

HABITAT ENHANCING MARINE STRUCTURES: CREATING HABITAT IN URBAN WATERS

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Introduction to Habitat Enhancing Marine Structures

Although maritime regions support a large portion of the world's human population, their value as habitat for other species is overlooked. Urban structures that are built in the marine environment are not designed or managed for the habitat they provide, and are built without considering the communities of marine organisms that could colonize them (Clynick *et al.*, 2008). However, the urban waterfront may be capable of supporting a significant proportion of regional aquatic biodiversity (Duffy-Anderson *et al.*, 2003). While urban shorelines will never return to their original condition, some scientists think that the habitat quality of urban waterfronts could be significantly improved through further research and some design modifications, and that many opportunities exist to make these modifications (Russel *et al.*, 1983, Goff, 2008).

Habitat enhancing marine structures (or HEMS) are a potentially promising approach to address the impact of cities on marine organisms including habitat fragmentation and degradation. HEMS are a type of habitat improvement project that are ecologically engineered to improve the habitat quality of urban marine structures such as bulkheads and docks for marine organisms. More specifically, HEMS attempt to improve or enhance the physical habitat that organisms depend on for survival in the inter- and sub-tidal waterfronts of densely populated areas. HEMS projects are targeted at areas where human-made structures cannot be significantly altered or removed. While these techniques can be used in suburban or rural areas restoration or removal is preferred in these settings, and HEMS are resorted to only if removal of the human-made structure is not an option.

Recent research supports the use of HEMS projects. Researchers have examined the communities found on urban structures including docks, bulkheads, and breakwaters. Complete community shifts have been observed where the natural shoreline was sandy, silty, or muddy. There is also evidence of declines in community composition, ecosystem functioning, and increases in non-native species abundances in assemblages on urban marine structures.

Researchers have identified two key differences between these substrates including the slope (seawalls are vertical; rocky shores contain multiple slopes) and microhabitat availability (seawalls have very little; rocky shores contain many different types). In response, researchers have suggested designing and building seawalls with gentler slopes or a combination of horizontal and vertical surfaces. Researchers have also suggested incorporating microhabitat, including cavities designed to retain water during low tide, crevices, and other analogous features (Chapman, 2003; Moreira *et al.*, 2006)

Why Use HEMS Projects?

Since HEMS are flexible, modular tools, they can be used by urban and waterfront planners, corporations, and local county and state governments to further a diverse set of goals including biodiversity enhancement and enhanced quality of life. HEMS projects can also support existing restoration projects.

Using HEMS projects can help managers achieve biodiversity goals by creating more diverse communities that are more similar to those found on natural rocky shores and sustaining struggling populations (Moreira *et al.*, 2006). The advantage and abundance of non-native species may also be reduced, diminishing the potential for future non-native species invasions. Research examining the impact of incorporating more microhabitat found more species present and increased biodiversity on the modified artificial substrate (Moschella *et al.*, 2005). These benefits also suggest that HEMS would be good tools to use if a company or government agency is legally mandated to create habitat as a remediation action (Alevras, 2008).

There are also quality of life goals that can be fulfilled because of the potential cultural benefits to implementing HEMS projects. People who live in cities value marine organisms for aesthetic and recreational uses including fishing, bivalve, and algae collection. HEMS installations may increase the population of these species, although care must be taken to avoid attractive nuisance situations. HEMS installations may help beautify a city's waterfront fulfilling waterfront aesthetic goals. HEMS can also provide urban residents including schoolchildren with increased

access to high quality environmental education opportunities, which has been linked to increased support for conservation measures, increased sensitivity to environmental issues, and improvements in learning and behavior (Savard *et al.*, 2000; Coyle, 2005; Bryant, 2006).

HEMS can also support the goals of existing restoration projects and increase the effectiveness of these existing projects. This may be through increased public support and funding, or through supporting the ecological goals of existing restoration projects. Improving habitat in urban waterfronts may facilitate the movement of organisms, connecting existing projects, including those in riverine systems, with each other and the ocean.

Incorporating HEMS Projects into the Waterfront

There are three main ways that HEMS can be incorporated into the waterfront – designing them into new construction, incorporating them into renovation projects, and retrofitting previously built structures. New construction and renovation projects that involve constructing new or replacement piers, seawalls, and other structures can incorporate HEMS projects into the construction, for example by creating microhabitat when concrete seawalls are being poured.

If possible, HEMS should be considered in the early planning stages of new construction and renovation projects. Although it is possible, it is not ideal to incorporate them later on, as the scope and type of possible applications will be severely restricted and more closely resemble retrofitting projects. Retrofitting project involve modifying existing structures to include elements of HEMS projects. They are necessarily more limited in scope because the physical and engineering limitations of the structure, as well as any constraints imposed by inspection requirements, will need to be considered.

