Habitat opportunities in harbours - Port of Rotterdam, NL

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Location: Port of Rotterdam (Scheurhaven & Pistoolhaven)

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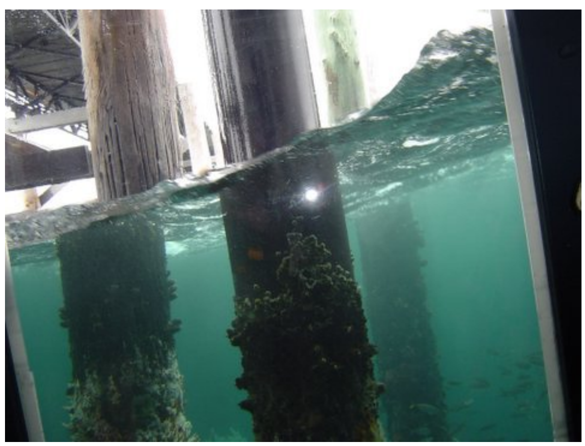
Involved parties: Deltares, Ecoconsult, Port of Rotterdam

Technology Readiness Level: 5

Environment: Ports & Cities, Estuaries, Lakes & Rivers

Keywords: Water quality, ports, nature creation, habitat enhancement

Building with Nature design	Traditional design
 Floating and hanging artificial surfaces can enhance habitat diversity and filter feeder biomass, if port water quality is good enough (like in Rotterdam). Constructions made of standard nylon ropes, strategically strung between the piles of a jetty, are a cheap way to do this. The photo shows such ropes four months after installation.	 Smooth steel and concrete structures, like sheet-pile walls or jetty piers, provide little grip for mussels and sea anemones. Further, compared to natural rocky habitats, artificial structures lack cracks and crevices, and profile variation.

5 Basic steps towards Building with Nature

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Abstract

Harbours are often seen as abiotic environments that are optimized for economic activities. While this is sometimes true, harbours also provide a habitat for many species. Simple measures can do a lot to provide additional ecological value.

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Project objective

Port areas mainly consist of man-made structures, such as seawalls, piles and pontoons. These hard structures are favoured as settling substrates by different organisms, such as algae, mussels, sponges and oysters. However, a too smooth substrate will hamper organism attachment and provide little hiding place for larger animals such as fish, lobsters and crabs. Traditional harbour structures create a smooth underwater environment. The present pilot experiment concerns simple but effective measures to make this environment more suitable for organisms to attach themselves and to create more habitat complexity for fish.

Project solution

In order to promote the settlement of mussels and consequently contribute to improve the water quality in the harbour, this pilot experiment aims to create a less smooth underwater environment via free-floating artificial substrates. This would enlarge the substrate suitable for settlement, increase the biomass of filter-feeders (e.g. mussels) and enhance habitat diversity in the port area. To enrich the habitats underneath pontoons and jetties so-called 'pontoonhulas' were developed. To enrich habitat around poles so-called 'polehulas' were used (‘hula’ is the name of the skirts of Polynesian hula dancers).

Governance context

The Port of Rotterdam has the ambition to become a sustainable and energy-neutral port. In this context, the port investigates various alternatives to make the port ‘greener’. When the Rijkswaterstaat-funded WINN project Levende Waterbouw reached the ears of port representatives, they were open to developing a number of pilot experiments.

Costs and benefits

The present pilot investigates simple and low-cost options to enhance filter-feeder biomass in harbour basins. Given their filter capacity, mussels are known to improve water quality by decreasing fine sediment concentrations, thus increasing light penetration through the water column (Dolmer, 2000). Generally, light stimulates algae growth and ,in turn, living algae produce oxygen. Since all organisms living in the water column use oxygen, mussels can be claimed to aid in promoting biodiversity in port areas by improving the water quality. Moreover, mussels are able to improve the ecosystem by retaining contaminants (Strogyloudi et al., 2006). Also, they create more habitat variety and complexity by creating hanging underwater forests, which can provide hiding places for fish.

Initiation, planning and design

As part of the Rijkswaterstaat Innovation Program (WINN), Deltares sought cooperation with Port Centre Rotterdam. The project and its scope were defined by the parties collaboratively. Ideas developed by Deltares and Ecoconsult as part of the Rich Revetment study and new ideas on the hanging ‘hula’ structures were proposed for implementation in a number of pilot experiments in the Rotterdam harbour.

