New Sydney Fish Markets
Aquatic Biodiversity Management Plan

Multiplex Constructions

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Abbreviations

Abbreviation	Description
ABMP	Aquatic Biodiversity Management Plan
ELA	Eco Logical Australia Pty Ltd
KFH	Key Fish Habitat
INSW	Infrastructure NSW
LAT	Lowest astronomical tide
nSFM	new Sydney Fish Markets
UNSW	University of NSW

1. Introduction

This Aquatic Biodiversity Management Plan (ABMP) has been prepared by Eco Logical Australia (ELA) for the construction of the new Sydney Fish Markets (nSFM). Development of an ABMP was recommended during the impact assessment phase of the project to ensure the suggested marine habitats were selected and installed to maximum habitat variability and connectivity. The ABMP also promotes collaboration between Infrastructure NSW (INSW), research institutions at the University of NSW (UNSW) and Macquarie University, and the construction team at Multiplex Constructions. The ultimate aim of this ABMP is to make recommendations for habitat improvements, document the built habitat and initiate the monitoring program to measure the success of the habitat.

This ABMP and content is a condition of the approved development application (DA – SSD 8925) for the nSFM, specifically condition B52(d) and B103:

MARINE STRUCTURES

B52. Prior to the issue of the relevant Crown Building Works Certificate, the detailed design of all marine structures (public pier, waterfront promenade, wharve structures and pontoons) must be submitted to and approved by TfNSW (Maritime). The drawings and specifications are to:

a) Comply with NSW Maritime's Engineering Standards for Maritime Structures and NSW Maritime's Guidance Note Documentation, AS 4997-2005 Guidelines for the Design of Maritime Structures and AS 3962-2001 Guidelines for Design of Marinas;

b) Fully and clearly describe all new works for land below the Mean High-Water Mark and all their components and interconnections;

c) Demonstrate the structural components have been designed by a practising structural Civil Engineer and experienced in the design of maritime structures;

d) Include all marine ecological aspects and initiatives within the Marine Ecological Assessment prepared by Ecological Australia dated 2 April 2019, so opportunities to increase marine biology are realised.

e) Include all management and mitigation measures within the Navigation Impact Assessment prepared by Royal HaskoningDHV, dated 20 September 2019.

MARINE ECOLOGY

B103. All recommendations within the Marine Ecology Assessment report (MEA), prepared by Ecological Australia, dated 2 April 2019 shall be implemented, including preparation of an Aquatic Biodiversity Management Plan (ABMP), which shall address OEH guidelines. Further, research from Macquarie University and University of NSW to enhance native habitat-forming organisms shall be included in the ABMP, once proof of the concept phase is completed, where relevant. Prior to the commencement of works, details demonstrating compliance with this requirement shall be submitted to the Planning Secretary and Certifier.

The guidelines identified in condition B103 relate to 'environmental seawalls' (OEH 2009).

1.1 Progress timeline

This report will be revised thought the program. An indicative timeline is shown in Table 1.

Table 1: Indicative timeline

Date	Activity	Responsibility
24-25 July 2017	Marine habitat mapping of Blackwattle Bay and surrounds	ELA for INSW
2019-2020	Demolition of wharves and concrete batching plant for nSFM site	Hansen Yuncken for INSW
2019-2022	Trial of seawall tiles and bioshelter	University of NSW and Macquarie University for INSW
2021-2024	Construction of nSFM	Multiplex for INSW
2024	Installation of aquatic habitat elements	Multiplex for INSW
2024-2029	Monitoring of habitat	INSW

1.2 Future updates

This report is a working document that will be updated when:

- Exact habitat modules and quantities are selected
- Habitat modules are installed
- The monitoring program is fully developed based on habitat placement (performed by others post-construction)
- Bioshelter trials are completed (early 2022, separate INSW and University project)

Future editions are recommended to expand the ABMP into Stage 2 of the nSFM construction (i.e. the connection to the eastern shore), and across the broader Blackwattle Bay Precinct design.

2. Existing habitat (pre-construction)

Marine habitat mapped was mapped by ELA in 2017, including Blackwattle Bay, Rozelle Bay, Jones Bay, Johnstons Bay and White Bay. Representative photos are shown in Figure 1. The majority of these bays are subtidal bare sediment. All foreshore areas consisted of seawalls, creating a narrow intertidal zone. Wall habitat varied depending on structure, including smooth vertical concrete, rough sandstone blocks and sloping boulder rubble. In Blackwattle Bay, the shallow subtidal zone on the western shoreline had a scattered rocky rubble that supported *Sargassum linearfolium*, a brown macroalgae. This type of narrow seaweed bed also occurs near Anzac Bridge and along the southern shore of Rozelle Bay and Jones Bay. The proposed marine enhancements for the nSFM will create a broad rock rubble reef to join the western seaweed bed to the corner of western promenade/unloading wharves. From there the habitat improvements will be a mix of fish aggregation devices and intertidal wall habitat, with the intent to create a linear habitat corridor across the entire end of Blackwattle Bay. Future development across the eastern shore of Blackwattle Bay could include similar habitat features to complete the habitat circuit, resulting in a near-continuous marine habitat zone from Bicentennial Park in Rozelle Bay, around Blackwattle Bay, to Pirrama Park in Jones Bay , a total length of over 3 km (Figure 2).

