MULTI-YEAR MONITORING TO DISTINGUISH ENVIRONMENTAL IMPACTS DUE TO WATERFRONT CONSTRUCTION FROM AMBIENT ENVIRONMENTAL CHANGE

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In tropical marine systems, water quality, coral health, fish habitat productivity and various other factors (e.g.: water temperature, salinity, turbidity) are all inter-related. Therefore, shoreline development, and the related design and construction of waterfront projects, may have a significant impact on the marine environment, both positive and negative, depending on the location and quality of science, engineering, and marine ecology undertaken during design, construction, and monitoring.

Evaluating the physical, ecological, and social impacts of coastal projects after construction is rarely undertaken in any quantitative manner, if at all. Baird is committed to evaluating the impacts of coastal projects, developing new means of documenting performance, and significantly improving the interaction and knowledge base between coastal engineers, marine ecologists, and others involved in coastal development. As part of our standard process, we include monitoring for a period of 2-5 years to quantify shoreline stability, water quality impacts, and increases in biological production as well as biodiversity.

In Barbados, Baird has built on its experience tracking shoreline / beach stabilization, turbidity changes, and colonization of submerged breakwaters by corals at various projects. Working closely with the Barbados Coastal Zone Management Unit ("CZMU"), Baird has designed a research protocol for tracking changes to shoreline, nearshore benthos, and broader reef environments in a series of private sector-supported shoreline control measures. This research in combination with a comprehensive database developed by the CZMU and a number of ongoing existing and planned coastal developments provides the basis for advancing the science in a meaningful way over the coming years.

This research is intended to prove the hypothesis that the proposed submerged breakwater structures are located far enough away from other habitats that they do not negatively impact adjacent and more productive areas. This applies to construction impacts and any changes to turbidity or currents that might affect existing natural habitats.

To determine when environmental arguments against development are valid and to counter those against research due to time and cost pressures, the goal is to identify what is important for minimizing environmental impacts of development.

Examples of this ongoing research program include:

Coral and Fish Population Impacts: Determine how breakwaters can be designed to create fish nursery habitat and thereby increase fish populations. This includes noting settlement rates and survivorship of coral colonies on underwater structures, estimating fish biomass, and collecting data on the occurrence of rare or threatened species.

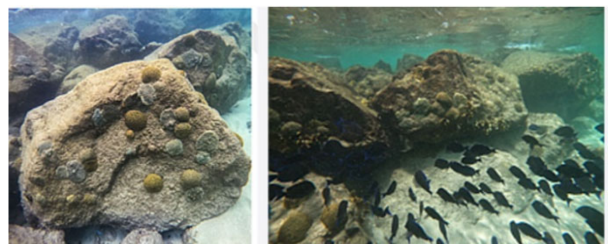

Figure 1 - Coral Health and Fish Habitat

Generally, the footprint for the structures is on benthos consisting of algae covered reef rubble or pavement, with little to no live coral. Marine biologists and ecologists survey the target areas, census biota, photo document the benthos, and map habitat and the precise location of any living coral. In the case of footprints on living coral colonies, they have successfully removed corals and placed them back on the breakwaters, where they have thrived. We have returned to the sites on a regular basis to document the establishment of coral as well as fish.

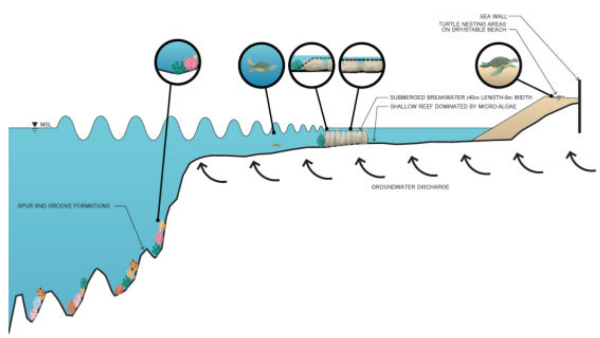

Figure 2 - Location of Proposed Structures is Crucial

Because the structures are exposed to better circulation in the water column and potentially better water quality due to regular tidal and wave activity, coral spat can become established on the breakwaters where it could not on the algal covered reef flats. The same structures also provide substantial voids and habitat for fish where previously very few were identified.

