National Environmental Science Programme

An eco-narrative of Geographe Marine Park – South-west 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

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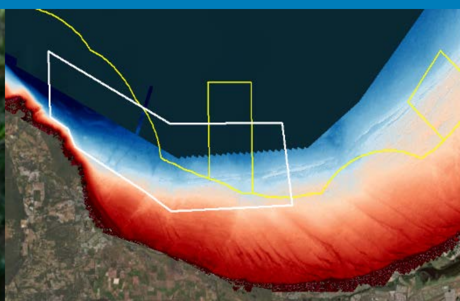
Final report on ecologically important features of selected Australian Marine Parks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Important Disclaimer

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EXECUTIVE SUMMARY

This report is one in a series of eco-narrative documents that synthesise our existing knowledge of Australia's individual 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.

Geographe Marine Park contains areas of high biodiversity and benthic productivity, although much of the Marine Park has not been surveyed. The Park contains some of the largest continuous seagrass meadows in Australia. These act as feeding, breeding, resting and nursery grounds for migratory and threatened seabirds, whales and numerous fish species. Because seagrass communities are particularly susceptible to changes in water quality, they are under constant threat from a range of potential stressors. These include an increase in human population on the adjacent coastline, high levels of regional nutrient flow from runoff, growth in tourism, recreational and commercial fishing, introduced marine pests, and global climate change. While our existing knowledge of these threats is insufficient to detect the full extent of current impacts or to predict future ones, an overall loss in the shallow water seagrass cover from 2004 and 2007 has occurred. The information in this eco-narrative collates all the existing information to form an initial characterisation of Geographe Marine Park to help better understand its ecosystem structure. However, most of our knowledge of ecosystems in the marine park are those based on seagrass. We know very little about other ecosystems, particularly deeper offshore habitats which represent approximately 50% of the marine park.

1. INTRODUCTION

The Geographe Marine Park is a part of the south-west network of Australian Marine Parks. It is located within and adjacent to Geographe Bay which is approximately 200 km south of Perth. Geographe Marine Park covers 977 km^2 and ranges in depth from 15 m to 70 m (Beeton et al., 2015). Activities in the Geographe Marine Park are regulated by four types of zones: Marine National Park Zone (IUCN Category II – 36 km^2), Special Purpose Zone (IUCN Category VI – 650 km^2), Habitat Protection Zone (IUCN Category IV) and Multiple Use Zone (IUCN Category VI -291 km^2; Figure 1).

Conservation values of the Geographe Marine Park include two Key Ecological Features (KEFs; www.environment.gov.au):

1. *Commonwealth marine environment within and adjacent to Geographe Bay*.
2. *Western Rock Lobster*.

These KEFs recognise the high benthic productivity and high biodiversity of a wide variety of fish and invertebrates that are supported partially or throughout their entire life history by the extensive seagrass meadows within Geographe Bay (Barnes et al. 2008), as well as the important habitat for western rock lobster (Chubb et al. 1989, MS Council 2012). The marine park also acts as feeding, resting, breeding and nursery area for a number of migratory and threatened seabirds, and is located within the migratory pathway of humpback and blue whales.

A combination of marine flora and fauna from the South-West and the Leeuwin-Naturalist bioregions is found in the Geographe Marine Park. South-West Australia is a recognized global hotspot of endemism for fish, corals, snails and lobsters (Roberts et al., 2002). Inshore from the Marine Park in Geographe Bay is the second most extensive seagrass meadow in Western Australia. This extends into the Geographe Marine Park to form one of the largest continuous seagrass beds recorded in Australia (Walker et al. 1987, Kirkman & Walker, 1989). These seagrass meadows extend further into the Geographe Marine Park than is the case for any other Commonwealth Marine Park (http://www.environment.gov.au/topics/marine/marine-reserves/south-west/geographe). This eco-narrative provides an overview of the current knowledge of the geomorphic, oceanographic and biological values within Geographe Marine Park.

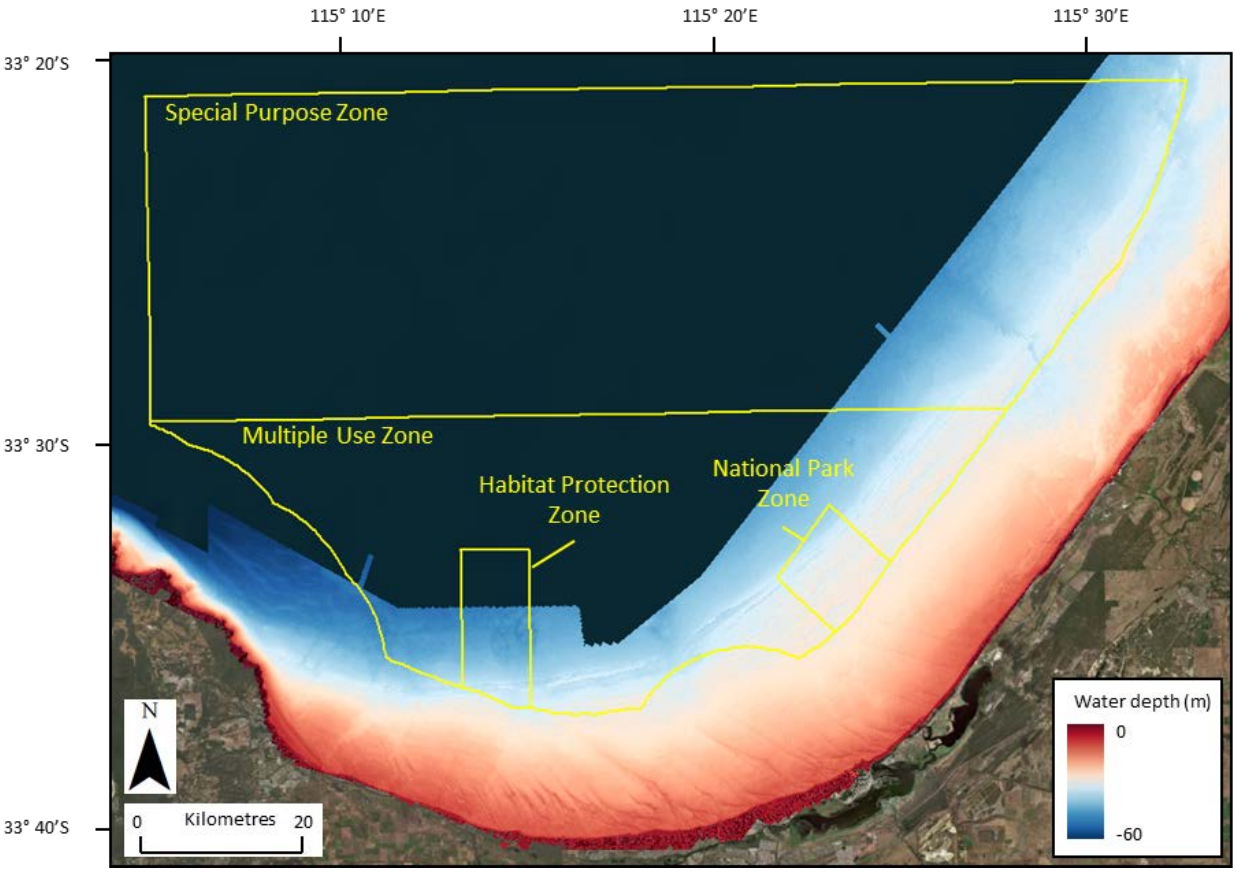

Figure 1: Map and bathymetry (5 m grid) of Geographe Bay with the yellow outline indicating the Geographe Marine Park boundary and internal zoning of the park. The coastal waters of Geographe Bay are part of Ngari Capes Marine Park which is overseen by the Department of Biodiversity, Conservation and Attractions of Western Australia.

