Marine Biodiversity Hub

National Environmental Science Programme

An eco-narrative of Perth Canyon 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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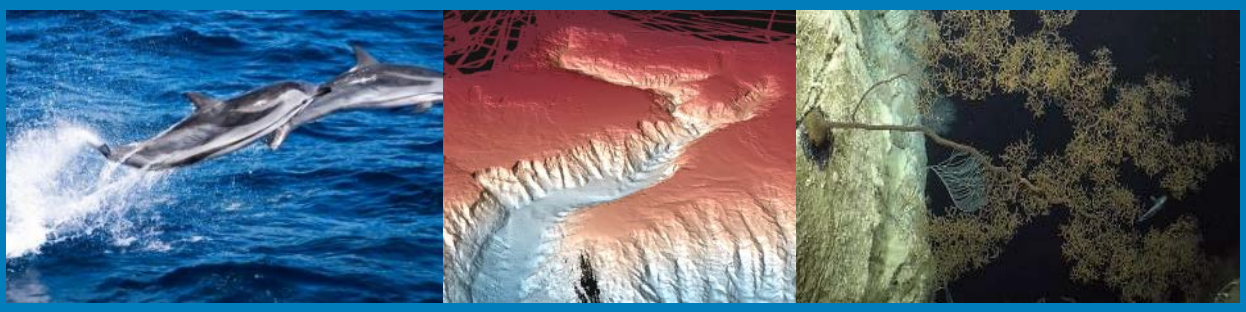
Milestone 14 - Research Plan v4 (2018)

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.

Perth Canyon Marine Park encompasses a diversity of benthic environments, ranging from gently sloping soft sediment plains to near-vertical towering cliffs of exposed bedrock. This geodiversity extends from the head of Perth Canyon at the shelf break to the slope-confined submarine canyons that dissect the lower continental slope. Spanning almost 4.5 km of ocean depths, Perth Canyon dominates the park and has a significant influence on the local ecosystem across the food chain. The size and location of the canyon is such that it promotes upwelling from the deep ocean, leading to plankton blooms that attract seasonal aggregations of larger pelagic fish, including whales. Over geological time, the canyon has evolved to provide extensive areas of benthic habitat suitable for deep-sea corals and sponges. The park is not without environmental pressures, however, with evidence that marine heat waves can affect the health of the ecosystem at upper trophic levels.

The information in this eco-narrative forms an initial characterisation of Perth Canyon Marine Park. Our knowledge of the park and of Perth Canyon in particular, is such that we can now better understand its ecosystem structure, which can be used to inform management and monitoring into the future. The key gap in our scientific knowledge of the park ecosystem is in the deepest areas, particularly for benthic communities on the lower continental slope to abyss. Targeted oceanographic and biological surveys covering these deep-water locations and to understand links between the deepest areas and the Perth Canyon in particular would contribute to an improved overall understanding of the park ecosystem. The importance of Perth Canyon Marine Park to seabird communities is also a recognised gap in our knowledge of this ecosystem.

1. INTRODUCTION

Perth Canyon Marine Park, located ~50 km offshore from Perth in the south-west marine region, covers an area of 7409 km2 and spans water depths of 140 m to 4600 m (Fig.1). The park is a Biologically Important Area for seabirds, blue whales, pygmy blue whales, humpback whales and sperm whales (http://www.environment.gov.au/webgis-framework/apps/ncva/ncva.jsf). The Marine Park also intersects the southern end of two national Key Ecological Features (KEFs): (1) Perth Canyon, adjacent shelf break and other west coast canyons KEF; (2) Western demersal slope and associated fish communities KEF.

This eco-narrative focuses primarily on Perth Canyon, providing an overview of the current knowledge of the canyon, including its oceanographic, geomorphic and biological values.

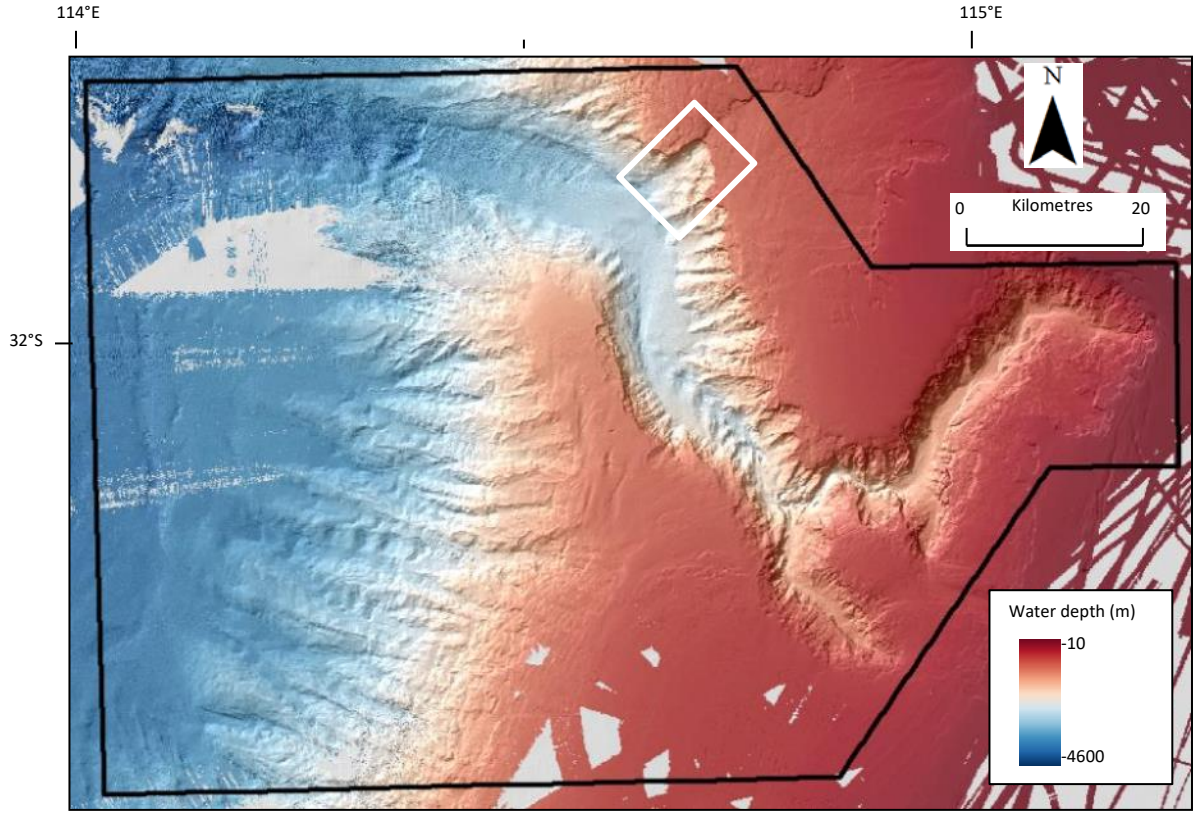

Figure 1: Seabed within Perth Canyon Marine Park, showing hill-shaded high-resolution (40 m) multibeam bathymetry data, which covers 97% of the Marine Park area. The black outline indicates Perth Canyon Marine Park boundary and the white inset box indicates the location of Fig. 5. Grey areas indicate areas with no data in the 40m grid.

