REST-COAST

Framework for co-development of restoration with NBS building blocks & ESS

Deliverable 4.2: A downscaling approach for developing restoration with NBS as building blocks

25/09/2024

WP4

Lead beneficiary: Wageningen University & Research

Authors:
Cengiz Arslan, MSc[1], Dr. ir. Jantsje M. van Loon-Steensma[1]

with support of:
Fabienne Horneman[2,3], Alice Stocco[3], Elisa Furlan[2,3], Caterina Dabalà[4], Francesca Coccon[4], Paolo Comandini[5], Silvia Torresan[2,3], Elitsa Hineva[6], Nataliya Andreeva[6], Mathis Cognat[7], Laura Puértolas Domènech[8], Ferran Bertomeu Pagà[9], Nil Alvarez Segura[9], Luciana Villa[10], Joanna Staneva[10], Benjamin Jacob[10], Pushpa Dissanayake[11], Andreas Wurpts[11], Massimiliano Marino[12], Rosaria Ester Musumeci[12], Matthijs Buurman[13], Albert Vos[13], Richard Marijnissen[14], Grzegorz Rozynski[15], Morgane Jolivet[16], Shylee Eigner Berg[17], Avi Uzan[18]

[1] Wageningen University & Research, The Netherlands
[2] CMCC, Venice, Italy
[3] Ca' Foscari University of Venice, Venice, Italy
[4] CORILA, Venice, Italy
[5] University of Padua, Padua, Italy
[6] IO-BAS, Varna, Bulgaria
[7] Seaboost, France
[8] ALBIREM, Barcelona, Spain
[9] Eurecat, Spain
[10] Hereon, Germany
[11] NLWKN, Germany
[12] University of Catania, Catania, Italy
[13] Province of Groningen, Groningen, The Netherlands
[14] Deltares, The Netherlands
[15] IBW-PAN, Poland
[16] TDV, France
[17] The Israeli Watersheds and Rivers Center, Israel
[18] INPA, Israel

REST-COAST

Large Scale RESToration of COASTal Ecosystems through Rivers to Sea Connectivity

This project receives funding from the European Union's Horizon 2020 research and innovation programme, under Grant Agreement 101037097

Prepared under contract from the European Commission
Grant agreement No. 101037097
EU Horizon 2020 Coordination and Support Action

Project acronym:	**REST-COAST**
Project full title:	**Large Scale RESToration of COASTal Ecosystems through Rivers to Sea Connectivity**
Start of the project:	01.10.2021
Duration:	54 months
Project coordinator:	Prof. Agustín Sánchez-Arcilla, Universitat Politècnica De Catalunya (UPC)
Type:	Restoring biodiversity and ecosystem services
Call:	H2020-LC-GD-2020-3
Deliverable title	Framework for co-development of restoration with NBS building blocks & ESS
Deliverable n°	D4.2
Nature of the deliverable:	Report
Dissemination level:	EU Council
WP responsible:	WP4
Lead beneficiary:	Wageningen University & Research
Citation:	Arslan, C & van Loon-Steensma, J. M. (2024). *Framework for co-development of restoration with NBS building blocks & ESS*. Deliverable 4.2. EU Horizon 2020 REST-COAST Project, Grant agreement No 101037097
Due date of deliverable:	Month 36
Actual submission date:	Month 36

Deliverable status:

Version	Status	Date	Author(s)
2.2	Draft	30 August 2024	C. Arslan, J. M. van Loon-Steensma
2.3	1st Revision	16 Sept. 2024	C. Arslan, J. M. van Loon-Steensma
2.4	2nd Revision	25 Sept. 2024	C. Arslan, J. M. van Loon-Steensma

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Preface

The Rest-Coast Project (Large scale RESToration of COASTal ecosystems through rivers to sea connectivity) is an EU Horizon 2020 research project (Grant agreement No. 101037097) whose overall goal is to address with effective and innovative tools the key challenges faced by coastal ecosystem restoration across Europe. The approach chosen for this project will deliver a highly interdisciplinary contribution, with the demonstration of improved practices and techniques for hands-on ecosystem restoration across several pilot sites, supported by the co-design of innovative governance and financial arrangements, as well as an effective strategy for the dissemination of results.

Task 4.2 of Work Package 4 is one of the overarching tasks within the REST-COAST project involving many work packages and restoration pilots. In this task, transdisciplinary methods are embraced in co-developing the Nature Based Solutions Building Blocks Framework as a systemic and integrated approach to large-scale restoration through synergies and harmonies among small and homogenous restoration units. The portfolio of spatially identified NBS Building Blocks resulting from the implementation of the framework at the pilots will be the input for large-scale implementation of restoration aligned with the climate adaptation plans of the pilots.

Summary

In Task 4.2 of Work Package 4, we have developed the NBS Building Blocks (NBS-BB) Framework to inform restoration upscaling in large-scale restoration pilots. The NBS-BB Framework is the output of intensive collaboration with involved Task 4.2 partners at 9 REST-COAST restoration pilots: Wadden Sea, Venice Lagoon, Ebro Delta, Rhone Delta, Sicily Lagoon, Arcachon Bay, Foros Bay, Vistula Lagoon and Nahal Dalia. Aligned with the participative co-development process, we started with the theory of NBS-BB by crafting a novel definition using the NBS literature and the collective experience and expertise from small-scale restoration pilots. Then, based on a conceptual IPO model, we designed the initial NBS-BB Framework, which is co-developed to its final refined version in multiple plenary meetings with our pilot partners.

According to the IPO model of the NBS-BB Framework, the pilot site is participatively delineated to distinct domains identified by their differentiating key biophysical and socio-economic parameters, which form the inputs in the model. Bounded by these inputs, the restoration potential in these domains are also participatively assessed in terms of targets in ecosystem services and biodiversity, forming the outputs in the model. Ultimately, the model suggests participative classification of effective restoration actions, which are inspired by NBS but limited by the pre-identified inputs and outputs in the delineated restoration domains, thus forming the NBS-BB as processes in the model. As part of the overarching scope of the NBS-BB Framework within the REST-COAST project, we further specify explicitly the intersection between specific work packages and the constituents of the model in designing our collaboration, i.e. Work Package 1 and 2 in key biophysical parameters at the inputs, Work Package 3 and Work Package 5 in key socio-economic parameters at the inputs, Work Package 1 and Task 4.1 in ecosystem services and biodiversity benefits at the outputs, and finally the knowledge and expertise in all the REST-COAST pilots embraced in the entire model.

In the next phase of Task 4.2, we moved from theory to practice through bilateral implementations of the NBS-BB Framework at 9 REST-COAST pilots. Thus, we put the conceptual design of the framework into practice in our participatory downscaling approach to spatially demarcated Coastal Units within the pilot site. This way, we obtained the preliminary inventory of NBS-BB that are spatially pinned per pilot. Pilot implementations were further expanded with justifying data per Coastal Unit and extended with complementary Coastal Units per pilot through our continued collaboration with a dedicated task force in each pilot. These spatially mapped NBS-BB constitute the main output of Task 4.2 and will be instrumental for closing the 'implementation gap' through finding synergies and trade-offs among the NBS-BB in the proceeding tasks of Work Package 4 to develop the ultimate large scale climate adaptation plans in the pilots.

Task 4.2 is an overarching task including all the restoration pilots within the REST-COAST. This implies transdisciplinary collaboration including diverse stakeholders, knowledge and expertise in the pilots. Accordingly, we have developed by-products including custom-design tools to facilitate participatory implementations as well as important lessons-learned from diverse implementation experiences. These by-products are also provided as complementary outputs of Task 4.2, which can contribute to not only scaling up in REST-COAST but also scaling across other EU projects and even beyond EU in mainstreaming restoration through NBS globally.

List of abbreviations

BDV	Biodiversity
CAT	Coastal Categories
CCR	Carbon Sequestration
CMCC	Centro Euro-Mediterraneo sui Cambiamenti Climatici
DEL	Coastal Delineations
EPA	Environmental Pressures Addressed
ESS	Ecosystem Services
EU	European Union
FP	Food Production
FW	Framework
GI	Gray Infrastructure
GUI	Graphical User Interface
IBW-PAW	Institute of Hydro-Engineering of Polish Academy of Sciences
INPA	Israel Nature and Parks Authority
IO-BAS	Institute of Oeanology in Varna
IPCC	Intergovernmental Panel on Climate Change
IPO	Input-Process-Output
IUCN	International Union for Conservation of Nature
KBP	Key Biophysical Parameters
KSP	Key Socio-economic Parameters
NBS	Nature Based Solutions

NBS-BB	Nature Based Solutions Building Blocks
PROVV	Provveditorato Interregionale per le Opere Pubbliche per il Veneto, Trention Alto Adige e Fruili Venezia Giulia
RCE	Reduction Erosion Risk
RFR	Reduction Flood Risk
SPA	Stiftung pro Artenvielfalt
TDV	Tour du Valat
UC	Università degli Studi di Catania
UN	United Nations
WP	Water Purification
WMR	Wageningen Marine Research
WUR	Wageningen University & Research

1. Introduction

1.1 Global change and Coastal Ecosystems

Human-caused climate change is increasingly causing harm to ecosystems and societies around the world. This includes rising sea levels, intensifying extreme weather events e.g. droughts and floods, recently emerging phenomena like ocean heat waves, all of which have adverse biodiversity and health impacts. Moreover, these issues can trigger conflicts on both regional and global scales due to water and food shortages (Bessembinder et al., 2023; Grases et al., 2020; Guerreiro et al., 2018; Kirwan & Megonigal, 2013; Myers et al., 2017; Piatt et al., 2020; Ridder et al., 2020; Smale et al., 2019; Stéfanon et al., 2014; Steffelbauer et al., 2022; Wang et al., 2020; Wheeler & von Braun, 2013). The impacts of these changes are not evenly distributed due to varying vulnerabilities of different regions and populations (Chausson et al., 2020; IPCC, 2022). Adding to these impacts, the interconnected nature of various components within the system leads to complex adaptation challenges that involve both spatial and temporal dimensions. We need comprehensive and adaptive solutions resulting from unique collaborations between science, policy and society to effectively address these challenges.

Coastal ecosystems are of critical importance resulting from the rich biodiversity and the broad range of ecosystem services they provide (Barbier et al., 2011; Lau et al., 2019; Mitsch et al., 2015; Spalding et al., 2014). Yet, coastal landscapes face unevenly distributed share of these interconnected and complex challenges posed by global change. There is an increasing trend globally in degradation and loss of these habitats. This rate accelerated significantly in the second half of the last century (up to 20% worldwide), due to e.g. conversion to cropland and flooded rice agriculture (Fluet-Chouinard et al., 2023). Recent research shows that unprecedented rates of change in e.g. sea level rise, biodiversity loss, water quality etc. will very likely amplify the existing hazards on coastal ecosystems and societies (Blowes et al., 2019; Han & Currell, 2022; IPCC, 2023; Kulp & Strauss, 2019). In response to this, international efforts are increasing to protect these delicate ecosystems, e.g. the Ramsar Convention on Wetlands, Target 6.6 of UN's Sustainable Development Goals, EU Green Deal, EU Nature Restoration Law etc. (EC, 2022; Matthews & International Union for Conservation of Nature and Natural Resources Ramsar Convention Bureau, 1993; UN, 2015).

1.2 NBS in Coastal Adaptation

These international efforts provide the required policy tools for developing comprehensive and adaptive solutions to protect, manage and restore these delicate coastal ecosystems. Research shows that adaptive and comprehensive solutions are essential in upgrading the existing infrastructure that is challenged by the mutually reinforcing impacts of global change. For instance, conventional monofunctional coastal protection, e.g. Gray Infrastructure (GI) including seawalls, storm surge barriers, dikes and dams, lags behind and remains ineffective with increasing sea level rise and intensifying storm events, thus failing its primary defense service for coastal ecosystems and societies (Chester & Allenby, 2019; Fletcher et al., 2019; Hinkel et al., 2014; Kim et al., 2022;

Morris et al., 2020; Tiggeloven et al., 2022). Given their effectiveness and reliability in successful coastal protection historically, owing to the best techniques and practices, it is not likely that GI will be discarded in coastal protection in short term (Schoonees et al., 2019; Waryszak et al., 2021). However, escalating impacts of changing climate and sea level rise require periodic re-calculation and reinforcement, e.g. heightening a dike, which make them very likely to be less effective due to higher probabilities of failure and exponential investment requirements (Marijnissen et al., 2021; Tiggeloven et al., 2020; van Loon-Steensma & Schelfhout, 2020). Thus, in alignment with the growing attention to the integrated and adaptive approaches in climate adaptation and disaster risk reduction, multidimensional and adaptive approaches are required as complementary to the conventional monofunctional coastal infrastructure.

Nature Based Solutions (NBS) are employed increasingly as a promising adaptation strategy in the last decades. NBS has converged as an umbrella term for ecosystems-based interventions in addressing the environmental and societal challenges effectively and adaptively. Since its first mention in 2008 World Bank report, NBS have become increasingly common practice globally. Coastal adaptation is one of the topics with growing international emphasis on NBS implementation, e.g. assessment reports of IPCC, EU Green Deal, UN Decade on Ecosystem Restoration, EU Nature Restoration Law etc., (CBD, 2022; EC, 2022; IPCC, 2023; World Bank, 2008). There are currently many examples of small-scale restoration pilots that prove NBS effective for coastal protection with multiple co-benefits (Keesstra et al., 2018; Narayan et al., 2016; Seddon, 2022; Short et al., 2019; Tiggeloven et al., 2022; van Loon-Steensma, 2021; van Loon-Steensma & Schelfhout, 2020). For instance, grass revetment of dikes with foreland salt marshes has multiple benefits, e.g. sea level rise adaptation by trapping sediment, climate change mitigation by carbon sequestration, and flood protection by wave dampening. Yet, effectiveness depends on seasonal and spatial presence of healthy salt marshes (Baptist et al., 2021; Temmerman et al., 2013; Vuik et al., 2019). Accordingly, NBS inherit a degree of complexity and uncertainty due to the inclusion of nature and its dynamic processes (Nesshöver et al., 2017; Sowińska-Świerkosz & García, 2022). Moreover, coastal systems are socio-ecological systems with geographical, morphological, ecological and social diversity, which add to the level of uncertainties and complexities. Upscaling escalates further complexities and uncertainties especially for long-term projections and planning. Therefore, one of the biggest challenges we face in coastal adaptation today is to take the leap from successful small-scale pilots to large-scale restoration.

1.3 REST-COAST for Coastal Restoration

EU Green Deal encompasses a series of policy initiatives, one of which include 4 sister projects to restore and enhance European ecosystems for healthy and climate-resilient Europe. REST-COAST is one of these projects aiming for climate adaptation and disaster risk reduction through large-scale restoration of coastal areas. The project will demonstrate how to achieve EU Green Deal targets on carbon neutrality by restoring threatened coastal ecosystems to enhance biodiversity gains and ecosystem services delivery. Thus, in taking the leap to large-scale restoration through NBS implementation, REST-COAST aims for *'Restoration Revolution'*, which is defined as overcoming present barriers, i.e. technical, social, financial and governance, to restoration established on scientific and management foundations (H2020 REST-COAST 101037097 – Ref. Ares(2022)7567861).

Accordingly, REST-COAST is structured into 7 work packages that are designed around transdisciplinary principles of knowledge generation and collaboration for upscaling coastal restoration (see Fig. 1).

Figure 1 – 7 work packages of the REST-COAST: The arrows indicate the interaction and information fluxes between different work packages (H2020 REST-COAST 101037097 – Ref. Ares(2022)7567861)

WP4 is one of the central work packages that interacts with and synthesizes the information from WP1-6 to develop a scalable adaptation plan at 9 REST-COAST pilot sites, i.e. Wadden Sea (NL/DE), Ebro Delta (SP), Venice Lagoon(IT), Rhone Delta (FR), Sicily Lagoon (IT), Arcachon Bay (FR), Foros Bay (BG), Vistula Lagoon (PL), Nahal Dalia (IR). Using this adaptation plan of WP4, which systemically packages NBS-BB into adaptation pathways, regional and local coastal managers and stakeholders will be able to deploy large-scale restoration through upscaling. Therefore, WP4 serves a crucial role in coordinating various spatial and temporal scales, taking into account climate data, ecosystem service metrics, and constraints on natural system functioning under future scenarios. This information is then incorporated into stakeholder needs, regional policy, and financial and risk management criteria (H2020 REST-COAST 101037097 – Ref. Ares(2022)7567861).

1.4 Task 4.2 of REST-COAST

This report is on Task 4.2 of WP4 in accordance with the definition in the proposal document of the REST-COAST project (see Box 1) (H2020 REST-COAST 101037097 – Ref. Ares(2022)7567861). Based on the knowledge and expertise emerged from restoration efforts at the pilots, we take an inventory of NBS implementation as building blocks that are defined by key biophysical and socio-economic parameters of those pilots. Our ambition is to develop a systemic downscaling approach to define NBS-BB with an integrated and holistic view on the coastal landscapes. Accordingly, pilots that are segregated into units of NBS-BB can explore synergies among these blocks to develop adaptation pathways for restoration upscaling in the succeeding tasks of WP4. Here, our NBS-BB approach provides a systemic and robust approach to fill the 'implementation gap' in upscaling NBS implementation as part of the 'Restoration Revolution' target of the REST-COAST.

Box 1 – Task 4.2 Description (H2020 REST-COAST 101037097 – Ref. Ares(2022)7567861)

Task 4.2 A downscaling approach for developing restoration with NBS as building blocks (M12-M36)
Task Leader: WUR **Participants: Eurecat, Deltares, Albirem, Hereon, NLWKN, CORILA, IO-BAS, UC, WMR**
This Task will analyse large scale restoration at the Pilots to identify smaller and more homogeneous units in terms of key biophysical and socioeconomic variables. We shall develop a systematic downscaling approach to define NBS as building blocks of large scale restoration, enabling a refinement of each NBS and the optimisation of synergies among the blocks. The combined set of NBS blocks will be further developed/implemented at each Pilot (green/blue coastal protection) in adaptation pathways with a low C footprint and reduced environmental impact. This approach will enable the replication of the considered NBS building blocks in a variety of coastal landscapes with enhanced connectivity between river and coast and between emerged beach/submerged nearshore. The downscaling approach will consider the hinterland geomorphology and infrastructures, to determine barrier effects in connecting fluxes and dynamics at short to long term scales. The proposed approach to restoration upscaling, interlinking NBS building blocks for large scale restoration projects, will advance present design/implementation, applying a co-development sequence that will consider jointly for each Pilot: a) the type of existing or targeted ecosystems; b) financial and socioeconomic conditions/constraints; c) ESS quantification per NBS building block; d) objectively assessed coastal adaptation potential; e) quantitative contribution to climate mitigation (blue Carbon) at local and landscape scales. Such a methodological approach to develop restoration at larger scales than in present practice, enables effective transdisciplinary collaboration through early engagement of citizens, field managers, government, private sector and financial sector, closing the "implementation gap". The proposed framework (D4.2) will result in quantified ESS across the Pilots, and when possible advancing towards monetizing these ESS at various scales in space (restoration extent) and time (restoration pace and climate rate of change) for multi-criteria comparisons of NBS blocks single/joint performance.

Task 4.2 of WP4 is one of the overarching tasks within the REST-COAST project, as schematized in Fig. 1. This implies the involvement of all abovementioned 9 pilots in Task 4.2 led by WUR. During the execution of our task, we have extended beyond the participants list given in the original proposal document as in Box 1. In accordance with co-development as one of our core methodologies in Task 4.2, involvement of more partners enables better inclusion and representation at the pilots as will be explained in detail during this report. In Box 2, we provide the extended list of partners at each pilot.

Box 2 – Extended list of Task 4.2 at 9 REST-COAST pilots

- **Wadden Sea:** Province of Groningen, Helmholtz-Zentrum Hereon, NLWKN-Forschungsstelle Kuste, Wageningen Marine Research (WMR), Deltares
- **Venice Lagoon:** Centro Euro-Mediterraneo sui Cambiamenti Climatici (CMCC), CORILA, Ca' Foscari University Venice, Provveditorato Interregionale per le Opere Pubbliche per il Veneto, Trention Alto Adige e Fruili Venezia Giulia (PROVV), University of Padua
- **Ebro Delta:** Albirem, Eurecat, Univ. Politècnica de Catalunya
- **Rhone Delta:** Tour du Valat (TDV)
- **Sicily Lagoon:** Università degli Studi di Catania (UC)
- **Arcachon Bay:** Egis Ports, Seaboost
- **Foros Bay:** Institute of Oeanology in Varna (IO-BAS)
- **Vistula Lagoon:** Institute of Hydro-Engineering of Polish Academy of Sciences (IBW-PAW)
- **Nahal Dalia:** Israel Nature and Parks Authority (INPA), The Israeli Watersheds and Rivers Center

1.5 Reading Guide

In Chapter 2, we will explain the theoretical background of how we have co-developed the NBS Building Block Framework (NBS-BB FW) with our participating partners. Starting with our WUR approach to Task 4.2, we will explain our novel revised definition of NBS-BB from REST-COAST perspective. Then, we will continue with how we capture this definition systematically in our conceptual Input-Process-Output (IPO) Model. Further, we will introduce our participative downscaling approach as Coastal Units, in which IPO model is implemented collaboratively to map the NBS-BB within the pilots in accordance with the NBS-BB Framework.

In Chapter 3, we will give an overview of REST-COAST pilot implementations of the NBS-BB Framework at 9 pilot sites. Thus, we will explore the potential of the framework as we move from theory to practice through multi-stakeholder pilot implementations. We will introduce the python-based application we have developed for effective and collaborative implementation of the framework in bilateral pilot workshops. Then, we will present some preliminary output from pilot implementations.

In Chapter 4, we will extend the implementation of the NBS-BB Framework at the pilots through (i) quantitative and qualitative data at the inputs and outputs attached to each NBS-BB, and (ii) Coastal Units per pilot and corresponding NBS-BB identified in each unit for a complete pilot overview. Accordingly, we will introduce the HTML based Interactive Web Map with embedded JavaScript and Google Maps API that we have developed to streamline the process of working together effectively on geospatial data. Then, we will provide the pilot output as an inventory of NBS-BB in accordance with our NBS-BB Framework.

In Chapter 5, we will discuss the strengths and weaknesses of the NBS-BB Framework accompanied by the experience and feedback from all interactions with our partners. Then, we will discuss some critical perspectives revealed out by the framework including stakeholder participation, co-development and integration. These perspectives, combined with all the NBS-BB output from pilots, will inform our discussion on within- and across-pilot multi-criteria comparisons, which will further be an essential input for the adaptation pathways for each pilot in succeeding Task 4.3.

A supplementary folder accompanies this report for the appendices including the minutes of several online and in-person plenary meetings, the minutes of bilateral pilots workshops, the tools developed by WUR and respective manuals etc.

2. Development of the NBS Building Blocks Framework

In this chapter, we will explain the theoretical background of NBS-BB and how we conceptually developed our NBS-BB Framework in a co-creative way by including our partners at 9 REST-COAST pilots. In accordance with the REST-COAST Project Proposal (H2020 REST-COAST 101037097 – Ref. Ares(2022)7567861), Task 4.2 of Work Package 4 focuses on analyzing large scale restoration at the pilots to identify smaller and more homogenous units in terms of key biophysical and socio-economic parameters. These smaller and homogenous units should be linked to NBS-BB by a systemic downscaling approach. Inspired by the downscaling approach in our task description, we also downscaled Task 4.2 into smaller compartments for a better understanding first and then to systemically develop our solution. Accordingly, we started from 'NBS building blocks' as this concept is the keystone of our task but also the bridging concept to the following tasks in adaptation pathways and upscaling plans. In the next chapter, we will explain in detail our methodology in co-developing the NBS-BB Framework.

2.1 Design of our co-development process in Task 4.2

Co-development of the framework is fundamental to Task 4.2 by definition (see Box 1). We designed this co-development process as a participative approach from 9 REST-COAST pilots. In this design, we conceptualized and drafted our research as the task lead at WUR and iterated our draft output in regular partner meetings for review and feedback for further development to draft a new version for the following meetings. This design proved successful in working together with our pilot partners effectively as portrayed throughout this report. The minutes for all the meetings are provided for reference in the supplementary folder as appendices.

We started with revising and redefining the NBS-BB to provide a more comprehensive perspective compared to the initial definition in the Glossary of the REST-COAST proposal (se Def. 1 in Box 3). In accordance with our co-development design, we developed the draft definition from a review of the NBS literature and then, reached a consensus on the final definition participatively together with our partners as detailed in Chapter 2.3 (please refer to the supplementary folder for the minutes of March 2022 semi-annual REST-COAST meeting, June 2022 Task 4.2 meeting).

Then, we drafted the NBS-BB Framework based on a conceptual IPO model (Chapter 2.4). IPO model systemically captures the NBS-BB definition by linking and parametrizing its key elements, i.e. key biophysical and socio-economic characteristics, coastal restoration units, ESS and BDV gains. Accordingly, IPO model was inspired by the sequential nature of restoration from degraded state (explained by inputs) to restored state (explained by outputs). The model further grasped the transformative nature of restoration using NBS, where processes links the inputs (thus, the degraded state) to the outputs (thus the restored state). We further reviewed and developed this draft framework participatively with our partners in accordance with the iterative co-development design of Task 4.2 (please refer to the supplementary folder for the minutes of June 2022 Task 4.2 meeting, October 2022 REST-COAST annual meeting).

In the next step, we drafted our participatory downscaling approach at the pilots to bridge the theoretical framing of NBS-BB to practical on site implementation in accordance with restoration demonstration essence of the REST-COAST (Chapter 2.5). Here, we introduced Coastal Units as the spatially identified areas within the restoration pilots. These Coastal Units are the output from participatively delineating and parceling out a larger restoration site for effective implementation of NBS. The theoretical framing of NBS-BB provides the guiding principle for participating stakeholders in identifying these Coastal Units in terms of (i) key biophysical parameters (KBP), (ii) socio-economic parameters (KSP), and (iii) biotopes, that display homogeneity within a Coastal Unit. From this draft, we reached a consensus with our partners on approaching Coastal Units from two orthogonal axes: one along land-to-sea continuum with different NBS categories and one along the coastline with distinct delineations. We further agreed on implementing the NBS-BB Framework in bilateral pilot workshops (please refer to the supplementary folder for the minutes of February 2023 Task 4.2 meeting).

In summary, we re-defined the NBS-BB by revising and distilling the NBS theory to coastal restoration in accordance with the REST-COAST goals. The conceptual IPO model was used to capture this definition systematically, which linked the theoretical framing to practical implementation through Coastal Units as the participatory downscaling output. Accordingly, Coastal Units are spatially identified restoration areas, which can be parametrized in terms of KBP and KSP but also contain biotopes that are quantifiable according to potential benefits in ESS and BDV. Eventually, the NBS-BB Framework of Task 4.2 was conceived from the sequential integrated output of the design process as portrayed in Chapter 2.6.

2.2 Theoretical underpinning of NBS as Building Blocks

Coastal ecosystems are among the most delicate ecosystems with critical importance to societies and habitats due to the rich biodiversity and the broad range of ecosystem services they provide (Barbier et al., 2011; Lau et al., 2019; Mitsch et al., 2015; Spalding et al., 2014). Increasing impacts of climate change escalate vulnerability of these ecosystems by putting extra pressure on the current state of habitats as well as existing coastal defenses (IPCC, 2023; Kulp & Strauss, 2019). Nature-Based Solutions (NBS) have been providing empirical evidence globally as an alternative to traditional schemes in coastal protection due to their multi-functionality, adaptivity and flexibility. There is a growing trend in policy-science-society spheres to adoption of NBS, especially against the direct threat from climate change (Keesstra et al., 2018; van Loon-Steensma & Goldsworthy, 2022; van Loon-Steensma & Vellinga, 2013; World Bank, 2008). There is ample evidence of global NBS implementations for coastal wetlands with multiple co-benefits including improved ecosystems services and biodiversity (Barbier et al., 2008; Costanza et al., 1997; Narayan et al., 2016; Seddon, 2022; van Loon-Steensma, 2021; Wamsley et al., 2010).

Accordingly, innovative approaches to coastal protection have been gaining attention in the research and policy arena, e.g. in the Netherlands. For instance, 2010 Delta Program has stimulated innovative dike concepts with multiple ecological and societal benefits (van Loon-Steensma et al., 2014b). Similarly, combining hard measures with nature values, e.g. dikes combined with foreland salt marshes, has been part of climate adaptation strategies (e.g. salt marsh height increases with sea level rise), enhance ecosystems services (e.g. vegetated foreshore adds to biodiversity, nature values, economy etc.) and reduce probability of failure (e.g. salt marsh attenuates waves) (Marijnissen et al., 2020; van Loon-Steensma & Kok, 2016). However, NBS have been mostly experimental, small-scale and pilot-based mostly because they (i) are relatively novel and therefore lacking standards and norms, (ii) inherit highly uncertainties due to their complex biophysical and socio-economic conditions, and (iii) have an intrinsically multi-stakeholder nature making them a playground for contestation and consensus.

To enhance their implementation – which will result in many co-benefits for biodiversity and other ecosystem services, more systemic and robust approaches especially for mainstreaming NBS in large scale coastal restoration are required. Our approach via NBS-BB aims to fill this 'implementation gap' by providing a systemic and robust approach to upscaling NBS implementation. Hence, NBS-BB are envisioned as the systemic and integrated restoration units, which help to manage, conserve or restore coastal ecosystems. Together, these spatially identified units should holistically and in harmony consolidate at the landscape scale for upscaled coastal restoration.

In REST-COAST's Task 4.2, we designed the whole process as a novel co-creative NBS-BB Framework (NBS-BB FW) by intensively collaborating with partners from varying disciplines at the 9 REST-COAST pilots. This explicitly enabled us to conduct transdisciplinary research in co-developing our NBS-BB Framework grounded in the actual implementation site, which is the implicit foundation of NBS theory and practice as advocated in the NBS literature (Cohen-Shacham et al., 2019; Kabisch et al., 2016; Nesshöver et al., 2017; Palomo et al., 2021). Thus, we started with the revision and refining of the definition of NBS-BB (Chapter 2.3), and then applied a conceptual IPO method on this revised definition (Chapter 2.4). We continued with our participatory downscaling approach for spatially identified Coastal Units at pilots (Chapter 2.5) and co-developed the NBS-BB FW eventually as the application of IPO method at each Coastal Unit (Chapter 2.6).

2.3 The Revised NBS-BB Definition

Empirical evidence globally has placed NBS among promising multi-functional and adaptive alternatives in coastal adaptation. There is a growing trend towards increased adoption of NBS in small-scale pilots (Keesstra et al., 2018; Seddon et al., 2021; van Loon-Steensma & Goldsworthy, 2022; van Loon-Steensma & Vellinga, 2013). However, despite the success stories of NBS in practice, upscaling NBS have been limited to theory at a higher level of common understanding through generic definitions, global standards and design guides (Calliari et al., 2019; European Commission, 2015; IUCN, 2020). Upscaling requires commitment to transform NBS from an umbrella term for ecosystem-based approaches (Cohen-Shacham et al., 2016) to a mainstream restoration praxis in the toolbox of large-scale coastal restoration.

Aligned with this novelty and genericity of NBS, the definition of 'NBS building blocks' was kept preliminary and generic during the proposal phase of the REST-COAST project (See Def. 1 in Box 3). As this term is fundamental part of our Task 4.2, we prioritized framing and elaborating 'NBS building blocks' more comprehensively in our co-development design with our partners. Thus, our first approach in co-development of the NBS-BB FW was to conceptualize the NBS-BB in a working definition within the scope of coastal restoration. Here, we aimed at merging higher level NBS theory with evidence-based NBS practice at pilots to identify NBS-BB as restoration units, which ensemble to scale-up coastal restoration.

Box 3 – Reference Definitions in Building Up the Definition of NBS Building Blocks

Def. 1: NBS Building Blocks in REST-COAST Definitions and Glossary
Combination of technical measures overcoming technical barriers in order to support NbS (e.g., natural accretion of sediment, nourishments, wetland creation, double dike, sandy levees, 'rich dike' multifunctional structure...).

Def. 2: IUCN's NBS Definition
Nature-based Solutions are actions to **protect**, **sustainably manage**, and **restore natural** and **modified ecosystems** that address societal challenges **effectively** and **adaptively**, simultaneously benefiting... **biodiversity** and **human well-being**... [through] flow from **healthy ecosystems**... [by targeting] major challenges like climate change, disaster risk reduction, food and water security, biodiversity loss and human health... (Cohen-Shacham et al., 2016)

Def. 3: Building Block Dictionary Definitions
i. A basic **unit** from which something is **built up**[1].
ii. The **basic** things that are **put together** to make something **exist**[2].
iii. Something that is **necessary** for making or **developing** another thing[3].
iv. A **unit** of **construction** or **composition**. Especially something **essential** on which a **larger entity** is based on[4].
Synonyms: component, constituent, element, factor, ingredient, member

[1]Oxford Languages. [2]Cambridge Dictionary. [3]Cambridge Business English Dictionary. [4]Merriam-Webster Dictionary

Therefore, we developed our own definition of NBS-BB. Here, we adopted the one of the most commonly acknowledged NBS definitions presented by IUCN (See Def. 2 in Box 3), which exclusively emphasizes the biodiversity benefits and human wellbeing from good practices of NBS, thus aligns perfectly with the REST-COAST targets. We integrated dictionary definitions of building block (See Def. 3 in Box 3) and our Task 4.2 description (See Box 1) within this reference IUCN definition to co-develop our own definition of NBS-BB. Together with the involved partners of Task 4.2 at all REST-COAST pilots, we reached a consensus on this working definition as the basis of the output framework.

Def. 4: Our novel NBS-BB Definition
*Nature Based Solutions Building Blocks (NBS-BB) are **basic units** of **construction** or **composition** that are identified from **downscaling** of large-scale coastal restoration sites. Bounded by/limited with the **key biophysical** and **socio-economic parameters** of those sites, these units are associated with **delivery** of enhanced **Ecosystem Services** (ESS) and improved **Biodiversity** (BDV). **Put together** either as **stand-alone** or in **harmony** with each other, NBS-BB are the **essential constituents** in **building up** and **developing** larger scale coastal restoration through **upscaling** at target sites. (Arslan & van Loon-Steensma, work in progress)*

In this definition, KBP and KSP are explanatory factors to delineate spatially homogenous areas, thus the Coastal Units, in a coastal landscape. ESS and BDV are objective factors that provide the overarching restoration targets emerging from these spatially homogenous areas. The NBS-BB are considered as restoration units based within these areas and bridge the explanatory factors to objective factors in systemic upscaling of coastal restoration.