All of the projects being studied had eroding beaches and algal covered reef flats fronting them prior to any field work or design activity. Although only in its initial stages this research clearly shows the positive impacts on various parameters including the establishment of coral on the submerged breakwaters, an increase in fish populations, stabilized beaches for shore protection, and public access where previously there was none.

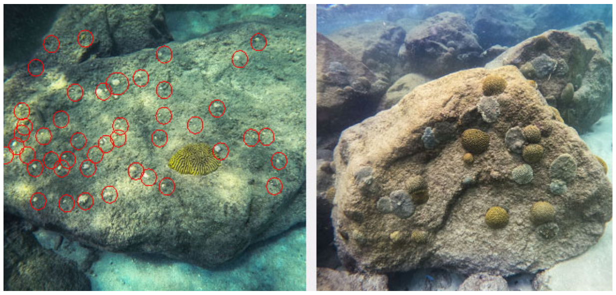

Figure 3 - New Recruitment and Genetic Variety

Turbidity: Assess the causes and impacts of turbidity, and how construction-generated turbidity compares to the resuspension of sediments caused by storm and wave events, and stormwater runoff impacts.

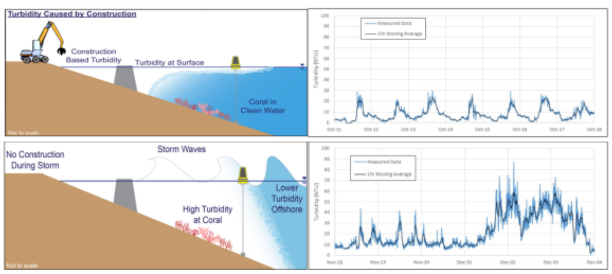

Figure 4 - Turbidity Measurements

Relative to wave-generated turbidity the disturbance of habitat due to breakwater construction occurs over short periods of time, is significantly lower in intensity, and is generally focused on the surface relative to wave events. Wave events create high turbidity levels near the bottom suggesting that construction-generated turbidity is far less impactful to corals.

Figure 5 - Construction Generated Surface Turbidity

Sand Compaction: Determine whether manufactured sand (created through crushing calcareous material) has significantly different gradations or compaction characteristics than natural sand. It has been suggested that manufactured sand may be less stable or that it is detrimental to turtle nesting due to higher compaction values.

Figure 6 - Sand Constituent Analysis & Compaction

A baseline study assessing the potential impacts of various sand sources on beach stability and compaction is underway to determine if sand sources impact turtle nesting. This is a prime example where marine ecologists, coastal engineers, and scientists can work together to provide an unbiased database on the benefits and negative impacts of coastal development on a particular environment.

The research includes looking at sand constituent analysis and compaction for various sand sources (artificial manufactured sand, dredged sand, and naturally occurring sand). The samples were measured at various locations and depths as indicated in Figure 7 below.

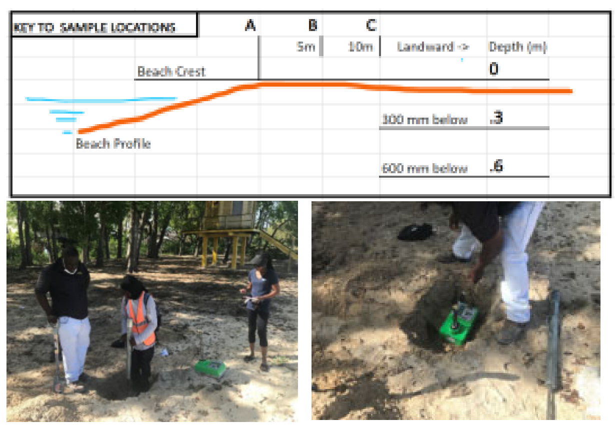

Figure 7 - Sand Compaction Testing at Depth

The results of this research suggest:

- There are effectively no discernable differences in compaction between the manufactured and natural sand at the locations tested.
- Compaction is at its maximum at the surface and decreasing with depth, correlating with increasing water content with depth.
- There are no discernable trends in compaction, density or water content trends from the beach crest landward.

