Design notes for the Wind Tower and Anti Trawl reef units

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Background

The following notes outline the reasoning behind key design features in the Wind Tower and Anti Trawl reef units we designed for Reef Arabia's artificial reef program in Bahrain. The units are relatively large (2 - 3m tall) concrete precast structures that incorporate historic architecture from the region in a way that attracts and supports commercially important fish.

Three underlying principles were involved in designing these units: ‘ADAM’, local culture and protective space.

ADAM

ADAM refers to our constructed (artificial) reef process that outlines four stages of a constructed reef program:

Assess How fish are using existing natural and constructed reefs in the area, local currents, waves, sediments, other users.

Deploy Reef units.

Assess How these reef units perform

Modify Existing or new reef units or their placement based on lessons learned from assessing the deployed reef units.

Prior to designing these units, we undertook extensive dives and video surveys of existing artificial reefs in the area as well as natural reefs. This was part of our first 'assessment' phase and increased our understanding of how different style artificial reef modules/materials are working and how fish are using them.

The 'design' phase included touring the old town of Bahrain and photographing features of key historic buildings that we felt were ideally suited to the target species.

The Bahrain reef program is the first of its kind, therefore our approach has been to include as many features as practically possible in the reef units in order to test how the local fish and other marine organisms use them. This will help guide future designs and deployments and maximise the benefits gained which is important because a lot of time and money has been invested in the program. This is the second 'assessment' phase of the ADAM process and will be conducted over 12 months and results will dictate whether 'modifications' are required for future deployments.
Local culture - 'culturally sensitive reefs'

Our second strategy is to look for ways to add value by incorporating local culture, customs and, in this case, local architecture into the reef unit design. Bahrain architectural style is unique to the area and we wanted to ensure that the underwater architecture was also suited to the local sealife. Incorporating local architecture adds a sense of ownership and we were keen to use these architectural features because they are also perfect for providing the required complexity in the reef units.

Protective space

Thirdly, we paid close attention to the concept we call 'protective space'.

Protective space is the foundation of any reef as it provides the 'space' that creates opportunities for nature to feed, avoid predation and reproduce. It is created by anything that forms a ‘wall’ or ‘roof' that provides protection from predation or currents.

A flat open field does not provide a lot of opportunity for nature; add grasses, trees, shrubs or high ground and protective space is increased and so too opportunities for nature. When building a reef, the reef units themselves should have voids, holes, angled surfaces and gaps that provide protective space and opportunity for fauna and flora. Artificial reef units that are designed without these void spaces will limit opportunity and species richness and diversity.

Protective space occurs both on the microscale, between two grains of sand or within a crack, and on the macro scale, between walls within each reef unit or between each reef complex.

Wind Tower Reef Unit

A prominent architectural feature of historic Bahraini houses is the wind tower or Bâdgir. The wind towers were designed to expel warm air in the day and catch cooling breezes at night and direct them into the house. We designed Wind Tower reef units to mimic this design.

These Wind Tower reef units offer ideal protective space for the project’s target fishes, such as bream, snapper and baitfish. Their height above surrounding structures is also very attractive for commercially important pelagic schooling fish that are migratory and pass through the area.

The long open vertical archways on all four sides provide open space for fish to swim through and plenty of light, yet they are still narrow enough to provide a sense of protection. The target fish will swim through open structures such as oil platforms or jetties but they tend to avoid 'caves' that have limited flushing of water and too much horizontal depth and limited number of escape routes.

Top of Wind Tower

A range of different sizes of protective space is provided by the corner turrets and the smaller turrets between them. The size of the gaps has been designed to match the target species for the project. By

The height of the corner turrets was increased in order to create pinnacles that will be attractive to fish. Shorter turrets would not have created sufficient protective space.
between each other to be attractive to fishes that like to school around reference points.

Sediment settling onto flat surfaces greatly limits growth of food such as algae and fouling organisms in the Arabian Gulf, limiting productivity of the reef unit, therefore the steps on the sides of the turrets were angled to shed sediment and encourage growth (Figure 2).

![Protective space is created by the gaps between turrets and colonisable surface length increased by 3.6m](image)

**Figure 1. Examples of how the top turrets provide protective space for fish as well as attractive structure to school around**

Gaps and holes also play an important role in maintaining water quality within enclosed areas. Without sufficient flushing, dissolved oxygen can decrease and metabolic byproducts from plants and animals can reduce water quality and reduce the attractiveness of a space. Just like rooms in a building need sufficient ventilation otherwise they feel ‘stuffy’ and uncomfortable.

**Figure 2. Example of how fish, oysters and urchins take advantage of the protective spaces provided by the turrets and angled surfaces that shed sediment**

**Vertical narrow archways**

The vertical archways on the upper tower section increase the protective spaces provided by the tower. Rather than one archway on each side (or no archways), the two archways next to each other double the protective space by doubling the number of walls. They create a network of columns that still allow sufficient flushing to maintain water quality but they provide increased opportunity to avoid predators. The width of the archways has been designed to suit the target fish species.