Figure 1: Representative photos of existing marine habitat in Blackwattle Bay

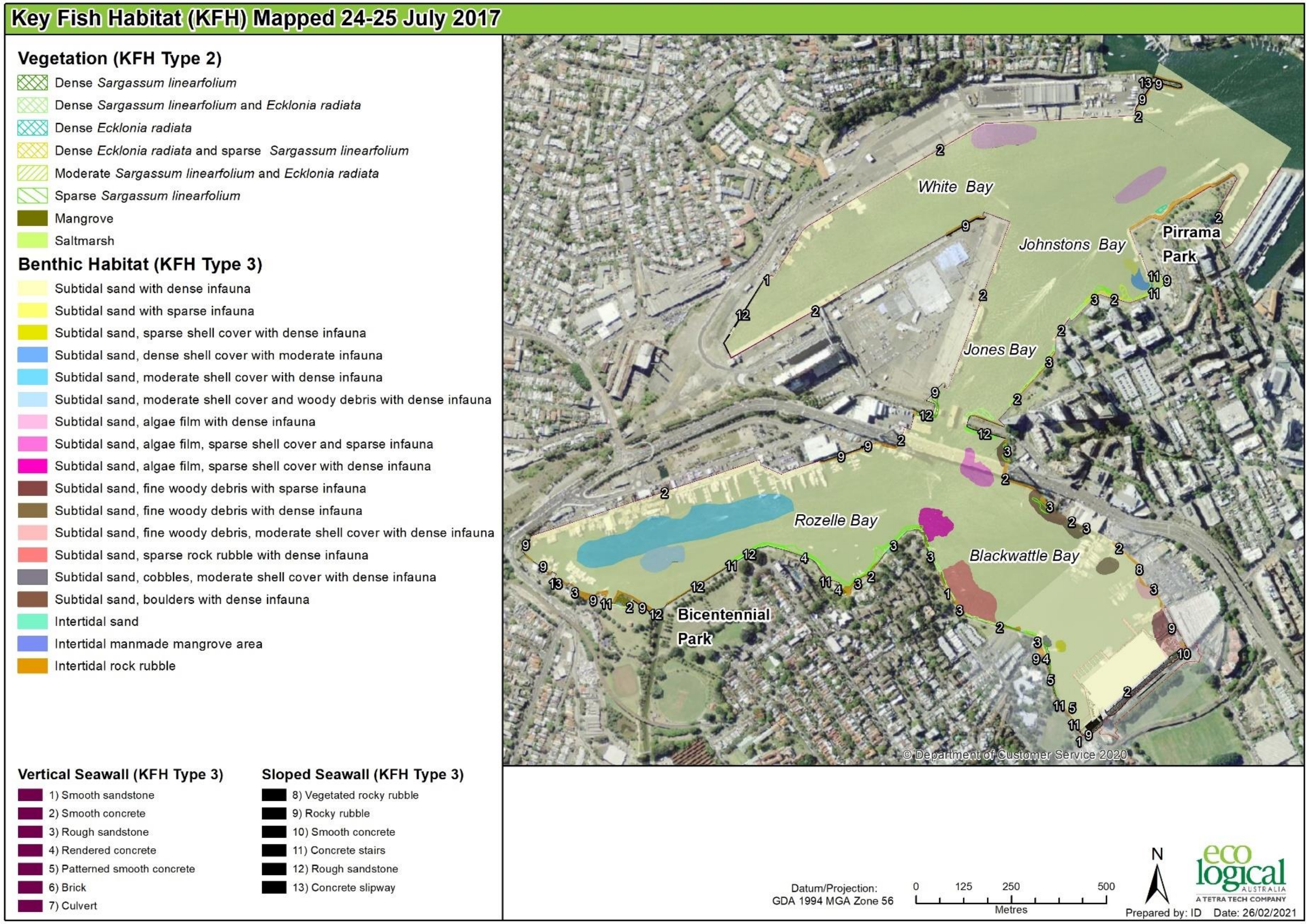


Figure 2: Key Fish Habitat (KFH) types mapped in Blackwattle Bay and adjoining bays

Other surveys of Blackwattle Bay (Bugnot et al 2016) found the aquatic habitat and biodiversity to be comparable, if not slightly worse, than nearby bays within Sydney Harbour (Rozelle, White and Johnstons Bay, Gore and Iron Cove). Fourteen fish species were recorded in Blackwattle Bay (Table 2). Bugnot et al (2016) identified other habitats including intertidal hard structures with the native *Saccostrea glamerata* (Sydney Rock Oyster), sub-tidal hard structures with kelp and sub-tidal sediments with worms from the Polychaete family. The subtidal sediment had high metal concentrations, with Annelids (worms) as the predominate infauna species. These are indicative of a disturbed environment.

Table 2: Previously recorded fish species in Blackwattle Bay (Bugnot et al. 2016)

Scientific name	Common name
Acanthopagrus australis	Yellowfin bream
Ambassis marianus	Estuary glassfish
Amblygobius sp.	Goby
Aspidintus dussumieri	Lance blenny
Dicotylichthys punctulatus	Three bar porcupinefish
Gerres subfasciatus	Common silver belly
Girella tricuspidata	Luderick
Lutjanidae	Snapper
Monacanthus chinensis	Fanbelly leatherjacket
Pelates sexlineatus	Eastern striped trumpeter
Rhabdosargus sarba	Tarwhine
Sillago ciliata	Sand whiting
Sillago maculata	Trumpeter whiting
Tetraodontidae	Toadfish

2.1 Aquatic habitat opportunities

Comparison of marine invertebrates on natural habitat and artificial structures shows there is a distinct reduction in diversity on surfaces that lack microhabitats (cracks and crevices) and when water-retaining features are absent (rockpools) (Browne and Chapman 2014, Chapman and Blockley 2009). In Blackwattle Bay, Bugnot et al. (2016) found no mobile invertebrates in the subtidal zone of hard structures. Bugnot comments that this is fairly common for artificial hard structures, but natural subtidal reefs tend to support a range of snails, sea stars and chitons, which are important grazers and predators (Marzinelli et al. 2014, Johnston et al. 2015). Therefore, habitat enhancement opportunities should aim to replicate natural elements, such as cracks, crevices and pools.

Opportunities to enhance or create new habitat in the Blackwattle Bay should aim to increase the abundance and diversity of sessile and less-mobile marine organisms that support a localised food web and improve ecological complexity, such as:

- filter-feeders (bivalves, barnacles and sponges)

- algal grazers (gastropods and chitons)
- macroalgae (e.g. turfing algae and large brown algae)
- colonial organisms (bryzoans).

Following establishment of low-trophic organisms, larger more mobile fauna would pass through and utilise the area, such as:

- crustaceans (bugs, shrimp, crabs)
- fish.

Species known to occur nearby in Sydney Harbour, but not found in Blackwattle Bay could colonise the bay if habitat conditions are suitable, and connectivity of neighbouring habitats support migration. Potential native species that would increase biodiversity in Blackwattle Bay are listed in Table 3. Future occurrence of any of these species may indicate successful habitat improvements in the bay, noting that baseline studies aren't inclusive of all taxa across every habitat and season. Habitat enhancement should aim to emulate the natural environment, creating habitats for native species and providing natural dissipation of wash and waves. An increase in colonisation of native species reduces the resources and opportunity for invasive species to establish.

A healthy balance of species across the food web is desirable. This could largely be achieved through habitat creation, but other indirect impacts from foreshore development could disrupt the desired balance. For example, artificial lighting has the potential to alter fish communities within urban estuarine ecosystems by creating optimal conditions for predators (Becker et al 2013). This is due to the increased abundance of small shoaling fish foraging in artificially lit areas, which in turn attract larger visual predators that consume smaller fish that would usually be hidden in the dark. To reduce potential impact to fish communities, the preference for low-wattage, low-spill lights should be considered, preferably of a warmer colour temperature so light doesn't penetrate to deeper water. Alternatively, impact could be minimised by positioning the light towards shallower water where there is less physical space for fish. However, as this is a working wharf and safety considerations need to be addressed around public space, especially where there is a potential drop into the water, lighting restrictions may only be possible where other feature lighting is intended from a creative perspective (e.g. reduce the amount of lighting directed at the water for aesthetics).

Table 3: Marine species absent from baseline surveys in Blackwattle Bay, but present in nearby areas of Sydney Harbour (Bugnot et al. 2016).