2.4 From Definition to Initial Framework: IPO Approach

The IPO models are used to reduce complex systems to compartments of three stages for more granular and systemic approach to better understanding. In a sequential approach the model defines the initial state of a system as the inputs, the bundle of actions to transform a system as the processes, and the results achieved from this transformation as the outputs (Liu et al., 2018; MacCuspie et al., 2014). Moreover, system elements are parametrized in the IPO models when compartmentalizing in order to develop a representative model of any complex system. Then the compartments of these models interact with each other through the relationality of the parameters.

Hence, we explored the potential of a conceptual IPO model in systemically and analytically capturing our novel working definition of NBS-BB. Accordingly, we approached the restoration pilots as the coastal systems with complex dynamics and fluxes of the near-shore and hinterland geomorphology and infrastructures. First, we applied the IPO model to our working definition to identify the three-staged-compartments and developed the very first draft of the foundations for the NBS-BB Framework (Fig. 2).

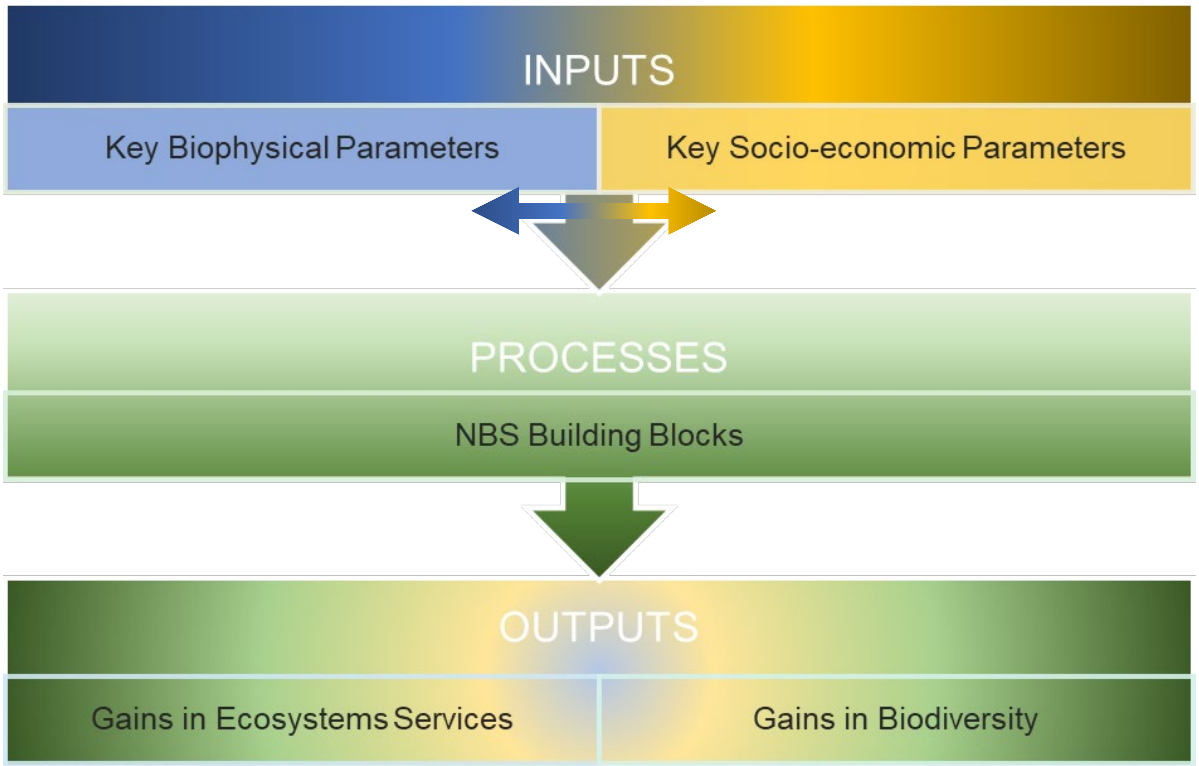


Figure 2 – The IPO model as the basis of the initial NBS-BB Framework

In this system-level approach, inputs explain the current state of a coastal system. Thus, the complex system can be parametrized according to its key biophysical and socio-economic characteristics. In alignment with our co-development design, these parameters are identified for each restoration pilot in a participatory manner. We intentionally altered the IPO model by adding the double arrow at the inputs (Fig. 2). Here, we emphasized the complex interactions not only of biophysical systems but also the bilateral interactions between biophysical and socio-economic systems. So, in our IPO model, we suggested that KBP and KSP should be equally weighted.

From restoration perspective, outputs explain the restored state of a coastal system. Here, we embraced the biotopes approach of the preceding Task 4.1 (Baptist et al., 2024). Accordingly, we incorporated benefits in BDV and ESS as parameters from quantitative and qualitative evaluation of the coastal biotopes. Accordingly, the restoration provides these benefits by transforming the current state of a restoration pilot to the restored state. So, we inserted the NBS-BB as the processes of our conceptual IPO model. These processes are also part of the participation at the restoration pilots, where stakeholders collaboratively identify the restoration action to bridge the inputs to the outputs. Therefore, we moved on to our practical downscaling approach from this theoretical underpinning to enable the implementation of the IPO model at the REST-COAST pilots.

2.5 Our Downscaling Approach: Coastal Units

NBS are novel and innovative approaches that implicitly bring transformative alternatives to the existing traditional infrastructure. So far, institutional foundation and policy support have been essential to the implementation of NBS. Accordingly, in the REST-COAST project, one of the flagships of EU Green Deal, we are given the opportunity to develop novel approaches to coastal NBS implementation in a transdisciplinary manner through collaborations among 9 restoration pilots, i.e. Arcachon Bay, Ebro Delta, Ems-Dollard Estuary, Foros Bay, Nahal Dalia, Rhone Delta. Sicily Lagoon, Venice Lagoon and Vistula Lagoon (Fig. 3).

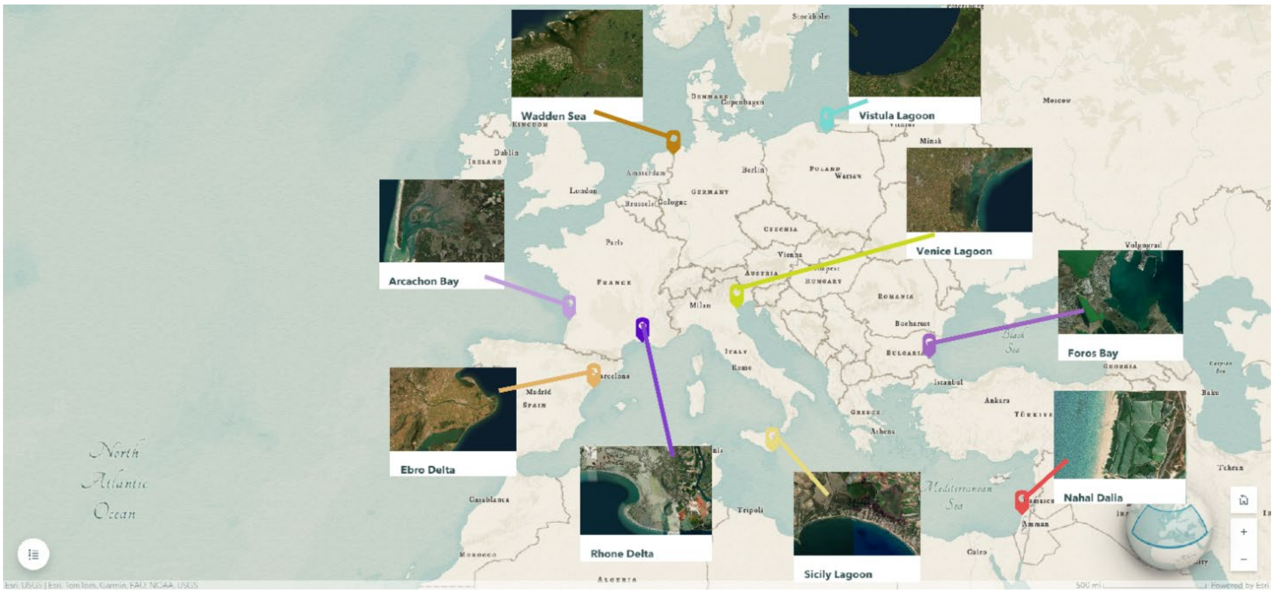


Figure 3 – 9 EU pilot sites involved in Task 4.2 of the EU Green Deal REST-COAST project: Arcachon Bay (FR), Ebro Delta (ES), Foros Bay (BG), Nahal Dalia (IS), Rhone Delta (FR), Sicily Lagoon (IT), Venice Lagoon (IT), Vistula Lagoon (PL), Wadden Sea (NL & DE). (*Map created by C. Arslan using ArcGIS*)

We benefited from the diverse morphological, hydrological, ecological, institutional and social characteristics of these pilots as well as the diverse knowledge and competences of the participating stakeholders in Task 4.2. Both in co-developing the working definition of NBS-BB and the conceptual IPO model of the NBS-BB Framework, we exploited this participative collaboration in the plenary meetings. Accordingly, this diversity of landscapes and expertise at the pilots revealed out the degree of complexities and uncertainties involved in these restoration pilots, some of this include, scale of restoration, e.g. couple of hectares to tens of hectares; local dynamics, e.g. almost no turbidity to extreme turbidity; degree of participation, e.g. financial and application support of local stakeholders vs. strong local opposition to external interventions etc.

Hence, we developed our participative downscaling approach to spatially identify Coastal Units for increased granularity in overcoming the complexities and uncertainties. Linked to the IPO model, these Coastal Units yield more precise identification of the key biophysical and socio-economic characteristics for the participating stakeholders. Accordingly, fairly uniform biotopes within these Coastal Units enable quantification of BDV and ESS benefits at the outputs. We further specified two orthogonal axes as reference for the stakeholders during the participative downscaling. The first axis is along land-to-sea, which is inspired by the REST-COAST vision in restoring river to delta continuity (Chapter 2.5.1). The second axis is along the coastline, which acknowledges the morphological, ecological and economical discontinuities along the coasts and is inspired by 2010 Delta Program in the Netherlands (Chapter 2.5.2).

2.5.1 Coastal Categories:

Healthy and functioning coastal ecosystems are the focus of restoration to improve delivery of BDV and ESS. These ecosystems are part of a broader system connected from seascapes to coasts to landscapes, yet they incorporate diverse local dynamics and fluxes (Geist & Hawkins, 2016). Accordingly, the main objective of the EU Green Deal embodied within the REST-COAST project is to upscale coastal restoration through river to delta connectivity by enhancing natural fluxes and dynamics to improve BDV and ESS (Sánchez-Arcilla et al., 2022). Informed by these broader perspectives of ecosystems connectivity in our spatial Coastal Units, the first orthogonal axis of participatory downscaling is along the land-to-sea continuum, where we introduce the *NBS-BB Categories*. These categories are identified as coastal zones where there exists distinct transition with diverse geographical, morphological and functional (e.g. industrial, livelihood, urban) differences. Here we identify five coastal zones; *Subtidal*, *Intertidal*, *Barrier*, *Hinterland* and *Upstream*. These *NBS-BB Categories* span the land-to-sea continuum connected from seascapes to coasts to landscapes (Fig. 4).

Figure 4 – The *NBS-BB Categories* along the land-to-sea continuum. Informed by the evidence-based NBS pilots and expertise of the stakeholders at the pilots, potential NBS-BB as restoration units are listed under each category (*for reference only, the list is not exhaustive*).

Due to the distinct transitional characteristics, these categories can be differentiated according to distinct restoration actions, e.g. submerged vegetation restoration applies to *Subtidal* category whereas defense line restoration applies to *Hinterland* category. These categories can be populated by past and ongoing evidence-based NBS implementations as well as the expertise of REST-COAST partners in the pilots. In our participatory downscaling approach, potential restoration actions from these categories are identified as the NBS-BB within a specific Coastal Unit that bridge the KBP and KSP to the benefits in BDV and ESS in accordance with the IPO model.

Hereby, we established the first link from the generic restoration units in the NBS-BB definition to the spatial Coastal Units in the pilots. In Fig. 4, an inexhaustive list of restoration units fitting under each category is provided from our initial scan of pilot expertise and NBS literature. The double arrow in the figure acknowledges these categories as part of a broader system with transient interactions in an integrated coastal landscape. Furthermore, we emphasize the potential upscaling of coastal NBS through synergies and interactions among different restoration units.

2.5.2 Coastal Delineations:

Coastlines are not homogenous and include diversity of land use (e.g. nature, residential and industrial), geomorphology (e.g. sandy, rocky and cliffy), and ecology (e.g. salt marshes, coral reefs and mangroves). In addition, functional diversity is strongly impacted by the landscape transformations, e.g. salt marsh restoration through managed realignment influences spatial distribution of ecosystems and habitats, and spatial diversity can vary significantly ranging from tens of meters to a couple of kilometers (Acosta et al., 2009; Henderson et al., 2020). This holistic view on coastline was widely acknowledged with the introduction of the adaptive delta management in the 2010 Dutch Delta Program. Especially in the Ems-Dollard estuary of the Wadden Sea, where industrial, residential and nature dominant areas exist together in close vicinity, dedicated interdisciplinary research teams created informed maps based on nature, land use and recreational values. Grounded on these maps, plenty of innovative NBS pilot implementations have been running in the coastal area ranging from salt marsh creation in front of an industrial port to clay ripening for local reinforcement of dikes (Fig. 5) (ED2050, 2021; van Loon-Steensma & Schelfhout, 2020; van Loon-Steensma et al., 2014a).

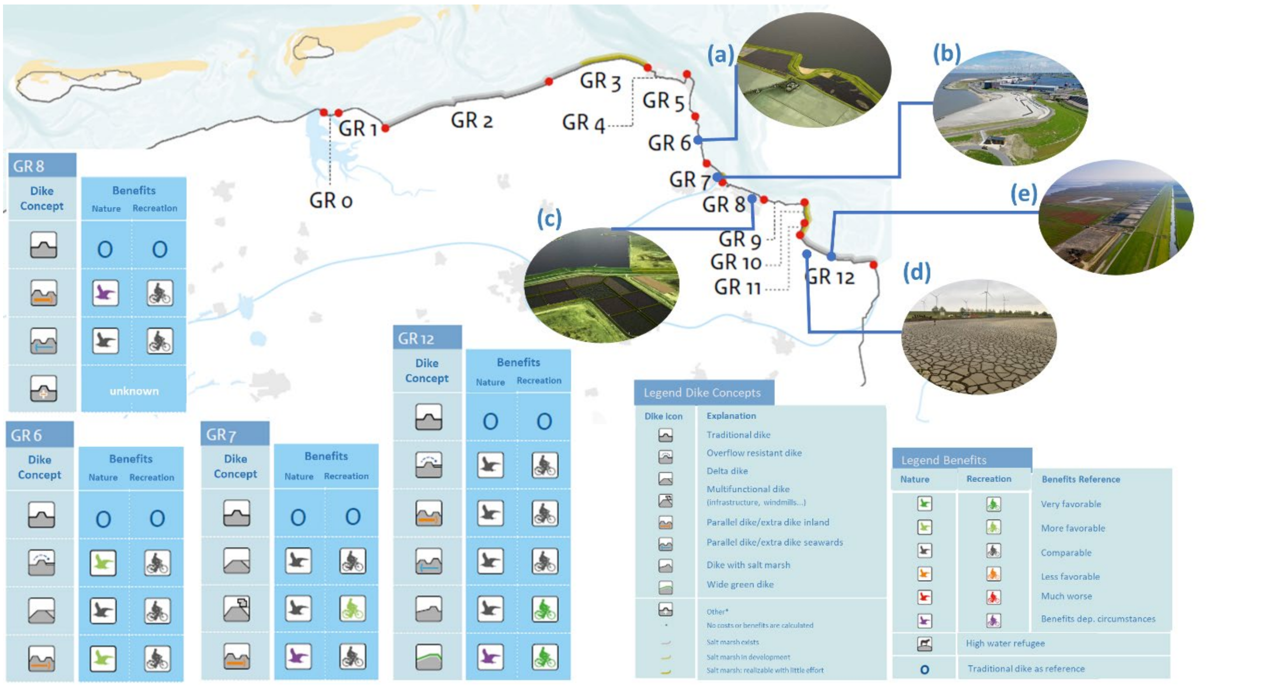


Figure 5 – Informed delineation maps along Wadden Sea coast of the Province of Groningen (NL). The map is the output of a dedicated multidisciplinary research as part of the 2010 Dutch Delta Program (van Loon-Steensma et al., 2014a). Nature restoration pilots have been realized following the information and data from this research: (a) Double Dike, (b) Marconi Project, (c-d) Clay Ripening, (e) Wide Green Dike (ED2050, 2021; van Loon-Steensma & Schelfhout, 2020).

Inspired by this research, *Coastal Delineations* is the second orthogonal axis of participatory downscaling when identifying Coastal Units. Accordingly, coastline is delineated into transects with either differentiated KBP and KSP or fairly uniform biotopes for BDV and ESS quantification. Hence, we established the second link from the generic restoration units in the NBS-BB definition to the spatial Coastal Units in the pilots. These coastal stretches span along the coastline of a coastal landscape and together with its hypothetically conjugate axis along the land-to-sea continuum, they compose a Coastal Unit.

2.6 The NBS-BB Framework:

The Coastal Units are spatially identified as the output of our participatory downscaling approach within a larger coastal landscape in the pilots. The identification of these units embrace transdisciplinary collaboration among diverse expertise and geographies at 9 REST-COAST pilots. The Coastal Units acknowledge coastal landscapes as holistic entities with multitude of complexities. Thus, they implicitly stimulate a more systemic approach to restoration upscaling through integration of these units. These units aims for increased granularity for deeper understanding of complex dynamics within each unit. Accordingly, a portfolio of effective restoration units is revealed in responding to the complex socio-ecological interactions at coastal landscapes. Synergetic integration of these units at landscape scale by a transdisciplinary team of managers, practitioners, local stakeholders and policy makers can inform upscaled coastal restoration using NBS for effective long-term coastal adaptation.

Hence, the fundamental premise of the NBS-BB Framework is the participatory downscaling at each REST-COAST pilot to map these restoration sites in terms of smaller and homogenous Coastal Units. In the proposed downscaling scheme, these spatial Coastal Units are linked with the theoretical NBS-BB definition through the conceptual IPO model. In our IPO approach, the Coastal Units are translated into input and output parameters to inform the selection of the best-fitting and optimal restoration process that bridges the implementation gap between the inputs to the outputs. Eventually, we obtain a portfolio of commensurable Coastal Units aligned with parametrization of KBP and KSP at the inputs and BDV and ESS at the outputs of the IPO model. These Coastal Units are the basis for within- and across- pilot assessment and comparison.

Task 4.2 is one of the overarching tasks within the REST-COAST project and designed by definition as a co-development process including partners from all 9 REST-COAST pilots. So, the NBS-BB Framework is explicitly linked to specific Work Packages and Tasks in the REST-COAST. WP1 – Hands-on Restoration of Coastal Ecosystems and Upscaling Potential will inform our framework in terms of stock-taking of evidence-based NBS, identification of key biophysical parameters per restoration action, and potential BDV and ESS benefits from specific restoration actions. Inputs from the models developed in WP2 – Climate Risk Reduction through Innovative Restoration are especially relevant for identification of key biophysical parameters that are essential for assessing and predicting restoration. Inputs from WP3 – Financial Arrangements / Business Plans for Restoration Upscaling and WP5 – Transformative Governance for Restoration Upscaling are important in identification of key socio-economic parameters, especially from the perspectives of innovative financing and transformative governance, respectively. The biotopes approach and translation of different biotopes into quantifiable benefits in ESS and BDV in Task 4.1 of WP4 – Adaptation Management for Restoration Upscaling are directly connected to the assessment of ESS and BDV gains within the identified Coastal Units. Moreover, for all the components of the framework beforementioned, the knowledge and expertise of the participating partners at all the REST-COAST pilots are paramount. Graphical representation of the NBS-BB Framework is given in Fig. 6 including the essential components with levels of collaboration.

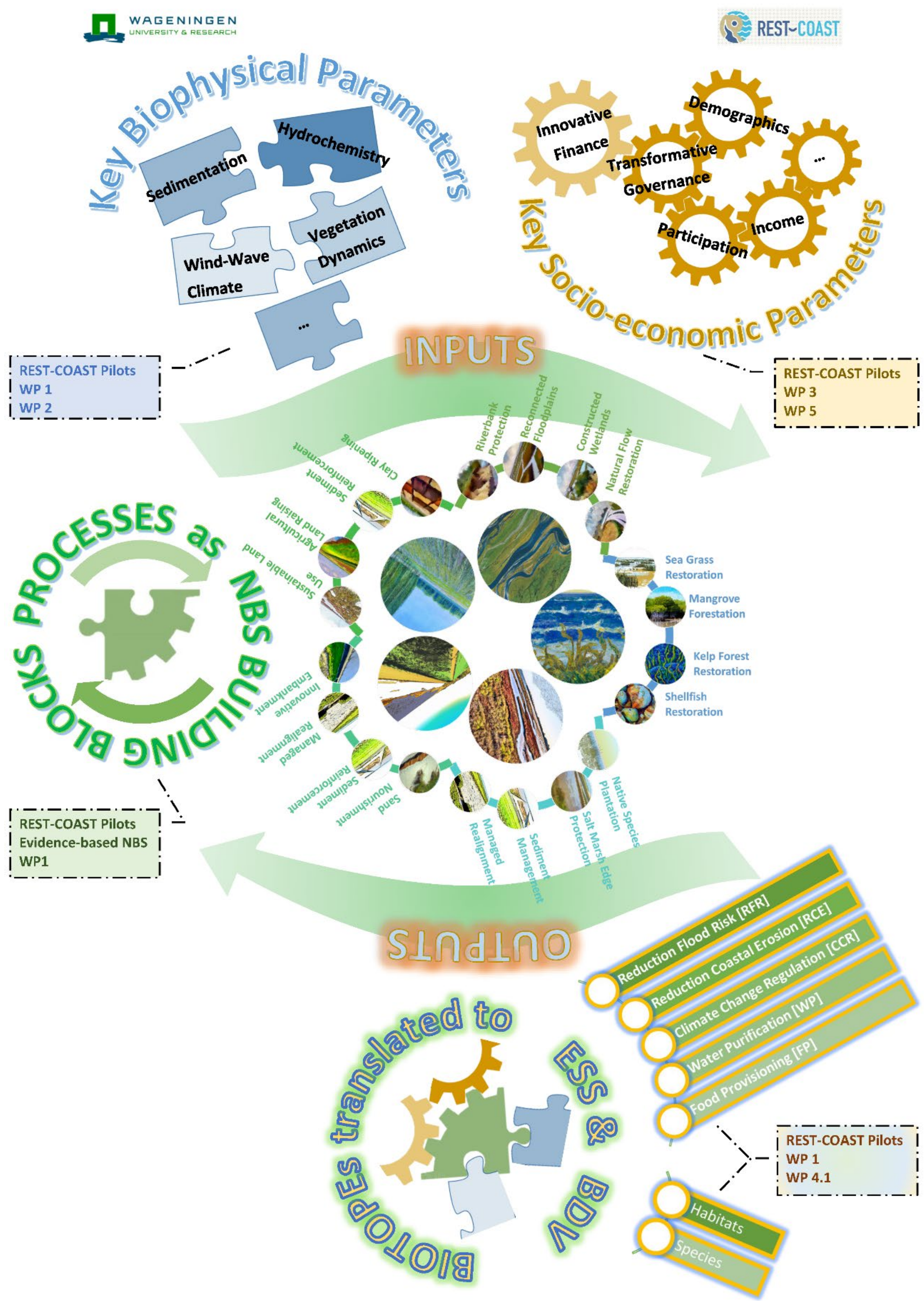


Figure 6 – The graphical representation of the NBS-BB Framework as the co-development process including 9 REST-COAST pilots and work packages. The framework is founded on a conceptual Input Process Output (IPO) method (Chapter 2.4), which is implemented in the participatively downscaled coastal restoration units (Chapter 2.5). In each unit, the key biophysical and socio-economic parameters at the inputs are bridged by the NBS-BB to the BDV and ESS gains at the outputs (Chapter 2.6).

3. Implementation of the NBS-BB FW at 9 REST-COAST Pilots

In Chapter 2, we explained the intensive co-development process of systemically defining NBS-BB including our participatory downscaling approach to identify Coastal Units in close collaboration with our involved partners at the REST-COAST pilots. The resulting NBS-BB Framework in restoration upscaling of EU coasts through NBS implementation (Fig. 6) is the main output of Task 4.2 by definition (Box 1). Next, we will explain in this chapter how we pursued our activities and collaboration further in moving from theory to practice, thus bridging the 'implementation gap'. In doing so, we panned dedicated bilateral pilot workshops to collectively implement the NBS-BB Framework at each REST-COAST pilot. In these workshops, we invited all the involved partners at these pilots as well as any relevant stakeholders within their network if applicable and feasible. As the task lead, we emphasized the inclusion of diverse disciplines and expertise due to the participative design of our framework, which makes the identification of components in the IPO model more solid. The bilateral pilot implementations aimed to have an extensive list of NBS-BB, which is identified within spatially defined Coastal Units at all 9 REST-COAST pilots. Thus, we made an inventory of spatial restoration actions as NBS-BB, which can promise within- and across-pilot comparisons of different NBS-BB either stand-alone or in harmony, as embodied in our novel REST-COAST definition of NBS-BB (see Def. 4). Hence, we moved the NBS-BB Framework from theory to practice for instrumentalizing it for the restoration upscaling at the REST-COAST pilots.

Therefore, pilot workshops facilitated the effective implementation of the framework as well as the progressive learning from this inclusive process for continuous co-development of the framework. We developed a python-based Graphical User Interface (GUI), which is briefly introduced in Chapter 3.1, as the platform for collective implementation during the pilot workshops. Then, we planned our bilateral workshops at six REST-COAST pilots as explained in Chapter 3.2. Finally, for the remaining three pilots, we generated an additional Pilot Implementation Form to facilitate their implementation of the framework as presented in Chapter 3.3.

3.1 Development of the Pilot Implementation Tool

We developed a GUI application based on python programming language to facilitate our bilateral online workshops in implementing the NBS-BB Framework effectively. Although the tool is beyond the scope of Task 4.2, we assessed it as essential in overcoming the challenges of online participation from diverse disciplines and expertise within a limited workshop duration. This is especially relevant in our case, where we require active participation at different parts of our framework (Fig. 6), i.e. participatory mapping of spatial units, identification of biophysical and socio-economic characteristics within these units, quantifying ESS and BDV benefits of biotopes belonging to these units.

In this GUI, we transformed the NBS-BB Framework into interactive fields to get user input as well as to inform users. In Fig, 7, the main windows where user input for implementing the framework is presented. Here, user input is prompted in blank sections, which are then mapped to the respective components in the NBS-BB Framework. We further incorporated informative pop-up screens to provide users with supplementary knowledge that can assist them in filling in the sections. When ready with implementation of the framework, users can submit their implementation to our local server. In this respect, the design of the tool facilitates both collective and individual implementation of the framework. Each submission is uploaded with specific stamp that can be differentiated for later analysis.

Built on an elaborated python script, this GUI application is deployed as a stand-alone executable file that can be run by any stakeholder independent of any labilities. Going beyond the time limit of workshops, this application can be implemented by users either individually or collectively at personal convenience. Thus, we aimed to achieve better resolution of the respective NBS-BB in the pilots through multiple implementation of the framework by diverse stakeholders. Furthermore, this tool enable the NBS-BB Framework to extend beyond Task 4.2, which adds more value to the effort put in developing it. In the supplementary folder, we provided the final version of the tool, *NBSBB_FW_Tool_v4.3.exe*, accompanied by a detailed user manual, *Tool Manual for Pilot Implementation.pdf*.

Figure 7 – Pilot Implementation Tool GUI (a) Main screen with general data fields for pilot and NBS-BB – Text input fields with white background (e.g. NBS Building Block) and information buttons for users with green background (e.g. View Framework). At the bottom of the GUI, graphical representation of IPO method of the NBS-BB Framework: Inputs on the left (user activated buttons for Biophysical Parameters and Socio-economic Parameters) and Outputs on the right (user activated button for ESS and BDV benefits). (b) Pop-up window to enter data on biophysical parameters when Biophysical Parameters button is pressed. (c) Pop-up window to enter data on socio-economic parameters when Socio-economic Parameters button is pressed. (d) Pop-up window to enter data for biotopes together with ESS and BDV benefits.

3.2 Pilot Implementation Workshops at 6 Pilots

In this chapter, we start with our design for the planning of the workshops. Rather than including this in the appendices, we believe that this process holds value in itself and can prove informative for participative exercises and collaboration in big consortiums like the REST-COAST project, where partners have individual responsibilities accompanied by additional co-development efforts.

Keeping this in mind, we started our workshop planning by identifying first at least one key partner at each pilot. This partner was assigned as our co-facilitator(s) within reach of the partners and local stakeholders at each pilot. Together with our co-facilitator(s) at each pilot, we explored the most feasible date for bilateral workshops and scheduled these workshops at least one month in advance (Table 1). This schedule includes the actual workshops with multiple stakeholders as well as pre-meetings with our co-facilitator(s) to discuss the details of the workshops, post-meetings with our co-facilitator(s) to evaluate the workshops and discuss the action points, and a field trip to our core pilot in the Ems-Dollard Estuary.

Effective planning of the workshops is important to be precise in who is involved and also to ensure that the participants are well-prepared for the workshops. For this, we provided The Pilot Implementation Tool accompanied with the manual in advance, so that the participants could explore the tool and elaborate on the potential Coastal Units of participatory downscaling. We further anticipated that in this preparatory period, Task 4.2 partners at pilots can identify and invite additional key stakeholders, e.g. social scientists, decision-makers, ecologists, local experts, NGOs etc. Thus, increasing diversity of disciplines and expertise implies identification of more inclusive and refined NBS-BB regarding the design of our framework.

Table 1 – NBS-BB Framework Pilot Implementation Schedule

April – May – June – July

2023

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
2 April	3 April	4 April	5 April	6 April	7 April	8 April
	Field Trip **Wadden Sea (NL)** 9.00-17.00					
...						
8 May	9 May	10 May	11 May	12 May	13 May	14 May
	Pre-meeting **Venice Lagoon (IT)** 10.00-11.00					
...						
21 May	22 May	23 May	24 May	25 May	26 May	27 May
	Workshop **Venice Lagoon (IT)**				Post-meeting **Venice Lagoon (IT)**	

	11:00 – 15:00				9.30 -10.30	
...						
4 June	5 June	6 June	7 June	8 June	9 June	10 June
				Workshop **Foros Bay (BG)** 11:00 – 13:00		
11 June	12 June	13 June	14 June	15 June	16 June	17 June
	Workshop **Arcachon Bay (FR)** 11:00 – 13:00	Pre-meeting **Sicily Lagoon (IT)** 10:00 – 11:00		Pre-meeting **Ebro Delta (SP)** 10:00 – 11:00		
18 June	19 June	20 June	21 June	22 June	23 June	24 June
	Workshop **Wadden Sea (DE)** 11:00 – 13:00					
15 June	26 June	27 June	28 June	29 June	30 June	1 July
		Workshop **Sicily Lagoon (IT)** 16:00 – 18:00				
...						
9 July	10 July	11 July	12 July	13 July	14 July	15 July
		Post-meeting **Sicily Lagoon (IT)** 16:00 – 18:00				

In Table 2, a general overview of these meetings per pilot is provided. The table includes the identified NBS-BB and participating stakeholders. Details of the pilot implementations are discussed in the following chapters. Aligned with our discussion above on planning, this table successfully hints at number and diversity of the participation in the workshops, which will also explain why different aspects of the framework either stand out or fall short at different pilot implementation.

Table 2 – General overview of the pilot workshops

Pilot Site	*Processes as NBS-BB*	*Location*	*Date & Time*	*Medium*	*Participants*
Wadden Sea (NL)	Agricultural Land Rising	Ems-Dollard Estuary	3 April '23 12AM-17PM	Field Trip	1. Province of Groningen 2. WUR
Venice Lagoon (IT)	Artificial Salt Marsh Reconstruction	Millecampi Teneri[1]	22 May '23 10AM-1PM	MS Teams	1. CORILA 2. CMCC 3. University of Venice 4. University of Padova 5. MEDSEA 6. SELC Soc. Coop.* 7. PROVV 8. WUR
Foros Bay (BG)	1. Seagrass Restoration	Natura2000 site	8 June '23 11AM-1PM	MS Teams	1. IO-BAS 2. WUR

	2. Brown Macroalgae Restoration				
Arcachon Bay (FR)	Seagrass Restoration using Roseliere	Bassin d'Arcachon	12 June '23 11AM-1PM	MS Teams	1. SEABOOST 2. EGIS-GROUP 3. Parc Naturel Marin Bassin d'Arcachon* 4. WUR
Ebro Delta (SP)	Salt Marsh Edge Protection	Bassa de l'Alfacada	15 June '23 10AM-11AM	MS Teams	1. ALBIREM 2. EURECAT 3. WUR
Wadden Sea (DE)	Sediment Management	Ems-Dollard Estuary	19 June '23 11AM-1PM	MS Teams	1. HEREON 2. NLWKN 3. BAW* 4. WUR
Sicily Lagoon (IT)	1. Salt Marsh Restoration 2. Island Building 3. Dune Revegetation 4. Hydraulic Connectivity 5. Seagrass Restoration 6. Beach Nourishment	Pantani Cuba & Longarini	26 June '23 4PM-6PM	MS Teams	1. University of Catania 2. SPA* 3. WUR

** Organizations that are not participants of the REST-COAST project. They are involved as key local stakeholders in the pilots.*
[1] Millecampi Teneri is one of the waterbodies identified according to the Water Framework Directive in the Venice Lagoon.

