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Concrete biodiversity improvements in harbors

ABSTRACT
Traditionally, harbors have been designed mainly for fisheries and for transport of goods and passengers. In recent years, water quality has improved in many harbors, and marine biodiversity is becoming increasingly important. In the present study, concrete elements - with complex surface designs - were deployed on harbor sea walls and at sites where coastal protection is needed. This was accomplished to improve the local marine biodiversity and fish abundance. Our study is conducted in the Vigo Harbor situated in northwestern Spain. A team of DTU researchers has just returned from a three weeks' fieldtrip monitoring underwater biodiversity in the Spanish harbor. We investigate whether 1) concrete harbor walls with different structures, and 2) new concrete elements deployed for coastal protection may improve the local marine biodiversity and fish abundance. We measure biodiversity by analyzing underwater video footage. Harbors often have a central place in cities, and increased marine life may eventually turn harbors into exciting blue parks for people to enjoy. Although the project is conducted in Spain, the project results are also relevant for other European harbors where local marine biodiversity is growing in importance.

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HARBORS AS FUTURE BLUE PARKS

For centuries, harbors have developed as the need for fishing and transportation increased. Traditionally, harbors have been designed to serve mainly industrial purposes. Most harbors are built with concrete elements, where only functional properties are prioritized. The chemical composition and lack of surface complexity, present on most concrete elements, is a poor habitat for many marine organisms. There are often poor conditions for fish and invertebrates to thrive and develop. About 20-30 years ago, no one was thinking of swimming in harbors, but in recent years, there has been growing attention on water quality in cities. The water quality in many harbors has improved, and it has become more attractive for many people to live near the harbors, marinas and beachsides. This is also reflected in the growing interest in houses and apartments for people to live near the sea.

In previous centuries, it was mainly poor fishermen who were living near the sea. In an economic aspect, prices of houses near the sea have increased and the demand remains high. Sometimes, apartments are built so close to harbors that you can almost fish directly from the balcony. Playgrounds and outdoor-fitness facilities are built at the harbors, and the increasing use of luxurious houseboats indicates further interest in life near the sea and harbors. Indeed, there is growing interest in enjoying harbor facilities and spending more time near the sea.

*Fig. 1: Schools of common two-banded seabream (*Diplodus vulgaris*) in Bouzas: Photo: Maria Moltesen*

With underwater cameras, we collect underwater footage to document resulting changes in biodiversity and fish abundance.”

IMPROVING MARINE LIFE IN HARBORS

Vigo is a Spanish city facing the Atlantic Ocean. The city is situated in a bay, protected by surrounding islands, including the Atlantic Islands of Galicia National Park. Impressively, Vigo Harbor is one of the major fishing ports around the world in the traffic of fishing for human consumption, both in terms of quantity and quality. Vigo harbor has more than 90 regular maritime services to major destinations in Europe, Africa and America.

Vigo harbor was the first fishing port in Europe. The harbor expanded tremendously in the 1960s when the new freezer trawlers, which revolutionized the fishing industry, became available. In addition, there are ferries with passengers docking at the harbor every day, as well as cruise ships visiting the harbor weekly during the season.

In 2021, a project called LIVING PORTS, sponsored by the European Union's Horizon 2020 research and innovation program, started in Vigo. The project is testing new methods to improve biodiversity in harbors. New types of concrete elements were deployed to improve marine biodiversity and fish abundance. With underwater cameras, we collect underwater footage to document resulting changes in biodiversity and fish abundance. We hope to document that the concrete elements will provide favorable habitats for several fish species and many other marine animals.

*Fig. 2: Some of the common fish species: Common two-banded seabream (*Diplodus vulgaris*); Moroccan white seabream (*Diplodus cadenati*); Corkwing wrasse (*Symphodus melops*); Thicklip grey mullet (*Chelon labrosus*); Bogue (*Boops boops*) in Bouzas: Photos: Maria Moltesen*

↖ Fig. 3: Top: The schooling species: Sand smelt (Atherina sp.) are small, pelagic fishes which is a common fish species in Portocultura, Mangrove Seawall. Photo: Maria Moltesen

↓→ Right/Bottom: Illustration of the three structures: 1) Mangrove, 2) Azuri and 3) Traditional. Illustration by Maria Moltesen

