Department of Primary Industries

Recreational and Aboriginal Fisheries Management

Long Term Management Plan – Tweed Heads offshore artificial reef

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More information

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Long term management plan

The NSW Department of Primary Industries (DPI) is responsible for the operation, including management, monitoring and maintenance of the Tweed Heads offshore artificial reef. This long-term management plan has been developed to provide clear direction on the implementation of environmental management best practices during the construction/installation, and operation of the reef.

This plan has been developed as part of the environmental assessment (EA) process and DPI is committed to carrying out the mitigation measures outlined in this plan and the EA. Assessment of ecological, biological and socio-economic impacts have been considered and are summarised in this plan.

1 Introduction

DPI aims to improve recreational fishing opportunities in NSW through the development of offshore artificial reefs in offshore locations. DPI manages recreational fishing in ocean waters off NSW under the *Fisheries Management Act 1994 (FM Act)* and the Offshore Constitutional Settlement. The primary objective of the FM Act is 'to conserve, develop and share the fishery resources of the State for the benefit of present and future generations. Further objectives under the Act include promoting 'ecologically sustainable development, including the conservation of biological diversity' and promoting 'quality recreational fishing opportunities'. The deployment of artificial reefs as a fisheries enhancement tool is consistent with these objectives.

Recreational fishing is an important leisure activity for approximately 12% of the NSW population (approximately 849,000 people over the age of 15) and provides significant social and economic benefits, with an estimated $3.42 billion generated in economic activity in NSW each year creating approximately 14,000 full-time equivalent jobs.

In NSW, approximately 22% of the total fishing effort takes place between the shoreline and 5 km offshore. The creation of new, high quality fishing areas through the deployment of offshore artificial reefs will enhance fishing opportunity by creating high relief, complex fish habitats. Recreational reefs will provide additional fishing locations and an alternative to heavily fished natural reefs. They also have the potential to increase the abundance and productivity of some demersal and reef species found there.

This proposal is considered an 'activity' under Part 5 of the *NSW Environmental Planning and Assessment Act 1979 (EP&A Act)*. The deployment of the offshore artificial reef structure requires a licence under Section 34 of the *Crown Lands Act 1989*, given the proposed deployment site is located in State waters (within 3 nautical miles) on unzoned land. Construction of artificial reefs is regulated under the Commonwealth *Environment Protection (Sea Dumping) Act 1981 (EP (SD) Act)*. The assessment of impacts identified components of the marine environment and potential impacts/issues related to those components that require further investigation and potential monitoring. The potential risks identified in the EA would be minimised or removed to an acceptable level of risk through implementation of the Long-Term Management Plan (LTMP). This plan aims to consolidate the mitigation and management measures that the DPI is committed to implementing.

1.1 Project planning

DPI has been responsible for the preparation of all documentation, stakeholder consultation, risk analysis, constraints identification and specialist flora and fauna investigations. DPI has coordinated a team of highly qualified environmental consultants who have extensive experience in oceanography and coastal processes of the NSW coast, cultural heritage and hydroacoustic surveying (Figure 1) to provide further expertise when required.

DPI reviewed relevant planning and legislative requirements, provided detail for requirements of artificial reef design and planning and provided an overview of the construction and deployment process. In addition, DPI developed a research and monitoring plan and procedures to assess potential impacts relating to threatened species, pest species, angler catch, fishing related marine debris and the monitoring of effects of scouring and deposition in the vicinity of the reef post deployment and its impact on the structural integrity of the reefs.

DPI engaged the services of:

- Umwelt Pty Ltd to investigate the cultural significance of the site and potential impacts on Aboriginal heritage and to undertake consultation (Technical Report A).
- The Manly Hydraulics Laboratory (Public Works) to provide expertise in coastal processes including wave behaviour and sediment movement and circulation (Technical Report B).
- Astute Surveying Pty Ltd to complete the acoustic survey of habitats in the vicinity of the proposed reef location (Technical Report C).

The technical reports are summarised within this document.

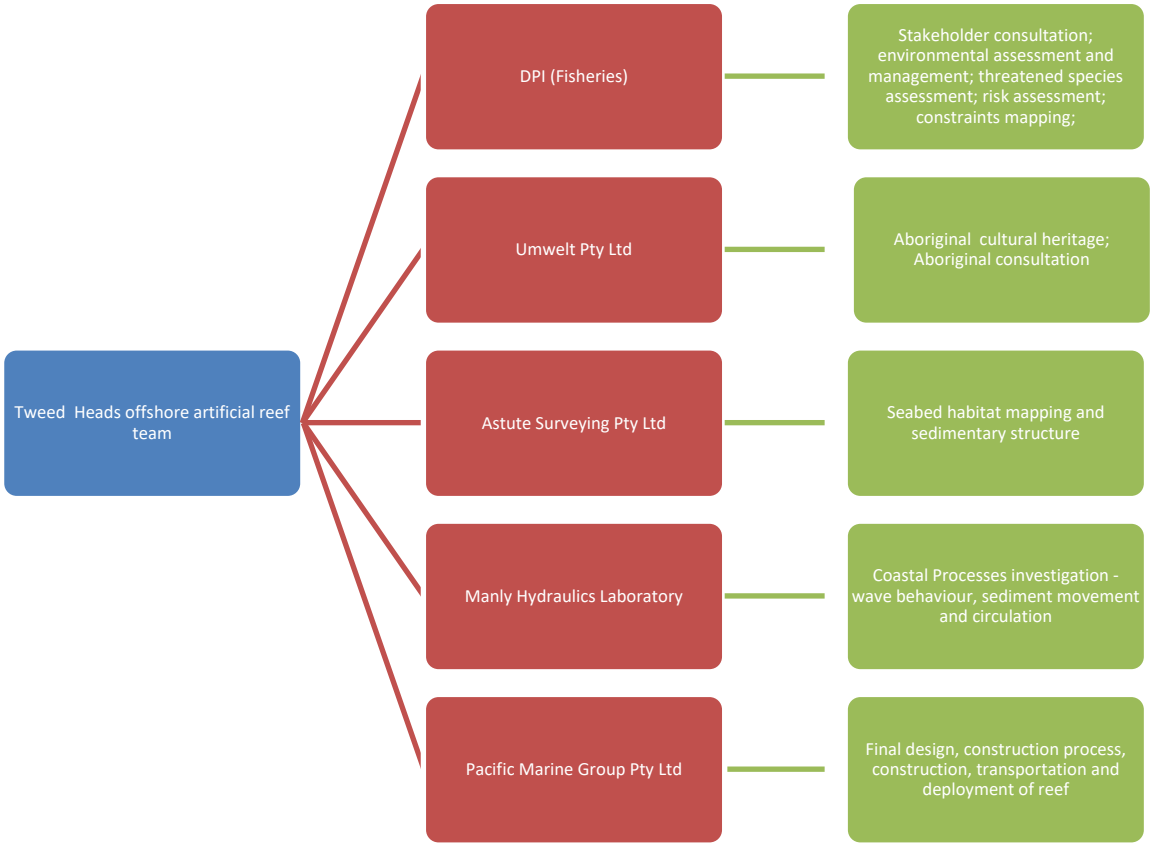


Figure 1 Tweed Heads offshore artificial reef EA team

1.2 Consultation with relevant Commonwealth, State and Local Government agencies and interested non-government organisations

Consultation was carried out by, email, phone calls and through stakeholder consultation meetings. Fisheries enhancement and the proposed offshore artificial reef were also included as agenda items as part of regular stakeholder meetings (e.g. The Recreational Fishing NSW Advisory Council (RFNSW) and the Recreational Fishing Saltwater Trust Expenditure Committee (RFSTEC)). In addition, consultation relating to the Aboriginal Cultural Heritage Due Diligence Assessment was carried out by Umwelt Pty Ltd and outcomes of this consultation were summarised in the corresponding report.

Additionally, a webpage specifically relating to the proposed Tweed Heads offshore artificial reef was launched at the beginning of the consultation period on the DPI Fisheries webpage (www.dpi.nsw.gov.au/fisheries/artificial-reef). The website was used to provide updates on the progress of the proposal and information regarding the environmental assessment, and an email address (fisheries.enhancement@dpi.nsw.gov.au) was provided as an additional avenue for community feedback.

Stakeholder consultation emails letters and phone calls were conducted between 29 August 2018 and 13 December 2019 (Table 1). The consultation letters provided the context for the

proposed Tweed Heads offshore artificial reef, a brief history of artificial reef deployment in NSW and set out the environmental assessment process currently being conducted by DPI in regard to the proposal. The letters contained DPI contact details and invited comment on the proposal; the objective being to provide an opportunity for community stakeholders to provide any comments on the Tweed Heads artificial reef proposal.

Table 1 Consultation letter distribution details

Group	Number
Aboriginal stakeholder groups	12
Recreational fishing stakeholders (including line and spear fishing clubs, recreational fishing associations and charter operators in the Far North Coast region)	38
Commercial fishing stakeholders (including fishing business owners, nominated fishers, professional associations and fishermen's co-operatives)	79
Conservation	9
Diving (retailers, charters)	2
Surf lifesaving clubs	2
Statutory authorities (including local, state and federal government)	16
Recreational licence agents and fishing tackle outlets (in the North Coast region)	7
Universities	3
Visitor information centres	1
Businesses/voluntary organisations	4
Total	173

Media coverage of the project has been conducted since 28 July 2017 when the Minister for Primary Industries announced that an artificial reef would be built off the coast of Tweed Heads and this announcement received widespread online coverage. Since this time several updates on the status of the Tweed project have been included in broader community consultation on the artificial reefs program including Newscast, and social media.

Several face to face meetings were held during the main consultation phase. These were mainly with user groups who had specific requirements regarding the placement of the reef including local fishing charter operators and local Aboriginal groups.

Responses from the statutory and non-statutory groups consulted were received via telephone, email and from the stakeholder consultation meetings. The proposal was generally well-received in terms of the location and design of the reef and the processes used in selecting these.

2 Project goals and objectives

2.1 Vision for the activity

The long-term vision for the deployment of offshore artificial reefs is:

'An activity that provides effective enhancement of saltwater recreational fishing in NSW; that supports conservation outcomes for fish and fish habitat; and that is undertaken within a clear management framework and consistent with the principles of ecologically sustainable development and ecosystem management'.

2.2 Goals for the activity

The proposed goals that have been designed to achieve this vision for the activity are as follows:

1) To manage the activity in a manner that minimises impacts on ecological sustainability and aquatic biodiversity and improves the knowledge of the activity and ecosystems in which it operates.
2) To enhance fishing opportunities through cost-effective reef deployment which complements other existing DPI programs to ensure sustainable fisheries resources and that maximise social benefits, consistent with achieving outcomes aligned with the priorities of the NSW State Plan.
3) To ensure the consistent production, deployment and monitoring of appropriate quality reefs.

3 Risk assessment

3.1 Introduction

As part of the Environmental Assessment, a workshop to review previous risk analyses assessing the impacts of artificial reefs was held on 6 February 2020, attended by DPI representatives who have expertise in artificial reef assessment, monitoring, design and construction. The aim of the workshop was to review existing potential issues/hazards associated with the proposed Tweed Heads offshore artificial reef and identify any new potential hazards. The risk assessment workshop assessed the likelihood of occurrence of such hazards and the consequence to key receptors if these hazards eventuated.

Risk analysis undertaken by DPI and industry professionals for the past seven offshore artificial reefs considered potential impacts relating to coastal processes and oceanography, ecosystem processes, contamination, fisheries (commercial and recreational) and interference with existing coastal infrastructure, obstructions and exclusion zones.

The risk analysis workshop review meeting in February 2020 assessed if based on updated information gained from reef monitoring and post installation operations by DPI if risk ratings required alteration or if new mitigative tools would be employed for the Tweed Heads

artificial reef. Combined with the constraints mapping process and the Coastal Processes, SWATH (acoustic) mapping and Aboriginal heritage consultant reports, the review sought to minimise or eliminate a number of potential risks associated with existing infrastructure, obstructions and exclusion zones (such as deep-water ocean outfalls, port restrictions, spoil grounds and historical shipwrecks), threatened species by avoiding critical habitats and marine protected areas.

The risk assessment focusses on issues identified through the risk assessment workshop, during consultation and identified for consideration through both State and Commonwealth legislation.

3.2 Methods

Environmental or ecological risk assessment has become an important means for identifying the likelihood and relative consequence of potential hazards associated with human activities. It is also now being widely advocated as beneficial for fisheries management [1]. The following risk assessment was based on the principles of Australian Standards for Risk Management 4360:2004 and Fletcher [1].

Typically, assessment of risk entails the identification of a potential hazard (i.e. some aspect of the activity that could affect the environment), a judgement of the likelihood that the hazard has of occurring and a judgement of the consequence of that hazard, if it did result from the proposed activity. Frequently, scientists and managers also consider those aspects of the environment that might be subject to the hazard; such aspects are often referred to as receptors.

Key points that need to be recognised in relation to the general risk assessment:

- The risk assessment benefited greatly from the initial site selection and constraints mapping which resulted in avoidance of major biological constraints, such as areas of natural reef and areas of conservation significance, navigational hazards and exclusion zones.
- The risk assessment was undertaken at a generic level.
- Risk is often scale-dependent; therefore, the risks were assessed using scales where they were thought to have the greatest potential impact. To reduce the subjectivity of this analysis, the scale on which each of the risks was assessed is listed in the risk assessment table.
- The risk analysis methodology deals mainly with impacts on the environment. However, the methodology has also been used to analyse relevant health and safety issues.
- The risk analysis is based on the proposed reef design.

The risk matrix gives the rationale for scoring probability/likelihood of a hazard occurring and of the consequence if the hazard eventuated. Scores of likelihood and consequence may then be combined into a matrix to provide a subjective judgement of significance. Based on this, each hazard/risk is identified as being of very low, low, medium or high significance. The result of the risk assessment does not mean that the project should not proceed, i.e. if the level of risk is high, but rather that the issue may need greater or less effort in management/mitigation or that further research on the receiving environment is required.

Note that health and safety impacts are assessed on a different scale to environmental impacts.

4 Tweed Heads offshore artificial reef management area

The location of the proposed artificial reef deployment site is situated 7.5 km south of the Tweed Heads river entrance, 2.4 km offshore from Dreamtime Beach at Wommin Bay within State waters in an approximate depth of 25-27 m LAT. The depth of water over the tallest steel structure will be approximately 16 m. The size of the deployment and management area is a 600 x 400 m square with the centre point of the reef located at 28° 13.446′ S, 153° 35.508′ E (Figure 2). The corner point co-ordinates (GDA94) for the reef management area will be situated at 28° 13.338′ S, 153° 35.322′ E (NW), 28° 13.338′ S, 153° 35.688′ E (NE), 28° 13.554′ S, 153° 35.322′ E (SW), 28° 13.554′ S, 153° 35.688′ E (SE).

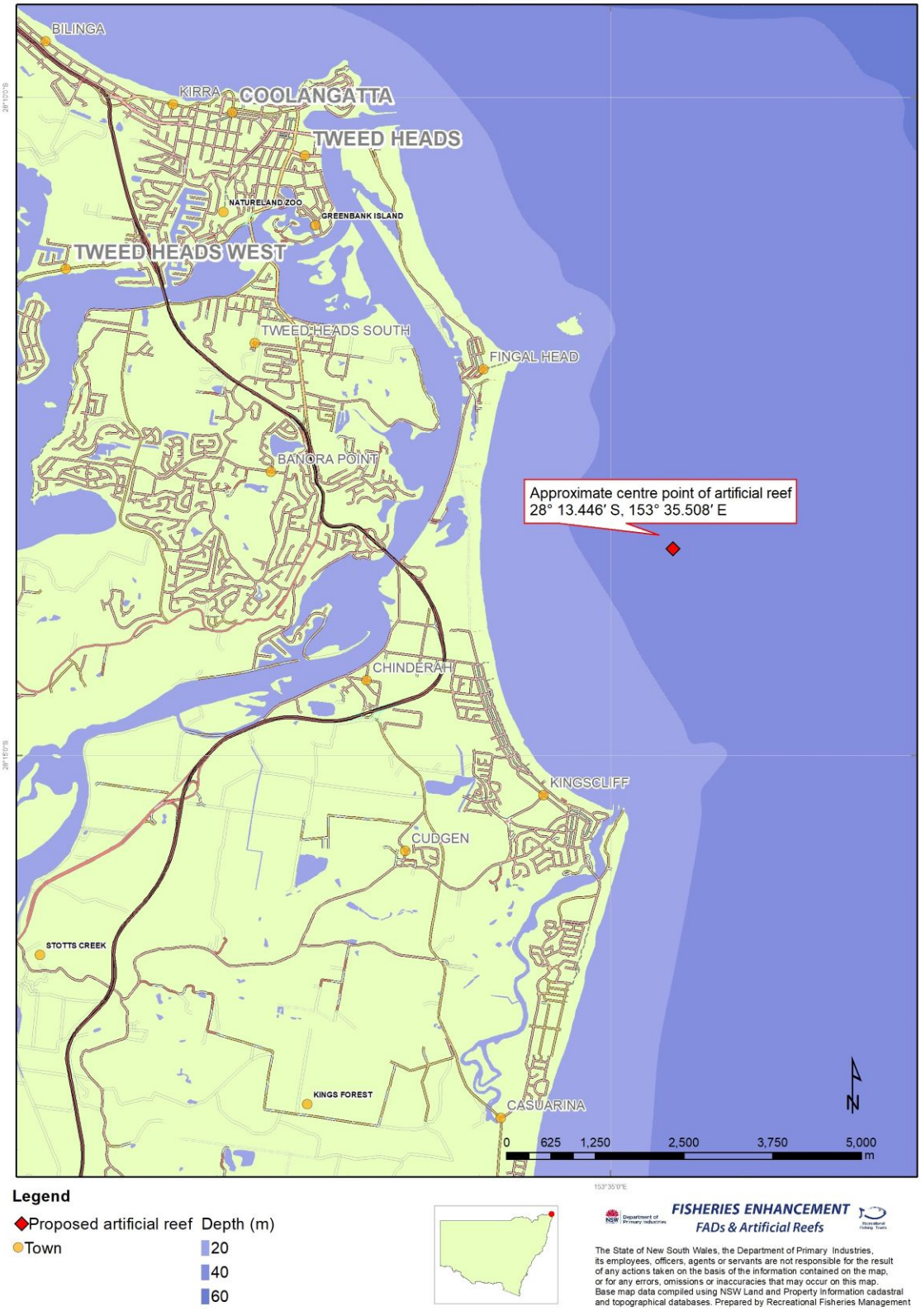


Figure 2 General location for proposed deployment of the reef

4.1 Socioeconomic considerations

Over 80% of fishing effort in NSW occurs in saltwater (estuarine, inshore and offshore waters). The Mid North and North Coast Fishing zones account for almost a quarter of the fishing effort in NSW (24%) ([2]). It is anticipated that the OAR will have high visitation rates given a large proportion of seasonal tourism based interstate fishing effort comes from Queensland.

The Tweed district waterways provide excellent beach, rock, and boat fishing opportunities. The Brunswick River is a particularly popular recreational fishing area within the Tweed region and is the northern boundary of the Cape Byron Marine Park.

Trip expenditures by anglers are classified as being either directly attributable to fishing (tackle, bait/berley etc.), indirectly attributed (accommodation, travel, boat fuel and hire), and other expenses (eating out, other entertainment, food and drinks etc.). Survey data shows anglers spent over $511M on the North Coast in 2012, the second highest spend in NSW. The flow on economic impact to the North Coast region included $734.65M in regional output, $353.55M in value add, $168.75M in household income and 3,320 full time equivalent jobs. Given the relative population to other coastal regions, this represents a significant spend and economic contribution that recreational fishing makes to these local economies ([3]).

A recent social return on investment study on previously installed artificial reefs in NSW found social returns of 8.8% in Port Macquarie and 9% on the Southern Sydney reef over the 50 year life of the reef using conservative assumptions (unpublished). Given expenditures by anglers in the Tweed region DPI anticipates similar or greater social return on this investment to the economy.

It is estimated that approximately 2460 hours of fisher effort were expended on the Sydney offshore artificial reef during the 2013/14 survey year, equating to a higher levels of recreational usage intensity than many natural NSW estuarine systems (Figure 3 [4]).

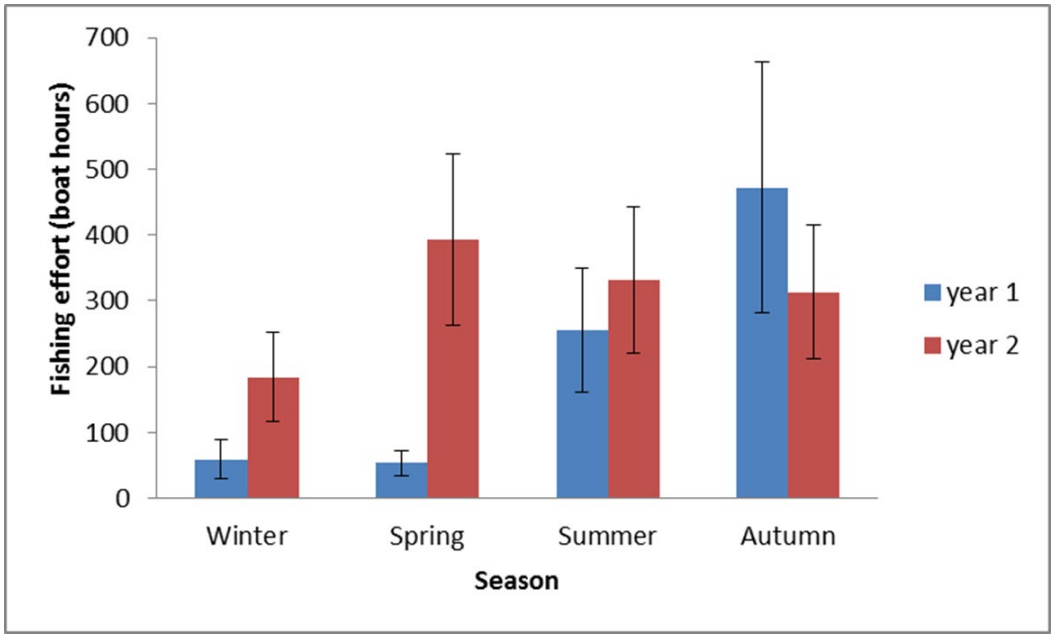


Figure 3 Average (± SE) fishing effort at the OAR site per season for the two sampling years (year 1 is June 2012- May 2013; year 2 is June 2013- May 2014)

The location and accessibility of the Tweed offshore artificial reef is expected to deliver similar direct social and broader economic benefits by providing increased recreational fishing opportunities in the region. The following have been identified as beneficiaries of the reef:

- recreational fishers who have an interest in healthy fish stocks and a quality marine environment;
- tourism and charter operators who base their businesses around the quality of the fishing experience and the abundance of fish; and
- tackle and boating industry that depend on having sustainable fish resources in the southern Tweed.

4.2 Environmental considerations

The North Coast Bioregion runs up the east coast of NSW from just north of Newcastle to just inside the Qld border. The total area of the bioregion is 5,924,130 hectares and the NSW portion is 5,692,351.6 hectares or 96.1 per cent of the bioregion. The NSW portion of North Coast Bioregion occupies 7.11 per cent of the state. The North Coast Bioregion has proven to be a popular place to live, with hundreds of 'holiday towns' lining the coast and eastern inland, including Port Macquarie, Ballina, Coffs Harbour, Byron Bay, Tweed Heads, Lismore, Alstonville, Dorrigo, Forster and Taree.

The Tweed, Richmond, Clarence, Coffs Harbour, Bellinger, Nambucca, Macleay, Hastings and Manning River catchments all fall in the North Coast Bioregion. The general trend in this bioregion from east to west is from a sub-tropical climate on the coast with hot summers, through sub-humid climate on the slopes to a temperate climate in the uplands in the western part of the bioregion, characterised by warm summers and no dry season. The soil and vegetation patterns in the bioregion are very complex because of the different substrates, the topographic variation and the climatic differences encountered across and along the bioregion. In the coastal dunes, deep siliceous sands and very well developed podsols can be found.

A detailed investigation of existing information and database searches relating to the study area has shown that there are several critical constraints which required further consideration to identify a suitable reef location. These included the preferred depth requirements, proximity to reef substratum, commercial fishing activities.

Reef siting and design should incorporate a variety of biological, economic, and physical sciences and engineering factors ([5]). Size, relief, complexity, location and biological factors can all influence assemblages of fishes on artificial reefs ([6]). Biological principles that should be considered include habitat limitation ([7]), habitat complexity ([8], [9]) and refuge from predators ([10]). Physical principles deal with the size of the reef structure ([11]) and the strength and stability of the reef materials. Reef size and its influence on species abundance is an ongoing debate. Where biomass has been reported in association with large artificial reefs, it may be composed of large but few individuals ([12]). Conversely, greater densities of fish on smaller artificial reefs have also been reported ([6]). The vertical relief, relative to water depth of an artificial reef, can also influence abundance and diversity. In temperate waters, diversity has been shown to be greater on low-relief artificial structures than on natural

structures ([13]). Conversely, a study of high-relief reefs found greater diversity on natural reefs than on artificial reefs ([14]). Psychological, social and economic aspects of human behaviour are also important when considering reef design, taking into account the requirements of possible end user groups ([15], [16], [17]).

Storm events with a return interval of 100 years are expected to produce a significant wave height offshore of Tweed Heads of 7.9 m (Hs) (Table 2). This parameter is to be taken into consideration as a primary design specification for the reef and its modules. The highest maximum significant wave height recorded at the nearby Byron Bay Waverider buoy managed by Office of Environment and Heritage and operated by Manly Hydraulics Laboratory was 7.64 m. This storm event occurred on 21 May 2009 when the Byron Bay Waverider buoy also recorded the highest individual maximum wave height (Hmax) of 13.7 m.

Measured wave data collected from the Waverider buoy at Byron Bay (Figure 4) shows the prevailing wave direction is from the south to south-east sector. This direction is dominant both in terms of the highest wave heights and the longest wave periods originating from the south-south-east direction. Both the highest wave heights and most frequent storm events originate from the south-south-east during winter, with summer conditions being typically lower wave heights and a relatively greater frequency of easterly and east-south-east wave conditions.