3.2.1 NBS-BB Tables: Preliminary Output from the Pilot Workshops

In the bilateral workshops with the pilots, we collaboratively worked on the NBS-BB Framework implementation tool with the participating organizations. With participants' full consent, we have also recorded these workshops for our own use during post-analysis. The pilot outputs from the tool implementation and comparative analysis of the recordings are compiled in the structured tables for systemic overview and multi-criteria comparisons within and across the pilots. In Table 3, a guidance on the main components of these structured tables and how to read these tables is provided in accordance with key references to the NBS-BB Framework.

Table 3 – Components of the structured output tables from pilot implementations of the NBS-BB FW

PROCESS	**NBS-BB**	*Nature Based Solutions Building Block* that is collaboratively identified as the main restoration *process* in a specific Coastal Unit within a REST-COAST pilot in accordance with Def. 4 in Chapter 2.3.
NBS-BB CAT		Drop-down list to select from the *categorical* axis of the Coastal Unit within a REST-COAST pilot in accordance with Fig. 4 in Chapter 2.5.1. The category indicates where the identified NBS-BB lies along the land-to-sea continuum.
DEL		Identification of the coastal *delineation* according to the participative downscaling of a REST-COAST pilot as described in Chapter 2.5.2. The delineation indicates where the identified NBS-BB lies along the coastline.

EPA		*Environmental Pressures Addressed* is a list of environmental pressures that a specific Coastal Unit is exposed to. The list provides insight on the urgency of the restoration action by the identified NBS-BB.
INPUTS	**KBP**	A list of *inputs* as *Key Biophysical Parameters* that are collaboratively identified in a specific Coastal Unit in accordance with the IPO method of the NBS-BB Framework as described in Chapter 2.6.
	KSP	A list of inputs as *Key Socio-economic Parameters* that are collaboratively identified in a specific Coastal Unit in accordance with the IPO method of the NBS-BB Framework as described in Chapter 2.6.
OUTPUTS	**ESS**	Drop-down list to select from a semi-quantitative scale of 5 for 5 specific *Ecosystem Services* addressed by the REST-COAST. These scores reflect the expert judgement per ESS on the expected impact of the identified NBS-BB in a specific Coastal Unit. These scores are at the *outputs* in accordance with the IPO method of the NBS-BB Framework as described in Chapter 2.6.
	BDV	Qualitative expert judgement on the potential *Biodiversity* benefits from the implementation of the identified NBS-BB in a specific Coastal Unit. This judgement is constrained by benefits for habitats and species according to the biotope maps produced per REST-COAST pilot. These benefits are the *outputs* in accordance with the IPO method of the NBS-BB Framework as described in Chapter 2.6.

In the following chapters, we will present the resulting output tables per pilot as the preliminary overview of the implementation of the NBS-BB Framework. For each pilot, we will also provide a brief information on the settings and progress of the workshops to highlight distinguishing points across the pilot implementations.

3.2.2 Wadden Sea

3.2.2.1 The Ems-Dollard Estuary (NL) Field Trip

We organized an in-person meeting with our key partners in the Province of Groningen on 3 April 2023 in Delfzijl, a city within the Ems-Dollard Estuary of the Wadden Sea. The estuary is of particular importance for the pilot stakeholders from various perspectives. One of these perspectives is the potential for upscaling through the ED2050 Program which aligns perfectly with the REST-COAST (ED2050, 2021). One other perspective is the estuary's location at the border of the Netherlands and Germany, which makes the estuary a perfect case for the transboundary collaboration within the upscaling targets of the REST-COAST. The last but not the least, many small-scale pilots have been implemented or planned in the estuary in accordance with the regional and national policy in multi-functional coastal defense and planning. One of the primary implications of these is the abundance of knowledge, data and expertise not only from natural sciences perspective but also from the social, economic and governance perspectives due to the financial and political support. This is especially important for our NBS-BB Framework regarding the balanced view on both biophysical and socio-economic parameters at the inputs as well as ecosystems services and biodiversity emphasis at the outputs.

In this in-person meeting with the Province of Groningen, we had a brainstorm on the optimal implementation of the NBS-BB Framework among many small-scale pilots in the estuary. We decided that we can implement the framework for an ongoing restoration planning because there exists a well-delineated small-scale pilot area that fits well to our Coastal Unit approach. In this Coastal Unit, we focused on the agricultural land rising as the restoration process in overcoming diverse environmental challenges in the region. Moreover, this restoration action is also implicitly dependent on the other potential restoration actions including clay mining and salt marsh restoration. This is essentially relevant for exploring synergies and trade-offs during restoration upscaling. Using the input from our partners as well as the existing knowledge and literature, we have implemented the NBS-BB Framework for agricultural land raising to develop the preliminary results as given in Table 4.

Figure 8 – Photos from the Ems-Dollard Estuary field trip. Left – On the dike protecting the Grote Polder. The polder area lies to the left of the dike. Industrial area and wind farms are in the distance. Right – The subsiding agricultural area behind the dike. Future upscaling of farmland rising as the climate adaptation plan in the area.(*Photo credits: C. Arslan, 2023*)

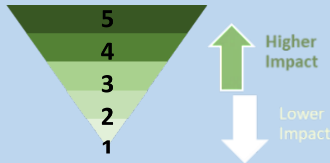
We concluded our meeting with a field trip in the Ems-Dollard Estuary visiting some locations of recent pilots (e.g. Marconi salt marsh restoration), planned pilots (e.g. Grote polder, see Fig. 8) and future upscaling (e.g. raising farmland behind the dikes, see Fig. 8). Using these observations and the existing research (ED2050, 2021), we discussed on extending our framework further to the whole estuary in the next phase of Task 4.2. In Chapter 4, we will provide an overview of multiple Coastal Units across the pilot.

Table 4 – NBS-BB Framework implementation at the Ems-Dollard Estuary (NL) – Field trip on 3rd of April, 2023.

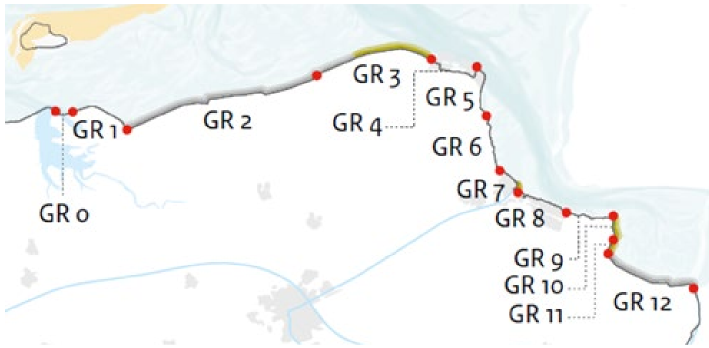
NBS-BB	NBS-BB CAT[1]	DEL[2]	EPA	INPUTS		OUTPUTS	
				KBP	KSP	ESS[3]	BDV[4]
Farmland Raising	Hinterland	*GR9 [53.2966° N, 7.0123° E]*	• Land subsidence • Salinization • Sea Level Rise (SLR) • Peat oxidation	• SLR rate • Groundwater Levels • Salt- & Fresh-water Divide • Sediment Budget • Subsidence • Salinity • Peat Oxidation Rate • Crop Resilience	• Transboundary Collaboration • Social Memory & Cultural Heritage • Nationally- & EU-Funded Restoration Projects • Income – Agricultural • Income – Tourism • Integrating results from WP3 on innovative financing • Integrating results from WP5 on transformative governance	RFR(1) RCE(1) CCR(4) WP(1) FP(5)	• No direct impact on habitats and species due to main focus on agricultural production • Side ecological benefits for local salt marsh species and benthic community from sediment management to supply the clay.

NBS-BB: Nature Based Solutions Building Block
NBS-BB CAT: A drop-down list for the NBS-BB Category along the land-to-sea continuum as defined in the NBS-BB Framework.
DEL: Coastline delineation as defined by the pilot partners according to the NBS-BB Framework (approximate coordinates of the center).
EPA: Environmental Pressures Addressed
INPUTS: KBP: Key Bio-physical Parameters – KSE: Key Socio-economic Parameters
OUTPUTS: ESS: Ecosystem Services RFR: Reduction Flood Risk; RCE: Reduction Coastal Erosion; CCR: Carbon Sequestration; WP: Water Purification; FP: Food Production; BDV: Biodiversity

[1,2] Coastal Units identified according to the *NBS-BB Categories* and *Coastal Delineations* are provided in the pilot map below.
[3] Semi-quantitative scores for 5 ESS defined in the REST-COAST project: Elementary quantification of expected ESS impact based on expert-led discussions is provided according to the color scale (with numerical scores for easier readability). Pilot will update these score aligned with their input to Task 4.1.
[4] Expert-based qualitative description of Biodiversity gains in terms of habitats and species by workshop participants. Pilot will update this column aligned with their input to Task 4.1.



[1]*Hinterland location on the NBS-BB Cat axis of the coastal unit (map from (ED2050, 2021))*



[2]*Coastline code GR9 on the Coastal Delineation axis of the coastal unit (map from (van Loon-Steensma et al., 2014a))*

3.2.2.2 The Ems-Dollard Estuary (DE) Workshop

We implemented the NBS-BB Framework for the German Wadden Sea pilot in our workshop with our REST-COAST partners in Germany on 19th of June, 2023 (please refer to the supplementary folder for the minutes *Appendix 13 - Wadden Sea DE Workshop Minutes NBS-BB Framework Implementation.pdf*). Participants to the workshop include; (i) Hereon and NLWKN as the REST-COAST partners of Task 4.2 in the Wadden Sea pilot, (ii) Bundesanstalt für Wasserbau (BAW) as one of the stakeholders focused on water quality, flood management and environmental protection in the German part of the Wadden Sea, and (iii) WUR as the facilitator. After a brief reintroduction of the NBS-BB Framework followed by the explanation of the main targets of the workshop, the participants decided to implement the framework in an arbitrary Coastal Unit lying on the German part of the Ems-Dollard Estuary. Although the main case study areas of the participants are more to the east of the German Wadden Sea (e.g. Jade Bay, Elbe Estuary), the rationale to focus on the Ems-Dollard Estuary was to exploit the uniqueness of the Wadden Sea pilot as the only transboundary case in the REST-COAST project, where strong bilateral coordination, collaboration and knowledge production are envisioned. Thus, using the interactive map gadget of the implementation tool, the participants agreed on a potential Coastal Unit to restore seagrass.

Accordingly, we used the implementation tool to apply our NBS-BB Framework in the identified Coastal Unit, where Seagrass Restoration is the process as NBS-BB. Due to the strong competence of the participants in hydro-morpho-ecological modelling of coastal ecosystems in this intensively studied estuary, identification of key biophysical parameters in accordance with the framework was sharp and plain, i.e. seagrasses are promising in naturally managing high sediment input from Ems river through increased accretion rates, decreased turbidity, improved filtration etc. However, identification of socio-economic parameters requires more diversity of knowledge and expertise especially in integrated approaches such as our framework. Immediately emerging as one of the bottlenecks, all of the participants acknowledged the importance of more inclusion from social sciences. This will stand out as one of the key learnings from all pilot implementations.

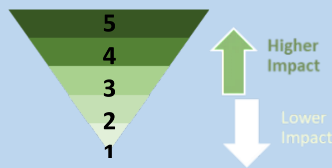
In Table 5, the preliminary results are provided for the implementation of the NBS-BB Framework in the Ems-Dollard Estuary with our German partners.

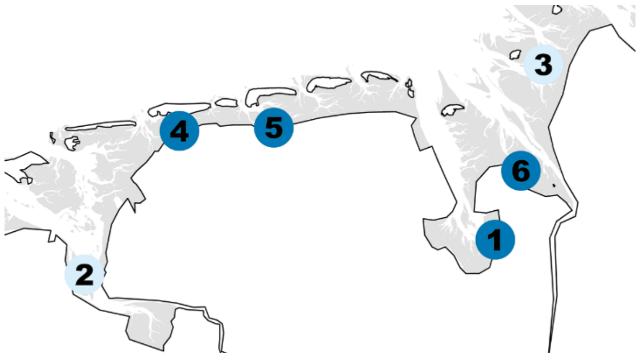
Table 5 – NBS-BB Framework implementation at the Ems-Dollard Estuary (DE) – Pilot workshop on 19th of June, 2023.

NBS-BB	NBS-BB CAT[1]	DEL[2]	EPA	INPUTS: KBP	INPUTS: KSP	OUTPUTS: ESS[3]	OUTPUTS: BDV[4]
Seagrass Restoration	Subtidal	*GR6 [53.3613º N, 7.0200º E]*	• Erosion • Flooding • Sea Level Rise • Biodiversity Loss • Eutrophication and hypoxia	• Sea surface elevation • Temperature • Salinity • Current velocity • Significant wave height • Sea bed stress • Sediment concentration	• Navigation e.g. public, private, commercial… • Channel and sediment management practices i.e. comparison NL vs. DE • Transboundary collaboration • Tourism • Integrating results from WP3 on innovative financing • Integrating results from WP5 on transformative governance	RFR(3) RCE(5) CCR(4) WP(4) FP(2)	• Benefits on habitats and species have not been directly quantified at the estuary. • Modelling output from WP2 can be a proxy for improvements in habitats. • Future integration of ongoing discussion on species evaluation in recently set-up PhD and Postdoc subgroups, e.g. IUCN Red List

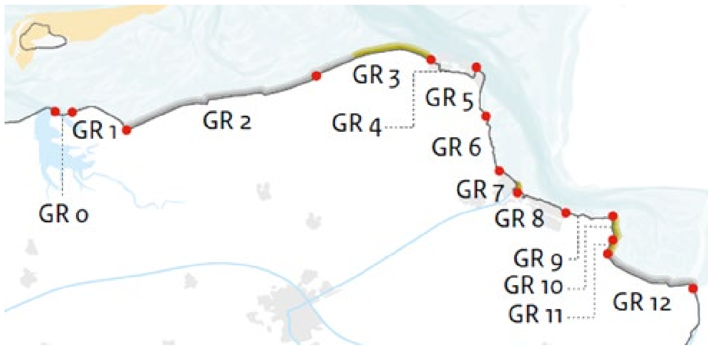
NBS-BB: Nature Based Solutions Building Block
NBS-BB CAT: A drop-down list for the NBS-BB Category along the land-sea continuum as defined in the NBS-BB Framework.
DEL: Coastline delineation as defined by the pilot partners according to the NBS-BB Framework (approximate coordinates of the center).
EPA: Environmental Pressures Addressed
INPUTS: KBP: Key Bio-physical Parameters – KSE: Key Socio-economic Parameters
OUTPUTS: ESS: Ecosystem Services RFR: Reduction Flood Risk; RCE: Reduction Coastal Erosion; CCR: Carbon Sequestration; WP: Water Purification; FP: Food Production; BDV: Biodiversity

[1,2] Coastal Units identified according to the *NBS-BB Categories* and *Coastal Delineations* are provided in the pilot map below.
[3] Semi-quantitative scores for 5 ESS defined in the REST-COAST project: Elementary quantification of expected ESS impact based on expert-led discussions is provided according to the color scale (with numerical scores for easier readability). Pilot will update these score aligned with their input to Task 4.1.
[4] Expert-based qualitative description of Biodiversity gains in terms of habitats and species by workshop participants. Pilot will update this column aligned with their input to Task 4.1.





[1]*Subtidal location (2) on the NBS-BB Cat axis of the coastal unit (map from (Dolch T. et al., 2017))*



[2]*Coastline code GR6 on the Coastal Delineation axis of the coastal unit (map from (van Loon-Steensma et al., 2014a))*

3.2.3 The Venice Lagoon

In the Venice Lagoon, we co-facilitated the pilot implementation workshop together with our key partners in CMCC and Ca' Foscari University of Venice. Accordingly, we organized a pre-meeting first on 9th of May, 2023 to discuss about the delineation of the lagoon and corresponding implementation of the NBS-BB Framework. For the purposes of environmental monitoring and data collection, the Venice Lagoon is divided into 14 water bodies, three of which are defined as 'heavily modified', according to the Directive 2000/60/EC. Among the 14 water bodies, we took into account 11 water bodies that are in the open part of the lagoon. Thus, we decided to assign these water bodies as our Coastal Units first, and then we planned to implement the NBS-BB Framework in a specific water body, which is also the pilot area for the REST-COAST project.

Then, we conducted the workshop in the Venice Lagoon on 22nd of May, 2023 with participants from; (i) CORILA and CMCC as the pilot co-leads, (ii) Ca' Foscari University of Venice, University of Padua and PROVV as the main partners of Task 4.2, (iii) Medsea as a REST-COAST partner, (iv) Selc Soc Coop as a local subcontractor of CORILA, (v), and (vi) WUR as the co-facilitator and task lead. As planned in the pre-meeting, using the pilot implementation tool, we implemented the NBS-BB Framework in the water body named PC2 Millecampi Teneri. The NBS-BB as the main restoration process in PC2 was identified as Artificial Salt Marsh Re-construction, which align with the main restoration targets within the REST-COAST. As revealed out during the workshop, there exists extensive data and knowledge on physical and ecological process within the water bodies due to the intensive monitoring of the lagoon. Combined with the diversity of expertise and experience of the participants, we identified smoothly the key biophysical parameters at the inputs of the framework.

Equally essential is the identification of the key socio-economic parameters, as emphasized in the development of the framework in Chapter 1.7. This proved more challenging due to lack of expertise and data. We identified some potential key socio-economic parameters using the experience of the participants in the restoration efforts of the lagoon. Nevertheless, we acknowledged the complex interactions and dynamics, which require specific expertise of social sciences for integrated approaches such as out framework. This is especially critical when the bio-physical and socio-economic parameters are coupled with reinforcing impacts, e.g. sediment management for commercial channel navigation. Please refer to the supplementary folder for the minutes, *Appendix 9 - Venice Lagoon Workshop Minutes NBS-BB Framework Implementation.pdf*, for a more detailed record of the workshop.

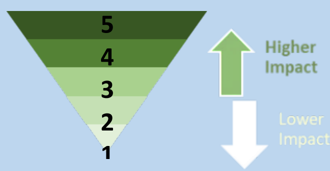
Preliminary output from the implementation of the NBS-BB Framework in the PC2 Coastal Unit is provided in Table 6. As the research in the pilot site continues, this preliminary output will also be revised, modified and upgraded with knowledge, data and expertise built throughout the course of the REST-COAST. In the next chapter, we will demonstrate in the PC2 Coastal Unit how these preliminary output evolves into more complete implementation of the framework. Furthermore, implementing the framework in all 11 water bodies in the Venice Lagoon can yield a complete overview of the lagoon for effective upscaling potential. Yet, this is beyond the scope of both Task 4.2 and REST-COAST.

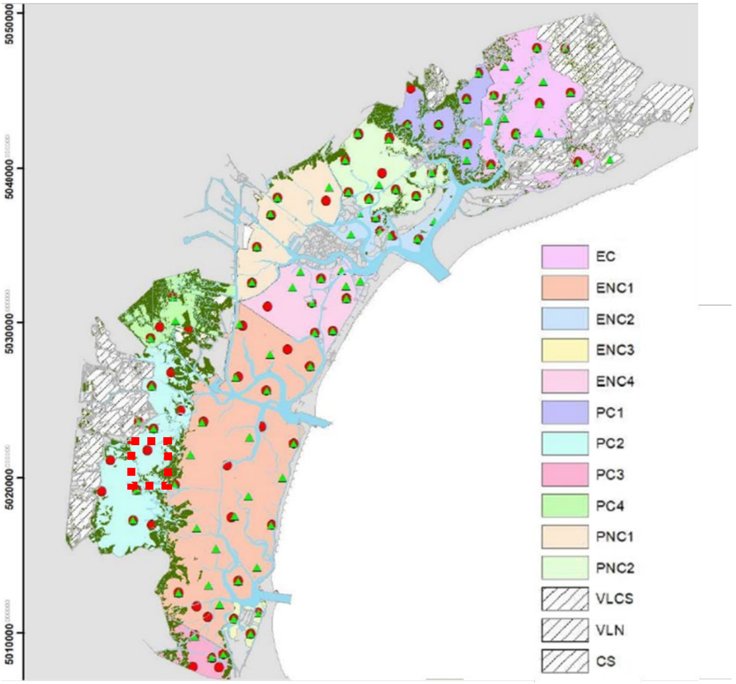
Table 6 – NBS-BB Framework implementation at the Venice Lagoon (IT) – Pilot workshop on 22nd of May, 2023

NBS-BB	NBS-BB CAT[1]	DEL[2]	EPA	INPUTS		OUTPUTS	
				KBP	KSP	ESS[3]	BDV[4]
Artificial Salt Marsh Re-construction	Intertidal	PC2 [45.3404º N, 12.2101º E]	• Lateral edge erosion • Anthropogenic drivers; ○ dredging, ○ land reclamation, ○ transportation ○ … • Sea level rise • Negative sediment budget • Wind-wave dynamics	• Granulometry; e.g. sediment type, size, distribution • Vegetation; e.g. Pioneer/annual/ perennial; Coverage; Species • Water quality • Water height • Salt marsh altitude • Bird species • Erosion rates • Sedimentation • Sediment compaction rate • Carbon sequestration • Seagrasses	• Fishing interests • Proximity to; ○ Inhabited areas ○ industrial areas • Available funds • Water traffic – public/private • Heritage / social memory • Political prestige • Integrating results from WP3 on innovative financing • Integrating results from WP5 on transformative governance	RFR(3) RCE(5) CCR(4) WP(4) FP(1)	• Benefits on habitats and species have not been directly quantified in the lagoon: Future integration of ongoing discussion in recently set-up PhD and Postdoc subgroups. • Modelling output from WP2 can be a proxy for evolution of salt marshes. • Data on number of bird species and number of breeding birds (by SELC Soc Coop).

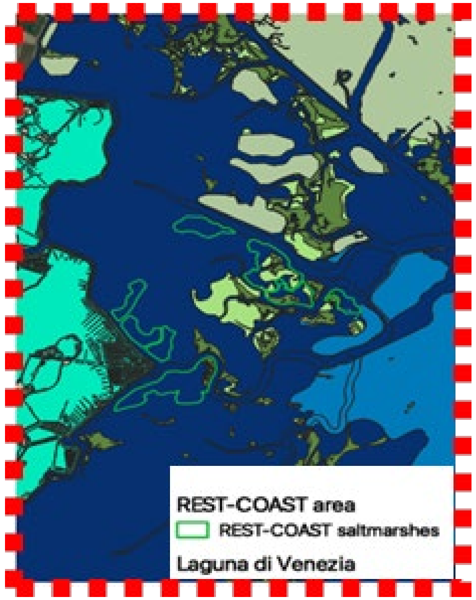
NBS-BB: Nature Based Solutions Building Block
NBS-BB CAT: A drop-down list for the NBS-BB Category along the land-to-sea continuum as defined in the NBS-BB Framework.
DEL: Coastline delineation as defined by the pilot partners according to the NBS-BB Framework (approximate coordinates of the center).
EPA: Environmental Pressures Addressed
INPUTS: KBP: Key Bio-physical Parameters – KSE: Key Socio-economic Parameters
OUTPUTS: ESS: Ecosystem Services RFR: Reduction Flood Risk; RCE: Reduction Coastal Erosion; CCR: Carbon Sequestration; WP: Water Purification; FP: Food Production; BDV: Biodiversity

[1,2] Coastal Units identified according to the *NBS-BB Categories* and *Coastal Delineations* are provided in the pilot map below.
[3] Semi-quantitative scores for 5 ESS defined in the REST-COAST project: Elementary quantification of expected ESS impact based on expert-led discussions is provided according to the color scale (with numerical scores for easier readability). Pilot will update these score aligned with their input to Task 4.1.
[4] Expert-based qualitative description of Biodiversity gains in terms of habitats and species by workshop participants. Pilot will update this column aligned with their input to Task 4.1.





[1]*Intertidal location on the NBS-BB Cat axis of the coastal unit PC2 (map adapted from [ISPRA, ARPAV])*



[2]*Salt marsh edges on the Coastal Delineation axis of the coastal unit PC2 (map provided by CMCC)*

3.2.4 The Foros Bay

Our partners in IO-BAS had been very inclusive in the co-development of the NBS-BB Framework since the kick-off of Task 4.2. Thus, they had a good understanding of the participative downscaling approach as Coastal Units and the corresponding delineation task for the pilot coastline. During the preparation period prior to the workshop, our partners developed a custom expert-based delineation map for the Foros Bay. The coastline was delineated into 27 coastal stretches with diverse semi-quantitative scoring based on the wave-exposure, which is identified as the main biophysical process impacting the bay.

We conducted our pilot implementation workshop at the Foros Bay on 8th of June, 2023. Participants to the workshop include; (i) IO-BAS as the main partner of Task 4.2, (ii) WUR as the facilitator and task lead. Resulting from this restricted structure of the workshop in terms of participation, we focused on a bilateral communication on; (i) further requirements and opportunities for the bay in implementing the NBS-BB Framework, and (ii) restoration vision, local context and challenges of stakeholder inclusion from IO-BAS perspective. More detailed overview of the workshop can be found in the minutes, *Appendix 10 - Foros Bay Workshop Minutes NBS-BB Framework Implementation.pdf*, as provided in the supplementary folder.

For the first point, i.e. implementation of the framework in the pilot, we agreed to implement the framework at 5 Coastal Units demarcated by 5 of 27 coastal stretches, which reside in the focus area of the REST-COAST. Accordingly, the implementation was performed by IO-BAS in these 5 Coastal Units using the pilot implementation tool after the workshop. Identified NBS-BB as restoration processes were mainly determined based on the two main biophysical parameters: wave exposure and bottom substrate. The main restoration focus is on seagrasses according to the REST-COAST targets in the pilot. Yet, our downscaling approach as Coastal Units and corresponding implementation of the framework in each unit proved informative and essential for designing diverse restoration action in each Coastal Unit. Furthermore, our partners emphasized the importance of integrated landscape approach from upstream to the sea in the Foros Bay, which aligns well with the integrated approach of our framework.

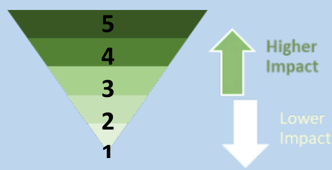
For the second point, i.e. local context and challenges, we acknowledged the distinct character of the Foros Bay pilot compared to the other EU pilots in terms of stakeholder participation and participative research. Managed by more central governance approach, the local stakeholders communicated the challenges of performing our participative downscaling method, which is an explorative research-based approach. However, local context fits better for decision-based participation in which the stakeholders make decisions based on the concrete and verified research output. This was one of the important key learnings from the co-development of our framework.

It is also important to note the lack of social sciences perspective in both identification of the Coastal Units and consequent implementation of the framework. In the workshop, we acknowledged the lack of expertise in social sciences and the need for coupling socio-economic parameters to the design of restoration with NBS in the Foros Bay. Preliminary output from the implementation of the framework in the Foros Bay is provided in Table 7.

Table 7 – NBS-BB Framework implementation at the Foros Bay (BG) – Pilot workshop on 8th of June, 2023

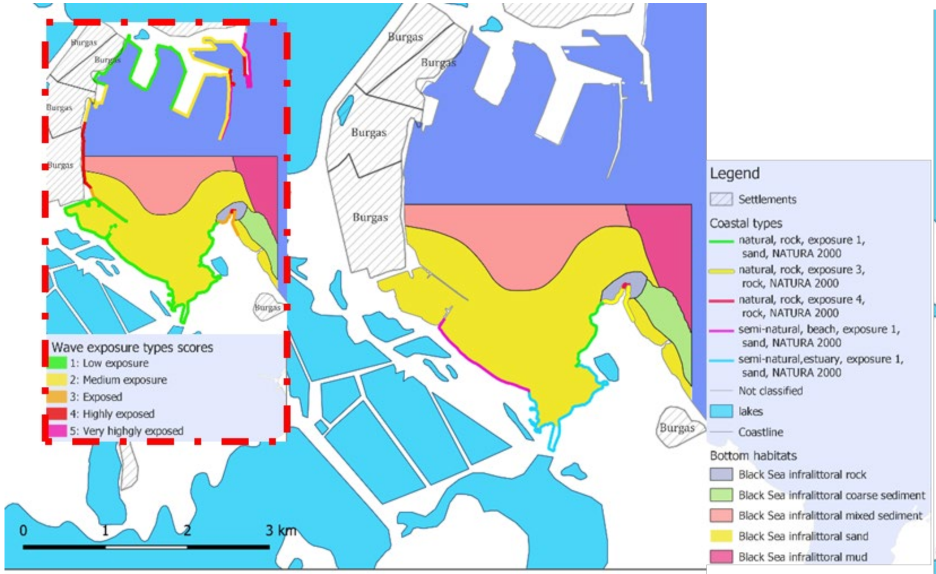
NBS-BB	NBS-BB CAT[1]	DEL[2]	EPA	INPUTS			OUTPUTS	
				KBP	KSP		ESS[3]	BDV[4]
Seagrass Meadow Conservation	Subtidal	*CS1* *[42.4526° N, 27.4577° E]*	• Environmental degradation due to anthropogenic impacts, e.g. pollution, industrial activities at port… • Cascading and compounding impacts from upstream to the bay, including: ○ Intensive agricultural activities ○ Degraded wetlands, river flow and banks, ○ High nutrient loads	• Wave exposure – wind fetch • Wave exposure – bottom substrate • Wave energy • Current speed • Bottom orbital velocity	Coastal landscape – Natural / **Semi-natural[(b)]** / Artificial	• NATURA 2000 site • Governed by Ministry of Environment and Water • Integrating results from WP3 on innovative financing • Integrating results from WP5 on transformative governance	RFR(1) RCE(2) CCR(5) WP(5) FP(1)	• Benefits on habitats and species have not been directly quantified for the bay: Future integration of ongoing discussion in recently set-up PhD and Postdoc subgroups. • Modelling output from WP2 can be a proxy for improvements in the seagrass flora. • Although all the restoration actions are expected to improve biodiversity by providing food and shelter for the flora and fauna, the brown macroalgae restoration is expected to have more impact on enhancing biodiversity.
Seagrass and other SAV[(a)] Restoration	Subtidal	*CS2* *[42.4482° N, 27.4712° E]*					RFR(1) RCE(2) CCR(5) WP(5) FP(1)	

NBS-BB: Nature Based Solutions Building Block
NBS-BB CAT: A drop-down list for the NBS-BB Category along the land-to-sea continuum as defined in the NBS-BB Framework.
DEL: Coastline delineation as defined by the pilot partners according to the NBS-BB Framework (approximate coordinates of the center).
EPA: Environmental Pressures Addressed
INPUTS: KBP: Key Bio-physical Parameters – KSE: Key Socio-economic Parameters
OUTPUTS: ESS: Ecosystem Services RFR: Reduction Flood Risk; RCE: Reduction Coastal Erosion; CCR: Carbon Sequestration; WP: Water Purification; FP: Food Production; BDV: Biodiversity

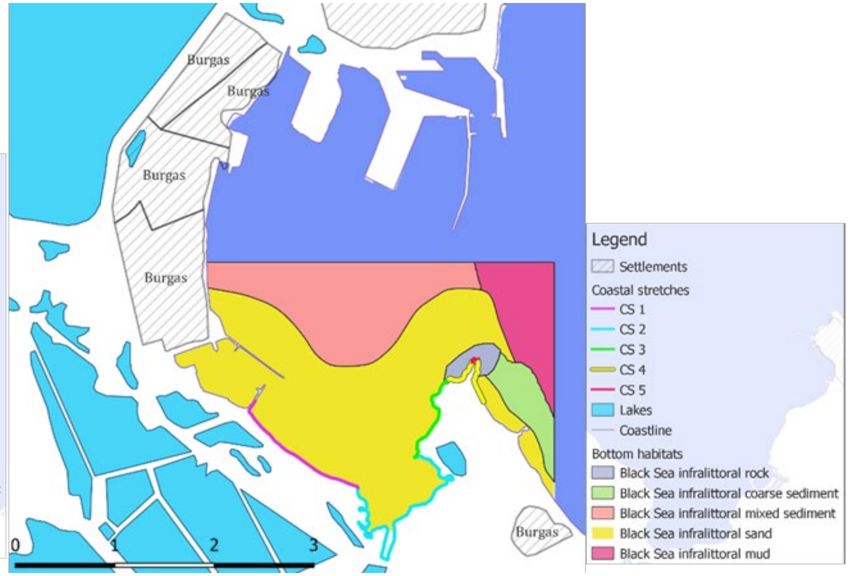


[1,2] Coastal Units identified according to the *NBS-BB Categories* and *Coastal Delineations* are provided in the pilot map below.
[3] Semi-quantitative scores for 5 ESS defined in the REST-COAST project: Elementary quantification of expected ESS impact based on expert-led discussions is provided according to the color scale (with numerical scores for easier readability). Pilot will update these score aligned with their input to Task 4.1.
[4] Expert-based qualitative description of Biodiversity gains in terms of habitats and species by workshop participants. Pilot will update this column aligned with their input to Task 4.1.
[(a)] SAV: Submerged Aquatic Vegetation
[(b)] NATURA 2000 site with artificial semi-penetrable underwater stone barriers for protection of the coast: qualify as semi-natural.

Seagrass Restoration	Subtidal	*CS3 [42.4560º N, 27.4746º E]*	• Environmental degradation due to anthropogenic impacts, e.g. pollution, industrial activities at port… • Cascading and compounding impacts from upstream to the bay, including: ○ Intensive agricultural activities ○ Degraded wetlands, river flow and banks, ○ High nutrient loads	• Wave exposure – wind fetch • Wave exposure – bottom substrate • Wave energy • Current speed • Bottom orbital velocity	Coastal landscape – **Natural** / Semi-natural[(b)] / Artificial	• NATURA 2000 site • Governed by Ministry of Environment and Water • Integrating results from WP3 on innovative financing • Integrating results from WP5 on transformative governance	RFR[(1)] RCE[(3)] CCR[(5)] WP[(5)] FP[(1)]	• Benefits on habitats and species have not been directly quantified for the bay: Future integration of ongoing discussion in recently set-up PhD and Postdoc subgroups. • Modelling output from WP2 can be a proxy to biodiversity for improvements in the seagrass flora. • Although all the restoration actions are expected to improve biodiversity by providing food and shelter for the flora and fauna, the brown macroalgae restoration is expected to have more impact on enhancing biodiversity.
Seagrass Restoration	Subtidal	*CS4 [42.4595º N, 27.4775º E]*					RFR[(1)] RCE[(4)] CCR[(5)] WP[(5)] FP[(1)]	
Brown Macroalgae Restoration	Subtidal	*CS5 [42.4614º N, 27.4794º E]*					RFR[(2)] RCE[(2)] CCR[(5)] WP[(4)] FP[(4)]	



[1]*Coastal types classified on the NBS-BB Cat axis accompanied by wave exposure scores in the inner map (maps provided by E. Hineva et al., IO-BAS, 2024)*



[2]*Coastline codes CS1-5 on the Coastal Delineation axis identified according to exposure and type (maps provided by E. Hineva et al., IO-BAS, 2024)*

3.2.5 The Arcachon Bay

We conducted our workshop for the Arcachon Bay on the 12th of June, 2023 with involvement from; (i) Egis and Seaboost as our core partners in the pilot, (ii) Parc Naturel Marin Bassin d'Arcachon as the main stakeholder in the Arcachon Bay, and (iii) WUR as the task lead and facilitator. More detailed overview of the workshop can be found in the minutes, *Appendix 11 - Arcachon Bay Workshop Minutes NBS-BB Framework Implementation.pdf*, as provided in the supplementary folder.