2. PHYSICAL SETTING

The majority of the Geographe Marine Park seafloor is covered by a veneer of unconsolidated Holocene sediments deposited over shallow, eroded Pleistocene clay and limestone formations which dip gently seawards (Paul & Searle, 1978). These limestone formations tend to be long and narrow, creating bands of hard substrate surrounded by unconsolidated sediments. Inside the Marine National Park Zones, approximately 40% of the area is reef or mixed reef and sand, while in the combined Multiple Use and Special Use Zones approximately 20% of the sites fall into these categories, which are exposed at the surface in various positions throughout the bay (Lawrence et al., 2016). The number of small rocky reefs increases with distance from shore and depth (Barnes et al. 2008). Reefs are spread through the entire marine park with a concentration found in and around the eastern National Park Zone and the southern portion of the Multiple Use Zone (Figure 1 and 5).

3. OCEANOGRAPHY

Geographe Marine Park is located inshore of the Leeuwin Current and thus is deprived of direct influence from this southward flowing warm waters (Figure 2). The weakened influence of the Leeuwin Current in this region limits the import of propagules and larvae into Geographe Bay from northern source populations. A fine-scale analysis of coastal waters in Geographe Bay (0-50 m) revealed areas of high larval retention potential (England et al., 2009) which could influence the recruitment, settlement and development rates of the local sessile assemblages (Smale, 2012). Instead, the park is affected by the Capes Current, a seasonal summer counter-current that flows northwards along the inner shelf from Cape Leeuwin to the north of Perth (Pearce & Pattiaratchi, 1999).

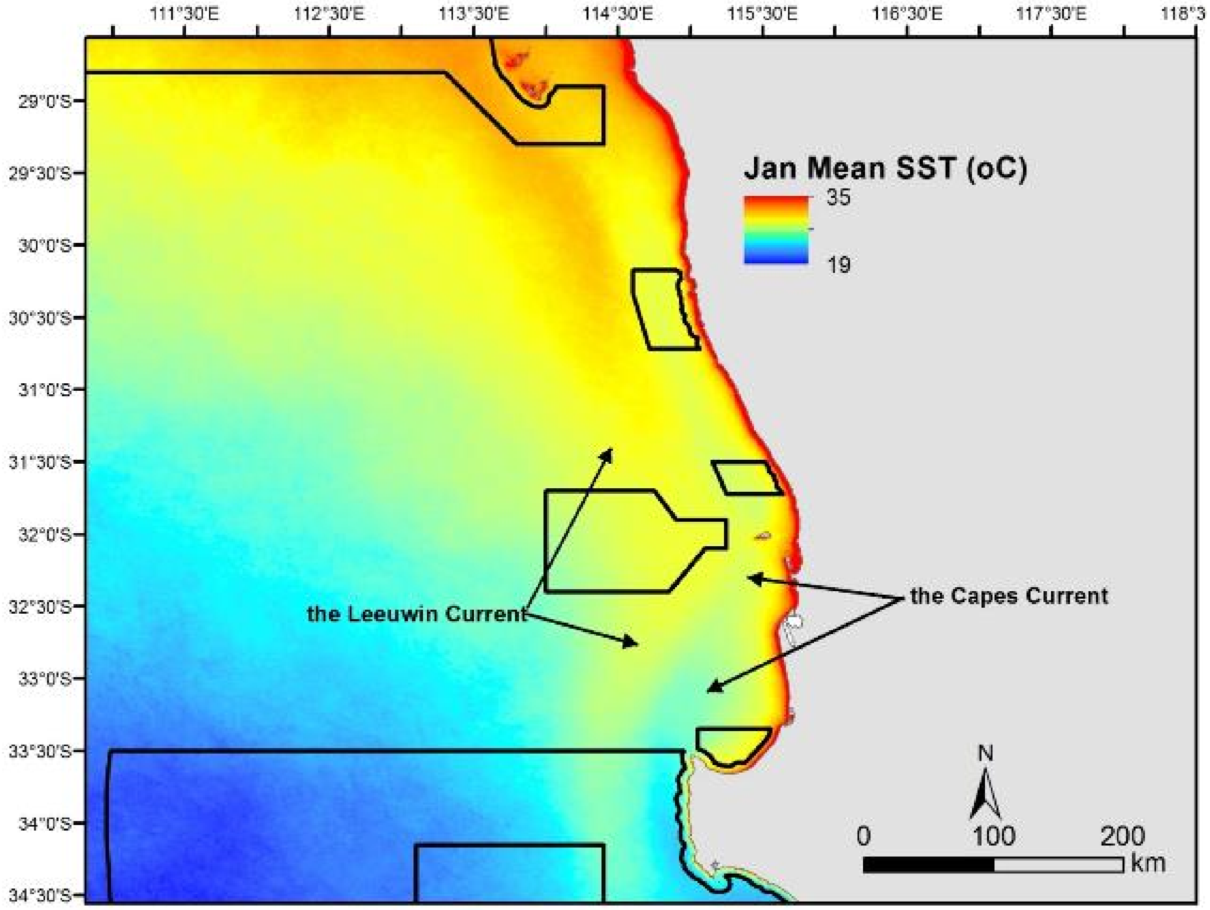

Figure 2: Mean SST for January, derived from MODIS satellite imagery between 2003 and 2016. The locations of the southward-flowing Leeuwin Current and the seasonal (summer) Capes Current are indicated.

In contrast to the warm Leeuwin Current, the Capes Current delivers cooler waters that are sourced from the base of the Leeuwin Current and driven by persistent and strong southerly winds during summer (Gersbach et al., 1999). Due to the oligotrophic nature of the Leeuwin Current, nutrient enrichment within the Capes Current is limited (Gersbach et al.,1999, Hanson et al., 2005). However, because of abundant light input during the summer months, this limited nutrient enrichment still raises primary production, leading to localised productivity hotspots in the shallow part of the Marine Park located in the euphotic zone (< 20 m depth) and on surface waters (Hanson et al., 2005). This enhanced productivity can be seen in the near coastal part of the maps of sea surface chlorophyll-a concentration derived from satellite imagery (Figure 3).

