

<b>WP 3</b>	<b>Milestone No. 28</b>
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**MARBEFES Project**

**Interim report on frameworks for modelling and assessing ecological phenomena in the BBTs**

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**Title of the document:** Interim report on frameworks for modelling and assessing ecological phenomena in the BBTs (M28)

**TABLE OF CONTENTS**

<b>1. Introduction.....</b>	<b>4</b>
<b>2. Actions for framework development.....</b>	<b>5</b>
<b>3. Activity 3.2a: Assessing seascape ecosystem organisation and function .....</b>	<b>5</b>
<b>4. Activity 3.2b (ii): Broadscale trait-based approaches: framework and planned activities .....</b>	<b>5</b>
<b>5. Causal path analysis .....</b>	<b>6</b>
<b>6. Outlook and future steps .....</b>	<b>7</b>
<b>7. References .....</b>	<b>8</b>
<b>8. List of appendices (<i>documents available for internal project use</i>).....</b>	<b>8</b>
<b><i>8.1. Assessing ecosystem organisation and function, guidance document.....</i></b>	<b>8</b>
<b><i>8.2. Broadscale trait-based approaches, guidance document.....</i></b>	<b>8</b>
<b><i>8.3. Table describing activities using trait-based approaches in MARBEFES WP3 .....</i></b>	<b>8</b>



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## 1. Introduction

This milestone documents actions and achievements in MARBEFES WP3 (Biodiversity and Ecosystem Tools) and task 3.2: *Tools for exploring ecological phenomena*, focusing on the development of frameworks for modelling and assessing ecological phenomena in MARBEFES Broad Belt Transects (BBTs). A summary of the task description based on the project proposal is given below:

### *WP3 Biodiversity and Ecosystem Tools*

***Task 3.2: Tools for exploring ecological phenomena*** (Lead ABO; IO PAN, LE ERIC, APN, IECS, KU, TU, CNR, UCD, GEOECOMAR, UC, FIHAC, CSIC, AWI, UEA, HCMR, NBE, BC3). This task will develop tools to explore ecological connectivity and the links between biodiversity and function across seascapes.

***Activity 3.2a: Guidelines for assessing seascape ecosystem organisation and function:*** Drawing on 3.1a, 3.2a will develop guidelines for characterising seascape diversity and function in the BBTs. It will generate guidance for the analysis of relevant parameters for key aspects of structure and function, advising how to integrate them across the seascape. It will also consider how existing monitoring frameworks can be adapted and data better used broadly in relation to broader seascape diversity, function and ecosystem services; determining the extent to which programmes can serve multiple purposes (e.g., biodiversity monitoring data for natural capital assessment).

***Activity 3.2b: Techniques for modelling ecological phenomena:*** It will compare models of seascape structure, function, stability, and dynamics for better understanding the connections between biological entities. The models will be reviewed according to criteria on data requirements and capabilities, culminating in advice on which can be best used in different circumstances. T3.2c will further develop selected models to improve coverage of the river-sea continuum, benthic-pelagic coupling, population-level drivers (e.g. sex-determined space use and better species representation (microscopic organisms, plants, algae, invertebrates, fish, apex predators)).

***Activity 3.2c: Metric of habitat function:*** It will create a metric of habitat function and linked provision of ecosystem services by developing a quantitative habitat-focussed matrix of key functions per habitat, using empirical data to define mechanistic links between habitats, key functions and services.

Note that Activity 3.2b (Techniques for modelling ecological phenomena) consists of three sub-activities, as follows; (i) ecological interaction networks, (ii) broadscale trait-based approaches, and (iii) Bayesian belief networks (hereafter referred to as causal path analyses). This document is structured according to the corresponding list of activities in the proposal.



## 2. Actions for framework development

During project months 13-24, MARBEFES task 3.2. advanced as planned, producing guideline documents for assessing seascape ecosystem organisation and function (Activity 3.2a) and for broadscale trait-based approaches (Activity 3.2b). Activity 3.2a progressed through online discussions with the corresponding partner for Activity 3.1a. Activity 3.2b advanced through the sub-activity (ii) providing guidance on the development and application of broadscale trait-based approaches in the BBTs. A two-day workshop was held in Turku, Finland (25-26.10.2023) (with an option for remote attendance), during which the work using trait-based approaches in WP3 was outlined. Trait-based approaches are central to several tasks within WP3 therefore links, complementarity and synergies were identified among tasks 3.2, 3.3, 3.4 and the different activities within these. Guidelines for the trait-based work under sub-activity 3.2b(ii) were provided to the BBTs and presented during an online meeting (13.6.2024). Guidelines produced within the task are available for project internal use (see appendices 8.1 and 8.2). In addition, the previously introduced approaches on ecological interaction networks (Activity 3.2b(i)) and the metric of habitat functioning (Activity 3.2c) are undergoing initial testing in selected BBTs. Overall, collective and individual partner actions included workshops and online meetings, researcher visits, literature reviews, as well as continued model reviews on data requirements and capabilities.

