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Coastbusters: Nature inspired solutions for Ecosystem based coastal management

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COASTBUSTERS: NATURE INSPIRED SOLUTIONS FOR ECOSYSTEM BASED COASTAL MANAGEMENT

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Conventional coastal protection solutions such as dykes and embankments are increasingly being challenged by changes in sea level rise, more aggressive climatic conditions, land subsidence, beach erosion etc. Maintenance of these conventional structures is becoming challenging; hence, innovative alternatives are necessary to guarantee coastal resilience.

The Coastbusters project aims to develop three nature-based solutions for sustainable coastal protection. These solutions will create new habitats based on known 'biobuilder species' in the form of biogenic coastal reefs. The purpose of the reefs is to induce natural accretion of sand, attenuate storm waves and reinforce the foreshore against coastal erosion, thus, adding to coastal protection. Three key biobuilding concepts were identified to be tested to strengthen conventional coastal engineering: (1) Tube-building polychaete worm reefs (Lanice conchilega), (2) Marine flora fields (seaweed and seagrass) and (3) Bivalve reefs (mussels and oysters).

Based on a critical assessment of the actual state of the art, adapted innovative designs were evaluated in an integrated feasibility analysis prior to further step up pilot projects in the field. The created biostabilisation power of the biogenic reefs was tested in both laboratory experiments and in-situ pilot projects along the Belgian Coast. For each of the three concepts, the goal is to find environmentally friendly ways to stabilize the shoreline and minimize local erosion by using an ecosystem approach. As for each of the three concepts the same ìsuccessî criteria are formulated, a uniform monitoring and evaluation approach is set up in an integrated way.

Introduction

Adverse effects of global changing conditions associated with natural disasters and climate change are currently indisputably present. Under current climate change scenarios, it has been estimated that along low coastlines, almost 30% of residences, if sited within 200 m from the sea, may be severely affected by erosion-related property losses over the next 50 years [15]. Societies across the world are facing the need to adapt to safeguard valuable resources and to reduce the vulnerability of communities to an increasingly uncertain future. To this end, classical engineering solutions, such as conventional hard coastal protection solutions (e.g. dykes, breakwaters and embankments) to attenuate waves and reduce erosion, have been applied. In the context of coastal protection, these hard stabilization structures are currently severely challenged in many locations and their value is questioned due to their costly and continual maintenance requirements, as well as, their relative lack of flexibility to any widening and height increase to keep up with the increasing coastal erosion risk. Additionally, such structures significantly alter the natural adaptive capacity of any coastline.

Under present and future environmental conditions, the world requires smart coastal protection strategies that are, sustainable, multi-functional and economically viable to help solve immediate and predicted coastal erosion and inundation problems. Coastal lowlands such as Belgium and the Netherlands are considered among the most vulnerable to sea level rise and related inundations. Moreover, sea level rise and the increased likelihood of severe storm surges are projected to be the highest in the tidal North Sea region, where both countries lay. These climate change effects may also worsen coastal erosion, a problem which already affects a large part of the Belgian coastline. In addition to these morphological aspects, the socio-economic characteristics of the Belgian coastal zone make the area vulnerable to flooding due to the increasing numbers of people and economic assets near the coast.

The Belgian coast until the late 1960's has been protected by hard coastal defence schemes (sea walls, groynes, breakwaters). Since then, awareness has grown that these hard structures have a negative effect on the stability of the dynamic coastal system and can induce erosion of the foreshore. Gradually, soft engineering solutions, such as beach nourishments have been adopted to safeguard the natural dynamics of the coast giving the beach a typical profile prone to dune erosion and subtidal beach accretion during storms events.