The top section is angled 90 degrees to the base section to provide areas for coral growth and to produce favourable current eddies.

Protective space is created in a variety of ways and is not just about holes or caves.

The key is to look at every surface, corner and solid area and explore whether modifications can be made to create more protective space.
**Large archways in bottom section**

A favourite eating fish in the project area is a grouper, locally called 'hamour'. This grouper prefers overhangs and caves. However, caves must not be too deep or enclosed as this reduces water quality, light and attractiveness. The bottom section of the Wind Tower has large archways on each side that hamour will find attractive. Archways on each side provide multiple escape routes and ensure good water quality and light.

![Large archways in bottom section](image)

*Figure 3. Photo top left: bottom archways and lower chamber for hamour (grouper) viewed from the inside and modeled after local archways used above doors and windows. Bottom photos: time lapse camera confirms the lower chamber is indeed being used by hamour and numerous other fish, especially when currents are running.*

**Indented lattice pattern**

The angled indented patterns on both the Wind Tower and Anti Trawl unit serve an important function and are not just included for decoration. They have been included as a test to see if the indented pattern is effective at reducing grazing by short spined sea urchins, common in the area. These urchins can significantly reduce the amount of algae on natural reefs as well as hard surfaces provided by rock breakwaters or concrete reef units. This algae helps fuel the food chain by supporting the millions of small shrimp and crabs that inhabit reefs.

Note how the indents have been positioned to minimise the number of horizontal ledges that may trap sediment and reduce growth.

![Indented lattice pattern](image)

*Figure 4. Angled lattice indent before and after deployment (3 months) demonstrating how the lattice reduces grazing and provides protective space that influences colonising biota - in this case its' favoured by the black sea squirt*
Antti Trawl Reef Unit

This unit is designed to discourage and prevent trawling in areas that contain important habitats that must be protected. Anti trawl units are an effective and cheaper alternative to policing an area.

Many anti trawl units are designed only to catch nets. This is a missed opportunity to further develop a reef area. We have designed this anti trawl unit to be large enough and have sufficient protective space of various shapes and sizes to enable it to function as a self contained mini reef. The size of the unit is based on our observations of the effectiveness of existing artificial and natural reef structures in the area.

The size of the unit can be scaled to suit the size of trawlers in an area. For this project, we designed a large unit to increase the 'fear factor' of getting nets caught on it.

Top

The top edge of the unit has rows of wedge shaped points in order to create numerous protective spaces and reduce flat areas that will have reduced growth due to sediment settling on them.

These points will provide settling spaces for sponges, corals and bivalves as well as swim through space for fish.

There are two different sizes in order to add diversity and test which size is more effective.

Holes

The row of arched holes have been sized to suit the size of the target fish the project is aiming to increase (eg yellowbar angelfish - lower photo) and are placed in a row based on observations of the way in which the target fish use natural coral bommies and artificial structures in the area.

Additional holes have been included to add more protective space and increase opportunities for nature to colonise the reef unit. Assessment of the reef units will include observations of the type of fauna or flora that take advantage of the different holes.

The size and shape of holes will influence the type of fish or other animal that uses them. Similar to how we vary the size of our doorways in buildings depending upon whether people or vehicles, trucks, or planes are going to access them.

Stability and durability are equally as important as protective space!
Other important features

Stability
As with any reef unit, consideration must be given to the stability of the structure in the anticipated wave climate, currents, the type of sediment its being deployed upon, effect of scouring and durability and toxicity of material.

Engineering studies were conducted on both the Wind Tower and Anti Trawl unit to ensure they would be stable in 1 in 100 year storm events, and the bases have been designed to support the units on the sediments found in the project area.

Durability
A high strength marine concrete is used that has a high resistance to seawater and there is sufficient concrete thickness to provide protection to the epoxy coated rebar inside.

Cultural sensitivity
We checked with appropriate authorities to ensure the chosen features would not be offensive to use.

Height
Don't forget to consider transport of the units to the barge/dock for deployment. You may need to pass under bridges or power lines. We made sure that the height of the reef unit when on top of the flatbed truck would fit under bridges or power lines.

Other Tech Notes in our series

Tech Note 1  ADAM - 4 essential stages for successful artificial reef design
ADAM is an essential process for new and experienced reef builders; small reefs of just a few units or very large reefs.

Tech Note 2  Shared principles of artificial reefs and cities
Comparing reef design to cities is a great tool for improving understanding amongst stakeholders and helping you design better reefs.

Tech Note 3  Estimating fish biomass using hydroacoustic
Ever wonder how many kilos of fish your reef has? Ever wonder which reef layout works best? Hydroacoustics can help confirm fish biomass and help assess effectiveness of different reef layouts.

Tech Note 4  Design notes for Wind Tower and Anti trawl reef units
Designing reef units that include local architecture is more than just copying a building. It requires a sound knowledge of the local species and reefs, and a very careful selection of architectural features.

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