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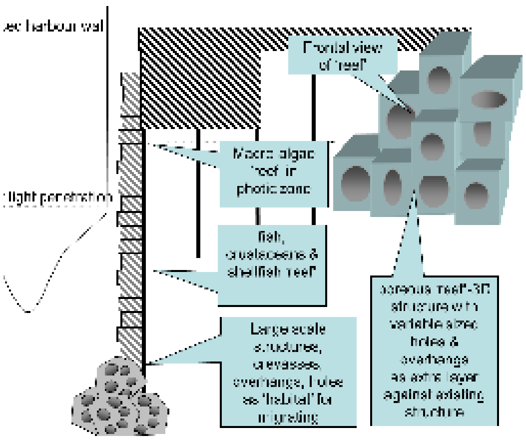
Pre-feasibility

In the Rich Revetment philosophy, eco-dynamic design scenarios were considered for four habitat types:

1. high-dynamic shallow habitats,
2. high-dynamic deep habitats,
3. low-dynamic shallow habitats and,
4. low-dynamic deep habitats.



The fourth habitat type is applicable to most harbour environments and therefore two pilot alternatives were evaluated for this type, namely constructing a

The large amount of hard substrate present in harbours was considered to offer opportunities for epifauna. In this respect, hard substrates can function as artificial reef structures. However, artificial hard substrates usually lack the variety of habitat characteristics of, for example, natural rocky coasts. Therefore, an optimal harbour wall was designed to resemble a natural reef by adding cracks and crevices of distinct sizes, making the wall suitable for colonization by small organisms such as algae, mussels and sponges, as well as by larger organisms such as fish and lobsters. Implementing such a reef wall would require the construction of new walls, which was not feasible for this pilot. Therefore, the present project only focuses on simpler solutions that can be applied in existing harbour basins.

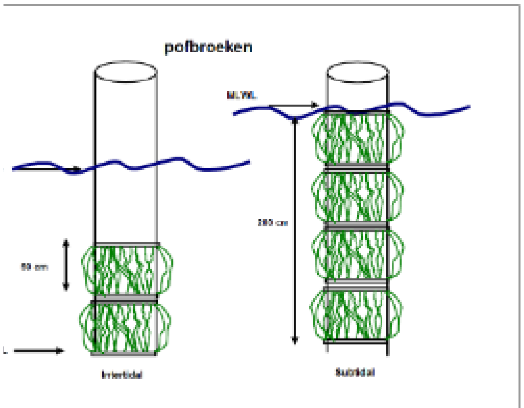
Firstly, a study of requirements and boundary conditions was executed by Ecoconsult (Paalvast 2007a). Several other pilot projects connected to the Rich Revetment concept started out in a similar way, by conducting feasibility studies that would define general questions or problems and offer potential solutions. Subsequently, the envisaged pilot project was investigated in more detail, making a selection of techniques and locations (Paalvast 2007b). Suitable harbour basins were selected based on expert knowledge of ecologists familiar with the system. Locations were selected based on salinity levels. Large fluctuations in salinity are a restricting factor for many organisms. As mussels were one of the target species, locations and timing of the experiments were adapted to optimize the potential for mussel establishment and survival. Some alternatives that were generated in the pre-feasibility phase are in the figures accompanying this text.

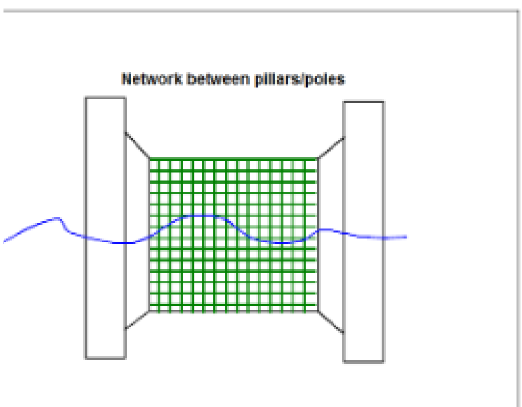
Feasibility

Two specific structures were selected for the Rotterdam harbour to further elaborate: polehulas and pontoonhulas.

1. **Polehulas:** consist of ropes suspended from a band that can be wrapped around a pole. The polehulas that were used in this experiment were composed of 301 ropes with a rope length of 55 cm and a rope diameter of 6 mm. The total rope length per polehula is 165 m and the total surface area is 3.1 m^2 of artificial substrate.
2. **Pontoonhulas:** are floating elements from which ropes are suspended. The floating element used in this experiment consists of a rectangular frame of PVC-tubes (diameter 125 mm) with on the inside a stretched nylon net with a mesh size of 12.5 x 12.5 cm. At the crosses of the

nylon net, ropes with a diameter of 12 mm are connected. The area of the pontoonhula, the

