park, characterised by high turbidity, rich nutrient levels and active sediment transport. The seabed within the park incorporates incised valleys and channels, tidal sand bars, gently sloping plains and small areas of localised reef. The valleys provide bathymetric relief of up to 40 m and define the ancestral pathways of the large rivers that drain into Joseph Bonaparte Gulf, including the Ord, Victoria and Daly Rivers. These offshore valleys were last active as rivers during the last ice age (ca. 18,000 – 10,000 years ago) when global sea level was tens of meters lower than present. Today, these valleys provide a conduit for the tidal transport of terrestrial sediments, mixed with carbonate marine sands. Tidal currents also shape the sand bars, which rise up to 15 m above the seabed and extend up to 20 km offshore. Reefs are restricted to small patch reefs in the northern part of the park, where they rise to within 2-3 m of the sea surface.

Our knowledge of biological communities associated with these features is limited. By inference from other studies further offshore in the Gulf, the patch reefs are likely to support sparse sponge and soft coral communities. Similar sessile assemblages are also expected to occur along the steeper side of incised river valleys. The park intersects the known distribution area for a range of pelagic megafauna, including a variety of dolphins and turtles. However, the park is not expected to be a major area for dugong, given the lack of seagrass, and the area is too shallow for whales. With proximity to coastal estuaries, the park overlaps the known range for the endangered Northern River shark, sawfish, stingray and catfish; plus a range of demersal tropical fish species.

The park is not without environmental pressures, with evidence for a consistent trend of warming surface waters and marine heat waves which can affect the health of the ecosystem at upper trophic levels. The region is also impacted by recreational and commercial fishing activities. The former are concentrated offshore from the Ord River mouth (Cambridge Gulf), whereas the latter range across the Joseph Bonaparte Gulf targeting prawns, barramundi and threadfin salmon. All these fishing activities result in some degree of direct and indirect impacts, including bycatch of a range of fish, invertebrates, sea snakes and sea birds.

The information in this eco-narrative forms an initial characterisation of Joseph Bonaparte Marine Park.

1. INTRODUCTION

The Joseph Bonaparte Gulf Marine Park (JBG Marine Park) spans the boundary between the North-west and North marine regions and it is a part of the North Marine Parks Network. The park covers 8597 km^2 of the southern end of the Joseph Bonaparte Gulf (JBG) and spans a water depth range of 15 to 75 m. The park comprises two zones, providing two types of IUCN category VI protection: a Multiple Use zone covering 6345 km^2 in the southern and central sectors and a Special Purpose zone covering 2251 km^2 in the north and no additional zoning of higher protection levels (Figure 1). The marine communities of the park form part of the Northwest Shelf Transition provincial bioregion and Oceanic Shoals meso-scale bioregion.

The JBG Marine Park experiences some of the highest tides in northern Australia (up to 7 m) which, together with a wide intertidal zone near the park, create a physically dynamic and turbid environment characterised by a high level of primary productivity. The park acts as a Biological Important Area (BIA) for foraging of threatened and migratory marine turtles (Olive Ridley and green) and during the nesting period of flatback turtles (www.environment.gov.au). The western boundary of the marine park also overlaps a BIA for breeding of Lesser crested tern. There is one listed Conservation Value in the JBG Marine Park, a Key Ecological Feature (KEF): carbonate banks and shoals, located within the Special Purpose Zone of the park[1].

This eco-narrative provides an overview of what is currently known about the JBG Marine Park, including its oceanographic, geomorphic and biological values.

[1] The National Conservation Values Atlas and the Management Plan for the JBG Marine Park lists the carbonate banks and terraces of the Sahul Shelf as a Key Ecological Feature located within the western sector of the Joseph Bonaparte Gulf offshore from the Cambridge Gulf. However, the national seabed geomorphology map (see Figure 4) shows this feature is actually a (sea) valley. This appears to be an error in the mapping of the carbonate banks and terraces KEF.

2. PHYSICAL SETTING

Located at the southern margins of Joseph Bonaparte Gulf, the physical environment of JBG Marine Park is strongly influenced by the combined input of numerous large rivers. These include the Ord, Durack, King and Pentecost rivers that enter via Cambridge Gulf, and the Victoria, Fitzmaurice, Daly, Reynolds, Finniss, Keep, Berkeley and King George Rivers. Together, these 12 rivers supply approximately 196 million tonnes of sediment to the Gulf annually (Lees, 1992). This estimate is based on an extrapolation of the measured sediment load from the Ord River of 644 t / km^2 per year. By comparison, the Murray River in southern Australia supplies 25 t / km^2 annually (Ludwig and Probst, 1998). With this significant river input, it follows that the seabed sediments within JBG Marine Park are a mix of terrigenous (land-derived) sediments and marine carbonate sediments, with the latter comprising modern and palimpsest (reworked older) material (Van Andel and Veevers, 1967; Lees, 1992). Sampling of seabed sediments by Lees (1992) across the area of the JBG now incorporated within the park, recorded a complex pattern of mixed silt, sand and gravel of terrestrial and biogenic extending from the rivers. Further offshore, seabed sediments become silty sand and clayey sand across mostly flat to rippled seabed.

