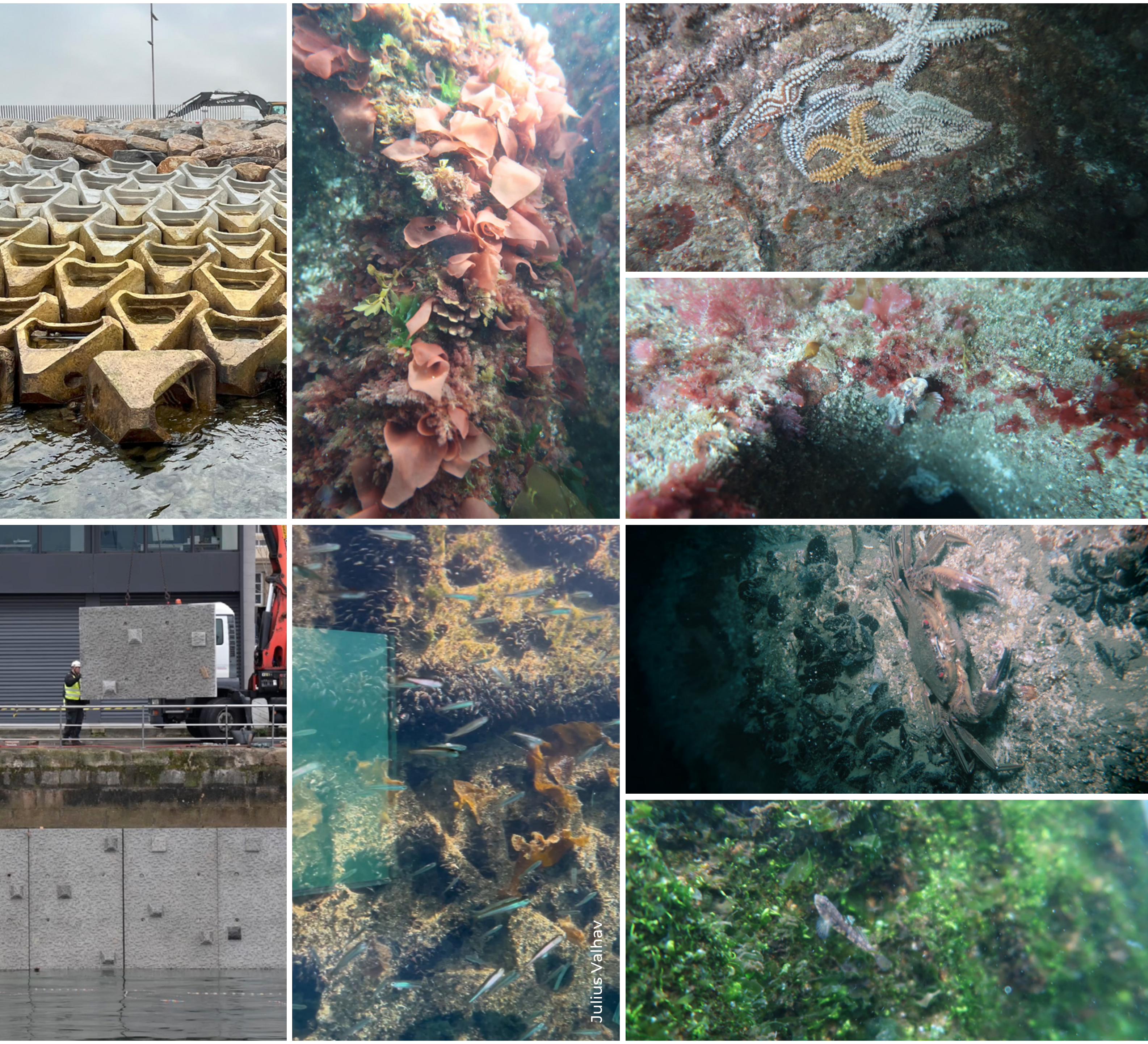
LIVING PORTS PROJECT

# ECO-ENGINEERED PORT INFRASTRUCTURE: **MONITORING RESULTS AND ANALYSIS**

- Created **New Habitats**
- Increased **Fish Population**
- Supported **Diverse Marine Life**
- Reduced **Underwater Noise**




Puerto de Vigo
Autoridad Portuaria de Vigo
DTU Technical University of Denmark
ECONCRETE
Cardama Shipyard
Funded by the European Union's Horizon 2020 programme (GA No. 970972)

# THE PROJECT

The Living Ports project **integrates eco-engineering principles with marine infrastructure to enhance ecological and societal benefits.** This project represents a crucial shift in the coastal and marine infrastructure (CMI) industry, moving away from "grey" construction to solutions based on nature inclusive design (NID) that foster ecological, structural, and socio-economic value.