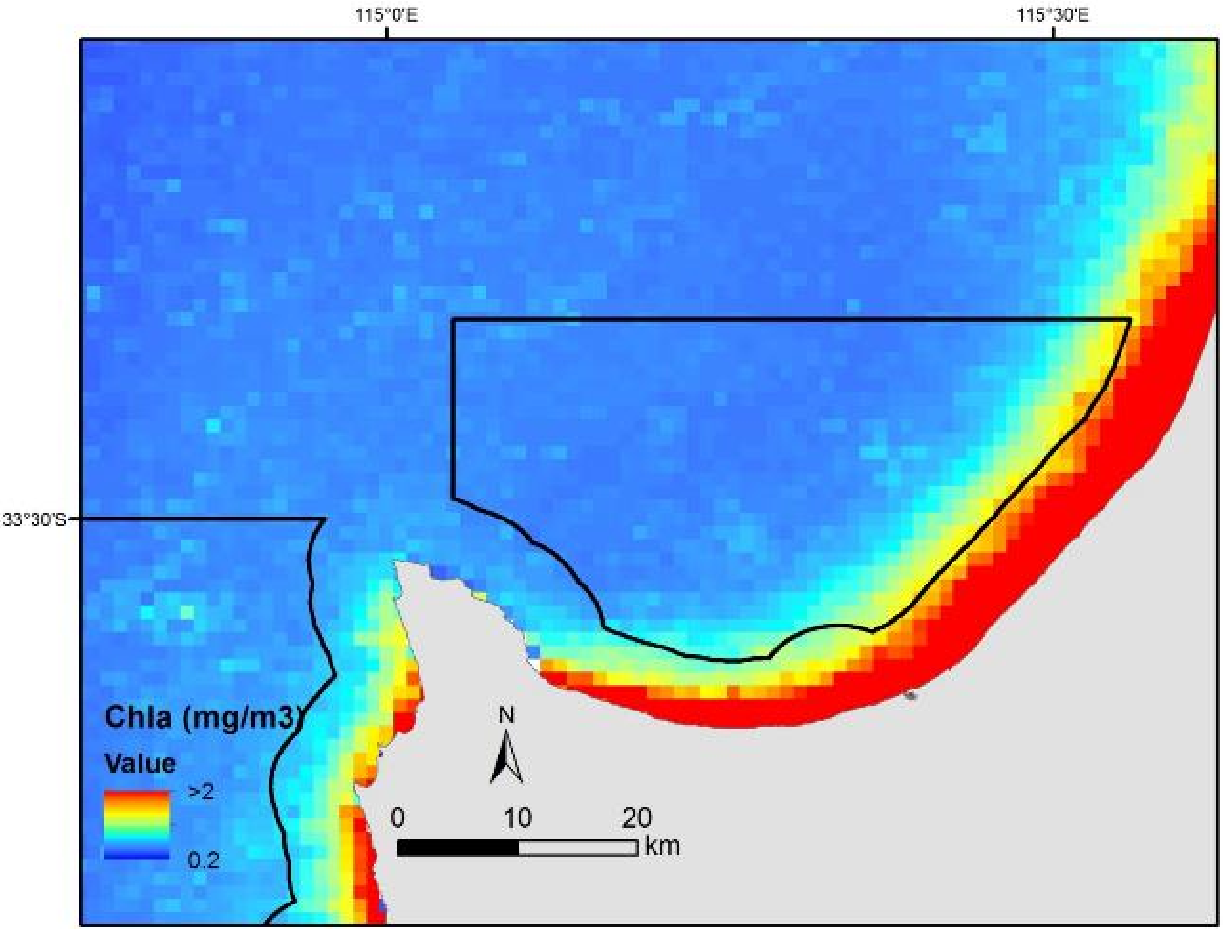

Figure 3: Mean annual chlorophyll-*a* concentrations over the Geographe Marine Park, derived from MODIS satellite imagery for the period 2002 to 2016. The long-term annual mean is 0.56±0.19 mg/m^3, ranging from 0.4 – 1.2 mg/m^3; with winter and autumn levels typically twice those in summer and spring. This overall mean is the highest among the marine parks in the south-west region and at the higher end nationally

The overriding influence of the Capes Current on the pelagic communities of Geographe Marine Park is to facilitate the recruitment, movement, and feeding of some of the iconic commercial and non-commercial species of Western Australia. These include the West Australia salmon (*Arripis truttaceus*), western rock lobster (*Panulirus cyganus*), pilchard (*Sardinops sagax*), Australian herring (*Arripis georgianus*) and tailor (*Pomatomus saltatrix*) (Gersbach et al., 1999; Pearce & Pattiaratchi, 1999; Hanson et al., 2005; Pattiaratchi, 2007).

Rising sea surface temperatures across the Geographe Marine Park may periodically harm marine fauna and flora. Since 2002, sea surface temperatures within the marine park warmed at an annual rate of 0.06 ^{0}C, based on satellite remote sensing data (Figure 4a). This rate is higher than the overall average across all Australian marine parks (0.046 ± 0.02 ^{0}C) (Figure 4b). In addition, marine heat waves can also affect the marine park, such as the unprecedented event in 2011 (Figure 4a), which was forced by La Nina conditions (Feng et al., 2013; Pearce & Feng, 2013). The 2011 event produced an SST anomaly of > 1.5 ^{0}C that lasted about three months from February to April (Figure 4c&d). Fish kills and sightings of iconic species - such as whale sharks and manta rays - outside their normal range, were reported after the 2011 event (Pearce & Feng, 2013). In addition, heatwaves can represent a significant threat to seagrass meadows by potentially causing steep declines in shoot abundance of the important seagrass species (Marba & Duarte, 2010). Although the impact of the marine heatwave event on the health of the temperate communities in the marine park was not directly quantified (Smale & Wernberg, 2013, Wernberg et al., 2013), investigation into effects of rising sea surface temperatures and extreme climatic events on the marine communities of the region should be included in future studies, given that the frequency and intensity of heatwaves due to La Niña is predicted to double in the future (Cai, 2006).

