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Hydromorphological Assessment of Coastal Waters: Is a GIS-Based Pan-European Assessment Method Feasible? †

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Abstract: Multiple human activities are concentrated along the coasts, causing various physical alterations to hydromorphological (HM) features of coastal ecosystems. We reviewed available knowledge and tools as a basis for the development of a GIS-based pan-European methodology for the assessment of hydromorphological alterations in coastal and transitional waters. We found that there are not many pan-European GIS-based spatial data available to define a baseline for hydromorphological assessment within transitional and coastal waters, although present conditions pressure data are available. Significant number of hydromorphological features of coastal and transitional waters could be assessed using GIS-based data, but combination of various data sources and assessment approaches is needed.

Keywords: coastal waters; hydromorphological assessment; hydromorphological features; Copernicus; EMODnet; large scale; ecological status

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1. Introduction

Coastal areas are exposed to increasingly intense pressures related to human use, including pollution from land based and marine sources, extraction of living resources (fishing, angling, aquaculture), pressures caused by continuous and impulsive underwater noise, physical alterations of natural habitats, and large-scale changes caused by climate change [1]. Increasing population density and urbanisation is enhanced by tourist activities in coastal areas. Many of these economic activities, and related infrastructure building, are concentrated along the coasts, causing various physical alterations to hydromorphological features [2]. These changes affect ecosystems in coastal and transitional waters and lower their resilience [3]. Human activities in these areas are foreseen to expand as part of the green and blue economies, which, in turn, often depend on the good state of transitional and coastal waters and on a healthy marine environment. In order to maintain coastal areas healthy and productive also for future generations, changes caused by human activities need to be measured and assessed in a harmonised way at the pan-European level, to support integrated management in line with the ecosystem approach and to inform spatial planning (on land and in the sea) [4].

The aim of our study was to provide a review of available knowledge and tools as a basis for the development of a GIS-based pan-European methodology for the assessment of hydromorphological (HM) alterations in coastal and transitional waters. Assessment methods published in scientific literature, available reports and work of expert groups were taken as a starting point. First key criteria was to select hydromorphological features that can be mapped and assessed by using the Copernicus coastal zone land cover/land use (CZ LC/LU) products [5]. Since we found that only few TraC HM features could be assessed only by using the CZ LC/LU product, we searched for other available pan-European GIS data to assess HM features. Since all HM features need to be assessed against the baseline conditions, we checked for available baseline conditions and their comparability with present condition GIS data layers.

2. Policies Impacts Hydromorphological Conditions of Coastal Ecosystems

Many EU policies and regulations support further economic development, but expansion of human activities will directly or indirectly impact transitional and coastal (TraC) water hydromorphological conditions (Figure 1). However, some of the regulations also aim to improve and maintain the status of transitional and coastal waters and require status assessments. An approach to the assessment of alterations to hydromorphological features in transitional and coastal waters is relevant for Water Framework Directive (WFD), Marine Strategy Framework Directive (MSFD), Maritime Spatial Planning (MSP) and Regional Seas Conventions (RSC) assessments [6–8]. Achieving the objectives of the EU Biodiversity Strategy 2030, that aims to put Europe's biodiversity on a path to recovery by 2030 and to ensure that by 2050 all of the world's ecosystems are restored, resilient, and adequately protected, is directly linked to the management of coastal and transitional waters, where many sensitive and endangered species and habitats are subject to degradation of their natural habitats, which is directly linked to the physical alterations in these areas [9,10].