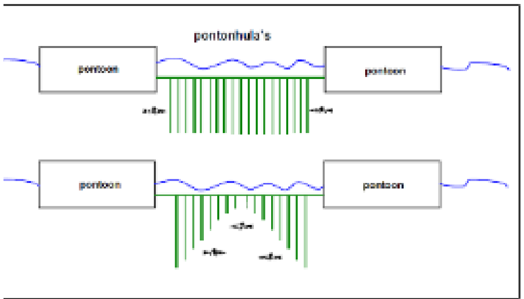


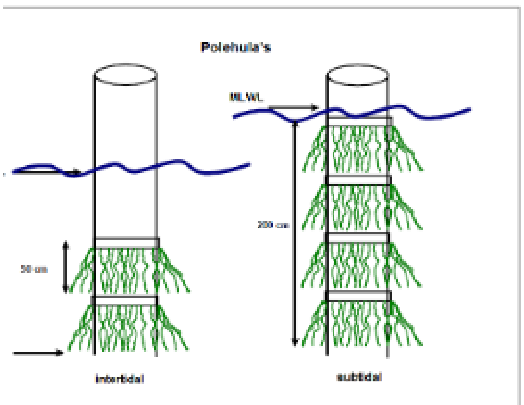


length of the ropes and the rope density may vary per pontoonhula. Two types of pontoonhulas were used in this pilot.

Pontoonhula Type I has a rope length of 150 cm, whereas the rope length of Type II decreases from 150 cm at the outside to 30 cm in the middle (bell shape, in Dutch "klokmodel"). The largest pontoonhula measures 160 x 200 cm with a rope density of 208 ropes per pontoonhula and a rope length of 150 cm. The total rope length is 312 m and the maximum total surface is 11.8 m^2 of artificial substrate.

Operational risk





At this stage, a potential risk for the daily operations of the Port was identified. It was feared that once the floating structures would be colonized by algae

Request for Proposal

The time from initiation to contract took about one year of regular, albeit low intensity, interaction. Before the project could actually start, the Port of Rotterdam insisted on solving the perceived risk of valuable nature developing in harbour basins that might limit the possibilities for maintenance and normal harbour operations. To tackle this problem, the Dutch Ministry of Agriculture, Nature conservation and Fisheries was approached with the request for a written and signed permit to remove the structures at any time. When this permit was acquired, the project could start and after reaching agreement on the proposed pilot structures and locations, the Port of Rotterdam asked Deltares to submit a proposal for enriching underwater habitat diversity in their harbour areas. Deltares, the Port of Rotterdam and Ecoconsult developed the plan together. General ideas on how to further enrich habitat diversity were developed by both Deltares and Ecoconsult at a later stage (Paalvast 2007a and Paalvast 2007b). The full program, including financing and execution of all construction and monitoring tasks, was agreed and undertaken by the various parties in a constructive and effective cooperation.

Status 2012

The hula structures will be applied in another project for the Port of Rotterdam: the widening of the Amazonehaven at Maasvlakte 1. The goal is to increase habitat diversity and at the same time possibly delay corrosion of the sheetpiled harbor wall by having the mussels filter oxygen out of the water before it reaches the steel wall, providing a valuable ecosystem service.

Construction

Before the actual construction, the conceptual designs from the previous phase were further detailed. After the detailed design had been finalized, the polehulas and pontoonhulas were placed at the dedicated locations.

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Detailed design and construction

The bare polehulas and pontoonhulas were placed in the Scheurhaven and the Pistoolhaven in March 2009. In the Scheurhaven, polehulas were placed around 5 wooden and 2 steel poles and in the Pistoolhaven the polehulas were placed around 3 steel poles. At the wooden pole, one polehula was placed above mean low water (MLW). Below MLW, three polehulas were added with an overlap of 10 cm. The aim of this variation is to determine the optimum position of the polehulas with respect to the water level. At the steel poles, only one polehula is placed below MLW around each pole.
Pontoonhulas type I, with a size of 85 x 230 cm, and a varying rope density of 40, 80 and 168 ropes were used in the Pistoolhaven. In the Scheurhaven two pontoonhulas type I, with a size of 160 x 200 cm and a fixed number of ropes per pontoonhula of 208, were used. Moreover, two pontoonhulas type II were used there, with an area of 160 x 200 cm and a fixed rope density of 208 ropes per pontoonhula.

Monitoring during Operation and Maintenance

Given the nature of the pilot, a monitoring program was set op to monitor the ecological development on the structures. Twice a year biomass and species diversity on the structures was determined. Status of the structures was checked each month for safety purposes. These monthly maintenance check-ups were also used to measure present biomass on the strings.

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Monitoring

The polehulas in the Scheurhaven were monitored 15 and 34 weeks after construction. After 15 weeks, barnacles (Balanus improvisus) and mussels (Mytilus edulis) were predominant below MLW. Above MLW, algae species Porphyra umbilicalis and Ulva linza, were predominant.

After 34 weeks, a significant shift to mostly mussel abundance was observed. Given the biomass of a reference pole (9,925 g/m^2), the biomass of the polehulas is maximum 11.4 times larger (112,996 g/m^2) and 8.5 times higher when averaged over all polehulas (84,031 g/m^2).