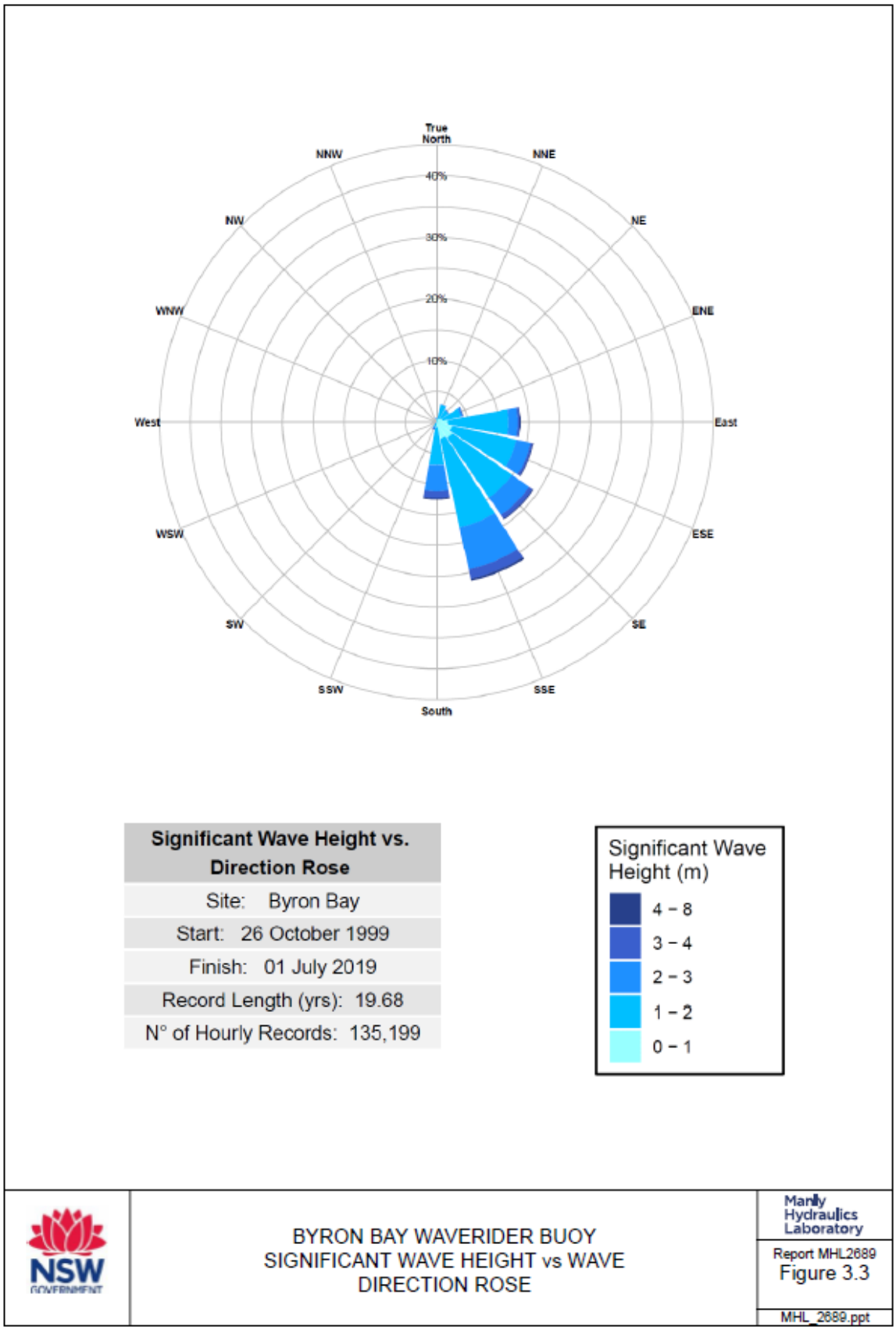


Figure 4 Wave rose of Byron Bay offshore wave datasets

Table 2 Byron Bay Waverider buoy extreme wave analysis results

ARI (yr)	Extreme Wave Analysis Results per Durations									
	1 hour		3 hours		6 hours		12 hours		24 hours	
	Hsig (m)	CI (±m)	Hsig (m)	CI (±m)	Hsig (m)	CI (±m)	Hsig (m)	CI (±m)	Hsig (m)	CI (±m)
1	5.3	0.2	4.9	0.1	4.6	0.1	4.2	0.1	3.7	0.1
2	5.7	0.2	5.2	0.2	4.9	0.1	4.5	0.1	3.9	0.1
5	6.2	0.2	5.7	0.2	5.3	0.2	4.8	0.2	4.3	0.2
10	6.6	0.2	6.0	0.2	5.6	0.2	5.1	0.2	4.5	0.2
20	7.0	0.3	6.3	0.2	5.8	0.2	5.3	0.2	4.7	0.2
50	7.5	0.3	6.7	0.3	6.2	0.2	5.6	0.2	5.0	0.2
100	7.9	0.3	7.0	0.3	6.4	0.2	5.8	0.2	5.1	0.2

The mean average wave direction at the Tweed Heads Waverider buoy is 96° (relative to True North) indicating that at the Waverider buoy site significant wave refraction has occurred as the waves move into shallow water with the average wave direction near parallel to the seabed depth contours. This result is illustrated by comparing the wave height and direction roses for the offshore Byron Bay and nearshore Tweed Heads Waverider buoys (Figs. 4 and 5). The lower wave heights and changes in wave direction recorded by the Tweed Heads Waverider buoy can be attributed primarily to wave refraction and shoaling, and to a lesser extent, friction attenuation effects as the waves move from deeper offshore waters into the shallower water at the Tweed Heads Waverider buoy site.

Application of the NSWaves computer application (NSW Government 2016 http://nearshore.waves.nsw.gov.au) indicated that wave conditions at the Tweed Heads Waverider buoy site can be considered representative of wave conditions at the proposed artificial reef location. However, the Tweed Heads Waverider buoy data set is not considered long enough for extreme value analysis and for the evaluation of artificial reef design parameters so the 40 year Byron Bay Waverider buoy dataset was adopted to determine design parameters for the artificial reef.

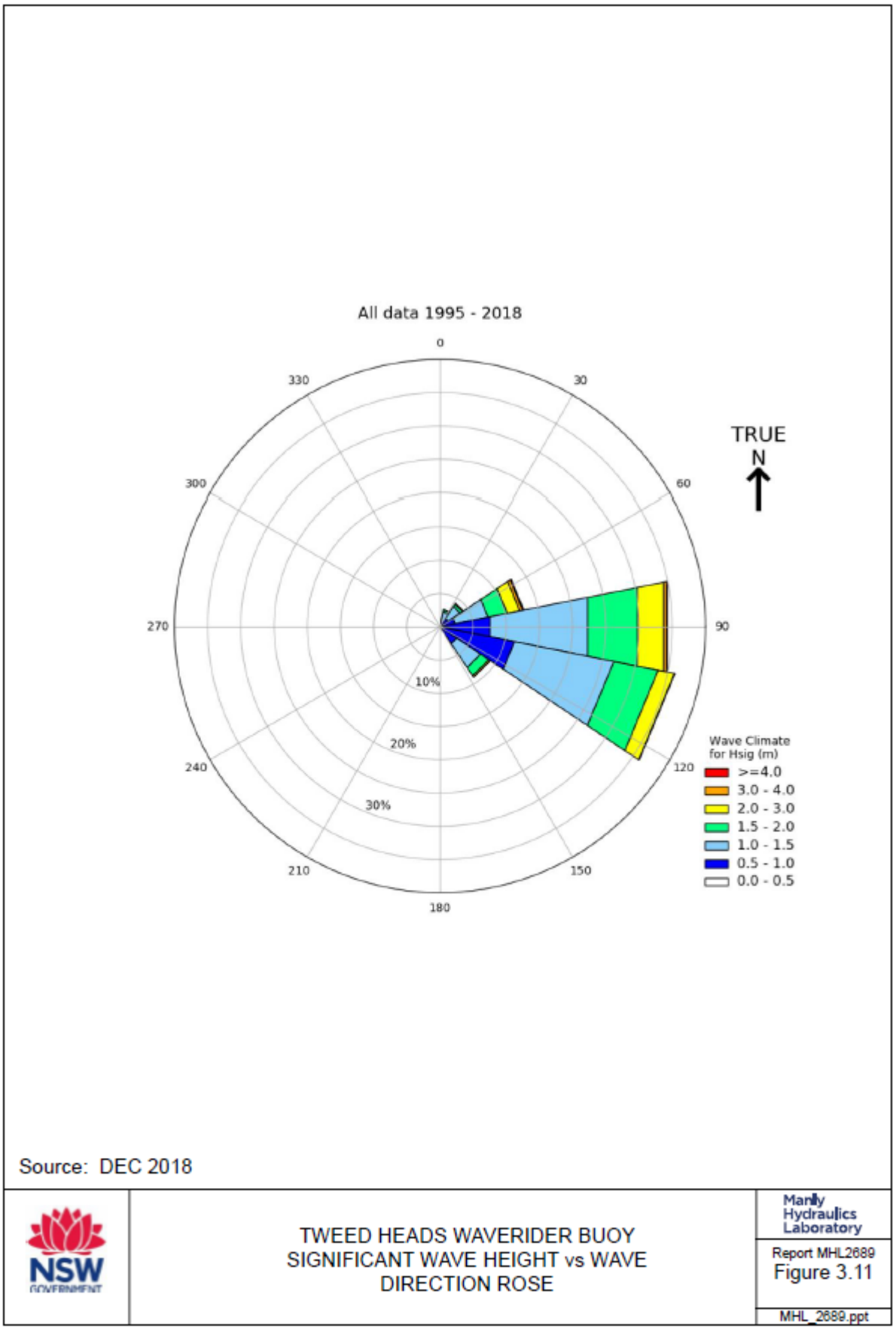


Figure 5 Wave rose of Tweed Heads offshore wave dataset

Water movements in the proposed offshore artificial reef deployment area may be caused by a variety of physical processes, including:

- tides;
- winds;
- density flows;
- coastal trapped waves;
- East Australian Current; and
- nearshore wave processes.

The proposed reef installation is not expected to have a great impact on the wave climate at the site or within the bay more broadly, provided sand does not accumulate significantly within or between the reef modules. Based on an assessment of the available information, the proposed installation of an artificial reef comprised of concrete block modules may have some impact on sediment transport by impeding sand movement potentially resulting in an accumulation of sand between adjacent modules if placed in a water depth of around 20 metres. This is turn may change the seabed bathymetry sufficiently to modify the wave climate at locations along Dreamtime Beach. Therefore, it was recommended that reef be deployed at around 27 m of depth (LAT) and modules designed for sand to pass through them to minimise wave pattern alteration and sand trapping leading to reef burial.

The area of seafloor identified as the potential OAR deployment site lies approximately 7 km south east of the Tweed Heads river entrance, 2.4 km offshore from Dreamtime Beach situated between Cook Island and Kingscliff. Inner and Danger reefs are subtidal reefs that lie 2.7 km to the north and 2 km to the north east of the artificial reef centre point respectively. Both subtidal reefs break during heavy swells. Cook Island nature and aquatic reserves are located north-north-west to the artificial reef centre point and are closed to recreational fishing year-round. Additionally, Fingal Head and Cudgen Headland lie 3.5 km to the north west and south-south-west respectively. The hydroacoustic survey and follow up camera surveys confirmed no presence of hard reef within at least 0.9 km of the proposed reef centre point. The closest known reef identified through LIDAR imagery is 1.85 km to the north of the proposed reef location (Figure 6).

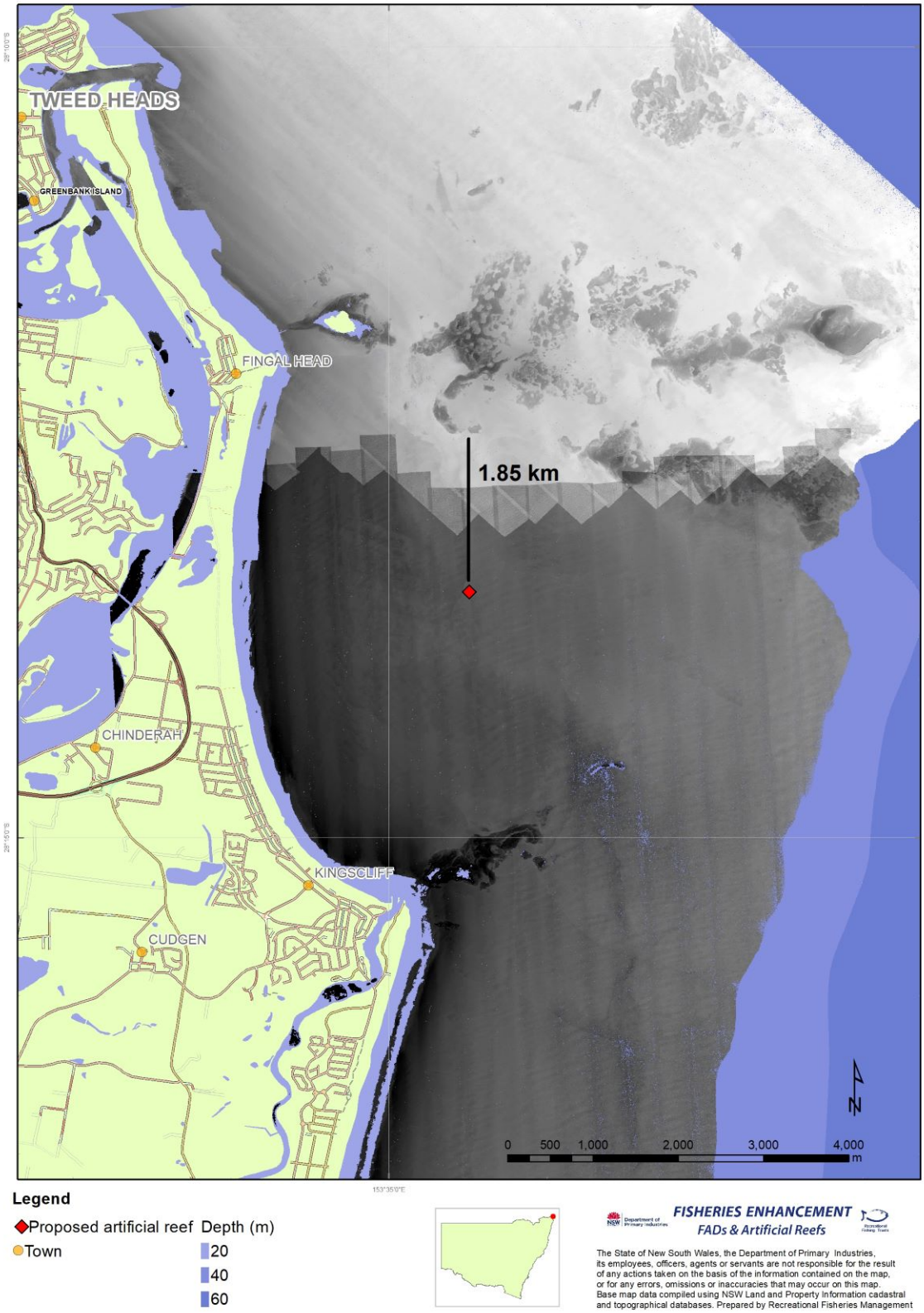


Figure 6 LIDAR reflectance imagery displaying presence of natural reef and distance from proposed artificial reef site

Astute surveying was commissioned to look in detail at the seafloor within the vicinity of the proposed reef deployment site and involved a multibeam echo-sounder (MBES) mapping survey including bathymetry, backscatter and MBES derivative surfaces (i.e. aspect, slope) that define the seafloor characteristics of the Tweed Heads reef site.

The aim of the surveys was to conduct a multibeam survey across the proposed reef deployment area, approximately a 2.8 x 1.9 km survey patch, to provide bathymetry, backscatter, slope and aspect data (Figures 7,8,9,10).

The maps provide a complete description of the physical characteristics of the sea floor within the proposed reef deployment area, highlighting the presence of suitable substrata for the artificial reef throughout the survey area. Swath acoustic mapping results illustrated a 2.8 km onshore-offshore depth gradient consistent with sediment substrata represented by intermittent increases in depth to approximately halfway across the transect before levelling off at 25 - 23.7 m (Figure 9). This indicates that the seafloor is predominantly unconsolidated sediments with the presences of shallow gutters and some slight ridges. A north-south transect was also prepared which represents an intermittent decrease in depth over 1.8 km ranging from approximately 25 m to 20 m (Figure 10). Figure 21 confirms the assumptions of SWATH surveys.

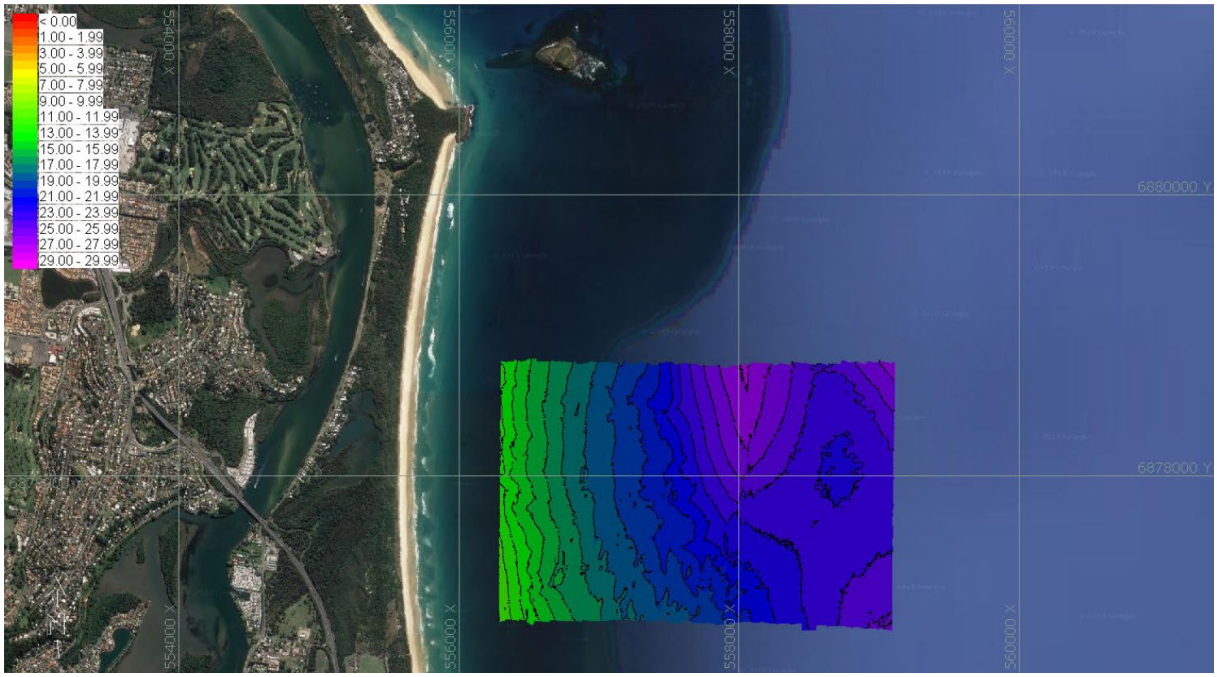


Figure 7 Colour gradient model depicting the depth contours (m) over the survey area

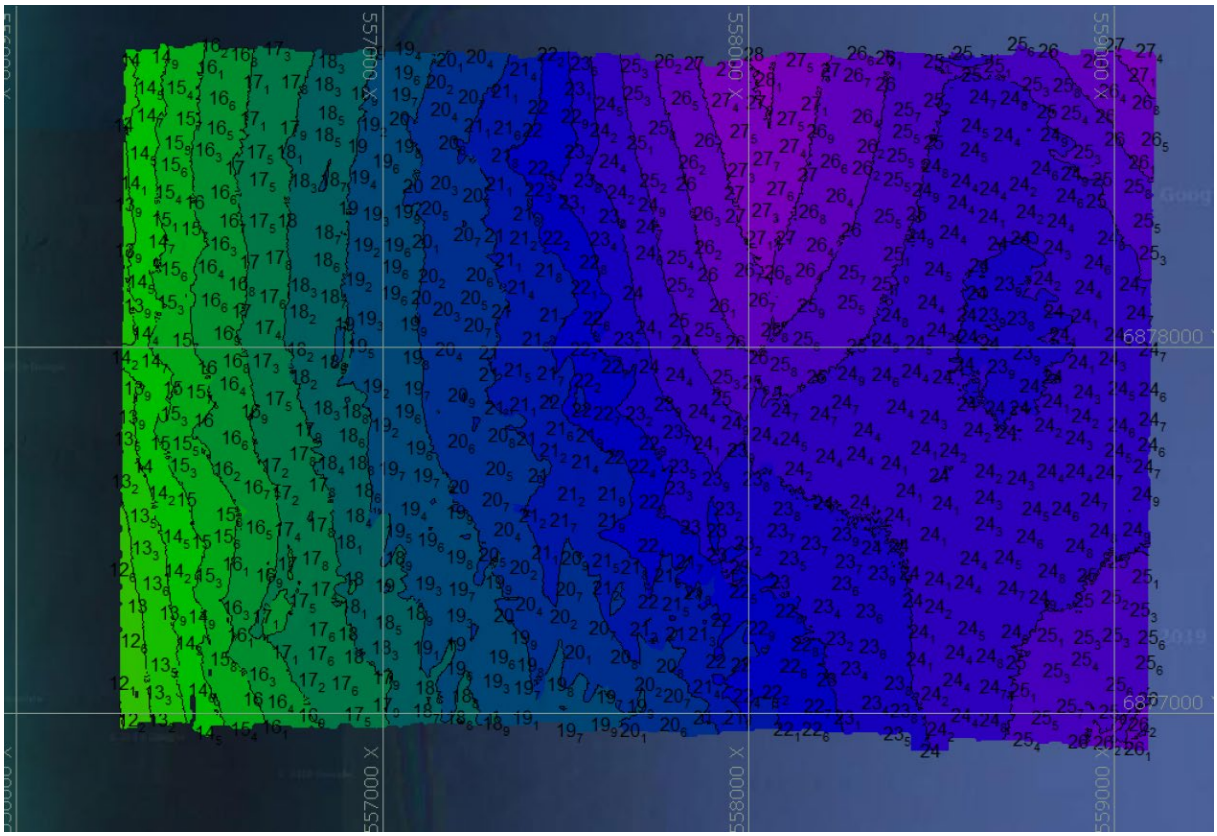


Figure 8 Colour gradient model zoomed in with soundings. Depths (m) are to LAT

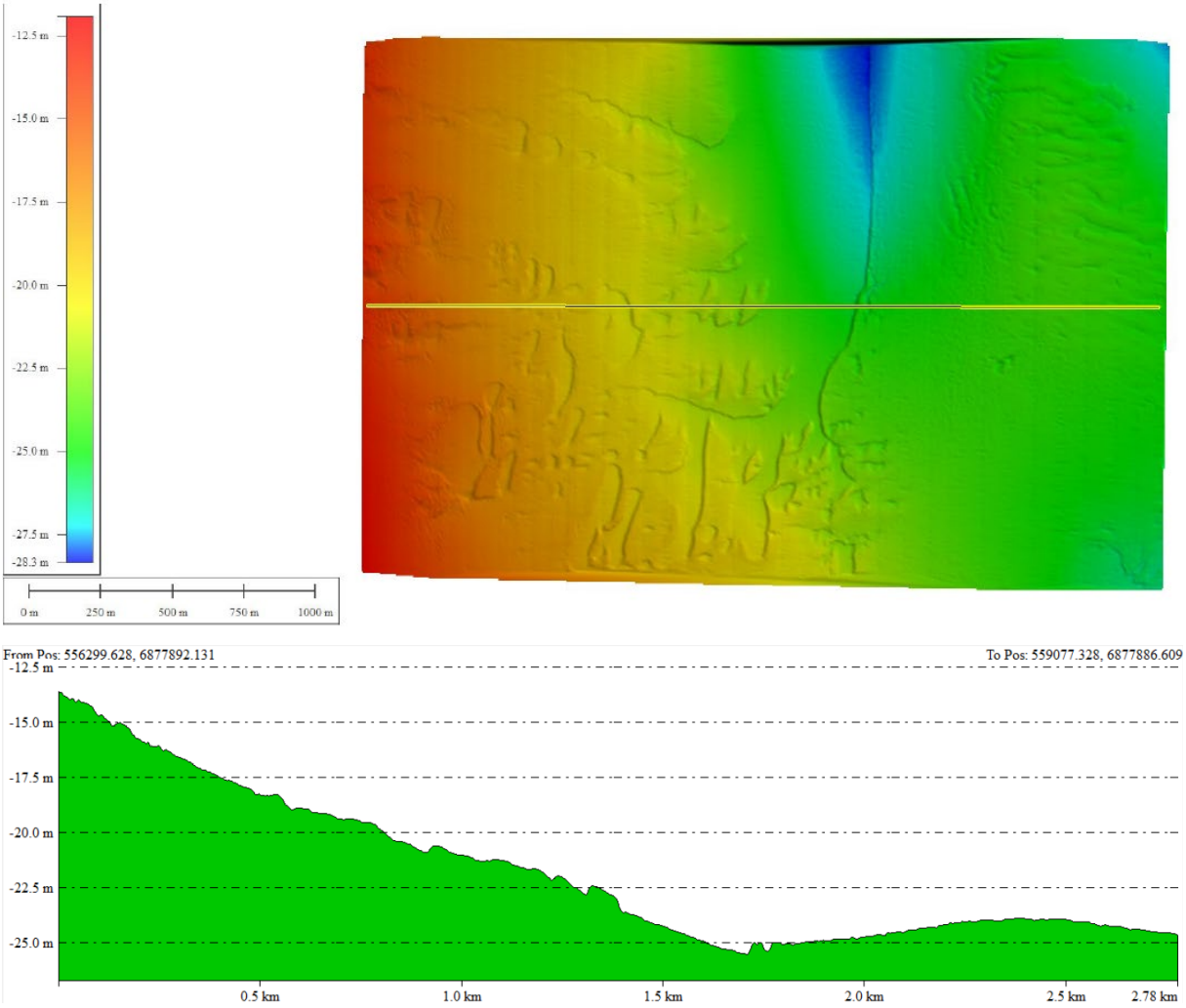


Figure 9 Transect line from west to east indicating the depth characteristics of the survey area

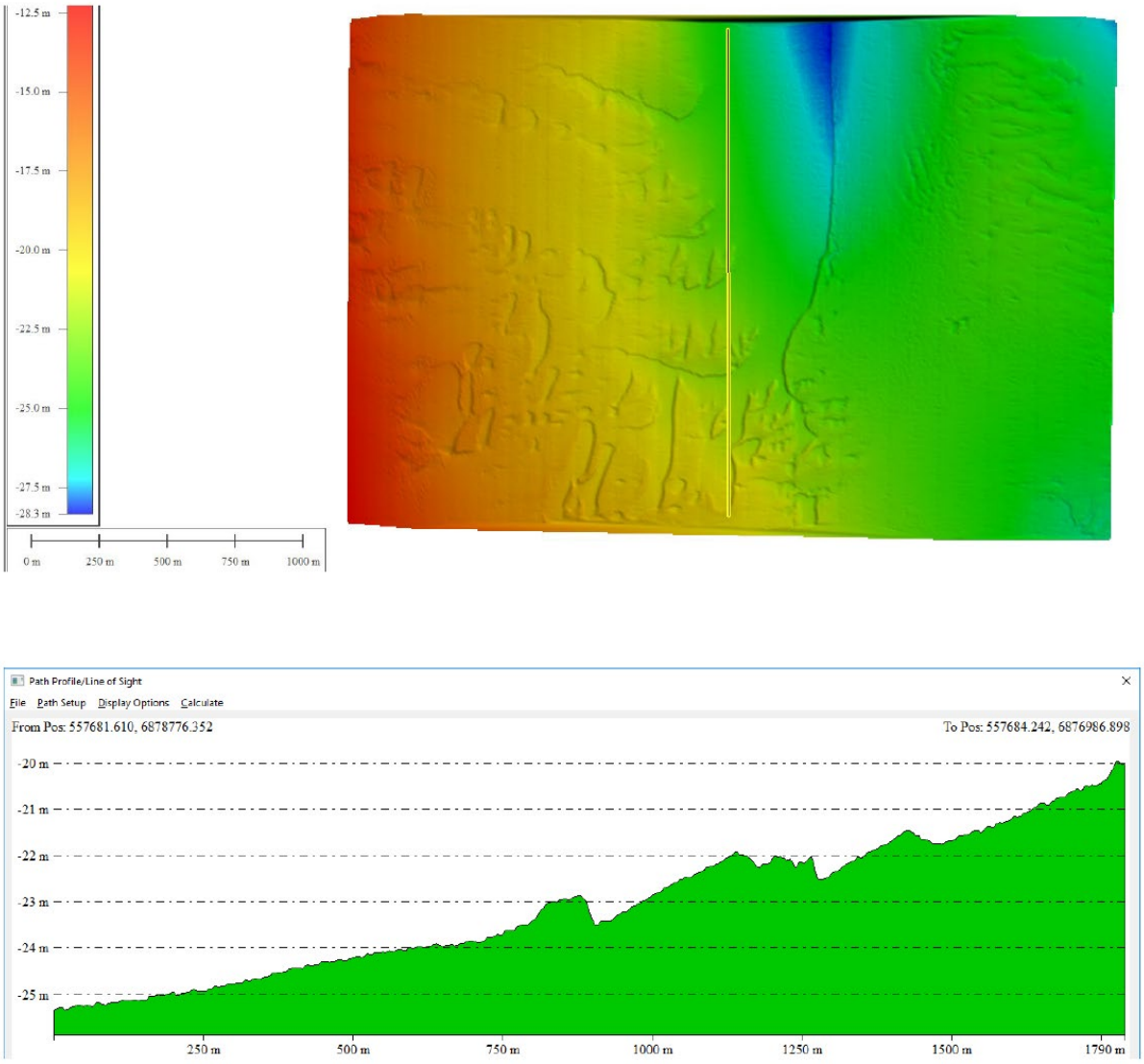


Figure 10 Transect line from north to south indicating the depth characteristics of the survey area

4.3 Biological considerations

Soft sediment and rocky reef assemblages

Offshore artificial reefs are considered to be most effective when placed in bare, sandy, 'habitat limited' environments. Selection of reef sites has therefore focussed on areas known or likely to consist of sandy substratum away from areas of naturally occurring reef. In NSW a few common groups make up the fish fauna of sandy areas ([18]). The elasmobranchs are often represented by Urolophid and Rhinobatid rays. There may also be many small planktivorous fishes. Other common and commercially important groups are the flatheads (Platycephalidae), which are voracious predators and whiting (Sillaginidae), which are benthic feeders. The flatheads and whiting were present across the proposed reef deployment area by site video surveys conducted by DPI.