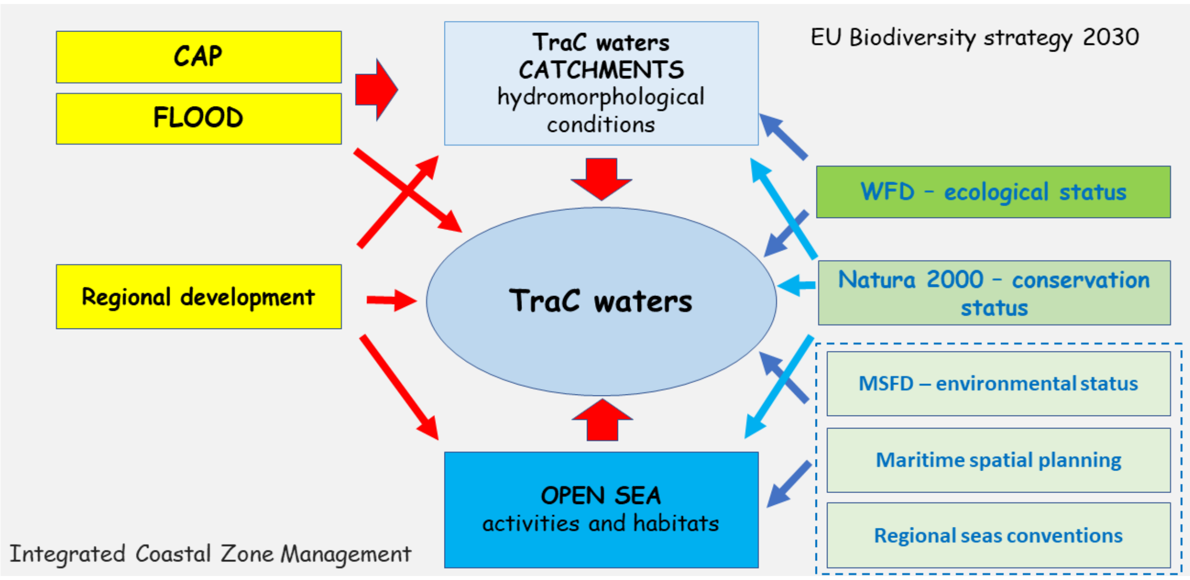

Figure 1. Schematic overview of selected key policies and policy instruments impacting transitional and coastal (TraC) waters hydromorphological conditions through TraC catchments, coastal zones and open sea. CAP — Common agricultural policies, FLOOD — Flood Directive, WFD — Water Framework Directive, MSFD — Marine Strategy Framework Directive.

The methodological aspects of the assessment of physical alterations are not yet agreed upon, but scientific work is under development in Water Framework Directive technical working groups and in technical groups under the Regional Sea Conventions [11]. In the Marine Strategy Framework Directive the topic is addresses under Descriptor 6, Seafloor integrity, which consists of two criteria, one addressing seafloor damage, and the other addressing physical loss. Both criteria have aspects that are related to the use of coastal areas (e.g., construction of ports, fortification of banks, protection against flooding or against erosion). Activities in working groups resulted in a WFD technical report with information about the methodologies used in European countries for TraC hydromorphological assessment and monitoring [11]. It was concluded that most used methods need improvements as most of them include only some hydromorphological aspects, were not reviewed or are a risk-based tools (e.g., TraC-MImAS, [12]) designed to provide a risk-based regulatory decision-support tool to help regulators determine whether new projects likely to alter hydromorphological features could risk the ecological objectives of the WFD.

The WFD requires member states to classify water bodies in terms of hydromorphology to support high ecological status (of fish, invertebrates, phytoplankton, macroalgae, seagrass and saltmarsh) and to put into place mitigation measures necessary to achieve at least 'good' status and prevent further deterioration of the status of water bodies [13]. A protocol for field survey of transitional and coastal waters generic hydromorphological feature recording is outlined in the European standard (EN 16503) titled "Guidance on determining the degree of modification of the hydromorphological features of transitional and coastal waters" [2]. As a follow up were developed the European standard EN 17123 — A guidance on hydromorphological assessment and classification of transitional and coastal waters [14], which can be used to measure the degree of hydromorphological alteration of transitional and coastal waters.

3. Knowledge and Data for Pan-European Hydromorphological Assessment

One of the challenges, recognised by experts working in the field of hydromorphology and physical alterations of these features, is to understand and assess physical alterations at larg pan-European scale. The Copernicus marine and land service (Land Cover/Land Use — LC/LU) has been mapping coastal areas and provides a monitoring system, which is capable of tracking trends and dynamics in coastal landscapes [4]. An approach with mapping of alterations in LC/LU in coastal areas to support assessments, required by various policies, was published recently [5]. Nevertheless, there is a clear gap in practical implementation of hydromorphological assessment approaches beyond local scales. Copernicus Coastal Zone land cover/land use (CZ LC/LU) products include coastal zone LC/LU data from years 2012 and 2018 and the layer of changes from 2012 to 2018 [5]. However, varied hydromorphological features ranging from the water-land interface up to coastal zone catchments and offshore zones need to be considered in the hydromorphological assessment [2,14]. In addition to Copernicus data, other pan-European data need to be checked and considered for the assessment. A review of the EMODnet data from a hydromorphological mapping and assessment point of view revealed that several data and products could be considered for the hydromorphological assessment: bathymetry, physics, human activities, sea-bed habitats, geology, alien species [15]. However, not all data are available for all seas or coast countries. Differences among EMODnet products exist also between type of the data; some data are given as locations (points) whereas other as areas (polygons). In addition, other GIS based data layers were searched that could be used to extract some hydromorphological conditions that impact coastal zones: Amber project and Global large dams where data for barriers were available, Copernicus Climate Change Services for river discharges, Free flowing rivers for data on river connectivity alterations, water use and sediment trapping [16–20]. However, not all data are directly available.