## 2 SITES, 1 CORE TECHNOLOGY

The Living Ports project is a large-scale deployment across two sites in the Port of Vigo, Spain, ecologically enhancing the port infrastructure to restore natural habitats, a key goal of the European Commission's Marine Directive and the EU's 2030 biodiversity strategy within the Green Deal.

**Figure 1. Map of the Port of Vigo with location of Coastalock armor units and ECOncrete seawalls**

In the Bouzas revetment, (Figure 1 left) **Coastalock, a single layer interlocking armor system** was installed replacing traditional rock revetment. In the Portocultura basin, (Figure 1 right) two **ECOncrete Seawall panel designs — Mangrove and Azouri —** were installed, enhancing the existing seawall.

Coastalock and Seawall panels were manufactured by a local precaster at a nearby location, using ECOncrete bio-enhancing Admixture in standard casting procedures, and installed by local contractors.

**Figure 2. Left: Coastalock units manufactured with bio-enhancing Admixture by a local precaster lining up for installation. Middle: Coastalocks shortly after installation in the Bouzas revetment. Right: ECOncrete's nature-inclusive Azouri Seawall design is proven to create diverse habitats for shelter, attachment, and growth, and to maximize surface area.**

# MONITORING AND ANALYSIS

The ecologically enhanced infrastructures were evaluated by researchers from the Danish Technical University (DTU), Central Institute for Environmental Protection and Research (ISPRA) and ECOncrete.

The study explored the effects on marine communities of fish and invertebrates, species settlement and biogenic buildup, concrete structural properties, underwater acoustic wave absorption and their relationships, by comparing the newly installed ecological enhancements to adjacent control sites – standard concrete seawalls in Portocultura, and rip-rap rocks in Bouzas.

## ECONCRETE COASTALOCK - BOUZAS REVETMENT

**Ecological Performance: The Coastalock revetment structure supports diverse marine life,** with significant positive associations observed for species such as goby (Gobiidae spp.) and sea bream (Sparidae spp.). At 12 months post-deployment, the Coastalock units had significantly higher richness than the rock rip-rap control (Figure 4).

**Key Findings:** A total of **10 unique species groups** (comprising 8 marine fish species and 2 invertebrate species from 6 families) were identified. These species exhibited varying patterns of distribution, with:

- **Upper inter-tidal zone:** 7 species groups.
- **Sub-tidal zone:** 3 species groups, including gobies and shrimps, were observed in the new tidal pools created by Coastalock.

**Figure 3. Biological development on Coastalock infrastructure. Identified species on and in Coastalock units: *Oscarella lobularis*, *Gibbula* sp., *Littorina* sp., *Mytilus* sp., *Pomatoceros* sp., *Psammechinus miliaris*, *Corallina officinalis, Saragassum hornschuchi, Balanus perforatus,* and *Mytilus galloprovincialis.***

- **Total observed individuals:** 404 individuals from the species groups were documented.
- **New marine habitats:** The Coastalock tidal pools created marine habitats that persisted during low tide; This effect was particularly pronounced in the upper Coastalock row. The Before-After Control-Impact (BACI) study on the Coastalock tidal pools revealed that species such as goby and shrimp were present during low tide, sustained by the water retention of the new habitat.
- **Goby abundance (MaxN):** There was a significant positive effect of Coastalock on goby abundance (BACI interactions $p < 0.02$).
- **Sea bream abundance (MaxN):** The sea bream abundance model showed a significant positive effect of the Coastalock (BACI interactions $p < 0.04$).