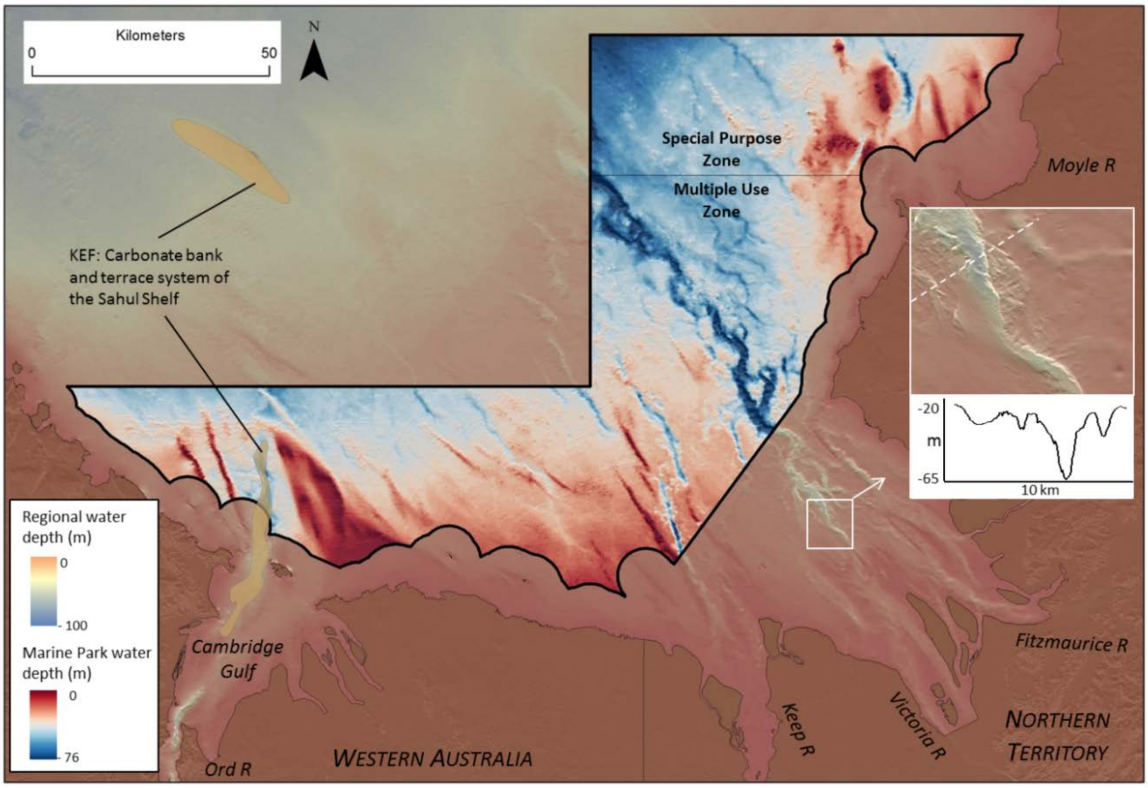

Figure 1. Joseph Bonaparte Gulf Marine Park with management zones indicated, showing hill-shaded 30 m bathymetry data (Geoscience Australia, 2018). Note different colour ramps for bathymetry within the park and outside the park. The inset image shows an area mapped by multibeam sonar to the south of the park, revealing the detail of 10 – 40 m deep channels and ancient river valleys that extend into the marine park.

The seabed within JBG Marine Park is generally flat to gently sloping, with a network of meandering to straight valleys and channels, several linear sand ridges and small patch reefs. The valleys and channels extend tens of kilometres in a northwest direction across the park, are up to 1.5 km wide and incise 30-40 m into the seabed.

3. OCEANOGRAPHY

Circulation of water and sediments within JBG Marine Park is driven by strong semi-diurnal tidal currents, with spring tidal ranges over 7 m that generate current velocities of up to 1.6 m/s on the inner shelf (Lees, 1992; Rothlisberg et al., 2005). With the large load of terrestrial sediment input, these tidal currents induce strong water column mixing and sediment resuspension, which results in higher turbidity (e.g., suspended sediment concentrations in excess of 100 mg/l) and enhanced nutrient levels across the park (Figure 2; Lees 1992). In fact, the JBG Marine Park has the highest mean turbidity value among all Australian Marine Parks (Figure 2b).