2. PHYSICAL SETTING

Perth Canyon Marine Park extends from the outer continental shelf to the lower continental slope of Australia's southwest margin. Perth Canyon and several small slope-confined canyons together cover 31% of the Park (Heap and Harris, 2008). Perth Canyon is the most significant seabed feature within the Park and is the largest of the 200 submarine canyons in the south-west marine region (Huang et al., 2014). The canyon has a surface area of 1505 km^2, a depth range of more than 4000 m (220 - 4680 m), and a volume of 440 km^3; enough to fill more than 800 Sydney Harbours.

Steepness of the seabed within the Marine Park is highly varied, ranging from <1^o across plateaus that flank Perth Canyon to greater than 45^o on escarpments within the canyon. This steepness is a key factor influencing benthic habitat potential within the park, with escarpments providing exposed rock surfaces for sessile organisms to colonise (as described below). In the upper reaches of Perth Canyon, hard substrate (interpreted from acoustic backscatter data) is estimated to cover 10% of the area around the canyon head, with an additional 31% covered by mixed hard and soft substrate (Huang et al., 2017). In contrast, sediment cover across the mid to lower canyon and adjacent slopes is comprised of mainly mud and sandy mud (Heap et al., 2008).

3. OCEANOGRAPHY

The surface waters in Perth Canyon Marine Park are characterised by relatively low primary productivity, without any obvious productivity hotspots. The long-term annual mean surface chlorophyll-a concentrations range from 0.2 - 0.4 mg/m^3 (Figure 2); winter and autumn levels are often twice those in summer and spring (http://northwestatlas.org/node/27500). These values are typical for the south-west region and nationally.

Since 2002, sea surface temperatures within Perth Canyon Marine Park display a clear warming trend at an annual rate of 0.05^o C, based on satellite remote sensing data (Figure 3a). This rate is slightly above the overall average across all Australian marine parks (0.046 ± 0.02 ^{o}C) (Figure 3b). In addition to this warming trend, the Marine Park is impacted by marine heat waves, with the most recent being the unprecedented event in 2011 (Figure 3a), which was forced by La Nina conditions (Feng et al., 2013; Pearce and Feng, 2013). The 2011 event produced a SST anomaly of >1.5 ^{o}C that lasted about five months, peaking in February when SST reached 2.5 ^{o}C above average across the entire Marine Park (Figure 3c&d). This marine heat wave may have had some impact on the health of sessile invertebrates and demersal fish near the canyon head (Smale and Wernberg, 2013; Wernberg et al., 2013; Pearce and Feng, 2013). In particular, the 2011 warming event led to a shift in community structure towards a depauperate state and a tropicalisation of fish communities (Wernberg et al., 2013). 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 and Feng, 2013).

The Leeuwin Current and Undercurrent are two major oceanographic features interacting with Perth Canyon and the Marine Park (Rennie et al., 2009a). The southward flowing Leeuwin Current has a depth of ~300 m and interacts only with the canyon head and promotes downwelling. The northward flowing Leeuwin Undercurrent interacts strongly with the canyon and is upwelling favourable (Rennie et al., 2009a). The Leeuwin Undercurrent often generates eddies within the canyon which transport organic materials and cause upwelling to the base of the Leeuwin Current (Rennie et al., 2009a). This forms a strong chlorophyll maximum layer, with chlorophyll-a concentrations two to three times of that at the surface. This nutrient-rich water can be uplifted into the euphotic zone (0 ~150 m) under the right conditions (Rennie et al., 2009a). For example, persistent southerly winds during summer can drive upwelling via the Leeuwin Undercurrent, which may penetrate into the euphotic zone at the canyon head. Other factors contributing to upwelling may include the offshore migration of the Leeuwin Current during summer, the enhanced vertical mixing caused by the southerly winds, and internal waves breaking at the canyon head. The summertime increase of sub-surface nutrients near the canyon head is likely to boost krill population and as a result attract feeding pygmy blue whales (Rennie et al., 2009b). In addition, the Leeuwin Current is the main transporter of biological larvae in this region. Because of its large size and topographic complexity, Perth Canyon is an important potential source area and recipient of larvae (Kool et al., 2015).

