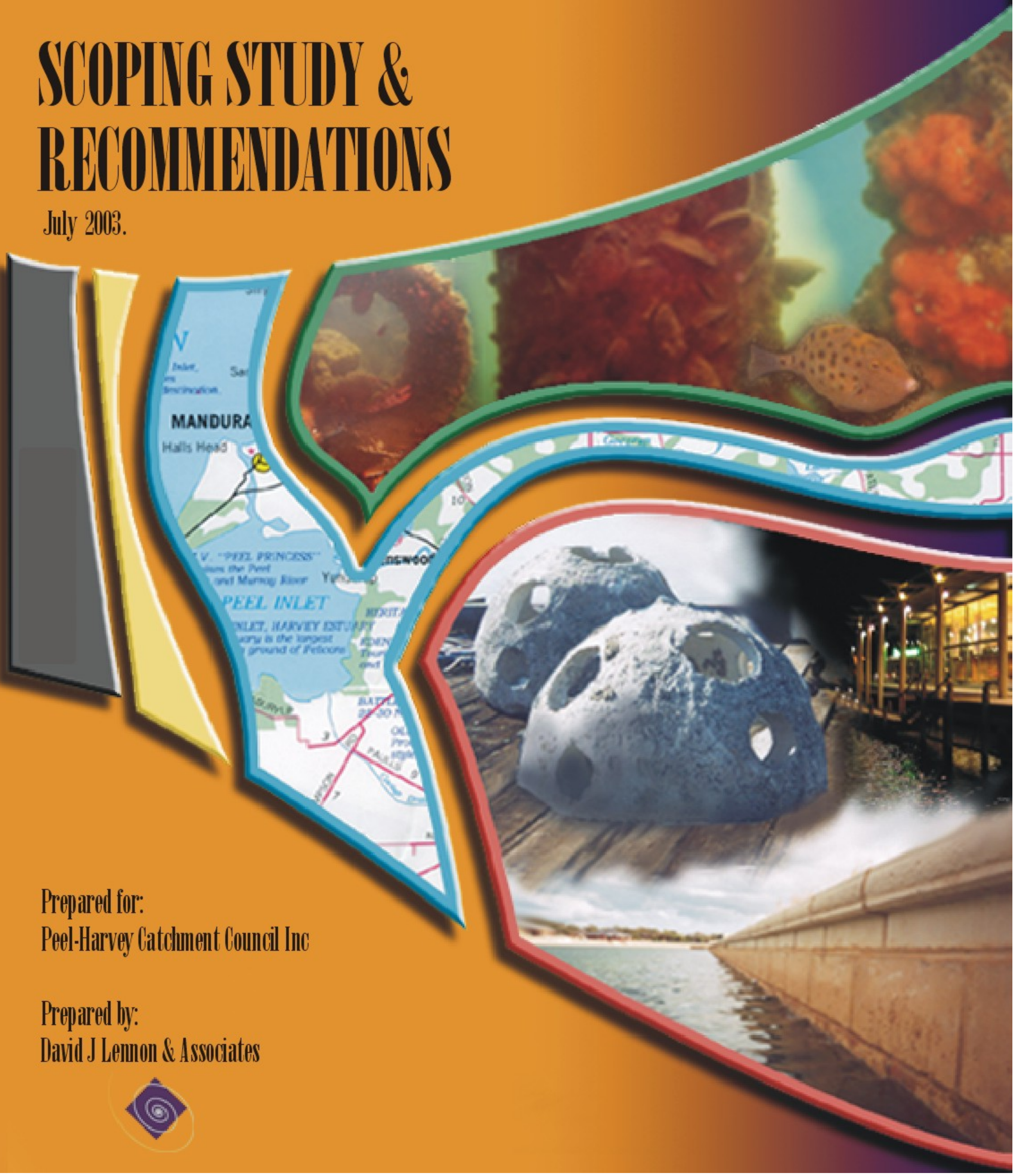
PEEL-HARVEY CATCHMENT COUNCIL (Inc.)

Marine Habitat Enhancement
Mandurah (Western Australia)

SCOPING STUDY & RECOMMENDATIONS

July 2003.



Prepared for:
Peel-Harvey Catchment Council Inc

Prepared by:
David J Lennon & Associates

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The contribution of the following agencies and individuals is gratefully acknowledged:

Christine Steer - Manager, Environmental & Cultural Development, Peel Development Commission
Bob Pond - District Manager - Peel, Water and Rivers Commission
Bruce Tatham - Chair Peel Inlet Management Authority
Edward Janiec - Chair of Interim Committee, Peel Region Fish Stocking & Management Association
Robert Tregonning - Senior Policy Officer, Env Assessment, Fish & Fish Habitat Protection - Dept of Fisheries
Brett Flugge - Director Planning & Development Services, Shire of Murray
Allan Claydon – Director, Works and Services, City of Mandurah
Rhoan Howard – Engineer, City of Mandurah
Brian Sharp - President Port Mandurah Residents Association
John Wroth – Project Manager, Port Bouvard Limited
Jim Scott – Marina Manager, Mandurah Ocean Marina
Chris Carmen – Managing Director, Port Mandurah
Murray Burling – Manager, Coastal & Ocean, Worley
Malcolm May – Director, Discrete Data Systems
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Dr Eric Paling – Murdoch University

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Executive Summary

Background

The Peel-Harvey Catchment Council Inc (PHCC) is seeking to investigate opportunities to enhance the fish habitat in the regions waterways, particularly in the man-made canal estates in the Peel region. To this end, the PHCC commissioned this feasibility study to provide recommendations and appropriate technical material to consider the placement of artificial habitat into nominated areas of the regions man-made waterways.

Funding for the feasibility study was provided by the Peel Development Commission, through the Regional Development Scheme, the Water and Rivers Commission and the Peel Region Fish Stocking and Management Association.

Study Approach

This study was conducted during the period from April to June 2003, and included the following: review of existing literature; two meetings with stakeholders supplemented by one-on-one meetings with developers and other relevant individuals; and above and below water inspection of potential sites.

In order to help prioritise where efforts and resources should initially be directed, each site was judged and ranked on 11 attributes. Enhancement strategies were then developed for sites ranked in the top three. These were:

1. Mandurah Ocean Marina and Hall Park Public Swim area.
2. Port Bouvard – Northport, and Port Mandurah – Mariners Cove.
3. Port Mandurah – Leeward.

Enhancement of the Peel Waterways

The initiative to investigate how the potential enhancement of the Peel Region's man-made waterways should be considered as a 'pilot 'program. It is an ongoing process of deploying modules and observing results.

An enhancement program such as this is not just about enhancing the physical attributes of waterways, but also about enhancing our understanding of the local system and how it is affected by our built environment. It is this improved understanding that can then be used to 'enhance' future decisions on the direction of the program, management of the Peel's waterways, as well as further coastal development and research. Environmental management plans are only as good as the information they are based upon and this program over its lifetime can contribute valuable data as well as foster greater interest and support from the community for the sustainable use of the region.
At this stage of the program, there is no objective to target the enhancement of specific species. However as experience is gained, it may then be appropriate to explore specific enhancement activities that target certain species, as well as how natural areas may be enhanced/restored or protected from wave erosion.

Methods of Enhancement

Three primary means of enhancing the constructed waterways are provided.

1. Structural Design Changes

Perhaps the foremost inadequacy in canal design from a biological perspective is our tendency for engineering, economic or aesthetic purposes, to construct straight lines. There are few straight lines in nature, yet our built environment has an abundance of straight lines as well as smooth faces. This limits the biological 'attractiveness' of the structure and could be likened to creating a level uniform meadow with only one type of grass.

This can be improved in a number of ways. If the structure (eg. canal wall) is yet to be built, then the construction of an irregular block face below the waterline can add diversity and ledges that will assist colonisation by encrusting organisms. This has the added advantage of helping to dissipate wave energy (ie. boat wash). Addition of modules such as Reef Balls to the base of the wall can further enhance its biological attractiveness.

An option for walls or breakwaters already constructed is the addition of rock spurs. Rocks or Reef Balls are placed in a pile just out from the toe of the rock wall; no rocks actually form a connection to the wall. This creates a node that fish can swim around and inbetween and increases the width and length of the walls 'useable' area. This option is recommended for Mariners Cove, Leeward, and Eastport.

Incorporation of intertidal habitat is another way developments can improve their biological productivity. Examples already exist at Mariners Cove, Leeward and Eastport. There exists the potential to introduce seagrass into some canal areas, for example Northport. This can be a community project and is highly recommended.

2. Enhancement using Reef Balls

Reef Balls are a US invention that has now become the world's leading artificial reef module, with over 500,000 deployed worldwide in 3,500+ projects. They are considered the best choice of module for the programs by the PHCC due to their stabiity, natural appearance, hollow void spaces, and effectiveness. Reef Balls can add valuable contrasting substrate to areas underneath jetties, along walls and within rock wall spurs.

It is recommended that four different sizes of Reef Balls be used, and initial numbers of modules for each site varies from approximately 40 to 180. Reef Balls are made using a patented mould system and it is recommended that 11 moulds be purchased, however this can be varied to suit the final program schedule and funding.

It is recommended that a non-profit organisation be established to construct and deploy the modules, and module construction could involve volunteers including school groups.

3. Enhancement using Non-Reef Ball Concrete Modules

There is the option of making custom modules out of concrete using balloons, buckets, sand, and other materials and some imagination. This could be something school groups could get involved in and they could then monitor their creations. This encourages students to think about what different animals require in the way of habitat, and could generate useful designs for elsewhere.

Value Adding Options

There is excellent potential to maximise the value gained from the program by constructing reefs in areas that are easily accessible or of high profile. For example the Dolphin Quay development could create public viewing areas, and snorkelling attractions could be created at Hall Park and Northport. Their easy access make them idea for school programs and research. These three sites could significantly boost awareness of the program via the installation of live feed underwater video cameras that transmit direct to websites, cafés, and Performing Arts Complex, etc.

Indicative Costs

Estimated base costs for the number of Reef Ball modules required at each of the recommended sites ranges from around $1000 to $11,000 plus deployment costs. The cost of purchasing and shipping Reef Ball moulds from the US ranges from approximately $3000 to $20,000 depending upon how many moulds are bought and whether air or seafreight is used. Estimated unit costs of the Reef Ball modules ranges from $20 for the smallest to $90 for the largest. The estimated cost for the full option of 11 moulds and deployment of modules at all recommended sites is summarised in the table below. The PHCC has the option of forming a non-profit group and applying for a Reef Ball Foundation Grant which provides a reduction of 30-40% on moulds.

Option	Cost of Moulds	Freight	Equipment	Estimated Total for Modules for all Recommended Sites	SUBTOTAL	Additional Expenses
Full Option – all sites as per Section 3 and 11 Reef Ball moulds.	$11,320 (RB Grant rates)	~$5,660 + GST (air) ~$4,320 + GST (sea)	$3,400	$65,760	$86,140	Training, deployment

Costs are basic estimates only and do not include cost of additional design work, permit approvals, monitoring, maintenance or value adding options.

Monitoring

Monitoring of enhancement programs should be considered an integral part, yet are sometimes neglected due to the focus of resources and energy on initiating a program.

There are three main non-commercial groups that could be approached to participate in monitoring:

1. Canal residents
2. Schools
3. Universities

The following are some broad objectives that the PHCC may wish to consider as monitoring objectives:

- Species composition along rock wall vs module enhanced rock wall.
- Species composition at a spur vs rock wall without.
- Variation in species associated with the various size modules located in the same area.
- Jetty without modules vs jetty with modules.
- Contribution of enhanced areas to local fisheries.
- Utilisation of modules by blowfish.
- Survey of canal residents as a measure of habitat value.
- Factors influencing the success of seagrass transplanting in man-made waterways.

1 INTRODUCTION

1.1 Project Brief

The Peel-Harvey Catchment Council Inc (PHCC) is seeking to investigate opportunities to enhance the fish habitat in the regions waterways, particularly in the man-made canal estates in the Peel region. To this end, the PHCC commissioned this feasibility study to provide recommendations and appropriate technical material to consider the placement of artificial habitat into nominated areas of the regions man-made waterways.

The Terms of Reference (TOR) request a report that "*outlines recommendations for up to 3 sites that would most benefit from habitat enhancement together with configurations for maximum productivity, effectiveness and environmental stability. This would also include a construction and implementation program detailing costings, timelines and equipment and space requirements. It is understood that the scope of this study does not guarantee that the 'environmental stability' of reef balls deployed can be determined, as this is dependant upon, among other things, available information regarding currents and substrate. Further studies may be necessary/recommended if a sufficient level of confidence in environmental stability cannot be gained".*

There was no directive for recommendations on how to increase specific species, or how to restore natural habitat. This study and resulting enhancement program will be the first for the area and therefore should be considered a pilot program which will provide a foundation of knowledge and experience to base further enhancement initiatives, should they be considered worthwhile.

The Steering Committee for the initiative is made up of a consortium of Peel regional organisations, including the Peel Region Fish Stocking and Management Association, the Peel-Harvey Catchment Council, the Water & Rivers Commission, the Department of Fisheries, Local Governments and the Peel Development Commission.

Funding for the feasibility study was provided by the Peel Development Commission, through the Regional Development Scheme, the Water and Rivers Commission and the Peel Region Fish Stocking and Management Association.

1.2 Study Approach

This study was conducted during the period from April to June 2003, and included the following:

Review of Existing Literature
The Peel Development Commission provided a collection of relevant impact assessments for the area as well as other reports produced regarding fish stocking, management and monitoring of the Dawesville Channel. Engineering plans for the various canals were obtained from Mandurah City Council. A literature search was also conducted of environment/biology journals for any published literature on the Peel Inlet and estuary.

Two Meetings were Held
Steering Committee, 4 Apr 2003 and attended by:

- Christine Steer - Manager, Environmental & Cultural Development, Peel Development Commission
- Brett Flugge - Director Planning & Development Services, Shire of Murray
- Edward Janiec - Chair of Interim Committee, Peel Region Fish Stocking & Management Association
- Bob Pond - District Manager - Peel, Water and Rivers Commission
- Jane O'Malley - Environmental Planning Officer, City of Mandurah
- Bruce Tatham - Chair Peel Inlet Management Authority
- Rob Tregonning - Senior Policy Officer, Environmental Assessment, Fish & Fish Habitat Protection - Dept of Fisheries

Meeting with Stakeholders, 7 Apr 2003, City of Mandurah and attended by:

- Steering Committee (as above)
- Mike Wadsworth - Waterside Residents Association
- Chris O'Loughlin - Waterside Residents Association
- Phil Curran - Peel Region Fish Stocking & Management Association
- Taka Wakamatsu - Murray Lakes
- Grahame heal - MCC
- Alex Hollick - Shire of Murray
- Jayson Miragliotta - City of Mandurah
- Fiona Valesini - Murdoch University
- Ian Potter - Murdoch University
- Allan Claydon - City of Mandurah
- Greg Harris - City of Mandurah
- Jane O'Malley - City of Mandurah

Other meetings were conducted with:

- John Wroth - Project Manager Port Bouvard
- Chris Carman and Jim Scott - Port Mandurah and Ocean Marina
- David Budd Diving Academy
- Rhoan Howard - City of Mandurah
- Murray Burling - Worley - Manager Coastal & Ocean consultants
- Malcolm May - Discrete Data Systems - Director
- Luke Smith - Australian Institute of Marine Science

Phone discussions:
- Brian Sharp - President Port Mandurah Residents Assoc.
- Dr Eric Paling – Director of Marine and Freshwater Research Laboratory, Murdoch University.

Inspection of Potential Sites
Site inspections consisted of visual observation above and below the waterline at the following locations:

- Port Mandurah - Cambria Is, Santavea, Mariners Cove, Leeward
- Ocean Marina
- Waterside Canals
- Performing Arts Complex boardwalk
- Hall Park Public Swim area

- Soldiers Cove
- Mandurah Quays
- Yanderup Canals
- Port Bouvard - Northport, Eastport + Marina

A tour by boat of the estuary was also conducted with commercial fisherman Bruce Tatham.

1.3 Study Area and Existing Environment

The study area, as per the TOR was the man-made waterways, however other areas were assessed that were spotted while travelling between sites. The study area is depicted in

The Peel Region, with a population of just over 70,000 and growth rate of 4%, is the fastest growing region in WA, and the City of Mandurah is the fastest growing city in Australia (Everall Consulting Biologist, 2002). The region is the main urban area outside of Perth that Perth residents, as well as tourists, travel to for holidays and retirement.

The study area is situated within the Peel-Harvey Estuarine System (PHES), which comprise the roundish Peel Inlet connected to the elongated Harvey Estuary. Total area of the PHES is 133km^2, with an average depth of 0.8m. The estuary is connected to the ocean via the natural Mandurah Channel in the northern end, and by the constructed Dawesville Channel in the south. Construction of the Dawesville Channel was undertaken to improve flushing and water quality of the estuary.

The estuary supports important amateur and professional fisheries as well as water based activities, and has some of the most important waterbird habitats in southwestern Australia supporting migratory birds protected under JAMBA and CAMBA. The estuary is also listed under the Ramsar Convention as a *Wetland of International Significance* (Everall Consulting Biologist, 2002).