Newly developed policy frameworks on innovative engineering solutions supplementing existing conventional coastal protection solutions are being promoted. Amongst others, this has led to recommendations to create or restore natural habitats, providing coastal protection in place of (or complementing) artificial structures [4]. Such ecosystem inspired approaches are based on the creation and restoration of existing coastal ecosystems, such as natural vegetation (e.g. mangroves, salt marshes, seagrass beds and dune vegetation) and biogenic reef structures (e.g. corals, oysters, mussels and tube building worms). Natural coastal ecosystems have some resilience capacity for self-repair and recovery, and can provide significant advantages over traditional hard engineering approaches against coastal erosion (Gracia et al 2017).

This global need of novel ecosystem-based coastal defence solutions to protect shore communities and associated infrastructure is inevitable [10], [11]. The above mentioned naturally occurring ecosystem engineering or biobuilding species have the capacity to reduce storm waves [1], [12] and storm surges [14], [16], [17], and can keep up with sea-level rise by natural accretion of mineral and biogenic sediments [5], [9]. Henceforth, the Coastbusters project, presented in this article investigated three ecosystem-based coastal stabilisation solutions using biobuilder species, which have the capacity to positively influence their surrounding environment through their own biogenic structure [3].

This project fits within the vision for further development of the Belgian coastal zone, which is under way, aiming at the integration of safety, natural values, attractiveness, sustainability and economic development including navigation and sustainable energy. The project was awarded an innovation grant from the Flemish government in March 2017 and runs for 3 years. This article describes the selection process of the concepts including their design, development (from laboratory tests into a pilot scale setup in front of the Belgian coast), deployment and monitoring.

Nature based solution design

The Coastbusters consortium leading this 3-year project consists of Dredging experts (Jan de Nul and Dredging International - DEME group), a textile manufacturer (Sioen industries), a marine consultant (eCoast) and a research institution (Institute for Agricultural and Fisheries Research, ILVO). The Southern part of the North Sea at the Belgian Coast, nearby the Broersbank sandflat (ca. 51°07,11'N – 002°34,45') has been chosen to test the concepts of biogenic subtidal reefs using "biobuilder species". The dimensions of the installations within the testing zone will be approximately 100m² per concept.
The Coastbusters project tests the ecosystem resilience, survivability and reef building capacity of three biobuilder types: (1) Bivalve reefs (*Mytilus edulis*), (2) marine flora reefs (seaweed and seagrass) and (3) reefs of tube-dwelling sand mason worms (*Lanice conchilega*) (Figure 1).

To test those nature-based solutions, suiting substrates or sockets are being used or specifically developed. The following innovative designs have been put in place to speed up/stabilize the formation of each biogenic reef type:

1 For the bivalve reef field test, a specific socket method (based on aquaculture technique) was used in combination with a string of 40 shellfish bags (artificial structures) as a substrate for colonisation. The deployment can be seen in Figure 4A.
2 For the flora reef field setup Coastbusters installed three reef concepts, parallel to the coastline, using bags and frames with innovative seeded textile bags (Algaetex ®Sioen) as a substrate. The in-field setup comprised four bags and two frames per reef as shown in Figure 2 and Figure 4B).
3 For the *Lanice* reef concept ex-situ tests in laboratory conditions were performed prior to in-situ tests. In the laboratory *Lanice* juveniles were cultivated to test several recruitment substrate prototypes in a Kreiseltank (see Figure 4). For the in-situ tests several artificial structures with protruding tubes at the beach were used, simulating a *Lanice* reef for efficient recruitment adding to coastal protection (See Figure 4C).

The main goal of this project is to find alternative, environmentally friendly ways to stabilize the shoreline and minimize local erosion by using an ecosystem approach. The use of biostabilisation – biological processes to increase sediment stability – or to reduce the potential for erosion by tidal currents and wave action can be a cost efficient and sustainable way to obtain a safe and resilient coastline. This alternative or addition to recurrent sand nourishment will influence the natural ecosystem of the beach in a positive way.

For each of the three concepts, the following goals were identified: (1) the organism survives the dynamic conditions of the foreshore and maintains its ecological functions, (2) the reef, built as a specific biogenic structure, is stable and creates ecological added value within the local coastal ecosystem (ecosystem services), and (3) the natural reef develops in such a way that local sedimentation and natural stabilisation of the foreshore occurs (adding to coastal protection).