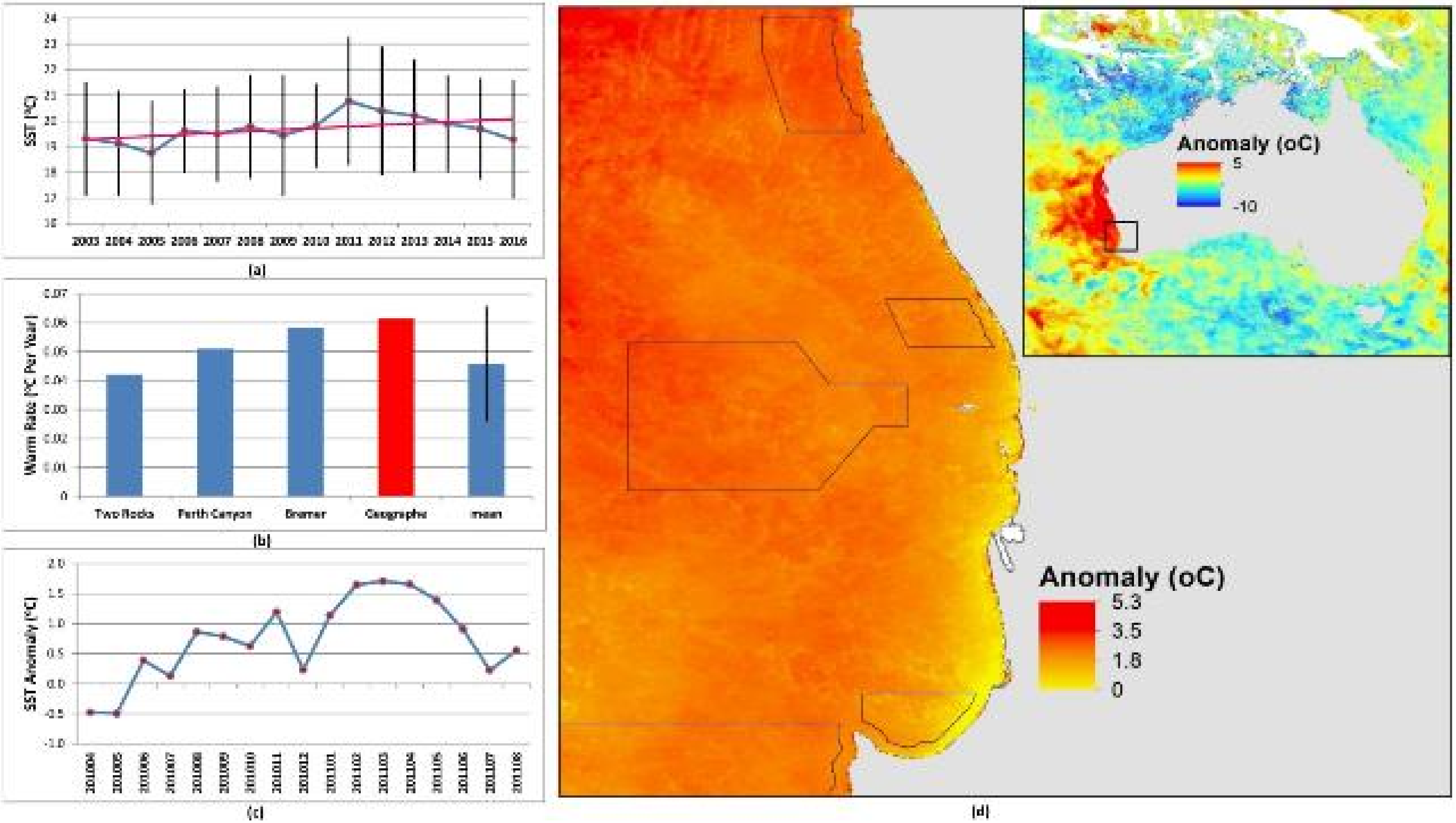

Figure 4: Sea Surface Temperature (SST) trends within Geographe Marine Park, showing: a) Annual average for 2003-2016 with standard deviation indicated by bars; the pink solid line indicates the linear warming trend; b) Warming rate (ºC per year) for Geographe Marine Park and three other marine parks in the south-west region against the national mean for all marine parks; c) Monthly SST anomalies in the Geographe Marine Park during the 2011 marine heat wave event; d) SST anomaly map for the marine heatwave of February 2011.

Geographe Bay is micro-tidal and experiences a predominantly diurnal fluctuation of up to to1.2 m. The daily tidal range varies biannually, however, with solstice tidal peaks occurring around December– January and June–July, producing a monthly tidal range that is about 20% higher than during equinoctial troughs during February–March and September–October (Fahrner & Pattiaratchi, 1994). Upwelling generally does not occur, and nutrient levels within the bay are largely dependent on terrestrial inputs (Lenanton et al., 1991).

South-west swells are refracted around Cape Naturaliste and arrive at different sections of the Western Australian coast with varying heights and angles. Geographe Bay is well protected from these swell waves by Cape Naturaliste, with gradually increasing exposure from south to north (Fahrner & Pattiaratchi, 1994). The swell waves typically have periods of 10 – 14 s while the wind waves are short-crested with periods of 5 - 10 s. Wave direction is strongly dependent on wind direction. Geographe Bay is well exposed to these waves during north-westerly winter storms or cyclonic events. Wind wave heights can become quite large during winter but are generally less than 1 m in summer (Fahrner & Pattiaratchi, 1994). The water column is well mixed with little stratification. Water temperature varies from 21.6 ^{0}C and 14.8 ^{0}C (McMahon et al., 1997) and salinity varies between 33.1 and 37.2 $^{0}/_{00}$ (Water Corporation of Western Australia, 2003).

4. GEOMORPHOLOGY AND POTENTIAL HABITATS

Only 25% of the Geographe Marine Park is represented by high resolution (5 m grid) bathymetric data (www.planning.wa.gov.au; http://matrix-prod.its.uwa.edu.au/marinefutures/research/project), and such data are restricted to the shallow portions of the park closest to the coast (Figure 1). The area covered by multibeam survey also has detailed habitat maps produced as part of the Marine Futures biodiversity survey (http://matrix-prod.its.uwa.edu.au/marinefutures/research/mapping).

A new seafloor mapping scheme (detailed in Appendix 1), designed to harness the predictive potential of detailed seafloor data, has been applied to the 5 m bathymetry dataset within the marine park. Across the mapped area, the seafloor divides into two slope categories that represent broad habitat settings (termed *Morphological Surfaces*): 99.6% is classed as low gradient *Plane* of < 2° and 0.4% as *Slope* of 2-10° (Figure 5).

These extensive low gradient (*Plane*), sandy substrates are colonised by seagrass beds, which extend into relatively deep waters of the park (up to 40–50 m) where sufficient light remains available for photosynthesis (Walker et al., 1987; Barnes et al., 2008). The linear reefs are interpreted as remnants of an ancient coastline (Paul & Searle, 1978). The steeper flanking *Slope* Morphological Surfaces provide hard, rocky substrates in the south-western region of the park that are suitable for colonisation by primarily *Sargassum* and *Ecklonia* (Lawrence et al., 2016). Morphological Surfaces can thus provide useful predictions of potential habitat, and more extensive bathymetric surveys will assist in understanding the extent of these habitat types within the park.