Delineation of the pilot was not performed in advance, so initially we elaborated on how to approach the Arcachon Bay from the perspective of Coastal Units. Our partners in the pilot have clear objective within REST-COAST to restore the relatively small area (<10 ha) of historical salt marshes using the Roseliere artificial seagrass device. Hence, we identified *Roseliere Seagrass Restoration* as the main restoration process, thus the NBS-BB in a specific Coastal Unit. We focused on the intertidal zone on the NBS-BB Category axis in accordance with the NBS-BB Framework. Then, we contemplated on the coastline delineations to enclose, thus to identify the Coastal Units. Focused on the biophysical processes and potential socio-economic indicators, we decided to focus on salt marsh edges and intertidal flats along the delineation axis. Accordingly, we performed our participative downscaling approach to identify two spatial Coastal Units: *Channel Edges* and *Intertidal Flats*. Despite the limited inclusion and diversity in the participative downscaling, clearly defined restoration target in a relatively small pilot area combined with EU Green Deal support of REST-COAST were enablers for successfully identified Coastal Units. Nevertheless, we will discuss the negative impacts of limited participation on the implementation of NBS-BB Framework in Chapter 5.

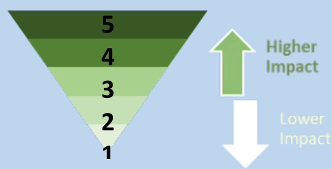
We implemented the NBS-BB Framework in these two Coastal Units rest of the workshop. A preliminary overview of this implementation is provided in Table 8. It has already been evident so far how detrimental it is for our framework to lack expertise in social sciences. Yet, in our Arcachon pilot workshop, inclusion of site manager as the main stakeholder proved extremely important for a holistic view of the pilot site within the whole Parc Naturel Marin. This included the identification of complementary socio-economic parameters alongside the biophysical parameters from the expertise of our partners.

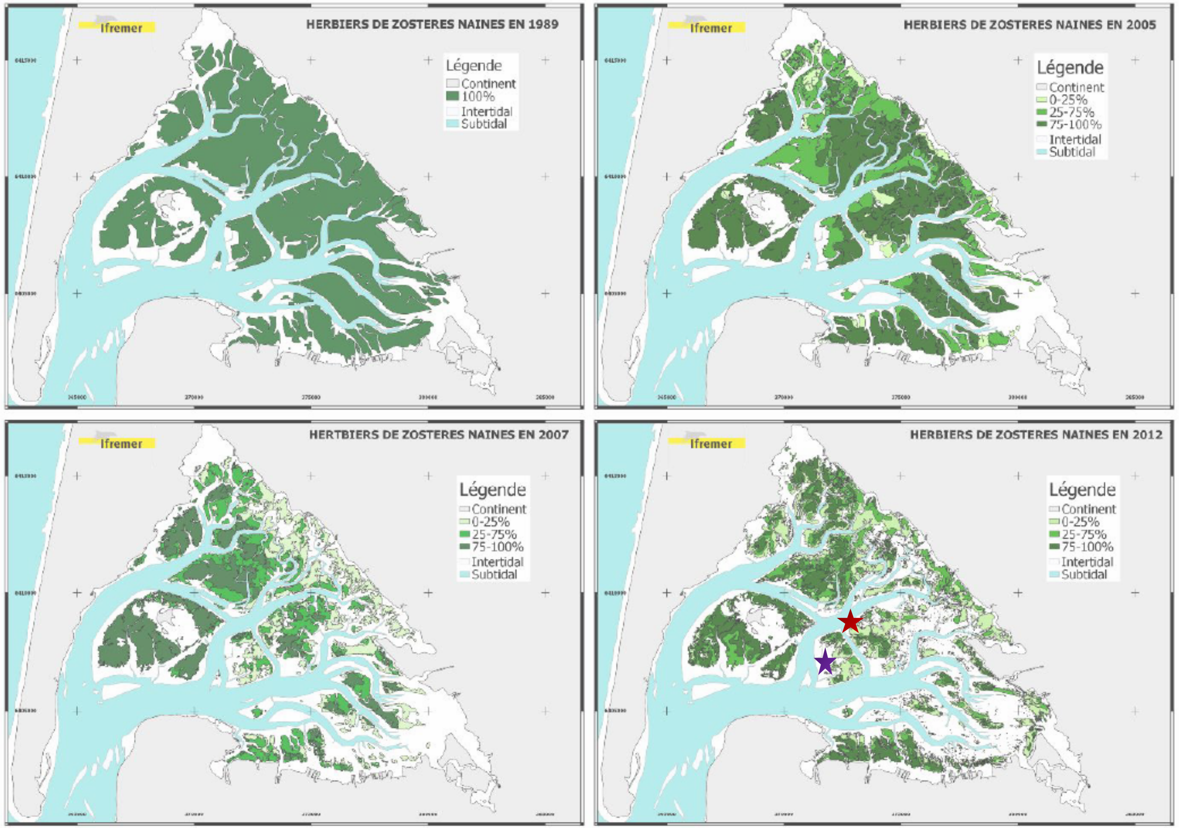
Table 8 – NBS-BB Framework implementation at the Arcachon Bay (FR) – Pilot workshop on 12th of June, 2023

NBS-BB	NBS-BB CAT[1]	DEL[2]	EPA	INPUTS		OUTPUTS	
				KBP	KSP	ESS[3]	BDV[4]
Roseliere[(a)] Seagrass Restoration	Intertidal	*CE1 [44.6746º N, 1.1034º W]*	• Sea level rise and increasing flood risk. • Direct anthropogenic impacts; ○ Urbanization ○ Tourism ○ Contaminants ○ Dredging ○ Oyster farming • Climatic impacts; ○ Waves ○ Currents	• Current velocity • Wave height • Water height • Granulometry; ○ Sand ○ Mud • Vegetation; ○ Species, ○ Density ○ Root/leave biomass • Carbon content • Sediment deposition rate • Bioturbation • Flushing time: proxy for freshwater	• Population density • Tourism, e.g.; ○ seasonal distribution ○ transportation by sea ○ personal luxury yachts • Oyster farming • Fishing (near-shore) • Channel traffic; e.g.; ○ Public ○ Private ○ Industrial • Agriculture • Dredging and harbor activities • Cultural heritage/Social memories • Long term economic transformation • Sociological impacts of submersion • Integrating results from WP3 on innovative financing • Integrating results from WP5 on transformative governance	RFR(5) RCE(5) CCR(4) WP(4) FP(1)	• Benefits on habitats and species have not been directly quantified for the bay: Future integration of ongoing discussion in recently set-up PhD and Postdoc subgroups. • Modelling output from WP2 can be a proxy to biodiversity enhancement. • Although main focus is on restoration of Z. noltei (seagrass), many biodiversity benefits of fauna and flora are expected.
Roseliere[(a)] Seagrass Restoration	Intertidal	*IF1 [44.6708º N, 1.0902º W]*				RFR(4) RCE(4) CCR(4) WP(5) FP(1)	

NBS-BB: Nature Based Solutions Building Block
NBS-BB CAT: A drop-down list for the NBS-BB Category along the land-to-sea continuum as defined in the NBS-BB Framework.
DEL: Coastline delineation as defined by the pilot partners according to the NBS-BB Framework (approximate coordinates of the center).
EPA: Environmental Pressures Addressed
INPUTS: KBP: Key Bio-physical Parameters – KSE: Key Socio-economic Parameters
OUTPUTS: ESS: Ecosystem Services RFR: Reduction Flood Risk; RCE: Reduction Coastal Erosion; CCR: Carbon Sequestration; WP: Water Purification; FP: Food Production; BDV: Biodiversity

[1,2] Coastal Units identified according to the *NBS-BB Categories* and *Coastal Delineations* are provided in the pilot map below. CE: Channel Edge, IF: Intertidal Flat
[3] Semi-quantitative scores for 5 ESS defined in the REST-COAST project: Elementary quantification of expected ESS impact based on expert-led discussions is provided according to the color scale (with numerical scores for easier readability). Pilot will update these score aligned with their input to Task 4.1.
[4] Expert-based qualitative description of Biodiversity gains in terms of habitats and species by workshop participants. Pilot will update this column aligned with their input to Task 4.1.
[(a)] Roseliere is an artificial seagrass device to control hydrodynamics and increase high current resistance to halt ongoing seagrass regression and help recolonization of the tidal flats (from Cailllibotte & Briere, Climate Risk Reduction through Innovative Restoration Arcachon Lagoon Pilot in REST-COAST Half-year Meeting, 28 March 2022).





Arcachon Bay: Evolution of seagrass coverage 1989 – 2012 (maps from (Cognat, 2019))

[1]*Intertidal zones on the NBS-BB Cat axis for the Arcachon Bay (see Legend)*

[2]*Coastal Units CE1 & IF1 identified along the Coastal Delineation axis in the Arcachon Bay: CE (red star) & IF (purple star)*

3.2.6 The Ebro Delta

The Ebro Delta workshop for the implementation of the NBS-BB Framework was planned to for June 2023. However, the participatory design of pilot implementations are prone to many internal and external factors in effectively realizing these workshops. The Ebro Delta workshop was instructive of some of these unfavorable conditions, e.g. increased work load combined with limited availability of our partners, unprecedented droughts in the region. So, we failed to conduct our workshop as planned and needed to improvise the framework implementation. Accordingly, we organized a pre-meeting with 2 of our task partners at Albirem and Eurecat on the 15^{th} of June. In this pre-meeting, we discussed the potential implementation of the framework in detail through communicating bilateral expectations. More detailed overview of this meeting can be found in the minutes, *Appendix 12 - Ebro Delta Workshop Minutes NBS-BB Framework Implementation.pdf*, as provided in the supplementary folder.

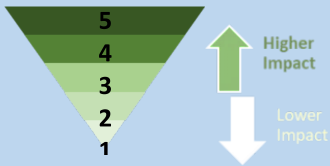
In the upcoming months following the droughts, our partners self-organized to implement the framework in the *Alfacada Coastal Unit* using the pilot implementation tool. The preliminary output from this implementation is provided in Table 9. Again all odds in carrying out a participative workshop, the lessons-learned from the Ebro Delta workshop are informative and noteworthy. First of all, we were exposed to the first-hand adverse impacts of climate change, i.e. the unprecedented droughts in the region, in our implementation-based research in nature restoration. Then, we learned by doing that the participative methodologies as in our NBS-BB Framework are, (i) place-based, i.e. diverse experiences in different pilots, (ii) institution-based, e.g. participation and collaboration among different organizations, and (iii) human-based, e.g. interests of local stakeholders.

We should also note the recurring theme of incomprehensive approach to the identification of socio-economic parameters due to the lack social sciences perspective in the pilot implementations. We will also discuss this in Chapter 5 as one of the key learnings in moving from theory to practice in our co-developed NBS-BB Framework.

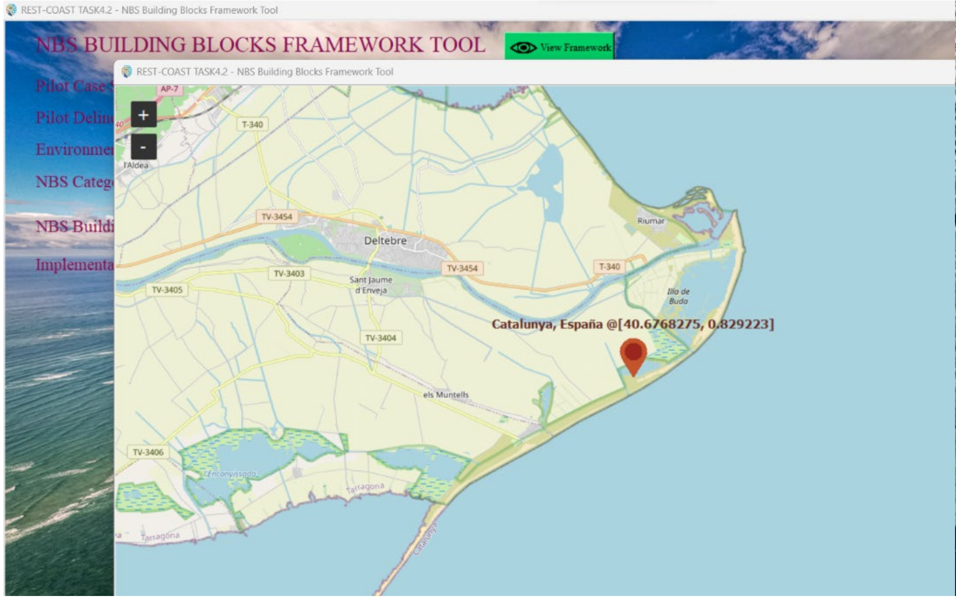
Table 9 – NBS-BB Framework implementation at the Ebro Delta (SP) – Pilot pre-workshop on 15th of June, 2023

NBS-BB	NBS-BB CAT[1]	DEL[2]	EPA	INPUTS		OUTPUTS	
				KBP	KSP	ESS[3]	BDV[4]
Salt Marsh Edge Protection	Intertidal	*Alfacada [40.6768º N, 0.8292º E]*	• SLR • Extreme weather events • Flood risk • Climate change • …	• Water physiochemical parameters: ○ conductivity ○ dissolved oxygen ○ pH ○ Temperature ○ Turbidity • Environmental parameters ○ Water column ○ Humidity ○ Air temperature ○ Precipitation • Soil parameters ○ Soil conductivity ○ Soil temperature ○ Soil pH • Habitats ○ Vegetation coverage • Biodiversity ○ Macrophytes species & abundance ○ Macroinvertebrates species & abundance ○ Microcrustaceans species & abundance ○ Fish species & abundance ○ Birds species & abundance • Greenhouse gas fluxes ○ CO2 ○ Methane	• National funding • EU funding (e.g. REST-COAST) • NATURA 2000 • Site management • Cultural heritage • Touristic interests • Proximity to agricultural fields • Training & dissemination activities • Economic value creation • Integrating results from WP3 on innovative financing • Integrating results from WP5 on transformative governance	RFR(4) RCE(3) CCR(5) WP(4) FP(2)	• Biotope maps developed for current situation and future scenarios can be proxy to biodiversity status. • Passive improvement of the salt marsh habitats is expected. • Healthy natural salt marsh will have positive impact on the fauna. • Transition from freshwater to salty water after restoration might negatively impact freshwater bird species.

NBS-BB: Nature Based Solutions Building Block
NBS-BB CAT: A drop-down list for the NBS-BB Category along the land-to-sea continuum as defined in the NBS-BB Framework.
DEL: Coastline delineation as defined by the pilot partners according to the NBS-BB Framework (approximate coordinates of the center).
EPA: Environmental Pressures Addressed
INPUTS: KBP: Key Bio-physical Parameters – KSE: Key Socio-economic Parameters
OUTPUTS: ESS: Ecosystem Services RFR: Reduction Flood Risk; RCE: Reduction Coastal Erosion; CCR: Carbon Sequestration; WP: Water Purification; FP: Food Production; BDV: Biodiversity



[1,2] Coastal Units identified according to the *NBS-BB Categories* and *Coastal Delineations* are provided in the pilot map below.
[3] Semi-quantitative scores for 5 ESS defined in the REST-COAST project: Elementary quantification of expected ESS impact based on expert-led discussions is provided according to the color scale (with numerical scores for easier readability). Pilot will update these score aligned with their input to Task 4.1.
[4] Expert-based qualitative description of Biodiversity gains in terms of habitats and species by workshop participants. Pilot will update this column aligned with their input to Task 4.1.



[1]Intertidal zone indicated by the marker on the NBS-BB Cat axis of the Alfacada Coastal Unit in the Ebro Delta (map from Implementation Tool executed by L. Puertolas & N. Alvarez, 26

[2]Coastline (red line) along the Coastal Delineation axis of the Alfacada Coastal Unit (map from N. Caiola, WP4 Workshop, 12 March 2024)

3.2.7 The Sicily Lagoon

Università degli Studi di Catania (UC) as our key partner in the Sicily Lagoon pilot had been active and involved in co-developing the NBS-BB Framework since the kick-off of Task 4.2. This close collaboration led to several bilateral meetings to co-facilitate the pilot workshop. So, we discussed in advance the potential implementation of the NBS-BB Framework in the lagoon by identifying potential Coastal Units aligned with past and future restoration efforts. These pre-meetings were also essential as we planned to include one key stakeholder external to the REST-COAST project. On 27th of June, 2023, we conducted our pilot workshop to implement the NBS-BB Framework. Participants to the workshop included; (i) 3 of our task partners from the UC, (ii) a key stakeholder from Stiftung pro Artenvielfalt (SPA), and (iii) WUR as the task lead and facilitator. More detailed overview of this workshop is included in the minutes, *Appendix 14 - Sicily Lagoon Workshop Minutes NBS-BB Framework Implementation.pdf*, as provided in the supplementary folder.

Involving SPA proved very essential for a more comprehensive implementation of our framework in terms of the diverse participatory design of our IPO approach. Hence, our partners in UC are experts in natural dynamics and ecosystems modelling. SPA, on the other hand, has very extensive experience and knowledge in nature restoration with BDV focus and social dynamics. SPA owns Pantano Cuba e Longarini, which are two neighboring lagoons in the REST-COAST pilot site and has been actively running restoration projects in the lagoon. So, involvement and open communication of this key stakeholder contributed significantly to the comprehensive implementation of our framework in the Sicily Lagoon pilot.

Accordingly, during the workshop, we had an overview on 6 Coastal Units identified in the pilot by our partners and elaborated on these Coastal Units from all stakeholders' perspectives. Considering the time and the effort required, the practical implementation of our framework in these Coastal Units were completed later together with our key partner in UC by using the discussions during the workshop and in our bilateral meetings. Preliminary output from this pilot implementation are provided in Table 10. It is noteworthy to mention that the identified Coastal Units, hence NBS-BB in each unit, were characterized mainly by the complementary restoration efforts executed by SPA. This aligned perfectly for future upscaling targets of REST-COAST in the Sicily Lagoon pilot by finding synergies and harmonies among NBS-BB.

Inclusion of SPA was also critical for comparative analysis of diverse pilot implementations since involvement of SPA can be a reference point for cross-pilot comparisons to inform the importance of diverse participation in the pilots, especially for effective and long-term restoration and upscaling. We will discuss this further in Chapter 5.

Table 10 – NBS-BB Framework implementation at the Sicily Lagoon (IT) – Pilot workshop on 27th of June, 2023

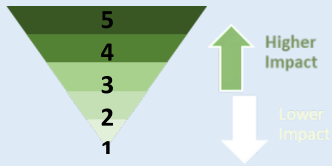
NBS-BB	NBS-BB CAT[1]	DEL[2]	EPA	INPUTS		OUTPUTS	
				KBP	KSP	ESS[3, 4]	BDV[5]
Dune Revegetation	Barrier	*#6 [36.7032° N, 15.0003° E]*	• Biodiversity loss • Coastal erosion (priority) • Coastal flooding • SLR • Extreme events • Urbanization	• Sediment budget • Sea level rise • Wave conditions • Vegetation coverage • Shoreline	• Rapid urbanization • Coastal squeeze • Tourism • Seasonal anthropogenic load • Local (in)participation • Integrating results from WP3 on innovative financing • Integrating results from WP5 on transformative governance	RFR(4) RCE(5) CCR(3) WP(1) FP(1)	• *Ammophila arenaria* is used for models specifically. • Modelling output can be proxy to biodiversity enhancement. • Ongoing discussion in PhD and postdoc subgroups on BDV evaluation, e.g. IUCN Red List
Hydraulic Connectivity	Hinterland	*#3.1 Inter-lagoon [36.7078° N, 15.0196° E]* *#3.2 River-Sea [36.7079° N, 15.0032° E]*	• Biodiversity loss • Coastal flooding • SLR • Extreme events • Urbanization	• Sea level rise • Wave conditions • Water levels • River discharge • Precipitation • Vegetation coverage • Species conditions • Environmental flow requirement	• Rapid urbanization • Coastal squeeze • Tourism • Seasonal anthropogenic load • Social perception of restoration. • Tension between locals and SPA. • Integrating results from WP3 on innovative financing • Integrating results from WP5 on transformative governance	RFR(5) RCE(1) CCR(1) WP(4) FP(1)	• SPA monitors fauna and flora status in the lagoon after restoration. • Modelling output can be proxy to biodiversity enhancement. • Ongoing discussion in PhD and postdoc subgroups on BDV evaluation, e.g. IUCN Red List

Salt Marsh Restoration	Hinterland	#1 *[36.7084º N, 15.0134º E]*	• Biodiversity loss • Species with extinction threat, i.e. marbled duck • Intensive agriculture • High nutrient loads and pollution • Habitat destruction, i.e. heavily modified lagoon for fish farming	• Nutrient load • Upstream sediment load • Salinity • Freshwater input • Species distribution, i.e. fauna and flora • Water levels • Sea level rise	• LIFE Marbled Duck PSSO project: completed/impact assessment • Restoration in privately owned lagoon by SPA • Main focus on species protection and increasing BDV values • Tension between locals and NGO • Social perception of restoration • Integrating results from WP3 on innovative financing • Integrating results from WP5 on transformative governance	RFR[1] RCE[1] **CCR[5]** **WP[5]** FP[1]	• Ongoing monitoring in the restoration site. • Successful results for Marbled Duck, the main focus of the project. • In addition, benefits measured for enormous number of species, including around 20 other bird species as well as many other plant and animal species. • *Spartina alterniflora* and *Phragmites australis* are used for modelling change under future scenarios.
Bird Island Building	Hinterland	#2 *[36.7114º N, 15.0137º E]*				RFR[1] RCE[1] **CCR[5]** **WP[5]** FP[1]	
Seagrass Restoration	Subtidal	#4 *[36.6962º N, 15.0025º E]*	• Biodiversity loss • SLR • Extreme weather events • Urbanization • High nutrient loads and pollution • Climate change • Sediment deficiency	• Sediment budget • Sea level rise • Wave conditions • Vegetation coverage • Shoreline • Temperature • Bathymetry • Salinity • pH • Nutrient loads	• Rapid urbanization • Coastal squeeze • Tourism • Seasonal anthropogenic load • Intensive agricultural activities upstream • Integrating results from WP3 on innovative financing • Integrating results from WP5 on transformative governance	**RFR[5]** **RCE[5]** **CCR[4]** **WP[4]** FP[1]	• *Posidonia oceanica* is used for modelling change under future scenarios. • Modelling output can be proxy to biodiversity enhancement. • Ongoing discussion in PhD and postdoc subgroups on BDV evaluation, e.g. IUCN Red List.

Beach Nourishment	Barrier	#5 *[36.7002° N, 15.0235° E]*	• Biodiversity loss • SLR • Extreme weather events • Urbanization • Climate change • Sediment deficiency	• Sediment budget • Sea level rise • Wave conditions • Shoreline • Bathymetry • Vegetation • Wind and current characteristics	• Rapid urbanization • Coastal squeeze • Social meaning: dunes and flood protection. • PhD grant funded by world leading offshore and dredging company • Integrating results from WP3 on innovative financing • Integrating results from WP5 on transformative governance	RFR[5] RCE[5] CCR[1] WP[1] FP[1]	• Modelling output can be proxy to biodiversity enhancement. • Ongoing discussion in PhD and postdoc subgroups on BDV evaluation, e.g. IUCN Red List.

NBS-BB: Nature Based Solutions Building Block
NBS-BB CAT: A drop-down list for the NBS-BB Category along the land-to-sea continuum as defined in the NBS-BB Framework.
DEL: Coastline delineation as defined by the pilot partners according to the NBS-BB Framework (approximate coordinates of the center).
EPA: Environmental Pressures Addressed
INPUTS: KBP: Key Bio-physical Parameters – KSE: Key Socio-economic Parameters
OUTPUTS: ESS: Ecosystem Services RFR: Reduction Flood Risk; RCE: Reduction Coastal Erosion; CCR: Carbon Sequestration; WP: Water Purification; FP: Food Production; BDV: Biodiversity

[1,2] Coastal Units identified according to the *NBS-BB Categories* and *Coastal Delineations* are provided in the pilot map below.
[3] Semi-quantitative scores for 5 ESS defined in the REST-COAST project: Elementary quantification of expected ESS impact based on expert-led discussions is provided according to the color scale (with numerical scores for easier readability). Pilot will update these score aligned with their input to Task 4.1.
[4] CCR and FP are not target ESS in the restoration planning of the Siciliy Lagoon within the scope of the REST-COAST project. The scores here are solely for participation practice purposes.
[5] Expert-based qualitative description of Biodiversity gains in terms of habitats and species by workshop participants. Pilot will update this column aligned with their input to Task 4.1.



[1,2]Land-to-sea zones on the NBS-BB Cat axis and demarcations on the Coastal Delineation axis for the 6 pre-identified Coastal Units in the Sicily Lagoon pilot (left) & enumerated coastal units are assigned to specific restoration processes as NBS-BB (right) (maps adapted from M. Marino et al., 2023, REST-COAST Annual Meeting in Gdansk, Poland)

3.3 Pilot Implementation Form at 3 Pilots

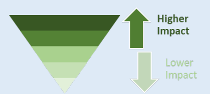
In Chapter 2, we portrayed our intense collaboration with 6 REST-COAST pilots, i.e. Wadden Sea, Venice Lagoon, Ebro Delta, Sicily Lagoon, Arcachon Bay and Foros Bay, for the co-development of the NBS-BB Framework. Then, in Chapter 3.2, we presented the output of the bilateral pilot implementations in moving from theory to practice to contribute to bridging the 'implementation gap'. The design of this co-development process, with 6 REST-COAST pilots involved in Task 4.2, aligned with the preliminary planning in the REST-COAST proposal. During the General Assembly in Gdansk in September 2023, project commissioner explicitly requested involvement of all the pilots in all of the overarching tasks of REST-COAST albeit the initial proposal. Upon this request, we started our communication directly during the General Assembly with the remaining 3 REST-COAST pilots, i.e. Vistula Lagoon, Rhone Delta and Nahal Dalia. We briefly introduced the NBS-BB Framework and consequently received their positive feedback and interest in the framework.

The Pilot Implementation Tool introduced in Chapter 3.1 was developed for the bilateral pilot workshops as an enabler for participation collaboration in an online environment. Post-processing of these workshops resulted in the structured output tables of Chapter 3.2. In the period following the General Assembly, we prepared the Pilot Implementation Form inspired by these preliminary output tables. Our partners in these 3 pilots can directly use this form to implement the NBS-BB Framework in their pilots as an alternative to the tool. Accordingly, our partners were flexible in organizing themselves for the framework implementation both due to time and effort required. We provided our partners the implementation guidance document which includes the re-introduction of the framework, a reading guide for the implementation form (as in Table 3), the implementation form (see Table 11), a filled out form as an example pilot implementation and also the manual for the Pilot Implementation Tool. This guidance document, *Appendix 17 - Generic NBS-BB Framework Pilot Implementation Form.pdf*, is provided in the supplementary folder.

Table 11 – Template for the NBS-BB Framework Pilot Implementation Form.

NBS BB	NBS CAT	DEL[1]	EPA	INPUTS		OUTPUTS	
				KBP	KSP	ESS[2]	BDV
|	Select Category	[##.##º N/S, ##.##º E/W]	•	•	•	RFR	•
				•	•	RCE	
				•	•	CCR	
				•	•	WP	
				•	•	FP	
				…	…		

NBS – BB: Nature-based Solutions Building Block
NBS CAT: A drop-down list for the NBS Category as defined in the NBS-BB framework.
DEL: Coastal/Water Body Delineation code/description together with the approximate coordinates at the center location.
EPA: Environmental Pressures Addressed
INPUTS – KBP: Key Bio-physical Parameters; KSE: Key Socio-economic Parameters
OUTPUTS – ESS: Ecosystem Services; RFR: Reduction Flood Risk; RCE: Reduction Coastal Erosion; CCR: Carbon Sequestration; WP: Water Purification; FP: Food Production; BDV: Biodiversity



[1] Delineation map should be provided as explained in the manual document APPENDIX I: Framework Implementation Manual.
[2] Here, an expert-based quantification of expected ESS impact should be provided according to the color scale.

Additionally, we organized bilateral online meetings with our partners in the Vistula Lagoon, Rhone Delta and Nahal Dalia to discuss the constituents of the document we provided, and also to contemplate about the potential implementation of the NBS-BB Framework in their pilots. Our partners implemented the framework within their own initiative in the upcoming period and communicated the filled out forms as presented in the following chapters.

3.3.1 The Vistula Lagoon

The NBS-BB Framework implementation in the Vistula Lagoon was coordinated by our key Task 4.2 partner and pilot site leader from the Institute of Hydro-Engineering of Polish Academy of Sciences (IBW-PAW). However, information and data that was provided in the Pilot Implementation Form incorporated results from long term cooperation and consultation with the Maritime Office in Gdynia, Poland. The Maritime Office is the key stakeholder in the Vistula Lagoon, where they have full jurisdiction. Moving to the land, where the technical and protection belts lie within, the Maritime Office share responsibilities with the local authorities. These belts have been recently expanded from former land-water interface to include around 2 km to the hinterland (please refer to *Appendix 18 - Vistula Lagoon Pilot Implementation Form.pdf* as provided in the supplementary folder).

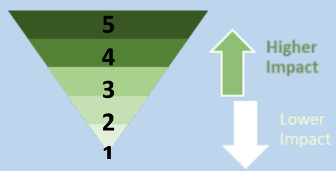
Preliminary output from the implementation of the NBS-BB Framework at the Vistula Lagoon is provided in Table 12. It is noteworthy to recognize the better overview and deeper understanding of the key socio-economic parameters in the table, which results from the proxy inclusion of the Maritime Office, thus the strong collaboration and steering as the key stakeholder on an actionable plan.

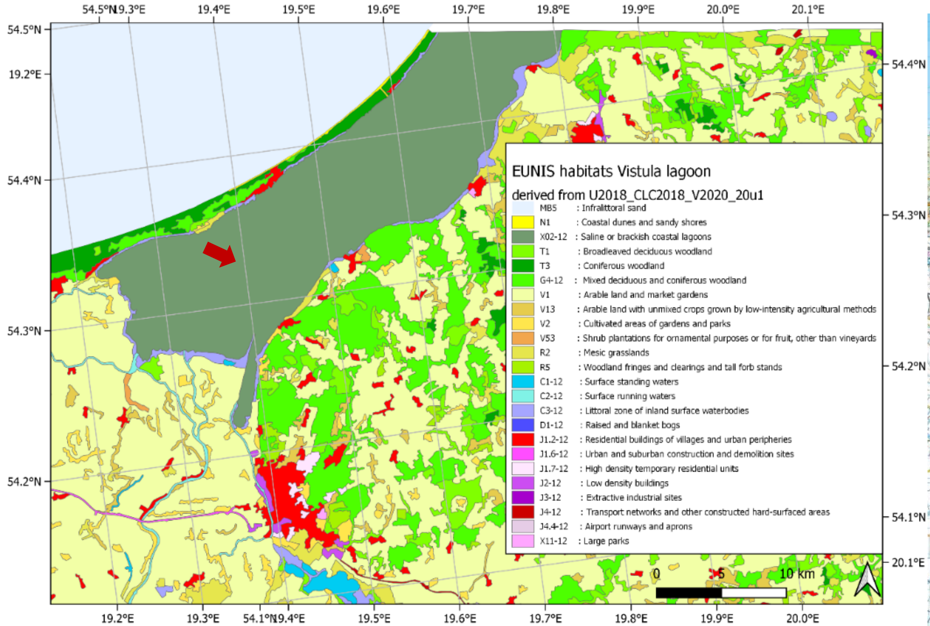
Table 12 – NBS-BB Framework implementation at the Vistula Lagoon (PL) – Pilot Implementation Form 8th – 10th of January, 2024

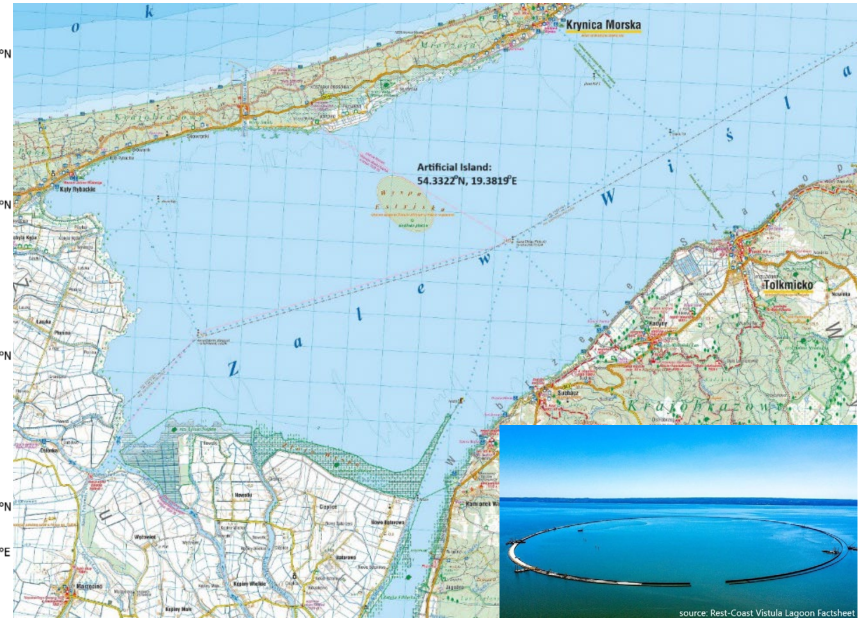
NBS-BB	NBS-BB CAT[1]	DEL[2]	EPA	INPUTS		OUTPUTS	
				KBP	KSP	ESS[3]	BDV[4]
Bird Island Construction	Intertidal	*WE [54.3322º N, 19.3819º E]*	• Poorly managed sediment • Biodiversity loss • Poor water quality • Climate change • …	• Wave action • Wave energy • Wave-driven currents • Wind-driven currents • Wind-driven storm surge	• National funding • EU funding (e.g. REST-COAST, LIFE…) • NATURA 2000 site • Strong legal framework • Economic stagnation • Lack of regional cooperation • Subsidies and policies • Transformative change • Integrating results from WP3 on innovative financing • Integrating results from WP5 on transformative governance	RFR(1) RCE(1) CCR(1) WP(2) FP(4)	• Diverse ecosystems in partly muddy and mostly grassland habitats. • Increase of waders in the muddy habitats. • Safe haven for bird species: at least 27 from Appendix of Bird Directive and 9 from Polish Red Book (of endangered species). • Resting grounds for ducks (gadwall, shoveler, widgeon), geese (grey, bean, white-fronted) • Hatching grounds for snipe, northern lapwing and redshank. • Colonization of rims by reeds: spawning grounds for fishes: bream and pike perch.