The PHES has been cited as the *most important 'commercial estuarine fishery (by weight of catch) in Western Australia'* (Lord & Associates, 1998) two of the important fisheries being crab and prawns (Fish Unlimited et al., 1997). Recreational fishing is also an important pass time in the area, and species caught include (Lord & Associates, 1998):

- Black bream
- Yellow tail trumpeter
- School prawns
- Western King prawns
- Blue manna crabs
- Yellow-eye mullet
- Sea mullet
- Cobbler
- Whiting
- Mulloway
- Tailor

Discussions with canal residents during the site visit for this study, indicated that the following were caught within the canals:

- Whiting

- Tailor (juveniles)
- Bream
- Blowfish
- Herring

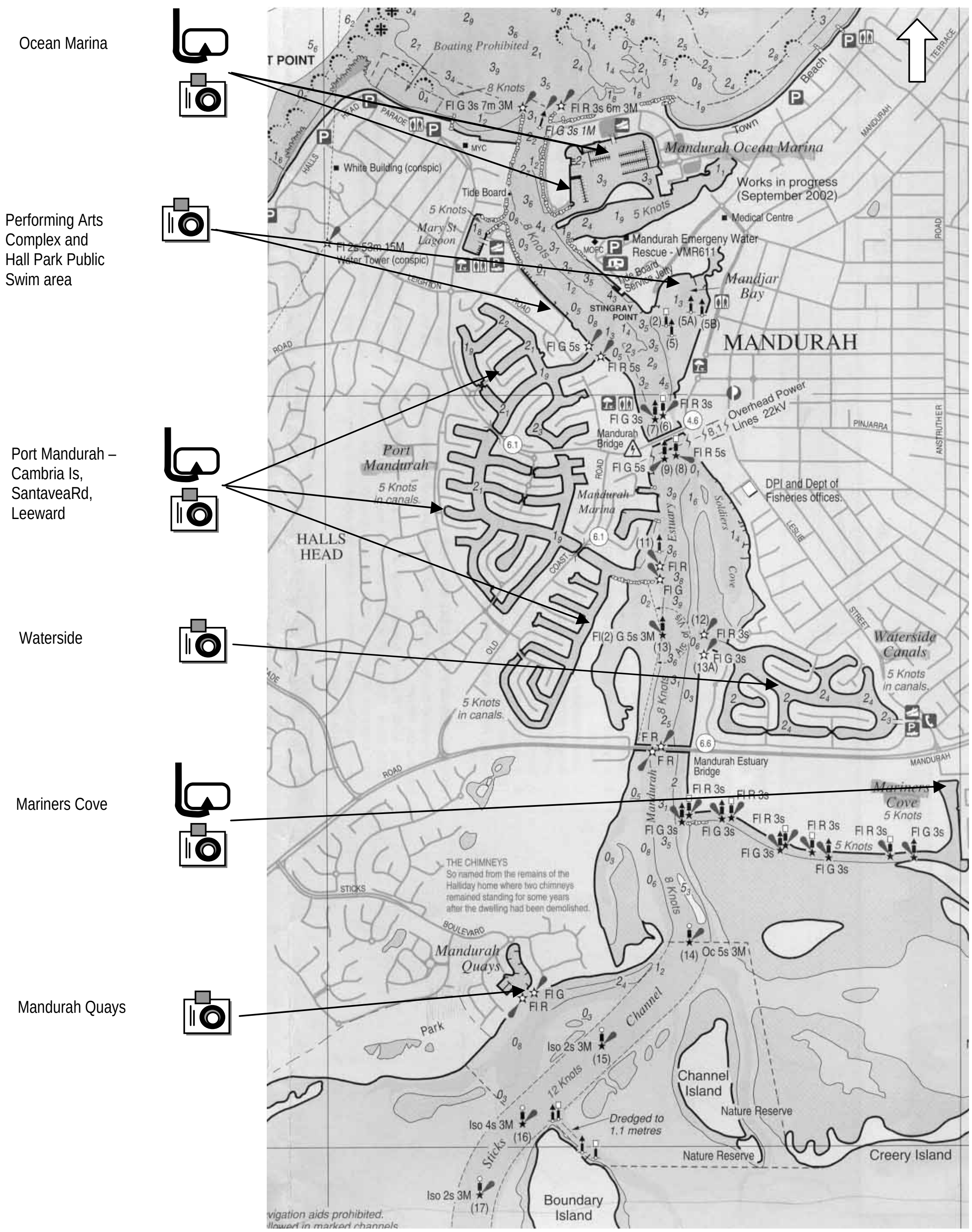


Figure 1. Chart showing study area and places where site assessments were conducted.

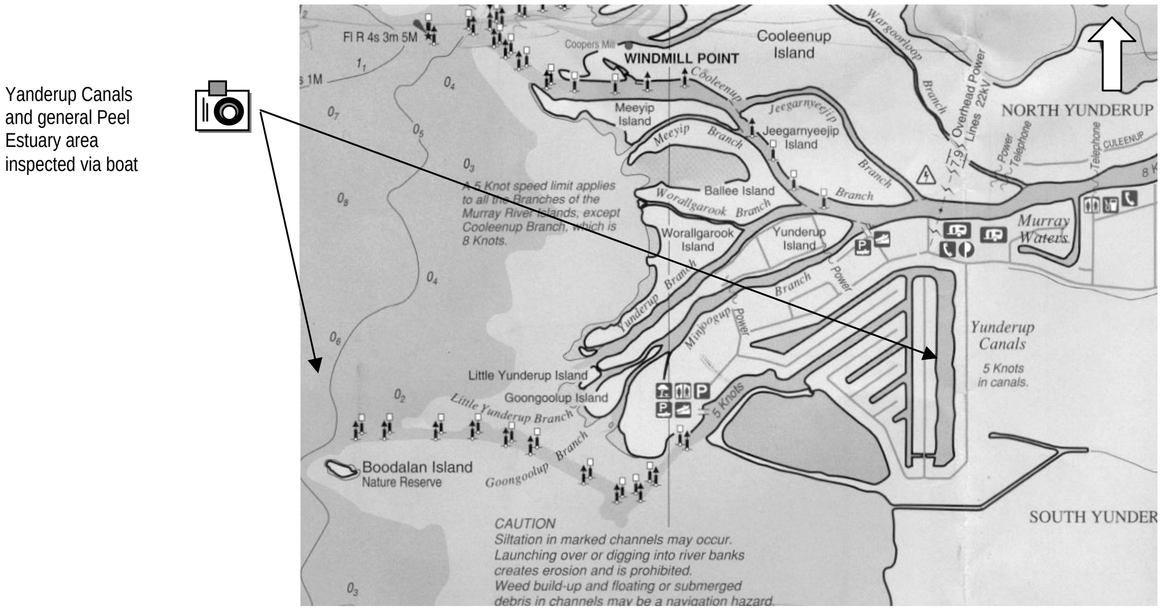


Figure 2. Chart showing location of sites assessed at Yunderup and general area of estuary.

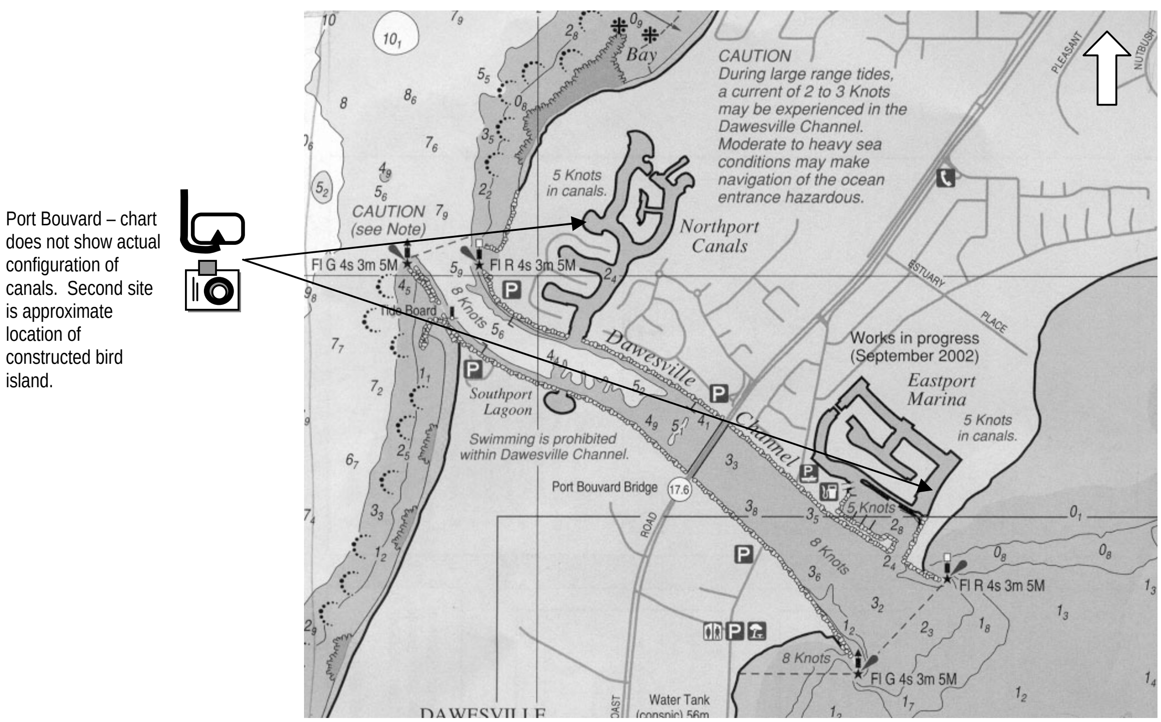


Figure 3. Chart showing general location of areas assessed at Port Bouvard.

2 HABITAT ENHANCEMENT

2.1 Background on Artificial Reefs

An understandable question that was often asked during meetings held for the project was 'do artificial reefs (ARs) work?' Or 'will adding Reef Balls work?' It is important to have realistic expectations for the project and what 'enhancement' may or may not do, and to define the term 'work' with regard to whether ARs work or not.

This section provides a brief overview on what is known about artificial reefs (or not known as the case may be), in order to help provide an understanding of how artificial reef modules attract and support species. It is impossible to specifically predict how each area will respond, therefore any enhancement program should have a process of evaluation, sufficient trial periods and flexibility.

2.1.1 Artificial Reefs – do they work?

The ability for ARs to attract fish as well as other marine life is well known. Jebreen (2001) undertook a comprehensive review of the literature on the biological effects of artificial reefs, and noted:

- Immigration by mobile species occurs rapidly, even before colonisation of reef surfaces has occurred, and can last more than two years.
- Fish have been recorded as travelling as far as 1.6 km from natural reefs to ARs.
- Catch rates and biomass are commonly higher on ARs compared to natural reefs.
- Growth rates appear to be higher on ARs compared to natural reefs.
- Up to 95% of the diet of fish associated with ARs is from the reef itself or the immediate reef-sand interface.
- Fish can be easier to catch on ARs, resulting in decreased fish stocks.

The last point is important to factor into AR programs, including those within the Peel Region. This issue is discussed in the following sections.

In addition, Polovina (1991) has cited studies in tropical and subtropical areas that have found that the biomass on ARs is on average seven times greater than natural reefs. However, in estuarine waters such as those found in the Peel-Harvey Estuary, factors such as water quality may limit the ratio of biomass on an AR. Indeed studies of fish biomass on ARs compared to natural reefs have found that if natural reefs in the same area have lower fish numbers, then so too will ARs placed within that area (Bohnsack et al., 1991).

Not all applications of ARs are focused on biodiversity and biomass. One study constructed an AR below a floating fish farm in the Red Sea to test whether the resulting reef community would act as a 'biofilter' and help reduce excess organic matter produced by the fish farm. The study found a reduction in chlorophyll-a (an indirect measure of nutrients) of 15-35% over ambient conditions (Angel et al., 2002). A residential canal enhancement program in Tampa Florida (USA) deployed small Reef Ball modules to attract oysters with one objective being to increase biofiltration of the water via the natural feeding of the oysters (Clark, 2000).

Some members of the scientific community still debate whether ARs merely congregate fish or actually increase productivity. There are limited large-scale long-term studies to help determine if fish stocks within an area increase or decrease. This is further complicated by the large variation in effectiveness of ARs or even natural reefs from area to area. Initially, it appears that fish migrate from surrounding areas and an AR takes time to reach a level of full production, in some cases five or more years. Constructing ARs is similar to constructing and establishing a community or city. We would not expect to establish a fully inhabited and operational city within a day or even years. Therefore it is important that the community is aware of realistic time frames and appreciate the progressive nature of enhancement programs.

The Reef Ball Development Group (RBDG) (see www.artificialreefs.org), based in the US, has deployed over 500,000 concrete artificial reef modules worldwide. They have adopted the term 'designer reefs' to describe ARs that have included careful assessment of habitat, placement, configuration, community needs, and scientific monitoring and to differentiate them from casual ARs constructed from waste materials. The RBDG believes that this approach is creating ARs that mimic natural reefs in form and function with typically 80% of the species diversity of nearby natural reefs achieved within the first year.

Regardless of whether ARs, including enhancement efforts within the Peel-Harvey Estuary, merely aggregate fish or increase overall productivity, fish are likely to utilise the structures deployed in the Peel-Harvey Estuary. It seems logical that if the structures help sustain a fish population, then these fish have a chance to reproduce and contribute to the greater productivity of the area.

2.1.2 How do Artificial Reefs Work

ARs appear to be attractive to marine species for the following: shelter (predator avoidance), food, shading, and current eddies that can help entrain plankton that fish can then feed on (Jebreen, 2001). There is some evidence that in tropical areas, escape from predation is more important than food (Bohnsack et al., 1991).

2.1.3 Size and Complexity of Artificial Reefs

The vertical and horizontal size of ARs, as well as how they vary in shape (complexity) directly affects species diversity and abundance. In general, the more complex an AR, the more diverse the species composition and greater the biomass (Jebreen, 2001). Horizontal area covered by an AR has been found to be more important than vertical height, and spacing between AR modules must also be considered (Grove et al., 1991).

2.2 Enhancement of the Peel Waterways

The initiative to investigate how the potential enhancement of the Peel Region's man-made waterways should be considered as a 'pilot 'program. It is an ongoing process of deploying modules and observing results.

This investigation and report is one of the starting points of a program that will grow and evolve as experience is gained on how the area reacts to enhancement. The enhancement program will provide valuable understanding of how different species are utilising the structures, and it will inevitably give birth to ideas and other programs as depicted in Figure

4. Progress can be reviewed and existing programs adjusted if necessary, and new ideas explored and developed.

At this stage of the program, there is no objective to target the enhancement of specific species. However as experience is gained, it may then be appropriate to explore specific enhancement activities that target certain species, as well as how natural areas may be enhanced/restored or protected from wave erosion.

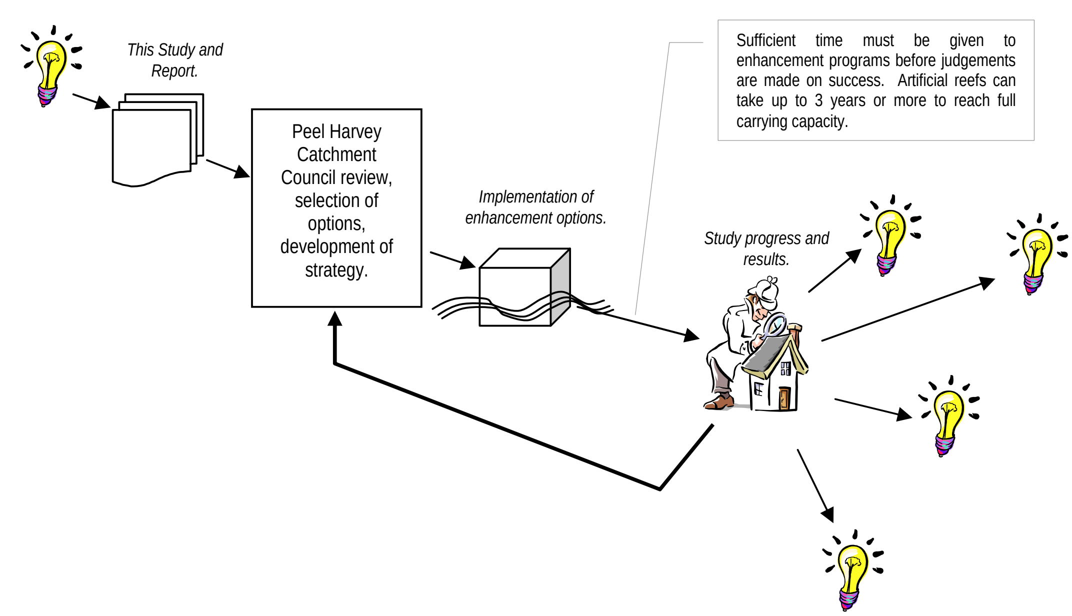


Figure 4. Pictorial representation of the enhancement program and its review and expansion.

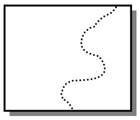
2.3 Methods of Habitat Enhancement

This section provides an overview of methods for enhancing marine habitats, and the following section (Section 3) describes which methods could be applied to specific areas.

This report focuses primarily on enhancement via the addition of concrete modules such as Reef Balls, however there are two other options that should be considered, and could be used in conjunction with or without the addition of Reef Balls. These are physical design changes that can be made to a coastal development that facilitate a more natural interaction with the environment, and the addition of other forms of concrete modules.

The major limitation with the first is that it is only economical to carry out before the structure is built, however there are a few new developments planned for the Mandurah area that may be able to explore these biological design options.

2.3.1 Structural Design Changes for Enhancement



Coastal developments and their various components that extend above and below the waterline are inevitably designed within a limited budget, and constructed to perform a specific function, and to be stable, long lasting and of a form that is considered aesthetically pleasing at the time. Chemical and physical stability are often considered, but this focus can overlook the potential interaction of the structures with the natural environment/biology of the area.

Perhaps the foremost inadequacy in design from a biological perspective is our tendency, for engineering, economic or aesthetic purposes, to construct straight lines. There are few straight lines in nature, yet our built environment has an abundance of straight lines as well as smooth faces. This limits the biological 'attractiveness' of the structure and could be likened to creating a level uniform meadow with only one type of grass. Our most vibrant cities are the ones located within a mix of natural environments such as by a river, mountains or sea, and they have a variety of different style suburbs serving different functions. By incorporating curves and irregular faces in marine structures, we can create below the waterline more 'vibrant' marine communities.

Figure 5shows an example of a very straight canal wall in Mandurah as well as an example of the opposite extreme (but commendable!) curved section. There are several ways straight lines and smooth faces on structures can be reduced without a significant increase in cost. Adding slight curves to canal walls is often not feasible from an economic or functional perspective, however developers should be encouraged to explore areas of a development that may be able to incorporate curved lines.

Figure 5. Photo of a typical straight canal wall, and another showing a variation is possible (Leeward and Eastport).

Enhancing canal walls or rock walls can be achieved in a variety of ways and can be constructed in a way that does not change the presentation of the wall above the water line. A few options are given below.

Option A – irregular block face

There appears to be a trend in the new and proposed canals in the Mandurah area to use smooth straight walls. This option aims to break up the smooth canal wall face by randomly placing blocks that protrude out from the wall face (Figure 6). This creates ledges that can support a greater diversity of growth (eg. filter feeders such as mussels/oysters) and provide shelter underneath for small crustaceans and fish. Canals typically have a fine layer of sediment covering the tops of surfaces and this limits growth due to smothering. The underneath ledges created by the extended blocks can provide escape from this smothering and allow settlement and growth of other organisms.