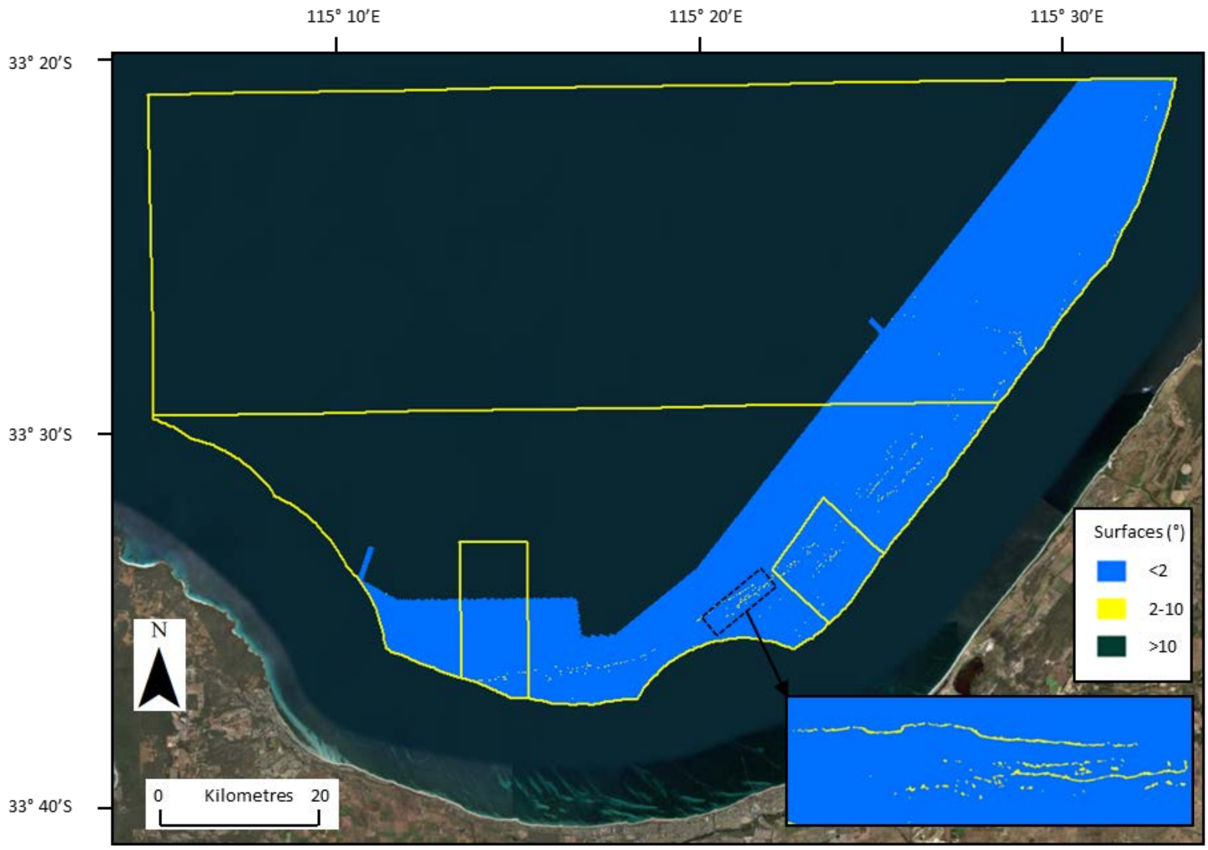

Figure 5: The surveyed portion of Geographe Marine Park has predominantly low gradient seafloor (*Plane*: 99.6%), with moderate gradient *Slope* (0.4%) Morphological Surfaces highlighting the rocky ridges marking ancient coastlines aligned subparallel with the modern shoreline. There are no steep (Escarpment) Morphological Surfaces.

5. THE ECOLOGICAL SIGNIFICANCE OF GEOGRAPHE MARINE PARK

High productivity, rich aggregations of marine life, and high levels of biodiversity and endemism of benthic and mobile marine fauna are found within the Geographe Marine Park (Barnes et al., 2008; Lawrence et al., 2016). The distribution of linear reefs (Figure 6a-c) is likely to have important ecological implications for fishes, invertebrates and algae in the surrounding seagrass meadows. For example, the abundances of fish species such as Maori wrasse (*Ophthalmolepis lineolatus*), western king wrasse (*Coris auricularis*), black-spotted parrotfish (*Austrolabrus maculatus*) and black-headed puller (*Pempheris klunzingeri*) were correlated with the presence of rocky reefs or proximity to the rocky reef edges associated with the Cape Naturaliste area adjacent to the marine park boundaries (Barnes et al., 2008; Galaiduk et al., 2017; Figure 6d).

Figure 6: Linear reefs are found in Geographe Bay and in the western part of National Park zone (a-c) which have a significant influence on occurrence and abundance of associated fish species such as endemic Western King wrasse (*Coris auricularis*; d)- top-right side) and Maori wrasse (*Ophtalmolepis lineolatus*; d)- left side of the image). Images courtesy of Fish Ecology Lab at Curtin University.

The nearshore sandy substrate of Geographe Bay is colonised by extensive seagrass beds, extending into relatively deep waters (up to 40–50 m) and into the Marine Park with almost half of recently surveyed sites within the Marine National Park Zone characterized by dense (> 50% cover) seagrass cover (Lawrence et al., 2016). *Amphibolis antarctica* and *Posidonia sinuosa* are the dominant seagrass species in the Geographe Marine Park (Figure 7a-b). Both of these seagrass species form continuous meadows at depths up to 35 m inside and outside the Marine Park, with patches of reef and another seagrass species, *Amphibolis griffithii*, increasing in occurrence with distance from shore and depth (Barnes et al., 2008). Macroalgae, primarily of the genera *Sargassum* and *Ecklonia*, was also found on hard, rocky substrates in the offshore regions of the bay, overlapping the south-western region of the Geographe Marine Park (Lawrence et al., 2016; Figure 7c-d).

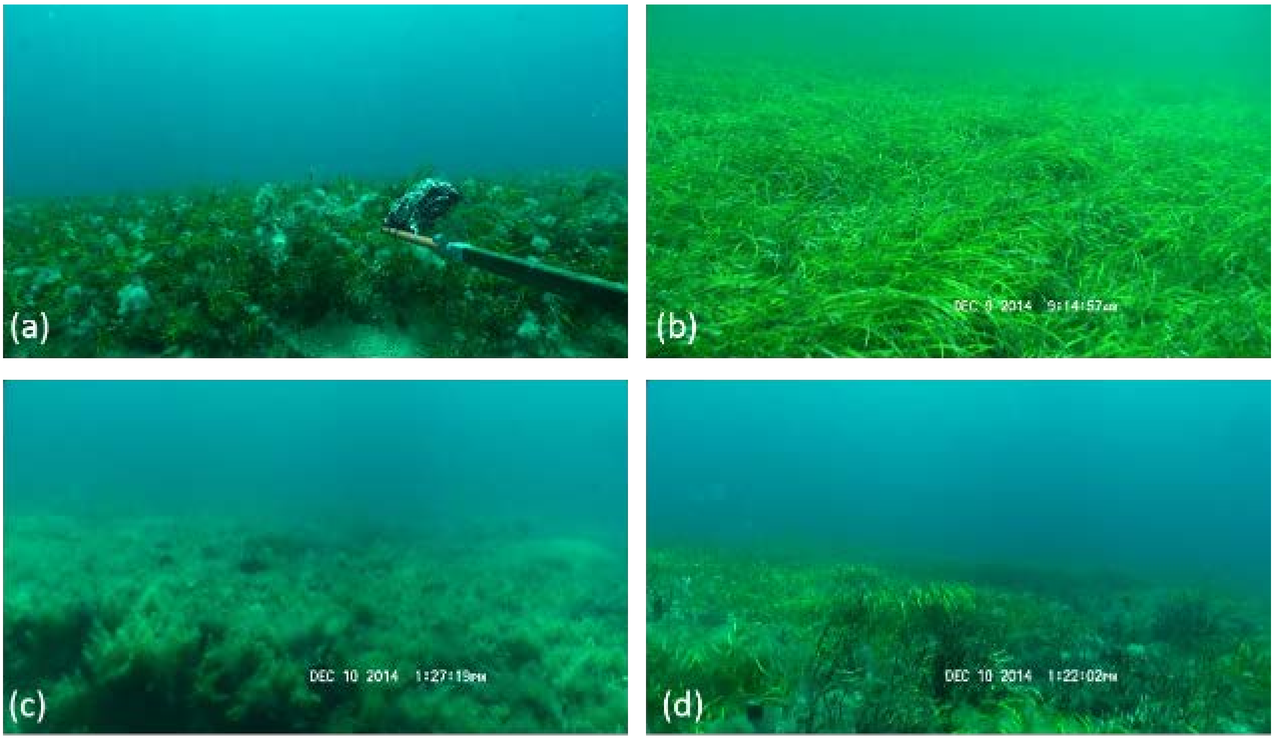

Figure 7: Seagrass meadows of *Amphibolis antarctica* (a) and *Posidonia australis* (b) could be found across Geographe Bay and the Geographe Marine Park extending to depths of up to 50 m, making this region second only to Shark Bay for seagrass extent. Hard substrates are often covered with various species of macroalgae such as Sargassum spp. (c) or *Scaberia agardhii* (d). Images courtesy of R. Galaiduk and the Fish Ecology Lab at Curtin University.