A uniform monitoring and evaluation approach is set up to verify for all three concepts whether the goals are being reached.

Three ecosystem based coastal stabilisation solutions

Coastbusters tests three concepts of biogenic subtidal reefs using "biobuilder species" as an alternative to conventional coastal engineering in the field, where up to now theoretical concept-validation is lacking and where ecosystem services will be used to validate the tested field setup. In 2018, all three reefs were successfully put in place (see Figure 7 illustrating the deployment) and monitored over the duration of the 3 year project.

Bivalve reef

The on-seabed present *Mytilus edulis* reef building socket and detached clumps of organisms are currently modifying the erosive character of the foreshore stabilizing the bed and attenuating the hydrodynamic energy of the waves, whilst accumulating sediment on the foreshore. In addition, mussel beds or other reef building species beds enhance biodiversity by providing shelter and nesting area for fish and crustacean species (e.g. crabs and shrimps). Further, mussels and, for instance, oysters are filter feeders filtering algae from the water column for food. By doing this they clarify the water by removing not only algae, but also silt and organic particles from the water column [2]. This additional ecosystem service makes the bivalve reef a worthy ecosystem based coastal stabilisation solution.

Flora reef

Sugar kelp (*Saccharina latissimi)* supports high primary productivity, magnifies secondary productivity, and creates a three-dimensional habitat structure for a diverse array of marine organisms, many of which are commercially

Figure 1. Coastbusters' logo (l) and 3 conceptual reef building ecosystem engineers

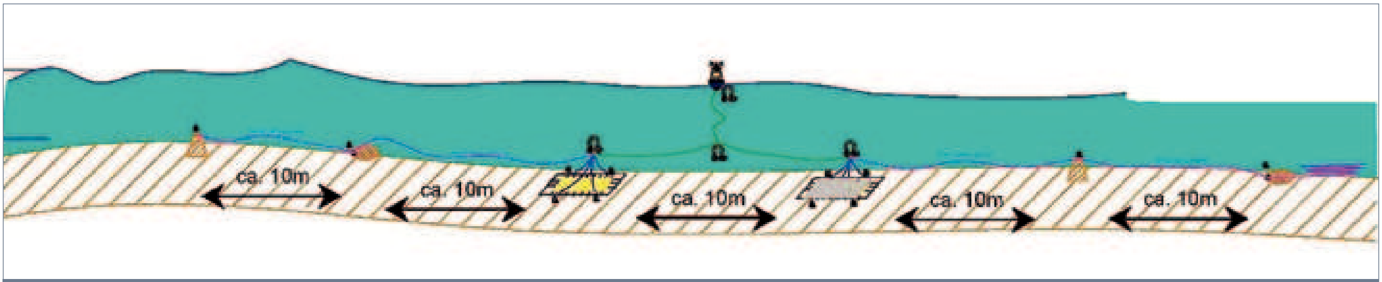


Figure 2. Flora Reef in-field test setup of impregnated seaweed Saccharina latissima seed bags and frames (m)

important. In addition, it has bio-remediation potential through filtering dissolved nutrients from the water column. These ecosystem services make the flora reef a good bio-builder, however it exhibits pronounced spatiotemporal variability and does not consolidate sedimentation. Kelps (and in extension seaweeds) need a hard substrate (natural or artificial) to develop. Consequently, the ecosystem services from the kelp flora reef are not primarily coastal protection but in combination with other reefs, these reefs can increase the overall ecosystem services delivered. In contrast, other types of flora reefs, like seagrass-based reefs have added value by enhancing sedimentation, hence, coastal protection. However, seagrass-based reefs require specific physical conditions, which might not currently be present at the Belgian coast.