Habitat and type	Group	Scientific name	Common name
Intertidal fauna	Mollusc	*Chiton pelliserpentis*	Snake-skin Chiton
	Mollusc	*Chthamalus antennatus*	Six-plated Barnacle
	Mollusc	*Morula marginalba*	Mulberry Whelk
	Mollusc	*Patelloida alticostata*	Tall-ribbed Limpet
Intertidal flora	Red seaweed	*Corallina officianalis*	Coralline Seaweed
	Red seaweed	*Hydrolithon* sp.	-
Subtidal fauna	Bryozoan	*Celleporaria nodulosa*	-
	Bryozoan	*Fenestrulina mutabilis*	-
	Bristle worm	*Galeolaria caespitosa*	Galeolaria Worm
Subtidal flora	Brown seaweed	*Ecklonia radiata*	Leather Kelp
	Brown seaweed	*Padina elegans*	Pandina
	Red seaweed	*Champia compressa*	Iridescent Algae
	Red seaweed	*Corallina officinalis*	Coralline Seaweed
Mobile fauna	Fish	*Apogon* sp.	Cardinalfish
	Fish	*Arripis trutta*	Australian salmon
	Fish	*Blenniidae*	Belenny
	Fish	*Brachaluteres jacksonianus*	Pygmy leatherjacket
	Fish	*Bramidae*	Pomfret
	Fish	*Carangidae*	Trevally
	Fish	*Decapoda*	Prawns
	Fish	*Mugilidae*	Mullet
	Fish	*Parupeneus spilurus*	Black spot goatfish
	Fish	*Pseudocaranx georgianus*	Silver trevally
	Fish	*Tetractenos glaber*	Smooth toadfish
	Fish	*Upeneichthys vlamingii*	Blue spot goatfish

3. Proposed habitat at the nSFM

Propose marine habitat to be installed around the nSFM include:

- Environmental seawalls
- Rock rubble reef
- Benthic fish aggregation devices
- Hanging fish aggregation devices
- Seawall tiles

An approximate location zone for each habitat type is illustrated in Figure 3, with exact locations dependant on water depth, building structure type, sunlight and access.

3.1 Seawalls

Seawalls are to be design and constructed in accordance to Environmentally Friendly Seawalls: A Guide to Improving the Environmental Value of Seawalls and Seawall-lined Foreshores in Estuaries (OEH 2009). Two seawall zones are proposed at the nSFM (Figure 4).

Seawalls that meet the OEH criteria are marked in Figure 4 between Grid W1 – 2 and 14 – E6 where the tidal waters have greatest interaction with the walls (i.e. excludes the stormwater passage behind the basement wall, Grid 2 – 14). It is noted that some areas will be absolutely or partially shaded, however, those areas will still provide functions in water retention, suspension of wrack and increased surface area for species that are not light-dependent. These walls marked in Figure 4 meet the requirements of Environmentally Friendly Seawall Guidelines (e.g. Figure 5) because they:

Maximise habitat diversity and complexity by:

- using boulders of various size and shape
- not cementing between blocks to create crevices
- incorporating rubble toes for vertical seawalls
- utilising natural building materials
- providing gentle slopes.

All other intertidal wall structures at the nSFM are not suitable as 'environmental seawalls' because they are either:

- the basement concrete wall (however a portion will have habitat tiles installed)
- the existing seawall that will be made safe and built overtop by the nSFM (although this will still receive tidal water, it is located in a dark and narrow corridor with specific structural requirements).

The proposed seawall cross-sections in Figure 6 show a gentle sloping wall with rock armour (300-900 mm well graded igneous rock rip rap), which is similar in appearance to the examples provided in the guidelines. In Figure 6:

- Type A walls have a 1:2 slope of rock armour covering the intertidal and subtidal zone
- Type B walls have a rock armour slope within the intertidal area, with the subtidal foot supported by a vertical sheet pile
- Type C walls include rip rap on the seafloor to prevent scouring from culvert discharge.

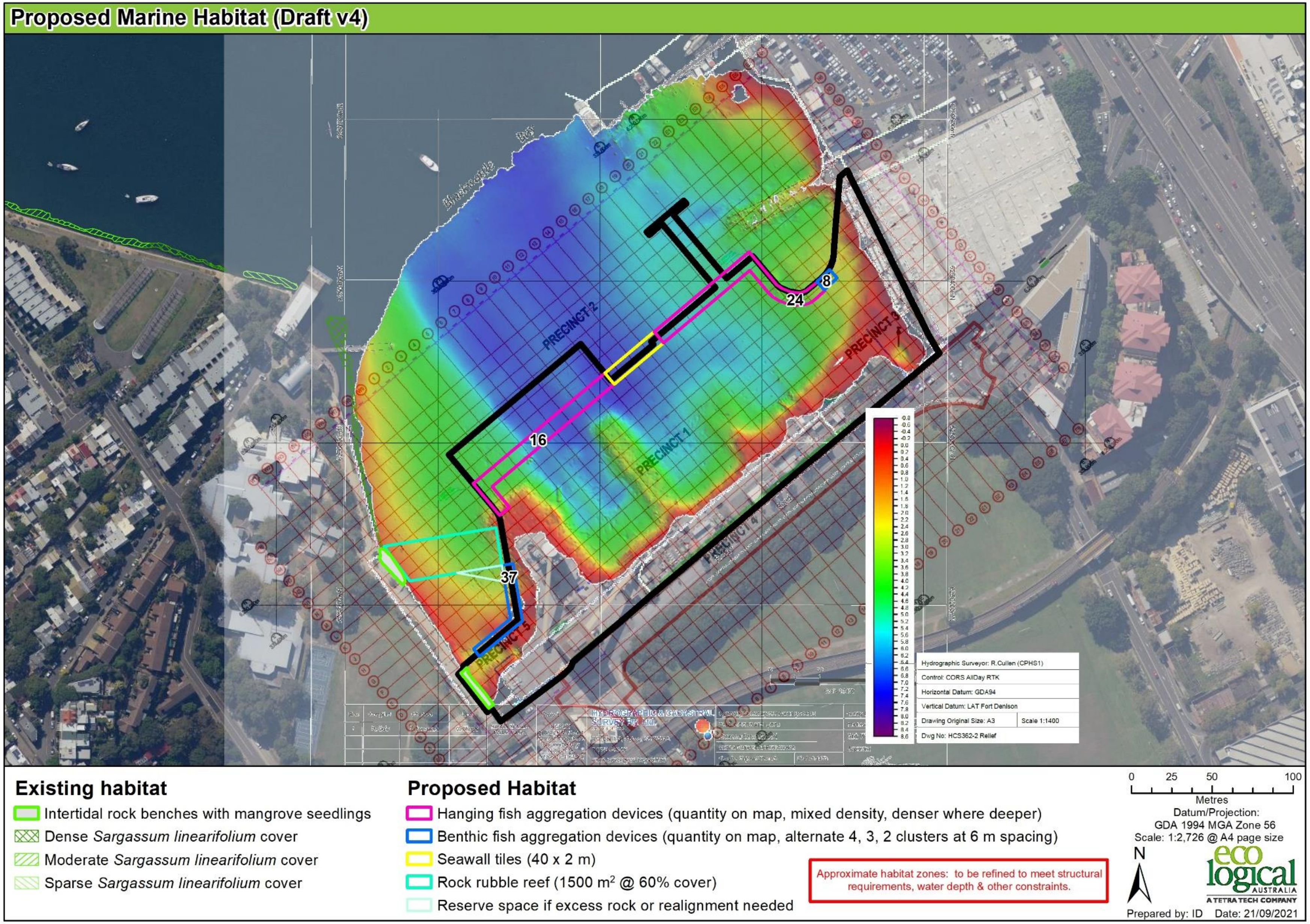


Figure 3: Draft zones of proposed habitat installation (depth relative to LAT)