NBS-BB: Nature Based Solutions Building Block
NBS-BB CAT: A drop-down list for the NBS-BB Category along the land-to-sea continuum as defined in the NBS-BB Framework.
DEL: Coastline delineation as defined by the pilot partners according to the NBS-BB Framework (approximate coordinates of the center).
EPA: Environmental Pressures Addressed
INPUTS: KBP: Key Bio-physical Parameters – KSE: Key Socio-economic Parameters
OUTPUTS: ESS: Ecosystem Services RFR: Reduction Flood Risk; RCE: Reduction Coastal Erosion; CCR: Carbon Sequestration; WP: Water Purification; FP: Food Production; BDV: Biodiversity

[1,2] Coastal Units identified according to the *NBS-BB Categories* and *Coastal Delineations* are provided in the pilot map below.
[3] Semi-quantitative scores for 5 ESS defined in the REST-COAST project: Elementary quantification of expected ESS impact based on expert-led discussions is provided according to the color scale (with numerical scores for easier readability). Pilot will update these score aligned with their input to Task 4.1.
[4] Expert-based qualitative description of Biodiversity gains in terms of habitats and species by workshop participants. Pilot will update this column aligned with their input to Task 4.1.







[1]*Intertidal zone on the NBS-BB Cat axis for WE (Wyspa Estyjska - Coastal Unit) in the Vistula Lagoon (map by G. Różyński, 2024 in the Vistula Lagoon Pilot Implementation Form)*

[2]*Physical demarcation (inset picture) on the Coastal Delineation axis of WE in the Vistula Lagoon (map by G. Różyński, 2024 in the Vistula Lagoon Pilot*

3.3.2 The Rhone Delta

The NBS-BB Framework implementation in the Rhone Delta was coordinated by our Task 4.2 partner and REST-COAST project leader from Tour du Valat (TDV). Accordingly, all the Coastal Units within the REST-COAST pilot site were identified aligned with our participative downscaling approach including diverse expertise in project management, geomorphology, hydrology and geography. Then, the NBS-BB Framework was implemented in each Coastal Unit using the Pilot Implementation Form to identify the corresponding NBS-BB as processes with biophysical and socio-economic parameters at the inputs, and ESS and BDV benefits at the outputs. The resulting *Appendix 19 - Rhone Delta Pilot Implementation Form.pdf* was communicated back to Task 4.2 lead as provided in the supplementary folder.

We present the preliminary output from the implementation of the our framework at the Rhone Delta pilot as in Table 13. TDV is the key partner of REST-COAST in the Rhone Delta with vast experience, deep knowledge and prestigious acknowledgement in conservation and restoration of the region. So, it is noteworthy to recognize how TDV approached holistically to the pilot site in identification of the Coastal Units. The NBS-BB Framework was further implemented in each Coastal Unit with a balanced natural and social sciences perspectives as reflected in the key biophysical and socio-economic parameters. The clear restoration targets in the pilot was also reflected at the outputs with also a balanced ESS and BDV benefits that are expected for each restoration action. Similar to the proxy inclusion of key stakeholders in the Vistula Lagoon pilot as in Chapter 3.3.1, action-oriented field expertise of TDV and its role as the co-manager of the pilot site provided proxy inclusion of diverse perspectives in the framework implementation.

Despite the late involvement of the Rhone Delta pilot in Task 4.2, which we consider a missed opportunity in co-developing the theory of NBS-BB Framework, the preliminary output in Table 13 is very impressive for moving the theory to practice in a holistic approach to restoration upscaling using the NBS-BB. As will be explained in Chapter 4, including TDV as our key partner in our dedicated task force is very promising for pilot-scale extension and expansion of these preliminary results.

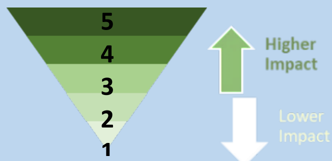
Table 13 – NBS-BB Framework implementation at the Rhone Delta (FR) – Pilot Implementation Form 28th of February – 11th of March, 2024

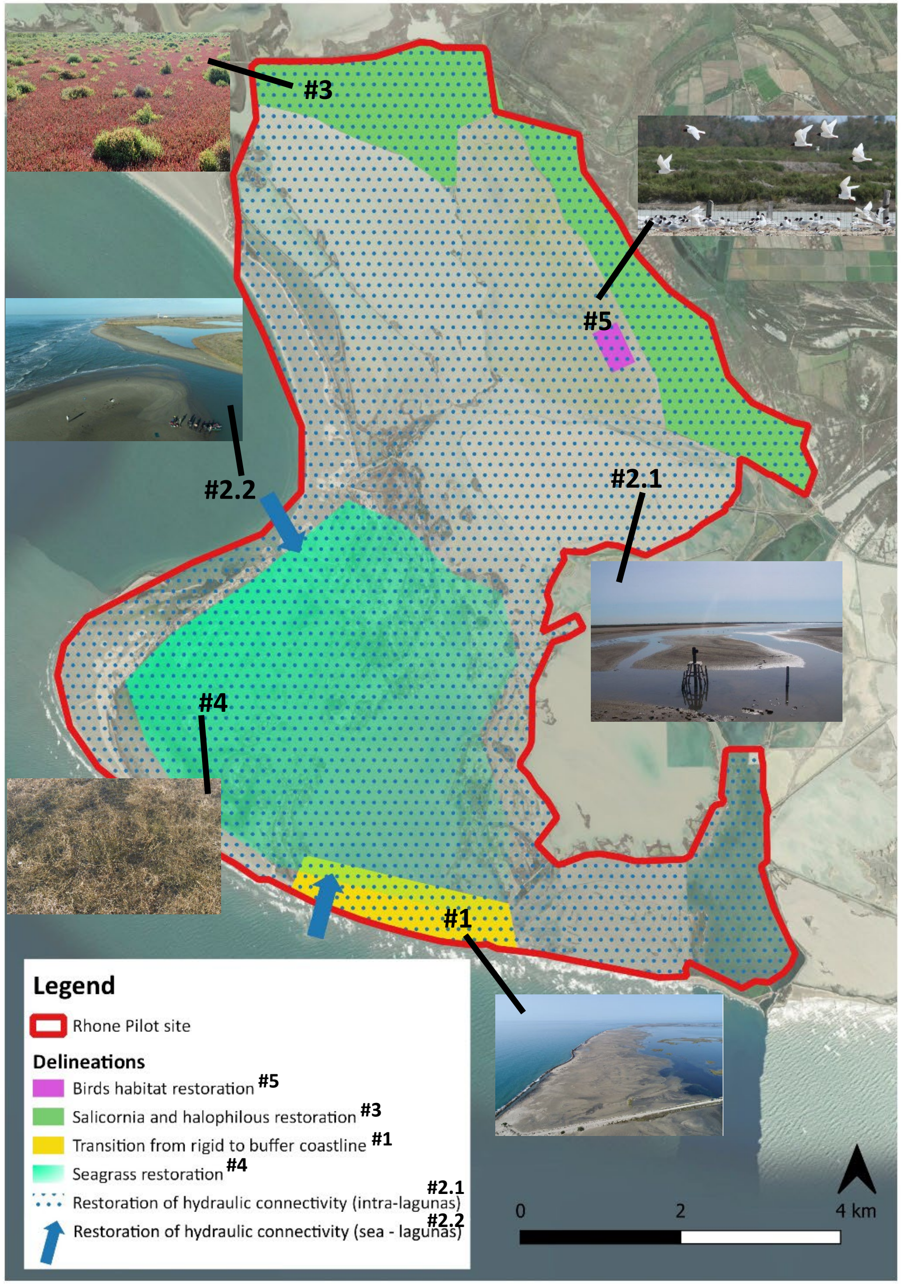
NBS-BB	NBS-BB CAT[1]	DEL[2]	EPA	INPUTS		OUTPUTS	
				KBP	KSP[(a)]	ESS[3]	BDV[4]
Dike Abolition	Barrier	*#1* *[43.3777º N, 4.6200º E]*	• SLR • Inundation risk • Dike maintenance: ○ progressive erosion, ○ dike subsidence	• Wave exposure: ○ overtopping ○ : attenuation • Sediment mobility	• Tourism : Landscape, beach • Natura 2000 site • Inundation management: Authorities involved • Objectives for spatial planning • Local people: Perception of inundation and erosion risk • Realignment strategy of inundation risk for local authorities	**RFR(5)** **RCE(1)** **CCR(1)** **WP(1)** **FP(1)**	• Expansion of sandy substrate for local flora • Enhancement of natural processes through passive restoration
Hydraulic Connectivity	Subtidal	*#2.1 Inter-lagoon* *[43.3986º N, 4.6307º E]* *#2.2 Sea-Lagoon* *[43.3913º N, 4.5976º E]*	• Artificial water levels: unmaintained management • Bad water quality • Blocked water flux and exchange upstream or with sea • Biodiversity loss • Salt concentration	• Wave exposure • Salinity • Biodiversity • Current dynamics • Sediment mobility • Nutrient load • Phyto-plankton • Benthic fauna • Precipitation	• Tourism : Fishing, bird watching • Natura 2000 site • Directive 2000/60/EC • Objectives for spatial planning • Local people: Perception of submersion risk	**RFR(1)** **RCE(1)** **CCR(5)** **WP(5)** **FP(5)**	• Improved water quality with positive impact on BDV. • Increase of seagrass extension. • Creating shelter for fish population and juvenile.

Salt Marsh Restoration	Intertidal	*#3 [43.4276° N, 4.6397° E]*	• Environmental degradation because of the salt industry • Unmaintained artificial water level management • Salt concentration	• Sediment mobility • Biodiversity • Salinity • Water levels • Precipitation • Nutrient load • Phyto-plankton • Benthic fauna	• Tourism : Landscape, bird watching • Risk inundation • Natura 2000 site • Authorities for inundation management • National spatial planning objectives • Directive 2000/60/EC • Perception of local people	RFR(1) RCE(1) CCR(5) WP(5) FP(5)	• Enhancement of natural processes through passive restoration.
Seagrass Restoration	Subtidal	*#4 [43.3782° N, 4.5858° E]*				RFR(1) RCE(1) CCR(5) WP(5) FP(5)	
Bird Island Construction	Subtidal	*#5 [43.4212° N, 4.6273° E]*				RFR(1) RCE(1) CCR(5) WP(5) FP(5)	

NBS-BB: Nature Based Solutions Building Block
NBS-BB CAT: A drop-down list for the NBS-BB Category along the land-to-sea continuum as defined in the NBS-BB Framework.
DEL: Coastline delineation as defined by the pilot partners according to the NBS-BB Framework (approximate coordinates of the center).
EPA: Environmental Pressures Addressed
INPUTS: KBP: Key Bio-physical Parameters – KSE: Key Socio-economic Parameters
OUTPUTS: ESS: Ecosystem Services RFR: Reduction Flood Risk; RCE: Reduction Coastal Erosion; CCR: Carbon Sequestration; WP: Water Purification; FP: Food Production; BDV: Biodiversity

[1,2] Coastal Units identified according to the *NBS-BB Categories* and *Coastal Delineations* are provided in the pilot map below.
[3] Semi-quantitative scores for 5 ESS defined in the REST-COAST project: Elementary quantification of expected ESS impact based on expert-led discussions is provided according to the color scale (with numerical scores for easier readability). Pilot will update these score aligned with their input to Task 4.1.
[4] Expert-based qualitative description of Biodiversity gains in terms of habitats and species by workshop participants. Pilot will update this column aligned with their input to Task 4.1.
[(a)] The following two points are shared, thus implicitly included, in all the Coastal Units: • Integrating results from WP3 on innovative financing, • Integrating results from WP5 on transformative governance





[1,2]Coastal units enumeration in the Rhone Delta in accordance with the NBS-BB Cat axis along the land-sea continuum and the Coastal Delineation axis along the coastline (map by M. Jolivet, Tour du Valat, 11 March 2024). Photos are representative of the NBS-BB in each coastal unit in the pilot. Photo credits: #1, Willm & Arnoud, Tour du Valat; #2., Boutron, Tour du Valat; #2.2, Willm, Tour du Valat; #3, Fontes, Tour du Valat; #4, Fontes, Tour du Valat; #5, Thibault, Tour du

3.3.3 The Nahal Dalia

The NBS-BB Framework implementation in the Nahal Dalia was coordinated by our Task 4.2 partner and pilot coordinators in Israel from INPA and The Israeli Watersheds and Rivers Center. After our first contact during the General Assembly of Gdansk in September 2024, we communicated the implementation guidance document to request the implementation of the NBS-BB Framework in the Nahal Dalia pilot. Our partners engaged positively with Task 4.2 and we coordinated two bilateral meetings in January 2024 and March 2024 to discuss the potential implementation of the framework in the pilot site.

Subsequently, our partners implemented internally the framework in 5 identified Coastal Units that match the restoration targets in the pilot site (please refer to *Appendix 20 - Nahal Dalia Pilot Implementation Form.pdf* for the pilot implementation as provided in the supplementary folder). We present the preliminary output for the Nahal Dalia pilot in Table 14, which we refined from the form that was communicated back to Task 4.2. The pilot implementation was mainly based on experts' knowledge and existing data. The framework helped the pilot team to elaborate on diverse NBS-BB as restoration processes, to define the environmental pressures that must be addressed, to assess the desired outcome for each restoration process, and thus to understand the parameters of interest in order to reach the desired outcome.

Our partners engaged on 5 Coastal Units spanning across the pilot in accordance with the participative downscaling approach. These Coastal Units hold potential to merge together across the pilot landscape to holistically upscale nature restoration through NBS approach. INPA and The Israeli Watersheds and Rivers Center incorporate diverse expertise and knowledge in natural and social sciences. As a proxy to diverse participation of stakeholders, this was reflected in the implementation of the NBS-BB Framework in Table 14 as balanced evaluation of the key biophysical and socio-economic parameters. Direct participation of diverse disciplines as part of the transdisciplinary approach of our framework can yield a more comprehensive implementation. Yet, considering the time and effort required for organizing local actors and stakeholders, which is beyond the scope of the pilot within Task 4.2,this kind of proxy participation is very valuable.

As we will discuss in Chapter 5, we appreciate these experiences from bilateral pilot implementations as the key learnings from our communities of practice, where we have co-developed our framework from theory to practice together with all the pilots. These key learnings are important contributions to our adaptive knowledge in coastal upscaling through NBS in the following phases of the REST-COAST project.

Table 14 – NBS-BB Framework implementation at the Nahal Dalia (IR) – Pilot Implementation Form 4th of February – 28th of February, 2024

NBS-BB	NBS-BB CAT[1]	DEL[2]	EPA	INPUTS		OUTPUTS	
				KBP	KSP[(a)]	ESS[3]	BDV[4]
Dam Replacement to Weir	Intertidal	*#1 [32.5901° N, 34.9171° E]*	• Lack of connectivity – Dalia stream and the estuary. • Water circulation – The fishponds' discharges are circulated in the reserve when the dam is closed. • Sedimentation – The dam maintains high-water level, sediment accumulates organic load. • Non-seasonal water level fluctuations – Maintained constant water level: no influence of seasonal winter floods and rain.	• The reserve serves as an operational reservoir for the fishponds. • Uncertainty regarding the frequency and adequacy of flood flow rates. • Separation between fresh water flow and saline water flow.	• The national perception of swamps area as a nuisance (source for diseases) • Wetland are seen as a resource suitable for agricultural use. • The consistent water level enables water extraction capabilities.	RFR(5) RCE(1) CCR(1) WP(4) FP(5)	• Unrestricted connection upstream/downstream: softshell turtles, otters, fish. • Increase BDV in the reserve due to WQ improvement. • Wading birds habitat creation .
Dam Relocation Upstream	Intertidal	*#2 [32.5859° N, 34.9180° E]*				RFR(5) RCE(1) CCR(5) WP(4) FP(5)	• Temporal connectivity during the wet season and late summer • Opportunity for species that can adapt to the managed water interface in the reserve.
Rewilding Fishponds	Hinterland	*#3 [32.5880° N, 34.9205° E]*	• Eutrophication – Infiltration of cultivated species due to fishpond effluents discharge. • Non-seasonal water level fluctuations – Maintained constant water level: no influence of seasonal winter floods and rain .	• Lowest elevation point: the drainage basin for the fishponds' water. • The water bodies as water purification and water reservoir. • Water leakage from the fishponds to the reserve through the levee.	• Nature Reserve Regulations: fishery effluents into reserve. • Easy approvals for discharging fishpond into reserve. • Status Quo- Water interface management since late 60's. • Existing national regulations on treatment of effluents: exemption of local fish farming operational role.	RFR(1) RCE(1) CCR(1) WP(5) FP(1)	• Improved water quality with positive impact on BDV. • Increase of seagrass extension. • Creating shelter for fish population and juvenile.

Flood Water Reservoir	Hinterland	*#4 [32.5880º N, 34.9205º E]*	• Water Regime and Level Regime- Water management and water levels prioritized by the needs of fishery irrespective of seasonal factors (environmental flow requirements): negative ecological impacts. • Connectivity – Fishery uses the nature reserve's water body as an operational reservoir: Alternative solution is required.	• Mediterranean climate - Strong water flow in a short time. • The existing dams maintain the operational reservoir. • Water quality: Eastern dam separates upstream Nahal Dalia (fresh) and the marshland (saline). • Water quality: Western dam obstructs sea water penetration into estuary and Nahal Dalia.	• Nature Reserve Regulations: fishery effluents into reserve. • Free capture of flood water: national regulations. • Maximizing flood water catchment: incentivized. • Distribution of use – *Kibbutz* has priority for irrigation. The rest is for the Water Authority. • Insufficient electrical infrastructure – Efficient flood exploitation requires large pumping station to manage rapid water flow in short time.	RFR[1] RCE[1] CCR[1] **WP[5]** **FP[5]**	• The reservoir will include natural elements and additional habitats. The water body will be used by a variety of birds. • Floating islands for target species – For example little tern.
Restoring Habitat Heterogeneity	Subtidal	*#5 [32.5826º N, 34.9184º E]*	• Engineered banks: steep without structural complexity, natural characteristics – reserve banks designed in alignment with fishpond embankments • Reduced ecological value and biodiversity for potential habitats: birds and other animals.	• Banks as the operational roads for fishponds. • Neglection of banks – Built from waste materials and not ecologically maintained. • Nature reserve as fishery's negative – unplanned reserve by definition: unused land by fishery.	• Operations of the environmental agency (INPA) are limited by fishponds: No action on the fishery side starting from the top of the embankments. • Habitat restoration has not received required attention. • Economic incentives of *Kibbutz* – avoiding expenses beyond fishery's functions.	RFR[1] RCE[1] CCR[1] **WP[5]** FP[1]	• Ecologically diverse bank sections with variety of habitats. • Diverse typologies with ecological niches for a variety of animals. • Seasonal water bodies in the northern part divided into estuary, seasonal and permanent flow channels – diverse ecological characteristics at low water.

NBS-BB: Nature Based Solutions Building Block
NBS-BB CAT: A drop-down list for the NBS-BB Category along the land-to-sea continuum as defined in the NBS-BB Framework.
DEL: Coastline delineation as defined by the pilot partners according to the NBS-BB Framework (approximate coordinates of the center).
EPA: Environmental Pressures Addressed
INPUTS: KBP: Key Bio-physical Parameters – KSE: Key Socio-economic Parameters
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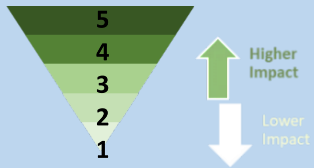
[1,2] Coastal Units identified according to the *NBS-BB Categories* and *Coastal Delineations* are provided in the pilot map below.
[3] Semi-quantitative scores for 5 ESS defined in the REST-COAST project: Elementary quantification of expected ESS impact based on expert-led discussions is provided according to the color scale (with numerical scores for easier readability). Pilot will update these score aligned with their input to Task 4.1.
[4] Expert-based qualitative description of Biodiversity gains in terms of habitats and species by workshop participants. Pilot will update this column aligned with their input to Task 4.1.
[(a)] The following two points are shared, thus implicitly included, in all the Coastal Units: • Integrating results from WP3 on innovative financing, • Integrating results from WP5 on transformative governance



[1,2]Coastal units enumeration in the Nahal Dalia according to the approximate coordinates of the potential restoration actions provided in the Pilot Implementation Form. More precise resolution on the NBS-BB Cat axis along the land-sea continuum (Table 14). More elaboration is required for demarcation of the coastal units on the Coastal Delineation axis (map by C. Arslan using ArcGIS).

4. Expanding Beyond Task 4.2: Interactive Web Map

In Chapter 2 and Chapter 3, we co-developed the theory the NBS-BB Framework and moved from this theory to practice by implementing the framework at 9 REST-COAST pilots, respectively. The implementation of all the pilots were analyzed and gathered together in structured output tables that were presented per Coastal Unit per pilot.

In the final phase of our task, we designed also a collaborative process, in which we continued the co-production of NBS-BB output at each pilot. This collaboration included:

- verifying the existing Coastal Units and corresponding NBS-BB;
- enriching the implemented framework with information and data in each Coastal Unit,
- expanding the framework implementation with more Coastal Units in each pilot.

So, we aimed for a dedicated task force composed of maximum 2-3 partners per pilot to collaboratively work on this purpose. This decision was essential considering the time and resource limitation in terms of initial Task 4.2 planning within the scope of the REST-COAST, and also partners' existing responsibilities beyond Task 4.2. As the task lead, we started with developing a new tool to optimize this process. Thus, we developed an HTML-based Interactive Web Map with embedded JavaScript and Google Maps API. This tool streamlined the process of working together on geospatial data, thus enabled collaboratively verifying, modifying, identifying and extending the NBS-BB in each pilot based on the NBS-BB Framework. So, we aimed to achieve a more integrated and holistic view of restoration upscaling in each pilot by expanding and extending NBS-BB that were spatially identified across the pilots. Furthermore, the geospatial knowledge and data produced in our task will enable smooth and efficient transition to the simultaneously progressing tasks within WP4, e.g. adaptation pathways, Vision-Strategy-Mission development per pilot, Quick Scan Tool for restoration upscaling etc.

We introduced the Interactive Web Map to our dedicated task force in April 2024 in an online meeting (please see the meeting minutes, *Appendix 22 - Minutes Interactive Web Map Meeting Partners April 2024.pdf*, as provided in the supplementary folder). In the next chapter, we will briefly explain the essential functionalities of the Interactive Web Map. Then, we will present in Chapter 4.2 an overview of the portfolio of NBS-BB at 9 pilots. We will also zoom into the output of the Venice Lagoon pilot as representative of our task force collaboration.

4.1 A Glimpse of the Interactive Web Map

The Interactive Web Map is an HTML project developed in JavaScript and uses Google Maps API for customizing the map's appearance and functions in our specific application. The project is built of an elaborated code for creation and alteration of the Coastal Units in the REST-COAST pilots in accordance with the NBS-BB Framework. The source code is delivered together with this report in the supplementary folder.

The users can run the HTML project in any web browser or html-supported platform on demand. So, the users are neither time- or location-limited nor dependent on any 3rd party for collaborating in this HTML project. The interactive map is activated by user upon loading the pre-identified Coastal Units. We transformed the existing Coastal Units (as in Chapter 3) in advance to geographical coordinates in .json file format, which is an easy-to-handle text-based data format for JavaScript. The default .json file is provided as part of the HTML project and up-to-date version can also be downloaded from our Google Drive server as instructed in the welcome page when the user runs the project.

The Interactive Web Map is initialized to an overview of all REST-COAST pilots as shown in Fig. 9. When the user hovers on the pilots, a pop-up with quick pilot facts and a link to the REST-COAST webpage with pilot factsheet appears. We also included a link to a shared file, which users can edit with additional information and data that is pilot-scale beyond the individual Coastal Units.

Figure 9 – Interactive Web Map interface after launching the HTML project

For each pilot, the pre-identified Coastal Units are drawn as polygons from the .json file containing the shape data when initialized after launching the project. These Coastal Units per pilot are only visible when users zoom into pilots upon left-click action on the pilot markers. The users can go back to the global view as in Fig. 9 at any time upon clicking *Overview Pilots* button at the top right corner. In Fig. 10, the Venice Lagoon is zoomed in, where the pre-identified Coastal Unit, *PC2 Millecampi Teneri*, is drawn as a polygon.

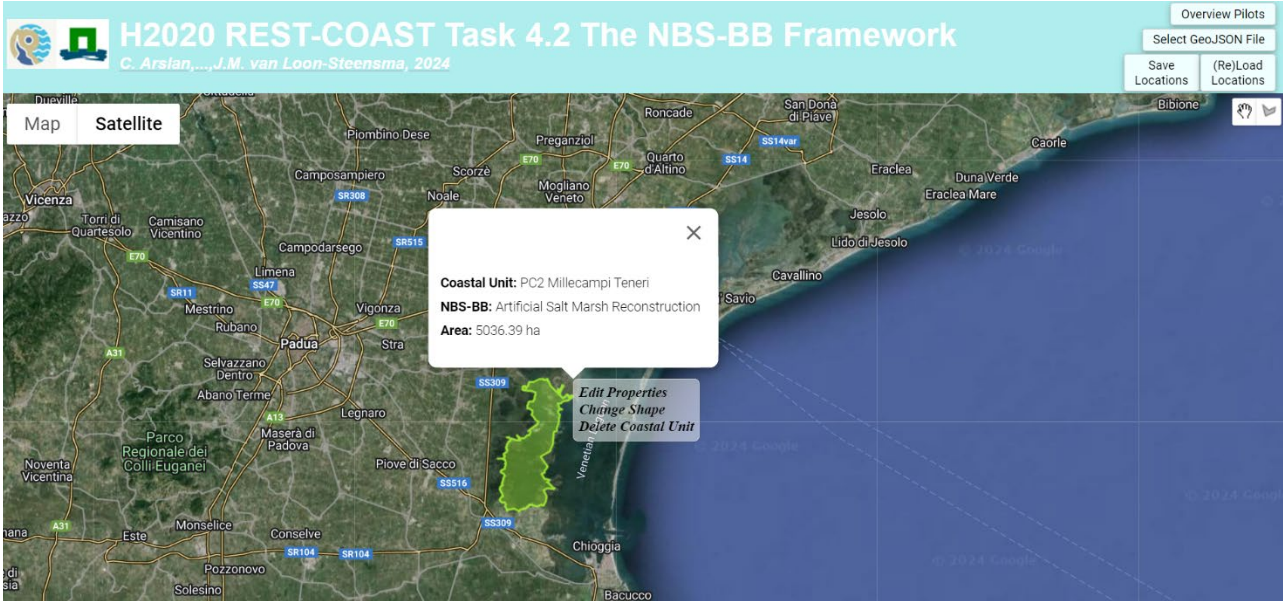


Figure 10 – The Venice Lagoon and *PC2 Millecampi Teneri* as the Coastal Unit identified within the pilot

Hovering on the polygon pops up a specific information window about the Coastal Unit as shown in the white box in Fig. 10. This information includes the Coastal Unit's code (as defined participatively during the pilot framework implementation), the NBS-BB as the restoration process within the Coastal Unit in accordance with the framework (as identified for each Coastal Unit during the pilot framework implementation), and the area of the Coastal Unit (as calculated automatically by the script using the polygon coordinates).

Users of the Interactive Web Map can also operate on these pre-identified Coastal Units by a right-click action on the polygons. Three specific functions are assigned to each polygon object created in the map as shown in the gray box in Fig. 10. These functions are;

- *Edit Properties*, which allows users to change first two lines of information in the polygon pop-up, i.e. code of the Coastal Unit and the NBS-BB assigned to it. In addition, the user can also define or modify the link to the structured output tables (as explained below).
- *Change Shape*, which allows users to modify the polygon shape by dragging polygon poin, which are the point coordinates encircling the Coastal Unit.
- *Delete Coastal Unit*, which allows users to remove the polygon from the map.

Furthermore, we transformed all the pilot implementation output in Chapter 3 to structured excel tables in Google Sheets and uploaded these tables in our dedicated shared folders. Then, each polygon in the Interactive Web Map is assigned a left-click action that links the identified Coastal Unit to the corresponding structured output table in accordance with the participative implementation of the NBS-BB Framework. Accordingly, upon clicking on the polygon, an NBS-BB Framework overview screen that is specific to the Coastal Unit is opened in a new tab as in Fig. 11.

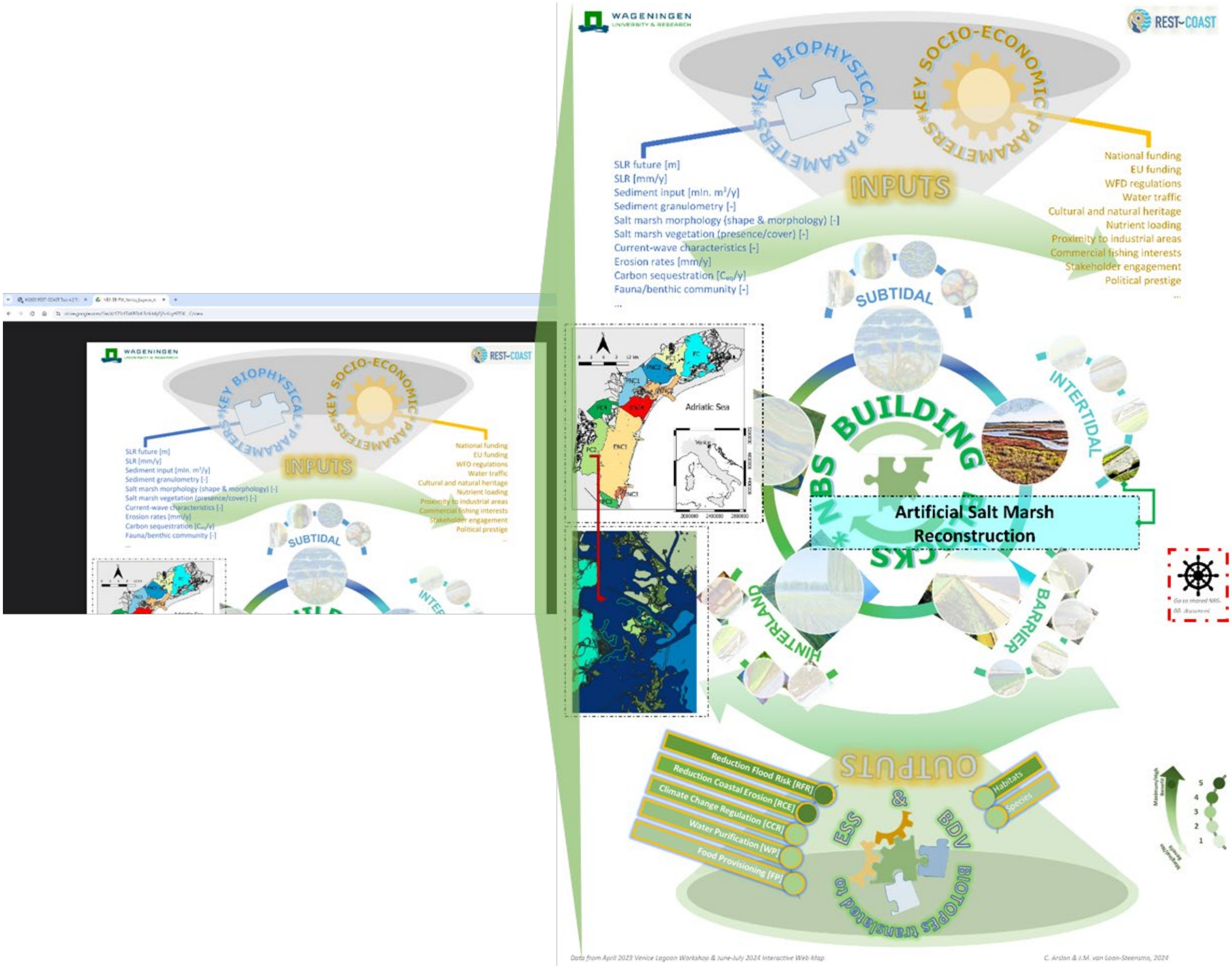


Figure 11 – Graphical overview of the NBS-BB Framework implementation at a specific Coastal Unit opens in new tab upon left-click action on a polygon in the Interactive Web Map (left). Original overview document specific to the *PC2 Millecampi Teneri* Coastal Unit in the Venice Lagoon pilot (right).

This overview document provides a summary of the pilot implementation using the graphical representation of the NBS-BB Framework in Fig. 6. As shown in red dotted square in Fig. 11, a link is embedded in this overview document that re-directs users to the shared structured output table of the Coastal Unit as shown in Fig. 12. Accordingly, for each Coastal Unit that we have incorporated in the Interactive Web Map in advance, there exists; (i) a specific graphical overview of the NBS-BB Framework implementation, and (ii) a structured data table that is based on the pilot implementations as explained in Chapter 3. So, part of the collaborative process requires the dedicated task force, first to verify the structured data table for their pilots, and then to enrich the implementation of the framework by adding requested data. We oriented this enrichment by adding specific columns, i.e. *Unit*, *Impact*, *Model*, *Data*, *Literature*, and cells, i.e. *Habitats*, *Species*, as shown in Fig. 12. However, our partners in this dedicated task force are expected to manipulate the table with additional rows and columns exploiting their key expertise and wide network in their pilot site.