The surface waters in JBG Marine Park are characterised by very high primary productivity. The long-term annual mean surface chlorophyll-a concentrations range from 0.6 - 27 mg/m^3, with a mean of 6.45±5.13 mg/m^3 (Figure 2a); winter levels are often higher than other seasons (http://northwestatlas.org/node/27500). While these values are among the highest for the Australian Marine Park network, they are likely over-estimates due to the dissolved and suspended materials brought in by rivers and the contamination of the MODIS satellite signal by bottom reflectance for shallow water areas (Rothlisberg et al., 2005). Therefore, the chlorophyll-a values in waters less than 20 m deep should be interpreted with caution.

The ambient wave climate of the JBG Marine Park is characterised by locally generated wind waves under the influence of persistent east to southeast trade winds. This sets up anti-clockwise circulation within the southern gulf that flows at a rate of about 0.5 m/s and supplements tidal mixing (Lees, 1992). In addition, modelling results indicate that the mean flows of the seasonal circulation are relatively weak in the park (Rothlisberg et al., 2005). The park is also affected by tropical cyclones, which generate waves and currents that can have destructive impacts on the shallow marine environment, particularly the patch reefs in the shallow waters of the JBG Special Purpose zone. Cyclone-generated waves can also scour the seabed, generating elevated levels of suspended sediments and reduced light availability (Dufois et al., 2017). In the last 50 years, 23 tropical cyclones have crossed the JBG Marine Park, the most recent of which was Category 2 Tropical Cyclone Kelvin in February 2018 (BOM).

Since 2002, satellite remote-sensing (MODIS) derived sea surface temperatures (SST) within JBG Marine Park display a clear warming trend at an annual rate of 0.048^{o} C (Figure 3a). This rate is slightly above the overall average across all Australian Marine Parks (0.043 ± 0.02 ^{o}C) (Figure 3b). According to the SST Atlas of Australian Regional Seas (SSTAARS) (Wijffels et al., 2018), which is based on 25 years (1992-2016) of AVHRR SST data, the decadal warming rate in the park is 0.305^{o}C. The park is also impacted by marine heat waves, with the most recent being an unprecedented event in 2015-16 (Figure 3c), which was forced by a record El Nino event (Zhang et al., 2017; Le Nohaic et al., 2017). The 2015-16 marine heat wave started during summer (Figure 3c & d), and continued well into spring (Figure 3c). The event peaked in June 2016 when SST reached 3.0 ^{o}C above average across the entire park (Figure 3c & d).