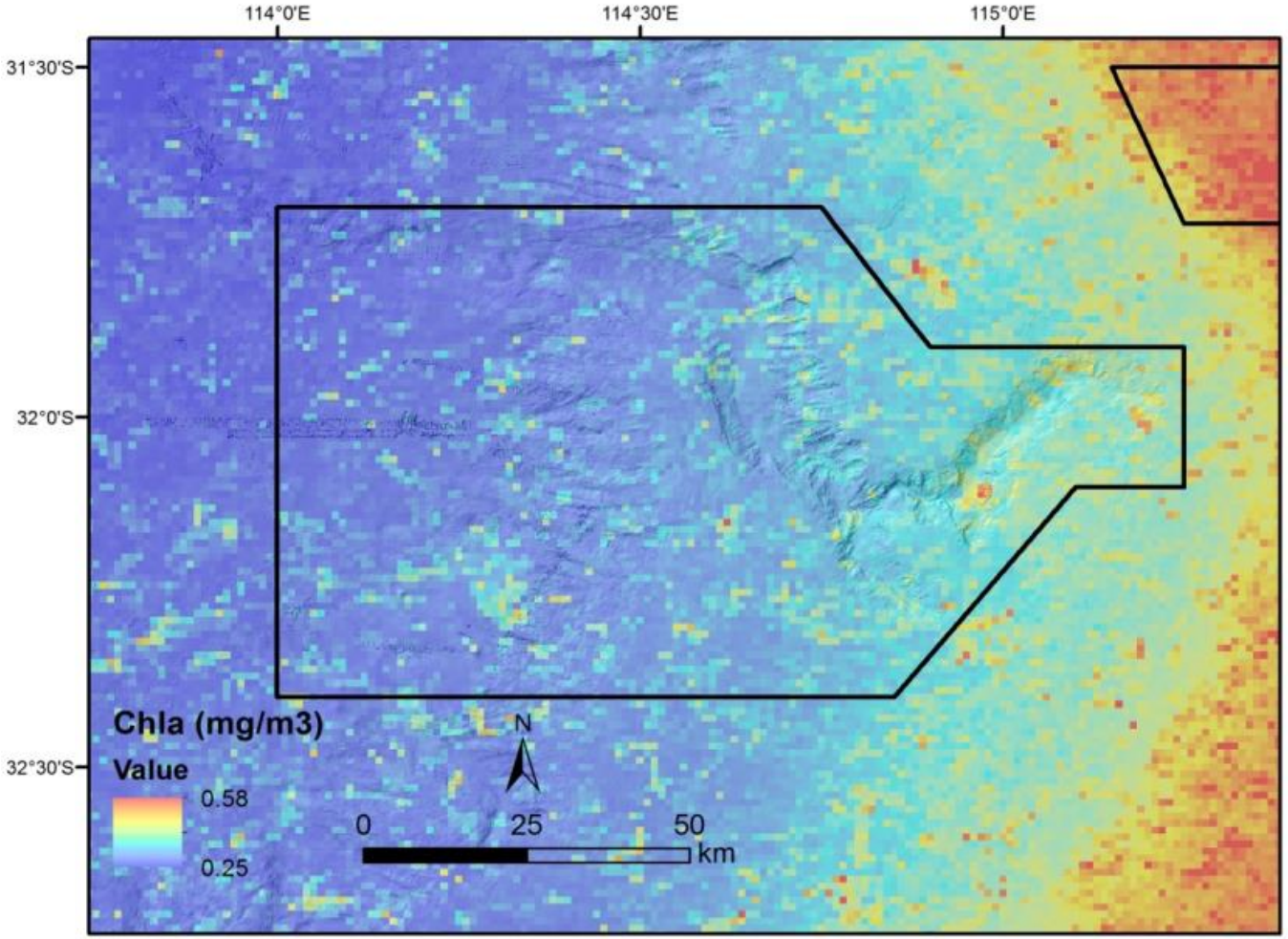

Figure 2: Mean annual chlorophyll-*a* concentration over Perth Canyon Marine Park, derived from MODIS satellite imagery for the period 2002 to 2016

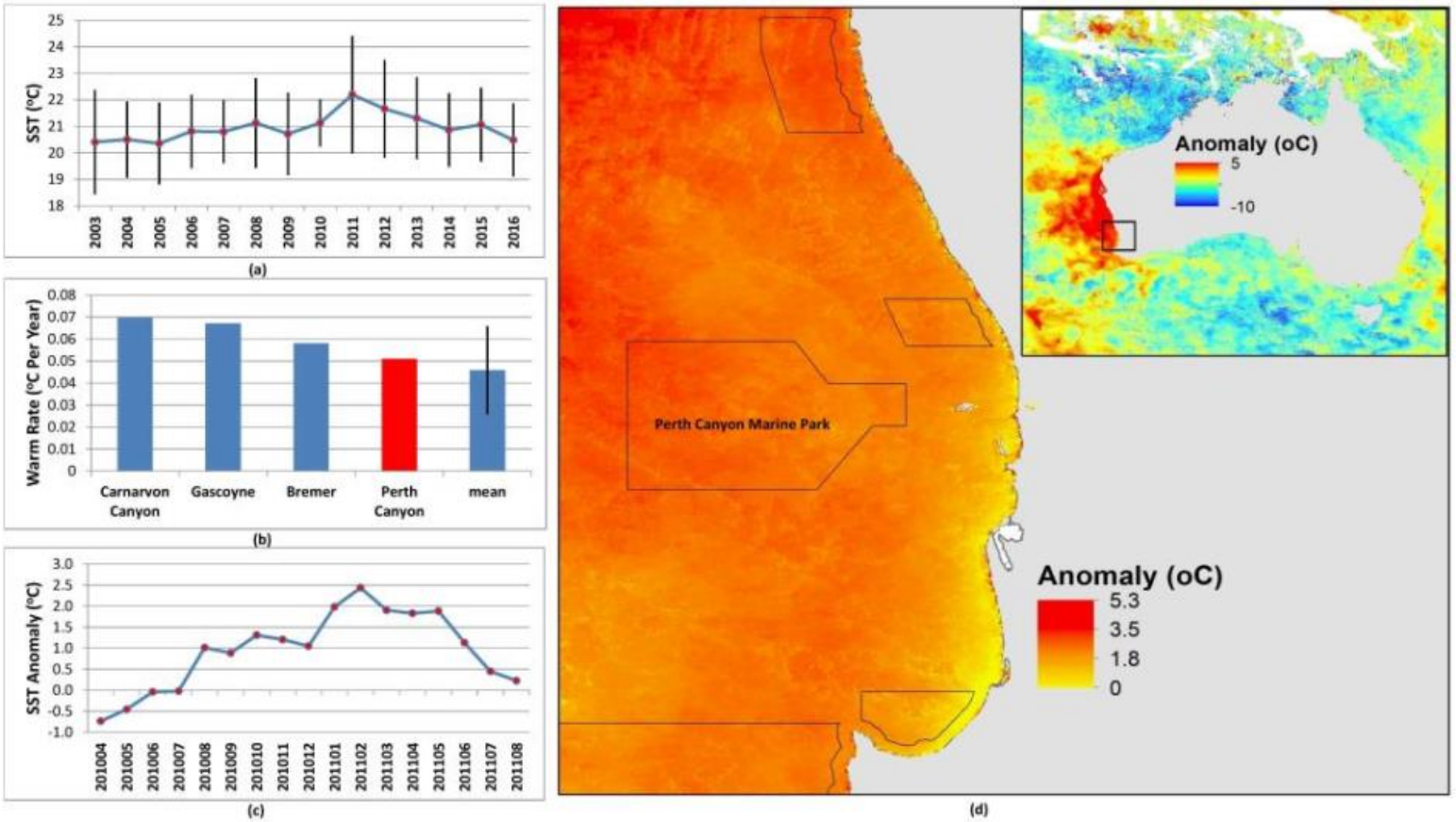

Figure 3: Sea Surface Temperature (SST) trends within Perth Canyon Marine Park, showing: a) Annual average for 2003-2016 with standard deviation indicated by bars; b) Warming rate (ºC per year) for Perth Canyon Marine Park and three other marine parks in the south-west region against the national mean for all marine parks; c) Monthly SST anomalies in Perth Canyon Marine Park during the 2011 marine heat wave event; d) SST anomaly map for the marine heatwave of February 2011.

