Key aggregation methods for the toolbox
Milestone M4.3

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1. GES4SEAS Project Summary

Human activities at sea (e.g., maritime transport, extraction of living and non-living resources, etc.) and in coastal areas (e.g., agriculture, leisure and recreation, etc.) have expanded considerably, leading to an increased level of pressures and subsequent degradation of ocean health and, ultimately, human health. Single and cumulative impacts of these activities are likely to increase, driven by human demands and enhanced by climate change.

Human activities evolve following socio-economic drivers leading to pressures, which often are studied in isolation from each other even though their impacts on marine ecosystems can interact, making the effects cumulative (e.g., synergistic, antagonistic or a combination). Knowledge on these interactions and their cumulative effects in the marine environment has increased in recent years, but huge challenges still remain to be solved. Thus, there is little predictability with which to inform decision-making processes, especially on ecological tipping points, which, if exceeded, could lead to a point of no-return for the system. In this context, an ecosystem-based management (EBM) approach to the management of human activities at sea and on land should ensure that the combined pressure of such activities is kept within levels compatible with the achieving Good Environmental Status (GES) (requirements of the Marine Strategy Framework Directive – MSFD), against a background of climate change. This means that the capacity of marine and coastal ecosystems to respond to human-induced changes is not compromised, enabling the sustainable use of marine goods and services by present and future generations.

Thus, the main objective of GES4SEAS is to inform and guide marine governance in minimizing human pressures and their impacts on marine biodiversity and ecosystem functioning, while maintaining the sustainable delivery of ecosystem services. This will be achieved through developing an innovative and flexible toolbox, tested, validated, demonstrated and upscaled, in the context of adaptive EBM approach. The toolbox will allow competent authorities to assess and predict the effect of multiple stressors (including climate change) and pressures from human activities, at the national, sub-regional, regional and European level. Ultimately, this will ensure they achieve GES, and support different policies at national, European and global levels (e.g. Birds and Habitats Directives (BHD), Biodiversity Strategy 2030, United Nations Sustainable Development Goals (SDG)).

Stakeholders and the key competent authorities (including national, regional and European levels) are integrated in a Practitioner Advisory Board (PAB) to co-create and validate the toolbox and the EBM approach. This will result on a real problem-solving approach with iterative and incremental development steps.

GES4SEAS will also rely on existing multi-actor networks to involve and engage with stakeholders. This multi-actor approach will ensure that the research and deliverables are relevant to marine managers all around the world. Lastly, it is important to highlight that the toolbox will be tested and demonstrated at 11 Learning Sites (LSs) covering all European regional seas (and also overseas), and environments. Thus, it is expected that GES4SEAS will achieve Technological and Societal Readiness Levels 6. This will be achieved by the participation of 20 partners, covering the four European regional seas and Canada.

It is expected that GES4SEAS will:

- Operationalize integrative and holistic solutions for EBM, based upon a software toolbox for analyzing, assessing and mapping cumulative pressures, GES and ecosystem services.
- Provide evidence (and training) to key stakeholders of the benefits of using the toolbox that will be developed in GES4SEAS for assessing the environmental status of marine waters and the ecosystem services considering the effects of multiple pressures so opt for using it.
- Ensure the EBM approach and guidelines for the management of Invasive Alien Species (IAS), harmful algal blooms (HABs) and jellyfish, the approach for monitoring top predators are used by end-users.
- Investigate, using models, the best ways to obtain thresholds of GES/non-GES status and tipping points (system breaking points).
- Reach and engage a wider society, and specifically young people and educators, on key messages steaming from this project, so GES4SEAS contributes to societal ocean literacy and responsible behaviours.

2. Introduction

The term "aggregation" is here used as defined in Barnard & Strong (2014):

> *Aggregation (also referred to as 'integration' in some literature) is defined as "any rule or rules which exist to standardise the bringing together of data at different spatial or temporal scales, or across different ecosystem components or aspects of the assessment".*

There are many ways to aggregate values from indicators or criteria (in general, any variable that may form the input data of an assessment), when assessing the environmental, ecological or chemical status of marine waters (Borja et al. 2013; Borja et al. 2014; Barnard & Strong 2014, Langhans et al. 2014; Dierschke et al. 2021). For this milestone, we have identified the main methods used currently in MSFD and WFD assessments and some additional methods which will be included in the toolbox, as a selection choice for the users.