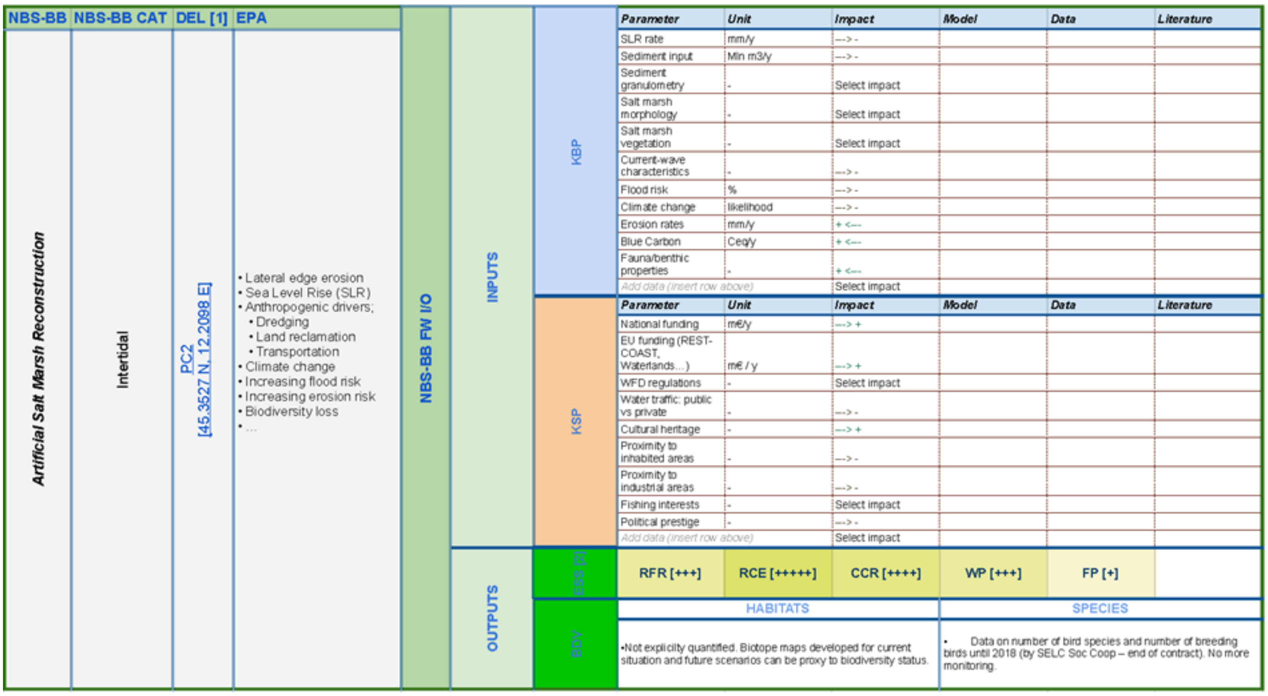


Figure 12 – Structured data table initialized with the output for the *PC2 Millecampi Teneri* Coastal Unit from the NBS-BB Framework pilot implementation workshop in the Venice Lagoon.

So, we aimed to complement the preliminary pilot implementations in this part of Task 4.2. These preliminary implementations are promising with diverse multi-stakeholder participation in, e.g. identification of the key biophysical and socio-economic parameters. Yet, they are also incommensurable, e.g. identification is limited to parameter name, due to time and resource limitations of the dedicated workshops. Specifically, these additional columns and cells provide us with deeper understanding on the fluxes and dynamics by adding multi-dimensional perspectives. Enriching the existing results with these information and data is especially important for verifiable comparisons of the NBS-BB within- and across-pilots.

Accordingly, *Unit* specifies the reference point of measurement for parameters. *Model*, *Data* and *Literature* specify the availability, accessibility and significance of the key parameters. They are also the basis for verification of the selected parameters as key parameters with reference to the scientific and practical commensurability. We also introduced *Impact* as a new indicator to add temporal dimension to our spatial analysis in accordance with our internal discussions within WP4. So, *Impact* indicator emphasizes the link between the input parameters and the NBS-BB as the restoration process in each Coastal Unit. Accordingly, we identified 4 routes of *Impact* for this interaction between the parameters and the restoration process: (i) the key parameter positively impacts the NBS-BB, thus enhances the success of restoration, (ii) the key parameter negatively impacts the NBS-BB, thus impedes the success of restoration, (iii) the NBS-BB positively impacts the key parameter, thus the restoration improves the actual status of the key parameter, (iv) the NBS-BB negatively impacts the key parameter, thus the restoration diminishes the actual status of the key parameter. These impacts can also be multi-directional. i.e. a parameter can be assigned multiple impacts to indicate both the spatial complexity of a parameter on a restoration action but also the temporal evolution of a parameter with a restoration action.

We also classified *Biodiversity* into *Habitats* and *Species* mainly for qualitative elaboration but also for quantitative assessments if exists. Thus, we can complement the semi-quantitative expert-based scoring of ESS with explicitly identified BDV benefits for better resolution of the Coastal Units and the corresponding NBS-BB as the restoration process.

As part of the expansion of framework within the pilot through identification of new Coastal Units, we further coded two functionalities in the Interactive Web Map. In the first method, the user can draw a new polygon by activating the drawing tool on the top-right corner of the map (see Fig. 13). In the second method, the user can load a shape file with a proper format, i.e. WGS84 projected coordinates of type polygon or multi-polygon stored in .geojson file format, using Select GEOJSON File button on the top-right corner of the screen (See Fig. 13). .geojson is an easy to export file format for GIS users, thus they can conveniently use the existing shapes in their GIS projects to identify new Coastal Units in the Interactive Web Map. When a new polygon is defined in either of the two methods, the users can associate the drawn polygon with a Coastal Unit by identifying its properties, i.e. the REST-COAST pilot site, the Coastal Unit identifier, the NBS-BB as the restoration process, and finally a link to the graphical overview of the NBS-BB Framework implementation. Then, linking this Coastal Unit to its corresponding structured data table, users can contribute with a new Coastal Unit with a new implementation of the NBS-BB Framework in their pilot site.

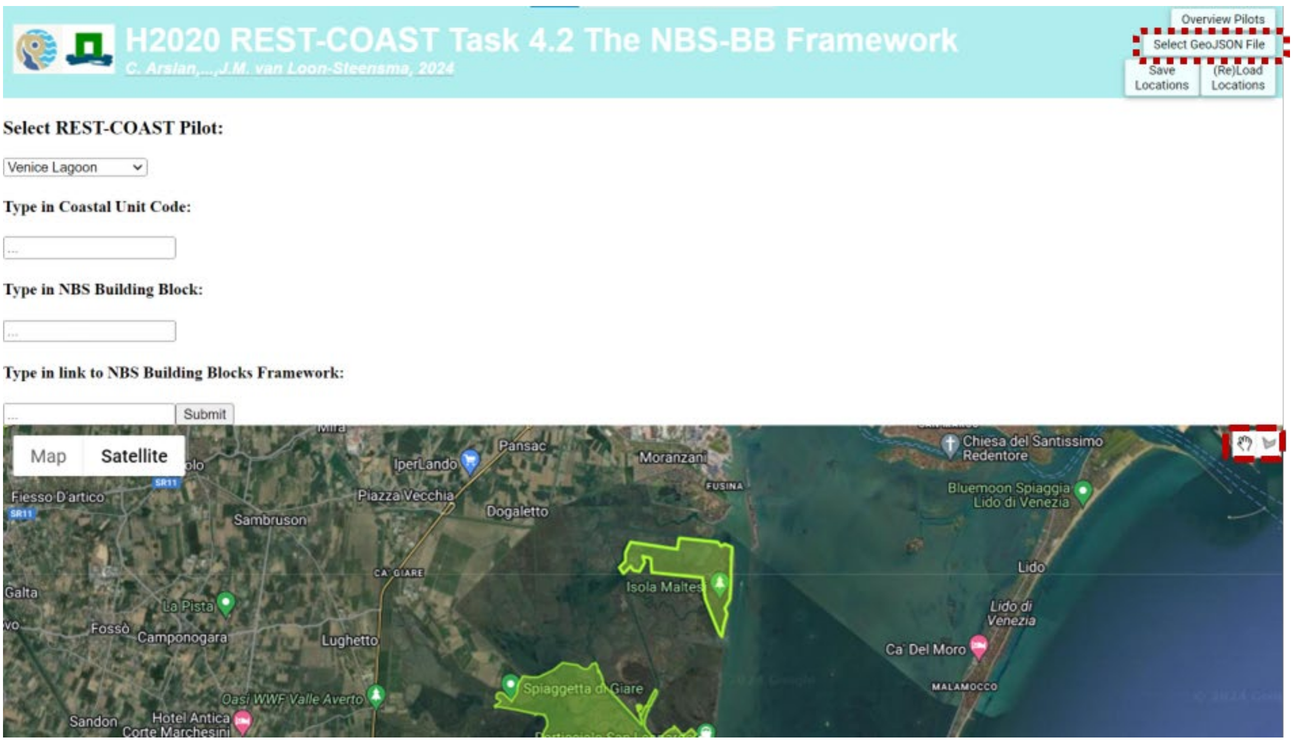


Figure 13 -Expanding the pilot implementation by defining new Coastal Units. First method: drawing tool (top-right corner of the map). Second Method: loading shape files (top-right corner of the screen). A hypothetical polygon drawn in the Venice Lagoon and the user-input block for this polygon to define it as a new Coastal Unit.

In Chapter 4.2, we will give the most recent portfolio of the NBS-BB per pilot. We will also provide some pilot-specific details for the framework implementations using the Interactive Web Map.

4.2 Portfolio of the NBS-BB in 9 REST-COAST pilots

The Interactive Web Map is a living project that has been co-developing with the efforts of the dedicated task force. This includes, first, verification of the spatial Coastal Units that have already been identified and then, aggregation with new Coastal Units in accordance with potential or planned restoration actions in the pilot. Each Coastal Unit is associated with a structured output data table as in Fig. 12 of Chapter 4.1 resulting from the implementation of the NBS-BB Framework in each Coastal Unit.

In this chapter, we will provide the overview of the portfolio of NBS-BB at each pilot using the Interactive Web Map interface for the identified Coastal Units. The associated structured output tables aggregate to an ample amount of data that should be regarded as the live appendices to this report and are readily available for access using the Interactive Web Map tool. We will provide here only the output for the Coastal Unit *PC2 Millecampi Teneri* of the Venice Lagoon pilot as an exemplary of the continued collaboration in the dedicated task force.

4.2.1 Wadden Sea

Wadden Sea pilot is the only transboundary pilot in the REST-COAST project. Specifically, the transboundary collaboration is focused on the Ems-Dollard Estuary, where restoration actions are planned both in the Netherlands and Germany. Informed both by individual and joint restoration actions and plans, Fig. 14 gives an overview of the Coastal Units for this pilot.

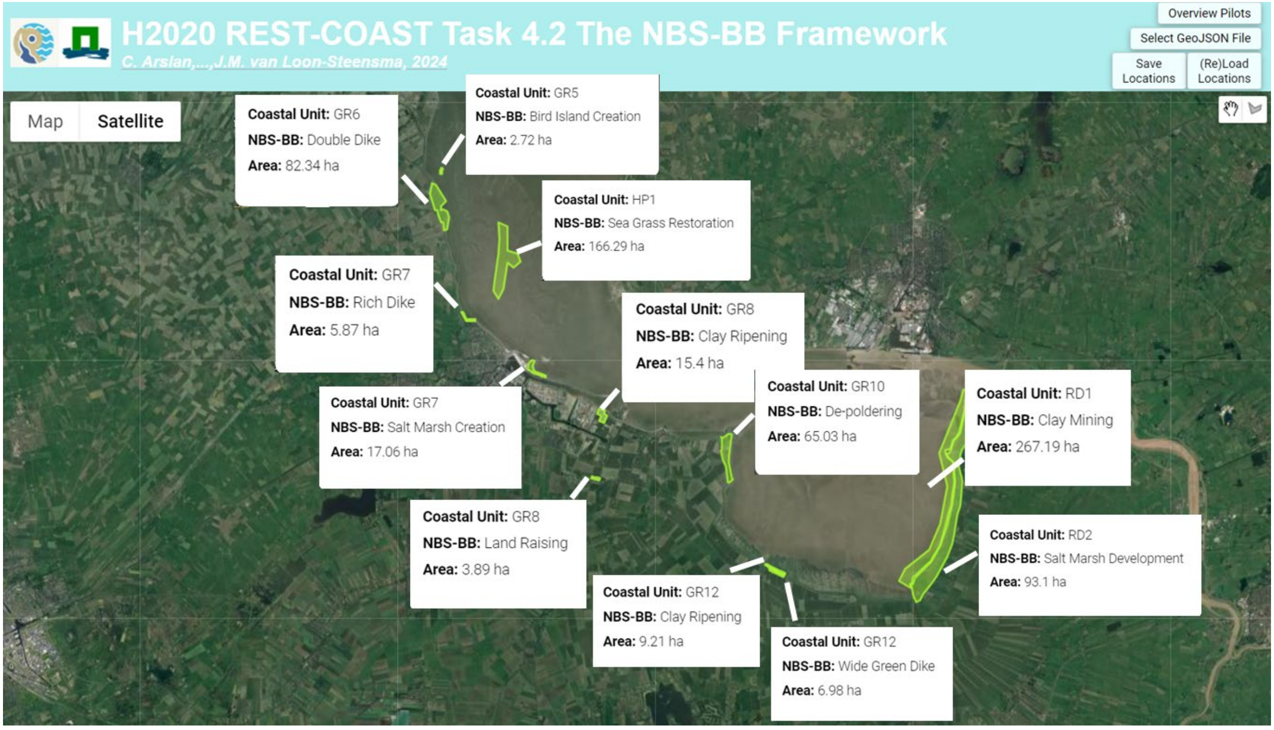


Figure 14 – Spatial distribution of the Coastal Units in the Ems-Dollard Estuary. Properties for each Coastal Unit are summarized in the informative pop-up window.

Farmland Raising was identified as the NBS-BB in our field trip to the Ems-Dollard Estuary (Chapter 3.2.2.1) and *Seagrass Restoration* was the focus of our workshop with our German partners (Chapter 3.2.2.2). In the map, spatially distributed Coastal Units with diverse NBS-BB associated to each Coastal Unit hold potential as complementary to each other at a landscape scale ranging from the subtidal areas to the hinterland behind the coastal protection.

4.2.2 The Foros Bay

Coastal restoration in the Foros Bay is focused on the sea grass conservation in the NATURA2000 area within the scope of the REST-COAST project. In the bilateral workshops with our partners, we elaborated also on the complementary restoration actions in the bay considering especially the potential future upscaling (Chapter 3.2.4). During our collaboration using the Interactive Web Map, we kept our focus on these restoration actions mainly in the subtidal areas. Accordingly, the Coastal Units are first verified and corrected as in the case of CS1 in Fig. 15 with an up-to-date polygon according to the monitoring of the sea grass distribution. Then, the structured output data tables are expanded with supporting data on the key parameters in accordance with the NBS-BB Framework. In Fig. 15, spatially distributed Coastal Units are shown in the Interactive Web Map.

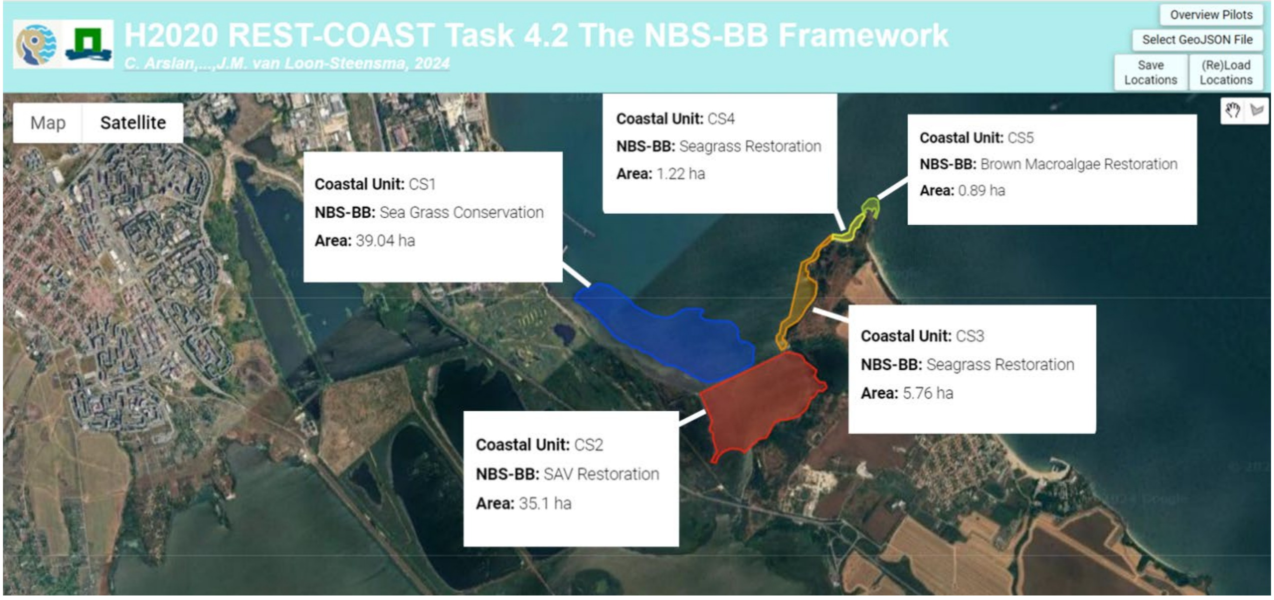


Figure 15 – Spatial distribution of the Coastal Units in the Foros Bay pilot. Properties for each Coastal Unit are summarized in the informative pop-up window.

4.2.3 The Sicily Lagoon

In our bilateral workshop with our partners and a participating stakeholder in the Sicily Lagoon pilot, we elaborated on the executed, planned and potential restoration efforts in the lagoon. We identified 6 NBS-BB that complement and hold potential to aggregate at the pilot landscape scale for the large-scale restoration in the lagoon. During the workshop, we implemented the NBS-BB Framework for *Dune Revegetation* (Chapter 3.2.7).

Together with our key partner in the pilot, we expanded and extended the implementation of the NBS-BB Framework in the lagoon by accurate identification of the Coastal Units spatially, each of which was coupled to its corresponding structured output data table in accordance with the framework. In Fig. 16, we provide the overview of Coastal Units and the associated NBS-BB in these Coastal Units.

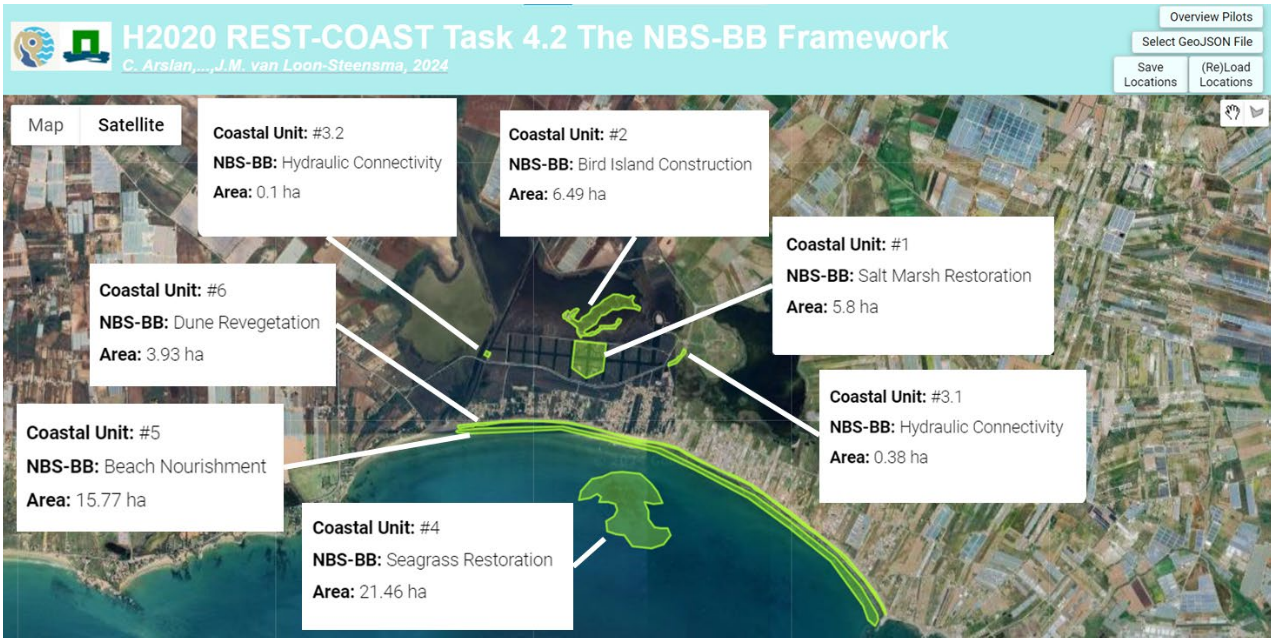


Figure 16 – Spatial distribution of the Coastal Units in the Sicily Lagoon pilot. Properties for each Coastal Unit are summarized in the informative pop-up window.

4.2.4 The Nahal Dalia

Our partners from the Nahal Dalia involved at a later stage in our task after the General Assembly in Gdansk, Poland in 2023 as explained in Chapter 3.3. Nevertheless, our collaboration proved efficient and effective for implementation of the NBS-BB Framework in the pilot. We started with the identification of existing, planned or potential restoration actions in the pilot as the preliminary list of NBS-BB in accordance with our framework (Chapter 3.3.3).

This set of NBS-BB in the relatively small Nahal Dalia pilot holds a promising potential of synergies and harmony with each other for later adaptation upscaling in the pilot. In the next phase involving dedicated task force for improving our preliminary findings, we collaborated with our partners in refining the existing Coastal Units, and verifying and expanding the structured output data associated with each Coastal Unit in accordance with the NBS-BB Framework. In Fig. 17, an overview of these Coastal Units for the Nahal Dalia pilot is presented.

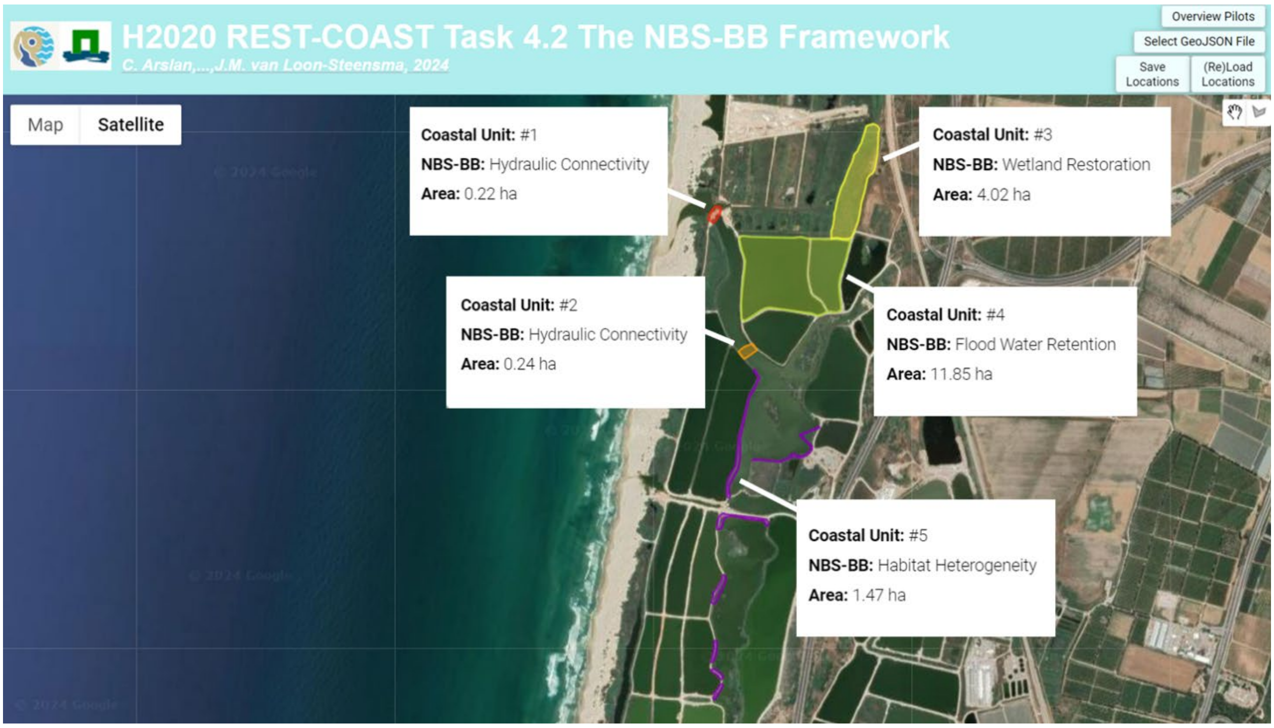


Figure 17 – Spatial distribution of the Coastal Units in the Nahal Dalia pilot. Properties for each Coastal Unit are summarized in the informative pop-up window.

4.2.5 The Vistula Lagoon

The Vistula Lagoon pilot involved in our task following the discussions during the General Assembly in Gdansk, Poland in 2023. The restoration action of this pilot within the scope of the REST-COAST project is clearly specified as and confined to the construction of an artificial island as refugee for birds. Our partners decided to identify *Bird Island Construction* as the one and only NBS-BB in the pilot with main focus on biodiversity improvement, and to focus on in depth implementation of the NBS-BB Framework for its corresponding Coastal Unit (Chapter 3.3.1).

In accordance with this approach from our partner, we collaborated on exact delineation of the Coastal Unit, which was followed by expanding the structured output data table in accordance with our framework using the Interactive Web Map. In Fig. 18, overview on the Vistula Lagoon pilot is provided including the specified Coastal Unit for the REST-COAST project.

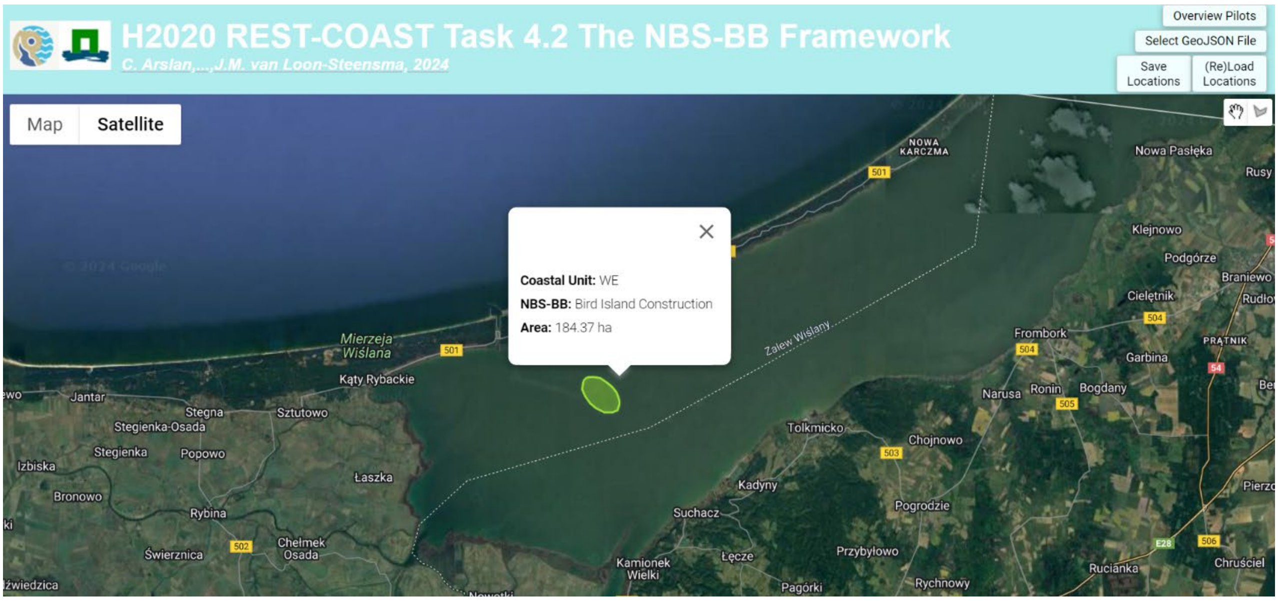


Figure 18 – Spatial marking of the Coastal Unit in the Vistula Lagoon pilot. Properties for the Coastal Unit is summarized in the informative pop-up window.

4.2.6 The Ebro Delta

We implemented the NBS-BB Framework for *Alfacada* Coastal Unit in the Ebro Delta pilot in our bilateral workshop. Focusing on the wetland restoration, *Salt Marsh Edge Protection* was identified as the main NBS-BB in the Coastal Unit and initial elaboration on the data was performed in accordance with our framework (Chapter 3.2.6.).

In the period following the initial implementation, we collaborated on aggregating the Coastal Units across the pilot considering the diverse restoration efforts and plans for large-scale restoration of the delta. In Fig. 19, overview of the complementary Coastal Units are presented including the NBS-BB identified within these Coastal Units. Our collaboration within the frame of dedicated task force is a living project using the Interactive Web Map tool. Thus, we expect more elaboration on the existing data tables and further aggregation of Coastal Units with corresponding implementation of the framework in these units. This will inform the delta scale future adaptation plans better with higher resolution on the potential NBS-BB scattered spatially across the pilot.

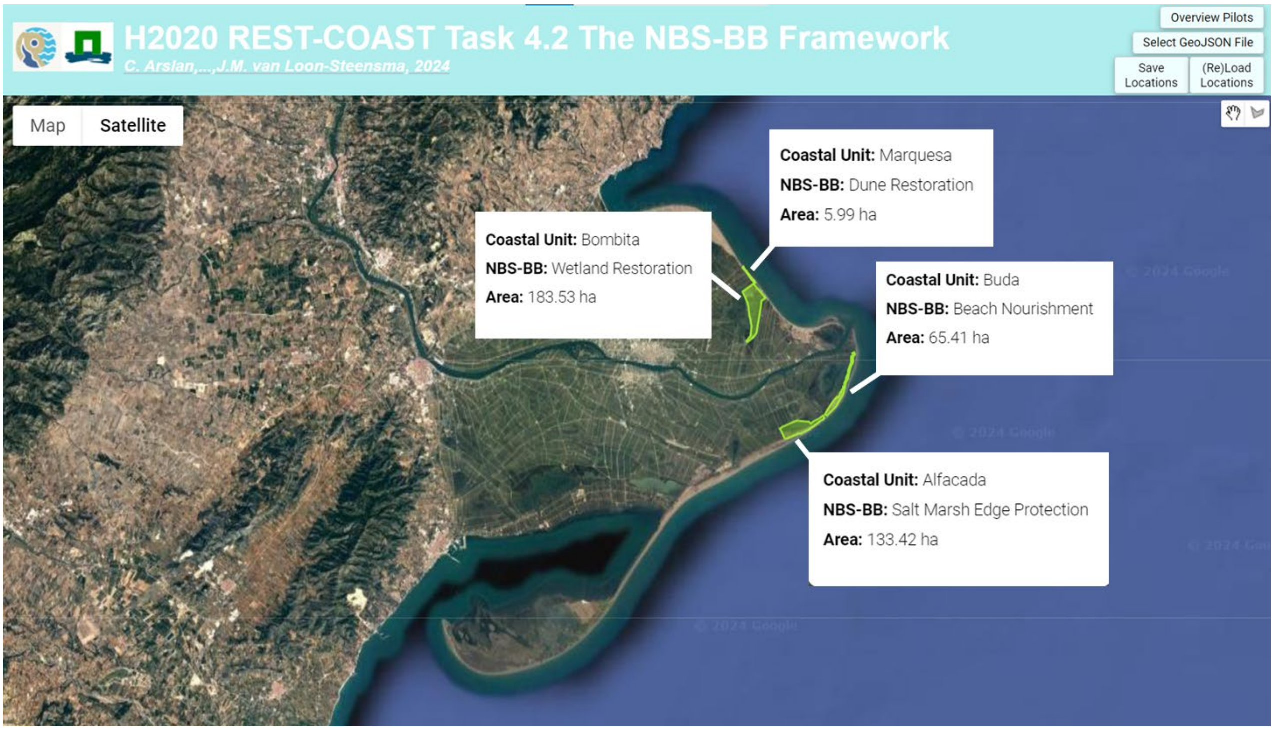


Figure 19 – Spatial distribution of the Coastal Units in the Ebro Delta pilot. Properties for the Coastal Unit is summarized in the informative pop-up window.

4.2.7 The Rhone Delta

Involvement of our partners in the Rhone Delta pilot followed the discussions during the General Assembly in Gdansk, Poland in 2023. Despite this late involvement, we initiated and executed an efficient collaboration with our partners with mutual flow of information and data in our online meetings. Using the Pilot Implementation Form, our partners implemented the NBS-BB Framework in their pilot site by identifying 5 restoration processes as NBS-BB by spatially assigning these into delineated Coastal Units (Chapter 3.3.2).

As presented in Fig. 20, spatial distribution of these Coastal Units hold potential for finding synergies for effective upscaling of restoration in the Rhone Delta. Thus, in our dedicated task force exercise using the Interactive Web Map tool, we focused on in-depth implementation of our framework in these Coastal Units by verifying and expanding data for identified key parameters in accordance with the framework.