4. GEOMORPHOLOGY AND POTENTIAL HABITATS

Perth Canyon has complex seabed topography, comprising the primary canyon and two large tributary canyons that join its southern flank, adjacent to an abrupt change in orientation from south- to north-west (Figure 1). This change in canyon direction appears to relate to the structural geology of the Perth Basin, in that it coincides with the intersection of the Vlaming and Zeewyck Sub-Basins (and Vasse Shelf) with the Yallingup Shelf. The complexity of Perth Canyon is revealed in detail by a new high-resolution (40 m) bathymetry and acoustic backscatter dataset that covers 97% of Perth Canyon Marine Park (https://schmidtocean.org). A new seafloor mapping scheme (detailed in Appendix A), designed to harness the predictive potential of detailed seafloor data, has been applied to this dataset. By linking the seafloor morphology to geomorphic process and substrate we can provide assessment of the stability of the potential habitats in Perth Canyon Marine Park. Across the mapped area of the Marine Park, the seafloor divides into three slope categories that represent broad habitat settings. Thus, 16% is classed as low gradient *Planes* of <2°, 54% as *Slopes* of 2-10° and 31% as *Escarpments* steeper than 10° (Figure 4).

The dominant morphological features of Perth Canyon are large and overlapping mass movements along its northern wall and upper reaches (Figures 1, 5; Appendix A). Comprising steep escarpments and blocks, these mass movements are evidence of ongoing geological events. Importantly, escarpments are characterised by exposed rock faces that provide ideal substrate for sessile biological communities (see below). Within Perth Canyon Marine Park, nearly a third of the seafloor (31%) is comprised of escarpments that may provide potential habitat for sessile communities, though water depths may be a limiting factor toward the lower continental slope.

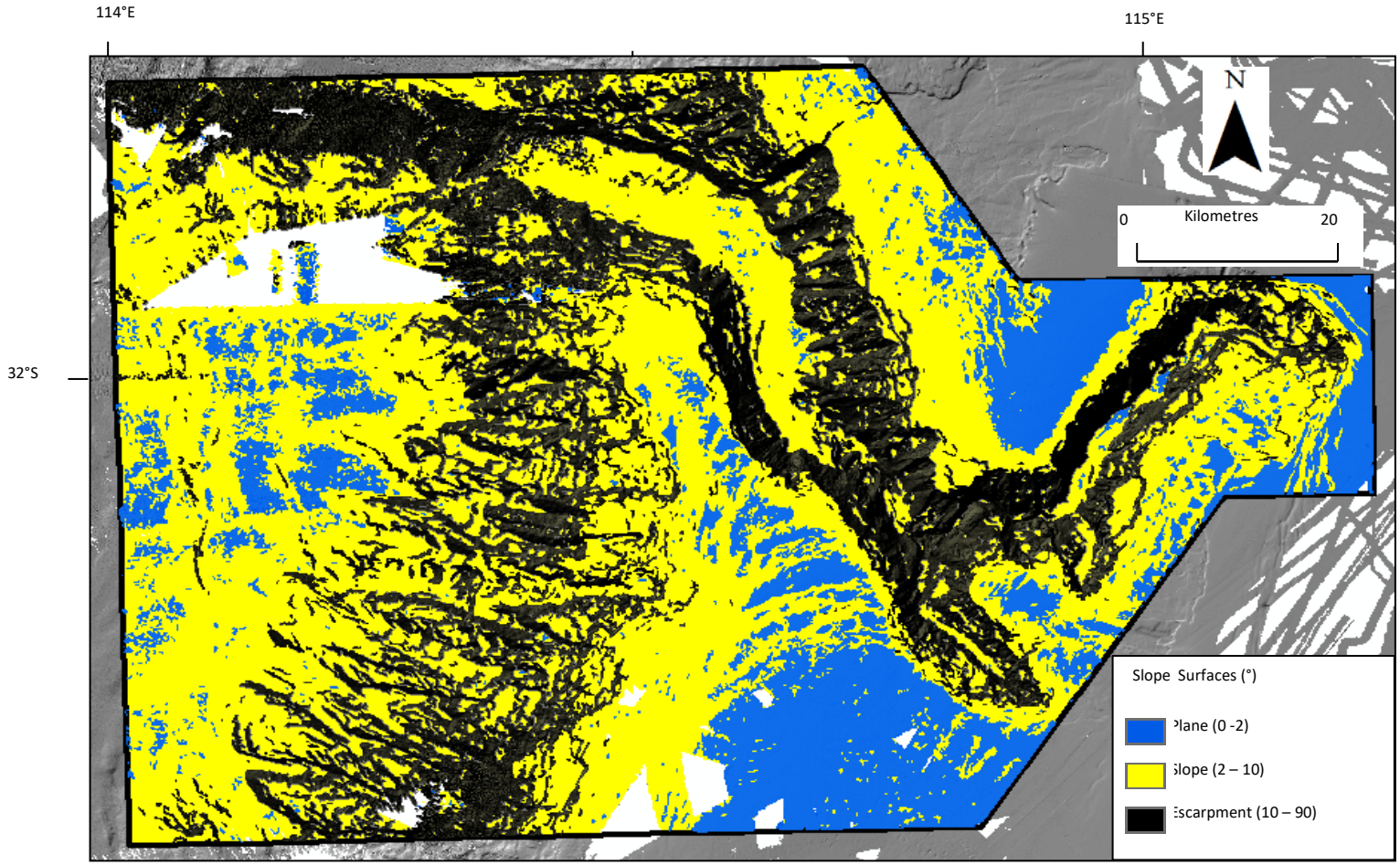

Figure 4: Seafloor Surfaces within Perth Canyon Marine Park mapped from the 40 m bathymetry grid (Fig. 1), using a 40m hill shade grid as the background.