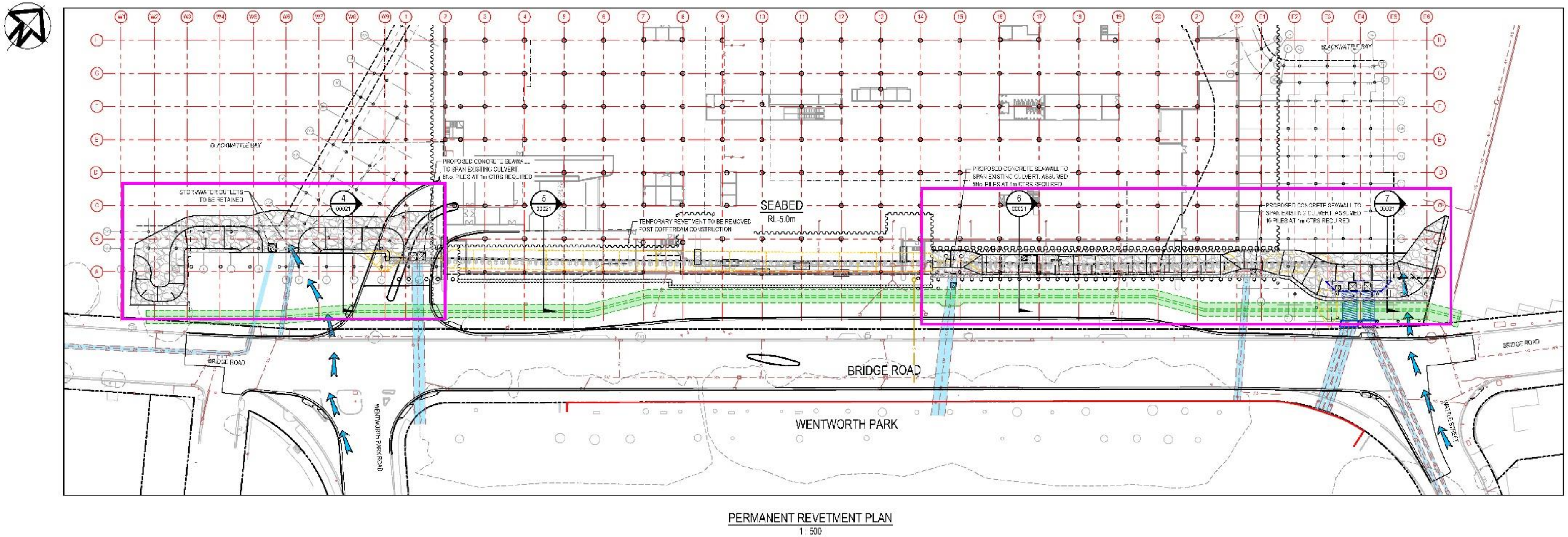


Figure 4: Seawall locations (purple boxes)