Offshore artificial reefs are likely to be most effective if habitat is a limiting factor for population growth. Subtidal rocky reefs harbour fishes that depend on this habitat for food, shelter and/or spawning sites at some stage during their lives. Many species are affected by the topography of the reef and are more abundant in areas of greater physical complexity. Some reef fishes may be very active, including wrasses and leatherjackets, and can traverse large areas of reef. There are also many less mobile, reef associated, species, which spend most of their time on or near the bottom and cryptic species that remain within caves, overhangs and crevices.

Fish surveys were conducted by DPI on the proposed offshore artificial reef deployment site and control sites representative of natural reef found nearby to the reef deployment area using baited remote underwater video (BRUV) units and tow camera (Figure 11). Results from these surveys indicated that the natural rocky reef supported a fish community that was different to the community identified on the proposed reef deployment site. In total, 15 fish species were identified on the natural reef site and 5 species on the proposed artificial reef site.

The natural reef exhibited a greater number of reef associated species including Crimson Banded Wrasse (*Notolabrus gymnogenis*), Eastern Blue Grouper (*Achoerodus viridis*), Eastern Hulafish (*Trachinops taeniatus*), Red Morwong (*Cheildactylus fuscus*) and Australian Mado (*Atypichthys strigatus*). The proposed artificial reef site showed a greater dominance of soft sediment associated species such as Flatheads (*Platycephalus spp.*) and Whiting (*Sillago spp*).

Commercially and/or recreationally important species observed on the natural reef site included Red Morwong (*C. fuscus*), Magpie Morwong (*Goniistius gibbosus*), Eastern Blue Groper (*A. viridis*), Sawtail Surgeonfish (*Prionurus microlepidotus*) and Blackspot Goatfish (*Parupeneus spilurus*). On the artificial reef site Northern Flathead (*Platycephalus aernarius*), Eastern Bluespot flathead (*Platycephalus caeruleopunctatus*) and Eastern School Whiting (*Sillago flindersi*) were observed.

The results of BRUV surveys conducted by DPI were consistent with other similar surveys and artificial reef sites prior to reef construction. They further support the hypothesis that the new offshore artificial reef will provide the building blocks for a reef habitat for a wide variety of reef associated fish species.

Figure 11 A still image from the baited remote underwater video (BRUV) deployment on the proposed offshore artificial reef site (top) and tow camera video of the natural rocky reef site located north of the reef deployment site in the same depth range (bottom)

Threatened and protected species, populations and endangered ecological communities

Results of the database searches revealed 43 species of fish (including seahorses, pipefish and ghost pipefish), 36 species of marine mammal (including whales, dolphins and seals) and 11 species of marine reptiles (including turtles and sea snakes) currently listed as either threatened or protected in the area (Table 3). New South Wales and Commonwealth registers of critical habitats were also searched within and beyond the study region. The nearest Greynurse Shark critical habitat location is at Julian Rocks, 43 km south from the proposed Tweed Heads offshore artificial reef site.

Only threatened species (from the initial search) that were known or considered likely to occur in the wider study area (based on general species distribution databases) and/or known to utilise habitat in the study area, were considered for further Assessment of Significance. Overall, 8 species of fish, 3 species of marine turtle, 4 species of cetacean and 1 sirenian were assessed according to OEH and DPI threatened species assessment guidelines ([19], [20]). A total of 10 species of fish, 6 species of marine turtle, 5 species of cetacean and 1 sirenian were assessed individually under the EPBC Act

Searches for seabirds likely to forage offshore and in the proposed reef deployment area were also carried out. Intertidal and wading birds, such as sandpipers, curlews and plovers, were excluded from the assessment as they are unlikely to be affected by the proposal. A total of 69 bird species were identified comprising of seabirds and birds of prey. The main groups of seabirds that were found to occur in the study region included albatrosses, petrels, shearwaters, terns, skuas, prions, gulls and gannets.

A threatening process is something that threatens, or could potentially threaten, the survival or evolutionary development of a species, population or ecological community [21]. Key Threatening Processes (KTPs) identified as being potentially relevant to the proposal are entanglement or ingestion of anthropogenic debris in marine and estuarine environments (TSC Act); injury and fatality to vertebrate marine life caused by ingestion of, or entanglement in, harmful marine debris (EPBC Act); and hook and line fishing in areas important for the survival of threatened fish species (FM Act).The risk assessment considered that the incidental capture of sea birds was very unlikely on the offshore artificial reef. From experience from the Sydney, Shoalhaven, Port Macquarie, Southern Sydney, Merimbula, Newcastle and Wollongong offshore artificial reefs, zero reports of interactions with sea birds have been reported. For this reason, no direct mitigation measure is considered to be required. If increased interactions with sea birds is reported and verified by DPI, an appropriate management response including but not limited to restrictions on some fishing practices (i.e. floating of surface baits) may be considered.

The artificial reef may potentially increase the risk of lost fishing gear and harmful marine debris entering the marine environment in the vicinity of the proposed reef. Threatened species including seabirds can ingest or become entangled in marine debris, such as plastics. In order to reduce this potential impact on seabirds, education using the reef user guidelines and existing DPI education programs would be provided on the potential impacts of harmful marine debris on marine life and the responsible disposal of litter and discarded fishing gear.

Following deployment of the reef, it is proposed for any incidents, recorded or reported interactions with threatened or protected fish species to be reported at 6 monthly intervals to the DPI Threatened Species Unit for further assessment as detailed in this plan. Incidents involving threatened and/or protected species include:

- Reports from reef users of incidental capture;
- Visual identification reports from reef users;
- Interaction with any of the DPI monitoring protocols including baited remote video, unbaited video drops, ROV or acoustic interactions of tagged animals with the acoustic receiver attached to the reef;
- Any interaction that involves the death of a threatened or protected seabird, mammal or reptile species will be immediately reported to the NSW Office of Environment and Heritage (OEH). The DPI will also provide education on threatened and protected species' identification, best practice for returning incidentally captured fish, minimising risks to seabirds and boating restrictions in the vicinity of large cetaceans. This educational information will be published as part the Tweed Heads artificial reef 'User Guidelines'.

Table 3 Threatened and protected species in the Tweed Heads area

Class	Scientific Name	Common name	Status under BC/ FM Act	Status under EPBC Act
Aves	*Anous stolidus*	Common Noddy		LM, M
Aves	*Ardenna bulleri*	Buller's Shearwater		LM
Aves	*Ardenna carneipes = Puffinus carneipes*	Flesh-footed Shearwater, Fleshy-footed Shearwater	V	LM, M
Aves	*Ardenna grisea = Puffinus griseus*	Sooty Shearwater		LM, M
Aves	*Ardenna pacifica = Puffinus pacificus*	Wedge-tailed Shearwater		LM, M
Aves	*Ardenna tenuirostris = Puffinus tenuirostris*	Short-tailed Shearwater		LM, M
Aves	*Calonectris leucomelas*	Streaked Shearwater		M,LM
Aves	*Catharacta skua*	Great Skua		LM
Aves	*Chlidonias hybrida*	Whiskered Tern		LM, M
Aves	*Chlidonias leucopterus*	White-winged Tern, White-winged Black Tern		LM, M
Aves	*Chroicocephalus novaehollandiae*	Silver Gull		LM
Aves	*Circus approximans*	Swamp Harrier		LM
Aves	*Circus assimilis*	Spotted Harrier	V	
Aves	*Daption capense*	Cape Petrel		LM
Aves	*Diomedea antipodensis*	Antipodean Albatross	V	V, LM, M

Class	Scientific Name	Common name	Status under BC/ FM Act	Status under EPBC Act
Aves	*Diomedea epomophora (sensu stricto)*	Southern Royal Albatross		V, LM, M
Aves	*Diomedea exulans (sensu lato)*	Wandering Albatross	E	V, LM, M
Aves	*Diomedea sanfordi*	Northern Royal Albatross		E, LM, M
Aves	*Diomedea antipodensis gibsoni*	Gibson's Albatross	V	V, LM, M
Aves	*Eudyptes pachyrhynchus*	Fiordland Penguin		LM
Aves	*Eudyptula minor*	Little Penguin		LM
Aves	*Falco cenchroides*	Nankeen Kestrel		LM
Aves	*Falco subniger*	Black Falcon	V	
Aves	*Fregata ariel*	Lesser Frigatebird, Least Frigatebird		LM, M
Aves	*Fregetta grallaria grallaria*	White-bellied Storm-Petrel (Tasman Sea), White-bellied Storm-Petrel (Australasian)	V	V
Aves	*Fregata minor*	Greater Frigatebird, Greater Frigatebird		LM,M
Aves	*Gygis alba*	White Tern	V	LM
Aves	*Haliaeetus leucogaster*	White-bellied Sea-Eagle	V	LM
Aves	*Haliastur sphenurus*	Whistling Kite		LM
Aves	*Hieraaetus morphnoides*	Little Eagle	V	
Aves	*Hydroprogne caspia*	Caspian Tern		LM, M
Aves	*Larus novaehollandiae*	Silver Gull		LM
Aves	*Lophoictinia isura*	Square-tailed Kite	V	
Aves	*Macronectes giganteus*	Southern Giant-Petrel	E	E, LM, M
Aves	*Macronectes halli*	Northern Giant-Petrel	V	V, LM, M
Aves	*Morus serrator*	Australasian Gannet		LM
Aves	*Onychoprion fuscata*	Sooty Tern	V	LM
Aves	*Pachyptila desolata*	Antarctic Prion		LM
Aves	*Pachyptila turtur*	Fairy Prion		LM
Aves	*Pachyptila turtur subantarctica*	Fairy Prion (southern)		V
Aves	*Pandion cristatus = haliaetus*	Eastern Osprey	V	LM, M

Class	Scientific Name	Common name	Status under BC/ FM Act	Status under EPBC Act
Aves	*Pelecanus conspicillatus*	Australian Pelican		LM
Aves	*Phaethon lepturus*	White-tailed Tropicbird		LM, M
Aves	*Phaethon rubricauda*	Red-tailed Tropicbird	V	LM, M
Aves	*Phoebetria fusca*	Sooty Albatross	V	V, LM, M
Aves	*Pseudobulweria rostrata*	Tahiti Petrel		LM
Aves	*Pterodroma heraldica*	Herald Petrel		CE
Aves	*Pterodroma leucoptera leucoptera*	Gould's Petrel	V	E, LM
Aves	*Pterodroma neglecta neglecta*	Kermadec Petrel (Western)	V	V
Aves	*Pterodroma nigripennis*	Black-winged Petrel	V	LM
Aves	*Pterodroma solandri*	Providence Petrel	V	LM
Aves	*Puffinus gavia*	Fluttering Shearwater		LM
Aves	*Puffinus huttoni*	Hutton's Shearwater		LM
Aves	*Stercorarius longicaudus*	Long-tailed Jaeger		LM, M
Aves	*Stercorarius parasiticus*	Arctic Jaegar, Arctic Skua		LM, M
Aves	*Sterna hirundo*	Common Tern		LM, M
Aves	*Sterna sumatrana*	Black-naped Tern		LM, M
Aves	*Sterna striata*	White-fronted Tern		LM
Aves	*Sternula albifrons*	Little Tern	E	LM, M
Aves	*Sternula nereis nereis*	Australian Fairy Tern		V
Aves	*Sula leucogaster*	Brown Booby		LM, M
Aves	*Thalassarche cauta cauta*	Shy Albatross, Tasmanian Shy Albatross	V	V, LM, M
Aves	*Thalassarche steadi*	White-capped Albatross		V, LM, M
Aves	*Thalassarche chlororhynchos*	Atlantic Yellow-nosed Albatross		LM, M
Aves	*Thalassarche eremita*	Chatham Albatross		E, LM, M
Aves	*Thalassarche melanophris*	Black-browed Albatross	V	V, LM, M
Aves	*Thalassarche salvini*	Salvin's Albatross		V, LM, M

Class	Scientific Name	Common name	Status under BC/ FM Act	Status under EPBC Act
Aves	*Thalassarche impavida*	Campbell Albatross, Campbell Black-browed Albatross		V, LM, M
Aves	*Thalasseus bergii*	Crested Tern		LM
Mammalia	*Arctocephalus forsteri*	New Zealand Fur-seal, Long-nosed Fur-seal	V	
Mammalia	*Arctocephalus pusillus doriferus*	Australian Fur-seal, Australo-African Fur-seal	V	LM
Mammalia	*Balaenoptera acutorostrata*	Minke Whale		Cet
Mammalia	*Balaenoptera bonaerensis*	Dark Shoulder Minke Whale		Cet, M
Mammalia	*Balaenoptera borealis*	Sei Whale		V, Cet, M
Mammalia	*Balaenoptera edeni*	Bryde's Whale		Cet, M
Mammalia	*Balaenoptera musculus*	Blue Whale	E	E, Cet, M
Mammalia	*Balaenoptera physalus*	Fin Whale		V, Cet, M
Mammalia	*Delphinus delphis*	Common Dolphin, Short-beaked Common Dolphin		Cet
Mammalia	*Dugong dugon*	Dugong	E	LM, M
Mammalia	*Eubalaena australis*	Southern Right Whale	E	E, Cet, M
Mammalia	*Feresa attenuata*	Pygmy Killer Whale		Cet
Mammalia	*Globicephala macrorhynchus*	Short Finned Pilot Whale		Cet
Mammalia	*Grampus griseus*	Risso's Dolphin, Grampus		Cet
Mammalia	*Kogia breviceps*	Pygmy Sperm Whale		Cet
Mammalia	*Kogia simus*	Dwarf Sperm Whale		Cet
Mammalia	*Lagenodelphis hosei*	Frasers Dolphin, Sarawak Dolphin		Cet
Mammalia	*Megaptera novaeangliae*	Humpback Whale	V	V, Cet, M
Mammalia	*Mesoplodon densirostris*	Blainvilles Beaked Whale, Dense-beaked Whale		Cet
Mammalia	*Mesoplodon ginkgodens*	Ginko-toothed Beaked Whale		Cet
Mammalia	*Mesoplodon grayi*	Gray's Beaked Whale		Cet
Mammalia	*Mesoplodon layardii*	Strap toothed Beaked Whale, Layards Beaked Whale		Cet

Class	Scientific Name	Common name	Status under BC/ FM Act	Status under EPBC Act
Mammalia	*Orcaella brevirostris*	Irrawaddy Dolphin		Cet, M
Mammalia	*Orcaella heinsohni*	Australian Snubfin Dolphin		Cet, M
Mammalia	*Orcinus orca*	Killer Whale, Orca		Cet, M
Mammalia	*Peponocephala electra*	Melon-headed Whale		Cet
Mammalia	*Physeter macrocephalus*	Sperm Whale	V	Cet, M
Mammalia	*Pseudorca crassidens*	False Killer Whale		Cet
Mammalia	*Sousa chinensis*	Indo-Pacific Hump-backed Dolphin		Cet, M
Mammalia	*Stenella attenuata*	Spotted Dolphin, Pantropical Spotted Dolphin		Cet
Mammalia	*Stenella longirostris*	Long Snouted Spinner Dolphin		Cet
Mammalia	*Stenella coeruleoalba*	Striped Dolphin		Cet
Mammalia	*Steno bredanensis*	Rough Toothed Dolphin		Cet
Mammalia	*Tursiops aduncus*	Indian Ocean Bottlenose Dolphin, Spotted Bottlenose Dolphin		Cet
Mammalia	*Tursiops truncatus*	Bottlenose Dolphin		Cet
Mammalia	*Ziphius cavirostris*	Cviers Beaked Whale, Goose Beaked Whale		Cet
Pisces	*Acentronura tentaculata*	Shortpouch Pygmy Pipehorse	P	LM
Pisces	*Campichthys tryoni*	Tryon's Pipefish	P	LM
Pisces	*Carcharias taurus (east coast population)*	Greynurse Shark (east coast population)	CE	CE
Pisces	*Carcharodon carcharias*	Great White Shark	V	V, M
Pisces	*Corythoichthys amplexus*	Fijian banded pipefish, Brown banded pipefish	P	LM
Pisces	*Corythoichthys ocellatus*	Orange spotted pipefish, Ocellated Pipefish	P	LM
Pisces	*Cosmocampus howensis*	Lord Howe Pipefish	P	LM
Pisces	*Epinephelus daemelii*	Black Rockcod, Black Cod, Saddled Rockcod	V	V
Pisces	*Festucalex cinctus*	Girdled Pipefish	P	LM
Pisces	*Filicampus tigris*	Tiger Pipefish	P	LM

Class	Scientific Name	Common name	Status under BC/ FM Act	Status under EPBC Act
Pisces	*Halicampus grayi*	Mud Pipefish, Grays Pipefish	P	LM
Pisces	*Hippichthys cyanospilos*	Blue Speckled Pipefish, Blue Spotted Pipefish	P	LM
Pisces	*Hippichthys penicillus*	Beady Pipefish, Steep-nosed Pipefish	P	LM
Pisces	*Hippocampus kelloggi*	Kellogg's Seahorse, Great Seahorse	P	LM
Pisces	*Hippocampus kuda*	Spotted Seahorse, Yellow Seahorse	P	LM
Pisces	*Hippocampus planifrons*	Flat Faced Seahorse	P	LM
Pisces	*Hippocampus trimaculatus*	Three-spot Seahorse, Low-crowned Seahorse, Flat Faced Seahorse	P	LM
Pisces	*Hippocampus whitei*	White's Seahorse, Crowned Seahorse, Sydney Seahorse	E	LM
Pisces	*Isurus oxyrinchus*	Shortfin Mako, Mako Shark		M
Pisces	*Isurus oxyrinchus*	Longfin Mako		M
Pisces	*Lamna nasus*	Porbeagle, Mackerel Shark		M
Pisces	*Lissocampus runa*	Javelin Pipefish	P	LM
Pisces	*Manta alfredi*	Manta Ray, Coastal Manta Ray, Inshore Manta, Price Alfreds Ray, Resident Manta Ray		M
Pisces	*Manta birostris*	Giant Manta Ray, Chevron Manta Ray, Pacific Manta Ray, Pelagic Manta Ray, Oceanic Manta Ray		M
Pisces	*Maroubra perserrata*	Sawtooth Pipefish	P	LM
Pisces	*Micrognathus andersonii*	Andersons Pipefish, Shortnose Pipefish	P	LM
Pisces	*Micrognathus brevirostris*	Thorntailed Pipefish	P	LM
Pisces	*Microphis manadensis*	Manado Pipefish, Manado River Pipefish	P	LM
Pisces	*Pristis zijsron*	Green Sawfish	PE	V, M
Pisces	*Rhincodon typus*	Whale Shark		V, M
Pisces	*Solegnathus dunckeri*	Dunckers Pipehorse	P	LM
Pisces	*Solegnathus hardwickii*	Pallid Pipehorse, Hardwicks Pipehorse	P	LM

Class	Scientific Name	Common name	Status under BC/ FM Act	Status under EPBC Act
Pisces	*Solegnathus spinosissimus*	Spiny Pipehorse, Australian Spiny Pipehorse	P	LM
Pisces	*Solenostomus cyanopterus*	Robust Ghostpipefish, Blue-finned Ghost Pipefish,	P	LM
Pisces	*Solenostomus paradoxus*	Ornate Ghostpipefish, Harlequin Ghost Pipefish	P	LM
Pisces	*Sphyrna lewini*	Scalloped Hammerhead Shark	E	CD
Pisces	*Sphyrna mokarran*	Great Hammerhead Shark	V	
Pisces	*Stigmatopora nigra*	Widebody Pipefish, Wide-bodied Pipefish, Black Pipefish	P	LM
Pisces	*Syngnathoides biaculeatus*	Double-end Pipehorse, Double-ended Pipehorse, Alligator Pipefish	P	LM
Pisces	*Thunnus maccoyii*	Southern Bluefin Tuna	E	CD
Pisces	*Trachyrhamphus bicoarctatus*	Bentstick Pipefish, Bend Stick Pipefish, Short-tailed Pipefish	P	LM
Pisces	*Urocampus carinirostris*	Hairy Pipefish	P	LM
Pisces	*Vanacampus margaritifer*	Mother-of-pearl Pipefish	P	LM
Reptilia	*Aipysurus laevis*	Olive Seasnake		LM
Reptilia	*Astrotia stokesii*	Stokes Seasnake		LM
Reptilia	*Caretta caretta*	Loggerhead Turtle	E	E, LM, M
Reptilia	*Chelonia mydas*	Green Turtle	V	V, LM, M
Reptilia	*Dermochelys coriacea*	Leatherback Turtle, Leathery Turtle, Luth	E	E, LM, M
Reptilia	*Eretmochelys imbricata*	Hawksbill Turtle		V, LM, M
Reptilia	*Hydrophis elegans*	Elegant Seasnake		LM
Reptilia	*Laticauda laticaudata*	Sea Krait		LM
Reptilia	*Lepidochelys olivacea*	Pacific Ridley Turtle		E, M, LM
Reptilia	*Natator depressus*	Flatback Turtle		V, M, LM
Reptilia	*Pelamis platurus*	Yellow Bellied Seasnake		LM

PE = presumed extinct, CE = critically endangered, E = endangered, V = vulnerable, CD= conservation dependent, M = migratory, LM = listed marine, Cet = cetacean and P = protected (FM Act). Note: All native birds, reptiles, amphibians and mammals in NSW are protected by the NSW National Parks and Wildlife Act (NP&W Act).

5 Module design, reef configuration and construction

5.1 Module materials and design

5.1.1 Concrete modules

The proposed artificial reef will consist of 8 clusters of 4 concrete modules and a steel 'fish grotto' (SFG) arranged to capture the predominant local currents at the proposed site (Figure 22).

Each concrete module has an approximate weight of 21.8 tonne, a base length and width of 4 m and a height of 5 m (Figure 13).

The proposal has been designed using two moulds, with both able to have additional features added to the mould to allow for additional variety of complexity and specification for native finfish species. The moulds are also able to be readily fitted with void formers of different shapes and sizes and can be altered so that each module is unique.

The design deflects horizontal flows into vertical lift that is favoured by bait fish. Further to this the design is omnidirectional, thus stable no matter the direction of waves and currents. It stands 5 m high and is 4 m in width and depth with a dry weight of 21.8 tonne. The module has smaller void spaces in the 'blades' for smaller fish and organisms to shelter in. The interior of the module is hollow allowing larger species to pass through.

Each module will require one Base Mould and four Side Moulds that slot together to form the final shape (Figure 14). The base mould will be placed on a casting bed, while a cage of reinforcing bar which has been pre-fabricated will be slotted on top of the base mould. Two side moulds can then be positioned in place and all void formers will be attached. The final two side moulds will be aligned, and all of the structure bolted together.

The standard arrowhead module will be customised into the following:

Arrowhead 1:

The standard Arrowhead module, as seen in (Figure 12), with the side moulds having various voids for smaller species to take refuge. These voids can be altered in both size and location with ease, allowing for a variety of designs.

Arrowhead 2:

The second Arrowhead module has no voids, instead possessing concrete faces with uneven or rough surface texture favourable for corals and encrusting species.

Arrowhead 3:

The third Arrowhead module has a series of galvanised mild steel panels in horizontal or near horizontal positions in the lower half of the structure and more open voids in the top half of the structure to increase the surface area and encrusting area for corals.

Arrowhead 4:

In order to increase complexity and variety in complexity, Arrowhead 4 has variety in void sizes and semi-enclosed habitat structures in the form of galvanised mild steel pipes to increase the surface & sheltered areas.

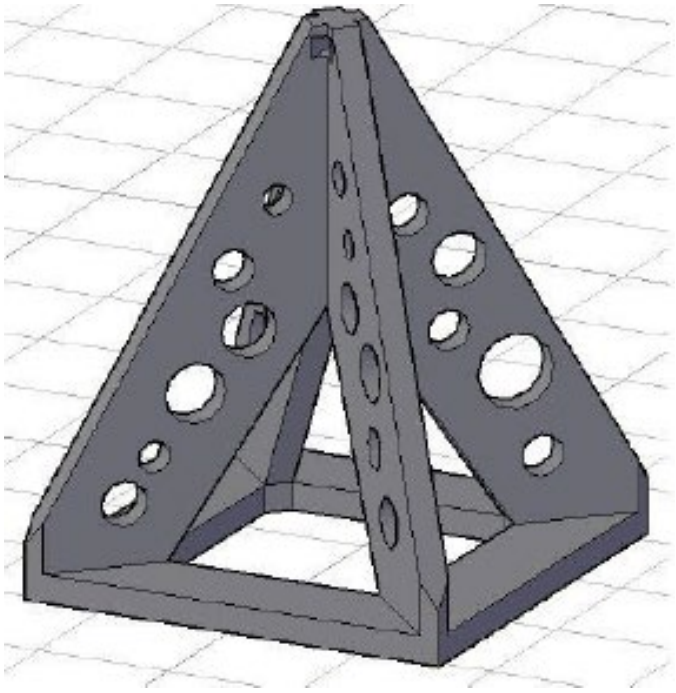


Figure 12 Standard Arrowhead Module

Figure 13 Arrowhead modules used for Stradbroke Island project

The formwork cage will be lifted onto the base mould and then all other moulds will be assembled around the cage. The cage will have chairs to sit on at the base as well as on the internal diagonals to ensure the reinforcing bar does not encounter the release agent on the moulds. The main task of the chairs is to ensure there is enough cover of concrete on top of the steel. Cover will significantly exceed 60 mm at all points in the structure.

The proposed concrete mix design, supplied by Boral, is Z40-10-POLYFBR, consisting of 100% recycled Emesh with a dosage of 6 kg/m^3. This will lead to 95.63% reduction in carbon footprint using fibre Emesh in place of steel reinforcing.

Trial mixes will be performed to test concrete and ensure all relevant standards and requirements are met.

Each concrete batch will be tested initially with a slump test to check the workability of the concrete and used as an indicator for a properly mixed batch. Further testing on the compressive strength of the concrete will be done through a cylinder test after 28 days of curing, to confirm that the concrete has reached the required strength over this period of time before the modules are deployed.

The moulds will be assembled on a pre-cast slab in Pacific Marine Group's (PMG) Townsville yard. The concrete mix will be poured into a spouted section at the top of the moulds. The mix will flow enough to reach all voids on the lower section of the base. A tremie will be used to pour the concrete into the mould, aiming to minimise the segregation of plastic fibres and aggregate from the mix. Without this tremie system, there is no guarantee the mix will stay homogenous. The tremie will be a ~100 mm PVC pipe which can be slotted through the mould down to near the base level.

External vibration will be used on the internal pyramid of the mould, aiding in removing air from the internal voids to create a more uniform structure. Vibration normally aids with creating a more refined surface on the concrete.

Breather holes will be used to ensure mix has flowed far enough. All faces are sloped to allow air to escape when the concrete is being poured. Once the mould has been poured, it will be left to cure for 40 hours prior to removing formwork. Once the initial curing time is complete, the side moulds will be stripped, the modules will be lifted from the base mould and placed into the yard to begin curing for 28 days prior to immersion in sea water as advised by AS3600.

The modules will be left to cure prior to mobilising barge to site. This curing process will be done by using sprinklers to moisten the modules. Geofabrics can also be used to cover the modules and be kept moist so the concrete retains its water content and the module doesn't crack. All modules will be soaked in water ever day depending on the temperature. If the temperature becomes an issue, standard curing agents will be used.

The modules have a high degree of stability in water depths >15 m and are suitable for a wide range of wave conditions in such depth of water (Tweed Heads approximately 25 m water depth).

Figure 14 Standard arrowhead formwork mould

5.1.2 **Steel Fish 'Grotto'**

The steel fish grotto has, a weight of 26 tonne, a base diameter of 11 m and a height of 10 m. Additional ballast will be installed once the grotto is on the seabed in the form of 6 x 8 tonne concrete blocks that are integrated into the legs of the grotto to meet stability requirements. The concrete blocks will be the same concrete mix as the arrowhead modules. The total weight of the grotto with ballast will be 90 tonne.

The design life of the structure is 50 years without anodes. This design life is achieved by incorporating a corrosion allowance into the design resulting in a structure that can

withstand in-place loading imposed by the 1/100 yr return design after member thickness reduction caused by 50 years of corrosion. The design has been checked for the assembly, launch, transport and installation load cases which are the most onerous design conditions.