### 3. Activity 3.2a: Assessing seascape ecosystem organisation and function

MARBEFES BBTs are provided guidelines for assessing seascape geochemistry and physical conditions (Activity 3.1a), and in parallel, guidelines for assessing ecosystem organisation and function (Activity 3.2a) (appendix 8.1). The latter guidelines focus on levels of biodiversity (alpha, beta, gamma), on spatial structuring of the seascape, and provide examples of fundamental metrics (richness, diversity, evenness) to describe structure and function. The examples in the guidance document address standard taxonomic approaches, trait-based approaches, and habitat-based approaches. In addition, widely accepted ecological theories and paradigms relevant for seascape ecology are mentioned. Finally, the guidelines provide a set of basic recommendations for BBT descriptions and further link to the ongoing development of trait-based approaches (see example below) and functional assessment in MARBEFES. Finally, the guidance document explores how data stemming from monitoring programs can be used more broadly, and what challenges still remain for employing monitoring data for multiple purposes.

### 4. Activity 3.2b (ii): Broadscale trait-based approaches: framework and planned activities

Traits can be defined as individual-level attributes describing species morphology, physiology, life-history, and behaviour (Violle et al. 2007). Species traits form a fundamental dimension of biodiversity, connecting the organisms to their environment. Trait-based approaches apply species attributes either as response traits (the traits determining how species react to changes in the environment) or as effect traits (the traits governing how species influence their environment by contributing to



ecosystem functions or processes). The fundamental trait-based approaches focus on these to link community composition to ecosystem functioning in a complex and changing environment. Traits also constitute a framework that allows for better understanding of what governs interactions among organisms (Olivier et al. 2024), which can help in predictions of the subsequent implications for ecosystem functioning from changes in biodiversity.

Here, the main activities advancing broadscale trait-based approaches under task 3.2 are listed. Appendix 8.2 provides the guidelines for the proposed work to the BBTs, focusing on assessment of traits on community level at habitat scale, as well as trait biogeographies. Appendix 8.3 provides an overview table of the general structure of the trait-based work in WP3 (across tasks 3.2-3.4).

1. *Assessment of traits on community level for different habitats*: to determine habitat variability employing the biological trait approach.
2. *Linkage of traits to ecological functions/services – blue carbon*: to develop a method for linking traits to functions, focusing on carbon flow and carbon sequestration in various benthic habitats, and basing analyses on empirical data.
3. *Trait biogeography*: to map single traits within and across BBTs, compiling an ecosystem barcode list based on the traits.
4. *Assessment of key traits*: to determine feeding rates and growth rates through review and collation of existing literature and data from BBTs. Aids the assessment of traits linked to carbon flow.

Coordination and harmonization across tasks will continue, enabling advancement and testing of trait-based approaches on a broad scale.

## 5. Causal path analysis

Causal path analysis methods in MARBEFES refers to two distinct but complementary methods: Bayesian Belief Network (BBN) and Structural Equation Modelling (SEM). They are both statistical methods of network analysis that aim at quantifying the relative strength of multivariate relationships among the factors of a network under a causal framework (the different causations within the network are hypothesized from prior knowledge). Both approaches have been extensively used in ecological science (Ramazi et al. 2019) but while the literature on using BBN to support (e.g.) Marine Spatial Planning or Ecological Risk Assessment is abundant (Gimpel et al. 2018), SEM approaches are rare and tend to be used to explain the current state of ecological system; SEM confronts hypothesized causal relationships with empirical data to test the theoretical understanding of a system (Grace et al. 2010). BBN is a probabilistic graphical model that represents conditional dependencies between random variables where these association may or may not be causal (again causation or no causation is hypothesized from prior knowledge). This means that SEM is best for empirical validations of



theoretical concepts while BBN has better predictive and diagnostic (scenarios) abilities (Gupta & Kim 2008).

In this MARBEFES activity, infrastructure has been constructed for multiple SEM concepts relating to hypothesized description of seabed services to be applied to the Irish Sea BBT in a first instance before deploying them for other BBTs (data permitting). Work is currently focused on coupling these conceptual models to make them compatible with the Bayesian Belief Network approach. In the same way, BBN application and direct SEM comparison will be first implemented in the Irish Sea BBT before being deployed elsewhere.

## 6. Outlook and future steps

The previous (M27) and the current (M28) 3.2 milestones focus on tool development and provision of associated guidance documents to BBTs. The upcoming 3.2 milestone (M29) is scheduled for project month 34 (June 2025) and will contain results from first testing in BBTs, including the application of ecological interaction networks, broad-scale trait-based approaches, a metric of habitat functioning, as well as causal path analysis. Before then, active assessment and revision of guidelines continues in tight collaboration with WP2 as well as through parallel activities in WP3. As an immediate step in the near future, work during the General Assembly in October 2024 will be built around interactions within WP3 (among tool developers), between WP3 and WP2 (BBTs, or tool appliers), between WP3 and WP1 (stakeholders), as well as the other parts of the consortium (WP4-6).



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## 8. List of appendices (*documents available for internal project use*)

**8.1. Assessing ecosystem organisation and function, guidance document**

**8.2. Broadscale trait-based approaches, guidance document**

**8.3. Table describing activities using trait-based approaches in MARBEFES WP3**



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