WP 3	Milestone No. 3.2

MARBEFES Project

Interim report on frameworks for modelling and assessing ecological phenomena in the BBTs
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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 A3.1a, 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) broadscale trait-based approaches, (ii) ecological interaction networks, 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.

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2. Actions for framework development

Work during the first year of framework development (M1-12) spanned activities 3.2b and 3.2c., which contribute to activity 3.2a. Collective and individual partner actions included multiple webinars, researcher visits, literature reviews, as well as model reviews on data requirements and capabilities, with efforts resulting in three leaflets and two sets of draft guidelines for BBTs by M12 (appendices 5.1-5.5).

3. Frameworks in brief

Below, we provide a brief summary for each approach explored for use in BBT assessments of ecological connectivity and links between biodiversity and function across seascapes. All approaches explore biodiversity-ecosystem functioning but are complementary in their focal point (Figure 1). Traits (although based on community composition estimates) describe functional diversity through species attributes and food web networks focus on interactions as the biodiversity dimension of interest. These biodiversity elements are then related to ecosystem processes or help infer them. For all the approaches, the relationship between biodiversity and ecosystem functioning are applicable to testing in spatially complex seascapes. Much of the initial testing in the BBTs is likely to focus on benthic habitats, benthic habitat-forming species and associated invertebrate and vertebrate communities, but all approaches are applicable to broad taxonomic groups (theoretically possible to include taxa from microbes to mammals). Further, all approaches are adaptable to differing data availability among BBTs, and options for qualitative vs. quantitative diversity information are described. See the appendices for more detailed examples of the proposed approaches, adaptation options for different data availability and related output in the form of leaflets as well as guidelines (internal drafts).

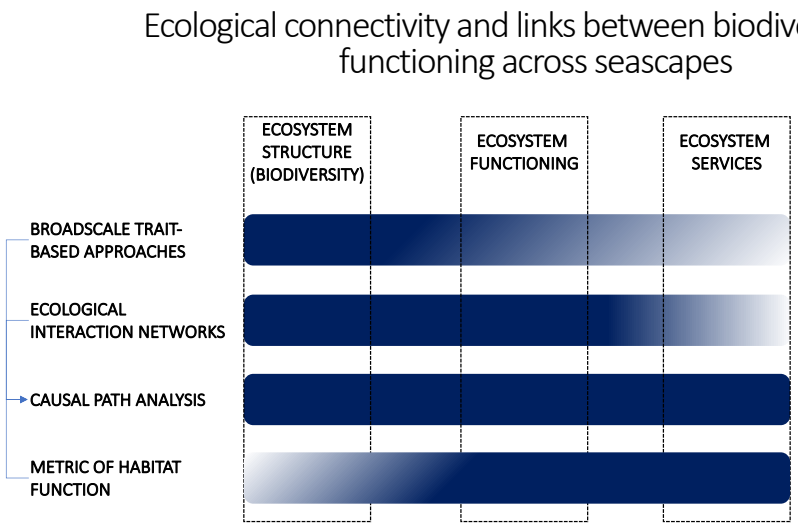

Figure 1. Conceptual figure describing emphasis of approaches on biodiversity, ecosystem functioning and services across the seascape. Trait-based output, interaction networks and the metric of habitat function are to feed into the overarching causal path analysis.

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3.1. Broadscale trait-based approaches (Activity 3.2b)

Traits can be defined as individual-level attributes describing species morphology, physiology, life-history, and behaviour (Appendix 5.1). Species traits form a fundamental part 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, or to better understand interactions among organisms resulting from changes in biodiversity.

BBT-specific ecological assessments using biological trait approaches have already emerged through MARBEFES (Magni et al. 2023, Salo et al. 2023, Olivier et al. *unpublished*), showing readiness for further development of trait-based approaches in a BBT setting.

- Magni P., Vesal S.E., Giampaoletti J., Como S., and Gravina M.F. (2023). Joint use of biological traits, diversity and biotic indices to assess the ecological quality status of a Mediterranean transitional system. *Ecological Indicators* 147: 109939. https://doi.org/10.1016/j.ecolind.2023.109939
- Salo T., Rinne H., Rancken E., Blanc J-F., Salovius-Laurén S., and Nordström M.C. (2023). Environment- and scale-dependent changes in the functioning of invertebrate communities associated with *Fucus vesiculosus*. *Estuarine, Coastal and Shelf Science* 290: 108411. https://doi.org/10.1016/j.ecss.2023.108411
- Olivier P., Lindegren M., Bonsdorff E., and Nordström M.C. (*Revised version submitted*) A network of biological traits: profiling consumer-resource interactions.