There are a number of recognised threats to the local seagrass communities from the population growth and tourism which are predicted to result in reduced water quality due to inputs of nutrients from residential and agricultural areas (Barnes et al. 2008). These run-offs can cause excessive growth of epiphytic algae and shading of seagrass leaves (Kendrick et al. 2002). Rising seawater temperatures, frequent heatwaves and changing water chemistry due to climate change are also suggested stressors for the seagrasses in Geographe Bay

(Barnes et al., 2008; Wernberg et al., 2013). A previous report that mapped the change in seagrass cover in the shallow waters of Geographe Bay documented a loss of approximately 768 ha of seagrass cover between 2004 – 2007 (Van Niel et al., 2009). It is not clear, however, what proportion of documented canopy loss can be attributed to the aforementioned factors.

5.1 Pelagic fauna

5.1.1 Cetaceans

Geographe Bay is an important seasonal migratory habitat for the protected humpback (*Megaptera novaeangliae*) and pygmy blue whales (*Balaenoptera musculus brevicauda*; Salgado Kent et al., 2011). The high prevalence of acoustic noise from vessel traffic in this region could affect the capacity of the migrating whales to communicate with each other and perceive important cues in their environment (Salgado Kent et al., 2012).

5.1.2 Seabirds

Despite numerous species occurring in globally significant breeding colonies throughout the continental islands of southwestern Australia (Dunlop & Wooller, 1990; Surman & Wooller, 2003), minimal research has examined the pelagic seabirds that are likely to use the Geographe Marine Park. Geographe Bay is recognised as an important foraging area for threatened soft-plumaged petrel (*Pterodroma mollis*) as well as important pre-migration aggregation area for the migratory flesh-footed shearwater (*Puffinus carniepes*) and migratory wedge-tailed shearwater (*Puffinus pacificus*; http://www.environment.gov.au/topics/marine/marine-reserves/south-west/geographe).

5.1.3 Sea turtles

Leatherback (*Dermochelys coriacea*) and loggerhead (*Caretta caretta*) turtles are the predominant turtle species found in south-western Australian waters, with both species caught in low numbers but regularly by trawlers, netters and cray fishermen in Geographe Bay (Elscot & Bancroft, 1999; Limbourn & Westera, 2006; Figure 8a). This area is potentially the southernmost foraging ground for these species (Elscot & Bancroft, 1999). Some green turtles (*Chelonia mydas*), a stranding hawksbill turtle (*Eretmochelys imbricata*) and juvenile endemic flatback turtles (*Natator depressus*) have also been found in the region (www.ala.org.au; Elscot & Bancroft, 1999).

5.1.4 Fishes and sharks

Geographe Bay provides important habitat for a number of limited-range endemic fish species as well as commercially and economically valuable species, including important nursery habitat for many shelf species (e.g. dusky whaler sharks use the shallow seagrass habitat as nursery grounds for several years before ranging out over the shelf to adult feeding grounds along the shelf break; DEWR 2006). According to Lawrence et al. (2016), there were 148 species of fish recorded in the Geographe Marine Park using baited camera systems. The fish assemblages of Geographe Bay were unique in their composition in comparison to other assemblages in south-west Australia (Galaiduk et al., 2017). The composition of the fish assemblages differed between sand, seagrass, and reef/algal habitats. The most abundant species were Western king wrasse (*Coris auricularis*), Footballer sweep (*Neatypus obliquus*), Silverbelly (*Parequula melbournensis*), Rough bullseye (*Pempheris klunzingeri*), trevallies (*Pseudocaranx* spp) and Yellowtail horse mackerel (*Trachurus novaezelandiae*) with majority of these species showing preference for mixed habitat (Lawrence et al., 2016; Figure 8b-d).

A number of flathead (*Platycephalus* spp) and whiting (*Sillago* spp) species were mainly found in bare sand habitat. Southern goatfish (*Upeneichthys vlamingii*) was mainly found in seagrass habitat (Lawrence et al., 2016). A recent study by Galaiduk et al. (in press) found that juveniles and mature adults of iconic fishes targeted by commercial and recreational fisheries are extensively utilising Geographe Bay during their lifecycle. Using spatial modelling techniques, they demonstrated that juvenile individuals of Baldchin groper (*Choerodon rubescens*) and Australasian snapper (*Chrysophrys auratus*), as well as mature adults of West Australian Dhufish (Glaucosoma hebraicum), are closely associated with shallow areas of the bay with high structural complexity habitats. In contrast, juveniles of Dhufish are more likely to be found in deep water areas with high complexity relief (Figure 8e-f). They also predicted the western part of the bay to be a hotspot for the cumulative abundance of these species. Currently, greater Geographe Bay area is considered the southern limit of distribution of WA endemic Baldchin groper (Cure et al., 2015). A number of sharks and rays have been observed inside and near the Geographe Marine Park as well as one species each of octopus, cuttlefish, squid and crab (Figure 9).

The South West Trawl Managed Fishery (SWTMF) which covers Geographe Marine Park, includes two of the state's smaller scallop fishing grounds—Fremantle and north of Geographe Bay (WAFIC, 2015). It is a multi-species fishery including scallops (*Amusium balloti*), western king prawns, mixed whiting species, blue swimmer crabs and other mixed fish. Good scallop landings were taken in 1990 and 2010, but catches are generally low due to variability in recruitment (Sporere et al., 2014). The SWTMF is a gear-based managed fishery with a total of 13 operating licences. This is seen as a comparatively small, low-activity fishery in which effort is related to the abundance of scallops in any given year, which can be highly variable which, in turn, affects its operations from year to year (Kangas & Zeller, 2014).

Recreational fishing is a common activity in coastal waters of Geographe Bay and located primarily in nearshore protected waters outside of the Geographe Marine Park. Some degree of inshore (20 – 250 m depth) recreational fishing activities of demersal (West Australian dhufish and pink snapper) and pelagic fish species are still known to occur within the Marine Park (Fletcher & Santoro, 2018). It is estimated that approximately 23% and <1% of recreational boat-based fishing effort in the entire West Coast Region is associated with the inshore demersal and pelagic fishing respectively (Ryan et al., 2017).