For all three of these options, the same basic planning structure can be used. An individual HEMS project will need to start with project planning, including stakeholder input and definitions of the goals and objectives for the project. The project design will then need to be considered, including site selection, choosing the type of habitat to be built, the design of the HEMS module, monitoring methods and securing project funding. Successful construction requires proper site preparation and construction planning. A rigorous monitoring, maintenance, and management stage requires a funding commitment and working teams for each section. Finally, outreach and education goals need to be defined, along with key audiences and venues for dissemination of results. Information on planning environmental projects in general is abundant and can be adapted to suit the particular needs of HEMS projects (see for example, Wilber *et al.*, 2000; Borde *et al.*, 2004; Clewell *et al.*, 2005)

It is also helpful to consider the installation of individual HEMS projects within the context of regional planning as the characteristics of the surrounding landscape impacts the abundance and species richness of smaller patch restoration projects (Hodgkinson *et al.*, 2007). A habitat backbone, which is a “planning and design approach aimed to create a network consisting of stable (key) patches surrounded by patches of a more temporary nature,” may be an effective tool in areas such as ports that are constantly being upgraded and rebuilt (Snep and Ottburg, 2008).

Designing Habitat Enhancing Marine Structures

Planners will want to take the physical characteristics of the site, the biological requirements of local and target species, social and economic concerns, and safety and engineering issues into consideration when designing their HEMS project. These may include for example the habitat requirements of species, the wave energy and other physical characteristics of the site, the engineering limits of structures for retrofitting, navigational conflicts, and the cost of fabrication and installation.

The material selection is also important in designing HEMS projects. Concrete, including both traditional and more recent mixtures, has been used successfully to build artificial reefs and other marine structures. Natural materials, including wood, shells, and rocks, can also be used to fabricate HEMS. Materials including steel, fiberglass, fiber-reinforced plastic, PVC, ceramic, and composite materials have been used in Japan and the U.S., however the efficacy and environmental safety of these materials should be studied further. Electrodeposition is another method that could potentially be used to create HEMS, although this too needs to be studied further. The use of rubber tires, including those ballasted by concrete, as well as decommissioned vehicles and oil and gas platforms is not recommended for HEMS use. The former may shed organisms in storms, and the latter is not easily designed to fit in a specific urban location. Further, cleaning decommissioned vehicles can be prohibitively expensive.

There are three main classes of HEMS that have been described so far – those that provide vegetative substrate, those that provide hard substrate, and those that provide other types of substrate. Within each of these classes there are projects that can be built on different surfaces, including the seawall, seafloor, piers, and the water column.

Vegetative substrate can be incorporated in two main ways – first, by encouraging plant growth, and second, by using artificial vegetation where environmental conditions, including excessive prop wash, will not support vegetation. Vegetation baskets - containers mounted to seawalls that hold growing media for aquatic plants - have been used successfully in the Cuyahoga River. Vertical gardens, which are structures that provide a vertical surface on which plants can grow, have been used in terrestrial settings to create aesthetically pleasing areas and could be adapted for use on sea walls. Vegetative substrate can also be incorporated into the seafloor by creating seaweed reefs out of concrete or rock and planting beds of seagrasses. In some areas, increasing the light available below docks with commercially available products may be required before seagrasses can grow successfully near these structures.

Techniques that incorporate hard substrate into urban structures are generally trying to address micro-habitat issues or reintroduce the habitat structure provided by hard substrate. Seawall texturing (relief integrated into or attached to seawall faces), seawall refuges (openings created in seawall caissons to provide refuges), and piling habitat (texturing designed into or added to pilings that provides habitat for local marine species) are three examples of technologies that attempt to increase the amount of microhabitat available. The habitat structure provided by hard substrates can be reintroduced using artificial reef units such as “ReefBalls,” and rocky islands, or rocks piled to imitate small islands or rocky outcrops that occur with rocky shorelines.

There are also other substrates that are valuable as habitat that can be incorporated into the urban waterfront. Woody debris or logs can be attached to the face of seawalls or placed on the seafloor where they and other detritus are lacking in the urban waterfront. At the foot of seawalls, cobble substrate can be used to create shallow water to benefit local organisms; these structures are commonly called habitat benches. Habitat baskets can also be used on seawalls. These are baskets or troughs hung from seawalls that contain gravel, cobbles, or without substrate in order to function as large tide pools. Wave breaks can be adapted to and designed to create calmer waters and sections of soft, shallow seafloors in the urban waterfront that can provide habitat for juvenile fish and other organisms that are sensitive to wave action. The use of geotextile bags filled with sand as well as piles of oyster shells have also been suggested as ways to provide habitat for marine organisms. Netting installed on the seafloor may also be beneficial as a number of species including seahorses benefited from permanent swimming nets installed in Australia.

There are benefits and drawbacks to all of these methods, and selecting the appropriate type of HEMS is critical. Further, because functioning ecosystems are quite complex and multiple habitat types may exist and interact in important ways, project managers may want to consider using multiple HEMS at a location to realize greater improvements to the urban waterfront.

Concluding Thoughts

Among the challenges the future holds, there are many opportunities to improve our urban waterfronts. Movements to reconnect cities to their waterfronts and to transform urban waterfronts into places where urban residents can live and recreate provide opportunities to incorporate habitat into rebuilt urban structures. While current projects and green initiatives often end at the water’s edge ignoring the marine organisms that share our cities, HEMS are tools that can truly reconnect cities to their urban waterfronts. With HEMS projects we can provide both humans and marine organisms with high quality spaces to use. The utilization of properly executed HEMS can help create an aesthetically pleasing urban waterfront that fulfills the economic and social goals of cities while providing the habitat needs of marine organisms.

References are available upon request.

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