Broadscale trait-based approaches in task 3.2. will, as the next steps, focus on formulating theoretical and mechanistic models of trait expression, and on applying them holistically across groups. The following workshop is scheduled for M14. Trait-based approaches have become ubiquitous in marine ecological research and are part of multiple tasks and activities within MARBEFES, not only in task 3.2., and coordination and harmonization across tasks is required.

3.2. Ecological interaction networks (Activity 3.2b)

With their explicit link between biodiversity and functioning, ecological interaction networks representing food webs offer a versatile tool for assessments of marine community structure and processes, resilience, and dynamics in changing environments. Ecological interaction networks can help increase our understanding of how organisms are connected within the food web, as well as of connectivity across multiple habitats in complex seascapes. The available leaflet (Appendix 5.2.) and guidelines (Appendix 5.3.) together provide a primer for ecological interaction networks, as well as describe data requirements and possibilities for BBTs aiming to quantify food web structure (topology) and/or functioning (energy fluxes, bioenergetic modelling), as common currencies across the seascape. Although the guidelines focus on trophic interactions, corresponding network approaches

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can be used for non-trophic interactions (e.g., facilitation), or to assess associations or co-occurrences of species, traits (e.g., Olivier et al. *unpublished*), or functions across habitats.

Ecological interaction networks will as the next step be applied to BBT data. Initial testing has been discussed with Baltic Sea BBTs, and participation is open to all.

3.3. Causal path analysis (Activity 3.2b)

The MARBEFES proposal specified Bayesian belief networks (BBN) as a main approach for the activity. As the initial actions identified benefits with including BBN as well as structural equation modelling (SEM) as parallel and complementary approaches, we hereafter refer to *causal path analysis*, which is an overarching framework encompassing BBN, as well as SEM (Appendix 5.4.). Causal path analysis is a powerful statistical framework that aims at quantifying the relative strength of the multivariate relationships among the key factors of a network. In a MARBEFES context, the approach has the potential to explicitly represent and assess how the environmental setting and associated ecosystem functioning delivers services and societal goods and benefits.

The leaflet provides information on the causal path analysis approach, and the setting for the upcoming work within the activity. The next actions and the timeline until M24 will be decided on by M14.

3.4. Metric of habitat function (Activity 3.2c)

The proposed metric of habitat function allows BBTs to assess functioning and ecosystem services across habitats (see guidelines in Appendix 5.5). A literature review was conducted to capitalize and build on already available approaches, however, none was found entirely suitable for the purpose. The objective was a quantitative, habitat-focussed matrix adaptable to BBTs with different levels of data availability. The resulting guidelines accommodate this and allow BBTs to use different levels of information available, from combining habitat maps and expert knowledge (level 1) to incorporating empirical information with high spatial resolution on ecosystem processes (level 4). Regarding the instructions for the spatial analysis, the approach was harmonized with other guidelines in MARBEFES, more specifically, task 4.1. on Ecological Value Assessment.

The proposed guidelines for the Metric of habitat function are now available for (internal) feedback, and synergies with other WP3 approaches will be explored. Initial testing in the Menorca Channel BBT is planned.

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4. References

Magni P., Vesal S.E., Giampaoletti J., Como S., and Gravina M.F. (2023). Joint use of biological traits, diversity and biotic indices to assess the ecological quality status of a Mediterranean transitional system. *Ecological Indicators* 147: 109939. https://doi.org/10.1016/j.ecolind.2023.109939

Salo T., Rinne H., Rancken E., Blanc J-F., Salovius-Laurén S., and Nordström M.C. (2023). Environment- and scale-dependent changes in the functioning of invertebrate communities associated with *Fucus vesiculosus*. *Estuarine, Coastal and Shelf Science* 290: 108411. https://doi.org/10.1016/j.ecss.2023.108411

Olivier P., Lindegren M., Bonsdorff E., and Nordström M.C. (*Revised version submitted*) A network of biological traits: profiling consumer-resource interactions.

5. List of appendices

5.1. Broadscale trait-based approaches, leaflet

5.2. Ecological interaction networks, leaflet

5.3. Ecological interaction networks, guidance document (internal)

5.4. Causal path analysis, leaflet

5.5. Metric of habitat function, guidance document (internal)

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