**Comparing Species Richness: Coastalock (12 months post deployment) and Rocks (installed approx. 20 years ago)**

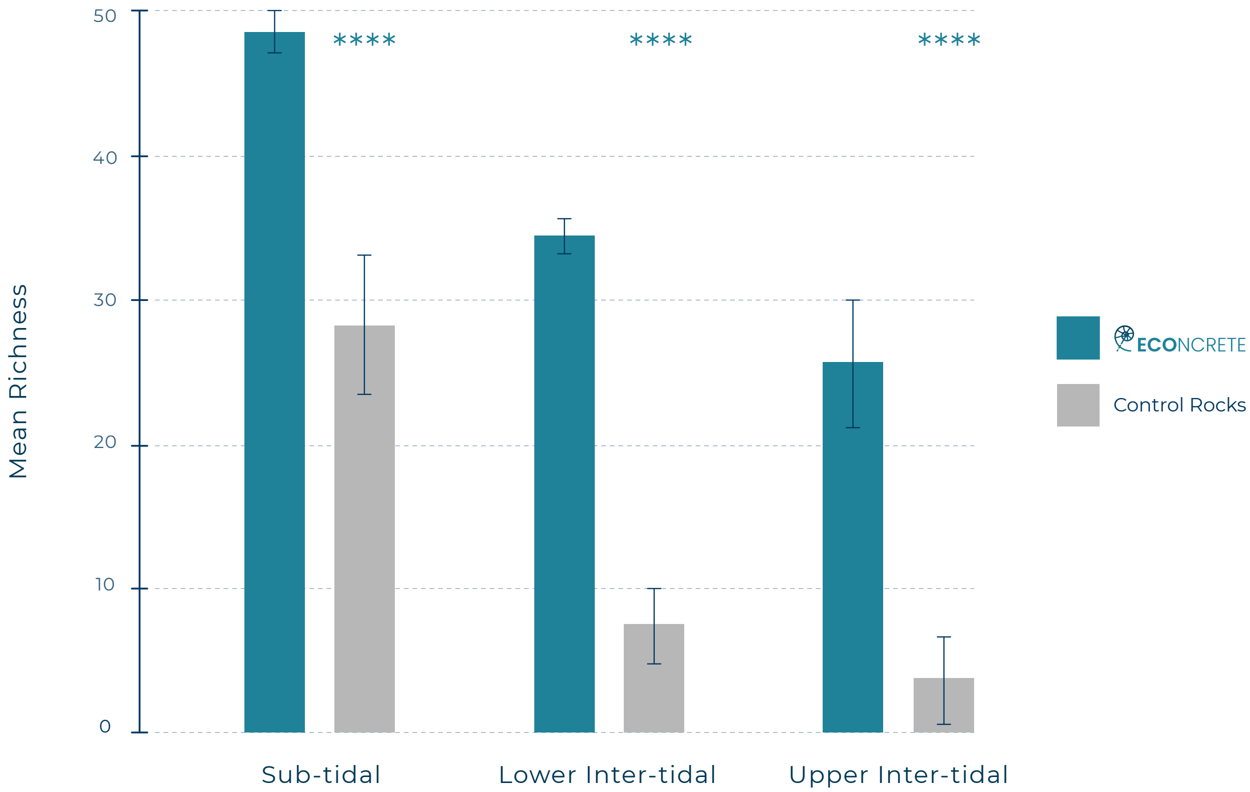



**Figure 4. Species richness of ECOncrete Coastalocks compared to the adjacent control rocks (rock rip rap was installed roughly 20 years ago) at three different tidal zones, 12 months post-deployment of the Coastalocks. Error bars represent standard deviation. (**** = p < 0.0001)**

## ECONCRETE SEAWALL - PORTOCULTURA PORT BASIN

**Ecological Performance:** At 12 MPD, the ECOncrete Mangrove and Azouri seawalls hosted 54 invertebrate species, 30 algae species, and 3 fish species.

**The seawalls facilitated the growth of sessile organisms, including barnacles, sponges, and mussels.** At 12 MPD the ECOncrete seawalls manufactured with bio-enhancing admixture had significantly higher average richness on the intertidal units than the standard grey control seawall intertidal units.

**The ECOncrete seawalls demonstrated significant positive associations with species** such as sea bream (Sparidae spp.) and wrasse (Labridae spp.), suggesting that the combination of surface complexity and texture supports a diverse range of marine life.