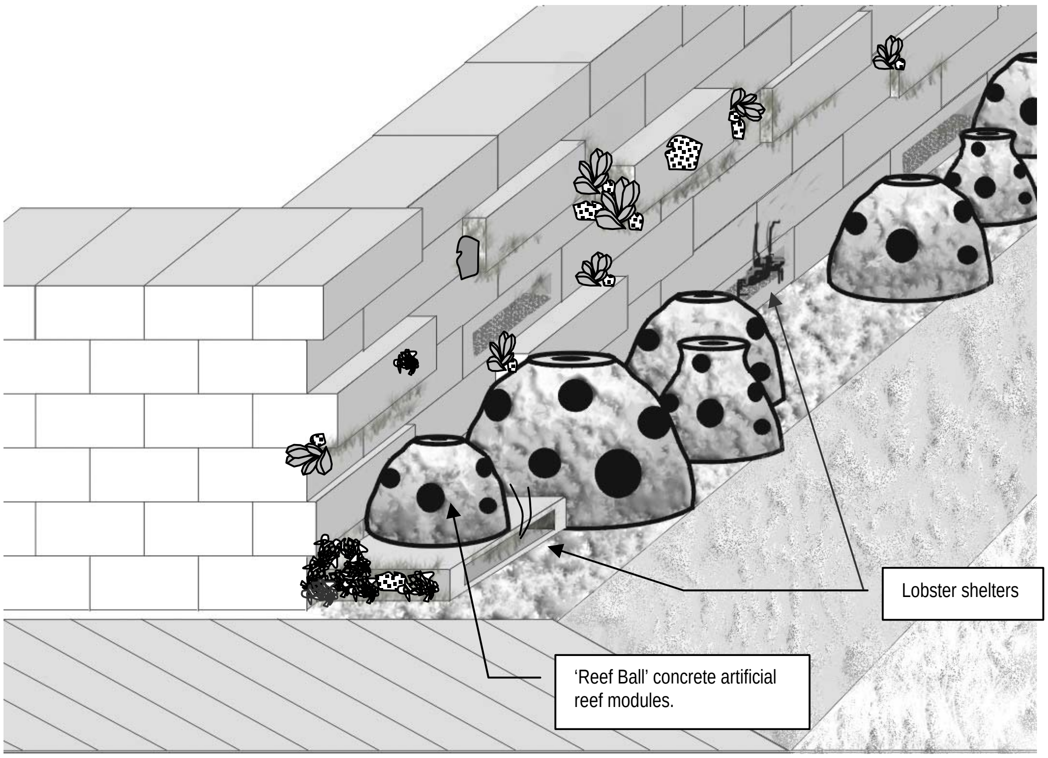
There are many possible variations on this theme that the project engineers could create with their knowledge of available materials, brick sizes and engineering requirements. For example, greater effect could be achieved using bricks with irregular faces, or the occasional hollow brick. Hollow bricks on the bottom layer would create ideal shelters for crabs and lobsters, and possibly octopus, which have all been seen (and caught) in the canals in the Mandurah area.

An added advantage of such design, especially with the artificial reef modules Reef Balls added is the dissipation of wave energy (eg. boat wash). Vertical canal walls can double wave height, therefore the irregular surface and Reef Balls can dissipate some of this energy which would help reduce waves within the canal and possibly reduce forces on the canal slope. Concrete mattresses used on canal slopes can fail due to wave action.

The PHCC needs to be aware that boat wash could be sufficient to lift and move the Reef Balls away from the wall. This is unlikely, however, should trials prove this to be an issue, then either heavier modules could be used, or they could be secured with fibreglass rebar.

Changes to design of canal walls already approved may need to be reassessed and passed by Local Council.

Canal Wall – built-in enhancement with Reef Balls added



Presentation of wall above the waterline does not have to change yet biological attractiveness of wall below the waterline is significantly enhanced. Extended bricks should be random and do not have to be used throughout the whole wall.

An additional advantage is the dissipation of wave energy, especially with the Reef Balls added.

This drawing is for concept purposes only, and exact specifications of such a design would need to be tailored to each development and available bricks.

CONCEPT PURPOSES ONLY. NOT TO SCALE AND NOT FOR CONSTRUCTION	gmidavid@tpg.com.au	CLIENT Peel Harvey Catchment Council Inc. Western Australia	PROJECT Marine Habitat Enhancement – Mandurah: Scoping Study & Recommendations DATE May 2003 FIGURE Figure 6

Figure 6. Example of how the biological attractiveness of canal walls below the waterline can be improved.

Option B – rip rap

This option involves the use of rock rip rap to armour slopes or to create breakwaters and there are two aspects to be considered. One is the size of rocks used and the other is the addition of rock 'spurs', which are discussed in 'Option C'.

The greatest diversity is created when rocks of variable size are used as this creates larger and more varied spaces. The best example of this was seen during the site visit to Mandurah Quay marina, which had a very large range of rock sizes below the waterline. When only one size is used the rocks fit neatly together and almost act like a smooth surface from a biological perspective.

Option C – rock spurs

Rock walls or breakwaters provide significant surface area, and there are many such structures in Mandurah, eg. Mariners Cove and Eastport Marina. Their main drawback is that they are straight, reducing the biological attractiveness of the structure because they become basically two dimensional. It is unlikely that it would be practical to create meandering rock walls; however a significant improvement can be made fairly easily below the waterline by adding rock 'spurs'. This can be done very easily during construction or afterwards using rock or Reef Balls.

The basic concept of a rock spur is shown in Figure 7. Rocks or Reef Balls are placed in a pile just out from the toe of the rock wall; no rocks actually form a connection to the wall. This creates a node that fish can swim around and in-between and increases the width and length of 'useable' area. Fish appear to not only use underwater structures for food and shelter but also for reference as though the structures help orientate them in some way, or perhaps satisfy some other need. An interesting example is the Fish Attracting Devices (FADS) that have been placed off the Mandurah coast. They consist of only a buoy and cable, yet this is enough to attract large schools of fish. The spurs can also help create upwelling eddies that trap plankton on which pelagic fish can feed.

It is important the spurs are not placed at regular intervals along a wall as this could decrease diversity. There does not need to be many; one per 50-80m of rock wall such as that at Mariners Cove is sufficient.

The spurs increase the utilisable area of the structure as depicted in Figure 7. There is an 'edge' effect around any structure or reef and different fish prefer to be at different distances from a reef edge. The longer and wider the edge, the greater the utilisable area. A straight and relatively flat rock wall has a narrow edge or utilisable area that fish can move in and out of. In the example shown in Figure 7, a spur of only 3m in length increases the volume of section 'A' to 2.5 times that of section 'B' adjacent to the wall.

There are several issues to be considered:

- Waves and currents – a rock wall is designed for the local wave climate and it would be essential to confirm with design engineers that the spurs would not reduce the effectiveness of the rock wall or cause scouring or other potential problems due to currents. If the spurs are relatively small and spaced infrequently, this is not likely to be an issue.
- Navigation by water craft – the spurs must not reduce navigable depth and present a hazard to water craft, which they could do if they extend into a channel and are built high enough. One way to avoid this would be to establish them between the rock wall and channel markers, or

other visible structure. Craft are less likely to pass between a channel marker and the rock wall.

- Dredging – if the channel has to be periodically dredged, then this must be taken into account and the spurs constructed so that they do not interfere with this.

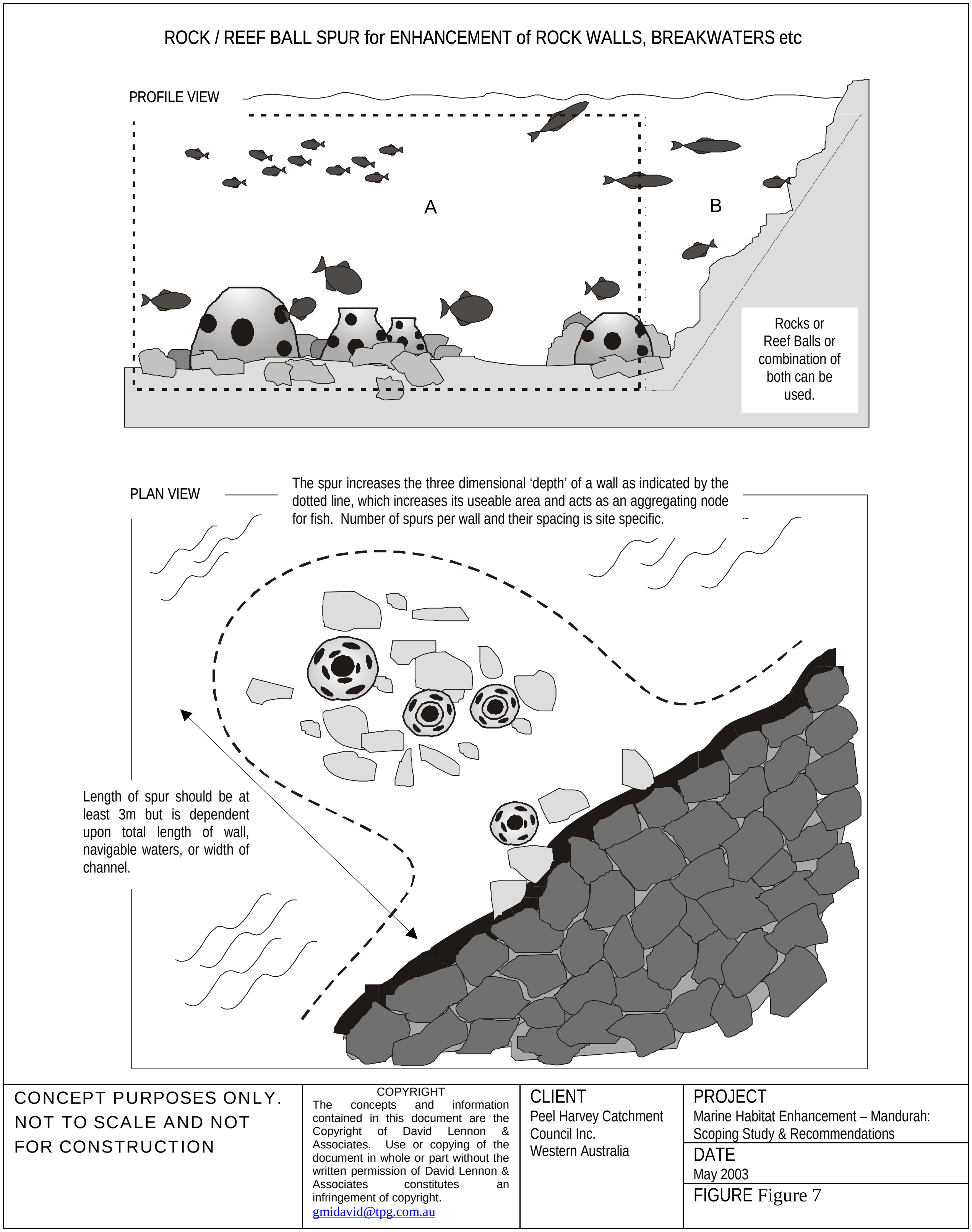


Figure 7. Drawings showing how a 'spur' can increase the biologically active area of a straight wall.

Option D – incorporation of marine vegetation
In nature, habitats are intrinsically linked and it is now accepted that intertidal habitats such as mangroves or saltmarsh areas are essential to the health and productivity of coastal ecosystems. Therefore it is beneficial if a development can incorporate natural intertidal areas either within the development or nearby. There were several excellent examples of this noted during the site visit to Mandurah. One was at Mariners Cove in the area surrounding the sales office, which is the Creery Island Nature Reserve. This area has a wonderful mix of vegetation that will not only provide food but also habitat for different life stages of terrestrial and aquatic animals. Canals that are enhanced adjacent to such areas have the potential to benefit the greatest. Reef Balls may be an option to provide protection to intertidal areas from boat wake. This is currently being undertaken in Florida.

Figure 8. Example of beneficial mix of wall and sand intertidal habitat (Mariners Cove).

Other examples are at Eastport (Port Bouvard), where sandy intertidal areas including small islands are being incorporated into the development, and at Mandurah Quay, which has small low lying sand bars with vegetation just out from the marina entrance. Such areas work well with habitats provided by jetties, rock walls etc.

Seagrass
Seagrasses help stabilise sediments and trap fine sediments and reduce their re-suspension therefore improving water quality. They also support nitrogen-fixing bacteria, provide shelter, and are a food source for many marine animals including prawns, crabs, fish, turtles and dugong. Seagrasses are considered one of the most productive ecosystems in the world and the combination of reef with seagrass meadows within a coastal development would be almost ideal.

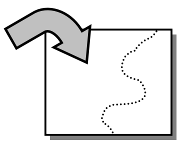
Seagrass is likely to be already in some of the canals, or will eventually find its way into the newer canals, however this could take many years. Another option is to transplant seagrass into areas within a development that has suitable water quality and sediment to support it. This has been achieved in projects around Australia including Cockburn Sound in WA, and a program has been proposed in Queensland by David J Lennon & Associates, whereby local residents are involved in planting the seagrass before the new canal is fully flooded.

The option to establish seagrass was not within the scope of this study to explore this option in detail, however contact was made with Dr Eric Paling, Director of Marine and Freshwater Research at Murdoch University. Dr

Paling has been involved in developing the methodology for transplanting *Posidonia* (strapweed) in Cockburn Sound, and didn't hesitate to offer support of initiatives to establish seagrass in canals. He felt *Posidonia* would not be an ideal species because it can clog motors and wash up on beaches. However *Halophila ovalis* (paddle weed) would be a suitable species as it currently exists in the Peel Inlet and is fast growing and could be established by transplanting rhizome fragments collected from an approved location, or by seed. It may be possible to obtain this seed from a seed bank operated by scientist Karen Hilman in Perth.

The sowing of seeds or transplanting of rhizomes could be a community exercise and would create a sense of ownership amongst participants and this could translate into greater respect and protection for it. It would also offer numerous research opportunities, and create a lot of media interest.

2.3.2 Enhancement using Reef Balls



The majority of man-made waterways in the Peel Region are already constructed, therefore it is not possible to incorporate structural design changes. The recommended enhancement option is therefore the strategic addition of specifically designed artificial reef modules called 'Reef Balls'.

Reef Balls are a US invention that has now become the world's leading artificial reef module, with over 500,000 deployed worldwide in 3,500+ projects. The PHCC investigated the option of Reef Balls prior to commissioning this study, and stated an interest in recommendations of their suitability for the Peel Region. They would be the best choice of module for the programs by the PHCC.

Reef Balls are produced using a patented mould system and high quality concrete with no toxic additives. The moulds are produced and sold by the Reef Ball Development Group (RBDG) which is a non-profit environmental organisation based in Florida with a mission *to "help restore and protect our world's ocean*". Reef Ball projects "*emphasize on-going research, public education, community involvement, and reefs that promote and support natural species diversity and population density"*.

Reef Balls come in a range of different sizes ranging from just a few kilos to over 5 tonnes. Specification of the recommended sizes for the Peel Region are provided in Table 1. This selection of modules would be an 'ideal' mix of sizes to maximise diversity. Two different sizes of module is better than just one size, and three different sizes is approaching an optimum combination to encourage diversity. The assemblage of species that each size attracts is site specific and will become apparent with time, and this knowledge will help direct future additions.

Table 1. Specifications of Reef Balls recommended for the Peel Region.

Reef Ball Style	Width (m)	Height (m)	Weight (kg)	Concrete Vol (m^3)	# of Holes
Bay Ball	0.9	0.61	170-340	0.080 - 0.10	4-16
Mini Bay Ball	0.76	0.53	68-90	0.02 – 0.03	4-12
Lo-Pro Ball	0.61	0.46	36-59	-	4-10
Oyster Ball	0.46	0.30	14-20	-	4-8

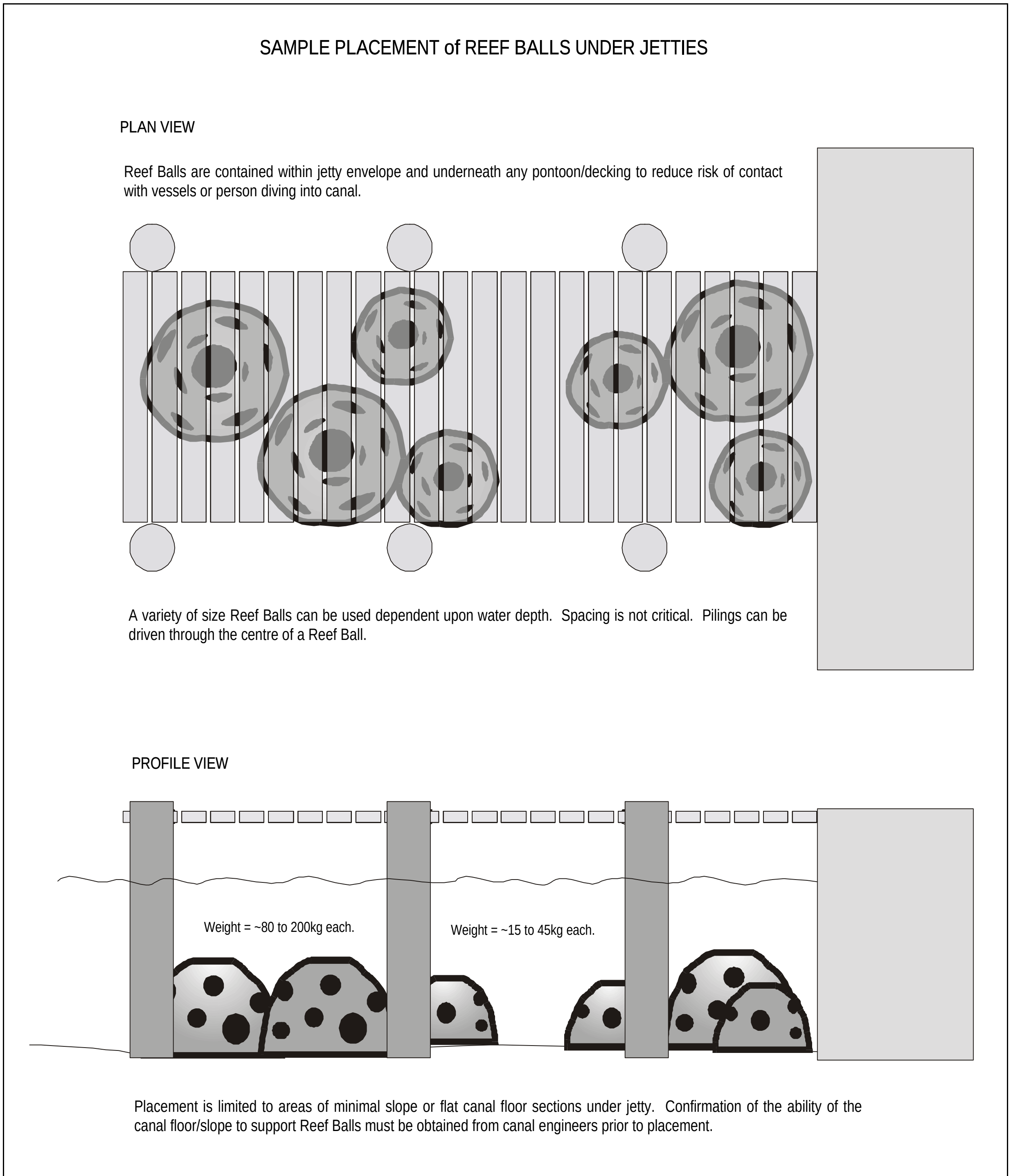
The modules have also been selected for their size and weight which matches the size of wall ledges available and typical water depth (ie <3m). Because they are concrete, their weight is an issue when it comes to ease of deployment, and the modules below the Bay Ball size are easily handled and lowered into position, eg. down canal walls. Since canal wall is the predominant structure, the smaller modules, ie. the Lo-Pro and Oyster Balls are likely to be used the most.