The following methods will be implemented with flexibility in the toolbox, having the possibility of selecting one or another, depending on the criteria, indicators, species, descriptors, etc., as well as the needs from end-users (i.e. national authorities, Regional Seas Conventions, etc.) or from legislation.

3. Selected methods

3.1 Method: one-out, all-out (OOAO)

Definition: When one indicator fails, the whole aggregation result indicates a failed achievement of the target status.

Rationale: This is the most conservative method, making sure only all indicators/criteria meet the requirements. The method can also be applied in a hierarchical way (clustering related indicators/criteria) for additional transparency/clarity where e.g. biological, chemical and supporting indicators are first rated using OOAO individually and in a second step their results are aggregated using OOAO too. Note, that this hierarchical structure has no influence on the outcome. (In a mixed assessment, the individual groups may apply an aggregation method different from the OOAO method. It has not been decided yet whether such schemes should be implemented in the toolbox.)

For more details see Borja & Rodriguez (2010) and Prato et al. (2014).

3.2 Method: partial OOAO

Definition: OOAO applied for a specific portion of indicators/criteria that are regarded as essential, other indicators/criteria may or may not contribute to the result.

Rationale: Enables to build sensible groups representative of the final result to be achieved. One example of this method is TOAO (two-out, all-out: if two variables do not meet the required standard, good status is not achieved) which is considered more robust than OOAO while being slightly less strict/precautionary.

For more details see Barnard & Strong (2014).

3.3 Method: proportions

Definition: This is a variation of the OOAO or TOAO method working with percentages of indicators/criteria instead of counts.

Rationale: This method works on the principle that a proportion of e.g. species within a higher group or a proportion of indicators are within agreed limits. While the absolute count (as in OOAO and TOAO) represents a varying proportion depending on the total number of indicators/criteria, the percentage is a normalized version of the counts. This can e.g. increase the comparability of between assessments having a different amount of indicators/criteria and is a better fit when many indicators/criteria are involved. The threshold value can be informed by examining the properties of the species and of the data (e.g. uncertainty). Ranges of percentages or proportions could be chosen as well.

For more details see ICES (2016).

3.4 Method: (weighted/hierarchical) average

Definition: The (possibly weighted and/or hierarchical) average of indicators/criteria values where the result should be above a certain threshold value. [This method could also be done using the median.]

Rationale: The indicators/criteria can be ranked according to their importance for the final result and thus assigned to have corresponding weights. The actual weighting (if any) can be done in several ways and the toolbox will include flexibility in choosing the weighting method. One way is also to use a hierarchical relationship between indicators/criteria/spatial extent to determine the weighting (e.g. as in the NEAT method). Another way is giving different weights to primary and secondary criteria (e.g. under MSFD or upon perceived strength of links to the desired outcome). If not enough information is available on the influence of the indicators/criteria, the weighting can be omitted.

For more details see Uusitalo et al. (2016).

3.5 Method: counts of indicators/criteria

Definition: A predefined set of indicators/criteria should achieve the result irrespective of which these are.

Rationale: It is often difficult to apply every indicator/criterion so getting e.g. a specific percentage of indicators/criteria above some threshold can already be an indication of achieving the result.

For more details see Borja et al. (2011).

3.6 Method: decision tree

Definition: A set of rules (if … then … else …) applied to specific indicators/criteria deciding whether results are used for aggregation and in which way they are used. The specific rules at each step can potentially include the other methods from this milestone, i.e. the conditions may be simple (e.g. OOAO) or sequential (e.g. if one criterion is met, a further criterion is evaluated consequently).

Rationale: Enable to set specific rules for each (set of) indicators/criteria that reflects how they depend on or supplement each other. This method can utilize interdependencies between indicators/criteria and derive decision rules on that basis. It is the most versatile of all methods, especially as it can include the other methods at each step in the decision process. Decision trees can flexibly include any rule at any step.

For more details see Sagarminaga et al. (2023), which included a very recent example of a decision tree (GES4HABS) developed by GES4SEAS.

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