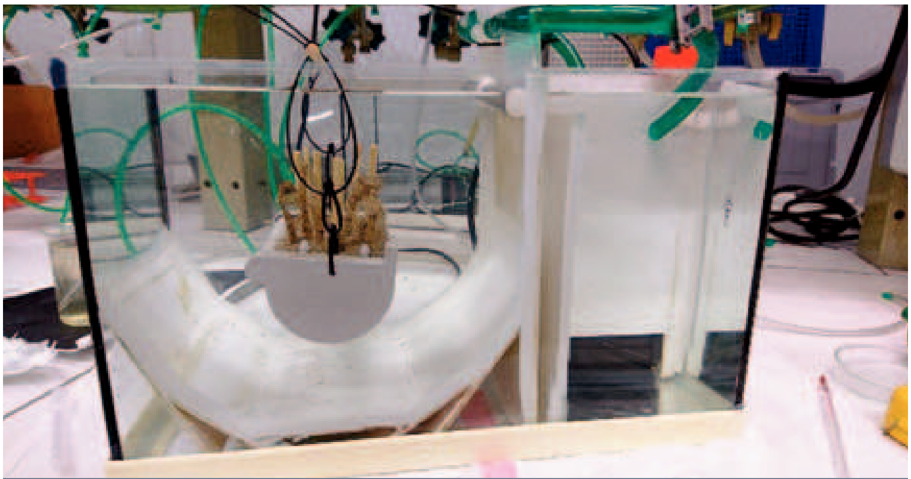


Figure 3. Lanice Reef laboratory set-up using Lanice juveniles in a Kreiseltank.

Lanice reef

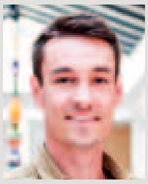
The physical reef characteristics of *Lanice conchilega* have been proven to consolidate sediment deposition within the biogenic reef and thus provide coastal protection. In addition, the biological community structure of associated fauna will presumably increase within the aggregations, thus showing a positive correlation and increase of macrobenthic fauna, which are feed for adult and/or juvenile fish in commercial fisheries. However, those biogenic aggregations are ephemeral, unless existing aggregations are renewed annualy through juvenile settlement. Hence, the spatial extent and patchiness of the biogenic reefs might fluctuate over time, presenting varying ecosystem services over time. Therefore, site selection is primal to ensure continuous juvenile settlement to create large self-sustaining *Lanice* reefs with optimal densities to fulfil their ecosystem services.

Conclusion

This work presents examples of three nature-based pilot projects aiming to enhance coastal protection by making use of bio-builder species. The drawback is that most suitable ecosystem engineering species depend on the specific site characteristics, for instance location, wave action, tidal height and sediment grain size, and other biological characteristics, such as species life-traits and ecology. Thereby, not all coastal locations are suitable for each type of reef. In addition, extreme events such as storm surges, might harm ecological systems to such an extent that returning to a state valuable for coastal protection can prove troublesome, or impossible. Information on resilience of specific engineering functions of species is lacking [8], meaning that use of engineering species for coastal protection requires systematic and continuous monitoring, to support and quantify claimed ecosystem services on longer spatial and temporal scale.

Figure 4. In-field installation of mussel *Mytilus edulis* socket (A), impregnated seaweed *Saccharina latissima* seed bags (B) and sand-mason worms *Lanice conchilega* (C) for induction of biogenic reef formation, respectively, Bivalve, Flora and *Lanice* reef.

Tomas Sterckx is a Project and Business Development manager at Dredging International. After graduating at the Universities of Brussels and Antwerp he worked a.o. at the Antwerp Port Authority and at projects for Development Aid in Afrika. The vast greatness of the River Congo became the outset of his enthusiasm for marine and environmental engineering and his first contact with Dredging International (DEME). After working in several international units at DEME he now specializes in nature based solutions, ecosystem based design, ocean pollution problems, multi-use of space and renewable energy. He considers the Coastbusters project (ecosystem based coastal defense), and the overall positive feeling towards nature based solutions it transmitted, as a great achievement.