The final mix of modules will depend upon which areas the PHCC decides to start with, and this decision can be done in consultation with David J Lennon & Associates and/or the RBDG.

Jetties

Discussions with the PHCC indicate that the enhancement of substrate underneath private jetties will be a priority. Figure 9 shows how Reef Balls can be added to jetties to increase the biological attractiveness of the structure. Experience from the US suggests that there isn't such a concern with spacing between modules as there is with larger reefs. Therefore placement can be at the discretion of the people involved in deploying the modules and/or the jetty owner.

Figure 9 is a simplified drawing showing Reef Balls under a jetty, and placement would be dependent upon canal slope and bottom material. It appears as though 70-80% of jetties constructed in the canal estates in the Peel Region have jetties that stop at the toe of the canal slope, therefore there is no flat bottom under the jetties (R.Howard, City of Mandurah Engineer, *pers. com.*). Waterside Canals are the only ones that have flat canal bottom under their jetties. According to drawings provided by Council, most canals have a wall slope of 1.5:1. While this is not excessive, it does mean that more detailed investigations, including perhaps a trial will have to be conducted to see whether Reef Balls will remain in place on such a slope or will slide down. If the slope is rock or compact sand, then the modules will probably stay in place. In some applications in the US the modules are secured by fibreglass re-bar hammered into the bottom. However some of the canals in the Peel region are using a concrete 'mattress', therefore this option would not be possible.



CONCEPT PURPOSES ONLY. NOT TO SCALE AND NOT FOR CONSTRUCTION	COPYRIGHT The concepts and information contained in this document are the Copyright of David Lennon & Associates. Use or copying of the document in whole or part without the written permission of David Lennon & Associates constitutes an infringement of copyright. gmidavid@tpg.com.au	CLIENT Peel-Harvey Catchment Council Inc. Western Australia	PROJECT Marine Habitat Enhancement – Mandurah: Scoping Study & Recommendations DATE May 2003 FIGURE Figure 9

Figure 9. Example of how Reef Balls can be used to enhance jetties.

Enhancement programs have the opportunity to increase the public's appreciation for the environment. Creating reefs by deploying waste/junk items such as tyres, pipes, scrap steel, etc does not carry a high degree of respect and is little more than dumping. This can promote an attitude that it is OK to throw junk into the sea, and in Queensland items such as boat batteries, shopping trolleys and even a fridge have been found thrown in. The effort and expense taken to use specific built modules for the enhancement program makes a strong statement to the community about the Council's commitment to improving the local waterways and the level of attention they deserve.

The main reasons why Reef Balls are a successful artificial reef module are the following:

- Durability – they are designed to last several hundred years therefore providing a lasting asset.
- Marine friendly concrete – they are made using a concrete mix that is less alkaline than normal therefore more attractive to fouling organisms, and no toxic additives including steel are allowed to be used.
- Productivity – they have proven to mimic natural reefs in form and function and are utilised by juveniles whereas other artificial reef types may only attract adults. No two modules are the same, as hole numbers and sizes vary in each module therefore habitat diversity is increased which helps mimic the diversity found in nature.
- Aesthetically pleasing – they are designed to look natural and once covered with natural growth they resemble natural rocks or bommies. This is a bonus for canal enhancement programs that will have snorkeling reefs and modules visible from the surface.
- Stability – due to their dome shape, hole in top and majority of weight in the lower one-third of the module, they are very stable. Reef Ball reefs have now survived several hurricanes off North America and have not moved whereas wrecks and even boulders nearby have moved.
- Promotion – using Reef Balls allows the groups involved to tap into the wealth of knowledge of the Reef Ball Foundation, access grants, gain international publicity, and have a proven product to promote.

Extensive information regarding Reef Balls can be found at the following websites:

www.artificialreefs.org
www.reefball.com

2.3.3 Enhancement using Non-Reef Ball Concrete Modules

There is the option of making custom or 'free-style' modules out of concrete using balloons, buckets, sand, and other materials and some imagination. This could be something school groups could get involved in. Under supervision, students could manufacture 'fish houses' and then monitor them to explore what marine animals take up residence in their house. This encourages students to think about what different animals require in the way of habitat, and could generate useful designs for elsewhere.

Species specific modules can be made that are particularly attractive to certain animals. Two examples would be habitat for lobster and octopus.

Lobsters are relatively easy to accommodate and mainly require overhangs or caves with wide low openings. Octopus can be harder to please, and are not communal animals and continual roam, therefore it can take a lot of octopus houses to gain one octopus resident.

Figure 10. Photo of unique custom made modules that could be suitable for school groups.

2.4 Integration with other Programs/Groups

If an enhancement program is initiated, it is recommended that efforts be made to tie the program in with other land based or estuary/river restoration/enhancement programs. For example, this may take place by a Project Leader from the marine enhancement program attending and giving a talk at a river bank restoration group meeting, and vice versa. Limited time and resources often do not permit this, however valuable sharing and cooperation can be developed between groups that are working with ecosystems that are interlinked. Programs such as 'Adopt a Wetland' or 'Adopt a Creek' make have working models that could be applied to 'Adopt a Canal' program for example.

An enhancement program can and should involve the community as much as possible, and discussions with the PHCC confirm this is their intent. In fact the programs will be dependent upon the community for donation of time, materials, equipment, and in some cases money. The programs recommended in this report assume that the PHCC, or whoever manages the program, consider at least the following groups outlined in Figure 11.

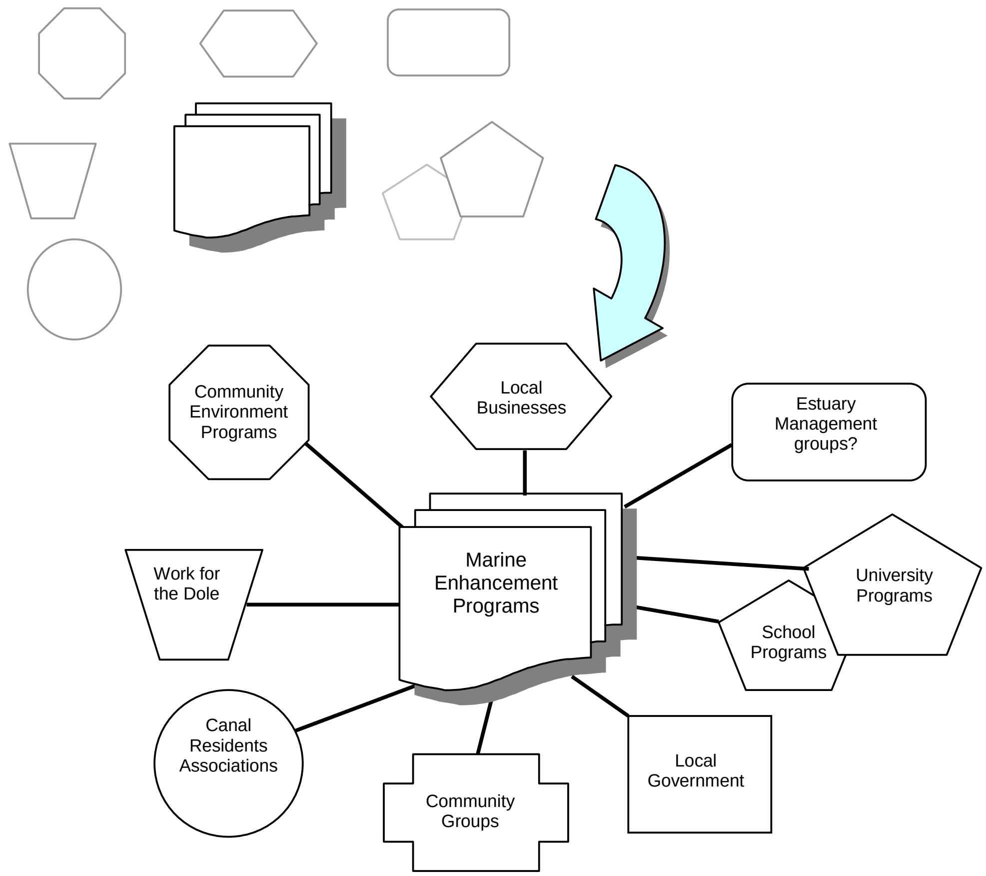


Figure 11. Illustration to emphasise involvement of numerous groups in marine enhancement programs.

2.5 Ranking of Sites for Enhancement

- *Program objective is general enhancement of biodiversity with no specific species targeted during the first stage of the program.*

In order to help prioritise where efforts and resources should initially be directed, each site was judged on its potential to benefit from enhancement and/or its ability to respond to enhancement and provide a return value, eg species diversity or abundance, or community benefits. This was done using the criteria outlined in Table 2. Enhancement programs should have clear objectives, and the objectives for the first stage of this pilot study into enhancing the man-made waterways is to increase biodiversity in general and gain a better understanding of how local species are interacting with materials added.

Assessment of such criteria is subjective or based on data where available, and presented only as a guide to demonstrate to the Steering Group the logic behind the recommendation of the most suitable sites. The criteria were not weighted for this study, however the PHCC are advised to consider adding their own weighting to the criteria as part of their internal assessment of options.

Table 2. Criteria used to assess and rank each site for enhancement potential.

	Feature / Attribute	Description	Rating
1.	Water Quality	Clarity/turbidity, salinity fluctuations, residence time of water (flushing rate), potential for serious contamination, stratification. NB: quality rating is relative to the existing system and between sites, and not pristine ocean or estuary waters.	★ = very poor ★★= poor ★★★ = average ★★★★ = good ★★★★★ = excellent
2.	Existing Substrate Material	Sediments and ability to support concrete modules	★ = very poor ★★★★★ = excellent
3.	Bottom Profile	Slope profile, space available for modules.	★ = very poor ★★★★★ = excellent
4.	Neighbouring Habitats	Habitats considered productive and/or essential contributors of food or shelter such as wetlands, saltmarshes, seagrass meadows.	★ = very poor ★★★★★ = excellent
5.	Existing Biota	Diversity/abundance of fish, crustaceans and fouling organisms as an indicative potential of what could be present.	★ = very poor ★★★★★ = excellent
6.	Potential Diversity/Abundance	Estimated potential of the site to attract a range of species and/or increase abundance, as well as attract new species, relative to existing species at the site.	★ = very poor ★★★★★ = very high
7.	Permit Requirements	Complexity of permit process to carry out enhancement options.	★ = very complex/costly ★★★★★ = none required
8.	Access and Ease of Deployment	Availability of suitable access points and travel distance from module construction area (by land and water).	★ = very limited access ★★★★★ = excellent access
9.	Educational Value	Ability for the site to be used for community, school, or university studies, or education.	★ = very poor ★★★★★ = excellent
10.	Value Adding Potential	Ability for enhancement to contribute significantly to the 'value' of the area, or incorporate other value adding options such as underwater live video, educational trails.	★ = very poor ★★★★★ = excellent
11.	Sponsorship Potential	Attractiveness of the site and its enhancement for sponsors, ie exposure, 'feel good' factor, potential return on investment.	★ = very poor ★★★★★ = excellent
12.	Cost – reported in Table 4	Estimated level of cost to implement a suitable enhancement program for the site, including transport, permits, number of modules, deployment, monitoring, and other ongoing costs.	★ = very low ★★★★★ = very high

Table 3. Ranking of each site for enhancement potential.

★ = very poor, ★★= poor, ★★★ = average, ★★★★ = good, ★★★★★ = excellent

Site	Water Quality	Existing Substrate Material	Bottom Profile + space	Neighbouring Habitats	Existing Biota	Potential Diversity/ Abundance	Permit Requirements	Access and Ease of Deployment	Educational Value	Value Adding Potential	Sponsorship Potential	*TOTAL SCORE*	RANKING
Ocean Marina (incl Dolphin Quay)	★★★★ (potential for oil/heavy metals)	★★★★	★★★★★	★★★	★★★★	★★★★★	★★★★	★★★★★	★★★★★	★★★★	★★★★★ (high public profile)	*48*	1
Hall Park Public Swim area	★★★★★	★★★★★ (currents could be an issue)	★★★★	★★★★	★★★★	★★★★★	★★★?	★★★★	★★★★★	★★★★	★★★★★ (high public profile)	*48*	1
Northport – Village Beach and Bouvard Village	★★★★★	★★★★	★★★	★★★	★★★★	★★★★★	★★★★	★★★	★★★★★ (snorkeling beach for school projects)	★★★★★ (options such as u/w webcam)	★★★★★ (high public profile)	*46*	2
Mariners Cove (Sales Office + marina area)	★★★	★★★★★	★★★★	★★★★★ (Creery Wetlands Nature Reserve)	★★★★	★★★★	★★★★	★★★	★★★★★	★★★★	★★★★★ (high public profile)	*46*	2
Leeward Canals	★★★	★★★★★ (good mix of rock sizes)	★★★★★ (incl. ledge at foot of canal wall)	★★★★★ (Nature Reserve)	★★★★	★★★★	★★★★	★★★	★★★★	★★★★ (tie-in with Nature Reserve)	★★★★ (mainly residents)	*45*	3
Eastport Marina	★★★★ (potential for oil/heavy metals)	★★★★	★★★	★★★★ (diverse channel plus Nature Reserve)	★★★	★★★★★	★★★★	★★★★	★★★★	★★★★	★★★★★ (high public profile)	*44*	4
Eastport – Foreshore Reserve Canal	★★★★	★★★★	★★★ (mattress revetment)	★★★★★ (Adjacent to Nature Reserve))	★★★ (not established yet)	★★★★★	★★★★	★★★	★★★★	★★★★	★★★★	*43*	5

Site	Water Quality	Existing Substrate Material	Bottom Profile + space	Neighbouring Habitats	Existing Biota	Potential Diversity/ Abundance	Permit Requirements	Access and Ease of Deployment	Educational Value	Value Adding Potential	Sponsorship Potential	*TOTAL SCORE*	RANKING
Soldiers Cove	★★★★	★★★★★	★★★★	★★★★★ (small barrier saltmarsh island)	★★★?	★★★★	★★★?	★★★★	★★★	★★★	★★★ (mainly residents)	*41*	6
Performing Arts Complex boardwalk	★★	★★★	★★★★	★★★	★★★	★★★	★★★	★★★★	★★★★★	★★★★	★★★★★ (high public profile)	*39*	7
Mandurah Quays	★★★★	★★★★? (excellent varying rock sizes)	★★★?	★★★★ (nearby saltmarsh islands)	★★★★ (ample abundance already)	★★★★	★★★?	★★★	★★★	★★★	★★★ (mainly residents)	*38*	8
Santavea Rd Canals	★★★	★★★ (good variable rock rip rap, 30cm soft mud)	★★★?	★★ (potential for seagrass?)	★★★	★★★★	★★★★	★★★	★★★	★★★	★★★ (mainly residents)	*35*	9
Cambria Is Canals	★★★	★★★	★★★?	★★	★★	★★★	★★★★	★★★	★★★	★★★	★★★ (mainly residents)	*32*	10
Waterside Canals	★★★	★★★	★★★?	★★	★★	★★★	★★★★	★★★	★★★	★★★	★★★ (mainly residents)	*32*	10
Yanderup Canals	★★ (estuarine, tannin rich, turbid)	★★★	★★★?	★★	★★★	★★★	★★★★	★★★	★★★	★★★	★★★ (mainly residents)	*32*	10

From this ranking, the sites that fall within the top three are:

1. Mandurah Ocean Marina and Hall Park Public Swim area.
2. Port Bouvard – Northport, and Port Mandurah – Mariners Cove.
3. Port Mandurah – Leeward.

This system of ranking the sites has limitations just as any system does. It is, however, a useful starting point and encourages discussion and analysis of the sites. It is also provides a useful summary of the merits of each site, which the PHCC or other groups can take into consideration and perhaps narrow down. For example, a group or Council could choose to select the sites only on their ability to attract maximum diversity, or closeness to natural wetland areas.

The following points should be considered regarding the ranking of sites.

- Assessing the sites required a level of judgement based on experience of similar areas, and the information gained during the short time available for the site visit. Therefore the rankings are a starting point and a guide only, and should not be considered to be absolute and final, or a mandate that the PHCC cannot choose to prioritise other sites. Comments from the PHCC are welcome.
- Ultimately, it will be the decision of the groups involved as to which areas are enhanced first.
- Available funding and its source, eg sponsorship, will also play a role in dictating where efforts are directed.
- The rankings should NOT be taken to mean that the lower ranked areas are not worth attention. It is likely that residents or other groups could have different objectives than those represented by the attributes used in this ranking system, therefore lower ranked areas could become higher priorities.
- The rankings have no weightings attached to the different attributes, therefore all attributes are considered to be of equal importance. The PHCC may wish to add weightings if necessary to help internal decision making.
- The success of each program at each site, and the ability for each site to achieve the ranking it has been given is very much dependent upon the effort put into it. For example, one of the reasons the No. 1 ranked site the Ocean Marina (and proposed Dolphin Quay) is a leading site is because of its close vicinity to Mandurah, its public access and significant potential to use the enhancement for public display/education. However, if this aspect is not utilised fully, then the value of the site will be decreased.
- The rankings can be extrapolated to cover the other canals within the same development as the site surveyed, eg the rankings for Santavea Rd canal could be used for other canals nearby. However, prior to deployment some investigation of factors such as canal floor should be made.

2.5.1 Ranking by Cost

Cost was separated from the main ranking table because it is highly variable. For example one site may only require a few modules, however a canal estate could utilise hundreds. Cost was included however to provide an indication of the cost of initiating a reasonable level of enhancement at each site. The costs are relative to the specific area, therefore the lowest and simplest enhancement option is used as a benchmark for the others. Costs also take into account expenses such as transport of modules to site, deployment, promotion, permits, signage, and additional design studies. Details of enhancement strategies for the top sites are provided in Section 3.

Table 4 Approximate enhancement cost to initiate enhancement.

★ = very low, ★★= low, ★★★ = medium, ★★★★ = high, ★★★★★ = very high cost

Site	Cost
Eastport Foreshore	★★★
Northport	★★★
Ocean Marina (incl. proposed Dolphin Quay)	★★★
Leeward	★★
Eastport Marina	★★★
Hall Park Public Swim area	★
Cambria Is	★★
Santavea Rd	★★
Mariners Cove (Sales Office + marina)	★★
Waterside Canals	★★
Performing Arts Complex boardwalk (u/w lighting could add an ongoing cost)	★★
Soldiers Cove	★★
Mandurah Quays	★★
Yanderup Canals	★★

The least expensive option is the Hall Park Public Swim area. This site only requires a small number of modules and has minimal transport and deployment difficulties. This is discussed further in Section 3.