The design is modular in nature and comprised of multiple octagonal levels. The modular design allows for safer fabrication. The 5 modular sections are shown in Figure 15, with each section shown in a different colour.

Complexity and structural integrity are achieved by using large structural members and large vertical plates. These plates also aid in creating vertical eddies, anchoring the structure, and creating shade for native demersal fish. The following design features and criteria have been included in the design:

- Stable dome shape creating internal void and promoting vertical water flow
- Tall profile to attract pelagic fish and allow for substantial habitats at different heights in the water column
- Open skeletal structure that is ideal for mobile sand substrate environment
- Unobstructed internal void for pelagic and mesopelagic fish in the upper zones
- Internal steel lattice like structure to protect baitfish from predators
- Steel thickness great enough to allow for corrosion
- Structural complexity of steel beams and plates for a greater variety of habitats
- Omnidirectional design for stability and effectiveness in any current
- Added variety in complexity in the form of:
    - Vertical chains
    - Horizontal arms on the top module. For clarity, the horizontal or near horizontal plates in all five levels are not shown in Figure 15. These plates are made of galvanised mild steel.

Welding shall be conducted in PMG's Townsville yard. Qualified and experienced tradesmen shall conduct the fabrication work in accordance with PMGs standard weld operation procedures and job specifications.

The welding work will be carried out under the direct supervision of the Workshop Manager and the Project Manager. Welded joints will be prepared and tested to relevant standards. PMG will subcontract an independent 3rd party NATA accredited service provider to conduct weld testing as per specification.

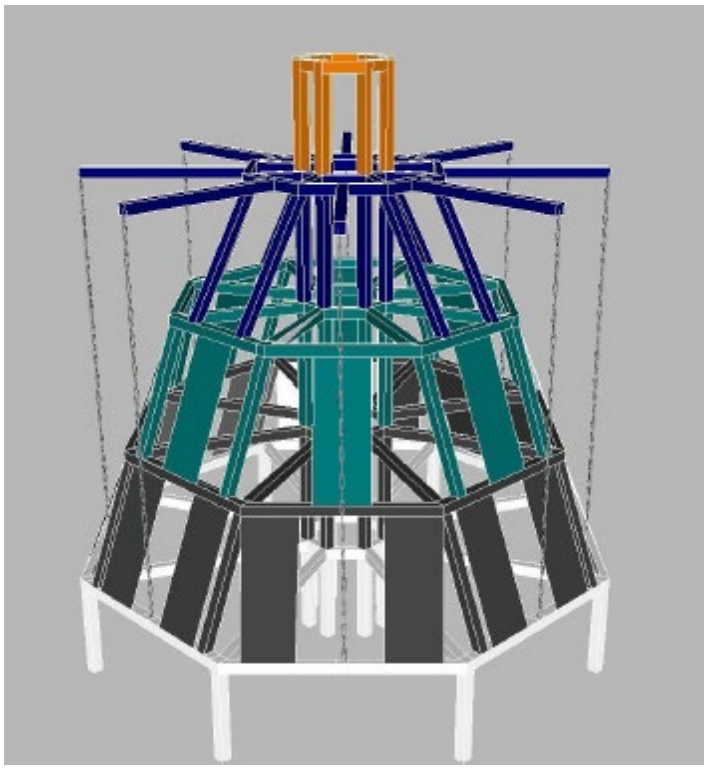


Figure 15 Steel Fish Grotto (SFG).

All calculations include a safety factor which is commensurate with the level of uncertainty of using empirical calculations.

Arup deem the risk of significant deposition around the structure to be low. If this is not found to be the case, the structure will be modified by cutting out members or adding additional shielding as required to meet stability criteria.

5.2 Reef construction and staging methodology

Fabrication of both steel and concrete modules will take place in PMGs Harbor side South Townsville fabrication yard alongside the barges scheduled to tow the reef to site.

5.2.1 Transport and barge layout

180T Crane – Lifting Arrangement from Wharf to Barge for Arrowhead Modules

The Kobelco 1800-1F 180T Crane has a Derating of 25% applied for lifting on the barge. Using the boom length of 21.3 m with the applied derating, the crane can lift 22.45 T at a maximum radius of 20.1 m.

When loading the barge, four Arrowhead 1 modules are loaded first, as they are slightly outside the lifting radius when the crane is centred on the barge and requires the crane to move. After these are in place, the rest of the barge can be loaded with the crane back in the centre position (Figure 16).

180T Crane – Lifting Arrangement from Wharf to Barge for Steel Grotto

With the same boom length of 21.3 m and a derating of 25%, the Kobelco 1800-1F can safely lift 30.075 T at a maximum radius of 16 m. This allows for the steel grotto and its concrete ballast blocks to be easily loaded and secured behind the crane.

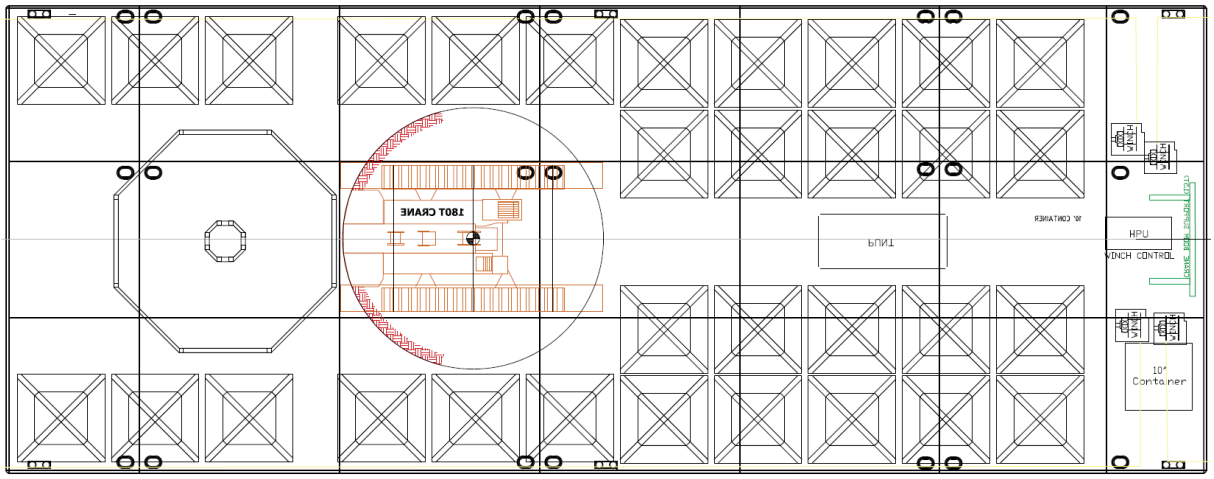


Figure 16 Barge load out diagram

The PMG vessel, crew and tug will steam from Townsville to Tweed Heads after loading and sea fixing the barge at the PMG facility (Figure 17). Average travel speeds for the vessel and barge combination will be somewhere between 3.5 to 5.5 knots depending on sea conditions and weather.

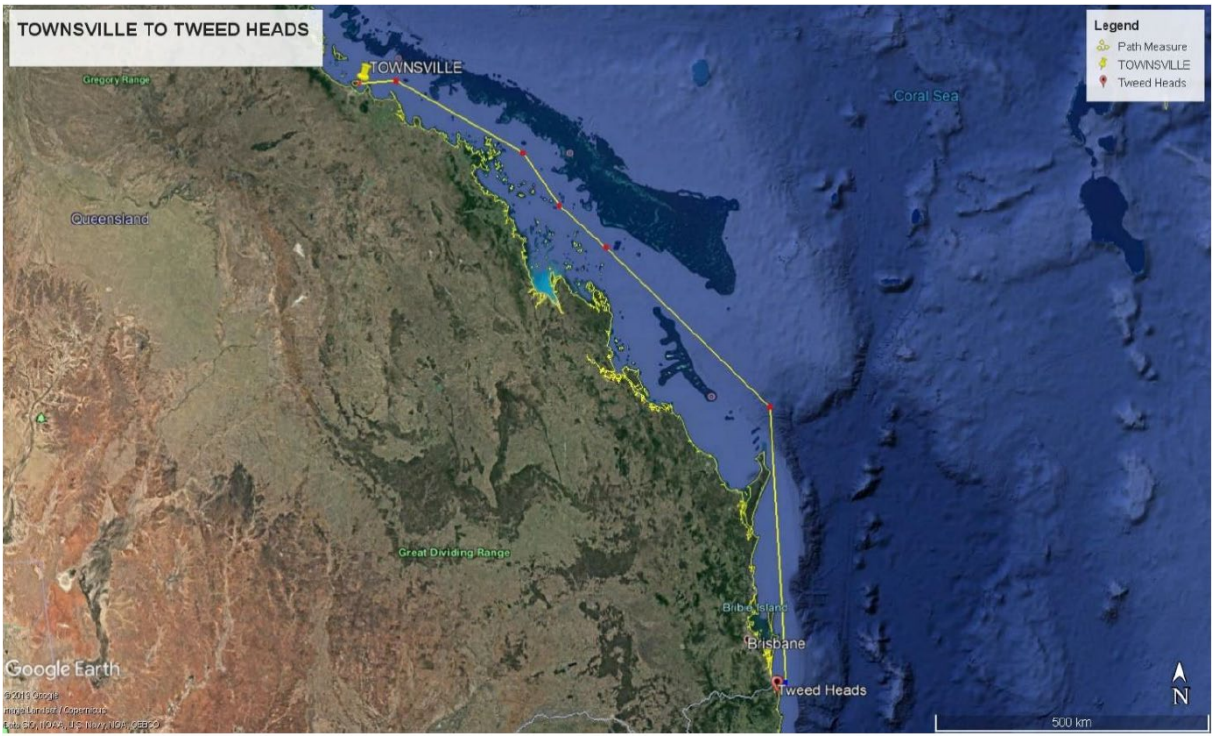


Figure 17 Transport tow route from Townsville to Tweed Heads reef installation site

5.2.2 **Installation**

The barge will have a 4-point anchoring system, with the bow anchors placed close to the barge and the stern anchors fully extended. Two modules will be deployed at the first cluster location, then the barge will be winched along its anchor wires to the second cluster location,

where two modules will be deployed. At this point, the anchors will be relocated by the Tug Boat so that this process can be repeated. The anchors will be relocated to the side, making sure to locate them away from the modules so as not to get fouled.

The crane hook will be fitted with a DGPS to ensure accurate placement of all modules.

A customised hydraulic release system has been developed (Figure 18) and certified for utilisation in the installation of Arrowhead modules. Marker buoys will also be used on the modules during the successful installation of each module.

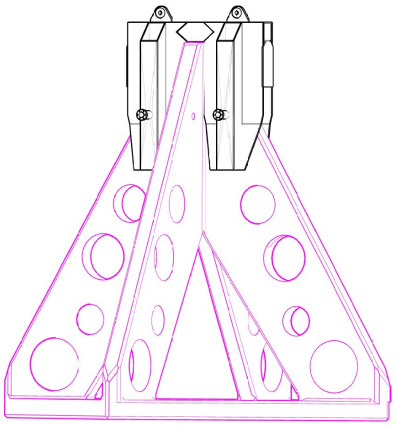


Figure 18 Customised release mechanism for module placement

The steel grotto will be deployed using a slip sling arrangement. Once in place on the seabed the ballast blocks will be set in place on all 8 legs. The methods described enable all modules to be safely, accurately and securely placed on the seabed.

5.2.3 Cluster arrangement

The arrangement of individual clusters consists of 4 individual modules, spaced from each other by 12 m, giving an overall footprint of 400 m2 per cluster. This arrangement and the allocation of different Arrowhead modules is displayed in Figure 19. The different arrowhead modules are based around changes made to the side moulds.

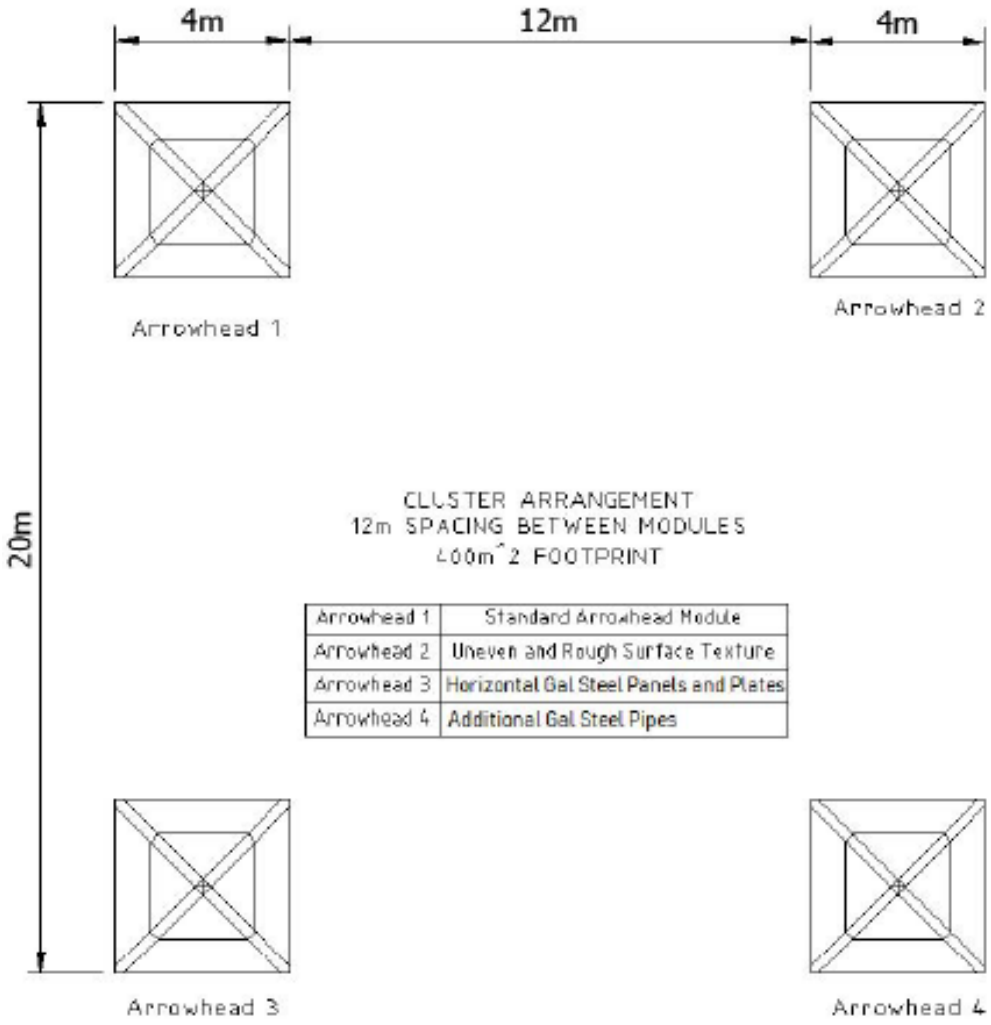


Figure 19 Arrowhead cluster arrangement

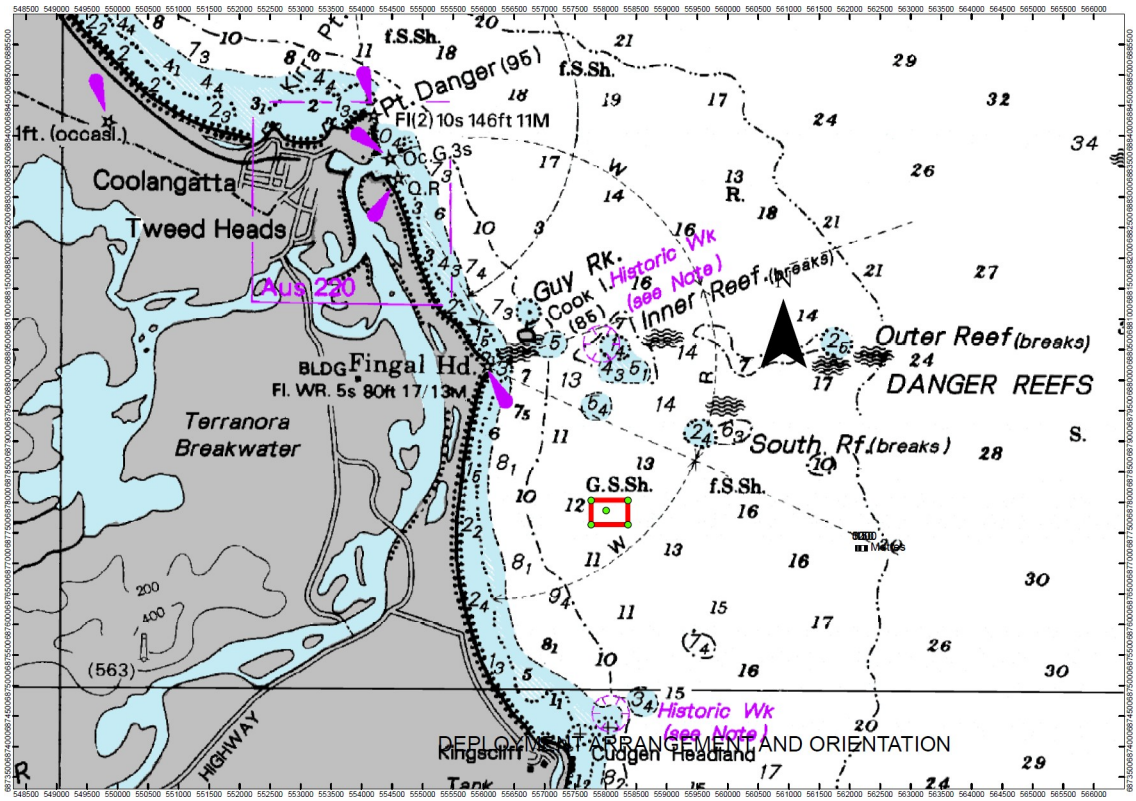
5.3 Reef Deployment site

Following the review of existing information and mapping of key characteristics of the study area and surrounds, constraints analysis identified a potential offshore artificial reef deployment area south of Tweed Heads. This is the area where, based on existing information, reef deployment would be suitable and unlikely to conflict with the physical, biological and regulatory constraints investigated. The analysis was limited to using the information available and was subject to revision once further data or field investigations of the seabed and consultation (particularly with commercial fishing businesses) had been undertaken.

The corner point co-ordinates (GDA94) for the 600 x 400 m reef management area are situated at 28° 13.338′ S, 153° 35.322′ E (NW), 28° 13.338′ S, 153° 35.688′ E (NE), 28° 13.554′ S, 153° 35.322′ E (SW), 28° 13.554′ S, 153° 35.688′ E (SE).

5.3.1 **Map of deployment site**

The location of the proposed Tweed Heads offshore artificial reef deployment site is shown in Figure 20. The deployment site falls within the waters displayed in Australian hydrographic charts AUS364 Clarence River to Cape Morton and AUS813 Clarence River to Cape Danger.



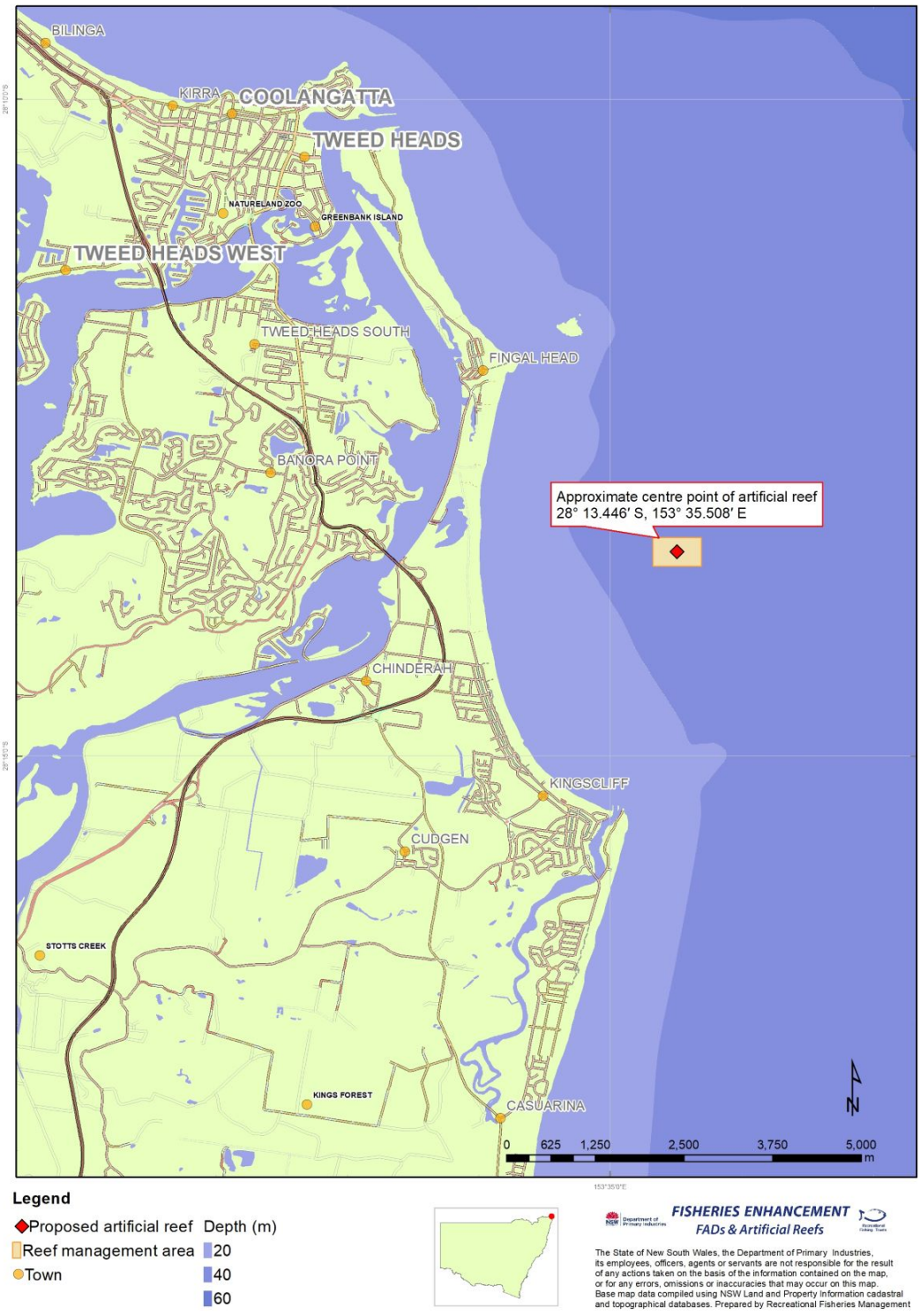


Figure 20 Location of the Tweed Heads offshore artificial reef

5.3.2 Photographs and/or video of the proposed site prior to deployment

Fish surveys were conducted by DPI on 26 February 2020 at the proposed reef centre point (28°13.446′ S, 153°35.508′ E) (Figure 21) and a control site representative of natural reef found nearby to the reef deployment area (28°10.876′ S, 153°35.607′ E) using tow camera and baited remote underwater video (BRUV) units (Figure 11). Results from these initial surveys

indicated that the natural rocky reef supported a fish community that was different to the community identified on the proposed reef deployment site.

The site specific surveys conducted by DPI consistently supported the hypothesis that it is expected that the new offshore artificial reef would support a wide variety of reef associated fish species. However, the community is likely to be made up of a larger number of species with greater diversity as the structure would likely provide ample space for both sand and reef associated species.

Figure 21 A still image of the substrate from tow camera video at the proposed offshore artificial reef site. (Image: DPI – February 2020)

5.3.3 Geographical position (latitude and longitude)

Table 4 and Figure 22 describe the geographical arrangement of the reef layout within the reef management area.

Table 4 Approximate geographical position of reef clusters and Steel Fish Grotto

Reef cluster	Latitude (Deg. Min. Sec.)	Longitude (Deg. Min. Sec.)	Latitude (Deg. Dec. Min.)	Longitude (Deg. Dec. Min.)	Latitude (Dec. Deg.)	Longitude (Dec. Deg.)
1	28°13'23.47"S	153°35'24.03"E	28°13.391'S	153°35.400'E	-28.223187	153.590007
2	28°13'24.60"S	153°35'26.27"E	28°13.410'S	153°35.438'E	-28.223499	153.590629
3 (centre)	28°13'26.73"S	153°35'30.48"E	28°13.446'S	153°35.508'E	-28.224093	153.591801
4	28°13'27.87"S	153°35'32.72"E	28°13.464'S	153°35.545'E	-28.224407	153.592421
5	28°13'29.01"S	153°35'34.95"E	28°13.483'S	153°35.583'E	-28.224724	153.593043
6	28°13'30.14"S	153°35'37.19"E	28°13.502'S	153°35.620'E	-28.225038	153.593664
7	28°13'27.55"S	153°35'27.16"E	28°13.459'S	153°35.453'E	-28.224320	153.590878
8	28°13'29.54"S	153°35'25.89"E	28°13.492'S	153°35.431'E	-28.224872	153.590525
Steel Fish Grotto	28°13'25.68"S	153°35'28.37"E	28°13.428'S	153°35.473'E	-28.223800	153.591215

*Coordinates are presented in Datum GDA94

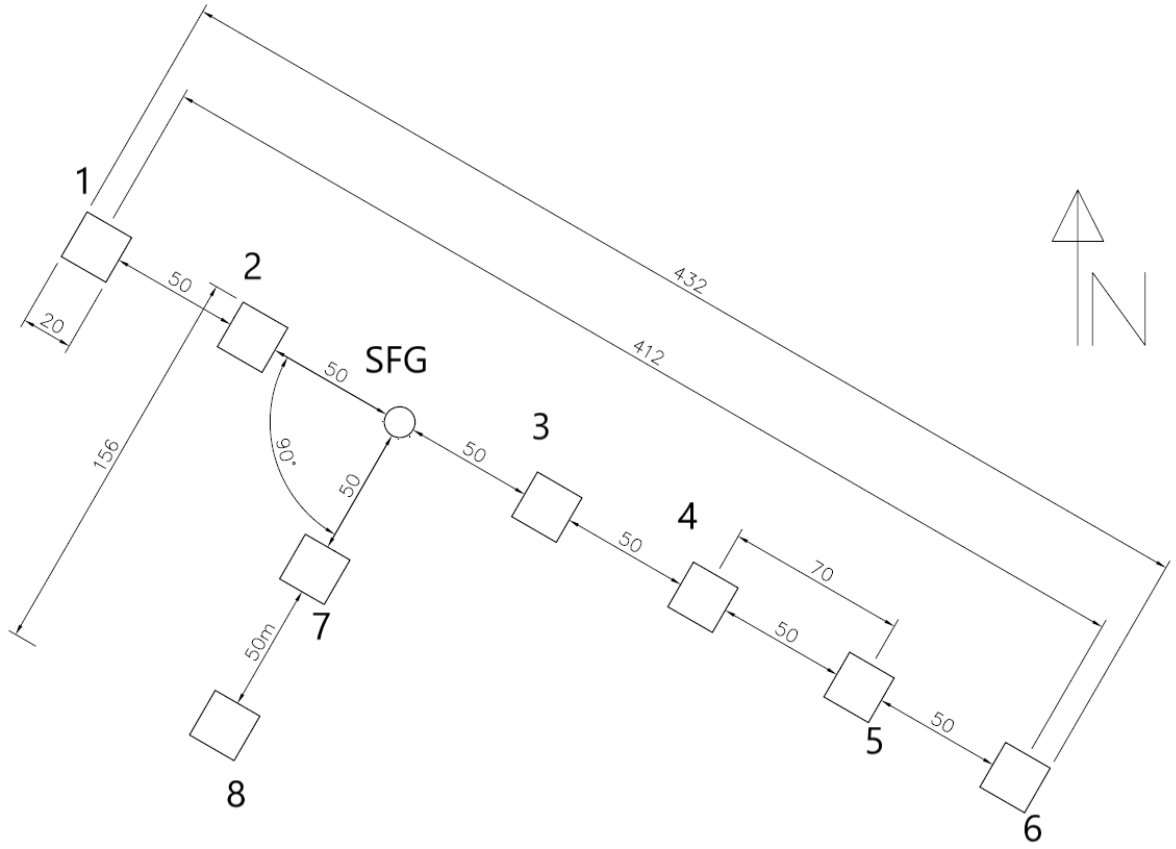


Figure 22 Proposed layout of clusters of concrete reef modules (4 modules per cluster) and the Steel Fish Grotto (SFG) within the reef management area

5.3.4 **'As-built' location confirmation**

Differential GPS (DGPS) would be used for surface positioning of the vessel and for subsea positioning of the modules. The final 'as-built' survey would be conducted by independent survey of the reef site. DGPS would be used to provide a position for each of the individual reef modules.