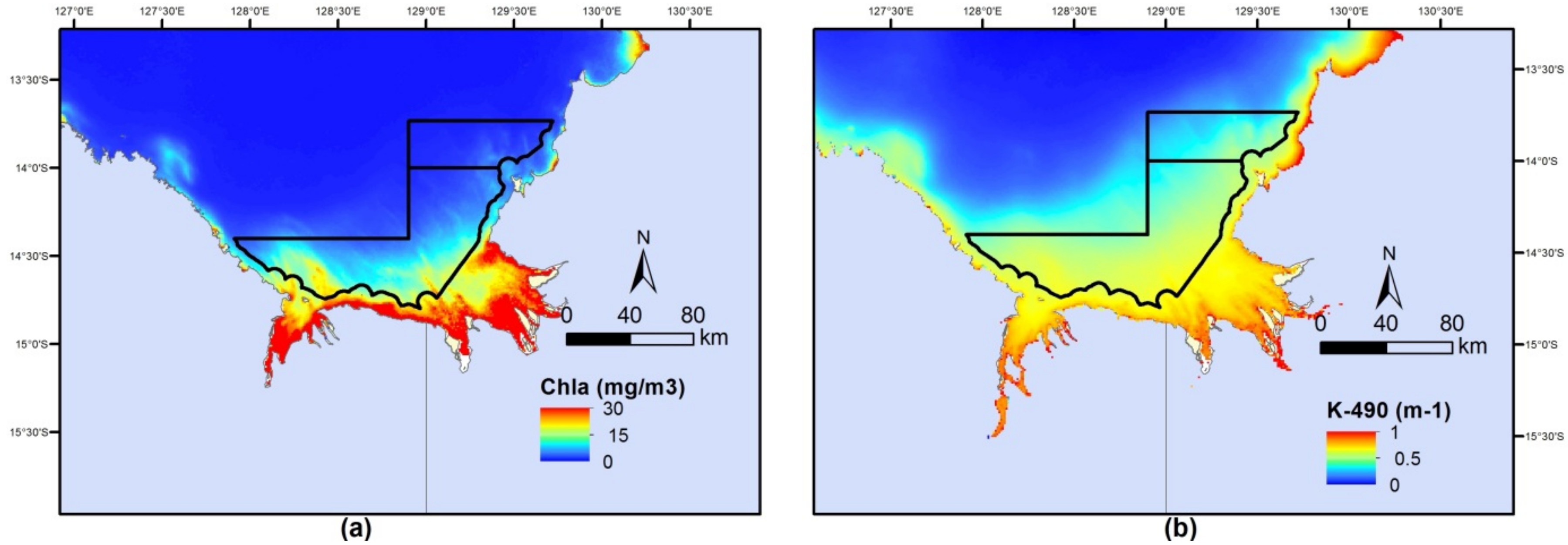

Figure 2: Sea surface properties across JBG Marine Park derived from MODIS satellite imagery for the period 2003 to 2017, showing: a) Mean annual chlorophyll-a concentrations (6.45±5.13 mg/m3); b) Mean annual K490 as a proxy for turbidity (0.196±0.034 m-1).