The most expensive sites are the Ocean Marina, Northport, and Eastport. This relates to the number of modules that would be used, time to position and deploy them, signage for public education, school programs that may participate, monitoring costs, and distance of transport of modules to actual deployment location.

Some expenses may not be actual costs as some resources will be donated.

3 ENHANCEMENT RECOMMENDATIONS

This section outlines how each of the top sites, as ranked in the previous section could be enhanced as a starting point for the first stage of this pilot program. The TOR required the top 3 sites to be discussed however rankings were very close and more than 3 sites have merit, therefore strategies for the top 7 sites have been provided. Strategies provided could also be applied in most cases to other sites.

Canal Jetties
The option of involving canal residents and enhancing the area underneath their private jetties is not discussed at this stage due to unsuitable canal wall slope in most canals. However, this needs to be confirmed and could be possible in some areas.

Indicative Costings
Indicative costings are provided for each site, however estimating costs is difficult due to the numerous components involved and the fact that it is not known at this stage what resources will be available and at what cost, if any. Therefore indicative costings are an estimate of the cost of modules required and token fee to for meetings and setting up of each site. Module prices are based on what is considered a medium-high cost per module and if cement, sand, gravel and silica fume is bought in bulk quantities the unit cost could be reduced by ~20%. US prices for modules delivered are almost twice the price used here. A $10 per module fee (regardless of size) has been factored in to help offset the cost of transport to site, which may require the use of a truck. Further costs for purchase of moulds, equipment and training is provided in Section 4.

3.1 Site 1 – Ocean Marina (including proposed Dolphin Quay)

This site includes the boat harbour, Commercial Fisherman's Jetty, associated retaining walls to the north and northeast, and the proposed Dolphin Quay complex, which will include shops, restaurants, cafes and market stalls.

3.1.1 Reef Type and Layout

Reef Ball modules consisting of:

- Bay Balls
- Mini Bay Balls
- Lo-Pro Balls

Three main configurations of modules:

1. <u>Commercial Fisherman's Jetty</u> – along the base of retaining wall in groups of three (two Lo-Pro and one Mini Bay Ball) with occasional gaps of approximately 0.5-2m between groups (Figure 12). There can be a variation of sizes of reef ball in each group and several could be placed in the southern corner.

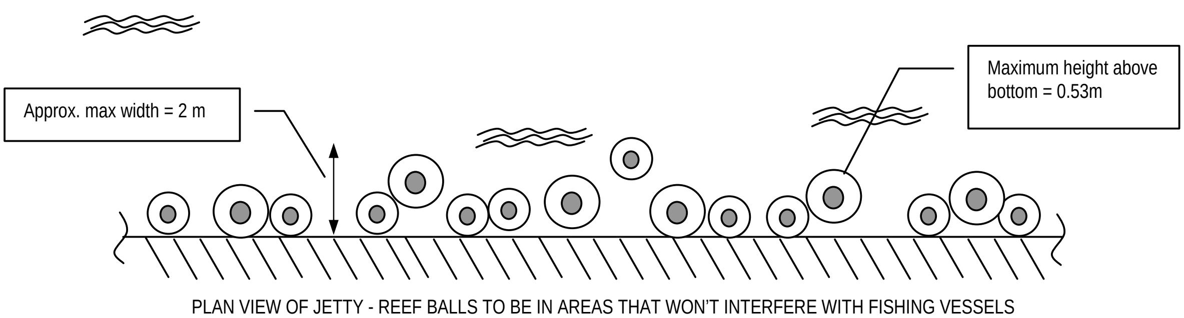


Figure 12. Basic configuration of module groupings to go along base of retaining wall.

No modules should be placed in navigable channels, areas that may require maintenance dredging, or where people may dive into the water and potentially hit the modules.

2. Marina wall – north to east section

This is the section of wall that runs from the public ramp at the northern side of the marina to the east and then south. There is already rock rip rap along this section however it provides minimal 3D habitat and would be ideally complemented by the void spaces provided by Reef Balls.

It is recommended initially that a total of 150m of wall be enhanced which is split into a 100m section along the northern wall and a 50m section along the eastern wall. To create more diversity it is suggested that modules be placed in 10m sections with 8-10m gaps between sections. Each 10m section would be made up of 5 Lo-Pro Balls and 3 Mini-Bay Balls. This equates to a total of 40 modules for the 100m section. These distances are only a guide and could vary when modules are actually placed. For example it may be worthwhile connecting two 10m sections without a gap between them.

The 50m section could follow a similar pattern but to add some variety, add 20 Oyster Balls. The addition of larger Bay Balls (5) could also be added to act as nodes along the walls.

3. Dolphin Quay

Recommended number of modules:
5 Bay Balls, 11 Mini Bay Balls,
20 Lo-Pro Balls, 15 Oyster Balls.

Dolphin Quay could use a multitude of options to capitalise on its high profile and patronage (see value adding section), and has the advantage of not being constructed yet. The following is considered a starting point and other options could be developed in consultation with the Project Developer. Dolphin Quay will naturally add a lot of structure to the marina, however it is unlikely to vary significantly from the existing pilings and pontoons. Therefore there is opportunity to use the development as a means to add more diversity.

The initial recommendation is to enhance the bottom under the main front of the large deck that is being built to accommodate tables (Error! Reference source not found.). The modules should be kept under the deck in order to prevent contact with boats and potential injury should someone accidentally dive on them. Due to the fact the development is not yet built, there could be the option of driving some of the pilings through Reef Balls. This has been done in the US and creates added diversity around the base of each piling. Modules could be grouped under either one or both corners as this is an area the fish will likely prefer, will have maximum water flow, and allows viewing from two sides. A total of 51 modules is recommended made up of three sizes to create maximum diversity.

There could be equal value in enhancing areas underneath other sections. This would help provide patrons added marine life to view while dining or strolling along. There is also the option to create viewing platforms as discussed in the value adding section.

Suggested areas for initial enhancement.

Figure 13. Dolphin Quay display board showing proposed development.

3.1.2 Strategy

Underwater video transects at all sites should be conducted prior to deployment if it is a part of the monitoring program.

There is no particular order for the three different areas. Deployment at Dolphin Quay will depend upon its construction process. program.

Modules can be deployed from the back of a flat bed truck parked at the various jetties/wharves, and lowered down to the base of the wall using a truck mounted crane. Inaccessible areas such as under jetties will require deployment by boat. At the shallow sections of wall, modules can be lowered by hand and manually placed into position by 2-3 people.

Modules could be stockpiled at an area nearby, for example the vacant block allocated to the Water and Rivers Commission, and a public display made from them (including signage for sponsors if appropriate).

Prior to deployment, it would be a good idea to remove all construction rubbish from the areas to be enhanced, if not elsewhere as well. This helps set the 'tone' for how the marine environment is to be treated in the area. A neighbourhood 'working bee' may be useful to achieve this and increase community ownership of the enhancement.

3.1.3 Value Adding Options

- *Public Viewing Platform*

There is potential to construct a reef that is incorporated into the design of the Dolphin Quay deck. Public viewing platforms could be provided by constructing open sections (with guard rails) that allow people to look down on top of modules placed in and around the pilings underneath the deck.

This area could be further enhanced by providing informative signage and underwater lighting for a nighttime experience.

- *Live Feed Underwater Video*

Another option could be the installation of an underwater live feed video camera such as the 'MarineCam' installed on the Busselton Jetty by Discrete Data Systems (DDS, 08-9226-0105) and the Water Corporation. Images could be transmitted to flat screen TVs on café/restaurant walls as well as associated websites, sales offices, Council offices, and Performing Art Complex foyer. This would not only provide entertainment, but help take the viewer below the water line and potentially feel more connected and aware of activity below. It would also collect valuable data for research purposes. Cameras directed to areas most likely to have the greatest growth of encrusting organisms would provide valuable time series images to study colonisation of a variety of surfaces and, among other things, could be used to direct future enhancement programs.

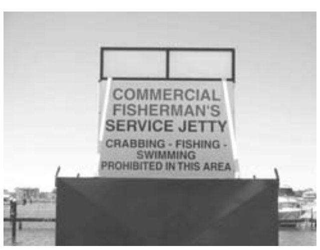
Such an option is highly dependent upon water clarity, therefore needs to be designed to provide close-up wide angle shots of modules, and should preferably be located midwater or no deeper than 2m in order to have sufficient light. Dark murky images would not provide positive promotion. Cameras angled slightly upwards from midwater depth would capture schooling fish. Exact positioning of cameras for the clearest and most interesting shots would require some testing and time to allow for colonisation and fish assemblage to build. A specific underwater landscape could be constructed for the camera to focus on, and is an area that later on could incorporate species-specific modules.

- *Feeding of Fish*

The sale of quality fish food for people to feed the fish within the viewing area(s) could be an option for this particular site. There would be no shortage of schooling fish attracted and this would provide dynamic video images as well as another way for people to interact with local marine life. However, feeding of wildlife as well as the potential to add nutrients to a system is not always appropriate, and would need to be controlled in some way (eg. at certain times only). This option is presented for consideration and is not a recommendation.

3.1.4 Benefits and Expectations

The area already has a relatively diverse assemblage of fish and encrusting species, therefore any added modules will be readily utilised. Additional diversity of habitat has the potential to increase this assemblage and possibly bring other species into the area.



Due to the high public profile of this site, it has the potential to contribute to community awareness about the enhancement initiatives in the region (including land based programs) and foster an attitude of respect and appreciation for the local marine life.

An added advantage of the Commercial Fisherman's Jetty area is that fishing is prohibited, therefore this area will protect fish stocks without requiring changes to existing usage.

Reef Balls along the walls would contribute somewhat to the dissipation of boat wash and potentially help reduce waves within the marina.

3.1.5 Indicative Costs

Costs are basic estimates only and do not include cost of additional design work, permit approvals, monitoring, maintenance or value adding options.

Ocean Marina	**Quantity**	**Approx. cost/unit**	**Total Unit Cost**
BAY BALL	5	$90.00	$450.00
MINI BAY BALL	34	$60.00	$2,040.00
LO-PRO BALL	58	$40.00	$2,320.00
OYSTER BALL	20	$20.00	$400.00
OTHER			$0.00
Module subtotals	117		$5,210.00
Project set-up costs			$3,000.00
Deployment costs			$1,170.00
Monitoring costs			
On-going maintenance			
ESTIMATED TOTAL	**$9,380.00**		

3.2 Site 2 – Hall Park Swim Area

This site is the public swimming area created by two floating pontoons installed perpendicular to the shore, approximately 50m apart and extending approximately 35m out into the Mandurah Estuary (Peel Inlet entrance). The bottom profile gently slopes to approximately 3m depth at the end of the pontoons and was generally featureless except for a small tyre and occasional small rock.

Sediments are coarse sand and shell grit at the deepest section and become finer towards the bank. There was a high concentration of burrows and siphon holes indicating an active benthic infauna. Tidal currents are strong with 8 knots marked on a maritime chart (WA 848). Visibility at time of the site visit was the highest of all sites surveyed and was approximately 6-8m. There was a school of approximately one hundred bream, plus banded sweeps, whiting and glassfish. The underside of the pontoons had an abundance of mussels and encrusting growth and showed excellent potential for enhancement.

This site is considered to have a very high potential for attracting an abundance of marine life due to its water quality, currents and featureless sandy bottom. Reef modules placed in this area will provide highly contrasting substrate and vertical relief, and create upwelling eddies that will appeal to pelagic fish. They will also provide some reduction in currents, which fish will utilise. Due to the good visibility, the reef could be an attraction for snorkellers.

The placement of reef modules in this area will have to be completed in small stages in order to assess the degree of scouring, accretion or erosion that may occur around the modules. One way to avoid problems with current and scouring would be to establish hanging 'gardens' that will be colonised by mussels and other organisms and act as fish attractors.

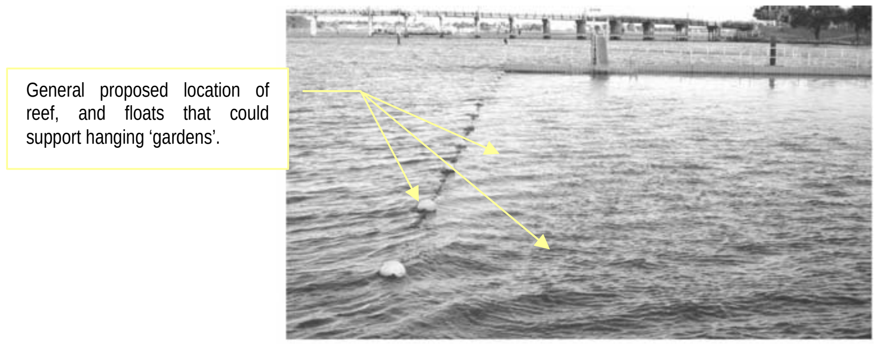


Figure 14. Swim area at deeper location showing where the reef and hanging 'gardens' could be constructed.

3.2.1 Reef Type and Layout

Two types:

1. Standard bottom based reef using the larger Bay Balls and Mini Bay Balls running parallel to current.
2. Hanging 'gardens' by suspending the small Oyster Balls from the pontoons and/or the float line closing off the swim area.

Recommended number of modules: 7 Bay Balls, 8 Mini Bay Balls.

Location for Type 1 could initially be at the deep end of the swim area as this location is likely to attract more fish. Modules should initially be orientated in a relatively narrow strip (~3-4m wide) parallel to the current with the largest modules (ie the Bay Balls) placed at either end so as to create maximum upwelling, and calmer areas in-between in and around the Mini Bay Balls. It is impossible to predict exactly the degree of scouring that may take place, therefore the configuration may have to altered.

Recommended number of modules: 26 Oyster Balls.

Hanging 'gardens' could create visually interesting micro-habitats as well as mussels for eating, and would not be prone to current-related problems such as scouring. Encrusting growth in this area will add colour and attract smaller interesting fish to watch. The idea would be string 1-3 Oyster Balls on suitable size rope and hang them from each pontoon towards the deeper end, although this may make them prone to tampering. Length of each should be approximately 1-2m. If possible, a great effect could be achieved by hanging several strings from the buoyed line, closing the area off which could attract a dynamic wall of schooling species and colourful growth. This line would need extra floatation added to support the weight and drag of the Oyster Ball strings, and may require a stronger float line. If the weight of Oyster Balls is too great, then a mix of modules could be suspended made from PVC pipe sections or other lighter material.

3.2.2 Strategy

Due to the uncertainty about the degree of scouring and subsidence that may occur, only half of the recommended number of Bay Balls and Mini Bay Balls should be deployed initially. These should be monitored over several weeks to judge the impact of currents. If the scouring/subsidence or other impacts to the existing bottom profile prove to be too great, then the modules should be removed. If it appears to be satisfactory, then more modules can be added, and monitored. An additional problem may be presented by sections of kelp and other seaweed that is carried along the bottom by currents in this area. This seaweed may become entangled around the bases of the modules. The subsequent increase in base size can increase the extent of scouring, and by its movement and abrasion reduce or wipeout the encrusting community on the module. However, as the tidal current changes direction, the weed may be removed and may prove not to be a significant problem.

Underwater video transects at all sites should be conducted prior to deployment if it is a part of the monitoring program.

Modules can easily be rolled down the beach and floated to the deep end, or carried in a 'fireman's lift' as shown in Figure 15. Final placement could be by scuba divers.

Figure 15. One method of transporting modules to shallow water reef sites. Photo courtesy of the Reef Ball Development Group.

Strings of Oyster Balls should be of various lengths to increase diversity, and spaced at varying distances from each other, eg. 1 to 5m. Strings attached to the pontoons may be prone to tampering, therefore it may be necessary to only deploy them along the buoyed line closing off the swim area.

3.2.3 Value Adding Options

- Interpretative signage on the pontoons and/or beach giving credit to sponsors/organisers, and basic description of the overall enhancement program, and common marine life that can be seen.
- Community involvement in deployment, eg sausage sizzle. Modules could be made on site.
- The site has ideal depth and visibility for school groups to deploy and monitor their own modules.
- Ease of access and visibility make it an ideal site for university research.
- The site is a no-fishing zone therefore providing an added bonus of acting as a protected area.

3.2.4 Indicative Benefits and Expectations

Providing the current does not prove to be too strong, this site could produce an excellent snorkeling attraction that is easily accessible to the local community. Its accessibility also make it attractive as a research site. It is likely to have one of the greatest diversities of encrusting communities and could attract large numbers of schooling fish as well as passing larger fish that are moving in and out of the inlet.

3.2.5 Indicative Costs

Costs are basic estimates only and do not include cost of additional design work, permit approvals, monitoring, maintenance or value adding options.

Hall Park Swim Area	**Quantity**	**Approx. cost/unit**	**Total Unit Cost**
BAY BALL	7	$90.00	$630.00
MINI BAY BALL	8	$60.00	$480.00
LO-PRO BALL		$40.00	$0.00
OYSTER BALL	26	$20.00	$520.00
OTHER			$0.00
Module subtotals	41		$1,630.00
Project set-up costs			$1,000.00
Deployment costs			$410.00
Monitoring costs			
On-going maintenance			
ESTIMATED TOTAL	**$3,040.00**		

3.3 Site 3a – Northport – Village Beach

Recommendations for initial enhancement of Northport are split into three main areas: Village Beach, Bouvard Village, and Bridge/Canal corners. This development has a vast array of areas that could be enhanced at a later stage as experience is gained from initial programs.

Village Beach has been constructed as part of Port Bouvard's Northport development, and is a swimming alcove bounded by curving canal walls (Figure 16). It is approximately 40m in width and 30m in length, and has a gentle sloping beach made from imported sand. Maximum depth is about 3m. Water clarity is good due to close proximity to the ocean.

This site has significant potential to become a valuable educational tool and a very enjoyable asset to Northport residents. Its location, quality sand, depth and water quality make it ideal for school reef building projects, and there is a primary school located nearby that is already working with Port Bouvard on projects such as dune restoration.

Discussions with John Wroth, Port Bouvard Project Manager, confirmed a reef option at this site would be explored and that it may serve an additional purpose of acting as a subtle barrier that will prevent boats from trying to enter the swimming area and beach.

Figure 16. Photograph showing Northport's Village Beach, an excellent site for a snorkeling attraction.

3.3.1 Reef Type and Layout

Mix of Bay Balls, Mini Bay Balls, Lo-Pro Balls and Oyster Balls.

Recommended number of modules:
12 Bay Balls, 15 Mini Bay Balls,
10 Lo-Pro Balls, 10 Oyster Balls.

The proposed layout is to create two main elongated reef groups running perpendicular to the beach starting at ~2m depth and extending to the extent of the alcove opening (Figure 17). This could be added to or altered depending upon results. This layout allows easy movement of demersal fish and bottom forages into the alcove and to the shallow areas. It will also have little impact on tidal flushing and will allow the passage of vessels to the beach if necessary, eg. during an emergency.

