Artificial Reefs in Australia

A GUIDE TO DEVELOPING AQUATIC HABITAT ENHANCEMENT STRUCTURES

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Artificial Reefs in Australia: A Guide to Developing Aquatic Habitat Enhancement Structures

This project was undertaken with the support of partners including the Fisheries Research and Development Corporation, Western Australian Department of Fisheries, Murdoch University and Ecotone Consulting.

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Disclaimer: The authors of this report advise that it is to be used as a basic guide in the initial stages of Habitat Enhancement Structure planning only. It's not guaranteed that information in the guide is free from errors and omissions. The nature of Habitat Enhancement Structure development elicits that policies, designs and techniques will change with time. Those acting upon information in this report do so entirely at their own risk and the authors accept no responsibility or liability from for any error, loss or other consequence which may arise from relying on any information in this publication.

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Introduction

Habitat Enhancement Structures (HES) are purpose built constructions placed in the aquatic environment (oceanic, estuarine, river or lake) for the purpose of creating, restoring or enhancing habitat for fish, fishing and recreational activities generally. HES involve the use of a range of objects and materials to create new habitat and provide ecological services in an aquatic environment. They include artificial reefs, Fish Aggregation Devices (FADs) and materials of opportunity.

HES have been created in at least 50 countries around the world for many varying purposes including snorkelling, SCUBA, surfing, energy production, eco-tourism, erosion mitigation, aquaculture, research, infrastructure and conservation. However, in the majority of cases HES are used for commercial, recreational and artisanal fisheries enhancement.

An artificial reef is any man-made or altered material placed into an aquatic environment to mimic certain characteristics of a natural reef. Artificial reefs are often used to create new fishing and diving opportunities, and to shift pressure from other popular locations. To date, at least 150 artificial reefs have been deployed in Australian waters and they are one of the most common types of aquatic infrastructure deployed for fisheries enhancement.

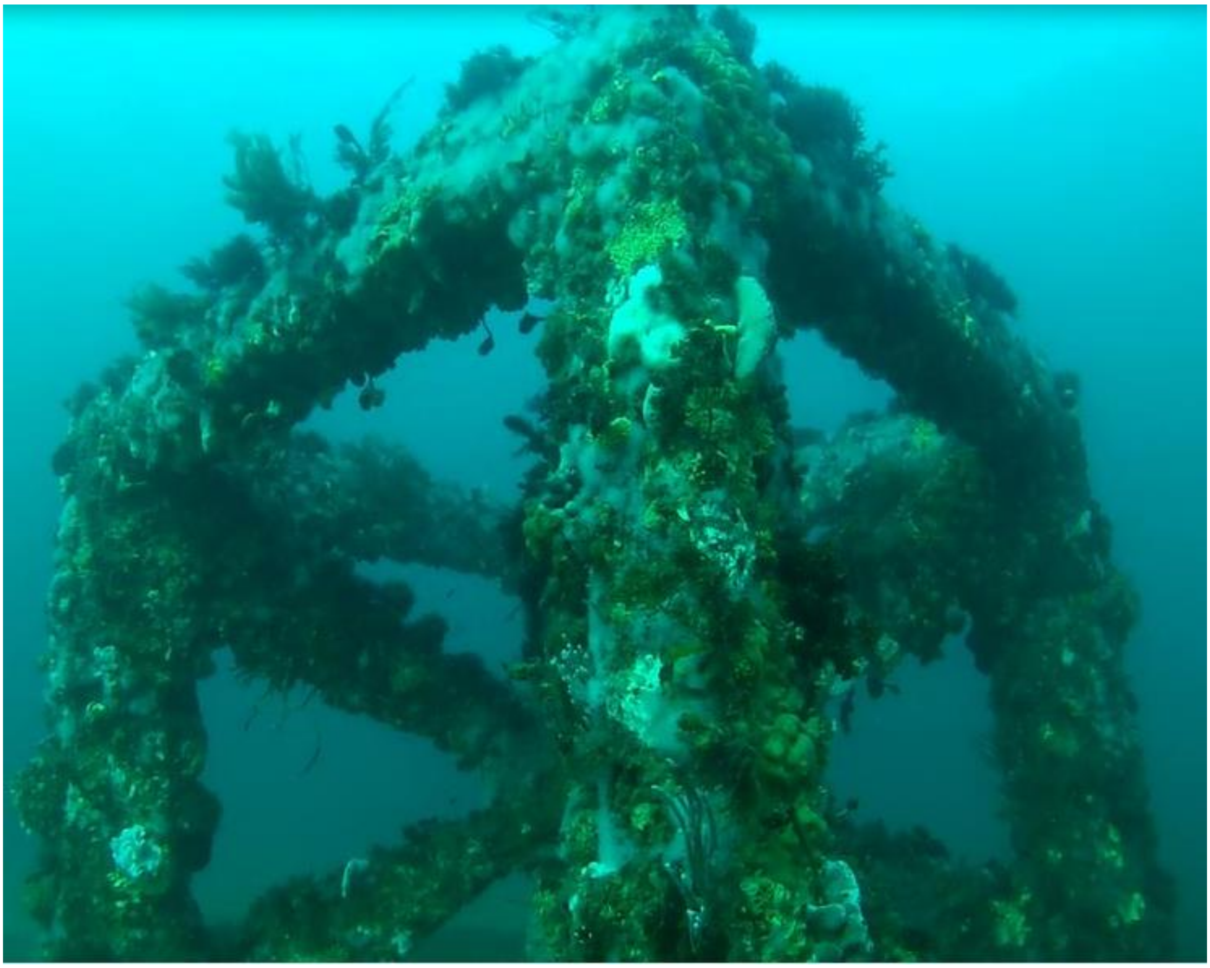


Figure 1: A previously bare surfaced concrete module from the South West Artificial Reef Trial in WA.

The purpose of this guide is to assist organisations to develop HES around Australia by detailing the major steps and considerations that are needed to deliver a purpose-built HES, particularly artificial reefs. The guide does this by containing a background and considerations for HES as well as describing the process from start to finish for HES development.

While HES also includes materials of opportunity, FADs, Large Woody Debris, restoration and translocation (of corals and seagrass), this document will mainly focus on purpose-built artificial reefs, as these are more commonly utilised around Australia, are environmentally friendly and have demonstrated clear ecological, social and economic benefits to communities world-wide through fisheries enhancement. The guide will also only consider HES deployed for the purpose of fisheries enhancement.