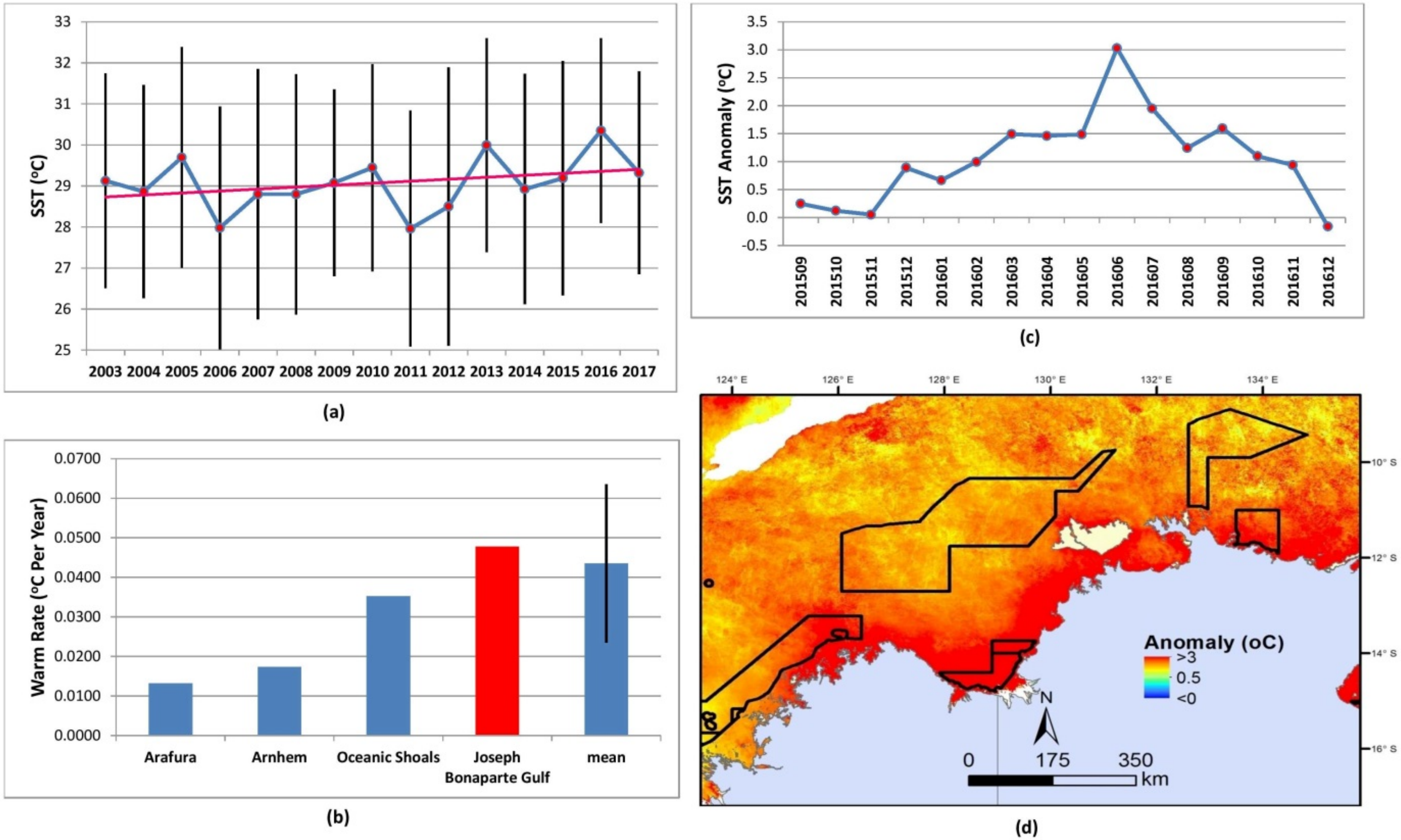

Figure 3: Sea Surface Temperature (SST) within JBG Marine Park, derived from MODIS satellite imagery for the period 2003 to 2017, showing: a) Annual average (blue line) and standard deviation (vertical bars); b) Warming rate (ºC per year) for JBG Marine Park and three other marine parks in the north region against the national mean (and standard deviation) for all marine parks; c) Monthly SST anomalies from the long-term average during the 2015-16 marine heat wave event; d) SST anomaly map for the marine heatwave of June 2016.

4. GEOMORPHOLOGY AND POTENTIAL HABITATS

The regional-scale geomorphology of JBG Marine Park is dominated by a low-gradient shelf, however, NW-oriented deeps/holes/valleys, tidal-sand waves and sand banks, also characterise the area (Heap and Harris, 2008; Figure 4). The valleys appear to be the seaward continuation of modern river channels, including the Victoria, Keep and Fitzmaurice rivers. As such, they are relict (inactive) features that record the exposure of the inner gulf as a coastal plain between 18,000 and 9000 years ago when sea level was 120 to 20 m lower than present (Yokohama et al., 2001). In contrast, the 10 to 20-km long linear sand and gravel ridges that form King Shoals and Medusa Bank Shoals rise up to 15-20 m above the surrounding seabed and are the product of modern tidal currents (Lees, 1992; Clarke and Ringis, 2000). The influence of tidal flows on distributing river sediment is also evident in the progradation (seaward extension) of a lobe of terrigenous sand that extends from the southern shore of the gulf, across the park and further into the gulf (Lees, 1992). The small patch reefs in the north-east of the park rise from depths of 10-20 m to within 2-3 m of the sea surface, and are therefore well within the photic zone. These reefs are, however, limited in extent and number, and cover areas <1 to 5 km^2. The majority of these reef features are located within the Special Purpose Zone at the northern end of JBG Marine Park (Figure 4).

A new seafloor mapping scheme (Nanson and Nichol, 2018) has been applied to the 30 m resolution bathymetry grid, which covers 100% of JBG Marine Park (Geoscience Australia, 2018). By linking the seafloor morphology to geomorphic process and substrate we can provide assessment of the potential habitats in the park. The seafloor is divided into two slope categories that represent broad habitat settings: 99.6% of the park area is classed as low gradient *Plane (*<2°) and 0.4% as *Slope* (2-10°) (Figure 4). While *Plane* Surfaces dominate most of the park, closer inspection reveals that the *Slope* Surfaces define the edges of the deeps/holes/valleys, and potentially provide locally rare but important habitat for sessile organisms adjacent to the valleys that probably function as conduits for high-energy tidal flows and nutrients.