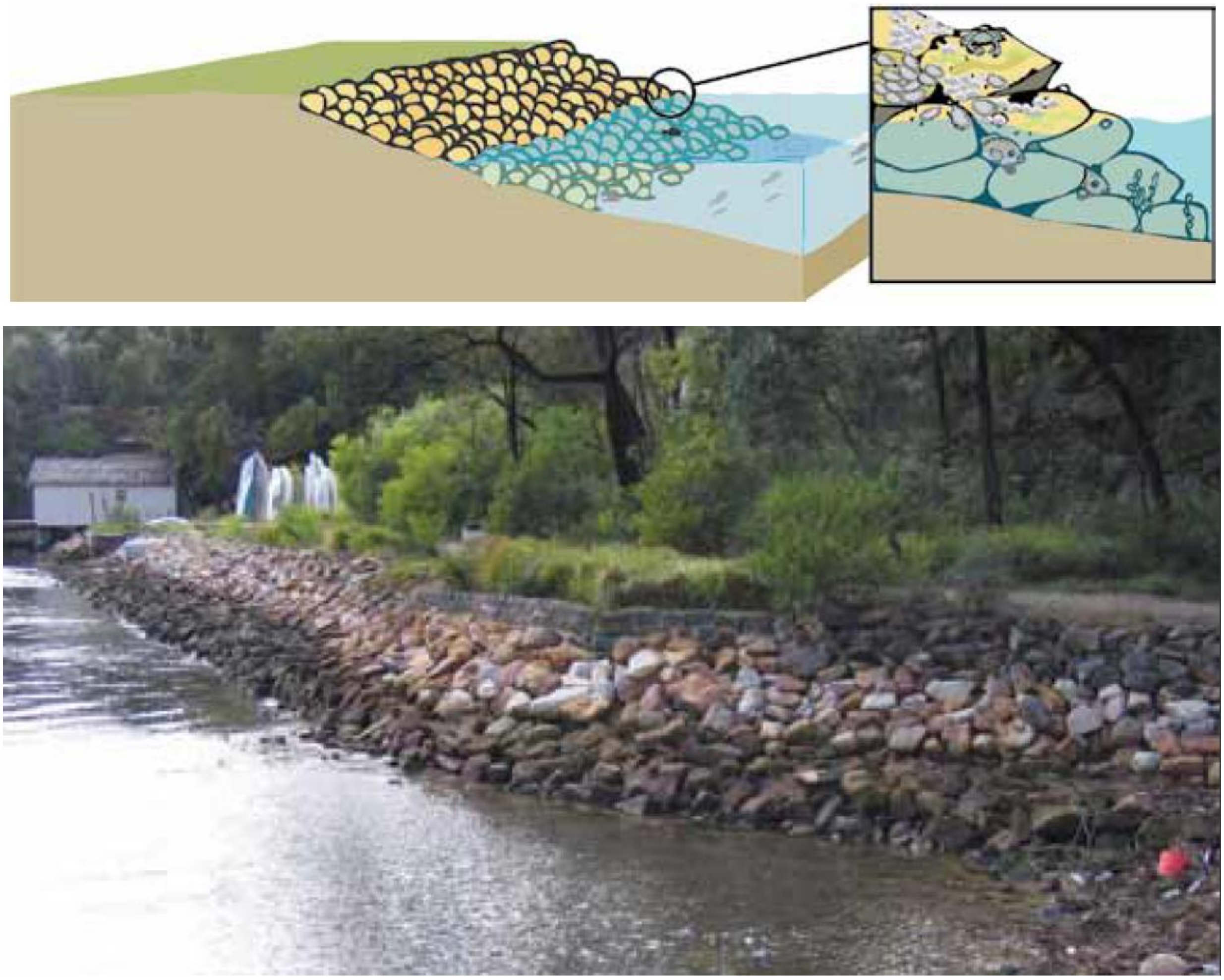
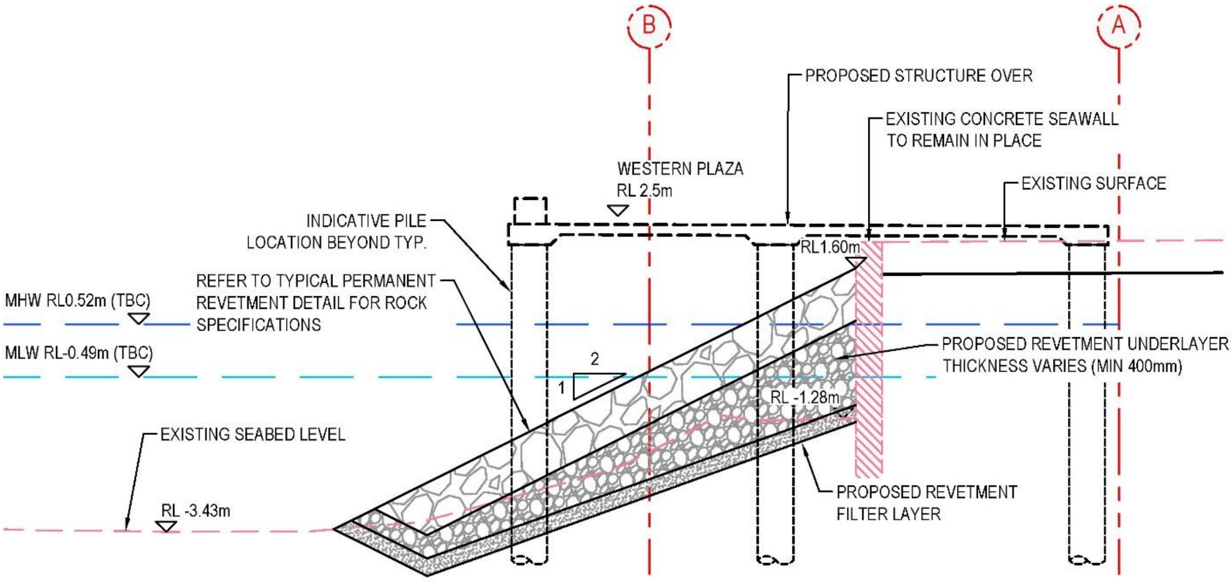
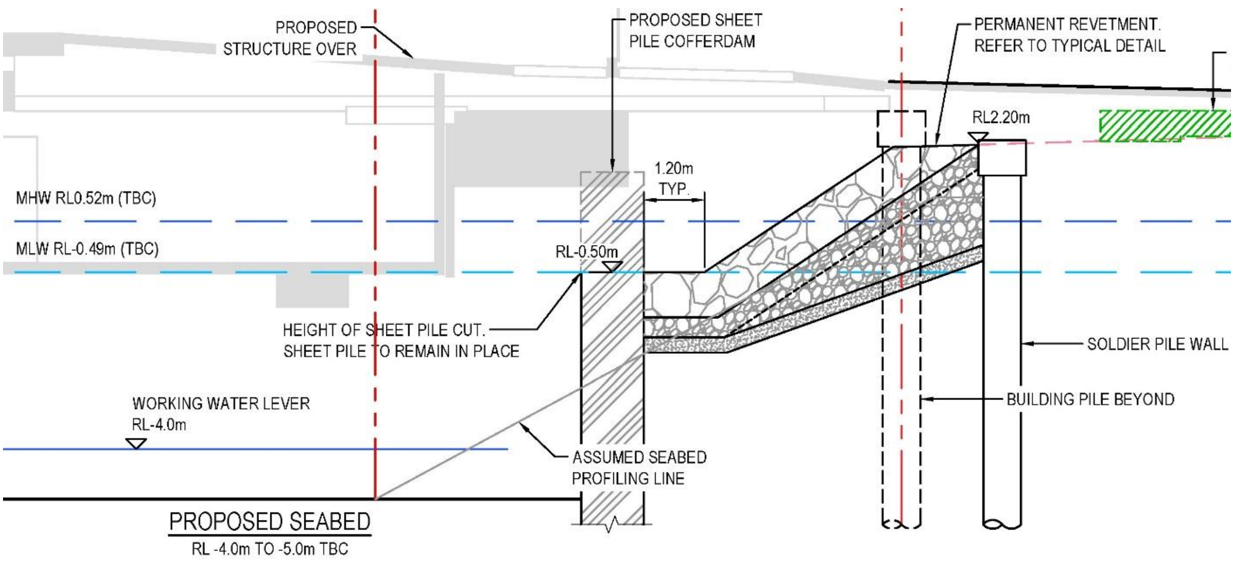


Figure 5: A boulder seawall with fish and other organisms utilising the crevices between the rocks as sheltered habitat (from pages 13 and 14 of the guidelines)