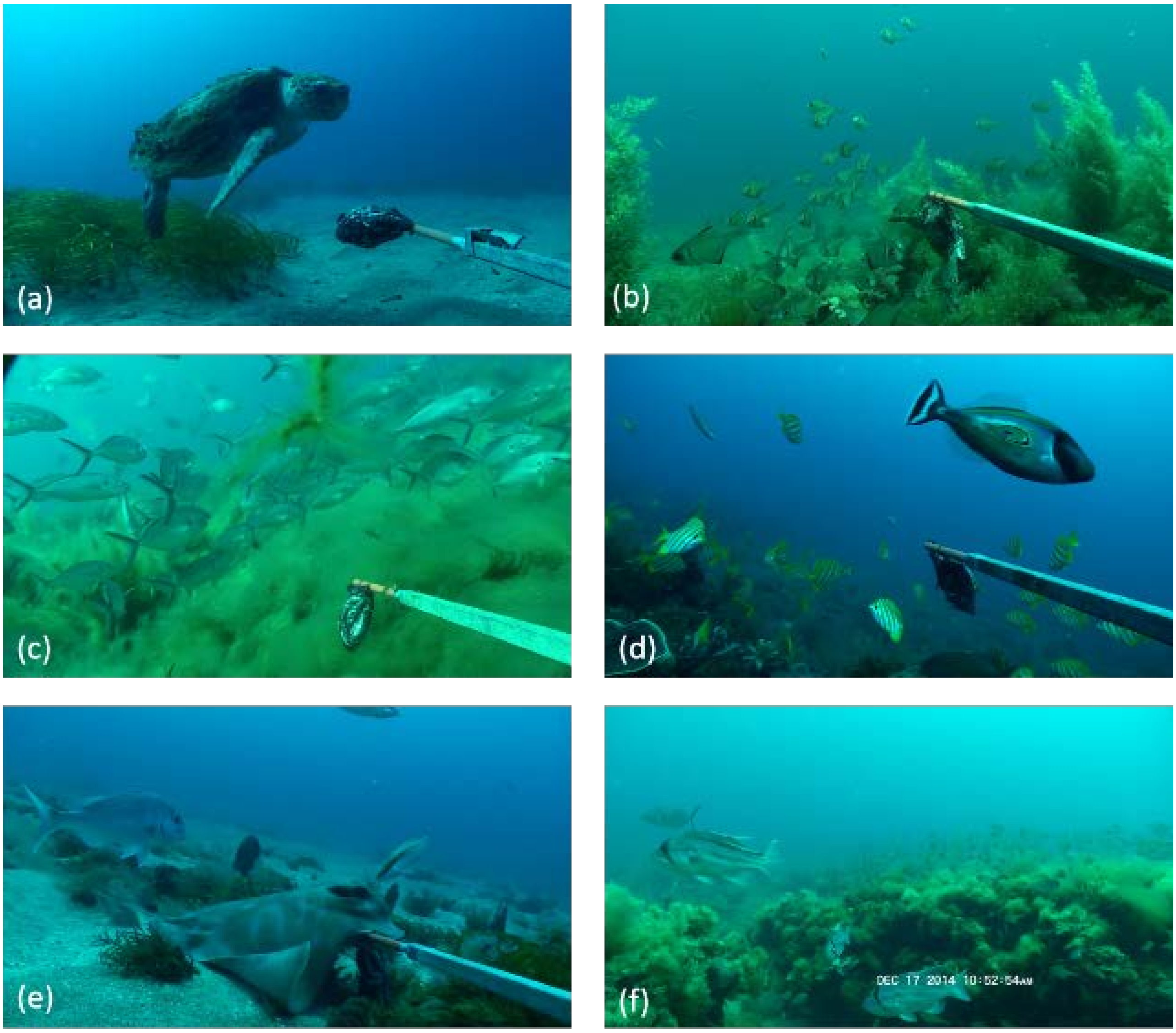

Figure 8: Examples of fauna commonly observed in and around Geographe Marine Park. (a) Loggerhead turtle (*Caretta caretta*); (b) Rough bullseye (*Pempheris klunzingeri*); (c) a school of trevallies from *Pseudocaranx* genus; (d) an endemic Horseshoe leatherjacket (*Meuschenia hippocrepis*, front) and a school of endemic Footballer Sweeps (*Neatypus obliquus*-background); (e) Australian bull ray (*Myliobatis australis*, front) and iconic Australasian snapper (*Chrysophrys auratus*, left); (f) iconic West Australian Dhufish (*Glaucosoma hebraicum*). Images courtesy of the Fish Ecology Lab at Curtin University.

Figure 9: Examples of sharks, rays and other mobile fauna that have been observed within and near the Geographe Marine Park: (a) Tiger shark (*Galeocerdo cuvier*); (b) Mako shark (*Isurus oxyrinchus*); (c) Smooth hammerhead (*Sphyrna zygaena*); (d) Short-tail stingray (*Dasyatis brevicaudata*); (e) Southern fiddler ray (*Trygonorrhina dumerilii*, front) and Shovelnose ray (*Aptychotrema vincentiana*, back); (f) Circular Stingaree (*Urolophus circularis*); (g) Squid (*Loligo* spp.); (h) Curious cuttlefish pair (*Sepia* spp.); (i) Octopus (right) meets fiddler ray. Images courtesy of the Fish Ecology Lab at Curtin University.

5.2 Benthic fauna

Very little research data exist on the abundance and distribution of benthic organisms in Geographe Marine Park, as most studies have targeted the nearshore areas of Geographe Bay. The main groups of invertebrates previously identified throughout Geographe Bay include sponges, ascidians, corals (hard and soft), sea stars, hydroids, bryozoans, gastropods, bivalves and sea urchins (Figure 10). Fourteen species of coral (Veron & Marsh, 1988), one zoanthid, seven species of sea star, one sea urchin, one sea cucumber, twelve species of ascidians, seventy-two sponge species, and two large molluscs – the bivalve, *Pinna bicolo*r and the gastropod, *Campanile symbolicum* have been recorded from Geographe Bay (Barnes et al., 2008). The sea stars, urchin and sea cucumber belonged to the species typically observed in seagrass meadows in temperate Australia (Storrie et al. 2003; Coleman, 2007). The sessile invertebrates could be found attached to seagrasses, in the sediment and attached to hard substrata. A recent study concurred that sponges were more common than all other invertebrate groups and were mostly found on hard, rocky substrates in the offshore regions of the bay, overlapping the south-western region of the Marine Park, and along the north-east coast (Lawrence et al., 2016). Since most of the sponges (> 90%) in previous studies could not be identified to the species level, it is likely that some of them will be unique for Geographe Bay and new species yet to be named by science (Barnes et al., 2008).

Figure 10: Some of diverse benthic fauna that have been observed inside and adjacent to Geographe Marine Park: a-c) High diversity of sponges forming extensive sponge gardens; d,e) corals; f) solitary ascidian *Polycarpa viridis* was the most abundant ascidian recorded in the Geographe Bay area; g) Biscuit sea star (*Tosia australis*); h) Red sea star (*Pentagonaster dubeni*); (i) sea cucumber Stichopus mollis. Images courtesy of Ronen Galaiduk, the Fish Ecology Lab at Curtin University, the South West Catchment Council and Mark Westera.

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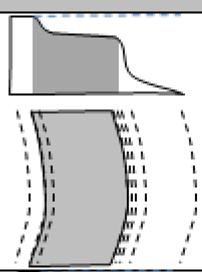
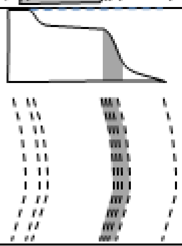
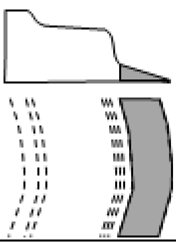
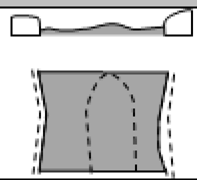
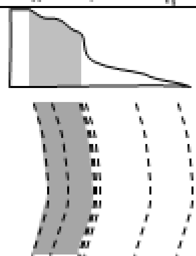
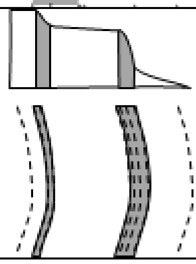
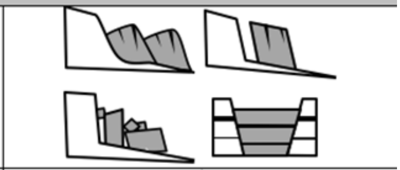
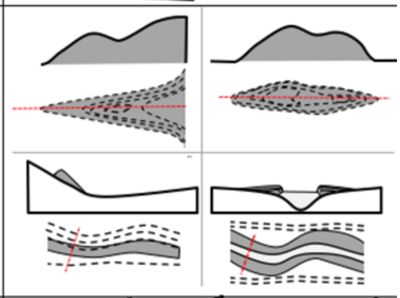
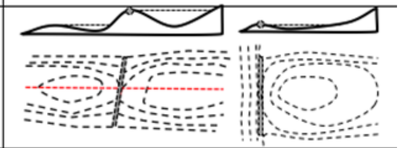
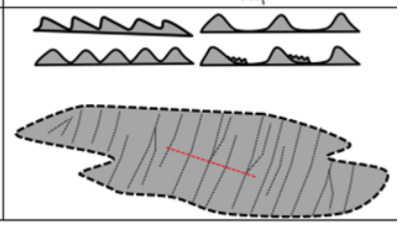
APPENDIX A