This site may have the potential to support seagrass. This would create an ideal mix of reef and seagrass, however this option would require further investigation to confirm suitable sediments, water quality and ability to transplant local species. Seagrasses may colonise the area naturally as they have done in canals in Queensland.

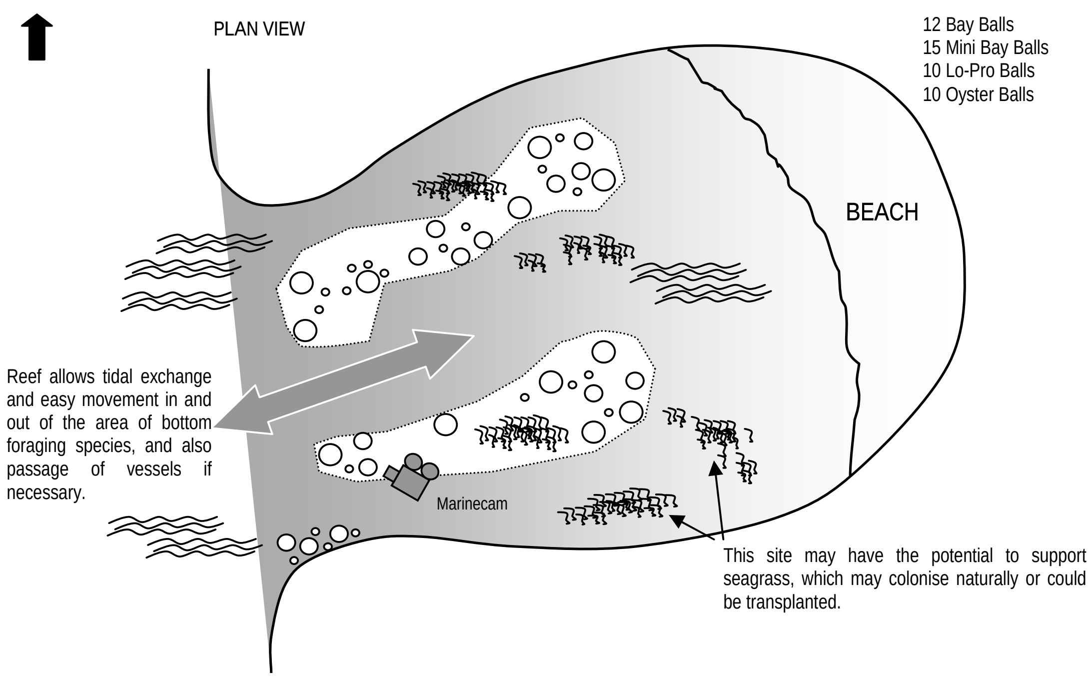


Figure 17. Potential layout of a minimum number of modules for Village Beach (Northport).

3.3.2 Strategy

The recommended numbers of modules are considered a suitable starting point but could be increased.

Underwater video transects at all sites should be conducted prior to deployment if the site is a part of the monitoring program.

Due to the community location and space of this site, it provides an ideal location for a 'fun day' involving residents and schools kids to help deploy the modules and record their location. This could be followed by BBQ and official launch ceremony that with an appropriate media identity (eg Rex Hunt) and media coverage. Smaller modules could be rolled or carried down the beach and floated to location, or transported on low skiffs. Heavier modules could be loaded on a suitable vessel at the Eastport marina and transported to site and deployed from the vessel. Small crab pot floats would need to be deployed prior as markers for where the modules are to go.

The seagrass option could be pursued after all modules have been placed, and the recommended person to contact is:
☞ Dr Eric Paling, Director of Marine and Freshwater Research Laboratory, Murdoch University, 08-9360-6121.

Port Bouvard may be able to provide temporary space to manufacture the modules and stockpile them while they cure (1-2 weeks). While stockpiled they could provide a novel promotional tool for the program and include signage explaining how the groups involved are committed to enhancing the living environment and increasing awareness and appreciation for it.

3.3.3 Value Adding Options

- School participation in constructing Reef Balls and/or other concrete modules, and follow up programs that allow the kids to explore the type of marine life that has taken up residence in their module, and how it may be using the reef. This helps educate on the varying habits and needs of marine life.
- Signage at the beach that shows the orientation of the reef, sponsors, location of various school group modules ('fish houses'), and pictures with a basic introduction to marine life typically resident. A catchment or estuary environmental message could be included, or reminders about litter and stormwater pollution etc.
- Installation of a live feed underwater video camera (by Discrete Data Systems, 08 9226-0105) as proposed for Dolphin Quay. This could feed directly into Port Bouvards high speed cable network and allow residents as well as the broader community to enjoy images of marine life. This could also assist with research and the images could be analysed by students.

3.3.4 Benefits and Expectations

- Matches well with Port Bouvard's choice of Rex Hunt as the promotional face for the development.
- Snorkeling attraction or even scuba diver training area.
- Biodiversity should be relatively high.
- It provides another 'no take' zone in the enhancement program.
- Regular visitors to the reef will come to know the long term residents of the reef such as dominant fish, may even give them names, and will start to notice natural cycles and behaviours. This can create a greater sense of ownership for the area.

3.3.5 Indicative Costs

Costs are basic estimates only and do not include cost of additional design work, permit approvals, monitoring, maintenance or value adding options.

Northport - Village Beach	**Quantity**	**Approx. cost/unit**	**Total Unit Cost**
BAY BALL	12	$90.00	$1,080.00
MINI BAY BALL	15	$60.00	$900.00
LO-PRO BALL	10	$40.00	$400.00
OYSTER BALL	10	$20.00	$200.00
OTHER			$0.00
Module subtotals	47		$2,580.00
Project set-up costs			$3,000.00
Deployment costs			$470.00
Monitoring costs			
On-going maintenance			
ESTIMATED TOTAL	**$6,050.00**		

3.4 Site 3b & 3c – Northport – Bouvard Village & Canal Corners

Bouvard Village is located to the west of the sales office and is designed to become the hub of the community with a mix of waterfront retail and residential units around a marina. This area already supports a diversity of marine life, including octopus. It has a smooth wall construction with a 2-3m wide ledge and, therefore, offers an opportunity for enhancement. Maximum depth is approximately 3m and visibility ranges from approximately 1m to 4m.

There are submerged ledges within the corners of canals and either side of the bridge connecting Bouvard Island. These ledges are out of the way of boat traffic and ideal for enhancement with modules, which will create corners full of nooks and crannies, and once established will add a 'softer' more natural look to the angled corners and odd rock. Additionally they are shallow enough for people passing by to look down and see encrusting growth and fish.

3.4.1 Reef Type and Layout

Enhancement of the base of wall areas and underneath jetties using Bay Balls, Mini Bay Balls, Lo-Pro Balls and Oyster Balls. Strategy for wall and jetties to be similar as that for other sites such as Ocean Marina and Dolphin Quay.

1. Wall Sections

Recommended number of modules: 30 Lo-Pro Balls, 60 Oyster Balls.

Scattered groups of 5-8 modules to provide enough critical mass, but spaces of 1-3m between groups (refer Figure 12). Initially a 50m length of wall, preferably within an area of greatest current/flushing, could be enhanced. This equates to a working length of approximately 30m once the spaces between groups are deducted. Three modules could be placed per metre of wall, therefore approximately 90 modules are required. Size will depend upon depth, and it is likely that it will require Lo-Pro and Oyster Balls.

2. Jetties

Recommended number of modules: 12 Bay Balls, 15 Mini Bay Balls, 15 Lo-Pro Balls.

A mix of 2 to 4 Reef Balls (Bay Balls, Mini Bay Balls and Lo-Pro Balls) for every 5 metres of jetty where bottom profile permits. Reef Balls are to be kept from jutting out past edge of jetty.

3. Corners

Recommended number of modules: 10 Lo-Pro Balls, 10 Oyster Balls.

Only a quick assessment of corner sections was made, and confirmation of stability of corners needs to be confirmed with canal engineers. There are prominent corners either side of the bridge connecting Bouvard that have enough space for groups of 5-8 modules made up of a mix of Lo-Pro and Oyster Balls. Initially two corners could be enhanced, however management may wish to consider enhancement of further areas.

3.4.2 Strategy

Underwater video transects at all sites should be conducted prior to deployment if it is a part of the monitoring program.

Placement of modules could be from a boat or in some cases lowered by rope to position. Care must be taken not to damage the sandstone walls. Preferred wall areas would be those that are visible, have greater flushing and relatively featureless surrounds. Site management should determine, in conjunction with residents, which areas are to be enhanced first.

Prior to deployment, it would be a good idea to remove all construction rubbish from the areas to be enhanced, if not elsewhere as well. This helps set the 'tone' for how the marine environment is to be treated in the area. A neighbourhood 'working bee' may be useful to achieve this and increase community ownership of the enhancement.

The Bouvard Village area could serve as a launch pad for other areas within the development. Water quality is likely to be marginally better in canals closer to the entrance to the Dawsville Channel, therefore these areas potentially have greater diversity.

There is the option in this area to add species-specific modules. For example, octopus houses since octopus have been sighted, and it is also likely that lobster will be present, and habitats specifically for lobster could be deployed. These habitats would need to provide narrow longitudinal openings and overhangs for the lobsters to retreat under such as the holes depicted in Figure 6.

3.4.3 Value Adding Options

- Installation of a live feed underwater video camera (by Discrete Data Systems) as proposed for the Village Beach and Dolphin Quay. This could feed directly into Port Bouvards high speed cable network and images could be displayed in Bouvard Village café's, sales office and associated websites. This could also assist with research and the images could be analysed by students. The camera would need to be strategically placed to show the best marine life. This may require a system that can be moved as it's hard to predict exactly which areas will have the most life.
- Species specific modules could be deployed at a later date. Examples could be lobster overhangs or octopus houses. The issue of taking such animals would need to be considered as a resident was already reported to have taken two large octopus from the marina.
- Underwater lights may be an option to help illuminate some of the reef areas near the cafés to help take the viewer below the water line and create a unique dining setting. An alternative could be above water wall mounted lights along walkways that shine down on the modules along the base of the walls. These would be easier to maintain and cheaper to run. Such lighting could provide glimpses of marine life not seen during the day, and may add a sense of mystery and discovery for walkers.

3.4.4 Benefits and Expectations

- This development is situated at the entrance to an ocean and an estuary. This means it receives a diverse array of marine life passing by and into the canals. It has the opportunity to support such species by providing a diverse habitat, whether it is for feeding, shelter or breeding.
- Encrusting growth should be above average and should therefore provide colour and diversity of texture.

3.4.5 Indicative Costs

Costs are basic estimates only and do not include cost of additional design work, permit approvals, monitoring, maintenance or value adding options.

Northport - Bouvard Village	**Quantity**	**Approx. cost/unit**	**Total Unit Cost**
BAY BALL	12	$90.00	$1,080.00
MINI BAY BALL	15	$60.00	$900.00
LO-PRO BALL	55	$40.00	$2,200.00
OYSTER BALL	70	$20.00	$1,400.00
OTHER			$0.00
Module subtotals	152		$5,580.00
Project set-up costs			$3,000.00
Deployment costs			$1,520.00
Monitoring costs			
On-going maintenance			
ESTIMATED TOTAL	**$10,100.00**		

3.5 Site – Mariners Cove

This canal development is under construction and adjacent to the Creery Island Nature Reserve, an important marshland and waterbird habitat. The site surveyed is the area around the site sales office and already has an abundance of fish life (including a blue manna crab hiding in a section of pipe) and diversity of habitat comprising of rock wall, pilings, vertical canal wall, and the adjacent marshland. There appeared to be a cool freshwater lens at the water surface suggesting there could be a freshwater source entering the area. This could decrease diversity if persistent, however could also contribute to the dynamics of the system.

This development has high enhancement potential due to its neighbouring nature reserve and has the opportunity to demonstrate how coastal developments can work with natural areas.

3.5.1 Reef Type and Layout

There are three main areas that modules could be added to initially and these are close to the site sales office. The program could be expanded to include canal sections at a later date. The problem with the canals is likely to be the limited level bottom under jetties for modules, however there are some areas within corners either side of bridges that could benefit from modules.

1. Jetty

Recommended number of modules:
5 Bay Balls, 8 Mini Bay Balls,
10 Lo-Pro Balls.

There is a single jetty adjacent to the site sales office in about 2.5m of water and with a suitable bottom for placement of modules (Figure 18) A variety of size modules are recommended to increase diversity and these are Bay Balls, Mini Bay Balls and Lo-Pro Balls. Modules should be placed directly under the jetty (see previous section Figure 9) so as to reduce risk of boats coming into contact with them and someone accidentally diving on them.

Figure 18. Photo of jetty at Mariners Cove that could be enhanced with Reef Balls.

Recommended number of modules: 3 Lo-Pro Balls, 6 Oyster Balls.

2. Concrete Wall
This is the wall that the jetty connects to and has a 1-3m wide sand ledge approximately 1m deep along its length. This ledge has scattered rocks and some construction waste such as short sections of large diameter pipe, one of which was being utilised by a blue manna crab. A row of Lo-Pro and Oyster Balls along this ledge would provide valuable habitat and also create a more visually interesting marinescape.

Recommended number of modules: 15 Mini Bay Balls, 15 Lo-Pro Balls Balls.

3. Spurs along rock wall
The rock wall located in the same area as the jetty could be enhanced by the addition of 3 spurs as described in section 2 and depicted in Figure 19. It is suggested that each spur be constructed from 5 Mini Bay Balls and 5 Lo-Pro Balls. These spurs would create intermediary nodes between the wall and the jetty effectively linking the two, and provide areas for larger fish to congregate around.

Addition of spurs would help break the uniform edge of the wall and add more biologically attractive depth.

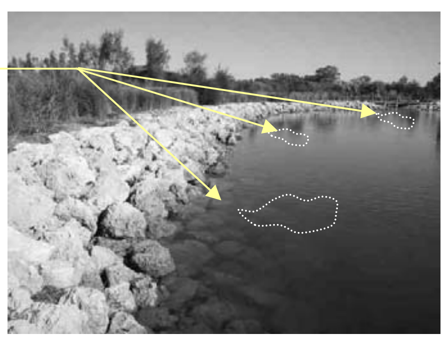


Figure 19. Photo of rock wall at Mariners Cove that could be enhanced by addition of spurs.

3.5.2 Strategy

Underwater video transects at all sites should be conducted prior to deployment if it is a part of the monitoring program.

There is no particular sequence for this area. Modules can be transported to the site by truck and lifted and lowered along the wall and under the jetty. Final placement under the jetty may require the use of snorkellers/divers. Constructing the spurs along the rock wall will first require a quick inspection along its length to identify suitable flat areas with minimal relief. Modules could then be deployed by either floating them to each location or by placement from suitable sized boat.

Prior to deployment, it would be a good idea to remove all construction rubbish from the areas to be enhanced, if not elsewhere as well. This helps set the 'tone' for how the marine environment is to be treated in the area. A neighbourhood 'working bee' may be useful to achieve this and increase community ownership of the enhancement.

3.5.3 Value Adding Options

- Signage explaining the program, location of modules and how they may contribute to productivity of the Creery Wetland.
- Include research of aquatic fauna around enhanced areas as part of the ongoing monitoring of the reserve by the Cedar Woods Waterbird Research and Monitoring Committee.

3.5.4 Benefits and Expectations

- Increased habitat for juveniles inhabiting the Creery Wetland area.
- Excellent PR tool close to the sales office.
- 'Feel good' factor for residents to have such an initiative taking place in their neighbourhood.
- Improved understanding of the functioning of the reserve.

3.5.5 Indicative Costs

Costs are basic estimates only and do not include cost of additional design work, permit approvals, monitoring, maintenance or value adding options.

Mariners Cove	**Quantity**	**Approx. cost/unit**	**Total Unit Cost**
BAY BALL	5	$90.00	$450.00
MINI BAY BALL	23	$60.00	$1,380.00
LO-PRO BALL	28	$40.00	$1,120.00
OYSTER BALL	6	$20.00	$120.00
OTHER			$0.00
Module subtotals	62		$3,070.00
Project set-up costs			$2,000.00
Deployment costs			$620.00
Monitoring costs			
On-going maintenance			
ESTIMATED TOTAL	**$5,690.00**		

3.6 Site 4 – Leeward (East)

This is a long canal to the east that runs almost north-south with a Nature Reserve recently established to the southeast (Figure 20), which is a major asset as it will work well with enhancement activity within the canal. This site offers the opportunity to demonstrate how the value of a Nature Reserve does not end at the waterline and can actually be supported by development nearby rather than compromised. There is already a significant length of rock wall constructed of varying rock sizes, which is a step in the right direction, however its biological usefulness is still limited due to its 'straightness' (refer Subsection 2.3.1). This can be enhanced by adding rock spurs and Reef Balls along the base. There may be further options around the Nature Reserve that could use Reef Balls or other structures.

Figure 20. Photos showing Nature Reserve and two wall types at Leeward Canals.

There was construction waste such as paint tin lids, sections of pipe and a sheet of corrugated iron/plastic on the bottom along sections where houses were located. Some of this waste could have blown in, however some of it was obviously thrown in. This should be removed as part of the enhancement program, and builders should take greater care. This is an example of how the enhancement program can assist with improving awareness of what is now considered acceptable practice. "Out of sight, out of Mind" is diametrically opposite to the goals of the enhancement program.

Jetties – further investigation needs to be conducted to confirm whether the canal wall slope will support Reef Balls.

3.6.1 Reef Type and Layout

Two main initial options:

- Construction of two spurs along the Nature Reserve rock wall.
- Addition of Oyster and Lo-Pro Balls along base of canal walls.

Spurs

Recommended number of modules:
2 Bay Balls, 10 Lo-Pro Balls,
10 Mini Bay Balls.

The objective here is to help improve the biological usefulness of the straight rock wall, and also create 'nodes' that fish will use for reference and will congregate around. There does not need to be a large number of spurs, and in some cases less is more. This is due to the island effect or greater contrast achieved when there are only 2-3 rather than 10 or more. Spurs are designed for each specific site because they must take into consideration numerous aspects such as available area (ie navigable waters), bottom slope, currents, maintenance dredging, and overall length of wall.

At Leeward, the necessity for the boat channel limits how far the spur can extend away from the wall. Generally, a distance of 3m+ is the minimum to provide sufficient contrast. Two initial spurs (~5m in length) constructed from Bay Balls, Mini Bay Balls and Lo-Pro Balls should be sufficient.

Recommended number of modules: 100 Oyster Balls.

Canal Walls

There is a suitable ledge at the base of the canal walls for placement of modules and water depth is approximately 0.5-1.0m. This is sufficient for Oyster Balls, and 2 modules per metre of canal wall should be adequate. A similar spacing as to that proposed for the Ocean Marina and other walls could be used, ie allow 1-3m gaps between groups of say 10-15 modules to help increase diversity.