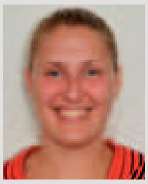


Emile Lemey works as Project Development Engineer at Jan de Nul Group. His background is in Bioengineering and Marine conservation. At Jan De Nul he has focused on nature based solutions projects in which ecological considerations are an essential part of the design phase. He worked as Environmental Engineer on the Coastbusters project during the realisation phase.

Marc Huygens is Environmental Manager within DEME-group, taking care of the operational environmental management on running marine works by developing, implementing and following-up project specific environmental engineering including field monitoring, dredging and disposal strategies, marine fauna and flora management, oil spill contingency, water and sediment quality assessment...including nature inspired solutions within the sustainable Blue Economy context

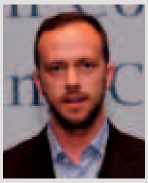
Jan Fordeyn studied at the University of Ghent and graduated as a naval architect in 1994. Since 2007, he helps develop projects around the world that fall outside the classic canon of marine construction and whose result relies on the symbiosis of different disciplines. As such he maintains close relations with experts, consultants, universities and manages several innovation projects.

Bert Groenendaal obtained his PhD in polymer chemistry in 1996 at the Eindhoven University of Technology (Netherlands). After a postdoctoral fellowship (1997) at the University of California at Berkeley he moved to industry (Bayer AG and Agfa-Gevaert NV, resp.) Since 2008 Bert is active at SIOEN Industries NV as R&D project coordinator, being responsible for all external projects (Flemish and European) for the company.



Alexia Semeraro studied Marine Biology at the University of Ghent (International Master of Science in Marine Biodiversity and Conservation). She's a young researcher at Flanders Research Institute for Agriculture, Fisheries and Food (ILVO) in Ostend working on the Coastbusters project.

Dr. Thibaud Mascart works as Environmental Engineer Marine Ecosystems within the DEME group. He is currently implementing environmental enhancements & mitigation measures for dredging contracts, deep-sea mining and off-shore installations across the globe. As marine seagrass biologist he advocates smart environmental protection and restoration of sensitive marine environments through innovative nature-inspired solutions. Within the Coastbusters project, he facilitates the academic-private partnership and focusses on the design and modularity of the biogenic reef, enhancing multiple ecosystem services.



dr. ir. Koen Van Doorslaer works as a design manager coastal engineering within the DEME group. He is currently involved in the project 'New Lock Terneuzen' where he is responsible for the design of the flood protection, dredging works and scour protection. He graduated his PhD on the reduction of wave overtopping to improve the stability of our coastlines. In Coastbusters, dr. Van Doorslaer is involved in the technical team designing the stability of the reefs and focusing on the impact of the reef on waves, currents and beach stability.

The main advantage to traditional (soft or hard) engineering is that the latter are generally over dimensioned and static, hence not responding to fast changing conditions. Integration of nature-based solutions into coastal protection allows a dynamic interaction between organisms and the natural evolution of the coastal system. In case of sea-level rise, nature-based solutions may be used to avoid if possible, and if not, delay the need for massive engineering measures for coastal protection.

Thereby, organisms that trap sediment to keep up with long-term sea level rise may provide a long-term sustainable protection and might, at least locally, reverse or delay ongoing trends. Moreover, given the adaptive abilities of ecosystem engineering or bio-builder species, solutions could be less over-dimensioned compared to traditional engineering solutions, which reduces costs during deployment, monitoring and maintenance. Thorough knowledge of ecosystem functioning, and ecosystem-based management is needed to make this approach successful [7].

To conclude, Coastbusters tests ecosystem-based coastal stabilization solutions to demonstrate their coastal protection efficiency and ecological added value on a large scale and long term. Nevertheless, Coastbusters is sharing best practices on design, development, deployment and monitoring adding pioneering knowledge in terms of emplacement, hydrodynamics and life-trait requirements of proposed nature-based solutions. In addition, Coastbusters aims to answer existing and future coastal protection challenges, driving to promote nature-based coastal engineering as the way forward to integrate multiple social, economic and environmental functions into innovative coastal resilience management. ■

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