5.3.5 **Depth of water over the reef**

Suitable depth is important to avoid creating a navigational hazard and for the stability of the modules (in terms of ability to withstand certain hydrodynamic forces), accessibility to recreational fishers (via boat) and would also influence the type of fish which would aggregate around the structure. Clearance depth over the artificial reef post deployment would be no less than 15 m (LAT). This would be confirmed post reef deployment.

5.3.6 **Distance from nearest land**

The Tweed Heads offshore artificial reef is to be located within State waters approximately 2.1 km offshore from Dreamtime Beach, which is the closest land to the reef management area as shown in Figure 23. The proposed reef centre point is 2.4 km offshore from Dreamtime Beach.

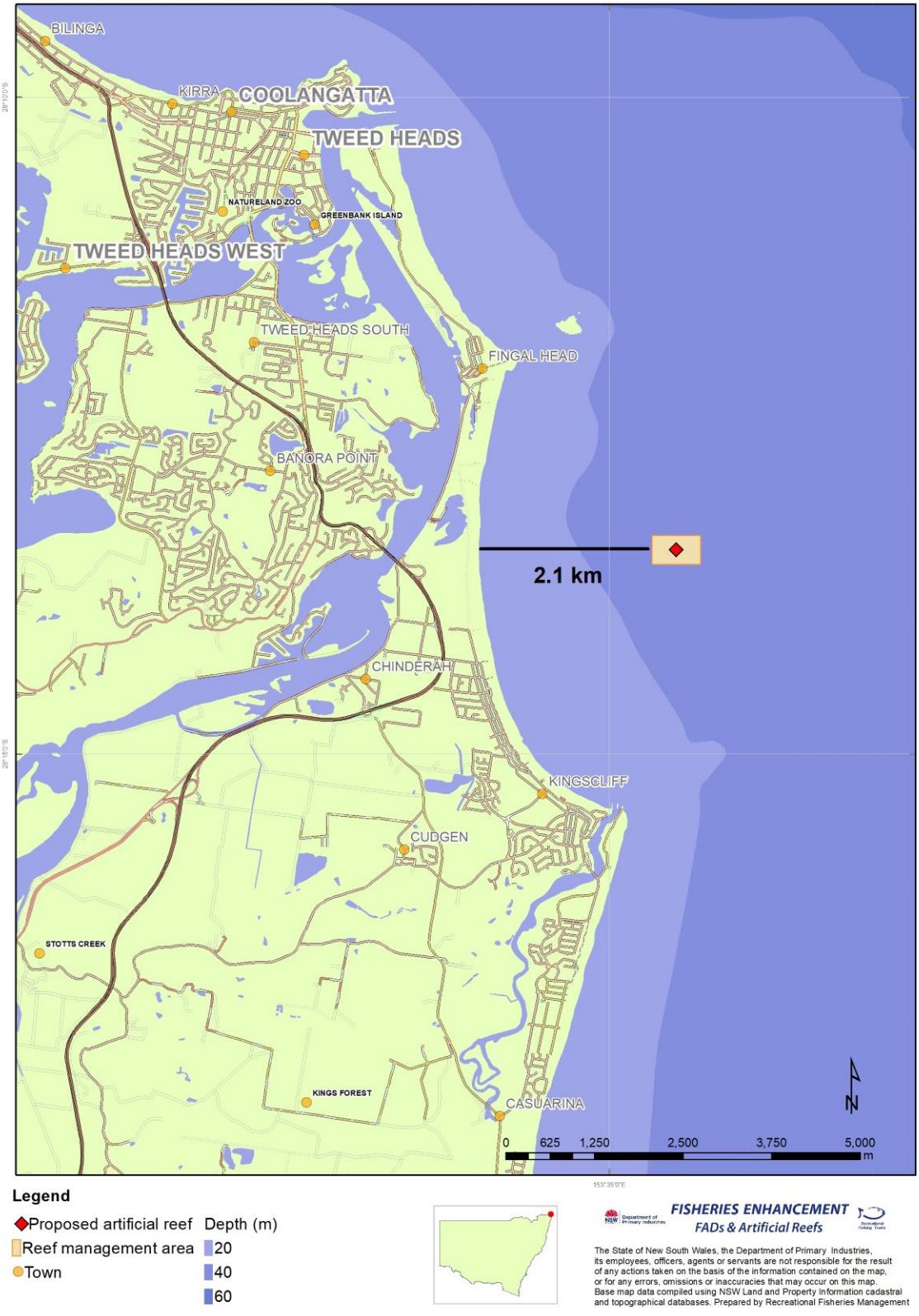


Figure 23 Map showing proposed artificial reef location and distance from nearest land

5.3.7 Biological characteristics

Reefs designed for the purpose of recreational fishing enhancement should be placed an appropriate distance away from existing reefs in order to create new habitats and create an opportunity to increase local productivity, rather than adding to existing reef habitat (typically a nominated distance of no less than 0.5 km). Natural reef habitats, habitats unique within an area, or locations known to support diverse benthic/epibenthic communities should therefore be avoided. Areas of conservation significance and habitats critical to the survival of a particular species are generally protected under NSW legislation and reefs designed for recreational fishing may not be compatible with the objectives of the protected area. Information on the occurrence and distribution of threatened species is generally sparse and may be limited to predictions based on presence of suitable habitat and/or records of a species occurring at nearby locations. It is especially difficult to predict where highly mobile individuals (such as fish or migratory marine mammals) occur due to their itinerant nature.

The proposed artificial reef deployment site has been chosen approximately 1.8 km south of the nearest natural reef to reduce the effect of 'draw-down' (that is individuals readily moving from the natural reef onto the artificial reef). Open sand/sediment expanses present a perceived impassable barrier to many demersal reef associated fish species.

5.3.8 Characteristics of the sea bottom at the site, and impact of material on biota at the placement site or other areas potentially affected by the creation of the artificial reef

Swath acoustic mapping results illustrated a 2.8 km onshore-offshore depth gradient consistent with sediment substrata is represented by intermittent increases in depth to approximately halfway across the transect before levelling off at 25 - 23.7 m. This indicates that the seafloor is predominantly unconsolidated sediments with the presences of gutters and some slight ridges. A north -south transect was also prepared which represents an intermittent decrease in depth over 1.8 km ranging from approximately 25 m to 20 m. DPI performed tow camera surveys which confirmed the presence of unconsolidated sediments (Figures 9,10,11).

Impacts on soft sediment assemblages

Offshore artificial reefs are considered to be most effective when placed in bare, sandy, 'rocky-reef habitat limited' environments. Selection of reef sites has therefore focussed on areas known or likely to consist of sandy substratum away from areas of naturally occurring reef. Soft sediment habitats can support extremely diverse macrofaunal assemblages.

Initial deployment of the OAR units would cause localised disturbance and re-suspension of sandy sediment in the area where the units are installed which may result in mobile macroinvertebrates being temporarily displaced (Table 5). A large proportion of animals living within the direct footprint of where individual modules are placed would also be lost through smothering. This would be limited to an area of ~556m2. This loss of sandy habitat occupied by the OAR modules, would, however, be negligible when considered in context with the extensive areas of similar habitat within and surrounding the reef installation area.

Once colonised, the habitat will continue to support a wide variety of marine organisms and provide greater habitat heterogeneity allowing a potentially diverse assemblage to establish.

Soft-bottom habitats adjacent to artificial reefs would be partially affected by current patterns and some minor scouring and deposition which may consequently affect grain size. It is possible that species numbers and/or diversity in sandy habitat adjacent to the reefs may decrease as a result of increased predation by benthic and demersal fish or decapods attracted to and/or growing on the reef, feeding in the adjacent sandy habitat. This effect is known as a 'feeding halo'. Halo effects of reefs may be confined to areas very close to a reef (within a few metres) or extend over a much larger area and may depend on the size of the reef and/or the trophic structure of fish occupying it. Furthermore, the habitat will continue to support a wide variety of marine organisms found living on or over soft sandy substrata. Increased predation on benthos is therefore not considered to have a significant impact within the wider study area.

Table 5. Risk assessment of soft sediment assemblages considered in the reef assessment

Environmental Aspect	Scale	Risk description	Risk Level	Mitigative measure	Treatment type	Risk Level
Flora and fauna						
Benthos	Sub-Local	Direct loss of habitat	A4	Careful selection of habitat type for deployment location. Swath mapping to confirm presence of reef habitat to provide adequate buffer. Efficient design of footprint to minimise loss of sedimentary habitat.	Accept	A4
Benthos	Sub-Local	Change to benthic fauna from changes to sedimentary characteristics	C4	Accept	Accept	C4
Benthos	Sub-Local	Changes to infaunal assemblages	B4	Accept	Accept	B4
Benthos	Sub-Local	Increased predation by fishes from the OAR on benthos	A4	Accept	Accept	A4

Impacts on adjacent rocky reef assemblages

It is considered likely that initial increases in fish numbers would be a result of attraction and aggregation, but that over time (once the reef has become established), the reefs would

contribute to overall production. The extent of impact on neighbouring natural reef may also depend on the size of the natural reef with impacts likely to be greater for a smaller neighbouring reef than a larger one. As a precautionary measure, maximum separation of the offshore artificial reef units from existing natural reef was aimed for as part of the constraints mapping in order to minimise potential draw-down effects. The convenience and likely popularity of the offshore artificial reefs could attract more recreational fishers, increase participation and length of time fishing and thus increase fishing effort rather than simply redistributing it. However, it is much more likely that fishing effort would not increase as a result of the deployment of the reef. Rather, it would merely transfer from other areas as access to the reef would be limited to boat-based fishers. This transfer of fishing effort could result in an increase in fishing pressure on a localised scale but would in turn potentially offer some relief to other areas that would have previously been fished. Therefore, an increase in fishing effort is not considered to have a significant impact within the wider study area. In summary, the site-specific surveys conducted by DPI supported the hypothesis that it is expected that the new offshore artificial reef will support a wide variety of reef associated fish species. However, the community is likely to be made up of a larger number of species with greater diversity as the structure will likely provide ample space for both sand and reef associated species.

Table 6. Risk assessment of rocky reef assemblages considered in the reef assessment

Environmental Aspect	Scale	Risk Description	Risk Level	Mitigative Measure	Treatment Type	Risk Level
Flora and Fauna						
Proximal natural reef	Intermediate	Drawdown effects – reduction in abundance/diversity of reef assemblages	C3	Careful selection of habitat type for deployment location. Swath mapping to confirm presence of reef habitat. Careful site selection to provide adequate buffer from natural reef.	Reduce likelihood	D3
Proximal natural reef	Local	Changes to demersal assemblages	A4	Careful selection of habitat type for deployment location.	Accept	A4
Proximal natural reef	Local	Changes to plankton assemblages	A4	Careful selection of habitat type for deployment location.	Accept	A4
Proximal natural reef	Local	Changes to pelagic assemblages	A4	Careful selection of habitat type for deployment location.	Accept	A4
Proximal natural reef	Intermediate	Changes to epibenthic assemblages	B5	Careful selection of habitat type for deployment location. Swath mapping to	Reduce likelihood	C5

				confirm presence of reef habitat. Careful site selection to provide adequate buffer from natural reef.		
Proximal natural reef	Intermediate	Increased fishing effort leading to increased fish mortality	C3	Existing bag and size limits and surveillance. Utilise additional input controls as appropriate - broad understanding on angler habits.	Reduce consequence	C4

5.3.9 Relation of proposed site to features of importance for amenity, navigation, or exploitation of cultural, historic or scientific interest, fishing, endangered, rare or migratory species or sensitive habitats (such as coral reefs or seagrass beds)

There are numerous boat ramps and amenities in the Tweed Heads region with 7 public boat ramps known to Roads and Maritime Services within 25 km by water of the proposed offshore artificial reef site (24, Table 7). This list includes three ramps within the Tweed River, two ramps within Terranora Creek, one ramp within Terranora Broadwater and one ramp at Cudgen Creek. It is expected that the majority of boaters will use the Kennedy Drive, Fingal Boat Harbour and Cudgen Creek boat ramps to access the artificial reef.

Table 7. Boat ramps and facilities within 25 km of the proposed Tweed Heads offshore artificial reef site

NAME	WATERWAY	ACCESS	CONSTRUCTION	CONDITION	NO. LANES	NO. TRAILER SPACES	FEE PAYABLE	LIGHTING	WASTE BINS	FISH CLEAN	PONTOON	BBQ	TOILETS
Kennedy Drive Boat Ramp (Ray Pascoe Park)	Terranora Creek	All times	Concrete	Good	2	11-20	N	Y	Y	Y	Y	Y	Y
Dry Dock Road Boat Ramp	Terranora Creek	All times	Concrete	Poor	2	0-10	N	Y	Y	Y	Y	N	Y
Lakes Drive, Terranora Inlet	Terranora Broadwater	All times	Concrete	Poor	1	0-10	N	Y	Y	N	Y	N	Y
Fingal Boat Harbour Boat Ramp	Tweed River	All times	Concrete	Good	2	21-50	N	Y	Y	Y	Y	Y	Y
Chinderah Boat Ramp (Oxley Park	Tweed River	Shallow at times	Bitumen	Poor	1	0-10	N	Y	Y	Y	N	N	Y

Riverside Drive Boat Ramp	Tweed River	All times	Bitumen	Good	2	0-10	N	N	N	N	N	Y	N
Cudgen Creek Boat Ramp	Cudgen Creek	All times	Concrete	Good	2	11-20	N	N	N	Y	N	N	N

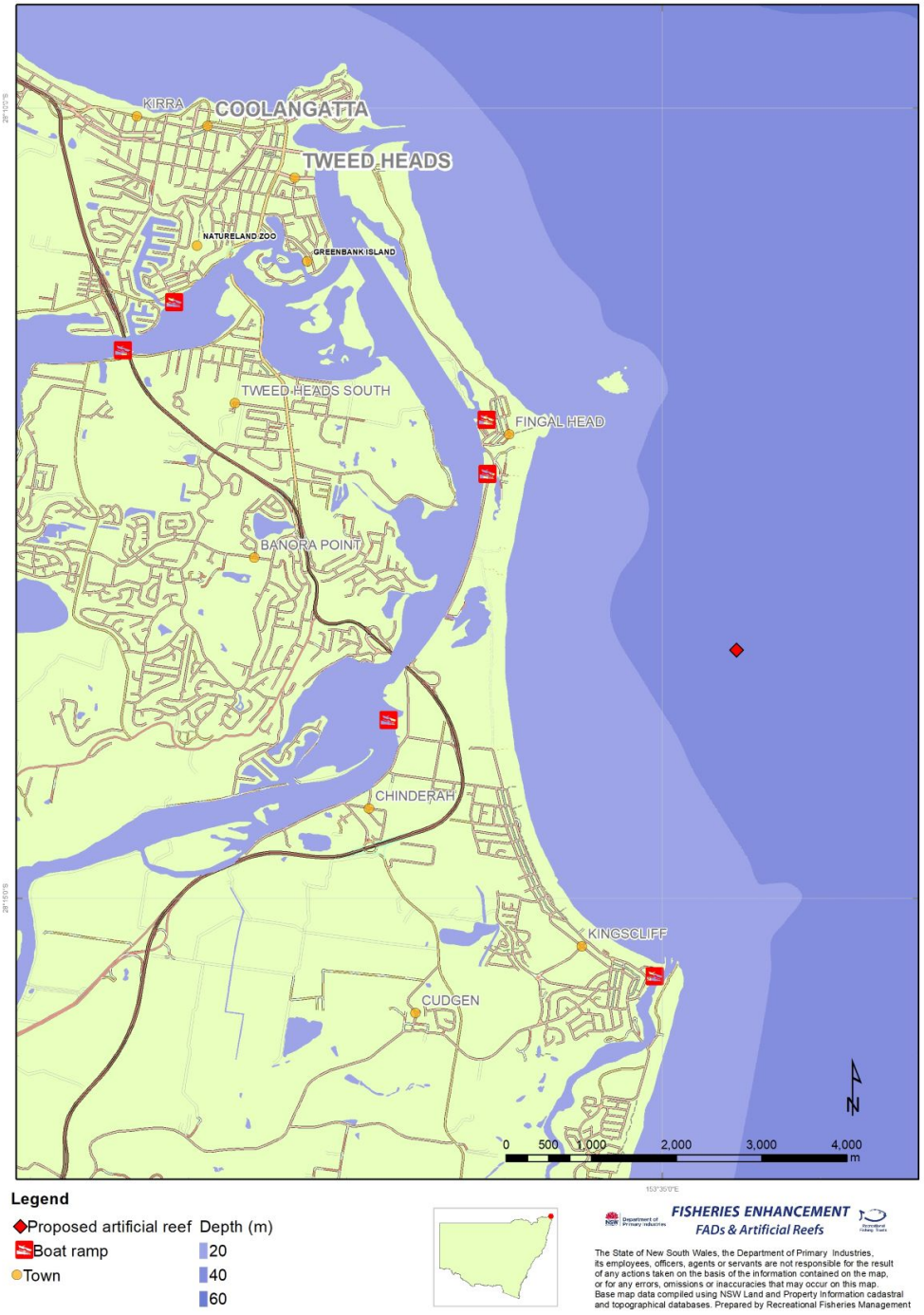


Figure 24 Boat ramps in the Tweed Heads region that may be used to access the artificial reef

5.3.9.1 Navigation

The proposed artificial reef has the potential to impinge on recreational and commercial vessel operations. The potential impacts of the proposed fishing reef on navigation and vessels are listed below and considered within Table8.

5.3.9.2 Clearance

There is a potential risk that vessels transiting over the offshore artificial reef may be damaged or damage the reef structures if their hull or propeller comes into contact with the structures. However, this would be mitigated by ensuring sufficient clearance at all tides and in high wave conditions. Adequate safe vessel clearance will be provided with a minimum of 15 m clearance from the uppermost part of the offshore artificial reef at Lowest Astronomical Tide (LAT) ensured for the proposed Tweed Heads offshore artificial reef.

Anchoring in the vicinity of the reefs would be strongly advised against. Target user groups would be informed about general boating rules in the vicinity of the reefs and recommended against anchoring in the area.

The potential impact of a vessel striking the reef has been prevented by ensuring suitable clearance from the upper part of the structures. It is not possible to completely remove the risk of anchor fouling/loss on the structures as the actions of recreational boat operators are hard to control.

Table 8. Risks and mitigation associated with clearance

Environmental Aspect	Scale	Risk Description	Risk Level	Mitigative Measure	Treatment Type	Risk Level
Navigation and Safety	Local	Clearance	D4	Sufficient clearance between the upper part of the reef and transiting vessels in severe weather conditions and under Lowest Astronomical Tide (LAT) would be ensured through constraints mapping process and swath mapping. Appropriate site selection, consultation and mapping on navigation charts.	Reduce Likelihood	E4

5.3.9.3 Increased vessel traffic

It is possible that there would be an increase or aggregation of small fishing vessels in the vicinity of the proposed offshore artificial reef locations which could increase the risk of collision or boating accidents.

A code of conduct and guidelines would be published to promote awareness of boating safety within the reef area and minimise navigational hazards such as anchor fouling and collisions. Recreational fishing vessels should give way to movement of commercial vessels and all other normal RMS boating rules and regulations apply.

The location of the artificial reef would not be marked with a buoy and light, because such markers can become a navigation hazard to small boats.

Table 9. Risks and mitigation associated with increased vessel traffic

Environmental Aspect	Scale	Risk Description	Risk Level	Mitigative Measure	Treatment Type	Risk Level
Navigation and safety	Local	Increased vessel traffic	A4	Accept	Accept	A4
Navigation and safety	Local	Collision from crowding	C3	Observe boating regulations. Spread effort through reef design/layout. Education.	Reduce likelihood	D3

5.3.9.4 Exploitation of cultural, historic or scientific interest

Conflict with areas of spiritual significance/dreamings

As discussed within DPI's Indigenous Fisheries Strategy and Implementation Plan – December 2002, Aboriginal people have strong cultural connections with the ocean and coast. Fishing has represented an integral part of their cultural and economic lives for thousands of years. Fishing has been an important source of food, a basis for trade and an important part of cultural and ceremonial life and the act of fishing is itself an important cultural practice and a key part of the cultural identity of Aboriginal fishing communities ([22]).

The project area is within the country of the Bundjalung people and more specifically, the Goodjinburra people in the Tweed coastal areas [23].

Roberts ([24]) notes the ongoing importance of fishing to Aboriginal communities throughout New South Wales, stating that fishing represents a cultural (as opposed to purely subsistence/recreational) activity that 'became a crucial means of survival when other traditional practices were undermined by colonisation' and has remained a largely accessible activity as compared to land-based activities. It is also noted that fishing remains an important activity for Aboriginal people today, despite the changes that have occurred in the environment and regulatory requirements over the intervening period.

It is widely accepted that Aboriginal people have inhabited the Australian landscape for the past 60,000 years. During that time, variations in climatic conditions would have exposed and inundated low lying areas, such as the East Coast of Australia. Prior to 7,000-8,000 years ago there was substantial variation in sea level changing the location of the active coastline. As the sea level gradually rose, land was inundated. Whilst the project area may have been exposed prior to7,000 years ago and would have been part of a landscape utilised by Aboriginal people, when sea levels rose to around current levels the project area and any archaeological record of human occupation that may have been present were subject to inundation. Over the subsequent 1000s of years, the project area has been subject to ongoing deposition of sand and other materials. The seafloor within the proposed reef deployment area offshore from Dreamtime Beach is currently 25-30 m underwater, and is flat, sandy, with no significant rock outcrops or features.

It is considered that if any Aboriginal objects remain at the project site due to its use prior to inundation, they are likely to have been buried by coastal processes and will not be impacted by the project.

Table 10. Risks and mitigation associated with conflict with areas of spiritual significance/dreaming's

Environmental Aspect	Scale	Risk Description	Risk Level	Mitigative Measure	Treatment Type	Risk Level
Heritage	Intermediate	Impacts on submerged Aboriginal deposits	C4	Appropriate site selection identified through consultation and Aboriginal cultural heritage due diligence assessment.	Reduce likelihood	E4
Heritage	Intermediate	Conflict with areas of spiritual significance/dreamings	C4	Appropriate site selection identified through consultation and Aboriginal cultural heritage due diligence assessment.	Reduce likelihood	E4

Historic shipwrecks

A desktop review of shipwrecks known or potentially occurring in the potential deployment region was carried out in February 2020 from the NSW Historic Shipwrecks Database ([25]) (Figure 25).

Several historic shipwrecks have been confirmed within the boundaries considered in the constraints analysis. A total of 13 shipwrecks have been confirmed or believed to be present within 10 km north and 10 km south of the coastline surrounding the proposed artificial reef site. The closest known shipwrecks to the proposed artificial reef site are the Fido, a steamer screw wrecked near Cook Island in 1907, the Alberta, a steamer screw wrecked on Sutherland Reef in 1890 and the Dellie, a steamer screw wrecked off Fingal Light; located 2.7, 3.3 and 3.7 km, respectively, from the reef site.

Unfound wrecked vessels from within the Tweed Heads area pose a potential deployment concern for the offshore artificial reef as the placement of the reef must not impede upon a historical shipwreck. It is possible that unidentified wrecks or debris could occur on the seabed throughout the area. Swath habitat mapping carried out by Astute Surveying provided full coverage information on the nature of the seabed in the proposed reef deployment area. A possible object of harder material than the surrounding area measuring 60 x 30 m was identified to the south-east of the proposed reef site during the hydroacoustic survey. A follow up camera survey of the site revealed that no objects were present at the site.

Table 11. Submerged shipwrecks known to occur within the Tweed region

Shipwreck	Vessel type	Year wrecked	Wreck location	Latitude	Longitude
Alberta	Steamer screw	1890	Tweed Heads, Sutherland Reef	-28.253783	153.592217
Fido	Steamer screw	1907	Tweed Heads, Reef near Cook Island, 1 mile from lighthouse	-28.199217	153.590367
Dellie	Steamer screw	1941	Tweed Heads, Fingal Light, near	-28.19548	153.56992
Friendship	Steamer screw	1912	Tweed River Heads, rocks at end of south wall	Unknown	Unknown
Cudgen	Lighter	1928	Tweed Heads	Unknown	Unknown
Tyalgum	Steamer screw	1939	Tweed Heads, Flagstaff Beach	-28.16876	153.55329
Terranora	Steamer screw	1933	Tweed River, north breakwater	Unknown	Unknown
Unidentified – Tweed Heads – possibly Terranora	Unknown	Unknown		-28.169174	153.552998
Anchor – unidentified Tweed Heads	Unknown	Unknown		-28.169162	153.552535
Coolon	Schooner	1901	Tweed Heads, on a sand spit	Unknown	Unknown
Alcides	Dredge	1903	Tweed River, Tweed Heads	-28.173567	153.547517
Unidentified Tweed River Ukerebagh Island – possibly Champion II	Tug	Unknown	Tweed River, Tweed Heads	-28.186483	153.551900
Jane	Schooner	1848	Tweed River	Unknown	Unknown

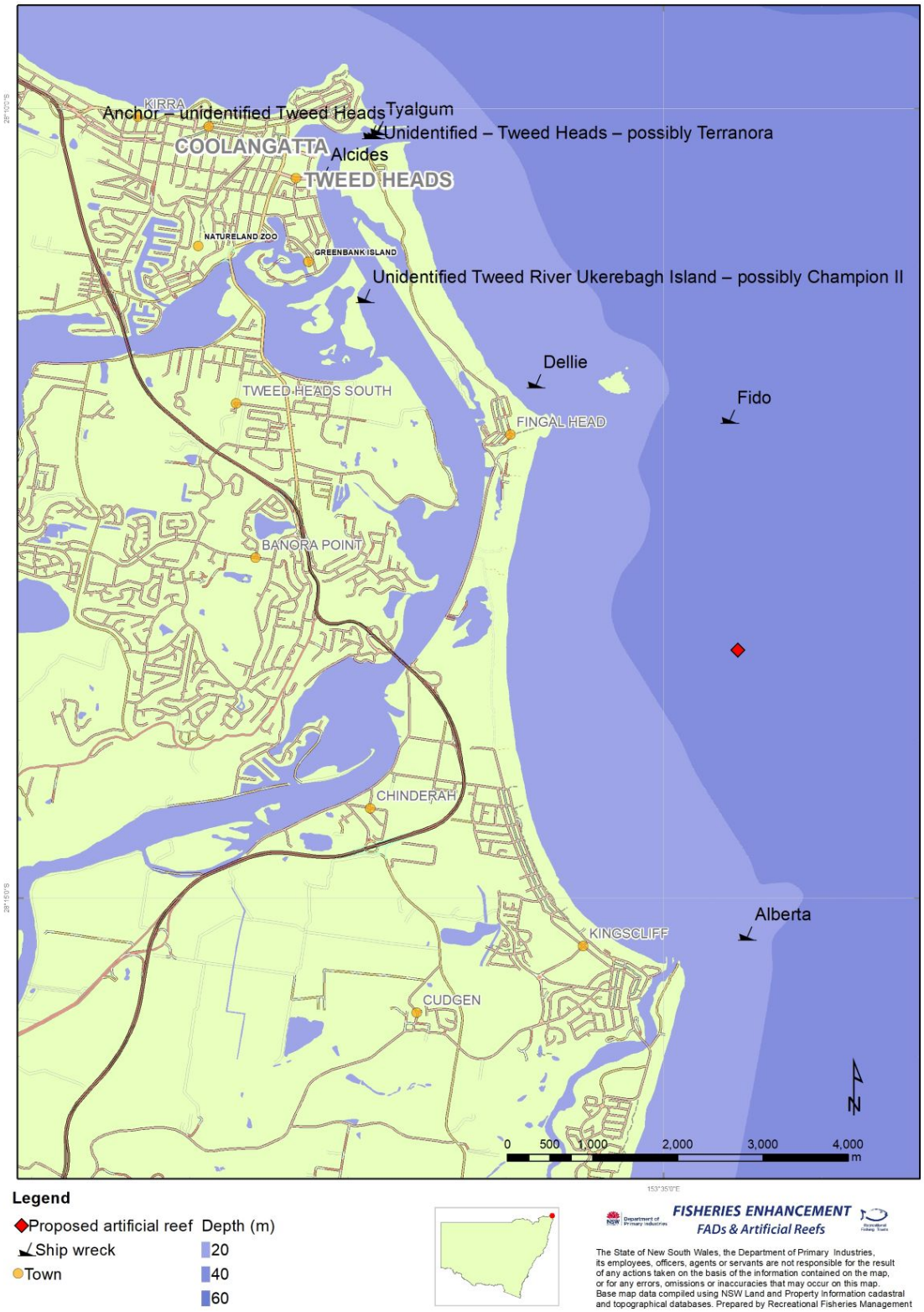


Figure 25 Locations of known shipwrecks in the greater study area

5.3.9.5 Fishing

Loss of commercial fishing ground

Commercial fisheries likely to be affected by the proposal include the Ocean Trawl and the Ocean Trap and Line fisheries. Based on the footprints of offshore artificial reefs built to date in NSW, a maximum loss of up to 556 m^2 of fishing ground is expected. However, the broader reef management area may be viewed as 'un-trawlable' due to risk of gear becoming hooked up on the units. Given the area of similar habitat in the area, this loss is considered to be minimal. This assessment is based on consultation with local commercial fishers. Loss of fishing area within the proposed study region is not considered to be a significant issue due to careful site selection with the reef to be located within an otter trawl net (prawns) fishing closure which extends from Coolangatta on the Queensland border in the north to Kingscliff in the south and offshore to more than 3.5 km (Figure 26). No commercial fish trawl fishers provided comment during the consultation phase of the project.