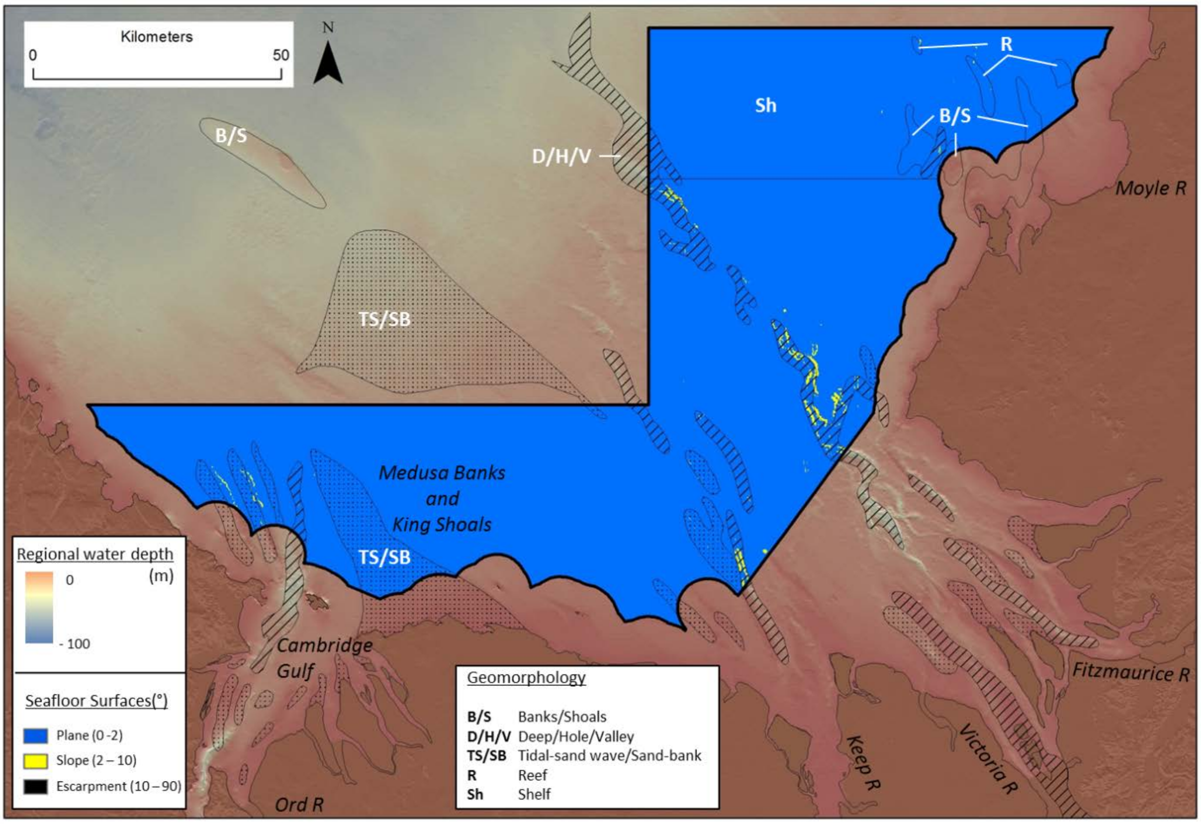

Figure 4. Seabed geomorphic features in JBG Marine Park and adjacent area (after Heap and Harris, 2008). Finer-scale features were mapped using a new 30 m bathymetry grid (Geoscience Australia, 2018) and classified as seafloor surfaces - Plane (99.6%), Slope 0.4%) and Escarpment (0.0%). While much of the JBG Marine Park area is characterised by low gradient Plane, steeper Slope surfaces border the Deeps/Holes/Valleys that traverse the park.

5. THE ECOLOGICAL SIGNIFICANCE OF JOSEPH BONAPARTE GULF MARINE PARK

The physical characteristics of the region have been reasonably well described, but the biological communities of this remote marine park are poorly understood. Most of the synthesis that follows is extrapolated from research and surveys performed in the broader Joseph Bonaparte Gulf (JBG) and draws on additional knowledge of the entire Northwest Shelf region.

5.1 Pelagic fauna

5.1.1 Megafauna

A number of whales, dolphins and porpoise species have broad distributions along north-west Australia, and these areas overlap with the JBG. In general, most of the whale species are pelagic migrants and are likely to transit through the offshore areas of the JBG especially during winter months on their way to calving grounds (Humpback whales) in the Kimberley (Bannister et al. 1996). However, sightings of whales are often restricted to deep waters and are very unlikely to be encountered in the JBG Marine Park.

A number of widely distributed dolphins occur in the coastal areas of JBG, including the Irrawaddy dolphin (*Orcaella brevirostris*), the spotted bottlenose dolphin, Risso's dolphin (*Grampus griseus*), the Indo-Pacific humpback dolphin (*Sousa chinensis*) and the pantropical spotted dolphin (*Stenella attenuate*). The Australian snubfin dolphin (*Orcaella heinsohni*), which was only recently described as a species new to science and may be endemic to Australia, uses the shallow water of the gulf as its feeding and breeding grounds (Thiele 2008). Among all these, only the Australian snubfin dolphin was previously observed in the northern part of the JBG Marine Park but others may occur inside the park (Kyne et al. 2018).

Dugongs (*Dugong dugon*) are not abundant in the JBG Marine Park due to lack of seagrass, but there were previous anecdotal sightings near the shallow seagrass patches along the eastern coastal boundary of the JBG and the eastern part of the marine park (Przeslawski et al. 2011, Kyne et al. 2018).

5.1.2 Turtles

There are no direct observations of turtle activities inside the JBG Marine Park (www.ala.org.au), however, five species of sea turtle have distributions that overlap the JBG and may occur in the marine park. Loggerhead (*Caretta caretta*), flatback (*Natator depressus*) and hawksbill (*Eretmochelys imbricate*) turtles are known to migrate and/or feed in the reef habitats and around the pinnacles on the mid-shelf of the gulf (Brewer et al. 2007a, Donovan et al. 2008). The mid-shelf is also a BIA foraging area for Olive Ridley (*Lepidochelys olivacea*) and green (*Chelonia mydas*) turtles, in areas foraging depths are less than 14 m (Whiting et al. 2007). In addition, a distinct genetic stock of flatback turtles is known to inhabit the gulf and adjacent areas of the North Marine Region and is likely to use greater JBG region including the adjacent marine park during nesting season (Limpus & Fien 2009; www.environment.gov.au).