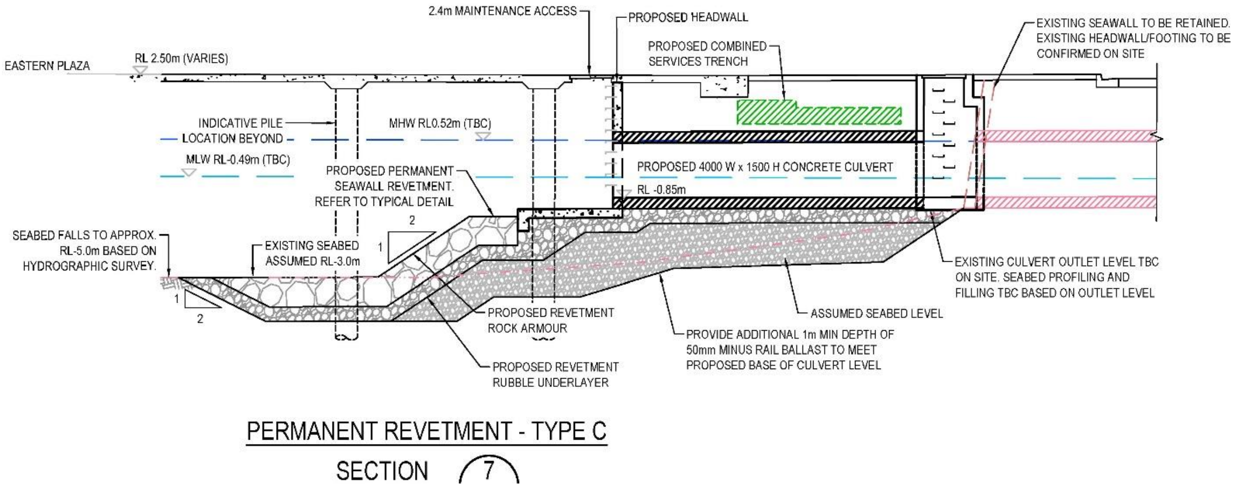
PERMANENT REVETMENT - TYPE A

SECTION 4



PERMANENT REVETMENT - TYPE B

SECTION 6



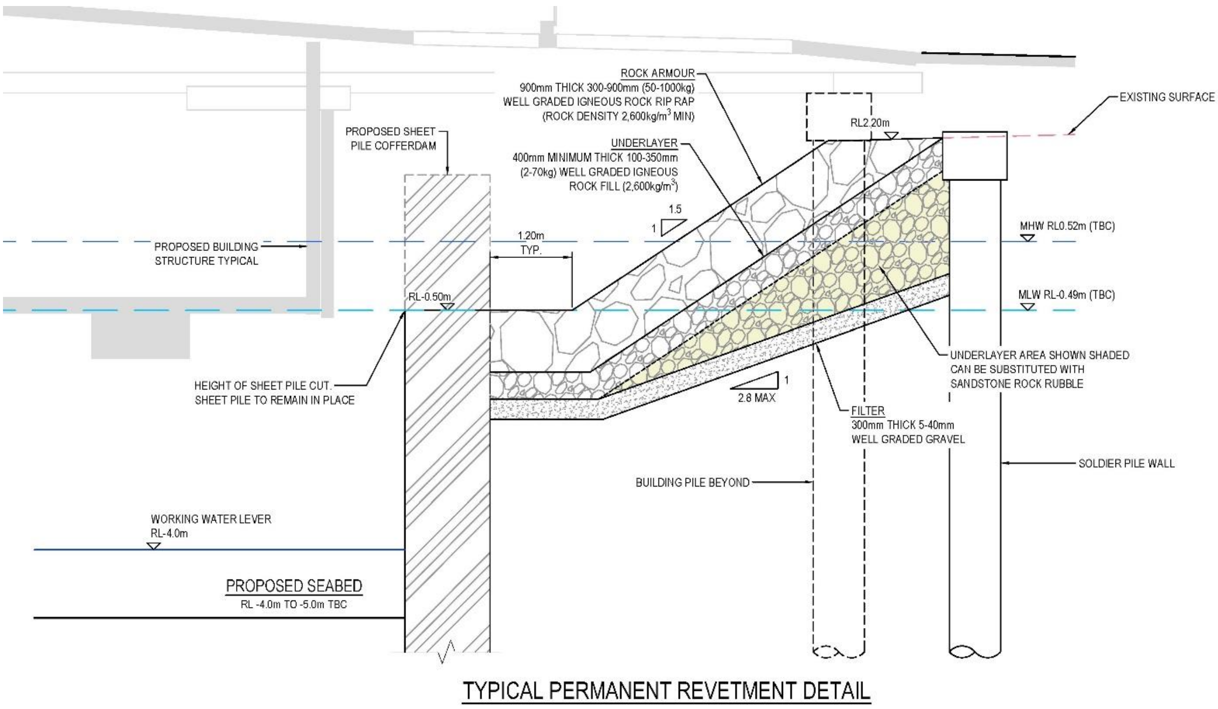


Figure 6: Permanent seawall Types A, B and C and typical detail of rock armour (see Figure 4 for locations)

3.2 Rock rubble reef

A rock rubble reef is suited to water <3 m deep from lowest astronomical tide (LAT) to connect the western shore macroalgae bed to the structure. See Figure 3 for suggested location.

Example rock rubble

3.2.1 Material and size

Sandstone irregular cut (free from fines). Dominant target size 500-700 mm (longest dimension), with other pieces minimum 300 mm to maximum 900 mm. Overall, approximately 450 m^3 of rock is required.

3.2.2 Design criteria

25 m wide x 60 m long placement of single layer of rock (approx. 0.5 m high average). Rock placed with random spacing between rocks or clusters of rock, but spaced no greater than a single rock length with the aim to provide structure for seaweed growth and shelter for fish movement in water shallower than about 3 m (from LAT). Therefore, estimated 60% rock coverage in this area. Total minimum quantity is calculated as 60% x 25 m x 60 m x 0.5 m = 450 m^3.

Suggested method is to lower from excavator on barge. No compaction is required. Rough placement is ideal, with minor repositioning required if rocks pose an obstruction to small boats.

3.3 Benthic fish aggregation devices

Benthic fish aggregation devices are suitable for subtidal and intertidal water <3 m deep (from LAT) within 5 m of the structure. See Figure 3 for suggested location.

Example benthic modules

3.3.1 Material and size

Seafloor module: Minimum 600 x 600 mm base, approx. 600 mm tall hard-surfaced, rigid, complex habitat. Suitable materials are marine concrete with irregular aggregate, ceramic, recycled oyster shell or marine-suitable metal. No plastic or degradable products. Approximately 45 units are required.

3.3.2 Design criteria

Structures are to be placed on the seafloor under the promenade/wharf (within 5 m from the edge) or immediately adjacent to this in open water to allow placement at any time during construction. The majority of the structure should be no deeper than about 3 m (from LAT) to allow sufficient light to reach the unit for plant growth. A suggested placement plan is below in Figure 7, but alternatives to this may be considered where units cause obstruction or depth isn't suitable.

Complex shapes are encouraged to increase surface area and provide a variety of fish shelter. Structures should be lowered gently to the seafloor by barge-mounted crane. Depending on weight and shape, structures may need to be pinned or slightly embedded into the substrate to improve balance. Purpose-built commercial modules are recommended as they have been tested and designed to maximise habitat. Other forms may be suitable if tested for performance.