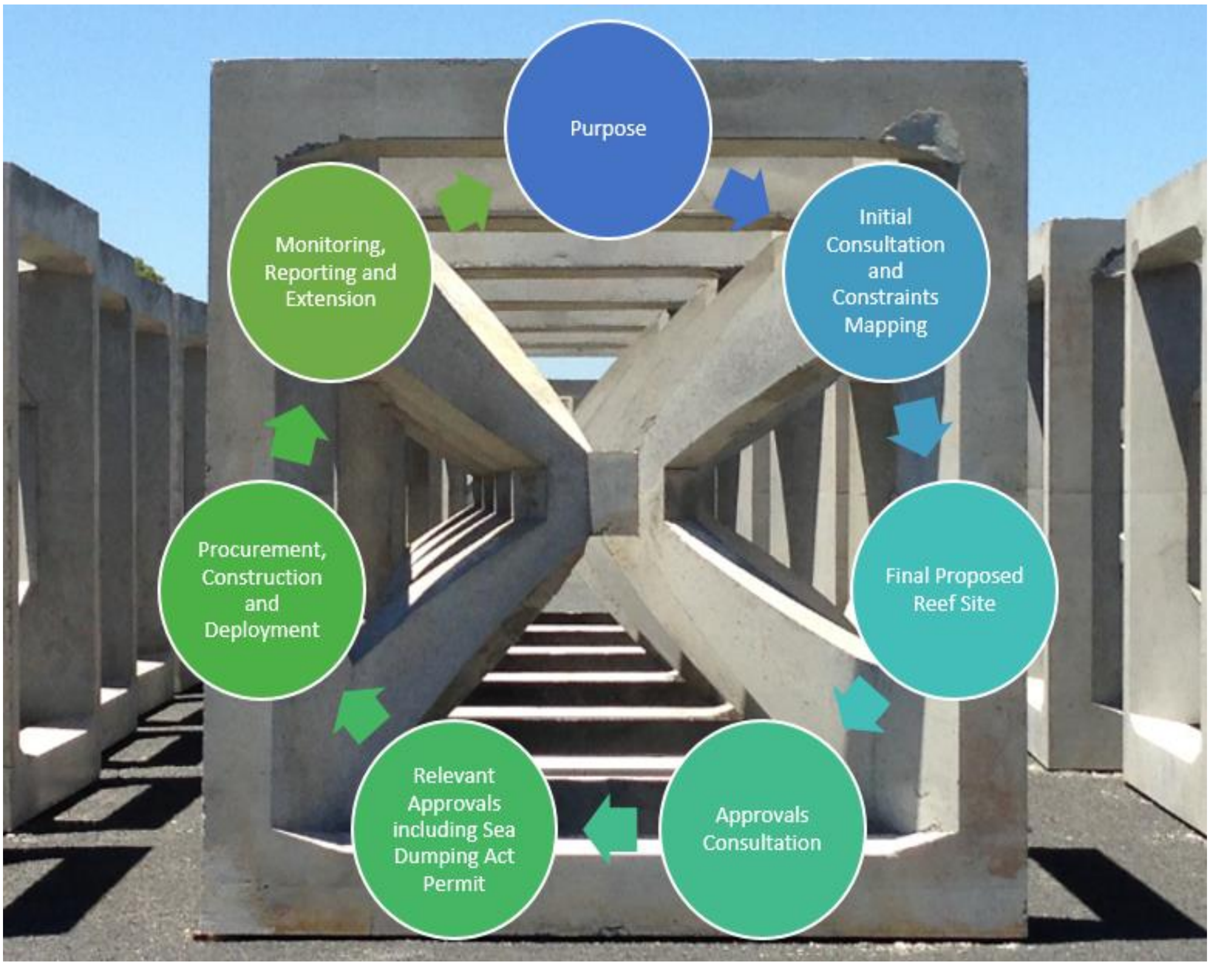
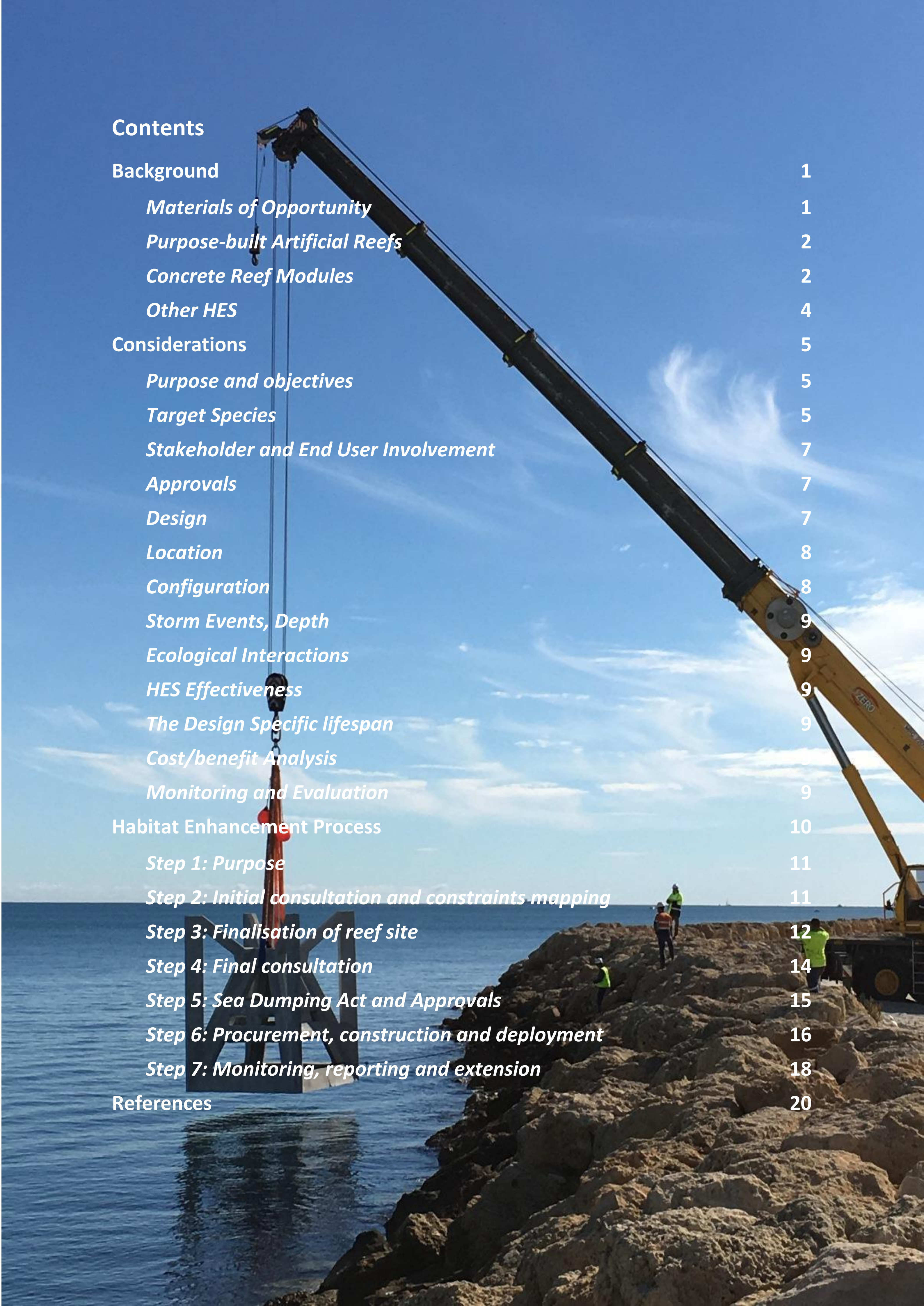


Figure 2: The broad-scale process for developing Habitat Enhancement Structures.