Table 12. Risks and mitigation associated with loss of commercial fishing grounds

Environmental Aspect	Scale	Risk Description	Risk Level	Mitigative Measure	Treatment Type	Risk Level
Recreational and commercial fishing	Local	Loss of commercial fishing ground	B3	Consultation with commercial operators and careful site selection to avoid important areas.	Reduce consequence and likelihood	D4

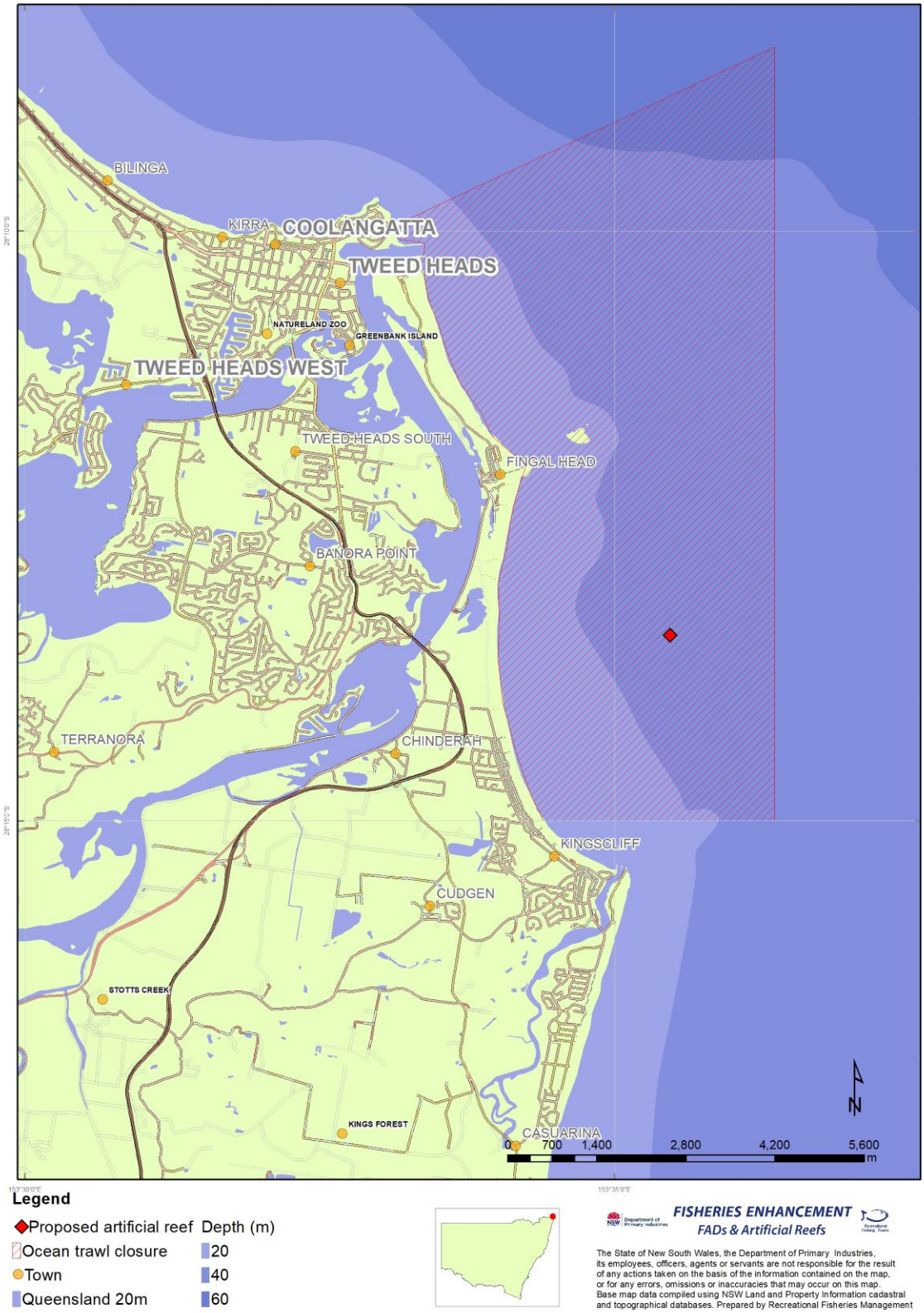


Figure 26 Otter trawl net (prawn) fishing closure

Conflict between other user groups

Recreational fishing involves a variety of user groups, including sportfishers, gamefishers, spearfishers and charter boat fishing. The proposed offshore artificial reefs are aimed at all recreational fishers. However, some limited commercial fishing may take place. Some overlap between user groups is therefore likely and the potential for conflict would be addressed through suitable management, including a code of practice for all users which is provided as part of the user guidelines for offshore artificial reefs.

In order to minimise potential conflict between user groups, consultation between sectors would be undertaken to resolve any issues of conflict (or similar).

Table 13. Risks and mitigation associated with conflict between user groups

Environmental Aspect	Scale	Risk Description	Risk Level	Mitigative Measure	Treatment Type	Risk Level
Recreational and commercial fishing	Local	Conflict between other user groups	B4	Education, consultation and adaptive management by implementing controls where applicable. Establish a complaints register to monitor conflict.	Reduce likelihood	C4

Risk offshore artificial reef does not achieve goals

The overall effectiveness and success of the reefs can be assessed only by monitoring of user satisfaction, structural integrity and impacts of the reef on the surrounding environment. If the proposal were shown not to meet its objectives and/or to have significant adverse impacts on significant components of the marine environment, then appropriate mitigative action would be taken and deployment of future reefs would need to be considered.

The reef is considered to be a success based on three primary objectives:

(i) Fish and benthic community development: the community identified to reside on the structure, although expected to be structurally different in terms of species diversity, should be comparable in terms of species richness to adjacent natural reef communities;

(ii) Structural integrity and module stability: the reef remains intact and structurally sound throughout its design life (50 years);

(iii) Stakeholder acceptance: the installation of the reef results in angler satisfaction reflected by high visitation rates.

If one or all of these objectives fail to be met, a number of mitigative actions may be required. For example, if the community is identified to be mono-specific in terms of species richness following the deployment of the reef with a clear dominance of a small suite of species including aggregation of a threatened or protected species, input controls such as gear or seasonal restrictions may require implementation. Depending on the species in question, restrictions may include the exclusion of bottom fishing with live bait and wire trace (aimed at reducing the likelihood of incidental capture of threatened species such as the Greynurse Shark (*C. taurus*) or the temporary closure of the reef during peak spawning periods in-line with key target species (e.g. early winter for inshore Snapper – *P. auratus*)).

Regular inspections of the reef during the initial 3 year post deployment period followed by periodic inspections over the design life of the reef will be implemented to investigate structural integrity of the reef and to identify any potentially detrimental issues related to the stability of the modules. Inspections will look for any obvious physical damage either from anchor damage or following large storm events that produce a significant wave height (Hs) in excess of 4.1 metres or evidence of module movement (sliding or over turning). If any of these impacts are identified, further investigations by the reef manufacturer (during the defects liability period) or by an appropriately qualified engineer would be used to identify a suitable mitigative response. Responses may include reef repositioning in the event of module movement or removal in the event of compromised structural integrity.

The probability of product failure or unforeseen physical damage which results in exposure of reinforcement fibres and subsequent compromised structural integrity is considered extremely low for this project due to the highly resilient submarine concrete aggregate mix selected. The concrete mix selected is the preferred product in both the marine civil and offshore construction industries due to its increased flexural strength, density and resistance to cracking over time [26], [27], [28], [29], [30]. In the unlikely event that a module is physically damaged (for example vessel strike) the decision-making process in Figure 32 will be followed to ensure the most appropriate outcome for the environment and management of future structural integrity of the module(s) impacted. Additionally, the bonding strength between the fibres and concrete medium are so strong, fibres have been shown to break rather than being separated from the concrete during laboratory testing [26].

Angler satisfaction is directly related to the useability and accessibility of the reef and the resultant fish community which takes up residence on the structures. Considerable attention has been applied to the site selection process of the reef to ensure it is located in an area where there is strong support for the reef initiative and where stakeholders (e.g. recreational fishers) can safely access the reef from suitable boating infrastructure (e.g. boat ramps) and where natural reef is limiting. Documenting the development of the fish community and dissemination of these results through meetings, online media (DPI website), social media (Facebook) and popular press (including newspaper and fishing magazines) will ensure stakeholders are well informed as to the development of the reef. Angler satisfaction will be directly related to visitation rates and usage.

Table 14. Risks and mitigation associated with the offshore artificial reef not achieving its goals

Environmental Aspect	Scale	Risk Description	Risk Level	Mitigative Measure	Treatment Type	Risk Level
Recreational and commercial fishing	N/A	Risk offshore artificial reef does not achieve goals	D1	Implementation of a monitoring plan to demonstrate if goals are met.	Reduce likelihood and consequence	E4
Pollution	Local	Poly reinforcement fibres exposed or released due to concrete mix not meeting the AS3600 standard for the correct exposure class of concrete (submerged – marine, B2)	D4	Most appropriate materials used for subsea concrete installations consistent with AS3600 in exposure classification B2 (submerged – marine). Preferred (best practice) material chosen for subsea use by industry. 5 yearly inspections for fibre exposure.	Reduce likelihood and consequence	E5

Gear hook-up

Potential safety issues which could occur as a result of recreational or commercial fishing in the direct study area include, but are not limited to, gear hook-up and collision. The risk of gear hook-up is considered relatively likely, particularly for recreational fishing gear, and could result in detrimental impacts to species vulnerable to entanglement or injury from fishing line and hooks. Vessels may foul their anchors on the offshore artificial reef. This may cause loss of the anchor and anchor line, and possible damage to the reef. In some circumstances, the loss of an anchor may cause consequential impacts on safety such as a disabled vessel drifting towards the coast.

Commercial otter trawling for prawns is excluded in the direct vicinity of the artificial reef. Additionally, fishers will be provided with a chart describing the exact location of each of the reef modules, including DGPS coordinates. However, a potential risk remains of gear hook-up on the reef units, which could result in damage to the reef, fishing vessel and safety implications for the vessel. The Australian Hydrographic Office will be notified of the final offshore artificial reef locations, so that a 'Notice to Mariners' can be issued, and the official hydrographic charts can be amended. NSW Maritime will also be notified of the final reef location so that relevant publications and maps are amended to show the location of the offshore artificial reef.

Provided commercial fishing businesses which operate in the region are made aware of the fishing reef location, follow a code of conduct and that structures are marked on the relevant AUS Chart, this potential risk is considered to be low.

Table 15. Risks and mitigation associated with gear hook-up

Environmental Aspect	Scale	Risk Description	Risk Level	Mitigative Measure	Treatment Type	Risk Level
Commercial Fishing	Local	Gear hook-up (commercial)	C2	Consultation, education, notice to mariners. Reef to be marked on nautical charts and NSW Maritime notified for inclusion in relevant publications. Commercial operators to be consulted and notified of final position.	Reduce likelihood	D2
Recreational Fishing	Local	Gear hook-up (recreational)	A4	Education (user guidelines), monitor, hydrographic charts. Removal of debris when required.	Reduce consequence	A5

Impacts on commercial fish stocks

It is considered highly unlikely that the proposed offshore artificial reef would contribute to a reduction in commercially fished populations in the wider area. It is possible that species most vulnerable to fishing mortality could be affected within the direct reef deployment area, but this is unlikely to have impacts at a population level. The positive impacts on secondary production of the Sydney offshore artificial reef have been demonstrated by ecological modelling [31].

Table 16. Risks and mitigation associated with impacts on commercial fish stocks

Environmental Aspect	Scale	Risk Description	Risk Level	Mitigative Measure	Treatment Type	Risk Level
Recreational and Commercial Fishing	Regional	Impacts on commercial fish stocks	E5	Accept	Accept	E5

Injury from boat strike or drowning (spearfishing)

It is anticipated that freedivers and spearfishers may utilise the reefs. The majority of spearfishers would benefit from accessing pelagic species (e.g. Yellowtail Kingfish) aggregating above the units in the top 10-20 m. There is however, a risk that spearfishers/freedivers would attempt to dive to depths beyond their limits.

The activity of SCUBA diving in the vicinity of the offshore artificial reef should be strongly discouraged in the User Guidelines and code of conduct because of the potential safety risks and conflict with recreational and commercial fishing activities.

Safety issues including, but not limited to, the risk of gear fouling and risks to spearfishers cannot be mitigated but can be managed through education. The User Guidelines would aim to provide the best possible information to inform different user groups on best practice and safety within the reef area.

Table 17. Risks and mitigation associated with injury or drowning (spearfishing)

Environmental Aspect	Scale	Risk Description	Risk Level	Mitigative Measure	Treatment Type	Risk Level
Navigation and safety	Local	Injury or drowning (spearfishing)	C1	Monitoring usage, education and awareness strategies.	Accept	C1

5.3.10 **Invasive marine pests and diseases**

There is potential for the spread of marine pests or diseases during the project with the key vector/pathway being the transport of vessels or equipment between ports. In particular vessel ballast water and biofouling of hulls or vessel niche areas, and the movement of vessels or infrastructure from other locations (with different risk profiles), can present significant translocation risk. However, there are no known marine pests within Townsville Harbour (where fabrication and loading of the transport barge will take place) which are likely to be transferred to and survive in the coastal waters of Tweed Heads. In addition, the reef

modules will be newly constructed and free from any pests and disease. There is a possibility of transferring larvae or aquatic pathogens/disease agents between ports in ballast water, however this can be mitigated by exchanging ballast water at sea or by using a ballast water treatment system if available.

The proposed reef structures could provide a substratum or habitat suitable for invasive marine pests (also referred to as 'introduced', 'alien' or 'non-indigenous' species). Invasive marine pests are defined as organisms (usually transported by humans) which successfully establish themselves and then overcome or displace otherwise intact, pre-existing native ecosystems ([32]). Although there is evidence that many exotic species establish populations more easily on artificial structures [33], the risk of increased potential for pest and disease issues associated with installation of the offshore artificial reef is considered to be small due to the isolated location of the structures in the open ocean rather than in estuarine environments as noted by the aforementioned study. Similarly, the risk to threatened species from invasive marine pests associated with the reef is considered very small.

Comparison of video observations over a three month period following deployment of the Sydney OAR showed that the majority of the structure had been covered by encrusting organisms, including serpulid polychaetes, barnacles, filamentous algae, bryozoans and hydroids. No introduced marine pests were observed ([34]). Likewise no marine pests have been observed on the subsequent six artificial reefs installed by DPI between Merimbula and Port Macquarie.

Ships' ballast water is a major vector for introduced species. Fouling of ships' hulls, aquaculture, the aquarium industry and bait industries are also potential vectors. Major ports and estuaries are potential hotspots for invasive species. Whilst the proposed artificial reef site is potentially at risk from colonisation by invasive marine pests, the scale of the potential impact is small and would be unlikely to have any significant impact on the marine environment.

The reef structures will be monitored for colonisation by marine pests. In the event that invasive (introduced) marine pests are identified on reef unit(s), the extent of the pest incursions will be defined noting affected area, species type, abundance and potential for further spread. Requirements for removal of marine pests (according to Biosecurity NSW) would depend on the extent and nature of the incursion but is likely to involve manual removal by divers in the first instance.

Table 18. Risks and mitigation associated with invasive marine pests

Environmental Aspect	Scale	Risk description	Risk Level	Mitigative measure	Treatment type	Risk Level
Invasive marine pests and diseases	Regional	Spread of invasive marine pests or aquatic disease agents during transport and installation	C3	Ensure equipment and vessels used during transport and installations are clear of all biofouling before making way to Tweed for commencement. Release and exchange ballast water or other storage/water tanks (if used) from vessel/s at sea, or treat using a ballast water treatment system, prior to movement between regions	Reduce likelihood	D3

				between ports of different biosecurity risk. Move directly to and from the port or berth and the work site to reduce the uptake of any marine pest or disease agent.		
Invasive Marine Pests	Local	Colonisation by invasive (noxious) marine pests	C3	Surveillance as part of other monitoring. Follow Biosecurity NSW advice if marine pests are identified.	Reduce consequence	C4

5.3.11 **Endangered, rare or migratory species**

Threatened and protected species, populations and endangered ecological communities

Threatened and protected species, populations and endangered ecological communities listed under relevant schedules of the Commonwealth EPBC Act, New South Wales BC Act and the FM Act were identified using the EPBC Act Protected Matters Reporting Tool ([35]), the Bionet Database ([36]) and the Atlas of Living Australia, as well as literature relevant to the Tweed Heads area in February 2020. A list of all threatened and protected species, populations and endangered ecological communities that have previously been recorded within the search areas are provided (Table 3). It is important to note that data in the searches comes from a number of different sources, may contain errors and omissions and should therefore be treated as indicative only.

Only threatened species (from the initial search) that were known or considered likely to occur in the wider Tweed Heads region (based on general species distribution databases) and/or known to utilise habitat in the area, were considered for further Assessment of Significance. These species were assessed according to OEH and DPI threatened species assessment guidelines ([19, 20]). It should be noted that this does not include 'protected' or 'conservation dependent' species, which do not require an Assessment of Significance. All seabirds were assessed collectively.

Assessments of significance (State)

Overall, 8 species of fish, 3 species of marine turtle, 4 species of cetacean and 1 sirenian were assessed according to OEH and DPI threatened species assessment guidelines.

Fish

The proposal was not considered to have a significant impact on any of the species identified in Table 3, hence Species Impact Statements (SIS) were not required.

Management of fishing related activities in NSW includes the implementation of a range of bag and size limits aimed at ensuring fisheries resources are managed in a consistent and sustainable manner state-wide. Current Fisheries regulations make provisions for the exclusion of the harming or taking of protected or threatened species. Proper management of these regulations by compliance activities in the far North Coast region will ensure these regulations are adhered to by fishers. It is therefore unlikely that the artificial reef would pose an inflated threat to listed threatened and protected species.

Fish species considered most at risk from fishing related activities such as incidental capture including the Great White Shark (*Carcharodon carcharias*), Greynurse Shark (*C. taurus*),

Scalloped Hammerhead Shark (*Sphyrna lewini*) and Great Hammerhead Shark (*S. mokarran*) are highly migratory and the transient nature of these species means that although they may pass in the vicinity of the reef they are unlikely to remain on the reef long enough to be vulnerable to the potential fishing related impacts identified. Passive and active monitoring of the reef through baited video and acoustic tagging will give adequate resolution by which the occurrence of these species will be identified. The reporting register for threatened and protected species provided to the DPI Threatened Species Unit at 6 monthly intervals will ensure assessment of numbers of threatened species are evaluated independently outside of the DPI Recreational and Aboriginal Fisheries Unit. In addition, any serious incidents involving threatened and protected seabird, mammal or reptile species will be reported to the NSW Office of Environment and Heritage (OEH).

The Greynurse Shark is known to aggregate at discrete locations within the wider far North Coast area. The nearest aggregation area to the study area is Julian Rocks, 43 km south of the proposed OAR deployment site. Given the distance from known aggregation areas, the proposal would not directly affect Greynurse Shark habitat. It is, however, possible that individuals could occasionally forage within the direct reef area. Although this species is most frequently sighted in or near sand-bottomed gutters or rocky caves, Greynurse Sharks are migratory along the NSW coast and may occasionally forage outside of aggregation sites over open sandy habitat ([37]). This considered, it is possible that individual Greynurse Shark could be at risk of incidental capture as a result of the proposal. Even if the sharks are returned to the water, capture related injuries can lead to early mortality due to infection and/or by affecting feeding efficiency. Given that the sharks are only likely to forage within the Tweed Heads region on occasion, it is unlikely that potential impacts associated with the reef would affect the life cycle of a viable local population to such an extent that the species is placed at the risk of extinction. Furthermore, providing that fishing activities in the direct reef area are properly managed and monitored, potential risks would be minimised or addressed before they become problematic.

The offshore artificial reef could represent foraging habitat for juvenile or adult breeding Scalloped Hammerhead Sharks due to the expected increase in fish numbers in the vicinity. However, it is considered unlikely that the artificial reef would disrupt the species' life cycle or place any local population at risk of extinction.

While there were no official records available for the Great Hammerhead Shark within the area of investigation, sightings of the species have occurred to the north in south-east Queensland and further south in NSW. The artificial reef site could represent foraging habitat for Great Hammerheads on occasions, however, based on the rarity of the species in the region, it is considered highly unlikely that the artificial reef would disrupt the species' life cycle or place any local population at risk of extinction.

The Black Rockcod (*Epinephelus daemelii*) inhabits coastal and estuarine rocky reefs throughout the NSW coastline. While adult Black Rockcod are territorial and unlikely to utilise the new artificial reef habitat, the pelagic dispersal of eggs and larvae may lead to juveniles recruiting on the reef structures and there is a subsequent risk of incidental capture of individuals. However, it is considered unlikely that the potential impacts associated with the artificial reef would affect a viable population to the extent that it would be placed at risk of extinction.

As the last sighting of the Green Sawfish was in the Clarence River, Yamba, in 1972, it is highly unlikely that the species would occur in the proposed study area.

While Southern Bluefin Tuna and White's Seahorse sightings were revealed from the Atlas of Living Australia search, it is extremely unlikely that these species would be encountered at the proposed artificial reef site based on their recognised distributions.

The Offshore Artificial Reef User Guide contains information on how to identify and report sightings of threatened or protected species and how to properly release unwanted fish species safely and with as little impact on the individual as possible.

Marine Turtles

For the species identified, the proposal was not considered to have a significant impact such that a Species Impact Statement (SIS) would be required. This was mainly due to the transient nature of these species and absence of important nesting, mating or feeding areas within the wider study area.

Cetaceans

The proposal was not considered to have a significant impact on any species of cetacean, such that a SIS would be required. This was mainly due to the transient nature of the species and the absence of important nesting, mating, feeding or resting areas within the wider study area.

Sirenians

Although pinnipeds and sirenians (particularly seals) could forage within the wider far North Coast area, the proposal was not considered to have a significant impact such that a SIS would be necessary. Based on the rarity of the species in the region, it is considered highly unlikely that the artificial reef would disrupt the species' life cycle or place any local population at risk of extinction.

Seabirds

The proposal was not considered to have a significant impact on any species of seabird, such that a SIS would be necessary.

Matters of national environmental significance (Commonwealth legislation)

Listed Threatened and Protected Species

The Department of the Environment EPBC Act Protected Matters Reporting Tool ([35]), the NSW government 'BioNet' database ([36]) and the Atlas of Living Australia were searched for listed threatened and migratory species, populations and communities listed in relevant Schedules of the EPBC Act that are likely or predicted to occur in the Tweed Heads region. Note that threatened species assessed under the EPBC Act include only those listed as 'extinct in the wild', 'critically endangered', 'endangered', 'vulnerable' or 'migratory'.

Note that a species may be classed as both a 'cetacean' and a 'migratory species' in addition to its protected status, e.g. the Southern Right Whale (*Eubalaena australis*) which is listed as 'endangered', but is also protected as a 'migratory cetacean'.

Searches for birds likely to forage offshore and in the proposed reef deployment area were also carried out. Intertidal and wading birds, such as sandpipers, curlews and plovers, were excluded from the assessment as they are unlikely to be affected by the proposal. A total of

69 bird species were identified comprising of seabirds and birds of prey. The main groups of seabirds that were found to occur in the study region included albatrosses, petrels, shearwaters, terns, skuas, prions, gulls and gannets (Table 3).

Only threatened species that were known or considered likely to occur in the wider study area (on the basis of their geographical distributions) and/or known to utilise habitat in the study area, were considered for further impact assessment.

No critically endangered or endangered ecological communities are known to occur within the proposed study areas.

The Commonwealth Marine Area

The Commonwealth marine area is any part of the sea, including the waters, seabed, and airspace, within Australia's exclusive economic zone and/or over the continental shelf of Australia, that is not State or Northern Territory waters. The Commonwealth marine area stretches from 3–200 nautical miles from the coast.

The proposed Tweed Heads artificial reef is proposed to be located within State waters.

Key threatening processes

The following Key Threatening Processes (KTPs) have been identified as potentially relevant to the proposal:

- Entanglement or ingestion of anthropogenic debris in marine and estuarine environments (BC Act); and
- Injury and fatality to vertebrate marine life caused by ingestion of, or entanglement in, harmful marine debris (EPBC Act).
- Hook and line fishing in areas important for the survival of threatened fish species (FM Act).

Entanglement or Ingestion of Anthropogenic Debris in Marine and Estuarine Environments (BC Act)

The NSW Scientific Committee has declared entanglement in or ingestion of anthropogenic debris in marine and estuarine environments to be a 'key threatening process' in NSW. Marine debris is mostly comprised of fishing gear, packaging materials, convenience items and raw plastics. The major sources of marine debris are from ship waste, recreational activities, aquaculture industry and both urban and rural discharges into rivers, estuaries and coastal areas ([38]). Marine debris, particularly plastics, can become entangled around or be ingested by marine animals. This can lead to a number of lethal or detrimental impacts such as:

- strangulation;
- increased drag;
- potential poisoning by polychlorinated biphenyls (PCBs);
- blockage and/or perforation of an individual's digestive system;
- wounds caused by line or net and subsequent infection; and
- gastric impaction by plastic bodies.

Even sub-lethal effects of entanglement or ingestion of marine debris may reduce an individual's fitness and ability to successfully reproduce, catch prey and avoid predation.

Records kept by the NSW National Parks & Wildlife Service and Taronga Zoo databases show that entanglement in monofilament line, presence of hooks in the mouth and/or gut, net/line wounds and gastric impaction of plastic bodies are the main reasons for injury or mortality in marine wildlife ([39]).

A number of threatened marine species (including marine turtles, seals and cetaceans) and a number of marine birds have been found to have ingested or become entangled in marine debris.

Injury and Fatality to Vertebrate Marine Life Caused by Ingestion Of, or Entanglement In, Harmful Marine Debris (EPBC Act)

This KTP is similar to the above KTP, but applies to vertebrate marine life protected under Commonwealth legislation ([39]). Department of the Environment has developed a Threat Abatement Plan to address the impacts of this KTP ([40]).

Hook and Line Fishing in Areas Important for the Survival of Threatened Fish Species (FM Act)

Hook and line fishing refers to the use of a combination of lines and hooks for catching fish, including lines composed of microfilament, wire and cord, with attached lures, hooks and jigs. Hand-lines, set lines, rod and reel fishing, trolling, lure fishing and fly fishing are all included in the activities identified as a key threatening process. This definition includes catch and release, not just the 'taking' of fish ([41]). Areas that are used for feeding and breeding are considered important for the survival of a threatened species and with the exception of Greynurse Shark, such areas are poorly defined, if at all, for the majority of threatened species considered in these assessments. Following identification, some of these areas may be declared as critical habitat, such as the Greynurse Shark aggregation sites along the NSW coast. The Greynurse Shark and Black Rockcod are considered particularly vulnerable to this KTP ([41]). Even when accidentally captured, hooks caught in fishes' mouths can result in damage that can impact on feeding behaviour and success. The effects of fish hooks can be more serious over a longer time if retained in the mouth, throat and stomach of fishes and sharks, and ultimately can lead to death ([41]). It is recognised that listing all hook and line fishing throughout NSW waters as a KTP would be unpractical and unwarranted. However, where known aggregation sites, spawning areas, important juvenile habitats and feeding areas are concerned, activities that could kill or adversely affect threatened fish species should be considered a threatening process and managed accordingly. A threat abatement plan is yet to be developed for this KTP.