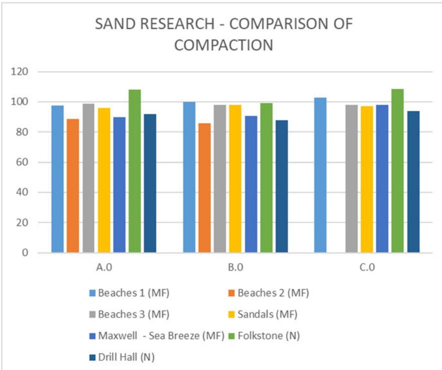

Figure 8 - Sand Compaction Test Results

Note that the Folkstone sample (green) in Figure 8 had the highest surface compaction (dredged natural sand from the Bridgetown careenage) and is associated with a high fresh water table relative to the other sites and beach profiles. Correlating the creation of natural beach rock (cemented sand) due to the interaction between salt water and fresh water lenses may be the cause of this high compaction at this location and requires more research.

Water Quality: Assess whether or not the construction of offshore submerged artificial reefs / breakwaters impacts various water quality parameters (temperature, salinity, chlorophyll-a, dissolved oxygen) in a manner which might negatively affect the surrounding marine environment.

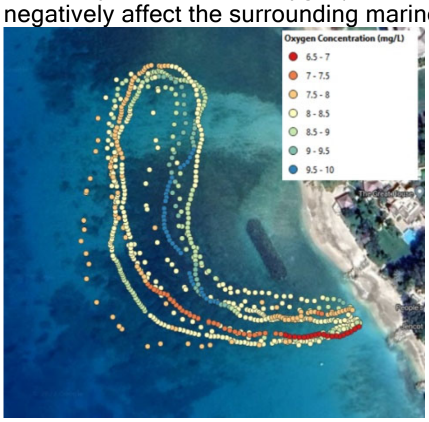

Figure 9 – Example of Water Quality Measurements

As part of the standard permitting process, Baird undertook measurements of select water quality parameters including temperature, salinity, chlorophyll-a, dissolved oxygen, and turbidity over the course of pre, during, and post construction phases of projects. There are significant limitations with interpreting this data as the parameters vary temporally and spatially; for example chlorophyll-a responds to sunlight so weather and time of day impact the results. In addition, we are not recording the critical supporting data at each site such as rainfall, local surface runoff, groundwater discharge, and wave conditions. These inter-related parameters all help to explain the behaviour of water quality in response to natural and anthropogenic events.

Substantial research remains to be done on the topic of determining the positive and negative impacts of various coastal structures including those intended to provide shore protection and beach stabilization. It is also necessary to establish guidelines so that consistent and useful data are collected. This includes identifying why, where, and the optimal frequency and density of data collection. Finally, we must identify which parameters should be the focus of future studies and develop guidelines for consistent data collection.

Better cooperation among coastal engineers, scientists, and marine biologists and ecologists is necessary in order to rapidly advance the science and ultimately improve the results of the projects for both the environment and the public. Based on our substantial experience over many decades we are convinced that many of these projects, although often controversial for one reason or another, are generally to the benefit of both the environment and the public if properly designed, maintained, monitored, and evaluated.

Although this research is only in what we see as the initial phases of an ongoing and developing research program there have already been several advances noted in the projects being monitored. We also acknowledge that each design and construction project will have its own unique features and impacts that can, and should, be assessed for the particular environment in which they are being established.

- Offshore breakwaters / submerged artificial reefs (carefully placed to avoid existing healthy habitat) can create a healthy substrate for coral to become established and also create fish nursery habitat.
- Construction-generated turbidity is generally surface focused and far less impactful than previously thought. As a result, sediment loads on corals by construction are significantly less than loads from storm-generated wave events.
- There is no discernable difference beyond natural variability in compaction or stability between manufactured and natural sand.
- There are no significant differences in water quality parameters measured beyond those naturally observed by depth for pre, during, and post construction.

The data collected demonstrate that through environmental monitoring a general descriptive characterization of the area can be presented where none may have previously existed. At the close out of the post-construction monitoring the information will allow for the establishment of permanent monitoring locations for continued monitoring into the future by the CZMU.

Taken together, the parameters on turbidity, water quality and coral reef health, and fish populations can guide shoreline development design in the future so that construction impacts are mitigated, and habitat quality is enhanced. Cooperation between marine ecologists, engineers, and scientists could create excellent databases linking the various parameters and species' behaviour relative to site conditions whether or not they are impacted by natural or man made structures.