**Key Findings:** The Azouri seawall showed significantly higher Simpson's diversity than traditional concrete seawalls, supporting the hypothesis that the combination of nature-inclusive complexity, enhanced surface textures, and a bio-enhancing admixture creates a more favorable environment for marine organisms.

- The Azouri seawalls demonstrated significant positive associations with sea bream (*Sparidae* spp.) and wrasse (*Labridae* spp.) (Spring 2023, $p = 0.0004$).
- The Mangrove seawalls demonstrated significant positive associations with sea bream (*Sparidae* spp.) and wrasse (*Labridae* spp.) (Fall 2023, $p = 0.0388$).

**Figure 5. Biological development on ECOncrete seawalls. Species present on the seawall: *Botryllus schlosseri* (colonial tunicate), *Styela plicata* (solitary tunicate), *Bugula neritina* (Bryozoa), *Botrylloides leachi* (colonial tunicate), *Mytilus galloprovincialis* (bivalves), *Bugula neritina* (bryozoan), *Ulva* sp. (green algae), *Fucus* sp. (brown algae), *Plumaria elegans* (red algae), *Amphibalanus amphitrite* (barnacles), and *Mytilus galloprovincialis* (bivalves).**

**Biogenic Build-Up:** The Mangrove and Azouri ECOncrete seawalls demonstrated substantial biogenic buildup compared to the control seawalls made of traditional Portland cement without bio-enahcing admixture, after 12 months post-deployment (12 MPD):

- The ECOncrete seawalls accumulated 1,963 g/m² of inorganic matter, more than twice the amount observed on the control seawalls (grey concrete) (742 g/m²).
- The organic material accumulation was 370 g/m² on the ECOncrete seawalls, compared to 162 g/m² on the control seawalls (grey concrete).

### Average Richness of Seawalls and Control Walls, 12 MPD

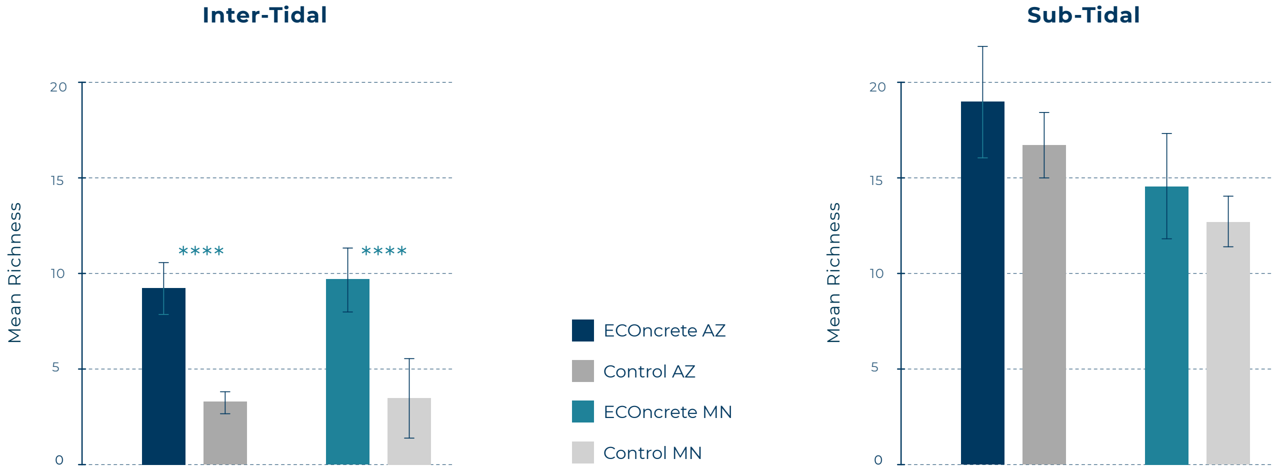
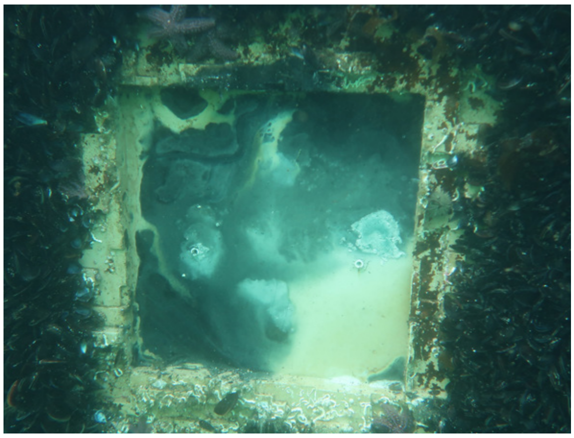