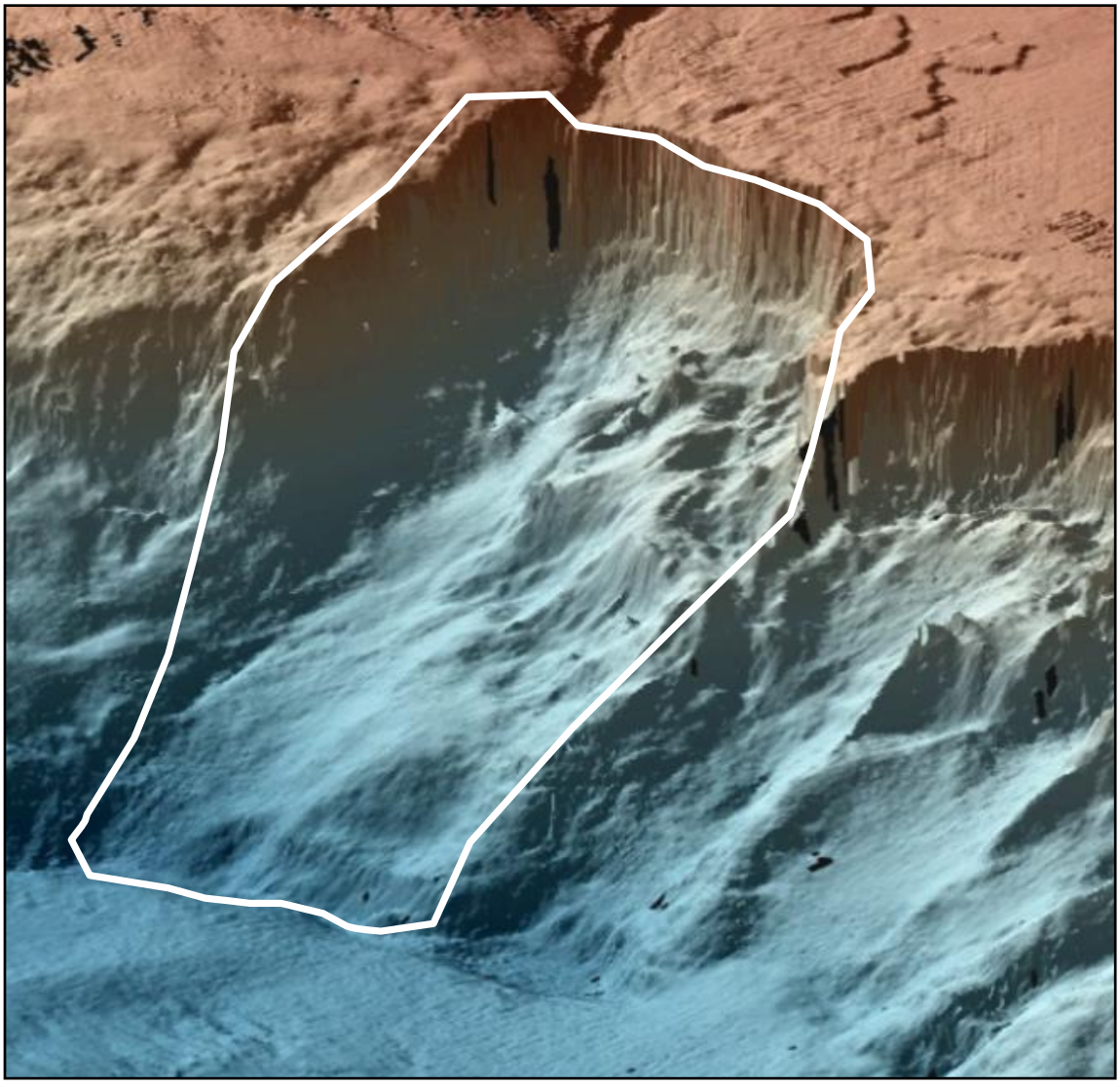

Figure 5: A mass movement feature (outlined in white) on the northern wall of Perth Canyon (refer Fig.1 for location).

5. THE ECOLOGICAL SIGNIFICANCE OF PERTH CANYON MARINE PARK

5.1 Pelagic fauna

The complex geomorphology of Perth Canyon facilitates the confluence of several oceanic processes (e.g. deep episodic upwelling events, meso-scale eddies described above) that support enhanced primary and secondary productivity and promote the seasonal aggregation of a range of marine organisms, from plankton to deep-diving cetaceans and large predatory fishes (Figure 6).

5.1.1 Cetaceans

The elevated krill diversity off the southwest coast of Western Australia (Sutton, 2015) explains why the canyon is a major feeding ground for a population of Australian pygmy blue whales (*Balaenoptera musculus brevicauda*), which are estimated to comprise several hundred to over a thousand individuals (Jenner et al., 2002; Jenner et al., 2008; Rennie et al., 2009b). Passive acoustic monitoring, satellite telemetry, photo-identification and aerial visual transect data indicate that these animals spend from days to weeks milling and foraging in the canyon during the summer months, prior to resuming their migration (McCauley et al., 2000; McCauley et al., 2004; Stafford et al., 2011; Gavrilov et al., 2012; Double et al., 2014; Owen et al., 2016).