Contents

Background

Artificial reefs and other HES have an extensive history dating back thousands of years. In the Mediterranean, tuna fishers accumulated ballast stones to fish between tuna seasons in Sicily, and Greek temple stones were disposed during harbour construction creating reefs as early as 3,000 BC (Riggio 2000; Surman 2015). HES have been created all over the world, earlier HES's were mainly constructed of materials of opportunity such as woody debris, rocks and rubble and sunken vessels (from ancient fishing boats to modern warships).

In 1952, the Japanese Government began subsidising artificial reefs, triggering a phase of reef development. Japan now have over 130 diverse reef modules purposely designed to target an array of species such as oysters, octopus, squid, algae, abalone, sea urchins and demersal and pelagic fish (Thierry, 1988; Polovina and Sakai 1989; Barnabe and Barnabe-Quet, 2000; Surman 2015 Unpublished). Since then Southeast Asia has been at the forefront of HES development with China, Korea and Japan investing well over $3 billion since the 1970s.

Materials of Opportunity

Since 1979, the United States of America has developed a significant program that decommissions offshore oil rigs transforming them from functioning oil extraction plants to artificial reefs. The program is known as 'Rigs to Reefs (RTR) and the concept has been extended to several countries throughout Southeast Asia. With many offshore oil rigs around the world coming to the end of their productive lives, the RTR concept could be expanded globally in the near future. RTR is known as one of the more acceptable 'materials of opportunity' still in use and these oil rigs require serious environmental approvals before being converted into a reef.

Figure 3: Materials of opportunity, from left to right; the Tangalooma Wrecks (www.queensland.com), Tyre reef at Moreton Bay, Queensland (www.divingthegoldcoast.com) and disused oil rig (www.nytimes.com).

HES constructed from materials of opportunity include pre-existing materials and structures not constructed for the purpose of HES. These materials can include concrete blocks used for building, rubble, stones, polyvinyl pipe, tyres, derelict ships, car bodies, oil extraction equipment and disused armed forces equipment and vehicles. Most materials of opportunity have become unfavourable globally, due to adverse environmental effects and stability during severe weather events.

Some of the negative effects include pollution from heavy metal leaching, asbestos and a range of hydrocarbons as well as the destruction of natural habitat when structures that are not stable move on the ocean floor. Current Australian artificial reef policy has shifted to purpose-built HES due to environmental responsibilities, however adequately cleaned and modified (re-purposed) types of materials of opportunity including decommissioned oil and gas infrastructure may have its place in future developments with strict cleaning, alteration, management and monitoring of these structures. Due to general preferences in HES type, this guide will focus only on purpose-built HES.

Purpose-built Artificial Reefs

Purpose-built artificial reefs are specifically designed for target species, habitats, effects (such as upwelling) or purposes having specific shapes, voids, surfaces and profiles. A big benefit of purpose-built artificial reefs is that the shape, size and form can be altered to increase the abundance of certain species and to meet objectives. Modern purpose-built reefs can have substantial positive effects on surrounding aquatic ecosystems and can be built out of metal framework, steel, steel-reinforced concrete or concrete as well as recycled plastics, ceramics and fibreglass. Examples of these reefs include species specific reefs (such as abalone habitat reefs), larger Offshore Artificial Reefs (OAR), such as the Sydney OAR (a 12m tall metal structure aimed at facilitating the propagation of pelagic species) and concrete fish homes (such as Fish Boxes ™ and Reef Balls ™) designed to form habitats for a myriad of different species.

Figure 4: Purpose-built artificial reefs, from left to right; Abalone habitat reef, a Fish Box™ and the Sydney OAR (http://haejoo.com/).

Concrete Reef Modules

The most practicable and common artificial reef type in Australia is high strength marine-grade reinforced concrete reefs. An advantage of purpose-built concrete reefs is that moulds can be fabricated to create a range of different sizes, shapes, voids and structures. They are also pH balanced, non-toxic, built with universally available material and can provide more suitable surface textures for colonising organisms, such as corals.

Figure 5: Concrete reef modules awaiting deployment.

There are many different concrete module designs that are used all over the globe. Designs vary for different environments and water depths and are continually evolving (shape, size, and weight, internal and external surfaces) to better accommodate target species. In Japan and Korea, commercial fishers and aquaculturists harvest sea cucumbers, abalone, shellfish, squid, octopus, lobsters and finfish from purpose-built artificial reefs. Variation in module design allows reefs to mimic different natural reef profiles and varying habitat complexity. Knowing the target species and environmental conditions drives artificial reef design choice. For example, larger modules with larger openings and high vertical profile would better suit large cods and groupers as well as pelagic species as they can swim through the modules, while smaller modules with lots of habitat complexity may favour cryptic species and concentrate higher numbers of smaller fish. Many reefs mix differently shaped and sized modules to accommodate larger species abundance and diversity.

Steel Reef Modules

Along with concrete, welded steel is the preferred material for artificial reef construction (Diplock, 2010 and Surman, 2015). These reefs can be built to be considerably larger then concrete modules. The structures have a large amount of surface area and vertical profile with structures as tall as 35m in Japan.

The large vertical profile allows substantial amounts of habitat in different areas in the water column benefitting benthic or bottom dwelling species (such as flathead and flounder), epi-benthic species (those close to the bottom, such as snapper and emperor) and free ranging pelagic species (such as mackerel and kingfish).

Many steel reefs are specifically designed to congregate smaller baitfish. This is done by providing a large surface area in which colonising organisms such as macro algae are a source of food for smaller invertebrates which are then a food source for baitfish, and providing a protective area for baitfish to avoid larger predators.

Metal panels can also be incorporated into the design of steel reefs to take advantage of currents and tides to create upwelling that increases primary productivity (food sources for larval fish). Steel lattice like structure added to steel reefs can also provide shelter and safe areas for baitfish to congregate.


Figures 6-8 from Top: The Rottnest Fish Towers, The Queensland 'Fish Caves' (http://haejoo.com/) and a samson fish found on pelagic HES caught on jig.

A recent study on the Sydney Offshore Artificial Reef found that the reef provided enough habitat and refuge to safely support around 130kg of Mado (a small schooling species of fish found on coastal reefs) on the reef that fuels fish production by feeding on zooplankton supply (Champion et al, 2015).

Differing colonising communities will establish on Steel and concrete structures borers preferring concrete over steel until the steel has corroded, however other species, such as corals can prefer metal. For example, a study in Hawaii found that the highest coral recruitment occurred on metal rather than concrete reefs (Fitzhardinge, 1989).