It is recommended that approximately 50m of wall be enhanced initially. More than this can be included if funds permit, however using fewer may not provide enough critical mass to make a noticeable difference. Therefore this will require approximately 100 Oyster Balls.

3.6.2 Strategy

Underwater video transects at all sites should be conducted prior to deployment if it is a part of the monitoring program.

Spurs

The critical issue at this site is the boat channel. The spurs cannot extend in a fashion that could result in boats coming into contact with them. A way around this, as suggested by Bob Pond, District Manager Water and Rivers Commission, would be to construct them between the rock wall and the existing channel markers. Boats are not likely to try to pass between the channel markers and the rock wall and it makes it easy for boaters to remember where the spurs are. Modules would have to be kept to the rock wall side of the channel marker. There were at least two channel markers that could be used, and estimated distance between marker and wall is approximately 5m. A final check with relevant authorities should be made to confirm that such an initiative would be approved.

It is recommended that a total of 11 modules be placed in a random half circle fashion between the channel marker and rock wall. These could be placed from a boat and either lowered or dropped. A final check by a snorkeller/diver will need to be under taken to ensure no modules extend into the channel and to map the location of each model for chart and research purposes.

Canal Walls

The recommended strategy is to start with the new sections of canals, especially those closest to the Nature Reserve and in the best flushed sections. The PHCC will have to decide where exactly they are placed first and whether residents contribute funds. Oyster Balls can simply be lowered by hand into position. They should not be in a perfectly straight line and should have varying size gaps between them as well as larger 1-3m gaps between groups of 10-15.

This site has a significant amount of wall that is fairly uniform in habitat and water quality, and therefore offers the opportunity to compare biodiversity around Oyster Balls compared to regular rocks.

3.6.3 Value Adding Options

- Add Oyster Balls to the edge of the rock wall.
- Explore other areas around the Nature Reserve. There may be an application for Reef Balls to protect saltmarsh areas from boat wash.
- Use the area for research to gain a better understanding of whether such methods of enhancement are beneficial to species utilising the Nature Reserve.
- Establish a 'no take' zone along the rock wall, especially around the spurs.

3.6.4 Benefits and Expectations

- A 'softer' edge to the canal development that is boardering a Nature Reserve.
- Addition of habitat that may appeal to juvenile species moving out of the estuary.
- Improved aesthetics along the base of the canal walls.
- Dissipation of boat wash and reduction in waves.

3.6.5 Indicative Costs

Costs are basic estimates only and do not include cost of additional design work, permit approvals, monitoring, maintenance or value adding options.

Leeward Canals	Quantity	Approx. cost/unit	Total Unit Cost
BAY BALL	2	$90.00	$180.00
MINI BAY BALL	10	$60.00	$600.00
LO-PRO BALL	10	$40.00	$400.00
OYSTER BALL	100	$20.00	$2,000.00
OTHER			$0.00
Module subtotals	122		$3,180.00
Project set-up costs			$2,000.00
Deployment costs			$1,220.00
Monitoring costs			
On-going maintenance			
ESTIMATED TOTAL	**$6,400.00**		

3.7 Site 5 – Eastport

This area is still under staged construction and consists of a marina, canal estates and a Foreshore Reserve. This reserve is still being finalised, presenting an ideal opportunity to significantly improve its biological attractiveness below the waterline. The reserve includes a small shallow bay with two rocky islands at its mouth and a rock wall extends southwest to the Dawesville Channel (Figure 21). Jetties only extend to the toe of the canal wall slope, therefore not providing any level bottom for placement of modules under the jetties. This may not be the case for all jetties, however, and this option requires further investigation.

Discussions with John Wroth, Port Bouvard Project Manager, indicate that additional enhancement of the reserve area would be favourably viewed by the developer, and they would like to discourage boats from entering the small bay. A constructed reef in the entrance would be one way of accomplishing this but would allow smaller paddle craft.

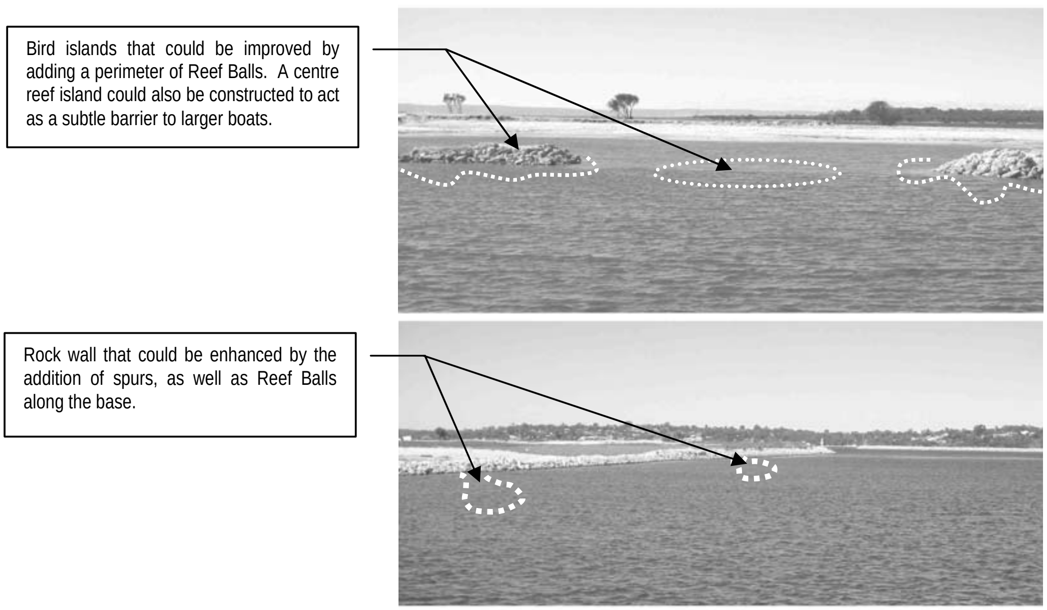


Figure 21. Photos of shallow bay within Eastport Foreshore Reserve and rockwall.

3.7.1 Reef Type and Layout

Three main initial options:

- Reef Ball enhancement of bird islands.
- Spur addition to rock wall using Reef Balls and perhaps species-specific modules.
- Addition of smaller modules to canal wall base including species-specific modules.

1. Bird Island

Recommended number of modules: 9 Bay Balls, 12 Mini Bay Balls, 20 Lo-Pro Balls, 18 Oyster Balls.

These islands will provide valuable bird retreats and some underwater habitat, but still suffer from very limited ‘volume’ for use by marine life. They could be improved by changing their regular shape to one with a more irregular footprint without changing the above water appearance. Rocks could also be scattered at their perimeter edge to create more 3D reef. The better option is to do both of these with Reef Balls, which will also provide the void spaces that rocks cannot.

NOTE: the substrate around these islands was not investigated, therefore final layout and placement will be dependent upon further investigation and discussion with canal engineers.

The largest size Reef Balls possible that the water depth will allow should be used in order to provide maximum cavity space. Shelter for predator avoidance will likely be sought after in this area due to the close vicinity of the Dawesville Channel and a variety of predator species passing through the area. As with the other areas, the aim should be a maximum variety of shape and size within the budget available.

Modules should be placed around the base of the island in a fashion that maximises the length of reef 'edge' (Figure 22), if possible, a smaller patch reef located 3-8m from the island would be beneficial. The reef could be constructed in the centre and would have a channel running through it to allow for easy movement of demersal species. This may change with experience of how the site is performing. A better option might be Reef Balls forming a wall at the opening to the small bay as this could add protection to juveniles within the bay.

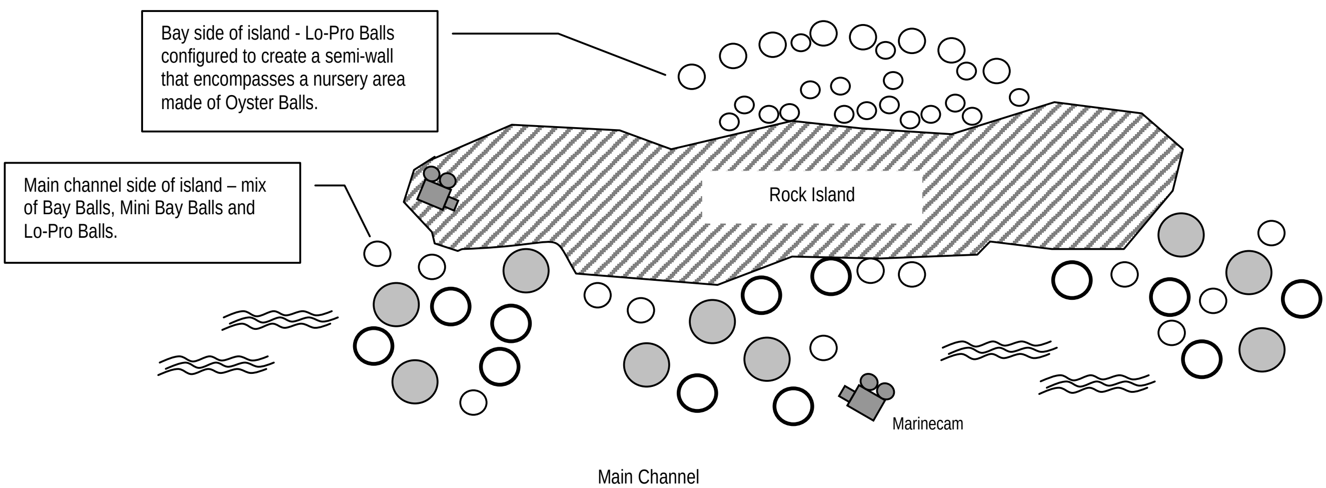


Figure 22. Sample layout for constructed island at the Foreshore Reserve – Eastport.

2. Spurs

At least two spurs should be added if possible to the rock wall leading to This channel is wide and could probably handle larger modules and spurs that protrude further from the wall. The spurs can be basically the same design as the spurs recommended for Leeward. There are no existing channel markers so the issue of vessel traffic needs to be considered.

Recommended number of modules: 100 Oyster Balls.

3. Canal Wall Base

Enhancement can be by the addition of Oyster Balls as per other walls discussed previously. They should be placed in areas where flushing is greatest and added to other areas later as required. The recommended number of 100 will cover at least 50m.

3.7.2 Strategy

The first step is to confirm with canal engineers that sediments will support the modules around the islands, whether spurs can be added to the rock wall. Two locations for the spurs should be selected and somehow marked or recorded by GPS/visual transits.

Underwater video transects at all sites should then be conducted if part of the monitoring program.

Modules could be trucked to the Eastport marina and loaded onto a suitable workboat with hoist sufficient to lower the modules over the side. Canal wall modules can be deployed progressively as they become available.

3.7.3 Value Adding Options

- Live feed underwater marinecam strategically located at the island combined with a surface cam that records bird activity on the island. This would provide excellent footage for research purposes.
- Numerous other options would be possible but would require a more detailed inspection of the area and development plans.

3.7.4 Benefits and Expectations

- This development has a lot of straight walls and is next to a reserve. It is highly desirable that this area soften its straight lines underwater to increase its biological attractiveness. This should help enhance the reserve, which will subsequently reward residents with abundant birdlife and marine life.
- This site will provide valuable data on how features such as the small bay function and the type of marine life that it supports.
- Results from this initial enhancement will form a foundation for expansion of the program and provide the knowledge to design more targeted options.

3.7.5 Indicative Costs

Costs are basic estimates only and do not include cost of additional design work, permit approvals, monitoring, maintenance or value adding options.

Eastport Marina	**Quantity**	**Approx. cost/unit**	**Total Unit Cost**
BAY BALL	5	$90.00	$450.00
MINI BAY BALL	20	$60.00	$1,200.00
LO-PRO BALL	30	$40.00	$1,200.00
OYSTER BALL	20	$20.00	$400.00
OTHER			$0.00
Module subtotals	75		$3,250.00
Project set-up costs			$2,000.00
Deployment costs			$750.00
Monitoring costs			
On-going maintenance			
ESTIMATED TOTAL	**$6,000.00**		

Eastport Foreshore	Quantity	Approx. cost/unit	Total Unit Cost
BAY BALL	15	$90.00	$1,350.00
MINI BAY BALL	22	$60.00	$1,320.00
LO-PRO BALL	32	$40.00	$1,280.00
OYSTER BALL	118	$20.00	$2,360.00
OTHER			$0.00
Module subtotals	187		$6,310.00
Project set-up costs			$3,000.00
Deployment costs			$1,870.00
Monitoring costs			
On-going maintenance			
ESTIMATED TOTAL	**$11,180.00**		

3.8 Comments on the Other Sites

This section provides brief comments on the remaining sites as all areas should be considered, and the above recommendations are only a starting point.

Yanderup Canals
This area is estuarine whereas the top sites covered in detail are all marine. Enhancement of Yanderup canals by the placement of modules under private jetties for example, could add valuable 'balance' to the enhancement programs which are mainly in marine areas, and would also offer the valuable opportunity for comparison studies. Diversity would be reduced compared to the more marine areas, however this does not mean this is of lesser biological value. The canals could be providing important habitat for estuarine species, and this should be explored further.

Soldiers Cove
This site has relatively good visibility (2-3m) and healthy looking sand. It also has small low-lying saltmarsh islands nearby that would provide productive habitat. Modules placed here would likely attract significant growth and add contrasting substrate. Modules may even be useful for reducing boat wash or wind waves that may be eroding the islands.

Performing Arts Complex
This is an ideally situated public building with jetties and shallow water that could provide a space for public viewing of modules in the water and on land. The foyer or even the area outside would be ideal for a display of the various size modules being used and signage explaining the program, websites, photos etc.

The PHCC should consider the option of placing a few modules in the space between the walkway and the complex. A range of sizes could be displayed in the varying water depth present. The only reservation with this site, and the main reason it was not ranked higher, is the fact that the water quality is average and there appears to be a lot of fine sediment in the area. This is likely to result in modules that do not have a lot of encrusting growth, and have a 'dirty' muddy appearance. People may assume that this is how the modules are working in other areas too. However, it is impossible to judge without actually testing and there may be steps that can be taken to reduce negative impressions from the community such as signage and photos of modules in other areas.

If they do appear to be attracting sufficient marine life, then the option of adding underwater lighting or strategic spotlighting would make a very interesting ever-changing display for passersby. An attempt to illustrate this display is shown in Figure 23. At present, when viewing the PAC at night from the nearby restaurants, it has a very dark waterline that could strengthen the perception that the land and sea are separate. Strategic lighting would soften this line, creating interesting green glowing areas and help take the viewer down into the water and perhaps foster a more connected feel for what happens below the waterline.

Figure 23. Artistic impression of modules and night time lighting at the Performing Arts Complex.

Approximately 20 modules could be used initially and this could cost about $850 (not including deployment costs).

Mandurah Quays

This area had an impressive assemblage of varying habitat and fish as well as active bird population. Therefore, there is no recommendation to add any modules to this site. Efforts have been made to stabilise the narrow beaches to the east of the marina entrance by using concrete and waste concrete such as concrete jacket pilings. Reef Balls may be able provide the same protection, but provide a more natural appearance as well as hollow spaces for crabs.

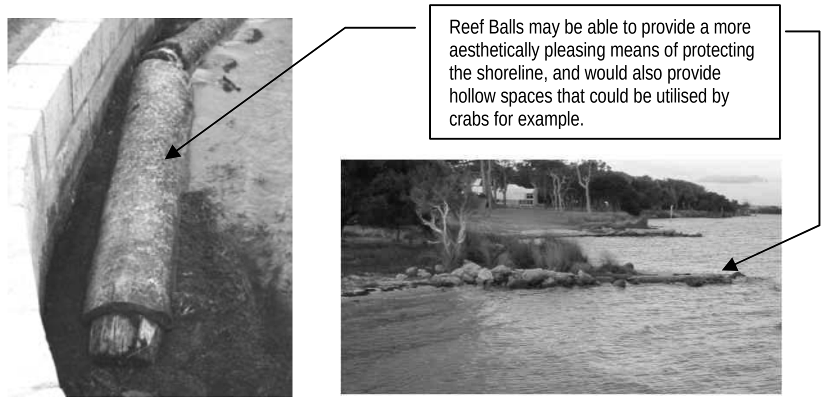


Figure 24. Photos of where Reef Balls could be used for beach protection at Mandurah Quays.

Waterside Canals

According to City of Mandurah engineer, Rhoan Howard, there are approximately 300 jetties in Waterside constructed over a level bottom, whereas the majority of canal designs in the area have sloping canal walls. This means that this development could place modules under the jetties. This option could be discussed with residents and if funds are available, then some trials could be undertaken . Waterside has been established for some time so residents are familiar with the type and abundance of fish caught, which provides useful anecdotal evidence to compare with post enhancement results.

There would be no clearly visible signs of improvement from enhancement due to the lack of water clarity, however, residents may notice changes in catch. Canals that have been prioritised to launch the program have the advantage of having clearer water, therefore allowing easier assessment of effectiveness.

Peel Inlet

It is understood that to deploy modules in the inlet would require a significant permit process. It is not advisable to rush into deploying modules in this area until further studies are undertaken to better understand the natural habitats available and their ecological functioning.

Due to the uniform nature of the canal floor, any structures added that provide vertical relief are very likely to attract fish. A Reef Ball reef within the centre of the inlet for example is likely to attract a large number of fish because of the extreme contrast it provides. Isolated reefs in such situations have been shown to have higher diversity and abundance than reefs closer to shore or other reefs. However, the issue of which species could benefit and which species are preferred needs to be incorporated into the design of the reef.

One initial option would be to add modules to existing rocky outcrops or islands as this would not creating such a drastic change in habitat. Local commercial fisherman, Bruce Tatham, suggested Boodalan Island might be an option for enhancement. This site was not surveyed as part of this study, but would be one site worth keeping in mind as a potential option.

Anecdotally, bank erosion is a growing problem due to the increased water level after the Dawesville Channel was opened (B.Tatham and B.Pond, *pers.com.*). Reef Balls have been proven to be effective at dissipating wave energy and protecting shorelines. The added advantage is that they also provide habitat and are more aesthetically pleasing than blocks. There may be some areas that could trial some modules

4 CONSTRUCTION and DEPLOYMENT PLAN

This section provides an overview of the process to help the PHCC source suitable areas and budget for equipment.

It is recommended that the PHCC contract qualified trainers from the RBDG to come over to Australia and train the relevant people involved. This ensures the latest techniques are gained, and their experience of overseas projects would be valuable. This also creates a worthwhile event for the media to cover. Alternatively, the RBDG has confirmed that the training could be conducted by David J Lennon & Associates, and this may be a slightly cheaper option than bringing trainers from the US. The RBDG generally requires one week to do the training and a comprehensive manual is provided.