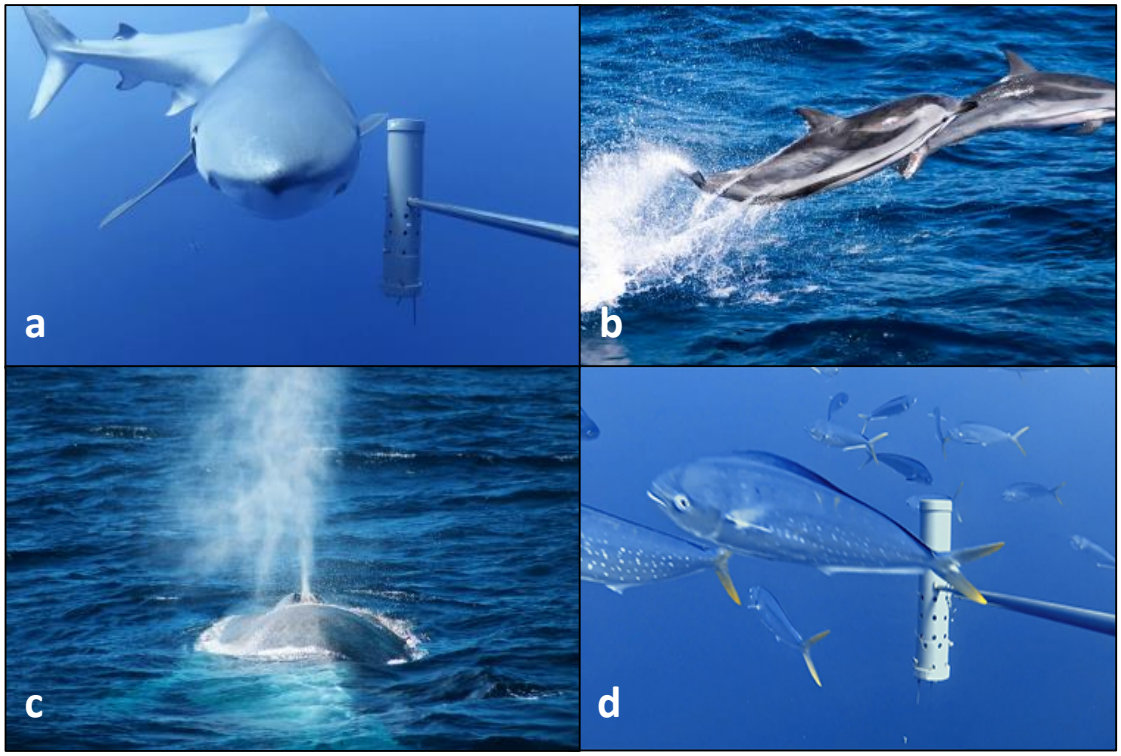

Figure 6 Examples of pelagic fauna observed in Perth Canyon Marine Park. (a) Blue Shark – *Prionace glauca*; (b) Striped dolphin; (c) Sperm whale; (d) Dolphin fish - *Coryphaena hippurus*

Additionally, acoustic observatories curated by the Integrated Marine Observation System (IMOS) have detected the presence of southern right whales (*Eubalaena australis*), Antarctic minke whales (*Balaenoptera bonaerensis*), fin whales (*Balaenoptera physalus*), and humpback whales (*Megaptera novaeangliae*) in the canyon, as well as recurring evening choruses from a number of unknown fish species (Erbe et al., 2015; Ward et al., 2017). Antarctic blue whales (*Balaenoptera musculus intermedia*) were also recently recorded during the austral autumn (April/May) through spring (November), suggesting that the canyon may be occupied by different cetacean species year-round (Balcazar et al., 2015; Balcazar et al., 2017).

Beaked whales are generally known to exhibit strong associations with canyon habitats in some areas, likely as a result of prey concentration and aggregation processes (Moors-Murphy, 2014). Whilst no dedicated research has been undertaken on these species in Perth Canyon, available stranding records for the Perth coast include Cuvier's (*Ziphius cavirostris*), Blainville's (*Mesoplodon densirostris*), Gray's (*Mesoplodon grayi*) or Andrew's (*Mesoplodon bowdoini*) beaked whales (Groom et al. 2014). Pygmy right whale carcasses (*Caperea marginata*) have also been documented (Kemper et al. 2013).

Recent predictive models developed from a combination of contemporary scientific expeditions and historical whaling archives revealed that Perth Canyon is a preferred habitat for sperm whales (*Physeter macrocephalus*), particularly immature sub-adult females (Johnson et al., 2016). This is consistent with observations from past vessel (McCauley et al., 2004) and aerial surveys (Bannister, 1968), and suggests that the canyon could be a critical nursery area for matriarchal sperm whale family groups.

Opportunistic sightings of large groups of Risso's (Grampus griseus), bottlenose (*Tursiops truncatus*) and striped (*Stenella coeruleoalba*) dolphins also exist for the area (Bouchet P, pers. comm.).

5.1.2 Seabirds

Despite numerous species occurring in globally significant breeding colonies throughout the continental islands of southwestern Australia (Dunlop and Wooller, 1990; Surman and Wooller, 2003), there has been limited research on the pelagic seabirds that are likely to use Perth Canyon. Wedge-tailed shearwaters (*Ardenna pacifica*) were the numerically dominant species encountered during visual transects undertaken west of the region (Hyrenbach et al., 2006). Some of these animals nest on nearby Rottnest Is (Bancroft et al., 2004) and are thought to associate with eddy-generated convergence zones during foraging. The canyon is also believed to be a critical feeding area for soft-plumaged petrels (*Pterodroma mollis*), though empirical evidence is lacking.

5.1.3 Fishes and sharks

A recent analysis of historical fisheries landings has identified Perth Canyon as a hotspot for tunas (*Thunnus sp*.), mackerels and marlins (Bouchet et al., 2017), in line with reported patterns that many fish and shark species of commercial interest tend to be more abundant within canyon habitats (Fernandez-Arcaya et al., 2017). Since 2010, a series of baited camera surveys have also taken place in the vicinity of the canyon head. These have yielded important insights into wildlife occurrence in the region, including:

- the first record of smalltooth sand tiger shark (*Odontaspis ferox*) within the temperate southeastern Indian Ocean, and first sighting in close to 30 years for the west coast of Australia (Wellington et al., 2017),

- repeated observations of neonate and young-of-the-year shortfin mako sharks (*Isurus oxyrhinchus*), supporting the idea that the canyon may play a role as a nursery ground for this heavily exploited species (Forres et al., In review).

Lastly, Bouchet and Meeuwig (2015) also documented the presence of ocean sunfishes (*Mola mola*), dolphinfishes (*Coryphaena hippurus*), silky sharks (*Carcharhinus falciformis*) and blue sharks (*Prionace glauca*).

A significant proportion of the total recreational fishing effort in the Commonwealth waters in the South-West region occurs from private recreational vessels targeting tunas and marlin (RecFish Australia, 2010). Fishing for these pelagic species from large recreational boats and yachts occurs particularly around Fish Aggregating Devices (FADs) deployed near the Perth Canyon. The relative percentage of effort attributable to private and charter fisheries in this particular region remains poorly defined, however, it is estimated that around 11% of recreational fishing effort in Western Australia was carried out in offshore areas (Australian Government, 2008). Due to the nature of the pelagic fishery, it is not easy to delimit a single area of importance as fluctuations in current, bait availability and local oceanographic conditions will dictate the distribution of gamefish species.

5.2 Benthic fauna

Perth Canyon's complex bottom topography and range of substrate types provide habitats for a diverse range of benthic species. The deep waters and large size of the canyon make it logistically difficult to study the creatures on the seafloor and there have only been three recent research voyages to document the benthic fauna of Perth Canyon Marine Park, two on the RV Southern Surveyor in 2005, and more recently a voyage on the RV Falkor in 2016.

Analysis of species-level data from Southern Surveyor voyages indicates Perth Canyon is a relative hotspot for benthic biodiversity. More than 27% of benthic species recorded along the south-western continental margin of Australia (McEnnulty et al., 2011) were found in Perth Canyon, which represents almost three times more species than found anywhere else during the survey. Furthermore, 7.5% of all species recorded from the survey were unique to Perth Canyon. These results are consistent with the generally accepted notion that canyons represent areas of high biodiversity associated with habitat heterogeneity and high productivity (McClatchie et al., 2006, Vetter et al., 2010, Huang et al., 2017), and also the suggestions of links between benthic communities and high pelagic production in Perth Canyon (Hayes et al., 2012).