Other HES

Other HES types aside from artificial reefs, include those that replicate or restore natural habitats including woody debris, shellfish reefs and translocation and restoration of corals and seagrasses. Wood is used for a variety of in-water restoration and enhancement activities including the creation of wood structures and resnagging. In freshwater and estuarine environments, woody debris is put into water bodies where they provide shelter and breeding locations, thermal variation, roosts for water birds and support the food web (Curtiss et al., 2006).


Figures 9 and 10: (left) Oyster Reef trial in Albany (image by Bryn Warnock) and (right) Wooden 'Fish Motels' (fishingworld.com).

Shellfish reefs are complex productive ecosystems that support a wide range of marine organisms. They provide shelter as well as direct and indirect food sources with research into oyster reef restoration in USA finding that restored reefs had 212% more biomass of fish and invertebrates than mud-bottom (Humphries and Peyre, 2015).

They also provide shoreline protection and can filter large amounts of water. Shellfish reefs can largely be captured under either Oyster Reef or Mussel Bed restoration. Finally the translocation or relocation of seagrass, corals and mangroves is a type of habitat enhancement that is important globally due to habitat loss and the ecosystem services these organisms provide, however these HES are not included in the scope of this guide. This is because the process of development of these HES greatly differ to artificial reefs and included HES types.

Considerations

This following section outlines the key considerations that need to be taken into account when developing a new HES. These factors include a range of social, legislative, ecological and economic aspects that need to be taken into consideration throughout the process and are all vital to the success of any HES developments.

Purpose and objectives

The starting point for any proposed HES is to define clearly, the purpose and objectives for the reef. The purpose needs to be based on why stakeholders, end users and managers are aiming to deploy a reef and the objectives need to steer the purpose. For example, a purpose may be to provide a safe fishing location for tourism, and objectives may revolve around safety, accessibility and enjoyment and could include being a safe distance from shore, near a populated coast, in an area protected from wind and large seas as well as creating a habitat that would favour target species in the area such as pink snapper or trevally.

Target Species

Target species are fish or other organisms that will most effectively increase end user satisfaction by being present on a HES. Assigning target species is an important factor in guiding purpose and objectives. The choice of species help guide what sort of HES design will be deployed, the proposed depth, habitat and location. Aspects that need to be considered include natural distribution and abundances of the target species in the area of the proposed reef location, seasonality, life history of target species and requirements and preferences of the species such as habitat (benthic/pelagic, temperature, visibility), shelter (refuges, surfaces, lighting) and food requirements (Surman, 2015).

Figure 11: Potential target species, samson fish (top left), baldchin groper (top right, other tuskfish species in states other than WA), mulloway (bottom left) and pink snapper (bottom right).

Materials

While materials vary for HES, the two main types include concrete and metal. The advantages and disadvantages of these materials can be seen in the table below (adapted from: London Convention and Protocol/UNEP, 2009; FRA-SEAFDEC, 2010 and FAO, 2015).

Table 1: Advantages and disadvantages of HES materials including concrete and metal.

Material	Advantages	Disadvantages
Concrete	• Compatible with the marine environment. • Durable, stable and readily available. • Readily formed into any shape for the deployment of prefabricated units. • Provides adequate surfaces and habitats for the settlement and growth of organisms, which in turn provide a substrate, food and places of refuge for other invertebrates and fish. • Universal and easily applied by community groups. • Concrete's weight makes modules stable and ensures module do not move during storm events.	• Concrete's weight, which necessitates the use of heavy equipment to manipulate it. This increases the land and marine transport costs. • The deployment of large concrete blocks or prefabricated units requires the use of heavy sea equipment, which is not only costly but also dangerous. • The weight on concrete increases the possibility of it sinking into the marine sediments. However constraints mapping should ensure that concrete modules are deployed on appropriate substrate to minimise this risk.
Metal	• Steel is easy to work, can be made in accordance to specific environments and species. • Steel is high strength, has a stable quality and is durable. • Possibility of developing large prefabricated units of very high relief and unmatched complexity. • Steel is free from harmful material and quickly colonised by organism and thus produces effects fast.	• Reduced design life in shallow or highly oxygenated water bodies (i.e. rough exposed coastlines). • High relief of large singular modules may cause stability issues requiring increased anchoring considerations of units resulting in increased reef costs. • Unit size may need specialised or large scale deployment equipment which will increase project costs.

Stakeholder and End User Involvement

Stakeholders and end users should have their needs and expectations met and feedback considered, throughout the project process particularly in early stages, when setting a purpose for the HES, as well as in the design, use, location and management of the HES. Formations of steering committees can assist in ensuring adequate representation of various individuals and groups involved.

Approvals

Installation of infrastructure such as HES (artificial reefs) requires environmental assessment and approval from relevant State and Commonwealth agencies and/or authorities. This can be seen in more detail on page 15.

Design

HES designs need to consider target species as well as other biological, ecological and physical aspects. In terms of biological and ecological factors, different HES designs may have a biological impact on their level of complexity. The creation of holes, crypts and refuges will allow for a large diversity and abundance of organisms to use the modules for shelter. Different organisms prefer different design features, for example, lobster and octopus prefer blind ended holes while other species such as smaller fish may prefer shaded open ended voids. A variation in size and a large amount of voids and refuges increases habitat complexity and thus increases the type and number of organisms that will use the modules, however cost should be considered.

Overall, the total surface area is much more important than the overall size in relation to productivity and reef biomass, so total surface area and internal surface area are also important when looking at different types of artificial reefs. 'The higher the surface area available for the settlement of algae and invertebrates, the greater source of food for other levels of the reef community and, therefore the greater productive capacity' (London Convention and Protocol/UNEP, 2009).

Figure 12: Different concrete artificial reef module designs for different purposes and species (http://www.subcon.com/).

Physical characteristics of reef module designs that need to be considered when planning a reef include:

- Surface texture
- Reef profile and orientation
- Shelter and shading
- Interstitial spaces
- Reef size, internal surface area
- Reef configuration
- Hydrological factors
- Social usage (e.g. space for fishers)

Location

The location of a HES needs to take into consideration ecological, environmental and social factors. While explained later in the HES process, the location needs to meet environmental standards while in an area accessible to end users that is within the distribution and requirements of target species.

Configuration

The configuration of HES varies with purpose, type, depth, current and tides. Artificial reef modules are usually installed parallel to the tide, perpendicular to prevailing currents and/or in clusters. Effective configuration can increase fisheries enhancement around the structures. Species preferences to different hydrological effects such as upwelling, eddies and slipstreams can enhance habitat, move nutrients and create feeding opportunities. Module configuration also creates interstitial spaces (corridors between modules) which in turn create new habitat. Specialised configuration can also enhance fishing opportunities by providing more space for fishers and by spreading fishing effort.

Figure 13: artificial reef module being tested in a university flume tank (Subcon Technologies Pty Ltd).