**Figure 6. Species richness between ECOncrete Mangrove (MN) or Azouri (AZ) SWs and the corresponding control walls, at two different tidal heights, 12 months post-deployment. Error bars represent standart deviation.*=p<0.05, **<0.001, ****=p<0.0001.**



## STRUCTURAL INTEGRITY

To enable structural analysis without impacting the seawall, separate tiles made from the same concrete mixes and textures were installed and later removed from intertidal and subtidal zones after 6 and 12 months for lab testing.

The Mangrove and Azouri seawalls (produced with C35/45 concrete strength class) demonstrated consistent compressive strength (48 MPa) over 12 months, with no significant differences between tidal zones or durations of exposure, indicating **the structural reliability of ecologically enhanced concrete infrastructure manufactured with ECOncrete admixture.**

Further, Thermogravimetric analysis (TGA), which is used to quantify key changes in the microstructure based on mass loss at specific temperatures, indicated differences between all types of designs, where Azouri tiles had the lowest loss of mass. These are associated with higher biodiversity on the Azouri tiles compared to the adjacent control.

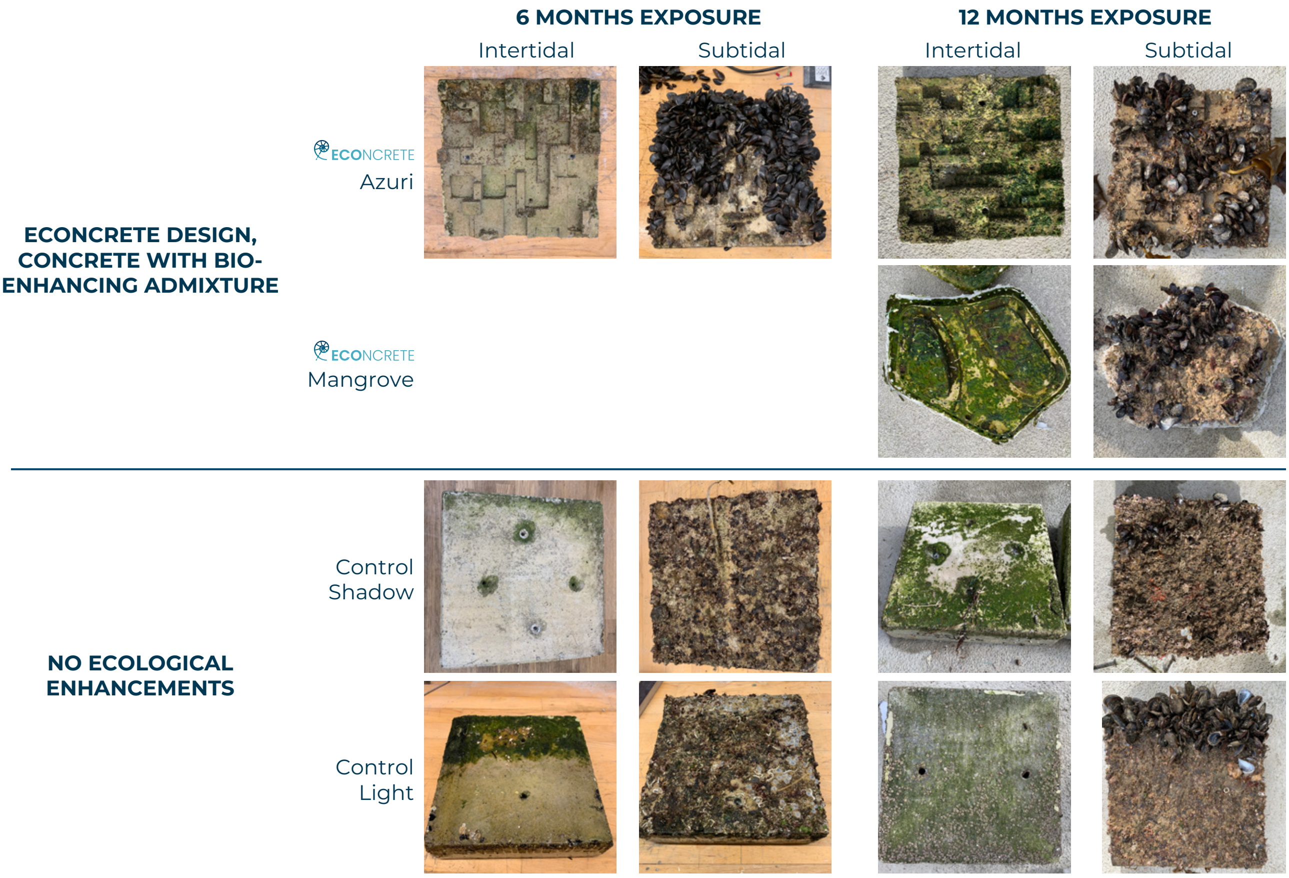