David J Lennon & Associates have setup construction areas and trained locals on making the modules in Indonesia and Australia. Should the option of bringing RBDG trainers from US be taken, David J Lennon & Associates could assist with site preparation prior to the arrival of the RBDG trainers. This would ensure that everything is ready to go when they arrive and save money by reducing the time they need to spend in the country.

4.1 Overview of Construction Process

1. Prepare site, order sufficient materials, arrange schedule of workers.
2. Prepare moulds which involves spraying sugar water release agent on the inside, pinning them together, and adding internal bladders and other hole making devices.
3. Mix concrete including additives such as silica fume and plasticiser, allow sufficient mixing time to ensure silica is fully mixed.
4. Pour moulds and ensure concrete is distributed fully.
5. If doing more than one, the mixer or poured mould will need to be moved to make space for the next unpoured mould.
6. Once moulds are poured, clean excess concrete off the outside of moulds, clean mixer and equipment and tidy area. Keep newly poured moulds in shade or draped with wet sack to prevent rapid drying (if sunny).
7. Allow Reef Balls to cure for minimum of 12 hours unless an accelerator is used.
8. After 12 hours, open moulds and brush or spray surface of Reef Ball to expose aggregate. Move Reef Ball on its base by hand or forklift and place in a suitable area for complete curing (~1 week).
9. Thoroughly clean and brush moulds inside and out and reset.
10. Repeat process.

Construction Site

It is only possible at this stage to provide some suggestions of the type of space required and equipment needed so the PHCC can make an informed decision. The final setup will be dependent upon how many moulds the PHCC purchase and construction schedule, and space available.

An ideal option would be the use of a local concrete mixing plant, however this is not essential and there are many other options.

A site with water and power is required, especially if modules will be made in the evenings, eg. with volunteers after work. Cement mixers can be petrol engine driven or electric, but the electric ones are far quieter.

The site can be a double car garage for small scale operations or open piece of land (eg. the area allocated to Water and Rivers Commission at Ocean Marina) or warehouse. The Indonesian Newmont Reef Ball program uses a leveled area by the sea and a shipping container to secure cement, tools, mixer, hard hats etc. The TampaBay Watch group in the US use a covered trailer(with colourful artwork on outside) and 20 moulds, and take all equipment to each location or school, make the Reef Balls on a weekend, allow them to cure for one week, and deploy them the following weekend. Reef Balls in Australia have so far been made in a two-car garage and in the front yard of a dive club, so construction of modules, especially the smaller ones can be done in a range of locations.

There needs to be the provision to stockpile sand and gravel, and a dry place for bags of cement. This area should be close to where the cement mixer can be located so that it is easy to move sand and gravel to the mixer.

This program is not likely to use Reef Balls larger than Bay Balls (~250kg), therefore the necessity for a forklift is not a high priority. Bay Balls can be turned on their side and rolled, and can be picked up by 3 adults, however it would be easier to move them via a dolly or other wheeled platform. Therefore a site with a concrete floor is preferable.

Mixing Concrete
Concrete required is a high MPA sand-gravel mix, and the RBDG is very strict with the additives that can or can not be used. The objective is to strive to create modules that are free from toxic additives and that provide the most suitable substrate for colonisation. The following is a list from the RBDG regarding materials/additvies that may or may not be used.

Prohibited Materials
- Copper, Zinc, Brass-Toxic to several forms of marine life
- Wooden materials-generally unstable but okay in certain areas (low energy cold waters)
- Toxic materials or materials that contain toxins
- Most plastics

Not Suitable For Waters With Corals (not recommended for other locations but acceptable)
- Iron/Steel/Aluminum-Not suitable for coral growth and reproduction (Iron is biologically active and harmful to corals)
- Materials with embedded fertilizers
- Fiberglass-flexing cause corals to fall off
- Non-pH neutral concrete-Okay, but a six month delay in growth should be expected, fouling community will not be natural species diversity.

Acceptable For Coral Inhabited Waters
- Limestone boulders
- pH neutral concrete (between 8.2-8.5 for sea water)
- Iron when fully embedded in low permeability concrete with a corrosion inhibitor admixture
- PVC plastics when partially embedded in concrete for stability

The size of modules required for the recommendations within this report would not have sufficient volume to require concrete to be ordered from a readymix plant. The largest recommended module is the Bay Ball which only requires 0.08m^3 of concrete. It is possible to buy mixers that have sufficient volume to make enough concrete for one Bay Ball in one go. This is highly recommended! An assembly line of sand, gravel, and cement can be setup to make it easier, and if there is sufficient demand, then more than one mixer may be necessary.

Stockpiling Modules
Modules require at least a week to reach full strength, and need to be out of direct sun, especially in summer as this will cause the concrete to dry too quickly. Tarps can be placed over them, and it is beneficial if there is rain to keep them damp and help reduce the alkalinity of the concrete prior to deployment. A stockpile area at a place such as the marina could be turned into a public information area for the program and would provide exposure for sponsors, and allow the public to view the modules.

Safety
Safety of workers is essential. Steel-toe boots and safety glasses are a must because the concrete does tend to splash. Rubber gloves are also important because the concrete has to be pushed into the mould or scraped off the outside.

Safety glasses and gloves can be bought for workers/volunteers and kept at the construction site.

4.2 Time Required to Construct the Modules

Bay Ball

Mould and area setup – 20 mins
Mix concrete – 30 mins
Pour concrete – 10 mins
Clean external mould surfaces and mixer – 15 mins

Total time = ~1 hr 15

This is the largest module recommended, therefore the smaller modules would take less time, and several moulds could be filled with one batch of concrete. This time also includes setup and cleanup, therefore to actually mix and pour additional modules would take less time.

The modules require about 12 hours to cure sufficiently before the moulds can be opened which is a major limiting factor on how many can be made in one day. Concrete accelerators can be used to decrease this time, and the Reef Ball trainers would provide instruction on this.

4.3 Permits

It is understood that there will be minimal permits required for the man-made waterways. It was recommended by the Director of Works and Services, Mr Allan Claydon, that a Memorandum of Understanding (MOU) be put together between Council and the PHCC regarding the placement of modules in selected areas.

Even though permits may not be required, it would be useful if a plan of final module configuration was produced and filed with Council. This may be required in the future for boating issues, dredging, further development etc.

5 ESTIMATED COSTINGS

The following provides a breakdown of costs involved and is based on a maximum of 11 moulds being ordered which would be the ideal number for supplying the number of modules recommended in this report. With this number of moulds, the PHCC could manufacture all modules required for the programs recommended in this report in just under three months. However, it is recognised that the PHCC may wish to initially order less moulds to start the program, therefore individual mould and shipping charges have been provided.

There is also the option of using a Bay Ball mould already in Australia and owned by David J Lennon & Associates. This mould could be used to help start the program by providing the opportunity for people to actually see a Reef Ball, how they are made, and therefore better understand the value of the concept. David J Lennon & Associates would be willing to provide this mould at no charge except for cost of shipment and replacement parts, and cost of conducting a two day training program. Details of this option would be provided at request of the PHCC.

5.1 Reef Ball Mould Pricing Options

5.1.1 Reef Ball Foundation Grant Program

The RBDG have a grant program (www.reefball.org/grantapp.htm) that facilitates the construction of reefs by non-profit volunteer organisations. It is understood that the PHCC will create a non-profit volunteer group to run the Reef Ball construction program and therefore this group would be eligible for such a grant. This would mean moulds could be purchased at cost which is 40% less than retail price (refer Table 5), and training by the RBDG would be at a reduced rate. The main conditions of a grant program as listed on the Reef Ball Foundation website are:

- *"The project must be for public benefit.*
- *The project must be in an area where Reef Balls have not been used before.*
- *A monitoring plan must be in place to include a minimum of two underwater video taping per year for a minimum of three years.*
- *Proof of access to an artificial reef permit is required.*
- *A publicity plan should be in place.*
- *Qualifying grantees may purchase unlimited sizes or numbers of molds from the Reef Ball Development Group, Ltd. at cost (40% off retail) (see www.reefball.com/reef.htm for pricing) (These molds will be restricted to use for your project or other qualifying grant projects only).*
- *Grantee must pay actual shipping charges for the mold systems F.O.B. Sarasota, FL.*
- *Grantee must show enough detail for RBDG to believe the project will actually be accomplished.*
- *The Reef Ball Foundation encourages other organizations to sponsor mold costs to create the match required for the program. If your organization wants to sponsor a match, please let us know, if you need a match, include that request with your application".*

The grant program option was discussed with Todd Barber, Chairman of the Reef Ball Foundation in order to clarify a few questions raised by the

PHCC. There will need to be further communication with Todd to fully clarify what is required, however the following covers a few of the issues:

1. The grant program license is issued for a specific project or geographical are; for example it could be for one specific canal development or for all the manmade waterways in the Peel Region.
2. The monitoring is to encourage continued community interest as well as greater understanding, and is conducted to a level that is manageable by the group/community. Therefore it would not necessarily have to include underwater video (although this is highly preferable) or highly specialised skills. It should be designed to assess as best as practicable the success of the project in achieving its goals.
3. Modules produced using the grant assisted moulds are not 'sold', but provided to sponsors in return for their sponsorship/donations. Sponsors do not have to actually use or receive modules, they can just be sponsors of the program in general and their funds for the range of expenses incurred.

The moulds are made of fibreglass and very sturdy, and typically last well in excess of the lifetime of most projects, so there would not likely be a need to purchase replacement moulds.

To apply for the grant program, the PHCC would need to complete an application provided by the Reef Ball Foundation Grant website: www.reefball.org/grantapp.htm, and Todd Barber and David J Lennon & Associates would be willing to assist with this application.

5.1.2 Reef Ball Contractor Option

Another option for constructing the modules would be to apply for a Reef Ball contractor license. Under this license, modules could be sold freely but a 15% royalty fee is payable to the RBDG for each module. There is no requirement of a monitoring program as there is with the grant program option, however this option would require Reef Ball trainers from the US to come over to Australia in order to certify the contractor.

5.1.3 Reef Ball Mould Prices

Table 5 provides both retail and grant program cost for each mould. Reef Ball Contractor price is the same as grant program prices.

Table 5. Retail and grant/contractor prices Reef Ball moulds.

Moulds	Full Retail Cost (US$1.00/A$0.64)	Grant Program/ Contractor Cost
Bay Ball	$3945 ea	$2476 ea
Mini Bay Ball	$2500 ea	$1562 ea
Lo-Pro Ball	$1328 ea	$828 ea
Oyster Ball	$976 ea	$601 ea
Total for 11 moulds as per recommendation	*$18,164*	*$11,320*

Prices are in Australian dollars and based on a conversion rate of $0.64

5.2 Shipping Costs

The shipping company Powerhouse International Pty Ltd was used for the airfreight of the Reef Ball mould ordered by David J Lennon & Associates back in 1997. An up to date quote for air and sea freight charges was obtained from Powerhouse International as a guide for this report. There are numerous charges involved, and the amounts shown in Table 6 are provided as a guide only.

Oceanfreight is almost half the cost of airfreight and would take 45 days, whereas airfreight takes approximately 3 days. A significant cost is incurred as a result of the various port and customs fees which are basically the same for air or oceanfreight.

Table 6. Estimated air and oceanfreight charges (USA to Perth) from Powerhouse International Pty Ltd.

Mould	Bay Ball	Mini Bay Ball	Lo-Pro Ball	Oyster Ball
# of Moulds	1	2	4	4
Airfreight	$630	$600	$1200	$500
Oceanfreight	$320	$320	$640	$320
US freight, export doc, Port Charges, customs, D/O fee etc	~$680 (can be shared over several moulds)	~$680 (can be shared over several moulds)	~$680 (can be shared over several moulds)	~$680 (can be shared over several moulds)
Subtotals Air / Ocean	~$1310 / $1000	~$1280 / $1000	~$1880 / $1320	~$1180/ $1000
+GST charged on total freight charge	10%	10%	10%	10%
+Duty charged on cost of imported item	5%	5%	5%	5%

5.3 Training in Module Construction

There are two main categories of modules that could be made: Reef Balls and free-style modules. Free-style modules are made using a similar marine concrete as used in Reef Balls, but use a variety of items such as wood, buckets and modeling balloons to create unique modules with a variety of holes, tunnels and voids. Modules can also be made to target specific species such as octopus or lobster. Making of this type of module can be a fun exercise for school kids, and David J Lennon & Associates can provide more details on this option.

Cost of training (refer Table 7) for constructing Reef Balls is based on Reef Ball Foundation Grant rates for two trainers from the US coming to Australia for ten days in country, with four days travelling time. This cost would have to be finalised with the RBDG. Table 7 also provides indicative fees if the training was conducted by David J Lennon & Associates. NOTE: length of training may vary depending upon number of moulds and how the program is structured.

Table 7. Indicative fees and expenses for training.

Fees and Expenses	Training by RBDG	Training by DJLennon
Number of days including travel	14	10
Fee per day	~$625 = $8,750	~530 = $5,300
Airfares	$4400	$800
Expenses	~150/d = $2,100	~$110/d = $1,100
Total (excl GST)	*~$19,250*	*~$7,200*

Prices are in Australian dollars and based on a conversion rate of $0.64

5.4 Equipment Purchase

The following table lists the main equipment items that would need to be purchased in order to setup a Reef Ball construction site.

Misc Equipment	**Cost**
Cement mixers x 2	$800.00
Form ply bases for moulds	$400.00
Safety Equipment	$200.00
Shovels, hammers, tarp, hose, etc	$300.00
Trailer	$1,000.00
Dolley	$300.00
Cement mixer stands	$200.00
Rope, floats	$100.00
Storage boxes	$100.00
Space rental	??
Insurance	??
TOTAL	**$3,400.00**

5.5 Cost per Reef Ball

To calculate the costings provided in Section 3 for the number of modules recommended, the following pricing schedule was used:

Bay Ball = $90 each
Mini-Bay Ball = $60 each
Lo-Pro Ball = $40 each
Oyster Ball = $20 each

These unit costs take into consideration cost of concrete, additives, and wear and tear of moulds. A minimal amount has been factored in for labour.

5.6 Summary of Costings

Table 8 provides a summary of the identified costs required to conduct the enhancement programs discussed in Section 3. This 'full option' scenario is perhaps unlikely to be the starting point for the PHCC, however it serves to help place the program in context.

Table 8. Summary of estimated costings for all recommended sites (moulds costed at reduced RB Grant rates).

Option	Cost of Moulds	Freight	Equipment	Estimated Totals Section 3	SUBTOTAL	Additional Expenses
Full Option – all sites as per Section 3 and 11 moulds.	$11,320 (RB Grant rate)	~$5,660 + GST (air) ~$4,320 + GST (sea)	$3,400	$65,760	$86,140	Training, deployment

Staged Approach

There is the option to conduct the program in stages by focusing on one or two areas at a time, therefore the above costs would not have to be covered all in one go. One of the developments may wish to make a contribution to the program by covering the cost of obtaining the moulds in return for a reduced rate on modules supplied over a period. Other sponsors (eg. Suncorp Metway who advertise at Mariners Cove) could cover the cost of training and/or equipment or modules. The program will attract a lot of media attention, and there is the potential for various environmental awards to be won.

6 MONITORING PLAN

It was not within the scope of this report to provide specific details of monitoring programs that should be conducted. It is also unrealistic to try to design a detailed program until a deployment plan has been agreed upon.

This section discusses the value of monitoring, and provides suggestions of who could be involved and possible objectives.

6.1 Why Monitor?

Monitoring of enhancement programs should be considered an integral part, yet are sometimes neglected due to the focus of resources and energy on initiating a program. An enhancement program such as this is not just about enhancing the physical attributes of waterways, but also about enhancing our understanding of the local system and how it is affected by our built environment. It is this improved understanding that can then be used to 'enhance' future decisions on the direction of the program, management of the Peel's waterways, as well as further coastal development and research. Environmental management plans are only as good as the information they are based upon and this program over its lifetime can contribute valuable data as well as foster greater interest and support from the community for the sustainable use of the region.

The RBDG includes a contractual requirement of all groups constructing Reef Ball reefs that they meet certain monitoring requirements which includes video transects of the area prior to deployment and periodically afterwards.

It is recommended that the PHCC (or whoever the PHCC feels most appropriate) form a group of dedicated individuals who will help ensure that monitoring does take place, and is conducted to an agreed standard. Having said this, it is also important to design monitoring programs that are realistic and practical because programs can often become bogged down due to unrealistic goals.

There are three main non-commercial groups that could be approached to participate in monitoring:

1. Canal residents
2. Schools
3. Universities

Canal residents can have a wealth of anecdotal evidence regarding species composition and diversity within their canals. This could be used to help design sampling programs, eg. time of year when certain species are found in the canal. They could also assist with routine observations of waterbird behaviour or other indirect indicators of potential benefit.

Several schools were mentioned in meetings conducted for this study, and it appears as though there would be a keen response received from local schools to participate in studies. School groups could also link with other schools via the internet that may also be conducting artificial reef projects. The Reef Ball Development Group would be an immediate source of numerous schools that are involved in Reef Ball programs.

Professor Ian Potter of Murdoch University has agreed to review proposed monitoring programs for their suitability as Honours projects. Professor

Potter should be contacted to confirm when such projects would need to be submitted for approval and for input as to the scope of study suitable for Honours students.

6.2 Objective of Monitoring

Perhaps the most important component of a monitoring program is the clear formation of its objective. The following are some broad objectives that the PHCC may wish to consider:

- Species composition along rock wall vs module enhanced rock wall.
- Species composition at a spur vs rock wall without.
- Variation in species associated with the various size modules located in the same area.
- Jetty without modules vs jetty with modules.
- Contribution of enhanced areas to local fisheries.
- Utilisation of modules by blowfish.
- Survey of canal residents as a measure of habitat value.
- Factors influencing the success of seagrass transplanting in man-made waterways.

Conducting fish census in canals is difficult due to poor water quality. One option might be the use of deployed underwater video cameras that are left in place for a period. This reduces the influence of an observer and is used by the WA office of the Australian Institute of Marine Science. Another video option could be the use of a permanently installed live feed system as proposed for Northport and Dolphin Quay.

7 REVIEW and ADDITIONS to AREAS

Enhancement programs evolve and the recommendations provided here are just one starting point. Milestones should be agreed upon prior to commencing programs for the various sites. This ensures that everyone involved, including local government (and sponsors) are aware of when activities will take place and when resources will be needed. It also helps remind people to be patient and allow the modules time to age and become colonised.

Each program for each site should set a date for review of progress and results and a meeting to decide upon future actions. This may include such options as moving existing modules, adding to existing modules, or adding modules to new areas nearby.

The program should also seek to review new data gained from other commissioned studies of the PHES, as well as objectives of land based restoration initiatives.

Depending upon the area, additions of modules may be straight forward or require additional professional advice.

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