Artificial reefs consisting of small clusters of modules have been found to be successful, particularly in the artificial reefs in WA. This allows fish a high level of habitat complexity in an immediate area, a larger area of interstitial zones (between reefs) and it allows a larger numbers of fishers to use the reef simultaneously, increasing its societal useability. Interstitial zones are pathways for fish migration between modules and are areas of high diversity and abundance. These areas include a module's interior space as well as corridors between modules. These zones increase liveable habitat for species and decrease mortality rates as fish have 'safer' passages between shelters.

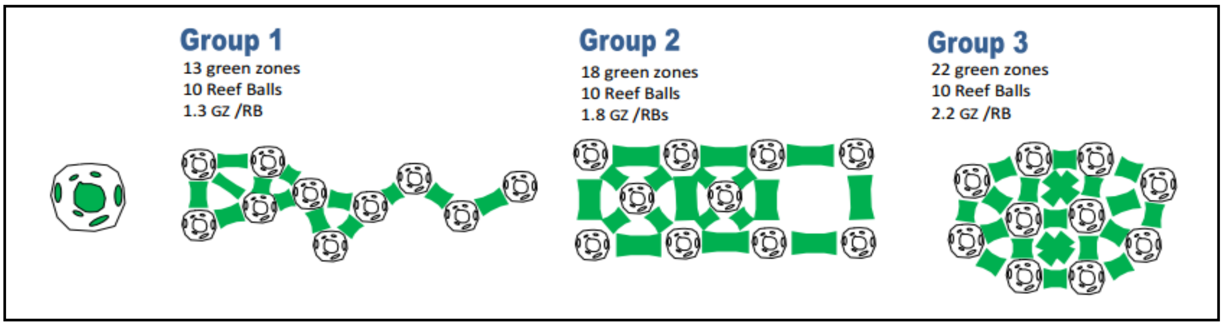


Figure 14: an example of interstitial spaces as 'Green zones' using ReefBallTM modules (Lennon, 2011).

Storm Events, Depth

HES designs need to be able to withstand a 1 in 100 year storm events and not become unstable, move position or collapse. They should have strong structural integrity and be deployed in appropriate water depths. Water depth should also be suited to HES design, purpose and target species.

Ecological Interactions

HES, if deployed for fisheries enhancement should be in areas with relatively low current fish diversity and abundance. Vulnerable and productive habitats and benthos (such as coral reefs) should be avoided. HES should not be deployed where they could significantly harm or damage any critically listed habitats or threatened species.

HES Effectiveness

It is extremely important that all aspects of the HES process and the environment are considered prior to deployment in order to maximise the effectiveness of HES. The HES type, design, configuration, materials, construction and deployment need to be considered in relation to hydrology (currents, tides), depth, light penetration as well as sediment dynamics, substrate characteristics and surrounding environments, objectives and target species.

The Design Specific lifespan

Design specific lifespans of HES need to be considered and evaluated against the investment going into the project and the benefits the HES will bring as well as the other considerations. Locations can also maximise or minimise life spans depending on hydrological and climatic events at the site. When applicable, HES with the longest lifespans (>30 years) should be utilised to allow for longer ecological development resulting in further economic and social benefits.

Cost/benefit Analysis

HES need to be carefully designed, approved and installed to ensure that the ecological, social and economic benefits of the HES outweigh the investment into the infrastructure. Innovative deployment methods and module design, local business contributions and community monitoring increase cost efficiency across the project. Relevant state fisheries regulators as well as state peak bodies should be contacted to provide indicative HES costs and project budgets.

Monitoring and Evaluation

HES need to be evaluated against the main purpose and objectives. They must also be monitored to meet legislative requirements. HES need ongoing structural monitoring, while ecological and social monitoring is extremely useful to measure the performance of HES.

Habitat Enhancement Process

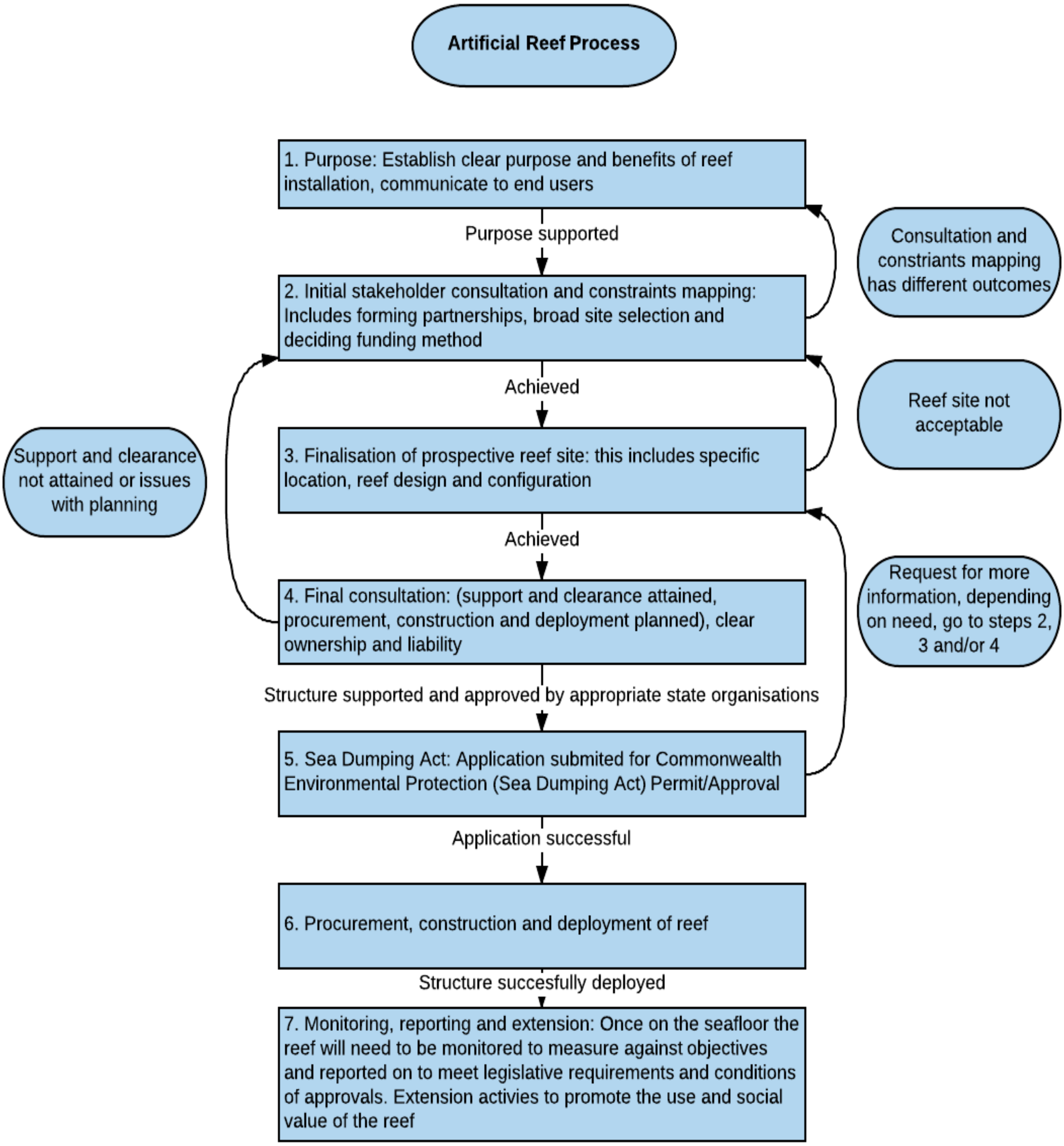


Figure 15: An in-depth flowchart of HES development process from establishing an initial purpose to extension activities in local communities following deployment.