As compared with the polehulas, dominance of mussels was even stronger at the pontoonhulas. No algae were observed there, possibly due to the limite

Given a maximum biomass of 348 kg at one pontoonhula in the Scheurhaven, the total time to filter the entire volume of water in the Scheurhaven can be calculated. Based on a study on the colonization of an artificial hard substrate by the same mussel (Joschko et al., 2008), a biomass of 348 kg corresponds with some 247,000 individuals, One mussel is assumed to filter around 35 cm^3/min (Dolmer, 2000). Given the total volume of water in the Scheurhaven of about 195,000 m^3, one pontoonhula is able to filter this entire volume in 16 days. Upscaling this to the entire Rotterdam harbour, around 35 pontoonhulas per harbour basin are able to filter the entire volume of water in the harbour within one month.

The monthly check-ups revealed that after a couple of months, the pontoonhulas significantly increased in weight due to the increase in biomass. Consequently, the structures started to sink. Fortunately, they were still attached to existing pontoons by several hawsers. To prevent the pontoonhulas from breaking loose, the number of hawsers attaching them to the pontoons was doubled to keep the pvc-construction of the hulas afloat.

End of life

Pontoonhulas can also help to reduce wave heights as the structures can absorb wave energy. The ropes of the pontoonhulas were included in SWAN-VEG, a numerical model that includes wave dissipation by vegetation. In this model, the wave height, wave period, length of section with ropes and the biomass can be varied. Depth was 4 m and it was assumed that the ropes were 4m as well. Structures achieved wave damping of 14% for a 10 m structure, a low biomass and a wave height of 0.1 m. Up to 80% could be achieved with a 30 m structure, a high biomass and a wave height of 0.5 m. By varying variables such as biomass and length, a conservative estimate can be determined for the wave reducing capacity of these structures. The hula-structures were removed from the field by the end of 2010. The pontoonhulas were transported to the Deltaflume of Deltares. There, they were put in the water and were exposed to both regular and irregular waves to determine their ability to reduce wave height. It was found that for floating structures, wave transmission closely resembles wave transmission by floating breakwaters with the addition that mussel structures penetrate deeper in the water column and are porous. Both these parameters influence the wave attenuation capacity of a structure (van Steeg & van Wesenbeeck 2011). Ideally, the mathematical model exercise should be expanded and the flume study should be used as a validation case for SWAN-VEG. However, this has not yet been done due to budget constraints.

Lessons Learned

The lessons learned from this project centre around the following aspects:

- artificial substrates are an effective method to increase biomass in harbour basins

- The aggregate of mussels provides an additional water filter capacity which can be beneficial for the ecosystem
- No information is available on the long-term development
- The weight of the pontoonhulas increased with almost 300 kg in less than four months
- The design of pontoonhulas can be optimized by making use of elements such as Mussel Seed Capture Installations
- Polehulas need relatively large rope diameters to be effective
- The artificial structures can be used to dampen wave action within harbour basins

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- Artificial substrates, such as polehulas and pontoonhulas, can increase the biomass in a harbour basin considerably. Thirty-four weeks after construction, one polehula yielded on average 8.5 times as much biomass as a pole with no hula around it. A pontoonhula is able to gather a total biomass of some 350 kg after 19 weeks. On both artificial substrates, the mussel Mytilus edulis is the dominant species. On the polehulas, different algae species were also found.
- The collection of all mussels on a single pontoonhula is able to filter the entire water volume of the Scheurhaven basin in 16 days. The additional filtration will contribute to improved light penetration into the water, to contaminant sequestration and a better overall ecological condition of the basin. This is in line with the main objective of the European Water Framework Directive.
- Biomass development and species composition have only been monitored in the first year after construction. This implies that so far no clear indication of their long-term development is available.
- After mussel settlement, the weight of the pontoonhulas increased with almost 300 kg in less than four months. Consequently, the original buoyancy of pontoonhulas was no longer sufficient to keep the structure afloat. For future designs buoyancy should be adapted to the increasing weight.
- The design of pontoonhulas can be optimized by making use of design elements of MZI's (Knowledge - Mussel Seed Capture Installations), which are developed to capture mussel seed at open sea. These structures are anchored and consist of steel cables and a large number of float levers.
- Polehulas can be improved by using ropes with a larger diameter. In the current design the rope diameter in the polehulas was 0.5 cm. This was rather small, as individual mussels ended up settling on several ropes.
- Floating mussel structures attenuate waves and can be used for this purpose in harbour basins. The amount of wave attenuation depends on the length of the structure and the rope density.
- To realize this pilot, a step by step approach was followed: 1) scope the opportunities and costs for potential eco-design solutions, 2) implement a small-scale pilot to obtain a proof-of-concept, 3) modify the design according to the lessons learned from the pilot and upscale to full scale. This gradual approach has proven helpful in the efforts to achieve an innovative approach that was actually implemented in the field.

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