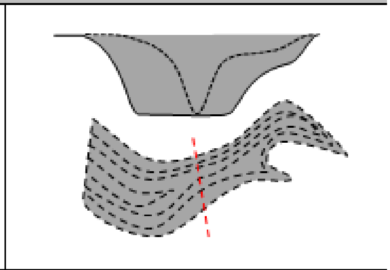
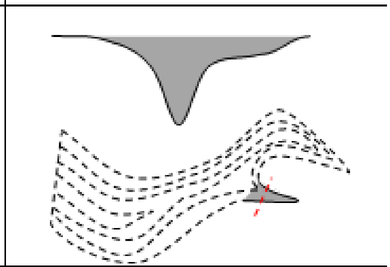
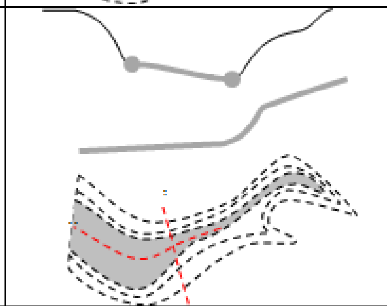
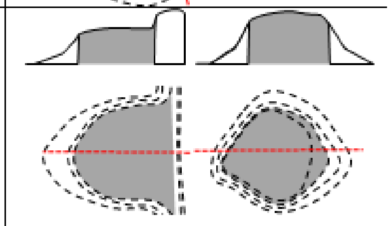
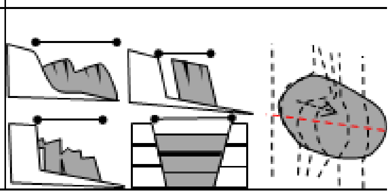
Geoscience Australia is currently developing a new seabed geomorphology classification that draws on the Harris et al. (2014) geomorphic map of the world's oceans, and Dove et al. (2016) two-part system for classifying seafloor morphology. This system enables morphological mapping of the seafloor, with extension of the approach to interpretations of seafloor geomorphology where and when data is sufficient for detailed geomorphic interpretation. Table A.1 illustrates examples from the suite of Provinces, Surfaces and Features. Figure A.1 illustrates the semi-hierarchical structure of the scheme.

Table A.1: A sample of the morphological units defined for the seabed mapping scheme (mapping units and their definitions are modified from: Heap & Harris 2008; Harris et al., 2014; Dove et al. 2016: http://nora.nerc.ac.uk/; https://www.iho.int; and https://www.cmecscatalog.org). Figure 4 illustrates the application of the "Surface" class to Geographe Marine Park.

Provinces	
Shelf (continental)	
Continental Slope	
Rise	

Surfaces	
Plane	
Slope	
Escarpment	

Features (highs)	
Block	
Ridge	
Sill (line)	
Bedform (field)	

Features (lows and other)	
Canyon	
Tributary-canyon	
Floor	
Platform	
Mass movement	

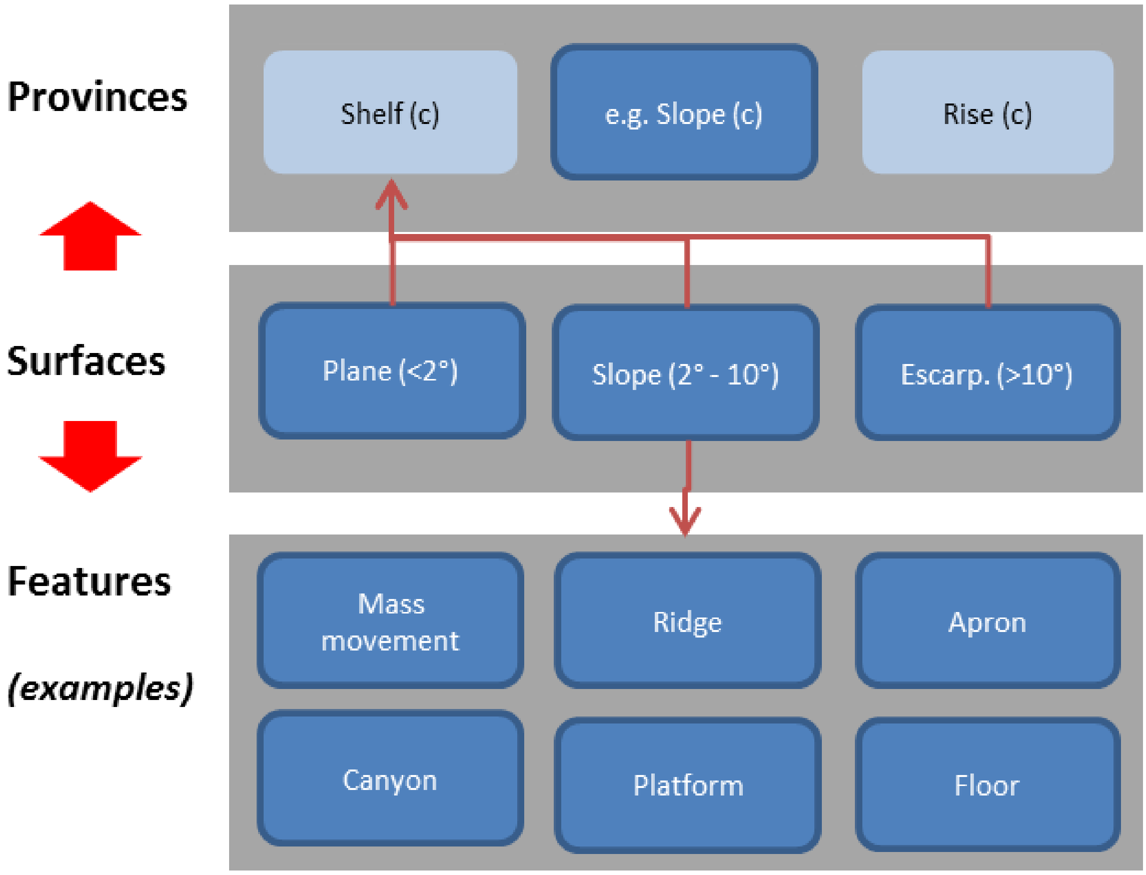


Figure A.1: *Surfaces* are the building blocks of higher level Provinces and are divided to define Features. For Geographe Marine Park, ridges are a key feature type in terms of providing raised hardground habitat.

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