Step 1: Purpose

Deciding the purpose of an artificial reef is the most important stage of the artificial reef process. It underpins the reef's success and dictates which path is taken for each of the steps outlined in this guide. Specific purposes will determine the broad location, specific site, type, target species, reef type and configuration. A clear purpose also drives the creation of objectives to assist in measuring the performance of a reef. For example, the purpose could be to enhance recreational fishing leading to objectives around access to target species and proximity to boat ramps.

To establish an effective artificial reef the need or desire for the reef must be clearly understood. The purpose of the reef should take into account the considerations explored in this guide, to assist in the further stages of development, such as site selection. For example, if the purpose is to provide increased target species in a safe fishing location, the reef should be in close proximity to shore, in a protected embayment and in a populated area. If the purpose of the reef is to concentrate pelagic sportfish for avid anglers, metal structures should be deployed further from shore at suitable depths and environments for pelagic species (such as in the paths of currents or migration routes).

Step 2: Initial consultation and constraints mapping

The initial consultation is done with other stakeholders (including government and non-government) and end users to establish the target species, reef type (design and configuration), location and other important factors. Individuals and organisations that need to be involved in this stage consultation include Local Government Authorities, end users, potential partners, end user peak bodies, clubs and associations and groups with demonstrated capacity and expertise in the area. The objective of this initial consultation is to determine whether the purpose of the reef (step 1) is reflective and the best outcome for the target end users, as well as:

- What is/are the target species(s) and why?
- What reef modules/design best suit the target species?
- Which location would best suit the end users and the target species?
- Are the modules and configuration suitable for the location?

Once these questions are answered and agreed upon between project managers, stakeholders and end users, constraints mapping and site selection can begin. Site selection is one of the most integral parts of the process in creating a HES. Like the construction of a park or sports stadium, an artificial reef site has to adhere to environmental requirements, be socially acceptable, be in a location accessible by the population and be in an area that fits its purpose and maximises its infrastructure. Constraints mapping assists in site selection by narrowing down a large area of potential reef locations to more specific and suitable area.

The most important considerations in constraints mapping include distance (from shore, boat ramps and population centres), shipping activity (lanes, anchorages and port authority zones), Depth, distribution of target species and military and mining activities. Mapping software such as ArcGIS can be used to reduce the size of an area by excluding areas that are not compatible with a reef installation such as ship anchorages and depths and is particularly beneficial if pre-existing benthic habitat maps are available to overlay on the map (note: may only be possible if data has already been collected in other studies).

Tables 2-4: the main components to site selection including biological/ecological, physio-chemical/environmental and social/anthropogenic factors. These will differ with your HES design and purpose.

Biological/ecological	Physio-chemical/environmental	Social/anthropogenic
• Existing fish communites • Protected and endangered species • Target species distribution • Competition for colonisation • Predation of target species • Larval availability • Sensitive habitats	• Sedimentation and turbidity • Light • Water temperature • Depth • Geomorphology • Water quality • Salinity • Wave exposure and energy	• Cultural or historic areas • Distance from shore • Marine Protected Areas • Military Areas • Mining and Shipping areas • Existing commercial fishing areas • Population size • Developement plans

Step 3: Finalisation of reef site

Once a broad site is selected, a more specific site can then be finalised. This is usually done by the creation of a steering committee composed of managers, stake holders and end users. Constraints mapping is then discussed and a final site selected, which is then tested. This step involves two stages. Stage one involves the biological and environmental analyses of the site and its characteristics to find an ideal deployment zone/reef site.

Firstly as part of a pre-assessment survey, a grid needs to overlaid on the final area chosen, its area varying, depending on the size of the reef to be deployed, for example a $2km^2$ grid when aiming to deploy a $200m^2$ artificial reef. At each grid intersection (in the previous example at every 500m), a depth reading needs to be taken and the habitat type evaluated. This can be done by towing a underwater camera along transect lines or dropping cameras at grid intervals to ascertain the habitat type (ie seagrass, low profile natural reef, sand, shale, coral etc) and is then best combined with GIS mapping technology (particularly LIDAR imagery). The most suitable area can then be side scanned to find the most ideal location for installation to ensure that the habitat is suitable (for example bare sand).

Once the habitat is identified as acceptable, side scan surveys and sediment probes can be used to look at sediment characteristics to ensure the type and depth of mobile surface sediments will suit the modules and ensure that they will be stable and not shift or sink once deployed. Stability analysis will also need to be undertaken looking at hydrological variables at the site such as wave and current conditions at the site as well as the influence of tides and extreme weather events such as cyclonic activity and 1 in 100 year storm events. This hydrological and climatic data then needs to be compared with reef module design and configuration and depth to ensure that the reef will survive its lifespan, be productive and meet its objectives and purpose.

Finally there should also be an ecological survey of faunal assemblages of the reef location and immediate area around the area. This is done to establish a baseline of the ecological community that currently exists in the area and to collect baseline data to compare with future monitoring results. The most suitable method for this would be the use of Baited Remote Underwater Video (BRUVs) which can collect footage of the habitat in the field of view as well as the abundance and diversity of other aquatic organisms at the site. Other methods of monitoring may also be used such as towed video, Diver Operated Video (DOVs) or acoustic methods in turbid water. Stage two involves seeking clearance for the site from factors that may preclude the identified site and the reef purpose and includes aspects such as submerged cables, mining leases, commercial fishing groups, Native Title claims and areas of heritage or cultural significance such as wrecks. Stage two is undertaken in the next step, in the final consultation with the organisations that manage these extra factors.