NEW CONCRETE DESIGNS WITH STRUCTURES TO IMPROVE BIODIVERSITY

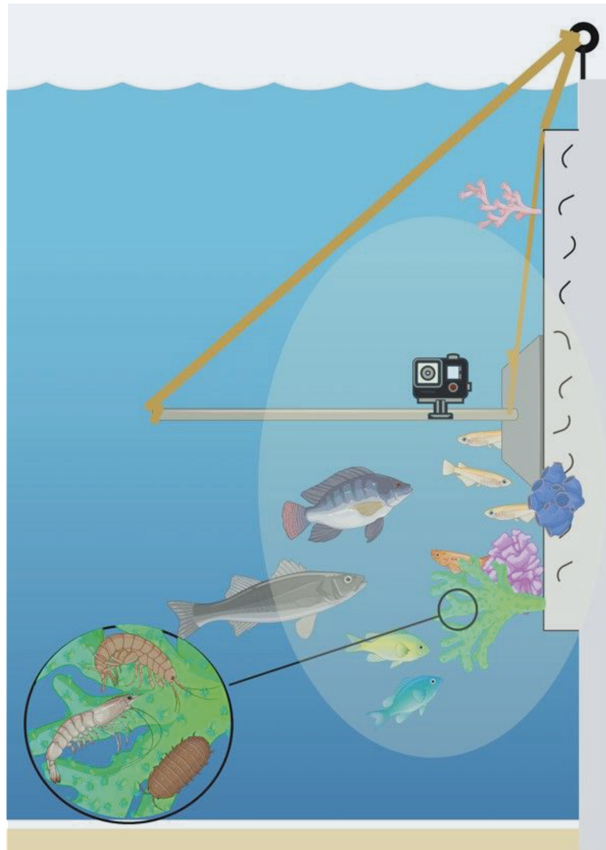
The project LIVING PORTS is introducing new concrete structures to the harbors. A company from Barcelona, Spain, ECOncrete, has designed the custom-built concrete elements with different structures, which have been placed 1) on the vertical walls in the Vigo Harbor and 2) on a nearby coastal protected area to improve marine biodiversity. Concrete elements with three different structures were deployed in the harbor area called Portocultura. The first structure has patterns resembling mangrove roots and is called “Mangrove”. The other structure in Portocultura has square patterns at different height levels and is called “Azuri”. The 3D square design increases the surface area and structure of the wall. For every concrete element, traditional concrete elements were deployed nearby for biodiversity and engineering property monitoring between the different harbor wall types (Mangrove, Azuri and Traditional). Thereby, the designed concrete elements with structures (210 m^2 Mangrove and 120 m^2 Azuri) are directly compared to the traditional concrete elements (60 m^2 Traditional) (Fig. 3). Mangrove and Azuri are designed for better attachment of sessile organisms such as barnacles, sponges and mussels and benthic communities such as mollusks and crustaceans, providing food and shelter for fish.

In another area of the harbor called Bouzas, coastal protection is traditionally done with boulders. ECOncrete has designed large concrete units (Coastalocks), each including a pool containing about 100 L of water. The weight of the Coastalock is 3410 kg.

↗ Fig. 4: Right: Deployment of camera unit by Julius Valhav at Portocultura. Photo: Maria Moltesen

← Left: Camera unit above sea level at extreme low tide. Photo: Maria Moltesen

↓ Bottom: Underwater cameras are recording horizontally and parallel to the seawalls.Illustration in BioRender by Tim Wilms



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We hope to document that the concrete elements will provide favorable habitats for several fish species and many other marine animals.”

↑ *Fig. 5: Bouzas Top left: Control site.Top right: Coastalock site. Bottom left: Coastal protection. Bottom Right: Coastalock and model.Photos: Maria Moltesen* ↓ *Fig.6: Coastalocks in Bouzas. Drone photo: Julius Valhav.*

↑ *Fig.6: Left: Divers deploying cameras on screws attached to the rocks. Photo: Maria Moltesen*

The pool resembles a rock pool, which is filled with water during high tide. This is possible because the tidal differences are about 4 meters in the Vigo area. The pools remain full of water, even when the water recedes at low tide. The site contains 100 large concrete units in 8 rows in the intertidal zone (Fig. 5 and 6). The pools in the large concrete units are intended to provide new habitats for fish and other marine organisms. The pools are mimicking natural rock pools which are often lost when harbors are expanding. Specifically, rock pools are often replaced with walls in harbor constructions. The large concrete units protect against waves, and the associated pools provide habitats that resemble natural rock pools, supporting biodiversity. The concept should work as a nature-inclusive design. Nature-inclusive designs refer to options that can be added to - in this case coastal protection - and the associated creation of appropriate habitats and better habitats for native species. The purpose of nature-inclusive design is to achieve functional properties (e.g., coastal protection) while also benefiting nature (e.g., providing habitats).