**Figure 7. Extracted tiles prior to analysis of the relation between structural performance and biological growth. Siff Lørup, DTU Sustain**


## ACOUSTIC PERFORMANCE

Understanding acoustic absorption in marine environments is key to evaluating how sound interacts with structures such as seawalls, bridge foundations, and breakwaters. Rising noise levels, a consequence of high-volume activities in port operations, can negatively impact ocean animals and ecosystems. High-volume noise impairs the ability of marine mammals like whales and dolphins to communicate and sense environmental cues vital for survival, like avoiding predators, finding food, and navigating to preferred habitats.

**ECOncrete's technology and design are aimed at enhancing acoustic wave absorption.** As part of the project, ECOncrete partnered with ISPRA to evaluate for the first time how integrating ecological concrete into the port's infrastructure affects noise pollution reduction. The findings provide valuable insights for marine acoustics, environmental monitoring, and coastal engineering.

**Methods**: The research involved two phases:

- **Laboratory Calibration:** Conducted in a 6m x 4m x 5.5m water tank filled with fresh water at room temperature. The setup included an underwater speaker, a reference hydrophone, and two test hydrophones. Calibration was ensured using a GRAS pistonphone. Data was recorded with a Tascam DR-100 MK3 and analyzed using Matlab and Raven software.