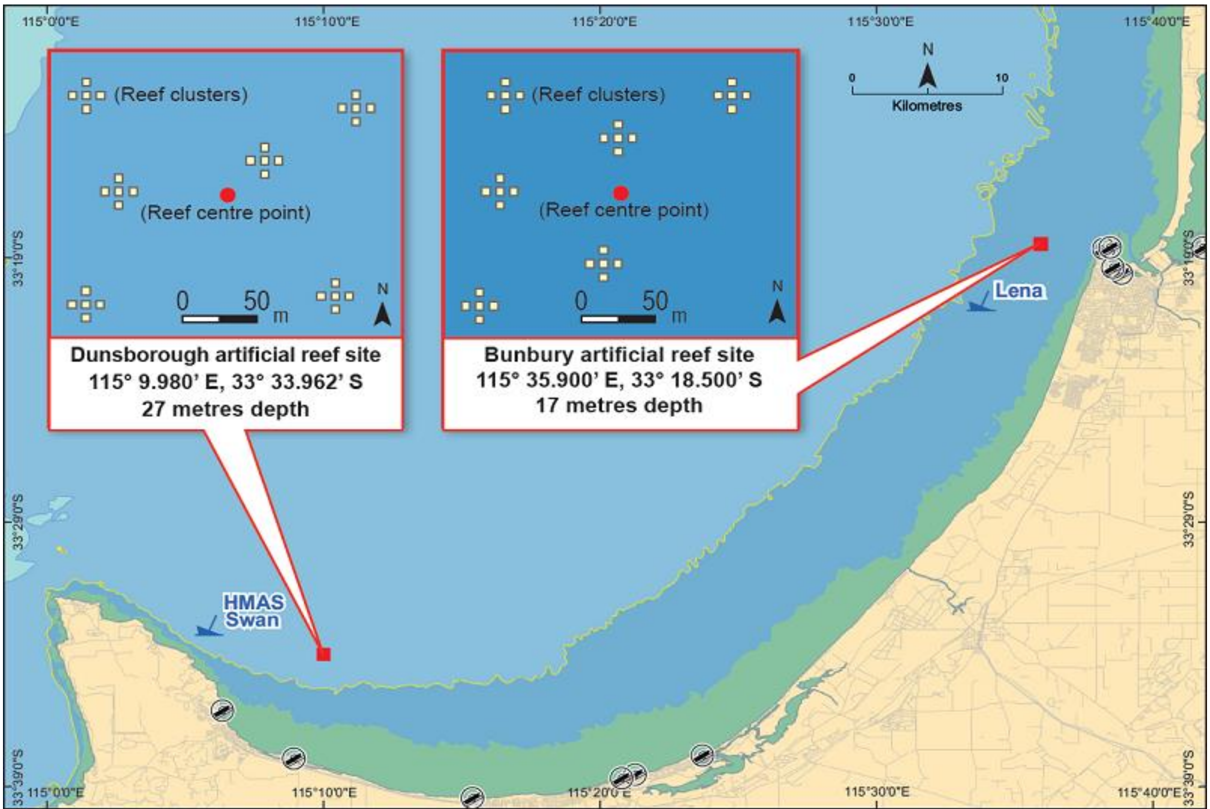


Figure 14 and 15: (top) the final reef sites that were chosen after a consultation period in Geographe Bay, Western Australia. The photo below shows the reef three years after deployment.

Step 4: Final consultation

The final consultation period involves establishing a framework to decide which stakeholders need to be consulted to what level and what outcome is required from that consultation. Local businesses, local interested groups, Local government authorities, government departments and the broader community need to be consulted with, however the level of consultation varies between jurisdictions. Communication tools on traditional and social media can be utilised to assist with engaging and informing relevant parties. Some of these tools include community meetings, updates, information pages on websites, advertisements, newspaper articles and establishing online groups and forums. Depending on the purpose of consultation and organisation, the results will vary between informing them, gathering support or attain clearance for the project. Letters of support and clearance from organisations such as the Royal Australian Navy and Australian Maritime Safety Authority are vital for attaining an exemption from the Dumping at Sea Act and preferable when seeking funding.

Tables 5 and 6: organisations that need to be informed and consulted with when developing HES projects (note that this list will vary between jurisdictions and while some of these groups it's a vital legal requirement to consult, others it is just beneficial to inform and gain support from).

Affected Stakeholders (Inform)	
Accommodation Providers	Fishing Stores
Any Mining, Oil or Gas Providers	Historical Societies
Aquaculture Council	Local Businesses
Boating Stores	Local Development Commissions
Chamber of Commerce and Industry	Local NRM and Conservation Groups
Commercial Marine Services	Local Recreational Fishing Councils
Community Groups	Local Shires and Councils
Diving Charters	Local Visitor Centres
Diving Clubs	Logistics Services
Diving Stores	Marine Rescue Services
Fish Stocking Organisations	Regional Development
Fishing Charters	Tourism
Fishing Clubs	Volunteer Sea Rescue Groups

Regulators/Clearance/Approvals (Consult)	
Australian Fisheries Management Authority	Relevant Natural Resource Management Organisations
Australian Hydrographic Office	Relevant Port Authorities
Australian Maritime Safety Authority	Relevant Recreational Fishing Peak Bodies
Maritime Archaeological Associations	Relevant State-based Fisheries Regulators
National Offshore Petroleum Safety and Environmental Management Authority	Relevant Environmental Regulators
Relevant Aboriginal Affairs Organisations	Relevant State-based Heritage Administrators
Relevant Commercial Fishing Peak Bodies	Relevant Transport and Infrastructure Regulators
Relevant Mines and Petroleum Administrators	Royal Australian Navy

Step 5: Sea Dumping Act and Approvals

To minimise any potential adverse environmental impacts of HES, and to optimise social, economic and ecological benefits, the HES process requires approval. Approvals vary with HES design, location, configuration, deployment and jurisdiction. HES in varying distance from shore are likely to require differing support and approval from Local, State and Commonwealth Governments as well as organisations that own or manage aquatic areas or resources (see step 4).

Approvals and permits are necessary to ensure that (DOEE, 2008):

- Appropriate HES sites are utilised
- Construction materials are suitable, environmentally friendly and prepared properly
- There are no significant negative impacts on the surrounding marine environment
- The HES pose no danger to navigation or end users
- That the HES is chartered on maritime maps
- The reef is aligned with state and commonwealth laws and policies

In Australia the majority of artificial reefs deployed for fishing enhancement (aside from some aquaculture purposes), require approval from the state government. There may be an exception in some states with freshwater systems, particularly on private land. Applications may also need to be aligned with state policies on Habitat Enhancement Structures. Any groups wanting to deploy HES need to contact fisheries regulatory bodies in their jurisdiction to find any relevant policy positions.

Artificial reefs deployed in Commonwealth waters must also obtain Commonwealth Government approval in the form of an exemption from the Environment Protection (Sea Dumping) Act 1981. The Sea Dumping Act fulfils Australia's international obligations under the London Protocol to prevent marine pollution by dumping of wastes and other matter. HES in state waters may also need an exemption depending on the HES type and relevant state policies.