The majority of impacts identified are relevant to threatened or protected species only if they were to move and/or recruit into the direct study area. Threatened or protected species, populations or endangered ecological communities that are most likely to be affected by the deployment of the reef are those that would compete directly with the target fish or crustaceans for the same food or the newly created habitat. Following deployment of the reef, it is proposed for any incidents, recorded or reported interactions with threatened or protected species to be reported at 6 monthly intervals to the DPI Threatened Species Unit for further assessment as detailed in this plan. A series of trigger points relating to threatened species has been established as part of the environmental management of the reef. As such, if aggregation of any given threatened species or a key non-threatened species within the reef area increases by an amount deemed 'of concern' by the DPI Threatened Species Unit, this may require a modification to the management of the reef. These measures are deemed

to potentially reduce the consequences of an aggregation of threatened species from a moderate risk to a low risk.

The DPI will also provide education on threatened and protected species' identification, best practice for returning incidentally captured fish, minimising risks to seabirds and boating restrictions in the vicinity of large cetaceans. This educational information will be published as part the offshore artificial reef 'User Guidelines'.

Table 19. Risk assessment of threatened and protected species considered in the risk assessment

Environmental Aspect	Scale	Risk Description	Risk Level	Mitigative Measure	Treatment Type	Risk Level
Threatened and Protected Species						
Fish	Local	Incidental capture	C3	Monitoring, reporting and education. Angler education on best practice and fish release guidelines. Monitor incidences/tagging/listening stations. Monitor occurrence and movement patterns in relation to offshore artificial reef. Monitor and manage/regulate as appropriate (seasonal closures/gear types etc.).	Accept	C3
	Local	Aggregation of threatened or protected species	C2	Monitoring and reporting in relation to trigger points. Utilising input controls as required.	Reduce likelihood and consequence	D3
	Regional	Interruption of movement corridors (e.g. GNS)	C4	Monitoring and reporting in relation to trigger points. Utilising input controls as required.	Accept	C4
	Sub-Local	Loss of habitat	E3	Careful selection of habitat type for deployment location.	Accept	E3
Marine Turtles	Local	Incidental capture/entanglement from marine debris	C3	Monitoring, reporting and education	Accept	C3
	Local	Increased risk of boat strike	C3	Education	Accept	C3
	Intermediate	Increased risk of acoustic disturbance	C4	Accept	Accept	C4
	Large	Interruption of movement corridors	E5	Accept	Accept	E5

	Intermediate	Loss of habitat	E4	Accept	Accept	E4
Cetaceans	Local	Increased risk of boat strike	C3	Education regarding acceptable approach distances to cetaceans via national guidelines for whale and dolphin watching. Monitoring, reporting and education of existing regulations.	Reduce likelihood	D3
	Intermediate	Increased risk of acoustic disturbance from boat traffic	C4	Follow national guidelines for whale and dolphin watching.	Accept	C4
	Large	Interruption of movement corridors	D5	Accept	Accept	D5
Pinnipeds and Sirenians	Sub-Local	Incidental capture/entanglement from marine debris	C3	Monitor marine debris and remove as per Long Term Management Plan	Reduce likelihood	D3
	Local	Boat strike (sirenians only)	E3	Accept	Accept	E3
	Intermediate	Increased risk of acoustic disturbance from boat traffic	D4	Accept	Accept	D4
	Large	Interruption of movement corridors	E5	Accept	Accept	E5
Seabirds	Local	Incidental capture	D3	Monitoring, reporting and education. Encourage reporting to WIRES.	Accept	D3
KTPs	Intermediate	Harm from marine debris and pollution (KTPs)	C3	Monitor for fouled gear and remove as necessary. Monitoring, reporting and education, adaptive management.	Reduce consequence	D3

5.3.12 **Areas of conservation significance**

For the purpose of this assessment, areas of conservation significance include areas declared as critical habitats under the NSW FM and BC Acts and Marine Protected Areas (which include Marine Parks, Aquatic Reserves and Nature Reserves). Distances of areas of conservation significance in relation to the proposed artificial reef, are listed in Table 20. Distances of proposed offshore artificial reef to areas of conservation significance and displayed in Figure 27.

Table 20. Distances of proposed offshore artificial reef to areas of conservation significance

Area of conservation significance	Designation	Distance to the proposed reef (km)
Cook Island	Aquatic Reserve	2.9
Cook Island	Nature Reserve	3.3
Ukerabagh Nature Reserve	Nature Reserve	4.3
Tweed Heads Historic Site	Historic Site	4.9
Tweed Estuary Nature Reserve	Nature Reserve	7.9

Nature reserves are areas of predominantly untouched land in a natural condition and are considered to have high conservation value. Their primary purpose is to protect and conserve outstanding, unique or representative ecosystems, native plant and animal species or natural phenomena ([42]). Nature reserves are generally terrestrial, but there are some with associated marine components.

National parks are areas of land protected due to their unspoilt landscapes, outstanding or representative ecosystems, native plants and animals, and places of natural or cultural significance. National parks provide opportunities for public nature appreciation, well-being, enjoyment and scientific research in addition to their role in conservation [43].

Aquatic reserves are marine areas managed to conserve marine biodiversity and support marine science, recreation and education. The kinds of fishing activities that are allowed in an aquatic reserve depend on the biodiversity values of the individual reserve. All aquatic reserves provide for boating, SCUBA diving, snorkelling and swimming. Fishing is permitted in some aquatic reserves as long as bait is not collected. In other aquatic reserves, however, fishing is prohibited in all or part of the reserve to help conserve all types of marine life in that area.

Historic sites or heritage places are areas of cultural significance which protect and promote cultural heritage values [44]. They may be an area of significance to Aboriginal culture, include areas associated with a person or event in history, or include areas containing a building, place, feature, or landscape of cultural significance.

Within the wider Tweed Heads region, there is one aquatic reserve, three nature reserves and one historic site considered relevant to the proposal.

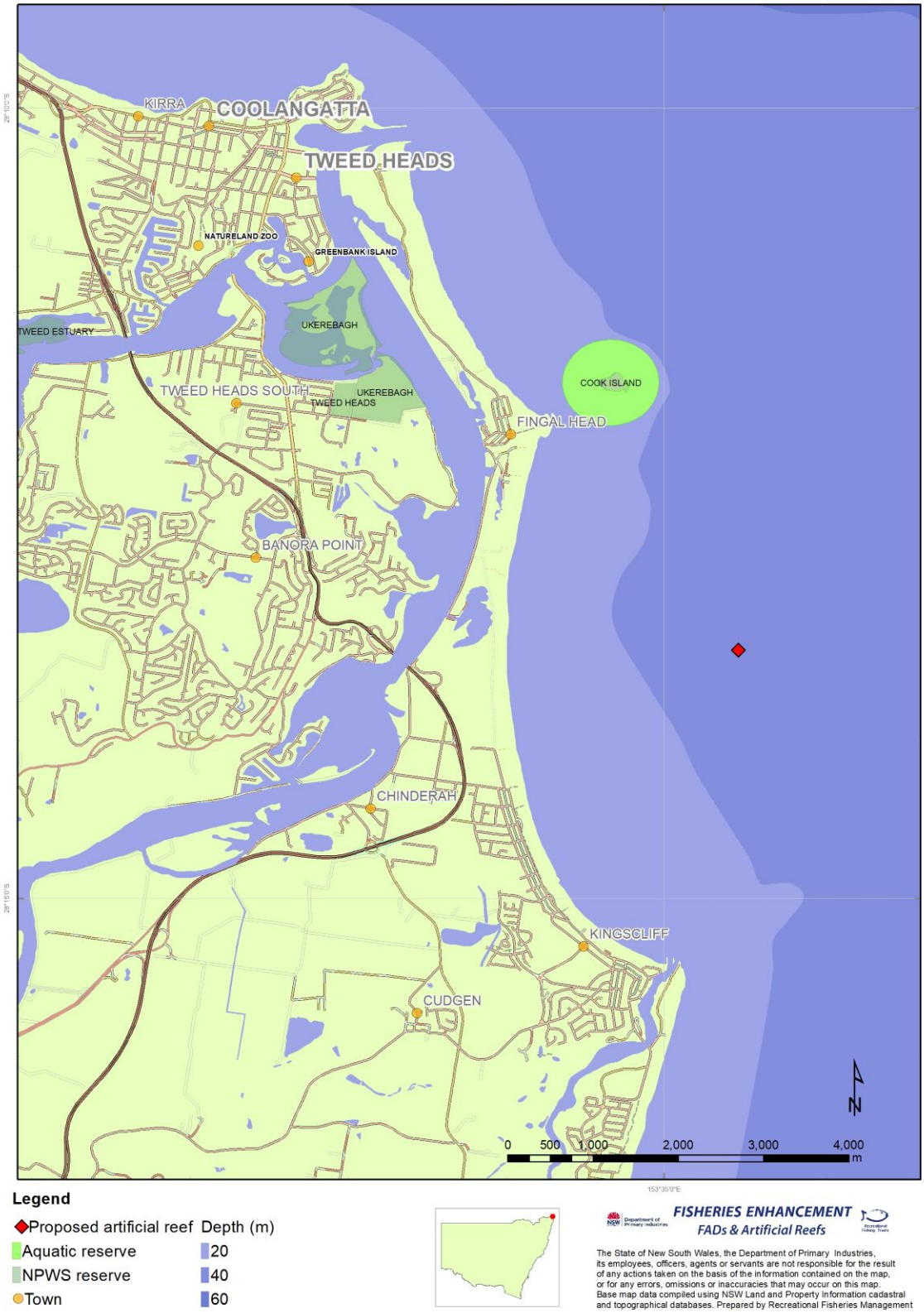


Figure 27 Location of areas of conservation significance in relation to the proposed Tweed Heads offshore artificial reef

5.3.13 **Ocean waves and currents**

Impacts relating to coastal processes are listed and discussed below. Overall the outcomes of the coastal processes study demonstrated that the proposed reef structure deployment would be sustainable in terms of coastal processes and cause no identifiable changes, other than in the immediate vicinity of each structure.

Placing the reef modules in relatively shallow water may, in principle, alter the wave propagation in the area and consequently affect the nearby shoreline morphology. Whilst the size of the reef deployment area and individual concrete reef units are relatively small in comparison to the characteristics of the adopted wave conditions used for the coastal processes analysis, should sand accumulation occur around the artificial reef modules result in a change in the local seabed bathymetry, there is potential to focus wave energy resulting in a change to the wave climate along Dreamtime Beach. As such, beach erosion and accretion processes may be altered by the deployment of the reef in much shallower water than previously installed artificial reefs that are deployed in water depths typically greater than 30 m.

The coastal processes report concluded that the proposed reef installation is not expected to have a great impact on the wave climate at the site or within the bay more broadly, provided sand does not accumulate significantly within or between the reef modules. Initial consideration was given to placing the reef in 20 m depth to provide fishing access for a broad range of users (eg spear fishers). However, the final proposed location has been relocated to deeper water based on the coastal processes report investigation. Additionally, reef modules are spaced and designed for sand to pass through them to reduce the probability of sand accumulating around the reef and affecting local wave climate.

Table 21. Risks and mitigation associated with inshore wave climate and change to beach erosion/deposition

Environmental Aspect	Scale	Risk Description	Initial Risk Level	Mitigative Measure	reatment Type	Residual Risk Level
Nearshore coastal	Large	Inshore wave climate	C3	Detailed coastal processes assessment to be undertaken. Avoid placement where there is risk of impacts to coastal processes.	Reduce likelihood and consequence	E5
Nearshore coastal	Large	Change to beach erosion/deposition	C3	Detailed coastal processes assessment to be undertaken. Avoid placement where there is risk of impacts to coastal processes. The initial proposed location has been moved to deeper water to eliminate this risk consistent with the coastal process investigation recommendations	Reduce likelihood and consequence	E5

The primary driving mechanism for currents outside Dreamtime Beach embayment is the East Australian Current (EAC) that typically flows south year round (albeit more strongly during the summer and autumn months) in deeper waters off the NSW north coast. The seabed bathymetry is complex north of Dreamtime Beach due to the presence of Cook Island and the Danger Reefs that lie to the east. Cook Island and the shallow reef areas influence the current behaviour through interaction with the irregular seabed on occasion resulting in complex current flow patterns off Dreamtime Beach. The EAC typically runs at 0.1 to 0.6 m/s, and can also be affected by local winds that seasonally create upwelling of deep nutrient rich colder waters onto the coast.

Ocean current movement in the Dreamtime Beach embayment is complex and driven by the interaction of meteorological conditions, waves, tides, shelf currents and the EAC. The Acoustic Wave And Current AWAC survey and Queensland Department of Environment and Resource Management (DERM) ocean current investigations conclude that Cook Island creates a divergence point for the generally south flowing EAC. As the EAC flows past Cook Island from the north it typically shifts to a more southerly direction as it enters the Dreamtime Beach embayment. Between Fingal Head and Cook island the water movement is more complex with a wide range of current velocities and directions observed. During the DERM current monitoring exercises in December 2010 strong flow south-east between Fingal Head and Cook Island was observed with maximum velocities of 0.6 m/s recorded. The southern extent that this higher velocity plume between Fingal Head and Cook Island reaches was not recorded during the DERM current monitoring exercises. Therefore, it is not known if the higher velocity currents reach the vicinity of the proposed location of the Tweed artificial reef or have the potential to move sediment at the reef site. Notwithstanding this uncertainty, there is evidence of onshore sand transport taking place in this general region.

Installation at the proposed reef location is expected to have a negligible impact on regional ocean currents within the Dreamtime Beach embayment, with only minor localised scour expected to occur in the immediate vicinity of the base of the reef modules during storm wave conditions.

Table 22. Risks and mitigation associated with local scouring/deposition around units

Environmental Aspect	Scale	Risk Description	Initial Risk Level	Mitigative Measure	Treatment Type	Residual Risk Level
Local seabed	Sub-Local	Local scouring/deposition around units	B3	Detailed coastal processes assessment to be undertaken. Avoid placement where there is risk of impacts to coastal processes. Consider alternative module arrangement options to further reduce this risk.	Reduce consequence	B5

5.3.14 **Summary of the reasons for selection of proposed site**

A detailed investigation of existing information and database searches relating to the study area has shown that there are several critical constraints which would preclude the deployment of an offshore artificial reef at depths of 20–40 m over a large proportion of the study area offshore of Tweed Heads. These included the preferred depth requirements, proximity to reef substratum and commercial fishing activities.

Following the review of existing information and mapping of key characteristics of the study area and surrounds, constraints analysis identified a potential offshore artificial reef deployment area offshore of Dreamtime Beach in Wommin Bay (Figure 28). This is the area where, based on existing information, reef deployment would be suitable and unlikely to conflict with the physical, biological and regulatory constraints investigated. The analysis was limited to using the information available and was subject to revision once further data or field investigations of the seabed and consultation had been undertaken.

Following consultation with relevant stakeholders, it was revealed that the placement of an artificial reef north of Cook Island would not be suitable due to exposure to stronger prevailing currents and greater sand movement than south of Cook Island. It was also considered that activities of commercial trawl fishers could be impacted upon if the reef was to be deployed outside of the prawn trawl closure boundary. A desktop review of known historic ship wrecks in the region revealed wrecks in the vicinity of Cook Island and east of Fingal Head but none within Wommin Bay. There were no active mining or exploration tenements, ocean outfalls, critical infrastructure or areas of conservation significance identified within the potential deployment area. A swath acoustic survey of the potential deployment area was completed and bathymetry and habitat type determined. A 500 m buffer was applied from the natural reef. Additional standalone technical reports were completed and summarised within this document including an Aboriginal cultural heritage due diligence assessment and a coastal processes investigation. These reports further confirmed the suitability of the potential deployment area providing that the shallower portion of the area of investigation was avoided due to potential sand deposition between reef modules which could impact upon wave behaviour.

The potential deployment area covered depths of up to 32 m. A location was proposed approximately 2.4 km offshore from Dreamtime Beach in a depth of 25-27 m Figure 29) to allow for a range of reef designs to be considered and particularly to increase vertical relief of the reef to up to 10 m while ensuring sufficient safe vessel clearance (>15 m) above the structures. This location is also accessible to boat-based fishing from Tweed Heads and Kingscliff. Notification letters were sent to relevant stakeholders between 29 August 2018 and 13 December 2019 there were no concerns with the proposed reef location.

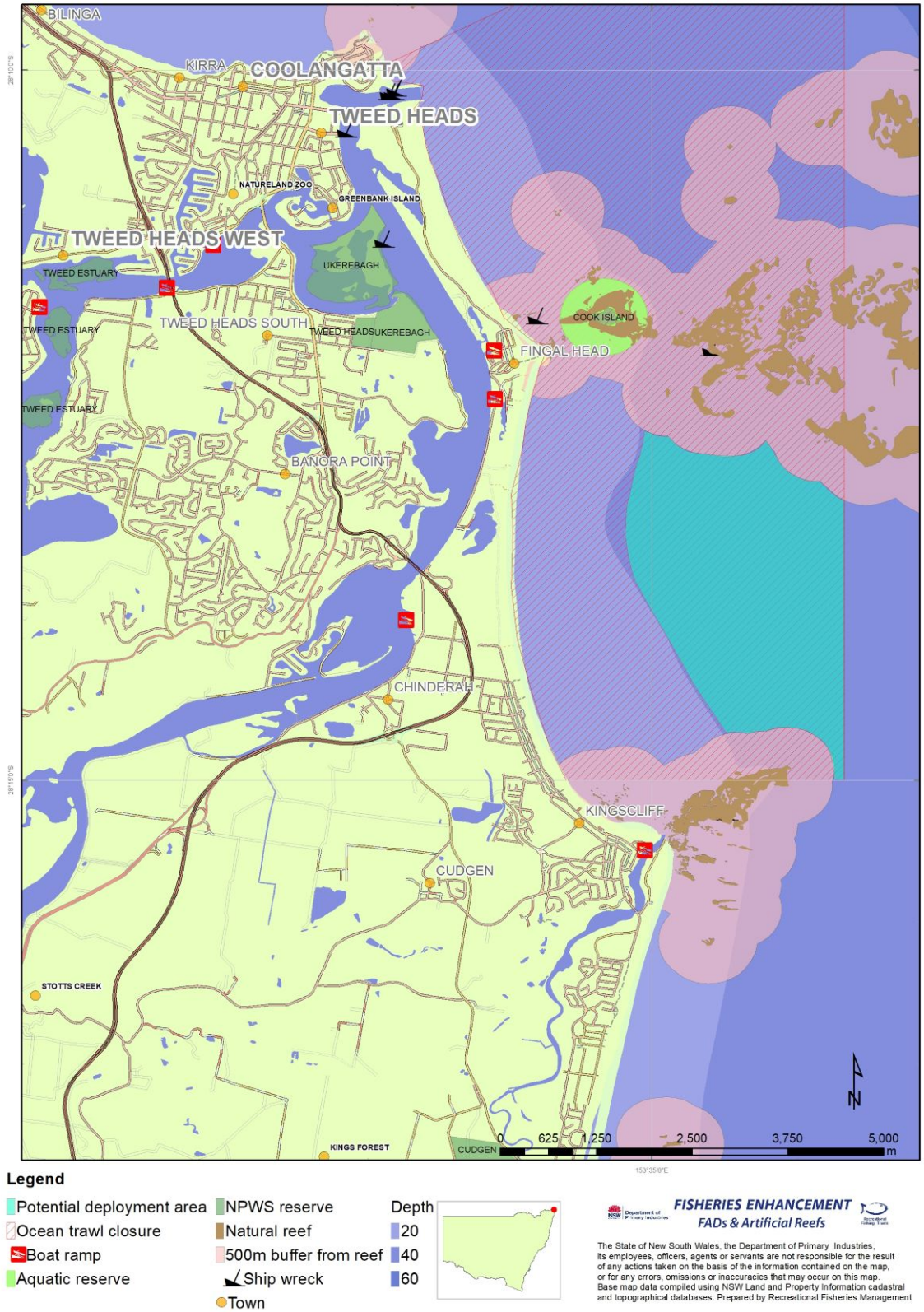


Figure 28 Potential deployment area identified through constraints analysis

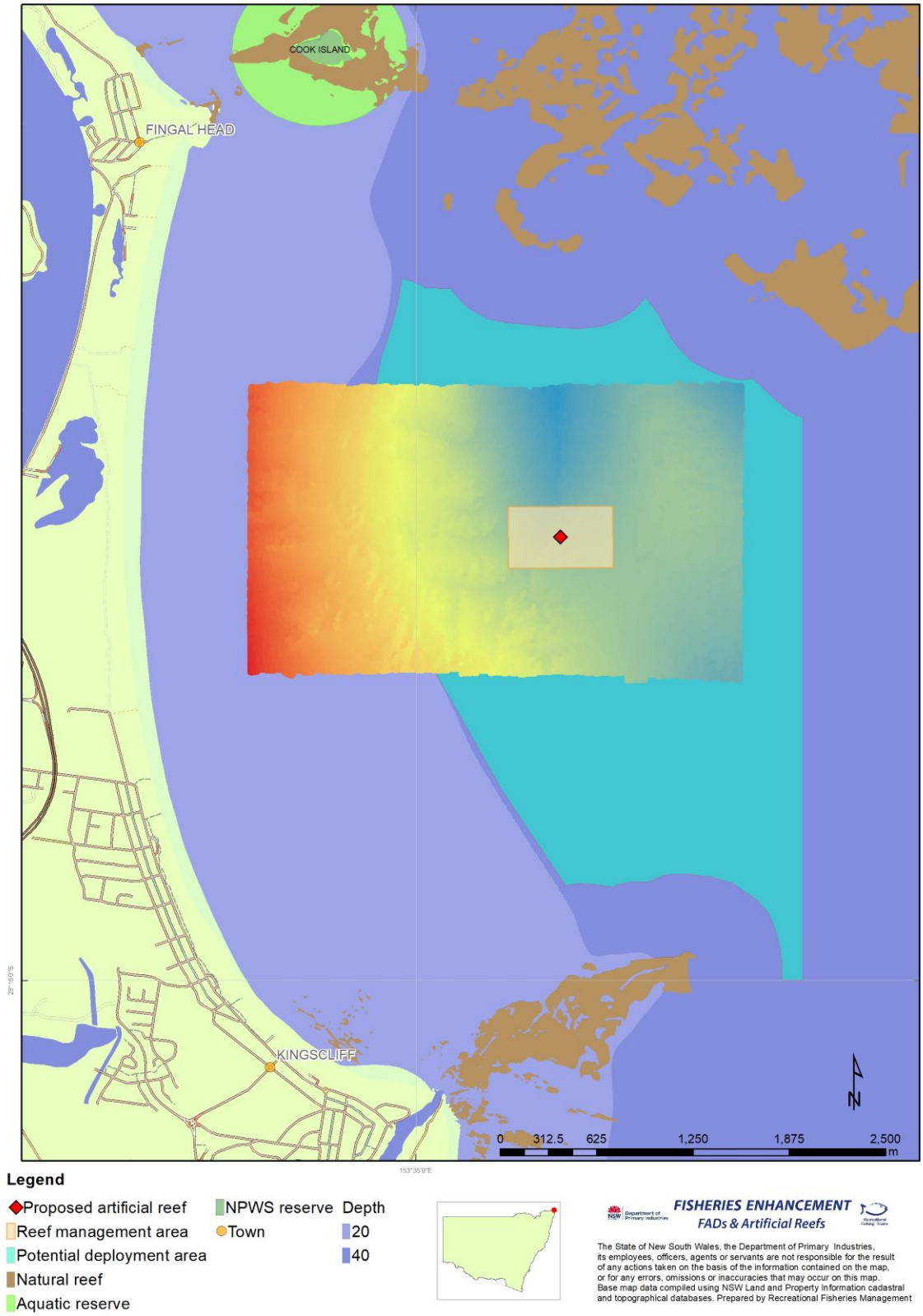


Figure 29 Proposed deployment site identified through constraints analysis including reef management area boundaries

6 Scope, duration and timeframes for monitoring

This section describes research and monitoring aspects related to the Tweed Heads offshore artificial reef that are designed to provide information that will lead to continuous improvements in the way the reef is managed, and future reefs deployed. Development of a monitoring strategy to meet objectives relating to interactions with threatened and protected species and quantifying the impact of the reef system with the broader ecological community requires a time frame that is consistent with the rate of recruitment to the artificial reef system and the ecological factors which drive this process.

Previous work associated with both estuarine and offshore reef systems has indicated that the fish communities remain dynamic over the first 2-3-year period post deployment. A three-year monitoring program will provide an adequate time frame to understand longer term trends in the nature of the fish assemblages associated with artificial reef systems (including interactions with threatened and protected species), physical forces acting on the structural integrity and stability of the reef, while providing insight into the level of variation between seasons and years.

The duration of the initial detailed monitoring at quarterly intervals for 3 years was considered sufficient based on the results of past and existing artificial reef research projects undertaken by the DPI. In addition, this was the time period previously stipulated by the Department of the Environment when approval was granted for the Sydney (SD2008/882), Shoalhaven (SD2014/2842), Port Macquarie (SD2015/3142), Southern Sydney (SD2017/3482), Newcastle (SD SD2008/882) and Wollongong (SD SD2008/882) offshore artificial reef projects.

6.1 Monitoring objectives

The monitoring objectives outlined in this LTMP address the existing requirements of the Environment Protection (Sea Dumping) Act 1981 and those identified in the EA for the Tweed Heads offshore artificial reef. This monitoring plan also incorporates monitoring and mitigation measures, which DPI has established in Long Term Management Plans (LTMP) from the seven previously deployed artificial reefs in the State's waters. In compliance with recommendations outlined in the EA and this document, DPI is committed to carry out the monitoring objectives listed in Table 23.

Table 23 Monitoring objectives , methodology and timeframes

Monitoring objective	Short description of monitoring description and expected outcome	Timeframes
• Measure fish assemblages, the colonisation of the reef &	BRUVs and unbaited ROV cameras will be deployed on the reef a minimum of 4 times a year. This would allow the monitoring of fish and benthic assemblages and the documentation of the development of the fish and benthic	Quarterly every 12 months for 3 consecutive

Monitoring objective	Short description of monitoring description and expected outcome	Timeframes
community development • Assess reef performance and popularity with recreational fishing groups	communities. The results of the survey would be included in DPI databases where relevant. A VR2AR acoustic listening station would be placed on the Tweed reef which would allow for the monitoring of fish assemblages and pelagic species which have acoustic tags. Assessment of the artificial reef performance and public response, including catch rates associated with recreational anglers will include reviewing charter operator log book data, feedback from local fishing clubs and trends in data collected from DPI's Integrated Monitoring Program (IMP) on fishing effort and demographics of recreational fishers.	years and then will be reviewed
• Assess and investigate movements and occurrence of threatened/protected & migratory species within the reef management area	The acoustic listening station (VR2AR) placed on the Tweed Heads reef would allow for the monitoring of fish assemblages, threatened species, and pelagic species with acoustic tags. Data collected would again be incorporated into DPI databases where relevant and is likely to provide information regarding the interaction with natural reefs and the potential risks associated with draw down effects. Data collected by remote video (e.g. BRUVs, ROV & UV) will be used to supplement this data set and inspect for fouled gear to prevent the risk of injury or entanglement. Any threatened species information will be incorporated in to the DPI Threatened Species Unit's database and updated every 6 months. Education and mechanisms to report sightings or interactions will be available to reef users in the "User guidelines" covering boat strike, incidental capture & acoustic disturbance will be available to users for best practice.	During the installation phase and then on a biannual basis. For 3 consecutive years before being reviewed.
• Reef structural integrity & stability • Accumulation of marine debris • Measure for invasive species	ROV camera surveys would be conducted by staff a minimum of 4 times a year; these surveys will allow a visual inspection of the reef to document reef stability and structural integrity, corrosion, investigate seabed/sediment characteristics including any scouring or deposition, monitor any obstructions or change to clearance height. The results of the survey would be included in DPI databases where relevant and compared to design documentation and previous studies to determine any change. Data collected by remote video (e.g. BRUVs, ROV & UV) will be used to supplement this data set. These surveys would also; • Monitor the level of gear or debris hook up; if there is a build-up of marine debris on the reef structures which poses an entanglement hazard, DPI will contract commercial divers to remove the debris. User guidelines will specify anchoring is not recommended within the reef management area to encourage best practice for users. • Monitor for the colonisation of marine pests, and make sure data including images or video are available for	•quarterly every 12 months for 3 consecutive years post installation, annually thereafter. • following large storm events which produce a significant wave height ≥ 4.1 m

Monitoring objective	Short description of monitoring description and expected outcome	Timeframes
	interpretation by subject matter experts (i.e. Biosecurity NSW)	
Assess Fibre reinforcement exposure or release	Professional subsea inspection of a randomised representative sample of concrete modules to detect any exposure or release of fibres to the marine environment. Refer to figure 32 for a decision-making process guideline for inspections that have detected fibres exposed to the marine environment. A report will be generated from each 5 yearly inspection and be submitted to DAWE <72 hrs for detections of exposed fibre or <30 days if no fibres are detected.	5 Yearly
Review user guidelines	User guidelines, DPI engagement with fishing clubs, social media & DPI webpages to promote best practice catch & release and provide user groups with informed sizes and bag limits. User guidelines to promote best practice, personal responsibility and safety within the management area. NSW DPI does not recommend SCUBA diving on the reef.	