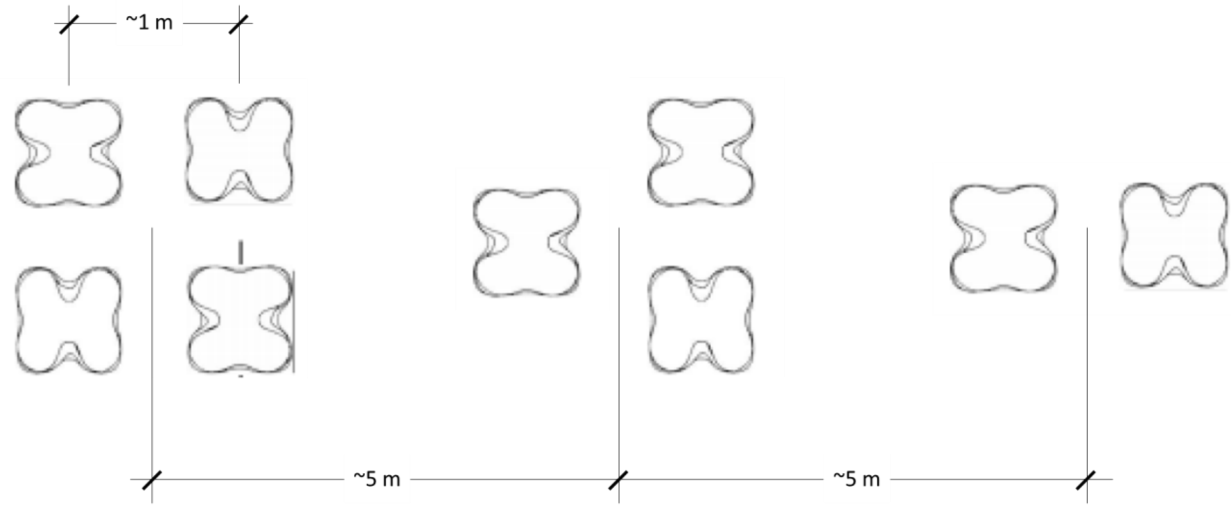
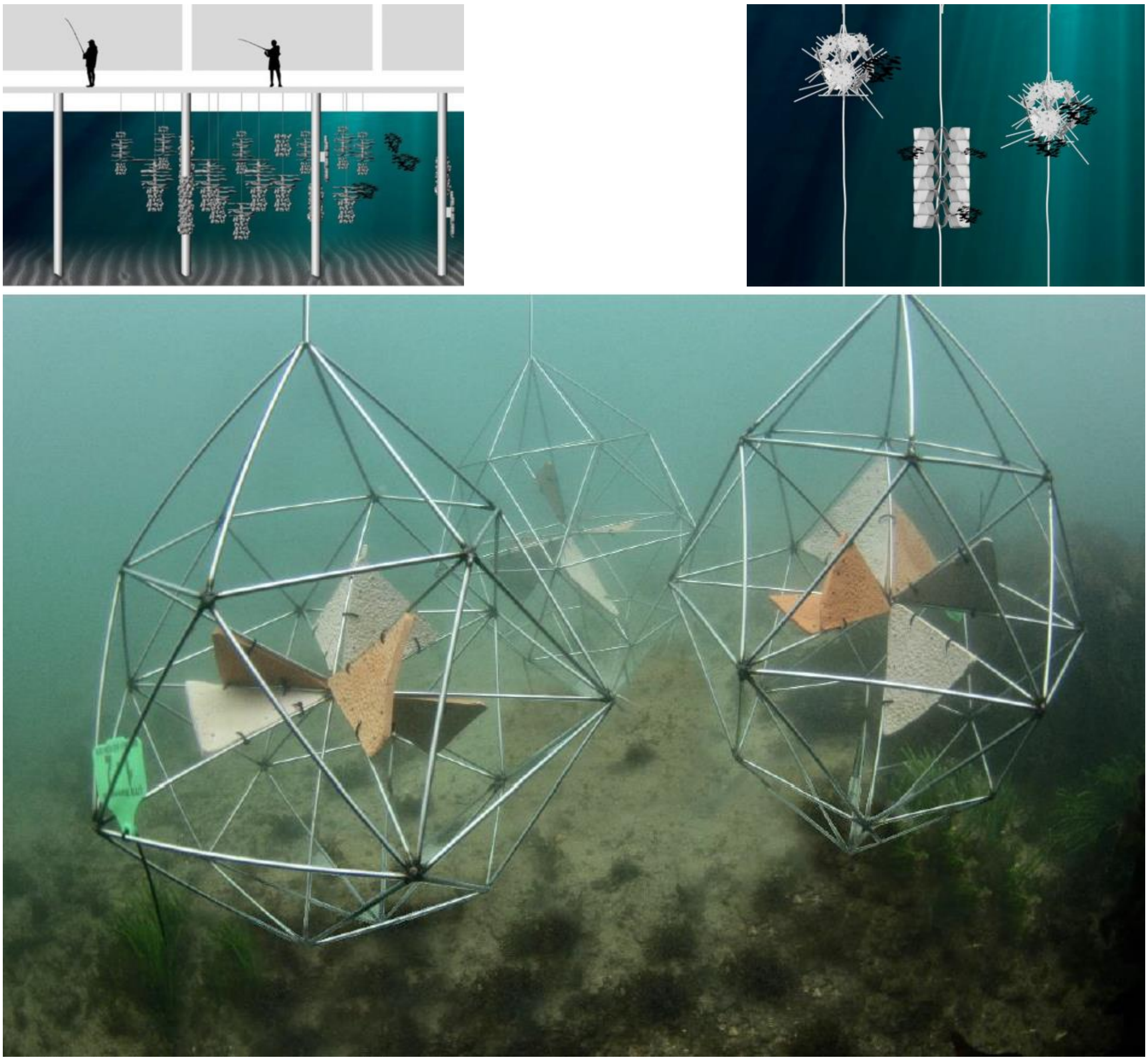


Figure 7: Plan view (not to scale) of suggested cluster placement of benthic units (to be refined at time of build)

3.4 Hanging fish aggregation devices

Hanging fish aggregation devices are suited in deeper water, as they can be mounted underneath the promenade or wharf and submerged in the top 1-3 m (from LAT). See Figure 3 for suggested location.



Example hanging fish aggregation devices

3.4.1 Material and size

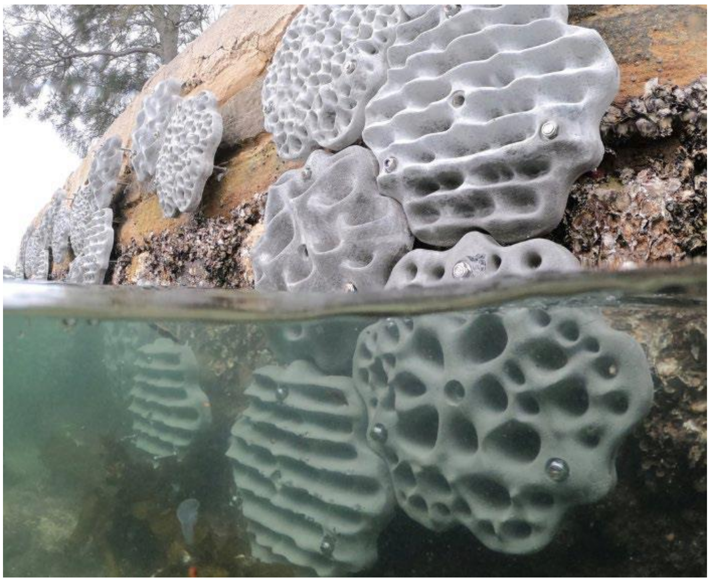
Suspended module: 600-1000 mm cube or irregular shaped complex polygon or similar with crossbars or panels to maximise surface area and voids. Suitable materials are marine-suitable metal rods (cage-like), ceramic panels and prefabricated marine-concrete. A lightweight design is preferable. Suspension cable and mounts to be marine- grade stainless steel or equivalent. No plastic or degradable products. Approximately 40 units are required.