5.2.1 Deep-sea corals

Corals are a conspicuous feature of Perth Canyon, particularly on steep rock walls and in depths ranging from 600 to 1800m (McEnnulty et al., 2011, McCulloch et al., 2016), with the coral fauna similar to that found in deep waters elsewhere in Australia. Hard corals include widespread species such as the matrix-forming stony corals *Solenosmilia variabilis* and *Madrepora oculata*, and solitary corals *Desmophyllum dianthus*, *Stephanocyathus spiniger* and *Deltocyathus magnificus*. Notably genetic comparisons of hard corals from Perth Canyon show close affinities with con-specifics in Western Australia (for *S. spiniger*) and Australia (for *M. oculata*) suggesting commonalities between the canyon and other deep waters areas (Miller et al., 2010).

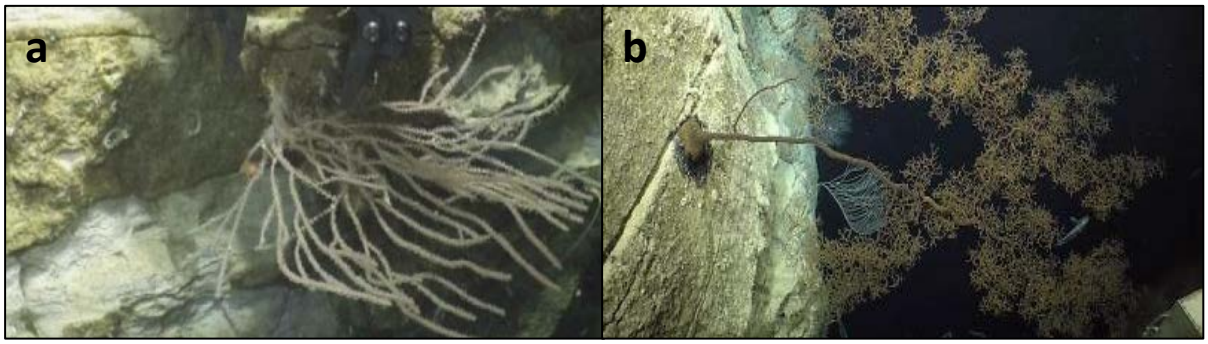

Figure 7 Examples of deep-sea benthic fauna observed on the walls of Perth Canyon, including (a) Gorgonian coral (Narella species), and (b) Black coral (Antipatharia species). (Images from McCulloch et al. 2016)

The octocoral fauna of Perth Canyon includes gold corals (*Chrysogorgiidae*), soft corals (*Nephtheidae*, *Anthothelidae*) and bamboo corals (*Isididae*) (McEnnulty et al., 2011). From the Southern Surveyor collections, the octocoral fauna appears similar to that in surrounding waters (McEnnulty et al., 2011), which is consistent with recent evidence that Australian Marine Parks do not harbour a higher octocoral diversity than areas outside the parks (Althaus et al., 2017). However, at least one new species of octocoral, *Anthothela aldersladei* was described from specimens collected in Perth Canyon in 2005 (Moore et al., 2017) and many as yet undescribed species were also annotated in the collections, suggesting diversity is currently underestimated, and endemism is likely high in octocorals in Western Australia (Alderslade et al., 2014). Antipatharian black corals were also observed frequently on the top of the steep canyon walls (McCulloch et al., 2016).

5.2.2 Sponges

Sponges are a dominant fauna in Perth Canyon at depths from 100-400m, although are rare below these depths. (Fromont & Pisera, 2011, McEnnulty et al., 2011). Forty-five nominal species of sponge were collected from the Perth Canyon area as part of the Southern Surveyor voyages of discovery in 2005, although all but nine of these were found in other locations on the Western Australian margin, predominantly in the south-west, but with some species occurring as far north as Ningaloo. The canyon represents the southern-most limit for lithistid sponges on the west coast of Australia (Fromont et al., 2012). One sponge species that has so far only been found in Perth Canyon, *Manihinea lynbeazleyae*, is new to science (Fromont & Pisera, 2011). Glass sponges, which are rare and only found in deep water, have also been recorded in Perth Canyon (www.ala.org.au, McCulloch et al., 2016).

5.2.3 Other benthic fauna

At the base of the canyon and away from the cliff face, seabed habitats are generally covered by bioturbated muddy sand, and in these a range of other sessile and non-sessile benthic species were observed (McCulloch et al., 2016). Below 400 m and to depths of 1500 m, decapod crustaceans are the most speciose fauna (50 nominal species recorded, with 20% of these recorded only in Perth Canyon), followed closely by Molluscs with 40 nominal species (McEnnulty et al., 2011) of which half were only found in Perth Canyon on the Southern Surveyor voyages.

Twenty-three species of Echinoderms have been recorded from Perth Canyon, seven of which represent unique records for SW Australia (McEnnulty et al., 2011). Brittle stars are

the most speciose group of echinoderms in Perth Canyon (12 species recorded), followed by starfish (six species), sea cucumbers (three species) and sea urchins (two species).

Of note is that many species were only recorded once or are rare in collections (Williams et al., 2010, McEnnulty et al., 2011), although this may well be related to the limited sampling across the region. As such, estimates of relative abundance and diversity are only indicative and are almost certainly underestimates. Other taxa observed in the canyon include anemones, hydroids, polychaete worms and brachiopods – all groups that are commonly found in deep-sea environments (McCulloch et al., 2016).