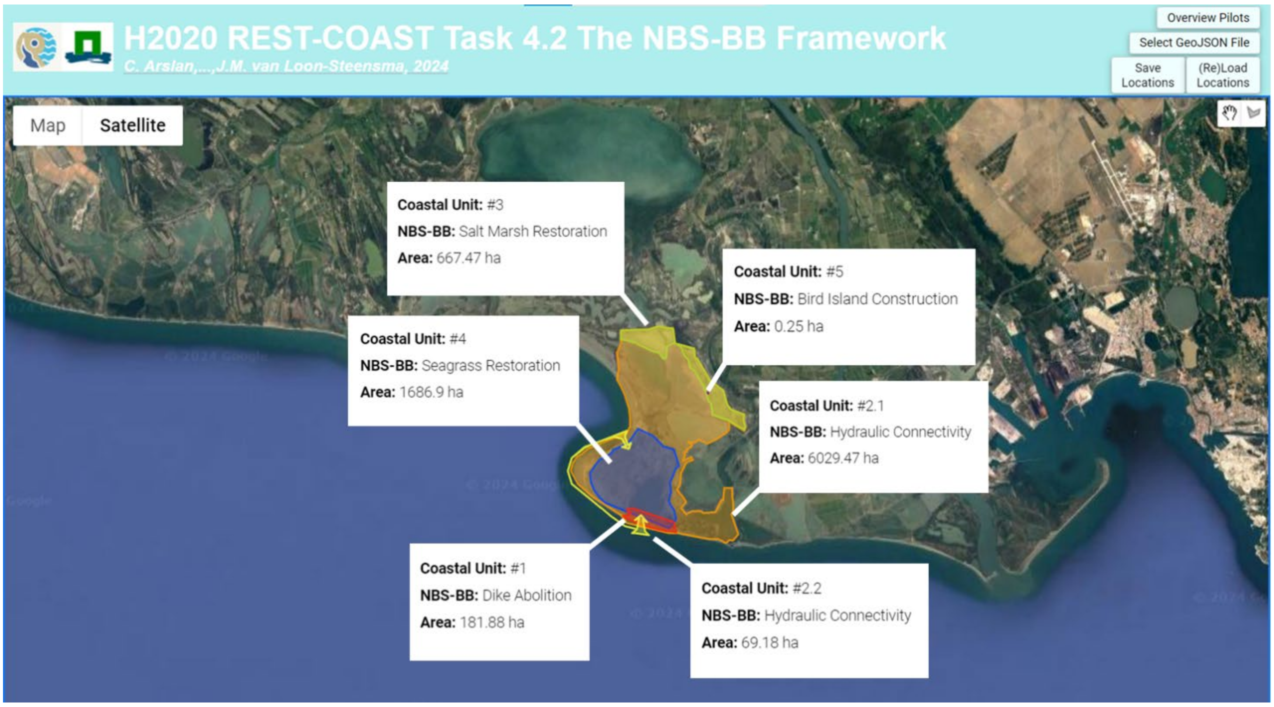


Figure 20 – Spatial distribution of the Coastal Units in the Rhone Delta pilot. Properties for the Coastal Unit is summarized in the informative pop-up window.

4.2.8 The Arcachon Bay

Within the scope of the REST-COAST project, our partners in the Arcachon Bay specifically focus on restoration of seagrasses in the bay following a multi-decadal degradation. Moreover, they conduct their research on a special restoration method using Roseliere device for efficient restoration of seagrasses. Considering the capacities and expertise of our partners, we focused on seagrass restoration as the main NBS-BB in the pilot. Correspondingly, we identified 4 Coastal Units scattered across channel edges and intertidal flats to implement the NBS-BB Framework during our bilateral workshop (Chapter 3.2.5).

Our further collaboration within the dedicated task force using the Interactive Web Map tool focused on spatial refining of these Coastal Units in the bay. Then, we agreed on diversifying the key parameters for each coast unit and expanding these parameters with verified data. It is important to note that the REST-COAST actions on seagrass restoration is only a part of the diverse restoration efforts in the bay according to *Plan de Gestion 2017-2032* in the *Parc Naturel Marin du Bassin d'Arcachon* (please refer to the pilot workshop minutes, *Appendix 11 - Arcachon Bay Workshop Minutes NBS-BB Framework Implementation.pdf*, as provided in the supplementary folder). As this collaboration is a living project, there is also a potential to aggregate the Coastal Units across the bay with diverse NBS-BB, which is beyond the scope of Task 4.2. This also requires active participation of the key stakeholders from Parc Naturel Marin D'Arcachon. In Fig. 21, overview of the existing Coastal Units in the pilot site are presented.

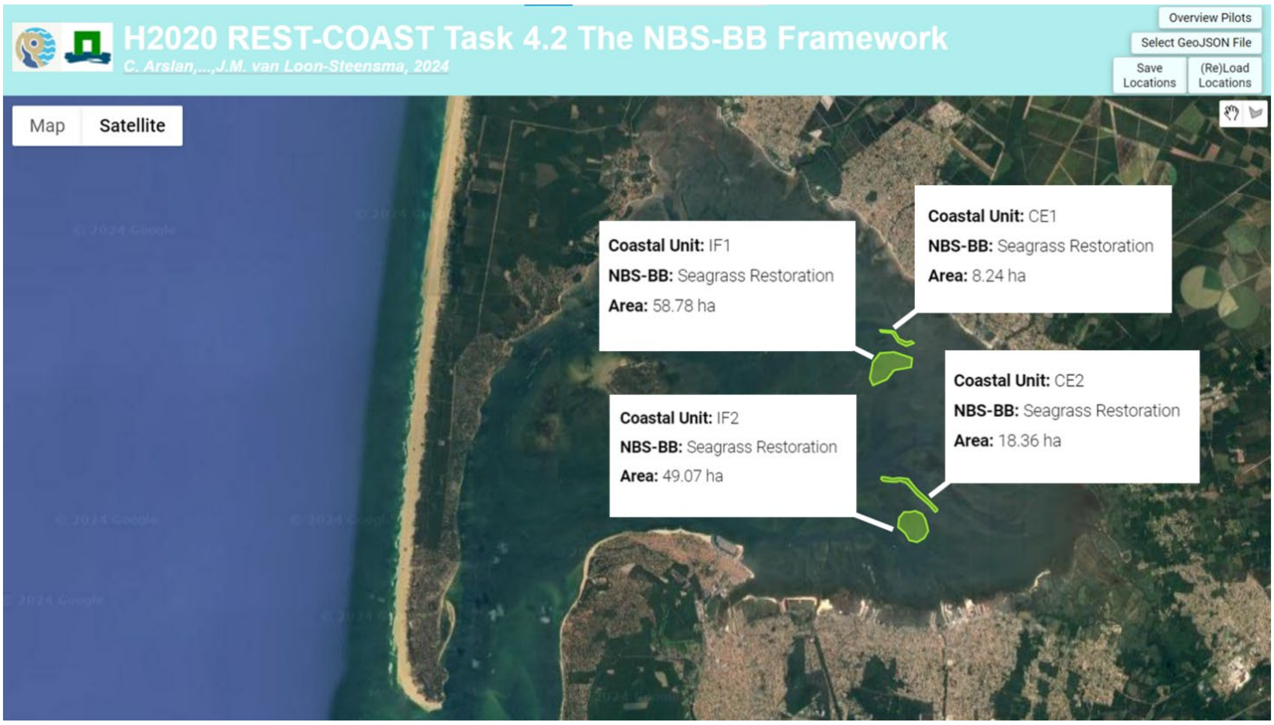


Figure 21 – Spatial distribution of the Coastal Units in the Arcachon Bay pilot. Properties for the Coastal Unit is summarized in the informative pop-up window.

4.2.9 The Venice Lagoon

We collaborated intensively with our partners in the Venice Lagoon in many in-person and online meetings since the beginning of Task 4.2. One of the outcomes of this collaboration is coupling the existing water bodies, which are essentially defined according to the Water Framework Directive, to the Coastal Units of our participative downscaling approach in accordance with the NBS-BB Framework. Considering the main REST-COAST pilot activities residing in one of these water bodies, we participatively implemented our framework in this water body identified as the Coastal Unit *PC2 Millecampi Teneri* during our bilateral pilot workshop. Focusing on *Artificial Salt Marsh Reconstruction* as the NBS-BB in this Coastal Unit, we developed the preliminary output data table in accordance with our framework (Chapter 3.2.3).

Due to the limited capacities and availabilities of our partners specifically for our task as well as the REST-COAST restoration focus on the pilots residing in PC2, we limited our participative collaboration to the Coastal Unit *PC2 Millecampi Teneri* and excluded the remaining water bodies from the implementation of our framework. In Fig. 22, an overview of the Venice Lagoon water bodies as potential Coastal Units is given. However, using our framework and supplementary tools that we developed, the map presents the potential for spatially aligned NBS-BB with synergies in restoration upscaling in the Venice Lagoon.

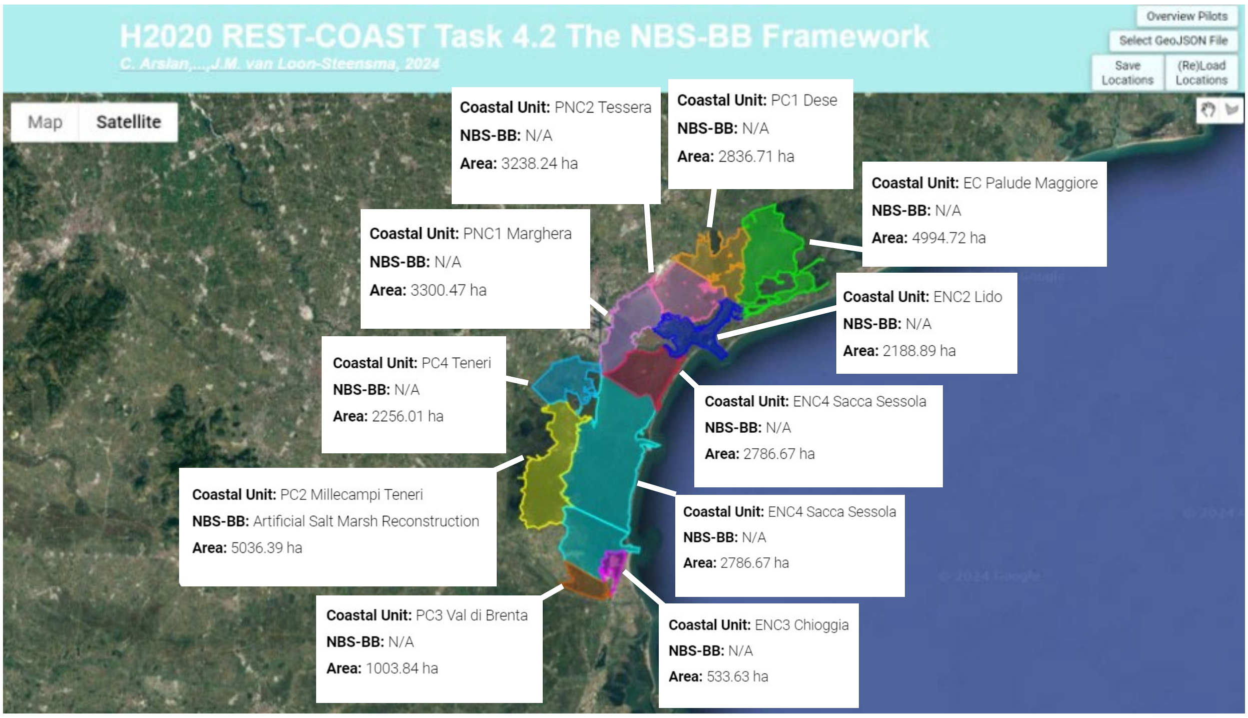


Figure 22 – Spatial distribution of the Coastal Units in the Venice Lagoon pilot. Properties for the Coastal Unit is summarized in the informative pop-up window.

Our close and efficient collaboration with our partners in the Venice Lagoon pilot continued during in-depth implementation of the framework using the Interactive Web Map tool. The preliminary results from the bilateral workshop (see Table 6 in Chapter 3.2.2) were verified and supported with existing literature and data in the structured output data table. As we mentioned in the introduction of this chapter, we present here these results as exemplary implementation of our framework in a specific Coastal Unit.

In Table 15, we see the structured output table from the in-depth implementation of the NBS-BB Framework in *PC2 Millecampi Teneri* Coastal Unit of the Venice Lagoon pilot. Compared to the preliminary results in Table 6 of Chapter 3.2.3, we can remark the verification of some key biophysical and socio-economic parameters at the inputs (e.g. replacing *salt marsh altitude* with *salt marsh morphology (shape & elevation)*) and further extension of the table with additional parameters (e.g. *sea level rise* and *sea level rise future*) as proposed for the dedicated task force activities. Furthermore, all the parameters are validated with supporting data from modelling, monitoring, measurements and literature depending on the availability of knowledge and data. Especially the literature column includes a sample of available literature although there exists a wider literature that is in reach on demand by our key partners in the Venice Lagoon.

We can also verify how the recently added indicator, *Impact*, increases the granularity of the input parameters by adding a new dimension in their interaction with the restoration action. This increased granularity is especially evident for parameters that display multi-directional impact. Moreover, this multi-directional impact can add both spatial resolution, e.g. salt marsh vegetation with both positive and negative impact on restoration depending on the location, and temporal resolution, e.g. salt marsh morphology with positive feedback on restoration. Furthermore, this temporal aspect can reflect patterns among parameters, e.g. a successfully developed artificial salt marsh in *PC2 Millecampi Teneri* will enhance the sedimentation processes in adaptation to sea level rise, which will be essential for the proceeding activities including adaptation pathway development and large-scale restoration in the Venice Lagoon.

At the outputs section of the table, we can observe the updated expert-based evaluation of the main ESS variables within the scope of the REST-COAST project. Expert assessment of habitats and species accompany this evaluation as part of the BDV enhancement targets. The activities within the scope of the dedicated task force also include refining the *Environmental Pressured Addressed* by this specific NBS-BB and verifying the coastal categories and delineations as part of the participatory downscaling practice. All parts of the table together, we obtain the output of pilot implementation of the NBS-BB Framework at a specific Coastal Unit that is downscaled participatively by the involved actors in the restoration pilot.

Table 15 – In-depth implementation of the NBS-BB Framework in the Venice Lagoon pilot: Structured data table as the output from partner collaboration using the Interactive Web Map Tool.

NBS-BB	NBS-BB CAT[1]	DEL[2]	EPA				PARAMETER	UNIT	IMPACT	MODEL	DATA	LITERATURE
Artificial Salt Marsh Reconstruction	Intertidal	PC2 [45.3527º N, 12.2098º E]	• Lateral edge erosion • Sea Level Rise (SLR) • Anthropogenic drivers; ○ Dredging ○ Land reclamation ○ Transportation • Climate change • Increasing flood risk • Increasing erosion risk • Biodiversity loss • …	NBS-BB FW I/O	INPUTS	KBP	• SLR future	m	KP ---> - BB	Lagoon scale: SHYFEM 0.25 m in 2050 and 0.36 in 2100 based on Copernicus	Copernicus	
							• SLR rate	mm/y	KP ---> - BB			2.76 ± 1.75 mm/yr 1993 - 2019 (Zanchettin et al., 2021)
							• Sediment input	Mln m3/y	KP ---> - BB			Net sediment loss of 0.3 Mm3yr−1 during 1927–1970 to 0.8 Mm3 yr−1 in 1970–2002 (Saretta et al., 2010)
							• Sediment granulometry	-	*Impact*		Lagoon scale: Atlante della Laguna (shapefiles 1975 - 1978, 1983 - 1984, 1997 - 1998)	Saretta et al (2010)
							• Saltmarsh morphlogy (shape & elevation)	- -	KP ---> + BB KP + <--- BB		Lagoon scale: Atlante della Laguna shapefile, EUNIS map 2021 LiDar 2017 from Venezia2021/Provv	Bonometto (2003), Bonometto (2008), Tagliapietra et al (2018), …
							• Salt marsh vegetation presence/cover	- - - -	KP ---> + BB KP + <--- BB KP ---> - BB KP - <--- BB		Classified monitoring data for the pilot site (PROVV), future monitoring envisioned in 2024 and 2026 + satellite image	
							• Current-wave characteristics	-	KP ---> - BB	SHYFEM lagoon scale	Tide gauge network 1983 - present (csv at lagoon scale)	Umgiesser et al (2004); Carniello et al (2009); Finotello et al (2023); ….
							• Erosion rates	mm/y	KP + <--- BB KP ---> - BB		Lagoon scale: Atlante della laguna (shapefile 1930 - 1955; 1955 - 1970; 1970 - 2000)	
							• Carbon sequestration	Ceq/y	KP + <--- BB		Monitoring conducted under REST-COAST in collaboration with INREA, data not yet available	85 ±25 ton OC km-2 year-1 (Puppin et al 2023)
							• WFD indices related to the fauna/benthic community structure	-	KP + <--- BB		Lagoon scale: ARPAV (csv for water column) - seasonal	

KSP

PARAMETER	UNIT	IMPACT	MODEL	DATA	LITERATURE
• National funding	m€/y	KP ---> + BB			From 1984 to 2010 the government allocated ± 10.3 billion euros (Munaretto & Huitema, 2012)
• EU funding	m€/y	KP ---> + BB			
• WFD regulations	-	Impact		ARPAV collects seasonal data for the WFD which can be downloaded in csv format from their website	
• Effect of boating	-	KP ---> - BB			Scarpa et al (2019); Zaggia et al (2017); map of the speed limits
• Cultural and natural heritage	-	KP ---> + BB			UNESCO (website + management plan)
• Nutrient loading	-	KP ---> - BB			
• Proximity to industrial areas	Km	KP ---> - BB			Frignani et al (2005)
• Commercial fishing interests	-	KP ---> + BB KP + <--- BB			80 million euros including secondary effects (Rossetto, 2000)
• Stakeholder engagement / influence	-	KP ---> + BB			
• Political prestige	-	KP ---> - BB			

OUTPUTS

ESS[3]

RFR[4]	RCE[4]	CCR[3]	WP[3]	FP[3]

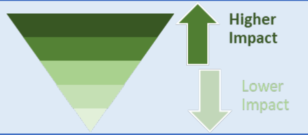
BDV[4]

HABITATS	SPECIES
• At the current point in time a lagoon wide biotope map has been developed using the EUNIS 2019 - 2021 typology, customized for the Venice Lagoon (map included in D4.1).	• Data on number of bird species and number of breeding birds until 2018 (by SELC Soc Coop – end of contract). Internal monitoring going on during the REST-COAST restoration activities.

NBS-BB: Nature Based Solutions Building Block
NBS-BB CAT: A drop-down list for the NBS-BB Category along the land-to-sea continuum as defined in the NBS-BB Framework.
DEL: Coastline delineation as defined by the pilot partners according to the NBS-BB Framework (approximate coordinates of the center).
EPA: Environmental Pressures Addressed
INPUTS: KBP: Key Bio-physical Parameters – KSE: Key Socio-economic Parameters
OUTPUTS: ESS: Ecosystem Services RFR: Reduction Flood Risk; RCE: Reduction Coastal Erosion; CCR: Carbon Sequestration; WP: Water Purification; FP: Food Production; BDV: Biodiversity

——→ — (KP) impacts negatively (NBS-BB)
——→ + (KP) impacts positively (NBS-BB)
— ←—— (KP) impacted negatively (NBS-BB)
+ ←—— (KP) impacted positively (NBS-BB)
KP: Key Parameter
NBS-BB: Nature Based Solutions Building Block

[1,2] Coastal Units identified according to the *NBS-BB Categories* and *Coastal Delineations* are provided in the pilot map below.
[3] Semi-quantitative scores for 5 ESS defined in the REST-COAST project. Expert-based quantification of the expected ESS impact for specific NBS-BB within the identified Coastal Unit in accordance with pilot input to Task 4.1. Numerical scores are also given as superscript for easier readability.
[4] Expert-based qualitative description of Biodiversity gains in terms of habitats and species by workshop participants. Pilot will update this column aligned with their input to Task 4.1.



5. Discussions

5.1 Task 4.2 in closing the 'implementation gap'

There is a growing attention to NBS in the regional and international policy agenda including EU Green Deal (Cohen-Shacham et al., 2016; Faivre et al., 2017; IUCN, 2020) with growing emphasis on conservation of biodiversity (CBD, 2022; EC, 2022; Murillas-Maza et al., 2023) and enhancement of ecosystem services (EC, 2022; Keesstra et al., 2018; Murillas-Maza et al., 2023; Paxton et al., 2023). Accordingly, the coastal areas take their share from this growing attention with many small-scale pilots to protect, manage or restore these delicate ecosystems (EC, 2022; Seddon, 2022; van Loon-Steensma & Goldsworthy, 2022; van Loon-Steensma & Schelfhout, 2020). However, effective coastal adaptation requires upscaling and mainstreaming coastal NBS. Taking the leap from evidence-based small-scale pilots to larger-scale restoration using NBS is one of the biggest challenges in current coastal climate adaptation. REST-COAST as one of the outcomes of this growing attention focuses on taking this leap by closing the implementation gap in favor of coastal NBS (Sánchez-Arcilla et al., 2022).

Task 4.2, as an overarching task in the REST-COAST project, aims for contributing to closing this implementation gap in 9 coastal restoration pilots across EU. Accordingly, the main output of our task is a portfolio of NBS-BB per pilot, which are scattered across the pilot landscapes in spatially mapped Coastal Units. In our approach, participatory downscaling to map Coastal Units is essential for optimal selection of NBS-BB as a restoration process. Compared to inhomogeneous and complex landscape characteristics and dynamics at pilot scale, Coastal Units possess differentiated biophysical and socio-economic characteristics, as well as biotopes with more homogenous and manageable domains. So, these Coastal Units are associated to the implementable restoration actions supported with verified data, thus the NBS-BB. Furthermore, spatial distribution of these Coastal Units offers the opportunity for systemic upscaling of large-scale restoration through synergies and harmonies among these NBS-BB.

5.2 The NBS-BB Framework: Designing the co-development

In downscaling to Coastal Units at 9 REST-COAST pilots in terms of biophysical, socio-economic and ecological characteristics, collaboration stands out as the key element in Task 4.2, especially given the geographical diversities of these pilots. This collaborations is reflected as the co-development of the NBS-BB Framework through our close collaboration with involved partners diverse in knowledge and expertise. In doing so, we started with harnessing the well-acknowledged NBS theory (Cohen-Shacham et al., 2016; European Commission, 2015; Seddon et al., 2021) and diverse expertise at small-scale pilots to develop our novel NBS-BB definition (Chapter 2.3). We constructed the NBS-BB Framework from this definition by employing the IPO model, which provides a compartmental foundation to explicitly design our collaboration with different work packages and pilots. Accordingly, the IPO model becomes the fundamental mechanism of co-development in our framework by first framing the spatial Coastal Units in terms of key biophysical and socio-economic parameters at the inputs and biotopes translated to ESS and BDV benefits at the outputs. Based on this compartmental structure of the IPO model, we had the opportunity to explicitly design our task's alignment with the tasks and responsibilities in specific work packages, i.e. WP1 and WP2 in key biophysical parameters of inputs, WP3 and WP5 in key socio-economic parameters of outputs, Task 4.1 and WP1 in ESS and BDV of outputs, NBS practices and knowledge in all pilots in NBS-BB identification of processes. Hence, our task ensures by design the overarching structure of WP4 (Fig.1) for interaction and information fluxes among work packages of the REST-COAST project. Thus, we co-developed the theory of *NBS-BB as a downscaling approach* in which the participatively identified NBS-BB transforms a spatially identified Coastal Unit from its actual/degraded state, which is explained by key biophysical and socio-economic parameters, to its desired/restored state, which is explained by ESS and BDV benefits.

Aligned with closing the implementation gap, we took our next leap from this theory to practice by implementing the NBS-BB Framework at each pilot as in Chapter 3 and Chapter 4. Accordingly, the practice of identifying Coastal Units as the spatial landscape elements revealed some informative outcomes from our participative downscaling approach. One of these outcomes is the diverse pilot-specific criteria when mapping coastal units, e.g. legislation focus in the Venice Lagoon and the Vistula Lagoon, re-naturalization focus in the Rhone Delta and the Nahal Dalia, restoration focus in the Foros Bay and the Arcachon Bay, project focus in Wadden Sea and the Ebro Delta. Thus, overall restoration objective and corresponding management and implementation strategies in each pilot is reflected back in the identification of the pilot-specific Coastal Units. This suggests that the pilot targets already defined in the REST-COAST proposal predominates the methods we developed.

Another important outcome is the weight of the natural sciences perspective in mapping the Coastal Units, e.g. wave exposure in the Foros Bay, sedimentation and currents in the Arcachon Bay, discharge and sedimentation in the Sicily Lagoon, chemical and ecological status in the Venice Lagoon. So, our balanced perspective of the biophysical and socio-economic parameters in the design of the framework was challenged in practice, most likely by our pilot partners' capacities and expertise in natural sciences. Nevertheless, the identified Coastal Units and the consequent implementation of the framework in these units proved the flexibility of our method. Moreover, participating partners recognized and acknowledged the significance of diverse participation during the workshops, which is also very instructive for the future implementations of our framework.

We also explored the power of tools as enablers of participation and collaboration to effectively implement our framework at geographically diverse locations withy diverse stakeholders. So, we developed two software tools to facilitate participation as part of our co-development design in Task 4.2, (i) a Python-based executable for the bilateral workshops in obtaining the preliminary set of NBS-BB per pilot, and (ii) an HTML-based Interactive Web Map to facilitate working collectively on verifying, extending and expanding this preliminary set of NBS-BB per pilot. It is important to note that developing these tools are outside the scope of Task 4.2 and given the time and resource restrictions, they are operational but also open for further development. Nevertheless, they have proved very functional in enabling collaboration and obtaining a diverse portfolio of NBS-BB spatially scattered across the pilots, thus constituting the fundamental premise of Task 4.2.

5.3 The NBS-BB Framework: Path to upscaling

The main output of Task 4.2 is the portfolio of NBS-BB per pilot that will be a valuable input for structured decision-making approaches in multi-criteria comparisons to evaluate and compare single or joint performances of identified NBS-BB within a pilot or across other pilots. The structured output tables as exemplified in Chapter 4.2.9 form the reference tables for selection of NBS with overall effectiveness based on decision-makers' criteria. Consequently, multi-criteria comparison beyond Task 4.2 by decision-makers at the REST-COAST pilots can include;

- parceling out large-scale restoration target to Coastal Units in accordance with our participative downscaling approach,
- identifying criteria for each Coastal Unit based on existing biophysical and socio-economic characteristics,
- identifying criteria for each Coastal Unit based on improvements in 5 ESS and BDV,
- assigning weights to each criteria based on the relative importance of each criterion,
- assessing performance of each NBS-BB by using the structured output tables,
- normalizing performance scores (refer to literature for techniques) to eliminate different units and scales in the criteria,
- calculating overall performance scores for each NBS-BB after normalization,
- ranking NBS based on overall performance scores to identify most effective solutions,
- analyzing joint performances for multiple NBS implementations.

It is important to mention that we provide here a simple illustration of the potential of Task 4.2 output in a multi-criteria comparison for effective restoration upscaling. Especially, in the ongoing and proceeding tasks of WP4, this output will be used in accordance with specific design and development in each task. In alignment with our cooperation with simultaneously progressing tasks within WP4, the pilots have already been incorporating the Task 4.2 output. Accordingly, the portfolio of NBS-BB contributes to the Vision-Strategy-Mission tables of pilots, which will then inform the development of adaptation pathways in Task 4.3. In the meantime, geospatial data we have developed in accordance with the framework will feed the Quick Scan Tool of Task 4.4. Ultimately, spatial portfolio of NBS-BB per pilot will be instrumental for closing the 'implementation gap' through finding synergies and trade-offs among these NBS-BB in adaptation upscaling plans of the pilots as the overall output of WP4. As we have mentioned, the NBS-BB Framework and corresponding pilot output are continuous co-development processes by design. Thus, enriching and expanding the geospatial data aligned with the framework can support upscaling restoration at the pilots but also scaling out the REST-COAST approach beyond the scope of the project.

5.4 The NBS-BB Framework Implementations: Power of collaboration

It is essential to ensure diverse and balanced participation of science-policy-society pillars in long-term success of large-scale restoration (Pérez et al., 2024). Small-scale pilots are important as proof of concepts for success of NBS. Yet, pilots are prone to bias among science (Schoonees et al., 2019; Tiggeloven et al., 2022; Vuik et al., 2019), policy (Pérez et al., 2024; Riisager-Simonsen et al., 2022; van Loon-Steensma & Goldsworthy, 2022) and society (Baptist et al., 2021; Seddon, 2022). Thus, challenges to upscaling start with small-scale pilot lock-in, where pilots can focus too much on spatially isolated compartments at the marine-coast interface ignoring connectivity along coastline and land-to-sea. We identify this fact as one of the crucial factors of *'implementation* gap', which needs to be bridged in *'demonstrating large-scale restoration'* as aimed in the REST-COAST project.

Accordingly, we designed the NBS-BB Framework as a co-development process involving varying partners at 9 REST-COAST pilots. Moreover, we emphasize the biophysical, socio-economic, ESS and BDV aspects equally in the framework using the IPO model. This implies participation of diverse disciplines and expertise, e.g. coastal hydro-morpho-geologists, coastal engineers and modelers, landscape architects etc. concerning biophysical parameters; sociologists, landscape artists, environmental managers, local governments, economists, industry, farmers etc. concerning socio-economic parameters; ecologists, environmental scientists, conservation NGOs, geographers etc. concerning ESS and BDV. Hence, we aim to ensure balanced participation, which we identify as essential for moving from small-scale pilots to restoration upscaling, thus bridging the *'implementation gap'*.

Therefore, the collaboration, interaction and knowledge flux among different tasks and work packages is extremely crucial for our task but also for the overall success of the REST-COAST project as well. Despite the challenges due to distant collaboration and individual workloads, our collaboration has successfully flourished so far owing to the great enthusiasm, the willingness to share, and the mutual respect of the involved partners in Task 4.2. Annual General Assemblies and conference collaborations, where we have had the opportunity to meet in person and discuss our development, have further clinched this collaboration. Besides, joint meeting of two EU Green Deal projects, REST-COAST and WaterLANDS, proved very promising for complementary collaborations, especially considering the balanced participation aspect of restoration upscaling.

We should nevertheless mention the inevitable challenges of keeping the balance at different progress phases. One of these challenges is related to tasks that are preceding but simultaneously progressing. This becomes apparent especially for the preceding tasks of Task 4.2, which had to continue their progress while requiring Task 4.2 output. Although it is extremely challenging to plan in advance these processes in detail for such big projects like REST-COAST, there might still be options to explore to overcome these challenges in the future projects. Another very important challenge has revealed itself as a recurring theme in bilateral pilot implementation (Chapter 3), which we identify as incomprehensive implementation of the framework in identification of the socio-economic parameters when moving from theory to practice. Thus, we have observed that natural sciences outweigh social sciences in terms of balance, mainly due to the natural sciences background of Task 4.2 partners. We identify this inherent complexities of participation as one of the most valuable key learnings in Task 4.2. Therefore, we further perform a stakeholder analysis of the bilateral pilot workshops as a complementary product to the portfolio of NBS-BB.

5.5 The NBS-BB Framework Implementations: Stakeholder analysis

Bilateral pilot workshops were very instrumental in obtaining our preliminary sets of NBS-BB per pilot as well as in demonstrating the NBS-BB Framework implementation for moving from theory to practice. Complementary to this main output, we had very valuable observations and experiences from these workshops as a result of geographical and institutional diversities. Thus, we performed a simple stakeholders analysis focusing on the key learnings per pilot as in Table 16. Inspecting this table , we can deduct some general conclusions concerning the participative design and implementation of the NBS-BB Framework:

- Participative processes demand time and effort of both facilitators and participants. This is especially more challenging as far as the transdisciplinary approaches concerned, where diverse disciplines and local stakeholders come together.
- However, mobilizing partners under the umbrella of a project is much more feasible as we experienced in our task under REST-COAST roof. So, ensuring balance and diversity of participation in advance during the planning stage is essential. Especially considering the social sciences as becomes apparent in the pilot implementations of our framework.
- Diversity of geographies matters: We see *locality* of approaches to participation concerning bureaucracy, legislation, perception, jurisdiction, competition etc. It is important to acknowledge and even anticipate these differences for flexibility and adaptability of participation.
- We recognize the importance and effectiveness of *Implicit Participation* especially when restricted in time and resources. Moreover, we identify two ends of the spectrum, both valuable and informing, when Implicit Participation is reflected to the pilot implementation by our partners: Collective decision-making by multi-stakeholders vs. Authority of institutions constrained by jurisdiction.
- Implementation of our framework is more comprehensive and effective when the relationship between participating bodies is built on synergy and cooperation rather than accountability and supervision.
- Large consortiums like REST-COAST should be able to anticipate barriers and hurdles to collaboration from increasing regional and global conflicts as they become part of the daily life.

Task 4.2 completes its mission within the REST-COAST project with this deliverable document according to the initial project planning. Nevertheless, we consider both the NBS-BB Framework and the output portfolio from the implementation of the framework as transient *metabolites* of a continuous co-development process due to their implicit participative nature. So, these products will inform upscaling efforts in the consecutive tasks in the REST-COAST but also hold potential to adaptively grow by ensuring balanced participation aligned with the future coastal adaptation. Thus, the stakeholder analysis in Table 16 is a valuable complementary output to reinforce our key learnings in contributing to the adaptive capacities while demonstrating restoration upscaling in the REST-COAST project.