5.1.3 Shore and Seabirds

Shorebird colonies in the JBG are typically distributed around most of the coastal areas which are considered to be of international significance for migratory shorebirds in the East Asian Australasian Flyway migration corridor (http://www.birdlife.org/). With exception of the Lesser crested tern (*Thalasseus bengalensis*), whose breeding area is known to overlap the western boundary of JBG Marine Park, shore birds are not expected to be found inside the marine park (http://www.environment.gov.au/webgis-framework/apps/ncva/ncva.jsf).

The distribution of a variety of seabirds extends into the gulf, with breeding colonies typically located on offshore islands or mainland beaches. Seabirds include various tern and booby species, lesser frigate bird (*Fregata areil*), the silver gull (*Larus novaehollandiae*) and the common noddy (*Anous stolidus*) are expected to be observed in the JBG Marine Park (Chatto 2001).

5.1.4 Fishes and sharks

Limited information is available about the fish and shark communities of the JBG region. However, it is reasonable to expect that the richness and evenness measures of the most common demersal fish assemblages are similar to those found in comparable habitats in north-western Australia (Dunstan & Foster 2010). A meta-analysis of historical datasets obtained by CSIRO from Soviet trawling expeditions around Australia in the 1960s and 1970s clearly identified a convergence of two tropical bioregions - Northwest Shelf and the Gulf of Carpentaria - in the general area of the JBG region (Koslow et al. 1999). To this day, this is the most comprehensive fishery dataset for this region. They identified that the dominant species in the Northwest Shelf were a suite of five lutjanids and the spangled emperor (*Lethrinus nebulosus*). The dominant species in the Gulf of Carpentaria assemblage was yellow-striped trevally (*Selaroides leptolepis*). Several species were common in both areas, such as the lizardfish(*Saurida gracilis*), rough flutemouth (*Fistularia petimba*) and one-band sea-perch (*Lutjanus vitta*) (Koslow et al. 1999).

Studies of the bycatch of the JBG prawn trawl fishery which operates outside the JBG Marine Park demonstrated that this region has high levels of endemism in its demersal fauna (Brewer et al. 2007b, Tonks et al. 2008). Based on these data, the five most common bycatch teleost species in the JBG are largehead hairtail (*Trichiurus lepturus*), blackfin threadfin (*Polydactylus nigripinnis*), smooth croaker (*Johnius laevis*), hairfin anchovy (*Setipinna tenuifilis*), and threadfin scat (*Rhinoprenes pentanemus*). The most common bycatch elasmobranch species in the JBG is the brown stingray (Tonks et al. 2008).

Anecdotally, sharks and catfish are common in coastal estuaries and offshore locations of the JBG. The endangered Northern River shark (*Glyphis garricki*) is known to occur in a few large tropical rivers, coastal habitats and macrotidal embayments in the Northern Bioregion (Pillans et al. 2009). Based on a recent meta-analysis of distribution patterns of this species (Kyne et al. 2018) they may occur inside the JBG Marine Park. In addition, green sawfish (*Pristis zijsron*), dwarf sawfish (*P. clavata*) and largetooth sawfish (*P. pristis*) all have distribution ranges which overlap the JBG Marine Park and may occur inside the park (Kyne et al. 2018). Furthermore, the breeding grounds of green sawfish are likely overlappinging the southern boundary of JBG Marine Park.

Until recently, the Kimberley Gillnet and Barramundi Fishery operated in the JBG region outside the Marine Park targeting barramundi (*Lates calcarifer*) and threadfin salmon (*Eleutheronema tetradactylum*) around estuaries in the JBG (Fletcher & Santoro 2018). The outer shelf habitats support small fisheries (mainly use trap and line) targeting deep water snapper (*Pristipomoides* spp), emperors (*Lethrinus* spp), snappers (*Lutjanus* spp) and other fishes. Other existing fisheries in the region are Northern Demersal Scalefish and the Joint Authority Northern Shark fisheries.