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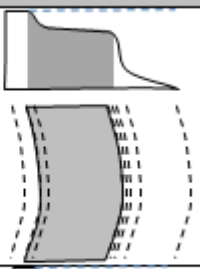
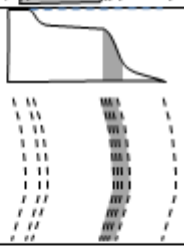
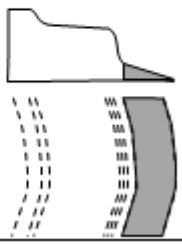
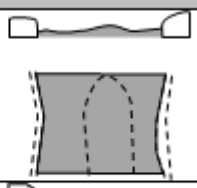
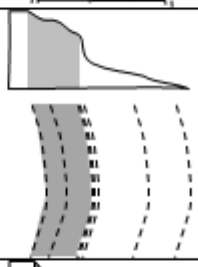
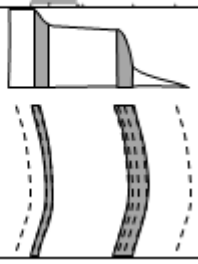
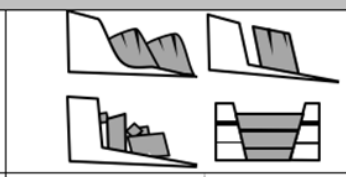
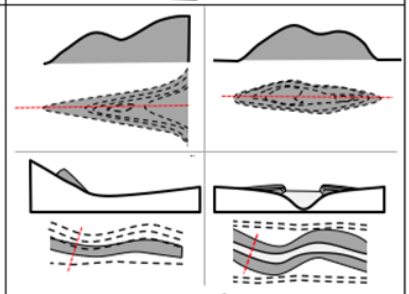
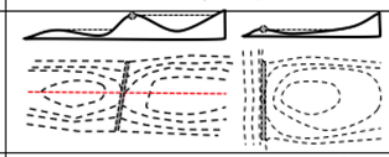
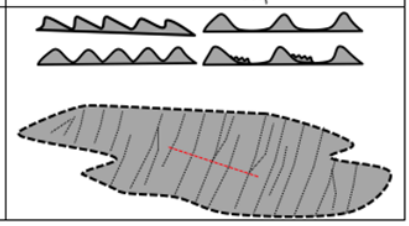
APPENDIX A

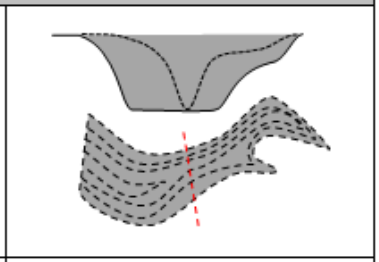
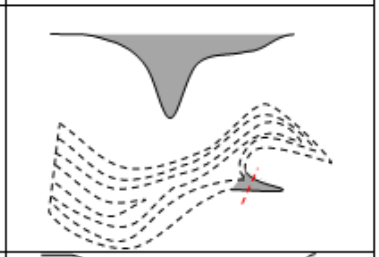
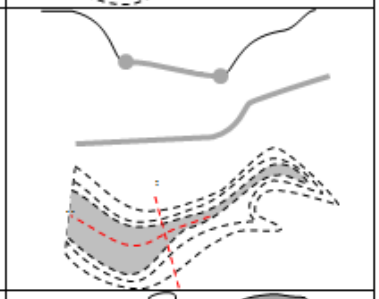
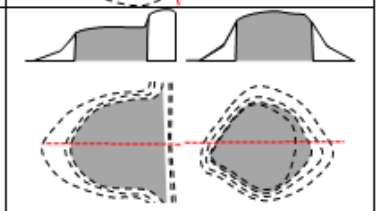
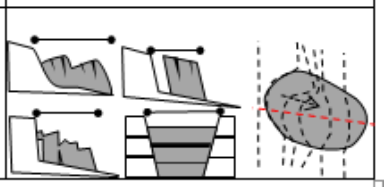
Geoscience Australia is currently developing a new seabed geomorphology classification that draws on the Harris et al. (2014) geomorphic map of the world's oceans, and Dove et al. (2016) two-part system for classifying seafloor morphology. This system enables morphological mapping of the seafloor where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

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 Perth Canyon 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	

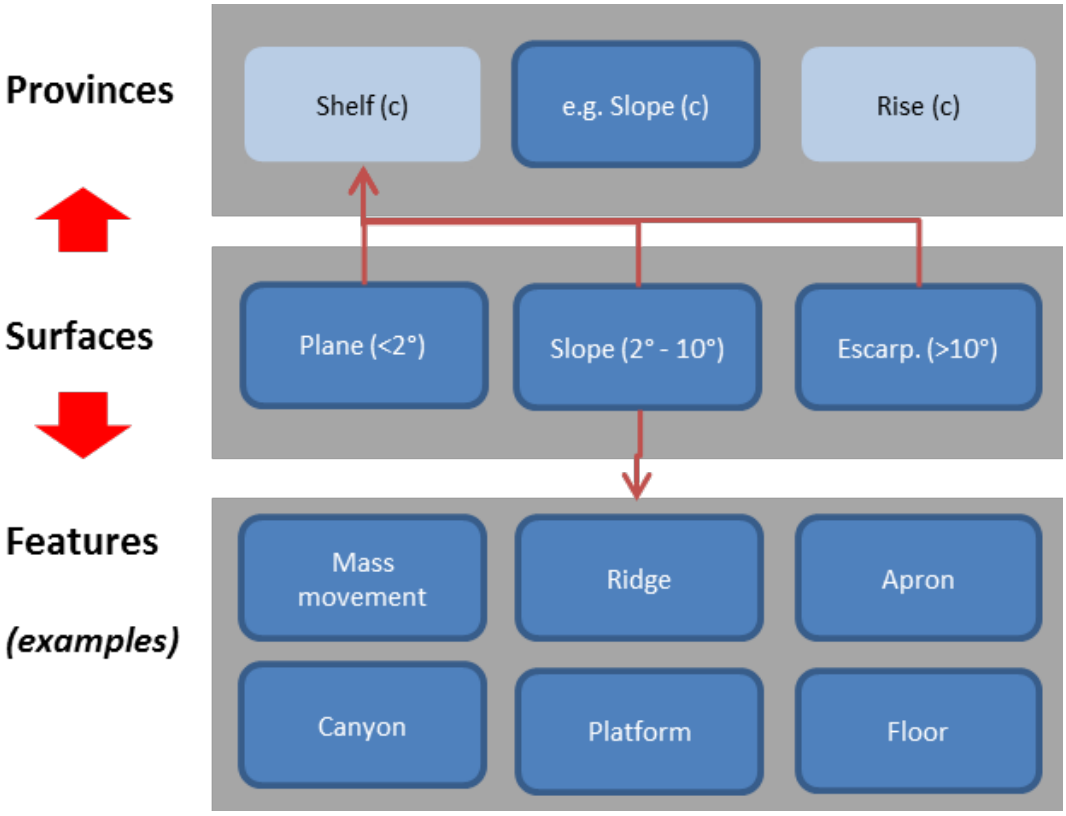


Figure A.1 *Surfaces* are the building blocks of higher level *Provinces* and are divided to define *Features*. Of the 34 *Feature* types we have described in our glossary, six dominate Perth Canyon Marine Park.

Australian Government | National Environmental Science Programme | Australian Government Australian Institute of Marine Science | CSIRO | Australian Government Geoscience Australia | IMOS Integrated Marine Observing System

Charles Darwin University | University of Tasmania | The University of Western Australia | NSW Government | Museums Victoria

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