3.4.2 Design criteria

Structures are to be suspended from the promenade/wharf so they are located 1-3 m below the water surface (from LAT), and no further than 5 m from the edge to allow sufficient light to reach the unit for plant growth. Complex shapes are encouraged to increase surface area and provide a variety of fish shelter. Suspension cabling and mounts must be built to hold at least six times the weight of the unit to allow for future growth of organisms and minor turbulence from boat wash and tidal motion. Purpose-built commercial modules are recommended as they have been tested and designed to maximise habitat.

3.5 Seawall tiles

Seawall tiles are to be mounted/precast along the basement wall in the intertidal zone where there is maximum light availability. See Figure 3 for suggested location.

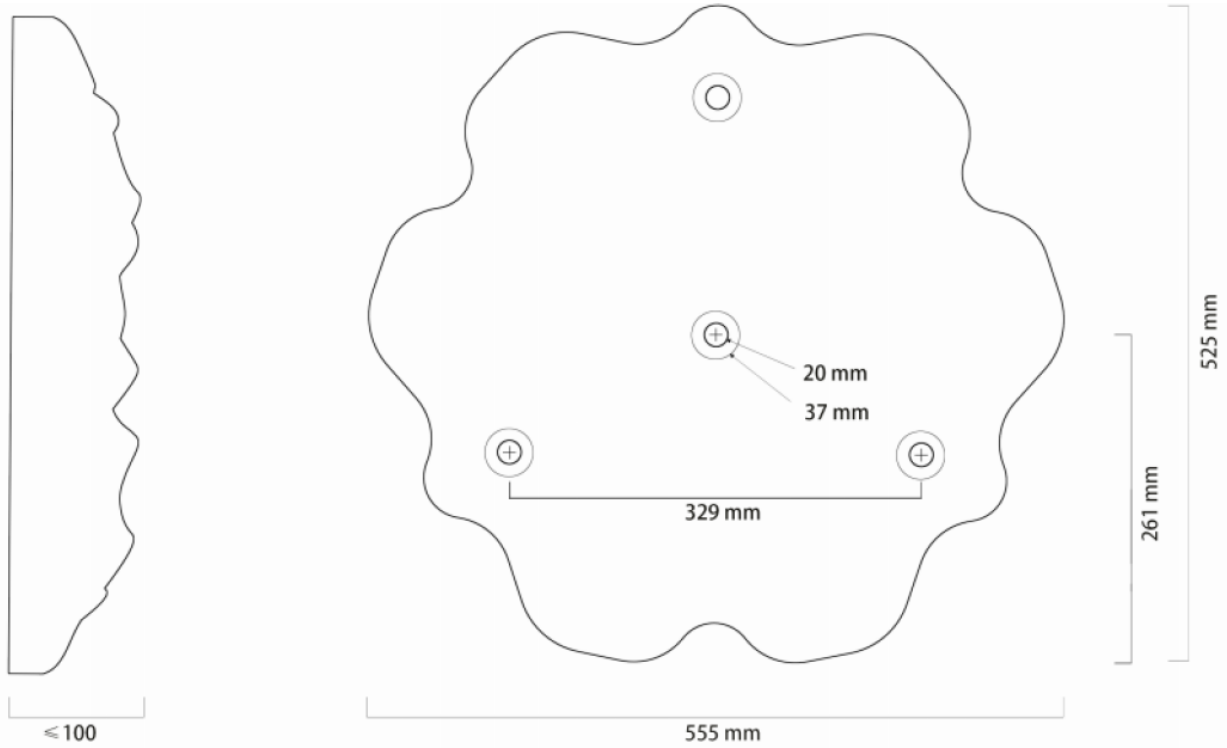


Volvo Ocean seawall: image courtesy of Reef Design Lab/ SIMS

Example habitat tiles

3.5.1 Material and size

As shown above. complex habitat tiles 40 m long x 2 m tall (max 4 tiles tall) bolted to bracket attached to wall. Total surface area of host wall is ~80 m^2.



Tile dimension (Reef Design Lab)

3.5.2 Design criteria

Seawall tiles aim to maximise micro-habitat and provide wet and cool refuge for small marine organisms. If prefabricated panels are used, the imprint must mimic the design intent of the tiles. Placement should cover the maximum to minimal tidal rage, or centred around the average range with some allowance for sea level rise. For example, it the top of the wall aligns with highest astronomical tide (RL 1.18), then the 2 m wall titles would cover the intertidal range.

3.6 Bioshelter

Prototypes of a bioshelter currently being tested by the universities. A unit was installed mid-January near Anzac Bridge, and will be trialled for 12 months. The final product will be approximately 5 x 3 m and likely placed in the intertidal zone along a seawall at the nSFM by others.

Bioshelter prototype models

This chapter is to be updated as progress on the research is made.

4. Built habitat at the nSFM (2024)

To be included in future revisions of this report. This section will document location and quantity of each habitat element installed, including photos and maps.

5. Monitoring

A five-year monitoring program is recommended following installation of habitat elements, which would be implemented by others post-construction. Details of the monitoring plan will be developed over the coming years and modified to suit the habitat elements installed. Sessile marine biota is expected to colonise the structures, and mobile species are expected to either forage, shelter or pass by the structures. As a guide, the monitoring program should consider the following themes, with the first point more suited to the wall tiles and rock rubble reef, and the second point suited to hanging or benthic habitat modules:

- Quadrat replicate sampling of colonising **algae** and **invertebrates** twice before installation at the host site and control site, then repeated at 6mths, 1yr, 2yr and 5yr after installation. Methods to consider include:
  - Visual census via snorkelling/diving
  - Photographic sampling for desktop analysis
  - Scraping/destructive sampling to include stratified or cryptic species
  - Stratified by depth (high intertidal, mid intertidal, subtidal)
  - Target different microhabitat structures (e.g. crevice size, light versus shade)
  - A combination or variation of the above.
- Static **fish** surveys twice before installation at host site and control site, then repeated within one week of installation (or once safe if still a construction site) to measure structural response, then at 6mths, 1yr, 2yr and 5yr to measure prey response, with each event replicated across the site and over 2-3 days. Methods to consider include:
  - Unbaited cameras for 1 hour at high tide (e.g. waterproof action camera mounted to a frame directed towards habitat), with footage analysed for total observations per species and behaviour (feeding, passing, sheltering)
  - Repeat over 2-3 days each survey event to capture variation
  - Trial method to determine constraints from water turbidity and boat wash.

The above themes and potential methods are to be refined in consultation with marine ecologists at Macquarie University (and others) and Infrastructure NSW in order to develop a robust and cost-effective program. A pilot trail may be required to adjust methods to suit Blackwattle Bay. Other reference sites across Sydney Harbour should be considered to compare the results.

6. References

Office of Environment and Heritage (OEH) 2009 *Environmentally Friendly Seawalls: A Guide to Improving the Environmental Value of Seawalls and Seawall-lined Foreshores in Estuaries.*

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