DTU AQUA DOCUMENTS MARINE LIFE WITH UNDERWATER CAMERAS

All concrete elements were deployed in the Vigo area in February 2023. In the LIVING PORTS project, DTU Aqua is assessing the marine biodiversity in Vigo. The associated field visits lasted three weeks and took place 1) in autumn 2022, forming the baseline, and 2) in spring 2023, after the concrete deployment, and 3) in autumn 2023, one year after baseline studies. We measure underwater biodiversity by analyzing underwater footage. We are collecting recordings from underwater cameras that are placed at specific locations (e.g., the concrete elements). The cameras make recordings for two minutes every 30 minutes. When SD cards are full and batteries empty, they are replaced with new ones, and cameras are positioned

> **The purpose of nature-inclusive design is to achieve functional properties (e.g., coastal protection) while also benefiting nature (e.g., providing habitats).”**

underwater again. In Portocultura, we can replace the cameras directly from the sidewalk, but at Bouzas we use snorkel and mask to position the cameras at water depths up to 5 meters, depending on the tide.

We get many thousands of two-minute recordings that are analyzed as a measure of biodiversity. We are especially interested in the mobile fauna (e.g., fish). The abundance of mobile fauna was recorded using the maximum number of individuals from a particular species observed in a single video frame. We use the maximum number per species observed at one time during the two minutes as a measure of the abundance of a given species. It is a standard method used in previous studies (Rhodes et al., 2020; Wilms et al., 2021). Species identification was carried out to the lowest taxonomic category attainable, implying that recorded individuals were ideally identified to species level and otherwise to genus, family or order level in case species-level was not feasible. Species-level identification may be difficult in situations with low visibility or obstruction by seaweed, rocks etc. Footage analysis is time consuming and done with human eyes. Currently, the company Anemo Robotics is developing hardware and software to advance both underwater recordings and subsequent video analysis (Fig. 8). During the upcoming 6 months, we hope to have all data analyzed. At that time, we will be able to determine if concrete elements with optimized composition and structures can improve marine biodiversity in harbors.

➔ *Fig. 7: Divers deploying cameras at Bouzas. Photo: Maria Moltesen*

↑ *Fig 8: Top: Underwater observatorium from seaside. Bottom: Observatorium from inside.*
→ *Right: Visitors at observatorium. Anemo Robotics camera and co-founder, Simon Madsen. Photos: Maria Moltesen*

"Harbors often have a central place in cities, and increased marine life may eventually turn harbors into exciting blue parks for people to enjoy."

UNDERWATER OBSERVATORY FOR VISITORS

As a part of the LIVING PORTS project, visitors can also observe marine life in the harbor at Portocultura from an underwater observatory. Cardama Shipyard, a global shipbuilding and repair company situated in Vigo, built the underwater observatory on floating pontoons (Fig. 8). Visitors can take the stairs down below sea level. Two large windows facing the surrounding seawater give visitors the opportunity to experience the biodiversity that develops on the new concrete elements and to observe the different species living in the area. The observatory is open to all people interested, basic information is provided in writing. Additionally, knowledgeable staff pass on information to visitors comprising local people, tourists etc.

To date, more than 35.000 visitors have explored marine life using the underwater observatory. Specific outreach programs on the marine environment are offered to students and citizens. The underwater observatory is gradually becoming part of the full experience when tourists visit Vigo Harbor. To develop harbors into blue parks, exhibitions that enable the public to explore the underwater world are needed to educate the public on these topics. Although many European cities have a beachfront, surprisingly few have exhibitions that provide access to the underwater world. Experiences from Vigo Harbor may serve as an example for other European cities to develop local blue parks.

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The Living Ports project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement GA970972

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Project LIVING PORTS homepage: https://www.livingports.eu/

The Living Ports project partners:

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LIVING PORTS PROJECT

DTU Technical University of Denmark

ECONCRETE

Cardama Shipyard

Puerto de Vigo

Autoridad Portuaria de Vigo

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