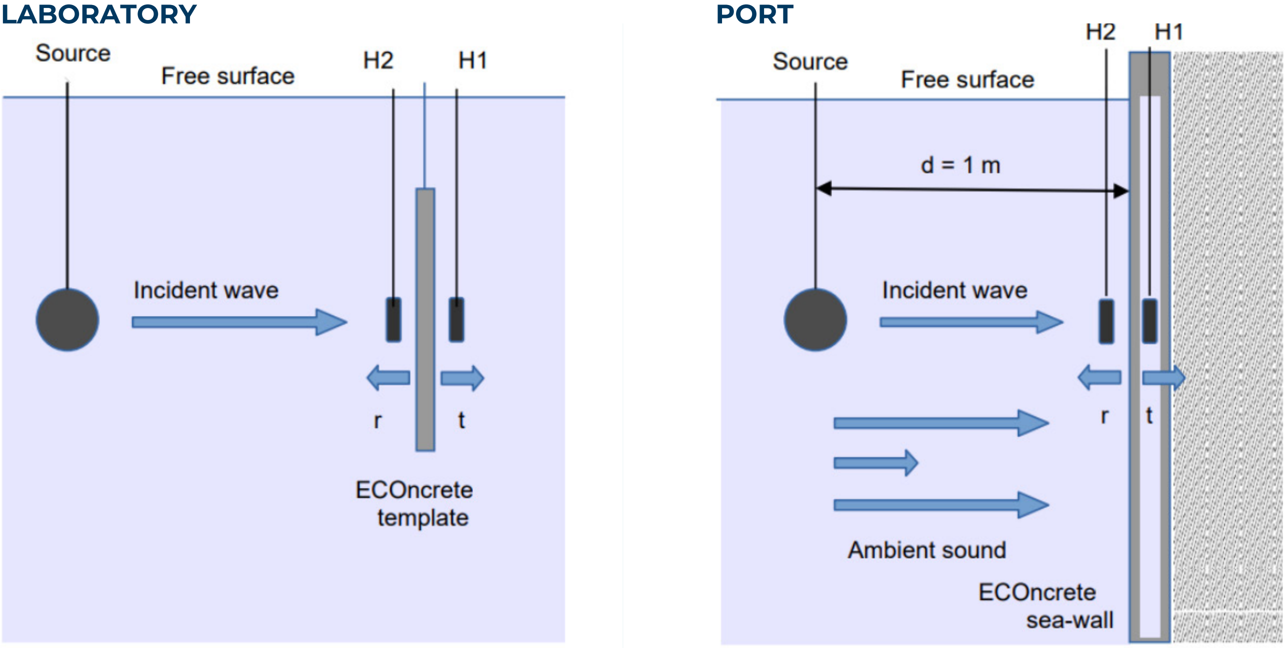



**Figure 8. Diagram of the measurement setup for laboratory testing and field assessments at the port: r = reflected wave; t = transmitted wave. Credit: Junio Fabrizio Borsani**

- **Fieldwork:** Three campaigns were conducted at the submerged ECOncrete seawall, across late spring, winter, and early summer to capture seasonal acoustic variations.
    - **Active Transmissions**: Sound propagation tests at varying frequencies, distances, and depths.
    - **Passive Transmissions**: Collection of ambient soundscapes, including anthropogenic sources (e.g., tugs, motorboats) and natural sounds (e.g., wind, waves, rain).

    The hydrophones and the Tascam recorder facilitated accurate data collection.

**Outcomes**: The Azouri design exhibited the highest acoustic absorption, outperforming both the Control and Mangrove models. The Azouri design achieved a 77% absorption rate with an insertion loss of 12.6 dB. All ECOncrete designs surpassed the 50% absorption target, particularly at high frequencies.

These findings **highlight the effectiveness of ECOncrete seawalls in improving acoustic environments.** With these absorption rates, we are mitigating noise pollution, allowing marine organisms to communicate more effectively, and enhancing their ability to hear in their natural habitat.

Maria Moltesen

# CONCLUSION

The Living Ports project demonstrates the potential and the feasibility to build infrastructure designed and engineered to create habitat, enhance biodiversity, and support ecosystem services.

This project highlights **nature-inclusive infrastructure** as a scalable solution for sustainable coastal development that can be seamlessly integrated in standard construction procedures.

**Key outcomes include:**

- **Coastalocks**: Tidal pools created new habitats for fish and invertebrates, increased sea bream and goby fish abundance, and combined habitat creation with coastal protection. The enhanced abundance around the Coastalocks revetment installation, suggests the ecological benefits of the structure's design and ECOncrete's bio-enhancing concrete admix..
- **Seawalls**: The Mangrove and Azouri designs supported diverse marine life, including 54 invertebrates and 30 algae species, while promoting biogenic buildup and benefiting fish species like wrasse and sea bream.
- **Acoustic and Structural Performance**: Eco-engineered designs reduced underwater noise and maintained structural integrity over time.

## NAUTILUS – UNDERWATER OBSERVATORY OPEN TO THE PUBLIC

As a part of the Living Ports project, the consortium also designed, manufactured and installed the Nautilus, an underwater observatory open to the public. It is a window into the waters of the port that allows visitors to closely monitor the biodiversity in the port basin and flourishing on the newly installed seawalls. The Port of Vigo reported over 75,000 visitors to the 'Nautilus' from its opening until May 2025, and over 100 schools.


## THE LIVING PORTS PROJECT

This 3-year project at the Port of Vigo (Spain) was led by ECOncrete and funded by the European Commission under the Fast Track to Innovation program of Horizon 2020. The interdisciplinary consortium of four partners included the Port of Vigo, the Technical University of Denmark (DTU) with the National Institute for Aquatic Resources (DTU Aqua), CARDAMA Shipyards and ECOncrete.

For further details see the first Living Ports Case Study and website - www.livingports.eu
For scientific monitoring reports, please reach out to info@econcretetech.com