The Sea Dumping Act also ensures appropriate site and material selection to minimise adverse impacts upon the environment and public and is a legislative requirement to HES developments. The only HES deployed in commonwealth waters that do not require an exemption from the Sea Dumping Act are FADs, however they still need approvals from related State Government Departments such as Transport. While the Environmental Protection (Sea Dumping) Act 1981 is the relevant legislation at the commonwealth level, applicable State legislation relevant will also need to be investigated. This may include marine tenure and tenements, marine transport and safety, aboriginal heritage and native title, other user groups including commercial and recreational fishing, aquaculture, local government, environmental protection and those listed in Table 6.

Other approvals may also need to be required depending on relevant location of the selected HES site. If the HES is to be deployed in a Marine Protected Area, related Departments should provide support. If it’s deployed within Port Authority or local shire boundaries, the relevant approvals must also be acquired (obtaining ‘some’ of these approval may negate the need to acquire an exemption from the Environmental Protection (Sea Dumping) Act).

Step 6: Procurement, construction and deployment

Once the relevant approvals are gained, procurement of the reef can begin. Reefs are usually installed by a company or organisation with artificial reef expertise that can design, construct and deploy modules however, in some cases community groups, commercial businesses and other organisations can also design, build and deploy their own reefs, however there is still a requirement to obtain engineering approval. Artificial reef Procurement is usually done at one of two stages:

- Step 2 or 3: Some organisations may desire to get an artificial reef expert at early stages to guide consultation and constraints mapping, potentially undertake approvals and to give input as to the suitability of the design for purpose and the site characteristics.
- Step 5: Some groups, particularly those with previous experience may wish to engage an expert or reef supplier at stage 5 to assist in acquiring the permit. While other groups may choose not to engage an external supplier and to build and deploy their own reefs.

Figure 16: Crane and barge deployment of concrete artificial reef modules in Western Australia.

Installation can be a costly stage of HES projects. Reef modules need to be cleaned, parts tested and an in-depth deployment procedure, including a risk assessment needs to be undertaken. Deployment for HES varies from simply pushing modules off a boat to large ships with cranes deploying 30m tall steel towers. Deployment is logistically challenging due to using large heavy materials and deployment tools in the marine environment. Therefore, deployment is best undertaken in the calmest conditions possible.

The majority of larger artificial reefs deployed are installed by using a crane and barge. Once modules are loaded onto the barge they are towed to the final reef site. Modules are then lifted by cranes and deployed to the sea floor and deposited using releasing mechanisms. Some crane hook attachments may be specialised to lift large singular modules or even multiple modules at once deploying in clusters. Some metal reefs are then anchored by chains being shackled to the module and mooring weights. For example, the Sydney Offshore Artificial Reef has 40 tonne moorings attached to each corner of the singular reef unit, while the Queensland 'Fish Caves' also have a similar anchoring system.

Some reefs have other innovative deployment methods such as the Perth Metropolitan Fish Towers. These two 70t four storey high modules were deployed in new a cost effective method that doesn't require ships, cranes or barges at the deployment site. Instead, the towers each have 4 buoyancy chambers which double as ballast tanks with valves that can be controlled by an umbilical cord that along with other ropes attach the unit to the vessel. A tug boat is used to tow the unit to the deployment site. The module is transported off the hardstand and lowered into the water via a ship lifter. It is then tethered to its vessel and towed to the site location. Once in the deployment zone, the valves in the ballast tanks are remotely opened and the module sinks to the seafloor. Once settled, the cables and ropes are released from the unit via a release mechanism and float to the surface with the assistance of a large float.

Figure 17: Tug boat towing a 'Fish Tower' module to its final deployment site.

Other types of HES have differing deployment methods. Timing of deployment is a crucial factor with Shellfish Reefs to ensure the best conditions for natural processes and to minimise mortality of living material. While any HES are being deployed, a notice to mariners needs to be put in place to reduce navigational hazards while working on the installations. An observer should also be in place to look out for interactions with sea life, particularly with endangered species. Once deployed, co-ordinates of modules will need to be recorded and given to the Australian Hydrographic Office to be put on navigation charts.

Figure 18: Large snag being installed on the Murray River (Source: Fish Habitat Network).

Step 7: Monitoring, reporting and extension

Monitoring is the process of gathering data and information over time to measure changes in an environment. There is a legislative need to monitor HES to ensure they have no adverse environmental impacts. HES should be socially, structurally and ecologically monitored to ensure they are performing at or above expectations and fulfilling approvals, objectives and purposes. Monitoring techniques are categorised into two areas, extractive and non-extractive methods. Extractive techniques are those that have an impact on biodiversity in that they extract, displace or disturb organisms, while non-extractive techniques involve observational analysis of species, that can occur at the HES site or off site (such as recording on slate or water proof paper, photography, videography and acoustic research). Non-extractive techniques are generally preferred as they have less of an impact on the marine environment.

Social monitoring is used to analyse the level of use of HES and how they have influenced or impacted the community. This is most commonly done by surveying end-users, stakeholders and beneficiaries regarding their direct and indirect interactions with the reefs. Structural monitoring involves analysing the structural integrity, stability, position and any changes to the surrounding environment that any HES installation may have caused. It can also study excessive scouring, corrosion, sedimentation or fouling by pollution.

Monitoring HES is best split into two different areas, specialist monitoring and community monitoring. Specialist monitoring involves monitoring to meet environmental approvals. Structural, social and some ecological monitoring of HES. If one or more HES are deployed in a state, a streamlined and standardised monitoring approach may decrease costs. The community can also assist with monitoring through data collection and analyses with what is known as citizen science, which is best used for ecological and social monitoring of HES. An example of citizen science is *Reef Vision*.

Figure 18: The *Reef Vision* Team for the South West Artificial Reef Trial in Western Australia.

Reef Vision monitors the Western Australia South West Artificial Reef Trial using local fishers and members of the community. Volunteers record boats on the reef and fish caught in logbooks, take part in surveys, record boat numbers using long range scopes and play an important role in BRUV monitoring. Local fishers use cheap, light and durable custom built BRUVs that utilise Go Pros and deploy them on the artificial reefs. In October, 2016, volunteers had collected over 160 videos on the reef lasting over 200 hours. Analysed footage to date has shown over 34,000 individual fish from 67 species and the program will expand to include other HES in WA. Using citizen science to monitor HES engages the community, provides large and cost effective data sets and creates stewardship and ownership over HES and aquatic environments.

Figure 19: A Dhufish, an iconic Western Australian species observed in volunteer footage on the artificial reefs.

Finally, it is strongly recommended that any HES developments produce a communications and extension plan to inform the community of deployment and how HES are performing against objectives. The plan should include scheduled discussions, notifications and events with the stakeholders, end users and community. Information on how to use the HES, code of conducts, site co-ordinates and monitoring results are all important to disseminate with the public. With HES objectives often including social utilisation and economic boosts, advertising the structure(s) and the opportunities related to the structure from recreating to commercially harvesting seafood is vital to the success of the HES. With the use of social and traditional media, local communities will often take ownership once the HES begins to develop and disseminate their own information which will in turn assist in support for future HES developments.

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