BRUV = baited remote underwater video, ROV = remotely operated vehicle and underwater video (UV)

Figure 30 Vemco VR4 with a 10 year battery life and remote download capabilities fitted to the Sydney offshore artificial reef

6.2 Monitoring timeframes

Environmental monitoring programs outline procedures to monitor potential changes in significant components of the marine environment and assess the structural integrity of the reef infrastructure, marine fauna interactions and environmental impacts (Table 23). The preliminary 3 year timeframe was selected based on the results from the previous NSW offshore artificial reef surveys. Development of a monitoring strategy to meet objectives relating to interaction with threatened and protected species and quantifying the impact of the reef system with the broader ecological community requires a time frame that is consistent with the rate of recruitment to the artificial reef system and the ecological factors which drive this process. Previous work associated with both estuarine and offshore reef systems has indicated that the fish communities remain dynamic over the first 2-3 year period post deployment. A three year monitoring program will provide an adequate time frame to understand longer term trends in the nature of the fish assemblage associated with artificial reef systems (including interactions with threatened and protected species), physical forces acting on the structural integrity and stability of the reef while providing insight into the level of variation between seasons and years. It is proposed to review monitoring timeframes 3 years post reef installation based on these results from monitoring conducted.

6.2.1 **Structural integrity and stability monitoring**

The structural integrity and stability monitoring will be used to undertake inspections of the reef infrastructure. Evidence of faults, damage, and excessive debris build-up will be the focus of the inspections which will be followed by appropriate maintenance. Inspections will be particularly important after a large storm event which produce waves in excess of 4.1 m (Hs), and the cleaning of infrastructure in order to minimise marine fauna entanglements. Routine visual inspections will be undertaken quarterly every 12 months for 3 years (then reviewed) with a minimum inspection period of every 5 years for the remainder of the reef design life or following severe storm events which produce a significant wave height ≥ 4.1 m.

Additional monitoring for the exposure or release of reinforcement fibres from the concrete structures will be conducted on a 5-yearly cycle. The inspections will be conducted by an appropriately qualified and experienced commercial diving company. The inspections will be conducted on a randomised sample of the reef modules which is statistically representative of the reef. Modules selected for sampling will be subject to a full video inspection with diver commentary describing the condition of the module as well as small areas scraped clean to inspect the concrete surface and report on condition of the product as well as any detection of exposed or released fibres.

If hand scraping using basic hand tools is precluded by growth of marine organisms to expose the concrete surface, a thorough camera inspection with diver commentary will replace the scraping method.

In the highly unlikely event that a module is physically damaged (for example vessel strike) the decision-making process in figure 32 will be followed to ensure the most appropriate outcome for the environment and management of future structural integrity of the module(s) impacted.

The inspection checklist includes:

- Date and type of observation conducted (diver vs. camera);
- Location and description of faults identified including: significant scouring or sedimentation; module damage including cracks, splits, breakages or exposure of reinforcement fibres and the location (GPS coordinates) of the module;
- A list of proposed actions to be undertaken (if any).

The structural integrity and stability monitoring will assess the effectiveness and suitability of the module design, such as whether it adequately withstands the sea conditions offshore of the Tweed Heads coastline as designed.

An intense East Coast low hit the NSW coast between April 20-23 2015 which produced gale force winds (>45 knots) and huge seas, with the most extreme effects felt along the Hunter-Sydney coast with strong winds, flooding rains and massive seas. The largest wave recorded at 3 pm on 21 April was 15 m, approximately the height of a 5 story building. The waves also exceeded 6 m for 30 hours, the longest duration of such high waves since 1987. Post storm inspections of both the Sydney and Shoalhaven artificial reefs were carried out in May 2015 in line with inspection conditions of respective sea dumping permits (SD2008/882 & SD2014/2842). DPI used surface deployed cameras to undertake the inspections. No damage was identified to either the single large Sydney reef unit or any of the 20 multiple modules which form the Shoalhaven reef. In addition, no significant scour or deposition was identified in the vicinity of either reef [45].

Figure 31 Inspections of the Sydney (upper image - 7 May 2015) and Shoalhaven (lower image - 18 May 2015) OARs following an intense east coast low that produced waves up to 15 m (Hmax)

6.3 Performance monitoring and review

6.3.1 Performance indicators

Performance indicators provide the most appropriate indication of whether the offshore artificial reef is meeting its objectives. A number of monitoring programs and existing DPI programs are to be used in conjunction with each other to gather information to measure performance indicators.

With the implementation of the new research, advisory and information management programs for the reef, a broader information base relating to the activity and its impacts will enable more precise performance indicators to be developed over time if required.

6.3.2 External drivers

External drivers are factors that are known to potentially impact on the performance of the reef but which are outside of the control of DPI (e.g. environmental conditions, social changes etc.). Any external influences that may contribute to a trigger being breached will be identified during monitoring of the reef and, if necessary, referred to any relevant managing agency for action. A number of external influences may contribute to trigger points being

reached. For example, the NSW Office of Environment and Heritage (OEH) administer interactions with marine mammals under the *NSW National Parks and Wildlife Regulation (2009)* and the *NSW National Parks and Wildlife Amendment (Marine Mammals) Regulation 2006*, introduced to protect marine mammals such as whales and dolphins while allowing people to appreciate them in the wild. These existing regulations specify the distances of approach and interaction with marine mammals. If interactions between reef users and cetaceans, pinnipeds, etc. were found to increase significantly post installation of the reef, then in addition to the DPI TSU being notified of these interactions, the NSW OEH would also be independently briefed. Management actions would require a combined approach from both the DPI and OEH to ensure a consistent method to address the issue. A passive approach such as increased education and an awareness campaign coordinated between the two agencies may suffice. However, if impacts continue to escalate, increased monitoring and compliance patrols combined with temporal exclusions zones may require consideration.

Build-up of marine debris identified during the monitoring of the reef to be as a result of purposeful dumping of material on or adjacent to the reef site is another external influence. If increased marine debris is entering the marine environment in the vicinity of the proposed artificial reef which is of a deliberate nature (i.e. intentional dumping of waste from vessels) then the NSW Roads and Maritime Service (RMS) would be notified and action taken under the *Marine Pollution Regulation 2006*. As current Fisheries Management Regulations do not manage this activity, an appropriate management response would be for DPI to administer a combined on-water operations with the RMS Boating Service Officers (BSOs) to target offenders and enforce these regulations.

6.3.3 **Trigger points**

Trigger points specify when a performance indicator has reached a level that suggests there is a problem with the activity and a review is required. Table 24 establishes the performance indicators and trigger points that will be used to measure effect of mitigation measures. No numbers for interactions with threatened species have been defined; instead a threshold for 'of concern' will be implemented. The reasoning behind this is that the types of threatened species and degree to which they are threatened is highly variable in regard to the operation of the reef. This has been determined in consultation with the DPI TSU.

By not defining a set point/number at which management measures would be imposed upon the operation of the reef, it allows the TSU to assess not only numbers of interactions with threatened species on the reef, but other aspects of threatened species management which may be relevant such as:

- the level of the threat that is or has occurred;
- the type of interaction;
- the frequency of the interactions;
- the season that the interaction is occurring (breeding/calving);
- any potential change in the threatened status;
- how much harm as a result of the interaction was occurring;
- sightings vs. hookings/entanglements; and
- if the species is recovering and numbers are increasing.

Without imposing numbers/thresholds on the interactions with threatened species the LTMP is more fluid and is more in line with current impact assessment that is being undertaken. Numbers are not used when assessing the level of impact on matters of National Environmental Significance but rather the process relies on professional judgement.

The 6-month reporting schedule and involvement of the DPI TSU (which is independent of DPI Recreational Fisheries Management) allows for an independent judgement of these levels of interaction. Also any significant interaction such as mortality would immediately be reported to the TSU.

If the level of interaction was to become 'of concern', potential management measures which could be imposed upon the reefs may include gear restrictions, closed seasons, fishing times, a restricted fishery and restrictions on the type of fishing. DPI as an agency would need to come up with an appropriate management response in relation to the interaction. Again, as the threshold is not quantifiable due to so many variables, it is important to deal with the interactions appropriately as they arise based on professional judgement.

Harm from Marine Debris: The proposal is likely to result in the concentration of, and increase in, recreational fishing activity in the direct reef area. This potentially increases the risk of lost fishing gear and harmful marine debris entering the marine environment in the vicinity of the proposed recreational fishing reefs. Threatened marine species, particularly marine turtles, pinnipeds, small cetaceans and seabirds, can ingest or become entangled in marine debris, such as plastics. Potential harm to marine animals from build-up of marine debris such as lost fishing tackle, anchor lines and other pollution is being monitored quarterly each year over the first 3 years post reef installation.

A commitment has been made by DPI that periodic inspection of marine debris will be maintained on the reef for its design life. The ongoing regularity of inspections will be based on a needs basis following a review of the scheduled quarterly monitoring over each of first 3 years. Annual debris removal has been scheduled over 3 years (i.e. the first debris removal will be conducted within 12 months of the reef being installed and annually thereafter for a period of up to 3 years, if required). This is deemed to be an appropriate management response and mitigative measure based on the unknown level of build-up. If an obvious entanglement hazard is identified outside scheduled maintenance and debris removal (including but not limited to free floating rope (discarded anchor lines), removal by contracted commercial divers will be facilitated as soon as practical.

In order to further reduce the impact of this KTP, education using the reef user guidelines and existing DPI education programs would be provided on the potential impacts of harmful marine debris on marine life and the responsible disposal of litter and discarded fishing gear.

Invasive Marine Pests: The proposed reef structures could provide a substratum or habitat suitable for invasive marine pests (also referred to as 'introduced', 'alien' or 'non-indigenous' species). Although there is evidence that many exotic species establish populations more easily on artificial structures, the risk of increased potential for disease associated with biota at the artificial reefs is considered to be extremely small due to their isolation in the open ocean rather than in estuarine environments. Similarly, the risk to threatened species from invasive marine pests associated with the reef is considered very small.

Invasive marine pest species including the Japanese and yellowfin gobies and New Zealand screw shell are generally associated with soft or unconsolidated sediments in bays and

estuaries and would be unlikely to occur offshore. Therefore they are unlikely to be of concern, primarily due to the location of the proposed Tweed offshore artificial reef. CSIRO modelling of the potential range of NZ screwshell (based on temperature tolerance) indicates it is very unlikely to survive in northern NSW.

Whilst the proposed reef site is potentially at risk from colonisation by invasive marine pests, the scale of the potential impact is small and would be unlikely to have any significant impact on the marine environment. Depending on the species identified a variety of management responses may be required. In the first instance, reef user groups would be informed of boating guidelines to minimise the spread of marine pests and a revised monitoring plan would need to be implemented in order to better document the extent of the incursion. Requirements for removal of marine pests (according to National Introduced Marine Pest Information System - NIMPIS) would depend on the extent and nature of the incursion but is likely to involve manual removal by divers in the first instance. This would be facilitated by the DPI upon advice from the DPI Biosecurity Unit.

Table 24. Trigger points

Incidental capture of threatened species		
Risk description	Trigger point	Justification/comments
Incidental capture from recreational fishing gear could potentially affect threatened fish, pinnipeds and seabirds that forage in the surface waters	Increases of incidental capture of threatened species or key non threatened species within reef area increases by an amount deemed 'of concern' by the DPI Threatened Species Unit (TSU) following reporting of the incident as specified in the project reporting section.	Increased incidences of capture of threatened species or key non threatened species within the reef area may indicate a change in species interactions or species interactions with the reef. This may require a modification to the management of the reef.
Data required	Availability/monitoring programs	
Incidences of threatened species capture within the reef area	Information on threatened species or key non threatened species is available from DPI and other government agencies (e.g. OEH) and through the Bionet database as well as through the ROV and BRUV surveys and through the angler advisory campaigns. This information would be sent to the DPI TSU every six months for review.	

Aggregation of threatened or protected species		
Risk description	Trigger point	Justification/comments
Aggregation of threatened or protected species	Aggregation of threatened species or key non threatened species within reef area increases by an amount deemed 'of concern' by the DPI TSU.	Increased aggregations of threatened species or key non threatened species within the reef area may indicate a change in species interactions. This may require a modification to the management of the reef.
Data required	Availability/monitoring programs	
Information on the residency of threatened and protected species within the reef area.	Information on threatened species or key non threatened species is available from DPI and other government agencies (e.g. OEH) and through the Bionet database as well as through the ROV and BRUV surveys, acoustic telemetry and through the angler advisory campaigns. This information would be sent to the DPI TSU every six months for review.	

Alteration/interruption of movement corridors		
Risk Description	Trigger point	Justification/comments
Cetaceans and some species of fish, such as the Greynurse Shark, that undertake migrations along the NSW coastline, could alter their migratory behaviour in response to the presence of the offshore artificial reefs.	Movement corridors of threatened species or key non threatened species within reef area alters by an amount deemed 'of concern' by the DPI TSU or other relevant government agency.	Changes in movement patterns and corridors of threatened species or key non threatened species within the reef area may indicate a change in species interactions and behavioural patterns. This may require a modification to the management of the reef.
Data required	Availability/monitoring programs	
Information on the migration routes and patterns of threatened and protected species within the reef area.	Information on threatened species or key non threatened species is available from DPI and other government agencies (e.g. OEH) and through the Bionet database as well as through the ROV and BRUV surveys, acoustic telemetry and through the angler advisory campaigns. This information would be sent to the DPI TSU every six months for review.	

Harm from marine debris and pollution (KTPs) / Gear hook up		
Risk Description	Trigger point	Justification/comments
Increased risk of lost fishing gear and harmful marine debris entering the marine environment in the vicinity of the proposed offshore artificial reefs.	Debris build up on the reef by an amount that the DPI Recreational Fisheries Unit believes is 'of concern'	Ongoing build-up of marine debris on the reef may require a modification to the management of the reef.
Data required	Availability/monitoring programs	
ROV inspection of the reef to assess the debris build up.	Annual reef monitoring and observance program and other DPI research projects/programs operating within the reef area.	

Invasive Marine Pests		
Risk Description	Trigger point	Justification/comments
The proposed reef structures could provide a substratum or habitat suitable for invasive marine pests (also referred to as' introduced', 'alien' or 'non-indigenous' species).	An incidence of a novel disease or pest within the reef area	Pests and diseases can pose significant risks to the environment. This indicator ensures that the reef and its management are appropriately responding to pest and disease issues. There are potential external drivers in this trigger point such as the introduction of pests and diseases through other aquatic or land based activities
Data required	Availability/monitoring programs	
Ongoing monitoring of the reef area, pests and records	Disease and pest notification procedures (in line with DAFF) and DPI Biosecurity	

of responses to pest or disease incursions

7 Environmental management

The following provides an overview of the proposed environmental management developed to provide guidelines for the operation of the offshore artificial reef.

7.1 Environmental reporting

Environmental reporting requirements for the Tweed offshore artificial reef will include the following:

- Colonisation and community development;
- Inspections of reef infrastructure , structural integrity and stability (conducted annually);
- Fibre reinforcement exposure inspections of concrete structures will be conducted at 5 yearly intervals. Any detections will be reported to DAWE within 72 hours, inspections clear of exposed fibres will be reported to DAWE within 30 days;
- Observations of marine fauna interactions (from the Marine Fauna Interaction Register);
- Threatened species interactions

Checklists will be maintained by DPI for environmental inspections and environmental audits.

7.1.1 Logs and registers

A number of registers will be maintained by DPI as part of the operation of the reef. A summary of the matters within the registers will be included in environmental management reports. The registers will include but are not limited to the following:

Complaints register

A complaints register will be maintained by DPI. The register will list information such as the following for each complaint:

- Date;
- Person/s receiving the complaint;
- Name, address and contact phone number of person/s making the complaint;
- Specific details of the nature of the complaint; and
- Action undertaken in response to the complaint.

Marine fauna interaction register

The marine fauna interaction register will list information such as the following:

- Date;
- Time;
- Fauna species (if known);

- Number of individuals;
- Approximate size;
- Nature of interaction;
- Description of displayed behaviour;
- Management issue; and
- Management actions.

7.1.2 Offshore artificial reef user education and awareness guidelines

Offshore artificial reef user education and awareness guidelines have been produced to form the basis of the offshore artificial reefs advisory/education. The guidelines provide information important for user groups to ensure minimal environmental impact and promote safety within the reef management area.

These guidelines are available via the DPI website and in print as required for distribution to relevant recreational fishing associations and clubs.

7.1.3 Inspection timing

Twelve scheduled inspections will be conducted over the first 3 years post reef installation to document the accumulation of any fishing or non-fishing related marine debris. The first inspection will be conducted within 3 months of the reefs installation being completed and the first debris removal will be conducted within 12 months of the reef being installed if required and annually thereafter for a period of up to 3 years.

At the conclusion of this initial 3 year assessment period, the results will be used to identify a suitable level of assessment required to identify and respond to marine debris accumulation. For example if debris build-up remains consistent over the first 3 years, annual removal and inspections may be required to be maintained. However, if limited debris is recorded with a trend towards a reduction in debris, inspections may be further reduced and align with structural integrity monitoring every to 5 years for the remaining design life of the reef (up to 50 years).

7.1.4 Inspection

A combination of remotely operated vehicle (ROV) and Baited Underwater Video (BRUV) will be used to provide an ongoing debris log. This log will be maintained by DPI and will include the following detail:

- date
- type of material identified (e.g. fishing line (mono or braid), anchor line, trap or net);
- approximate amount seen (length and diameter of lines) and distance the material extends (i) vertically; and, (ii) laterally from the reef;
- location of the debris (including GPS coordinates (where possible) and reef patch group);
- proposed removal methods (diver, barge/winch, other);
- threat presented by the debris.

7.1.5 Debris removal triggers

If the build-up of marine debris on the reef structures is identified to pose an entanglement hazard or if 'free floating' lines (i.e. tethered to the reef which extend into the upper water column above the structures) are identified this removal strategy will be implemented. Although commercial fishing is not expected to be undertaken on the reef, in the event of a net or fish trap being identified on the reef a team will immediately be mobilised to assess and remove the objects(s) in question.

7.1.6 **Debris removal**

If the amount of material identified can be safely removed by divers using a single knife only, a DPI commercial dive team (2815.1 qualified in accordance with minimum standards set by AS/NZ2299.1 Commercial Diving Standard) may be used to remove the hazard (note: special permission from the DPI – Fisheries NSW Occupational Diving Officer will be required).

If the hazard poses an entanglement or entrapment hazard to divers, DPI will contract an external commercial diving contractor with surface-supply capacity (as per AS/NZ2299.1) to complete the removal.

If the hazard cannot be safely retrieved by divers (e.g. commercial trawl net or large commercial fish trap), suitably experienced and qualified salvage contractors are to be sought by DPI to provide salvage advice.

Significant entanglement hazards which pose an immediate threat to marine mammals are to be reported to the NSW Office of Environment and Heritage (OEH) under the *NSW National Parks and Wildlife Regulation (2009).*

7.2 Contingency measures

In addition to the circumstances outlined above, the Deputy Director General DPI Fisheries NSW may order a review and/or make a modification to the Tweed offshore artificial reef in circumstances declared by the Minister as requiring contingency action, or upon the recommendation of DPI staff.

These circumstances may include (but are not limited to) food safety events, environmental events, and results of research programs or unpredictable changes on or around the reef over time. Notwithstanding the above, the Deputy Director General DPI Fisheries NSW may also make amendments to the operation of the Tweed offshore artificial reef that the Deputy Director General DPI Fisheries NSW considers to be minor in nature at any time.

7.3 Emergency contacts and response

If at any time during the deployment or operation of the reef an environmental risk/incident occurs, the DPI will immediately implement measures to mitigate the risk or the impact. The situation will be reported in writing within 24 hours to Department of the Environment and Energy (and any other relevant Government Agency or Authority), with a full report detailing:

i) the environmental incident that occurred and/or 'non-compliance' detected;

ii) the mitigation measures taken, and;

iii) The success of these measures in addressing the environmental incident that occurred and/or 'non-compliance' detected and any additional measures that are proposed to be taken.

Emergency contacts:

1) DPI Senior Fisheries Management Officer (Fisheries Enhancement)

Ph: (02) 4476 0822 (office hrs), 1300 550 474 (24hrs)

Email: fisheries.enhancement@dpi.nsw.gov.au

Other relevant emergency contacts include:

i) ORRCA Whale and Dolphin Rescue – Ph: (02) 9415 3333

ii) Fisheries Watch - for reporting illegal fishing – Ph: 1800 043 536

iii) For ALL other emergencies (NSW Police, Maritime, Fire, Ambulance) – Ph: 000

7.4 Decommissioning

The nominal operational lifespan of the Tweed artificial reef is estimated to be 50 years. It is likely, however, that the structures would remain operational for longer than this. Whether the units are removed intact or dismantled would depend on the outcome of structural inspections prior to removal.

Bonding strength of the fibres to the concrete is excellent and therefore any fibres exposed but still bound within the concrete could be removed without risk of the remainder of the fibre coming free of the module [26]. As such any physical damage would be considered qualitative and quantitative during inspections. If exposed fibres are found but can be contained without future risk to the environment or structural integrity of the module, remediation measures would be implemented and recorded during the inspection dive for reporting and follow up inspection comparison.

The following decision-making process has been prepared to provide guidance in the event that exposed reinforcement fibres are detected during an inspection and ensures positive outcomes for both the environment and future structural integrity of reef modules.

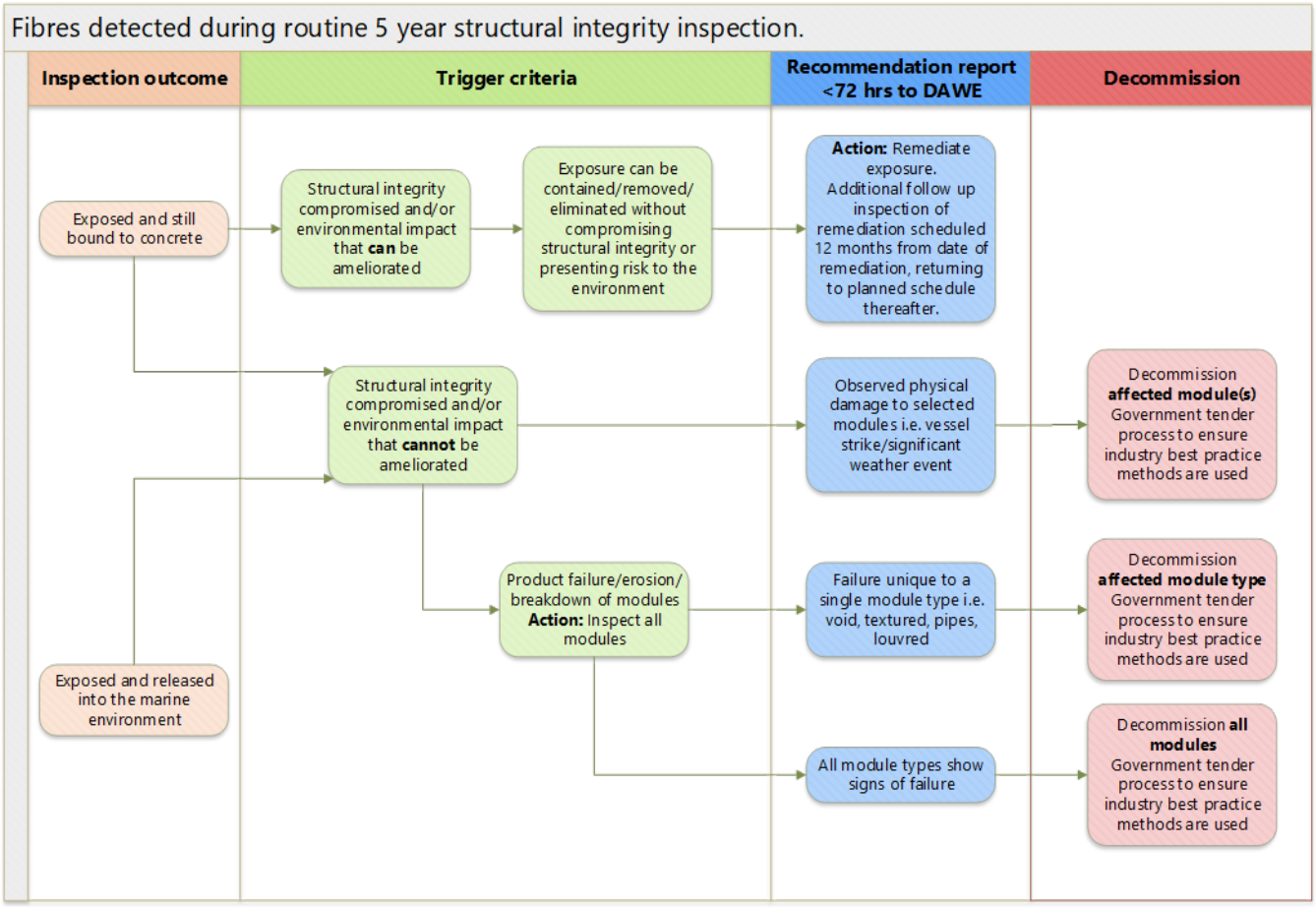


Figure 32 Decision making process for exposed fibres

These options would provide a contingency for decommissioning at any stage during the operational life of the reef if required. It is likely that the main impact of removing the structures would be a significant loss of attached flora and fauna and a loss of fish habitat, however, the overall environmental impact would depend on which option for decommissioning was considered most appropriate and the length of time the units had been in place. Removal of the units would therefore be subject to a separate environmental assessment prior to removal. Noting that decommissioning could occur at any stage within the life of the 50-year permit, a government tender process would be undertaken to ensure the most contemporary and best practice methods are employed to safeguard the environment.

7.5 Project reporting

Updates on the Tweed offshore artificial reef will be placed on the DPI offshore artificial reefs webpage (www.fisheries.nsw.gov.au), via social media (e.g. Facebook) and will be reported as required to other statutory agencies and departments.

Within 10 working days from completion of the reef installation, the DPI will provide a report that:

- details the date and time of the placement of the southern Tweed artificial reef;

- confirmation of the placement site boundaries to two decimal places of a minute (WGS84);
- the estimated maximum depth over the Tweed reef units (LAT), and the date and time of the observation; and confirmed that the highest point of the reef is no less than 20 m below sea level (LAT);
- details of inspections and any items removed or hazards rectified;
- proof of written notification to the Australian Hydrographic Office and NSW Maritime.

A report can be provided to relevant consenting authority(s) as requested addressing, but not limited to the following:

- identify the standards and performance measures of the project;
- describe all works carried out over the previous 12 months;
- a summary of complaints and a comparison to previous years;
- records of maintenance checks and activities;
- a summary of post deployment monitoring activities and preliminary results;
- 'non-compliance' and/or environmental incidents recorded or responded to in the previous year; including those that specifically involved threatened and/or migratory species (including sightings and/or incidental captures;

7.6 Long term management plan review

Review of this plan will be conducted as required from the date of approval and is the responsibility of the DPI Recreational Fisheries Management team. Issues relating to the operation and implementation of the plan will be collated by the DPI Senior Fisheries Manager (Fisheries Enhancement) for review and reporting and approval.

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