The JBG prawn fishery has become an important component of the Northern Prawn Fishery (NPF) in the past 10 years. It catches red-legged banana prawns (*Penaeus indicus*) and large volumes of bycatch outside the marine park (predominantly squid, bugs and scampi followed by sea snakes, rays, sawfish and sharks) (Brewer et al. 2007b, Fletcher & Santoro 2018). The reported catch of the banana prawn for 2017 is 5069 tonnes and the stock is deemed as not overfished and not subject to overfishing due to very low levels of effort, but the biomass was assessed as uncertain due to a lack of fishing effort in 2015 and 2016 (http://agriculture.gov.au).

A large proportion of the total recreational fishing effort in the Commonwealth Waters of this region occurs from private recreational fishers travelling from the Ord River mouth in the southern part of the JBG. Overall, the recreational fishing pressure is limited, though chartered mothership operations and cruising yachts occasionally access the various sandbanks, offshore islands and reefs throughout this entire region (RecfishAustralia 2010).

A primary threat to the biodiversity of the JBG region is associated with direct or indirect impact by fishery activities (i.e. bycatch of demersal fishes, invertebrates, elasmobranchs, sea snakes and seabirds), particularly those species dependent on specific habitat types (e.g. reef-associated organisms), or those with narrow range tolerances (sawfishes and river sharks). Sea snakes are regularly caught as bycatch in the NPF, while the mortality rate of turtles has been shown to decline since the mandatory use of Turtle Exclusion Devices was introduced in 2000 (Poiner & Harris 1996, Ward 1996). There are varying levels of documented bycatch across 195 taxa from 85 families including some vulnerable, threatened and protected species (Tonks et al. 2008).

5.1.5 Sea snakes

Sea snakes are very common in subtropical and tropical Australian waters and occupy a wide range of habitats and water depths, extending offshore from the coast to the reefs and banks. Although there is only a single specific occurrence in the JBG Marine Park (spine-bellied seasnake *Hyrdophis hardwickii*), there are at least two dozen known occurrences adjacent to the Marine Park (www.ala.org.au). Sea snakes are therefore expected to be common in the park, with as many as fifteen species which are known to occur in the Northern Territory (Storr et al. 1986). The composition of sea snake species in the JBG region include the commonly found ones around the north coast and in the NPF including the elegant sea snake (*Hydrophis elegans*), olive-headed sea snake (*H. major*), spine-bellied sea snake (*H. curtus*), small-headed sea snake (*H. mcdowelli*), and horned sea snake (*H. peronii*). However, because of such little work being within the marine park itself, it might not reflect the true diversity of snakes in that region (V. Udyawer pers. comm.).

5.2 Benthic fauna

Large expanses of sandbanks and plains are very common seabed types in the inner JBG, which includes the JBG Marine Park, and includes tidal sand bars (Carroll et al 2012). The sediment plains and banks are not biologically barren zones, however, as they support diverse infaunal communities. These communities play a key ecological role by contributing to nutrient cycling and sediment turnover (bioturbation) at the local scale. Sessile epifauna generally occurs only as isolated individuals on hardground banks and rocky outcrops, such as in the northern part of the park. Similarly, consolidated sediments along the edge of channels and valleys support a low abundance of macrofauna such as crustaceans and echinoderms (Przeslawski et al. 2011).

5.2.1 Corals

There are at least 11 records of scleractinian corals in the JBG Marine Park (www.ala.org.au), but few reef-forming corals have been found in the JBG, apart from small patches located near intertidal rock platforms (Clarke et al. 2001). A notable exception is isolated small branching hard corals (possibly *Stylophora pistillata*) recorded scattered around the outer JBG (Przeslawski et al. 2011).

5.2.2 Sponges

There has been no targeted study of sponges in the JBG Marine Park, although sponges from the nearby Oceanic Shoals Marine Park have been well-studied (Przeslawski et al 2015). Sponge diversity and abundance increase on raised geomorphic features in neighbouring regions of the JBG (Przeslawski et al. 2014). Due to the low number of banks and other features, sponge gardens are therefore unlikely to be common in the JBG Marine Park.

5.2.3 Other benthic fauna

Diverse infaunal communities have been characterised in the surrounding JBG but not within the marine park. Based on these studies, polychaete communities within the JBG Marine Park are likely different than the outer JBG and Timor Sea (Przeslawski et al 2018).

Pockmarks in the sediment may be indicative of fluid/gas seepage which can provide habitat to abundant or distinctive benthic fauna (Wasmund et al. 2009). They are widely distributed throughout the JBG (George & Cauquil 2010) including north of the marine park (Carroll et al 2012) but have not yet been reported within the park. Pockmark density is negatively correlated with polychaete species richness in the western Oceanic Shoals Marine Park (Picard et al 2018), but it is unknown if this same pattern exists in the JBG Marine Park.

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