Table 16 – Important agents for the implementation of the NBS-BB Framework in the pilots (Based on the Task 4.2 bilateral pilot workshops)

Pilot Site	Stakeholder(s)*	Function	Involvement Level	Key Learnings
Venice Lagoon (IT)	PROVV[1]	Administration	Observe and Learn	PROVV is very important in funding and decision making for the restoration actions in the lagoon. The Venice Lagoon is the only pilot with no direct REST-COAST funding of the actual restoration. Although PROVV is an important partner of the REST-COAST, its involvement in the workshop was mainly to *observe and learn* about the framework. From the perspective of Task 4.2, contribution of this partner in the workshop was very limited due to this accepted role. But introducing the framework to PROVV is promising for future collaboration in extending the framework to other water bodies.
Foros Bay (BG)	NP**	-	-	We carried out the co-development of the framework and the actual pilot implementation completely with our REST-COAST partners, as they were extremely active, enthusiastic and involved in Task 4.2. However, the Foros Bay pilot is *fundamentally* distinct from the other pilots concerning the participative processes due to: • Challenges in involving local stakeholders resulting from strong bureaucracy and formality in EU project mechanisms, • Stakeholders' negative perception of restoration when exposed to explorative processes rather than concrete data and results.
Arcachon Bay (FR)	MPA[2]	Site Manager	Knowledge and Expertise Sharing	2017-2032 Plan de Gestion is a strategic document for the management plan of the stakeholder organization in the Arcachon Bay. All the restoration actions and activities are framed, planned and executed according to this document in the bay. This includes the REST-COAST pilot site and our partners' activities in this site. Thus, there is a clear accountability and supervision relationship between our partners and the site management. Open communication and shared restoration ambitions contributed positively to the implementation of the framework. Yet, site manager views the whole basin holistically with many other restoration actions in addition to the REST-COAST pilot. This holds the potential to expand the framework to the whole Arcachon Bay.
Ebro Delta (SP)	NP**	-	-	The framework is internally applied with participation of Albirem and Eurecat. No direct stakeholder involvement and perspective in the implementation of the NBS-BB Framework in the pilot.
Wadden Sea (DE)	BAW[3]	Researcher	Observe and Learn	BAW, engineering research institute, is one of the important stakeholders active in restoration efforts in the German part of the Wadden Sea. They were invited by our partners to the workshop mainly to observe and learn about REST-COAST. This assumed role of *Observe and Learn*, which was explicitly declared in the beginning of the workshop, hindered their

				contribution to the implementation of the framework. This hints at the strong bureaucracy and legislation in Germany when actively involving potential competitor in a EU project in which they are not affiliated to. Although we missed the opportunity for diverse perspectives in our workshop, we revealed another key learning for participative studies involving Germany.
Wadden Sea (NL)	IP**	-	-	There is no direct involvement of stakeholders in our meeting and field trip with our partner, the Province of Groningen. However, we can assume implicit involvement of diverse stakeholder perspectives, e.g.local people, farmers, municipalities, environmental NGOs, water boards, the Ministry of Infrastructure and Water Management etc., because our partners are actively involved in many nature restoration actions with multi-stakeholder involvement. Given the time and resource restrictions in executing our task, this kind of proxy involvement proves extremely valuable especially for the key socio-economic parameters in the framework.
Sicily Lagoon (IT)	SPA[4]	Site Manager	Knowledge and Expertise Sharing	Inclusion of the key stakeholder from SPA played an integral role for the comprehensive implementation of the framework in the lagoon. The relationship and interaction between the stakeholder and our partners is built on synergies and cooperation. They complement each other both place-based and expertise-based in accordance with our framework such that: • Past and ongoing restoration actions by SPA in two lagoons both inform and informed by the REST-COAST activities on the coastal area, • Expertise of our partners in hydro-morpho-ecological modelling (linked to the biophysical parameters) with a focus on improved ecosystem services (linked to ESS). • Expertise of SPA in restoration of habitats and conservation of endangered species (linked to BDV) with wide experience in management and conflicts (linked to the socio-economic parameters).
Vistula Lagoon (PL)	IP**	-	-	There was no direct involvement of stakeholders in the framework implementation, which was completely carried out by our partner in the lagoon. However, concerning the financial and juristic accountability to the Maritime Office and other stakeholders in the lagoon and on the coastal area, our partner has strong collaboration and expertise, which was reflected back in the implementation of the framework. Given the time and resource restrictions especially for this pilot with late involvement in our task, this kind of proxy perspectives prove extremely valuable on the account of key socio-economic parameters in the framework.

Rhone Delta (FR)	IP**	-	-	The framework was internally applied by our partner in the pilot site. No direct stakeholder involvement in the implementation. However, TDV, as our key partner and co-manager of the pilot site, has wide and acknowledged knowledge and expertise in nature restoration and conservation. This implies a great potential for proxy involvement and implicit participation of diverse stakeholders, especially from the social sciences perspectives. This potential could have been more effectively realized unless; • The late involvement of TDV in Task 4.2 as explained in Chapter 3.3, • The restricted time and resources for overloaded work force with responsibilities in diverse tasks and work packages.
Nahal Dalia (IR)	IP**	-	-	The framework was internally applied by our partner in the pilot site. No direct stakeholder involvement in the implementation. The pilot site is relatively small with clear restoration targets framed by the national park authority and with sharp boundaries between the national park and the fisheries. So, the pilot site holds potential for holistic implementation of the framework given the proxy involvement of diverse stakeholders and expertise by two involved REST-COAST partners. Yet, we can reveal out some key learnings that hinder potential for more effective and comprehensive collaboration; • Late involvement of our partners in Task 4.2 as explained in Chapter 3.3, • Restricted time and resources for overloaded work force with responsibilities in diverse tasks and work packages, • Regional and global conflicts with adverse impacts on collaboration.

[*] Stakeholders analyzed in this table are not involved in REST-COAST but invited by our pilot partners as requested in advance of the pilot implementation.
[**] NP: No Participation, IP: Implicit Participation
[1] Provveditorato Interregionale per il Veneto, Trentino Alto Adige, Friuli Venezia Giulia (PROVV, Venice Water Authority) - Ministry of Infrastructure and Transport (Ministero delle Infrastrutture e dei Trasporti), **http://provveditoratovenezia.mit.gov.it/**
[2] Parc Naturel Marin du Bassin d'Arcachon, **https://parc-marin-bassin-arcachon.fr/**
[3] Die Bundesanstalt für Wasserbau, **https://www.baw.de/en/home/home.html**
[4] Stiftung Pro Artenvielfalt (Foundation Pro Biodiversity), **https://www.stiftung-pro-artenvielfalt.org/en/index.php**

6. Conclusions

In Task 4.2, we co-developed the NBS-BB Framework with partners from 9 REST-COAST pilots. Starting with a theoretical underpinning of NBS as building blocks, we constructed the framework, which adopts a participatory downscaling approach to Coastal Units to resolve the inherent spatial and temporal complexities and uncertainties of coastal landscapes. We developed novel tools and methods to enable effective participatory implementation of the framework when moving from theory to practice. The resulting NBS-BB Framework contends as a promising gadget to support decision-makers and implementors in choosing the most efficient ensemble of NBS-BB at landscape scale. The co-development process in Task 4.2 yields important insights into closing the *'implementation gap'* in favor of effective large-scale restoration:

- Challenges of upscaling: dedicated collaboration and participative inclusion are essential, yet resource-intensive in bridging the gap between small-scale pilots and large-scale long-term coastal restoration using NBS.
- The NBS-BB Framework stimulates a holistic view on the coastal landscape by systemic participatory downscaling of the coastal landscape into Coastal Units.
- The IPO model as the foundation of the framework provides a compartmental perspective on designing interaction among Coastal Units, biophysical/socio-economic/habitats/species characteristics and diverse REST-COAST work packages.
- The NBS-BB Framework embraces well-balanced participation and cooperation among science, policy and society aspects, as required for successful large-scale restoration.
- Successful collaboration and participation requires willingness to share and co-produce in mutual respect. Large and well-managed consortiums like REST-COAST are essential as enablers of this collaboration, which can extend beyond the project.
- Main output of Task 4.2 is a portfolio of spatially distributed NBS-BB per pilot, which will be instrumental for closing the 'implementation gap' through finding synergies and trade-offs among these NBS-BB in adaptation upscaling plans of the pilots.
- The NBS-BB Framework is continuous co-development processes by design supported by the novel tools developed for implementation of the framework. Accordingly, the framework can continue to support scaling up in the REST-COAST pilots as well as scaling out the REST-COAST approach beyond the project globally.

7. References

Acosta, A., Carranza, M. L., & Izzi, C. F. (2009). Are there habitats that contribute best to plant species diversity in coastal dunes? *Biodiversity and Conservation*, *18*(4), 1087-1098. https://doi.org/10.1007/s10531-008-9454-9

Baptist, M. J., Dankers, P., Cleveringa, J., Sittoni, L., Willemsen, P. W. J. M., van Puijenbroek, M. E. B., de Vries, B. M. L., Leuven, J. R. F. W., Coumou, L., Kramer, H., & Elschot, K. (2021). Salt marsh construction as a nature-based solution in an estuarine social-ecological system. *Nature-Based Solutions*, *1*, 100005. https://doi.org/10.1016/j.nbsj.2021.100005

Baptist, M. J., Marijnissen, R., Różyński, G., Musumeci, R. E., Marino, M., Borzì, L., Di Stefano, A., Jolivet, M., Stocco, A., Horneman, F., Rova, S., Torresan, S., Furlan, E., Dabalà, C., Coccon, F., Critto, A., Pranovi, F., Bertomeu, F., Ibáñez, C., . . . Cognat, M. (2024). *D4.1 Scorecard methodology (tool) for coastal system restoration effects on ESS and BDV*. https://rest-coast.eu/storage/app/uploads/public/665/5d1/11d/6655d111d137e488020797.pdf.

Barbier, E. B., Hacker, S. D., Kennedy, C., Koch, E. W., Stier, A. C., & Silliman, B. R. (2011). The value of estuarine and coastal ecosystem services. *Ecological Monographs*, *81*(2), 169-193. https://doi.org/10.1890/10-1510.1

Barbier, E. B., Koch, E. W., Silliman, B. R., Hacker, S. D., Wolanski, E., Primavera, J., Granek, E. F., Polasky, S., Aswani, S., Cramer, L. A., Stoms, D. M., Kennedy, C. J., Bael, D., Kappel, C. V., Perillo, G. M. E., & Reed, D. J. (2008). Coastal Ecosystem-Based Management with Nonlinear Ecological Functions and Values. *Science*, *319*(5861), 321-323. https://doi.org/10.1126/science.1150349

Bessembinder, J., Bintanja, R., van Dorland, R., Homan, C., Overbeek, B., Selten, F., & Siegmund, P. (2023). *KNMI's klimaatscenario's voor Nederland*. KNMI. https://edepot.wur.nl/639605

Blowes, S. A., Supp, S. R., Antão, L. H., Bates, A., Bruelheide, H., Chase, J. M., Moyes, F., Magurran, A., McGill, B., Myers-Smith, I. H., Winter, M., Bjorkman, A. D., Bowler, D. E., Byrnes, J. E. K., Gonzalez, A., Hines, J., Isbell, F., Jones, H. P., Navarro, L. M., . . . Dornelas, M. (2019). The geography of biodiversity change in marine and terrestrial assemblages. *Science*, *366*(6463), 339-345. https://doi.org/10.1126/science.aaw1620

Calliari, E., Staccione, A., & Mysiak, J. (2019). An assessment framework for climate-proof nature-based solutions. *Science of The Total Environment*, *656*, 691-700. https://doi.org/10.1016/j.scitotenv.2018.11.341

CBD. (2022). *Kunming-Montreal Global Biodiversity Framework* [CBD/COP/DEC/15/4]. Montreal, Canada. https://www.cbd.int/doc/decisions/cop-15/cop-15-dec-04-en.pdf

Chausson, A., Turner, B., Seddon, D., Chabaneix, N., Girardin, C. A. J., Kapos, V., Key, I., Roe, D., Smith, A., Woroniecki, S., & Seddon, N. (2020). Mapping the effectiveness of nature-based solutions for climate change adaptation. *Global Change Biology*, *26*(11), 6134-6155. https://doi.org/10.1111/gcb.15310

Chester, M. V., & Allenby, B. (2019). Toward adaptive infrastructure: flexibility and agility in a non-stationarity age. *Sustainable and Resilient Infrastructure*, *4*(4), 173-191. https://doi.org/10.1080/23789689.2017.1416846

Cognat, M. (2019). *Roles of environmental factors and biomorphodynamic interactions on spatio-temporal evolution of seagrass meadows in a mesotidal lagoon* (Publication Number 2019BORD0170) Université de Bordeaux]. https://theses.hal.science/tel-03372209.

Cohen-Shacham, E., Andrade, A., Dalton, J., Dudley, N., Jones, M., Kumar, C., Maginnis, S., Maynard, S., Nelson, C. R., Renaud, F. G., Welling, R., & Walters, G. (2019). Core principles for successfully implementing and upscaling Nature-based Solutions. *Environmental Science & Policy*, *98*, 20-29. https://doi.org/10.1016/j.envsci.2019.04.014

Cohen-Shacham, E., Walters, G., Janzen, C., & Maginnis, S. (2016). *Nature-based solutions to address global societal challenges*. Gland, Switzerland: IUCN. https://doi.org/10.2305/IUCN.CH.2016.13.en

Costanza, R., d'Arge, R., de Groot, R., Farber, S., Grasso, M., Hannon, B., Limburg, K., Naeem, S., O'Neill, R. V., Paruelo, J., Raskin, R. G., Sutton, P., & van den Belt, M. (1997). The value of the world's ecosystem services and natural capital. *Nature*, *387*(6630), 253-260. https://doi.org/10.1038/387253a0

Dolch T., Folmer E.O., Frederiksen M.S., Herlyn M., van Katwijk M.M., Kolbe K., Krause-Jensen D., Schmedes P., & Westerbeek E.P. (2017). Seagrass. In *Wadden Sea Quality Status Report. Eds.: Kloepper S. et al.* Common Wadden Sea Secretariat, Wilhelmshaven, Germany. qsr.waddensea-worldheritage.org/reports/seagrass

EC. (2022). *Proposal for a Regulation of the European Parliament and of the Council on Nature Restoration*. (COM(2022) 304). 2022/0195 (COD) Retrieved from https://environment.ec.europa.eu/publications/nature-restoration-law_en

ED2050. (2021). *Programme plan Ems-Dollart 2050 Programme 2021-2026*. https://eemsdollard2050.nl/english/why-this-program/.

European Commission, Directorate-General for Research Innovation. (2015). *Towards an EU research and innovation policy agenda for nature-based solutions & re-naturing cities : final report of the Horizon 2020 expert group on 'Nature-based solutions and re-naturing cities'*. Publications Office. https://doi.org/10.2777/440514

Faivre, N., Fritz, M., Freitas, T., de Boissezon, B., & Vandewoestijne, S. (2017). Nature-Based Solutions in the EU: Innovating with nature to address social, economic and environmental challenges. *Environmental Research*, *159*, 509-518. https://doi.org/10.1016/j.envres.2017.08.032

Fletcher, S., Lickley, M., & Strzepek, K. (2019). Learning about climate change uncertainty enables flexible water infrastructure planning. *Nat Commun*, *10*(1), 1782. https://doi.org/10.1038/s41467-019-09677-x

Fluet-Chouinard, E., Stocker, B. D., Zhang, Z., Malhotra, A., Melton, J. R., Poulter, B., Kaplan, J. O., Goldewijk, K. K., Siebert, S., Minayeva, T., Hugelius, G., Joosten, H., Barthelmes, A., Prigent, C., Aires, F., Hoyt, A. M., Davidson, N., Finlayson, C. M., Lehner, B., . . . McIntyre, P. B. (2023). Extensive global wetland loss over the past three centuries. *Nature*, *614*(7947), 281-286. https://doi.org/10.1038/s41586-022-05572-6

Geist, J., & Hawkins, S. J. (2016). Habitat recovery and restoration in aquatic ecosystems: current progress and future challenges. *Aquatic Conservation: Marine and Freshwater Ecosystems*, *26*(5), 942-962. https://doi.org/10.1002/aqc.2702

Grases, A., Gracia, V., García-León, M., Lin-Ye, J., & Sierra, J. P. (2020). Coastal Flooding and Erosion under a Changing Climate: Implications at a Low-Lying Coast (Ebro Delta). *Water*, *12*(2), 346. https://doi.org/10.3390/w12020346

Guerreiro, S. B., Dawson, R. J., Kilsby, C., Lewis, E., & Ford, A. (2018). Future heat-waves, droughts and floods in 571 European cities. *Environmental Research Letters*, *13*(3), 034009. https://doi.org/10.1088/1748-9326/aaaad3

Han, D., & Currell, M. J. (2022). Review of drivers and threats to coastal groundwater quality in China. *Science of The Total Environment*, *806*, 150913. https://doi.org/10.1016/j.scitotenv.2021.150913

Henderson, C. J., Gilby, B. L., Schlacher, T. A., Connolly, R. M., Sheaves, M., Maxwell, P. S., Flint, N., Borland, H. P., Martin, T. S. H., Gorissen, B., & Olds, A. D. (2020). Landscape transformation alters functional diversity in coastal seascapes. *Ecography*, *43*(1), 138-148. https://doi.org/10.1111/ecog.04504

Hinkel, J., Lincke, D., Vafeidis, A. T., Perrette, M., Nicholls, R. J., Tol, R. S. J., Marzeion, B., Fettweis, X., Ionescu, C., & Levermann, A. (2014). Coastal flood damage and adaptation costs under 21st century sea-level rise. *Proceedings of the National Academy of Sciences*, *111*(9), 3292-3297. https://doi.org/10.1073/pnas.1222469111

IPCC. (2022). Summary for Policymakers. In *Climate Change 2022 – Impacts, Adaptation and Vulnerability: Working Group II Contribution to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [H.-O. Pörtner, D.C. Roberts, M. Tignor, E.S. Poloczanska, K. Mintenbeck, A. Alegría, M. Craig, S. Langsdorf, S. Löschke, V. Möller, A. Okem, B. Rama (eds.)]* (pp. 3-33). Cambridge University Press. https://doi.org/10.1017/9781009325844.001

IPCC. (2023). Summary for Policymakers. In *Climate Change 2023: Synthesis Report. Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, H. Lee and J. Romero (eds.)]* (pp. 1-34). IPCC, Geneva, Switzerland. https://doi.org/10.59327/IPCC/AR6-9789291691647.001

IUCN. (2020). *Global Standard for Nature-based Solutions. A user-friendly framework for the verification, design and scaling up of NbS* [First edition]. Gland, Switzerland: IUCN. https://doi.org/10.2305/IUCN.CH.2020.08.en

Kabisch, N., Frantzeskaki, N., Pauleit, S., Naumann, S., Davis, M., Artmann, M., Haase, D., Knapp, S., Korn, H., Stadler, J., Zaunberger, K., & Bonn, A. (2016). Nature-based solutions to climate change mitigation and adaptation in urban areas: perspectives on indicators, knowledge gaps, barriers, and opportunities for action. *Ecology and Society*, *21*(2), Article 39. https://doi.org/10.5751/ES-08373-210239

Keesstra, S., Nunes, J., Novara, A., Finger, D., Avelar, D., Kalantari, Z., & Cerdà, A. (2018). The superior effect of nature based solutions in land management for enhancing ecosystem services. *Science of The Total Environment*, *610-611*, 997-1009. https://doi.org/10.1016/j.scitotenv.2017.08.077

Kim, Y., Carvalhaes, T., Helmrich, A., Markolf, S., Hoff, R., Chester, M., Li, R., & Ahmad, N. (2022). Leveraging SETS resilience capabilities for safe-to-fail infrastructure under climate change. *Current Opinion in Environmental Sustainability*, *54*, 101153. https://doi.org/10.1016/j.cosust.2022.101153

Kirwan, M. L., & Megonigal, J. P. (2013). Tidal wetland stability in the face of human impacts and sea-level rise. *Nature*, *504*(7478), 53-60. https://doi.org/10.1038/nature12856

Kulp, S. A., & Strauss, B. H. (2019). New elevation data triple estimates of global vulnerability to sea-level rise and coastal flooding. *Nature Communications*, *10*(1), 4844. https://doi.org/10.1038/s41467-019-12808-z

Lau, J. D., Hicks, C. C., Gurney, G. G., & Cinner, J. E. (2019). What matters to whom and why? Understanding the importance of coastal ecosystem services in developing coastal communities. *Ecosystem Services*, *35*, 219-230. https://doi.org/10.1016/j.ecoser.2018.12.012

Liu, L., Huang, G., Baetz, B., & Zhang, K. (2018). Environmentally-extended input-output simulation for analyzing production-based and consumption-based industrial greenhouse gas mitigation policies. *Applied Energy*, *232*, 69-78. https://doi.org/10.1016/j.apenergy.2018.09.192

MacCuspie, R. I., Hyman, H., Yakymyshyn, C., Srinivasan, S. S., Dhau, J., & Drake, C. (2014). A framework for identifying performance targets for sustainable nanomaterials. *Sustainable Materials and Technologies*, *1-2*, 17-25. https://doi.org/10.1016/j.susmat.2014.11.003

Marijnissen, R., Esselink, P., Kok, M., Kroeze, C., & van Loon-Steensma, J. M. (2020). How natural processes contribute to flood protection - A sustainable adaptation scheme for a wide green dike. *Science of The Total Environment*, *739*, 139698. https://doi.org/10.1016/j.scitotenv.2020.139698

Marijnissen, R. J. C., Kok, M., Kroeze, C., & van Loon-Steensma, J. M. (2021). Flood risk reduction by parallel flood defences – Case-study of a coastal multifunctional flood protection zone. *Coastal Engineering*, *167*, 103903. https://doi.org/10.1016/j.coastaleng.2021.103903

Matthews, G. V. T., & International Union for Conservation of Nature and Natural Resources Ramsar Convention Bureau. (1993). *The Ramsar Convention on Wetlands : its history and development*. Ramsar Convention Bureau.

Mitsch, W. J., Bernal, B., & Hernandez, M. E. (2015). Ecosystem services of wetlands. *International Journal of Biodiversity Science, Ecosystem Services & Management*, *11*(1), 1-4. https://doi.org/10.1080/21513732.2015.1006250

Morris, R. L., Boxshall, A., & Swearer, S. E. (2020). Climate-resilient coasts require diverse defence solutions. *Nature Climate Change*, *10*(6), 485-487. https://doi.org/10.1038/s41558-020-0798-9

Murillas-Maza, A., Broszeit, S., Pouso, S., Bueno-Pardo, J., Ruiz-Frau, A., Terrados, J., Jernberg, S., Iriondo, A., Dolbeth, M., Katsanevakis, S., Somerfield, P. J., & Fernandes-Salvador, J. A. (2023). Ecosystem indicators to measure the effectiveness of marine nature-based solutions on society and biodiversity under climate change. *Nature-Based Solutions*, *4*, 100085. https://doi.org/10.1016/j.nbsj.2023.100085

Myers, S. S., Smith, M. R., Guth, S., Golden, C. D., Vaitla, B., Mueller, N. D., Dangour, A. D., & Huybers, P. (2017). Climate Change and Global Food Systems: Potential Impacts on Food Security and Undernutrition. *Annual Review of Public Health*, *38*(1), 259-277. https://doi.org/10.1146/annurev-publhealth-031816-044356

Narayan, S., Beck, M. W., Reguero, B. G., Losada, I. J., van Wesenbeeck, B., Pontee, N., Sanchirico, J. N., Ingram, J. C., Lange, G.-M., & Burks-Copes, K. A. (2016). The Effectiveness, Costs and Coastal Protection Benefits of Natural and Nature-Based Defences. *PLOS ONE*, *11*(5), e0154735. https://doi.org/10.1371/journal.pone.0154735

Nesshöver, C., Assmuth, T., Irvine, K. N., Rusch, G. M., Waylen, K. A., Delbaere, B., Haase, D., Jones-Walters, L., Keune, H., Kovacs, E., Krauze, K., Külvik, M., Rey, F., van Dijk, J., Vistad, O. I., Wilkinson, M. E., & Wittmer, H. (2017). The science, policy and practice of nature-based solutions: An interdisciplinary perspective. *Science of The Total Environment*, *579*, 1215-1227. https://doi.org/10.1016/j.scitotenv.2016.11.106

Palomo, I., Locatelli, B., Otero, I., Colloff, M., Crouzat, E., Cuni-Sanchez, A., Gómez-Baggethun, E., González-García, A., Grêt-Regamey, A., Jiménez-Aceituno, A., Martín-López, B., Pascual, U., Zafra-Calvo, N., Bruley, E., Fischborn, M., Metz, R., & Lavorel, S. (2021). Assessing nature-based solutions for transformative change. *One Earth*, *4*(5), 730-741. https://doi.org/10.1016/j.oneear.2021.04.013

Paxton, A. B., Riley, T. N., Steenrod, C. L., Smith, C. S., Zhang, Y. S., Gittman, R. K., Silliman, B. R., Buckel, C. A., Viehman, T. S., Puckett, B. J., & Davis, J. (2023). What evidence exists on the performance of nature-based solutions interventions for coastal protection in biogenic, shallow ecosystems? A systematic map protocol. *Environmental Evidence*, *12*(1), 11. https://doi.org/10.1186/s13750-023-00303-4

Pérez, G., O'Leary, B. C., Allegri, E., Casal, G., Cornet, C. C., de Juan, S., Failler, P., Fredriksen, S., Fonseca, C., Furlan, E., Gil, A., Hawkins, J. P., Maréchal, J.-P., McCarthy, T., Roberts, C. M., Trégarot, E., van der Geest, M., & Simide, R. (2024). A conceptual framework to help choose appropriate blue nature-based solutions. *Journal of Environmental Management*, *352*, 119936. https://doi.org/10.1016/j.jenvman.2023.119936

Piatt, J. F., Parrish, J. K., Renner, H. M., Schoen, S. K., Jones, T. T., Arimitsu, M. L., Kuletz, K. J., Bodenstein, B., García-Reyes, M., Duerr, R. S., Corcoran, R. M., Kaler, R. S. A., McChesney, G. J., Golightly, R. T., Coletti, H. A., Suryan, R. M., Burgess, H. K., Lindsey, J., Lindquist, K., . . . Sydeman, W. J. (2020). Extreme mortality and reproductive failure of common murres resulting from the northeast Pacific marine heatwave of 2014-2016. *PLOS ONE*, *15*(1). https://doi.org/10.1371/journal.pone.0226087

Ridder, N. N., Pitman, A. J., Westra, S., Ukkola, A., Do, H. X., Bador, M., Hirsch, A. L., Evans, J. P., Di Luca, A., & Zscheischler, J. (2020). Global hotspots for the occurrence of compound events. *Nature Communications*, *11*(1), 5956. https://doi.org/10.1038/s41467-020-19639-3

Riisager-Simonsen, C., Fabi, G., van Hoof, L., Holmgren, N., Marino, G., & Lisbjerg, D. (2022). Marine nature-based solutions: Where societal challenges and ecosystem requirements meet the potential of our oceans. *Marine Policy*, *144*, 105198. https://doi.org/10.1016/j.marpol.2022.105198

Sánchez-Arcilla, A., Cáceres, I., Roux, X. L., Hinkel, J., Schuerch, M., Nicholls, R. J., Otero, d. M., Staneva, J., de Vries, M., Pernice, U., Briere, C., Caiola, N., Gracia, V., Ibáñez, C., & Torresan, S. (2022). Barriers and enablers for upscaling coastal restoration. *Nature-Based Solutions*, *2*, 100032. https://doi.org/10.1016/j.nbsj.2022.100032

Schoonees, T., Gijón Mancheño, A., Scheres, B., Bouma, T. J., Silva, R., Schlurmann, T., & Schüttrumpf, H. (2019). Hard Structures for Coastal Protection, Towards Greener Designs. *Estuaries and Coasts*, *42*(7), 1709-1729. https://doi.org/10.1007/s12237-019-00551-z

Seddon, N. (2022). Harnessing the potential of nature-based solutions for mitigating and adapting to climate change. *Science*, *376*(6600), 1410-1416. https://doi.org/10.1126/science.abn9668

Seddon, N., Smith, A., Smith, P., Key, I., Chausson, A., Girardin, C., House, J., Srivastava, S., & Turner, B. (2021). Getting the message right on nature-based solutions to climate change. *Global Change Biology*, *27*(8), 1518-1546. https://doi.org/10.1111/gcb.15513

Short, C., Clarke, L., Carnelli, F., Uttley, C., & Smith, B. (2019). Capturing the multiple benefits associated with nature-based solutions: Lessons from a natural flood management project in the Cotswolds, UK. *Land Degradation & Development*, *30*(3), 241-252. https://doi.org/10.1002/ldr.3205

Smale, D. A., Wernberg, T., Oliver, E. C. J., Thomsen, M., Harvey, B. P., Straub, S. C., Burrows, M. T., Alexander, L. V., Benthuysen, J. A., Donat, M. G., Feng, M., Hobday, A. J., Holbrook, N. J., Perkins-Kirkpatrick, S. E., Scannell, H. A., Sen Gupta, A., Payne, B. L., & Moore, P. J. (2019). Marine heatwaves threaten global biodiversity and the provision of ecosystem services. *Nature Climate Change*, *9*(4), 306-312. https://doi.org/10.1038/s41558-019-0412-1

Sowińska-Świerkosz, B., & García, J. (2022). What are Nature-based solutions (NBS)? Setting core ideas for concept clarification. *Nature-Based Solutions*, *2*, 100009. https://doi.org/10.1016/j.nbsj.2022.100009

Spalding, M. D., Ruffo, S., Lacambra, C., Meliane, I., Hale, L. Z., Shepard, C. C., & Beck, M. W. (2014). The role of ecosystems in coastal protection: Adapting to climate change and coastal hazards. *Ocean & Coastal Management*, *90*, 50-57. https://doi.org/10.1016/j.ocecoaman.2013.09.007

Stéfanon, M., Drobinski, P., D'Andrea, F., Lebeaupin-Brossier, C., & Bastin, S. (2014). Soil moisture-temperature feedbacks at meso-scale during summer heat waves over Western Europe. *Climate Dynamics*, *42*(5), 1309-1324. https://doi.org/10.1007/s00382-013-1794-9

Steffelbauer, D. B., Riva, R. E. M., Timmermans, J. S., Kwakkel, J. H., & Bakker, M. (2022). Evidence of regional sea-level rise acceleration for the North Sea. *Environmental Research Letters*, *17*(7). https://doi.org/10.1088/1748-9326/ac753a

Temmerman, S., Meire, P., Bouma, T. J., Herman, P. M. J., Ysebaert, T., & De Vriend, H. J. (2013). Ecosystem-based coastal defence in the face of global change. *Nature*, *504*(7478), 79-83. https://doi.org/10.1038/nature12859

Tiggeloven, T., de Moel, H., van Zelst, V. T. M., van Wesenbeeck, B. K., Winsemius, H. C., Eilander, D., & Ward, P. J. (2022). The benefits of coastal adaptation through conservation of foreshore vegetation. *Journal of Flood Risk Management*, *15*(3), e12790. https://doi.org/10.1111/jfr3.12790

Tiggeloven, T., de Moel, H., Winsemius, H. C., Eilander, D., Erkens, G., Gebremedhin, E., Diaz Loaiza, A., Kuzma, S., Luo, T., Iceland, C., Bouwman, A., van Huijstee, J., Ligtvoet, W., & Ward, P. J. (2020). Global-scale benefit–cost analysis of coastal flood adaptation to different flood risk drivers using structural measures. *Nat. Hazards Earth Syst. Sci.*, *20*(4), 1025-1044. https://doi.org/10.5194/nhess-20-1025-2020

UN. (2015). *Transforming our world: the 2030 Agenda for Sustainable Development*. Resolution Adopted by the General Assembly on 25 September 2015. https://doi.org/10.1007/s13398-014-0173-7.2

van Loon-Steensma, J. M. (2021). *Overzicht adaptatie-gerelateerd projecten Waddenkust*. Waddenacademie. https://edepot.wur.nl/550812

van Loon-Steensma, J. M., & Goldsworthy, C. (2022). The application of an environmental performance framework for climate adaptation innovations on two nature-based adaptations. *Ambio*, *51*(3), 569-585. https://doi.org/10.1007/s13280-021-01571-5

van Loon-Steensma, J. M., & Kok, M. (2016). Risk reduction by combining nature values with flood protection? *E3S Web Conf.*, *7*, 13003. https://doi.org/10.1051/e3sconf/20160713003

van Loon-Steensma, J. M., & Schelfhout, H. A. (2020). Innovatieve dijkconcepten : Waterveiligheidsopgave als katalysator voor innovatie in het Eems-Dollardgebied. *Landschap : tijdschrift voor landschapsecologie en milieukunde 37 (3): 130 - 139*. https://edepot.wur.nl/532283

van Loon-Steensma, J. M., Schelfhout, H. A., van Hattum, T., Smale, A., Gözüberk, I., & van Dijken, M. (2014a). *Innovatieve dijken als strategie voor een veilig en aantrekkelijk Waddengebied : Samenvatting van het Deltaprogramma Waddengebied onderzoek naar innovatieve dijken*

[Alterra-Report; No. 2535]. Ministerie van Infrastructuur en Milieu. https://edepot.wur.nl/320454

van Loon-Steensma, J. M., Schelfhout, H. A., & Vellinga, P. (2014b). Green adaptation by innovative dike concepts along the Dutch Wadden Sea coast. *Environmental Science & Policy*, *44*, 108-125. https://doi.org/10.1016/j.envsci.2014.06.009

van Loon-Steensma, J. M., & Vellinga, P. (2013). Trade-offs between biodiversity and flood protection services of coastal salt marshes. *Current Opinion in Environmental Sustainability*, *5*(3), 320-326. https://doi.org/10.1016/j.cosust.2013.07.007

Vuik, V., Borsje, B. W., Willemsen, P. W. J. M., & Jonkman, S. N. (2019). Salt marshes for flood risk reduction: Quantifying long-term effectiveness and life-cycle costs. *Ocean & Coastal Management*, *171*, 96-110. https://doi.org/10.1016/j.ocecoaman.2019.01.010

Wamsley, T. V., Cialone, M. A., Smith, J. M., Atkinson, J. H., & Rosati, J. D. (2010). The potential of wetlands in reducing storm surge. *Ocean Engineering*, *37*(1), 59-68. https://doi.org/10.1016/j.oceaneng.2009.07.018

Wang, F., Sanders, C. J., Santos, I. R., Tang, J., Schuerch, M., Kirwan, M. L., Kopp, R. E., Zhu, K., Li, X., Yuan, J., Liu, W., & Li, Z. a. (2020). Global blue carbon accumulation in tidal wetlands increases with climate change. *National Science Review*, *8*(9). https://doi.org/10.1093/nsr/nwaa296

Waryszak, P., Gavoille, A., Whitt, A. A., Kelvin, J., & Macreadie, P. I. (2021). Combining gray and green infrastructure to improve coastal resilience: lessons learnt from hybrid flood defenses. *Coastal Engineering Journal*, *63*(3), 335-350. https://doi.org/10.1080/21664250.2021.1920278

Wheeler, T., & von Braun, J. (2013). Climate Change Impacts on Global Food Security. *Science*, *341*(6145), 508-513. http://www.jstor.org/stable/23491201

World Bank. (2008). *Biodiversity, Climate Change, and Adaptation : Nature-based Solutions from the World Bank Portfolio*. © World Bank, Washington, DC. http://documents.worldbank.org/curated/en/149141468320661795/Biodiversity-climate-change-and-adaptation-nature-based-solutions-from-the-World-Bank-portfolio