4. Hydromorphological Features and GIS-Based Assessment

Review of the scientific literature, working group reports and other available reports revealed that there are not many transitional and coastal (TraC) waters hydromorphological assessment methods (Figure 2). European Standard EN 17123 [14] contains an extensive HM feature list. However, not all features have quantitative assessment what is a disadvantage as qualitative HM assessment features cannot be easily used in the routine GIS-based pan-European monitoring. On the other hand, features of the other assessment methods are quantified and have provided instructions for HM feature value calculation and assessment, but some criteria are adjusted to the local environment; Hydromorphological Alteration Index (HAI)/Hydromorphological Quality Index (HQI) [21] to the North-Atlantic, CMI (MISO-M) [22] to the Adriatic Sea in the Mediterranean, and German GIS based method [23] to the North Sea and Baltic Sea. Additional key difference between European standard and national methods is that assessment method provided in the EN 17123 does not necessary reflect WFD assessment classes and thus can have a wider HM modification meaning, whereas other methods were developed in order to implement WFD. German GIS based method use lowest number of HM features whereas, whereas in the Slovenian CMI most HM features used in the assessment are zone specific and include data from the 100 m landwards buffer zone. A 50 m landward buffer zone is also used in the Irish HAI/HQI whereas in the EN 17123 onshore artificial structures are considered. As several protection structures that impact coastal hydromorphology are land based, it is important to consider landward buffer zone. Although methods differ in the number of used HM features all methods use features that reflect morphological conditions as well as hydrodynamic conditions what is in line with the hydromorphological assessment elements listed in WFD. Based on the existing TraC HM assessment methods we prepared an extensive list of HM features.

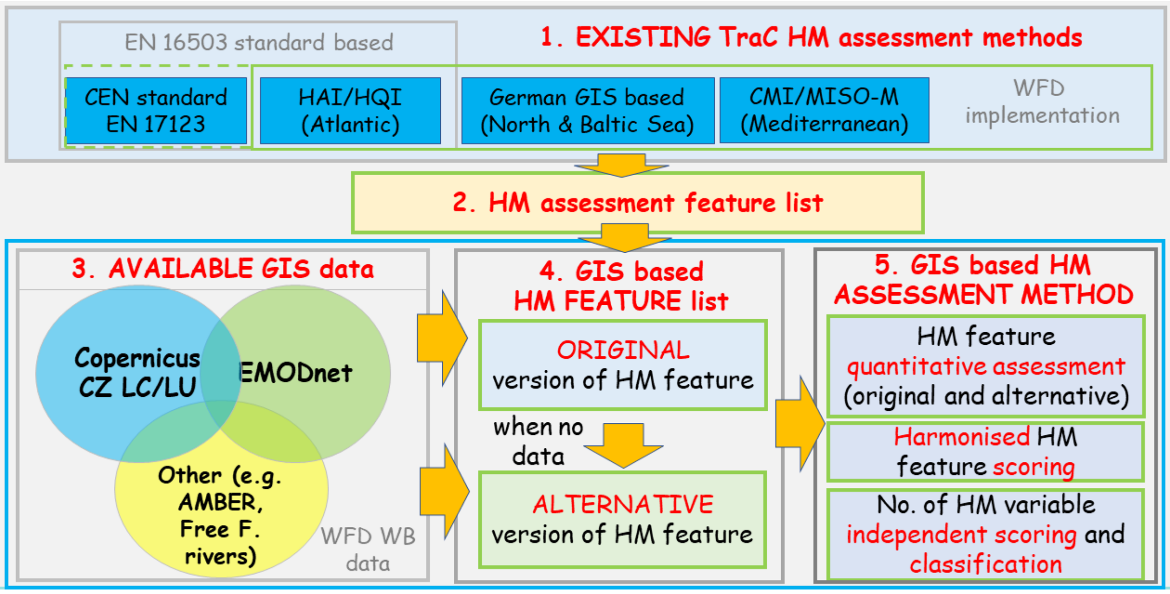

Figure 2. Schematic flow chart of the analytical procedure for development of the transitional and coastal (TraC) water GIS-based hydromorphological (HM) assessment method. Hydromorphological Scoring Index (HSI). HAI — hydromorphological alteration index, HQI — hydromorphological quality index, CMI/MISO-M — Coast Modification Index, WFD — Water Framework Directive, EN — European Standard, CZ LC/LU — Coastal Zone Land Cover/Land Use, WB — water body.

We checked whether HM feature from the list can be assessed using GIS-based hydromorphological data. In order to assess significant number of HM features it is necessary to develop some alternative versions and assessment of TraC HM features by using the CZ LC/LU product, EMODnet and some other GIS based products (Figure 3). Since all HM features need to be assessed against the baseline conditions, we checked for available baseline conditions and their comparability with present condition GIS data layers and found that defining the baseline conditions for varied HM features is a challenge as appropriate data from the past are limited. Nevertheless, significant number of hydromorphological features of coastal and transitional waters could be assessed using GIS-based data, but combination of data sources and assessment approaches is needed (Figure 3).

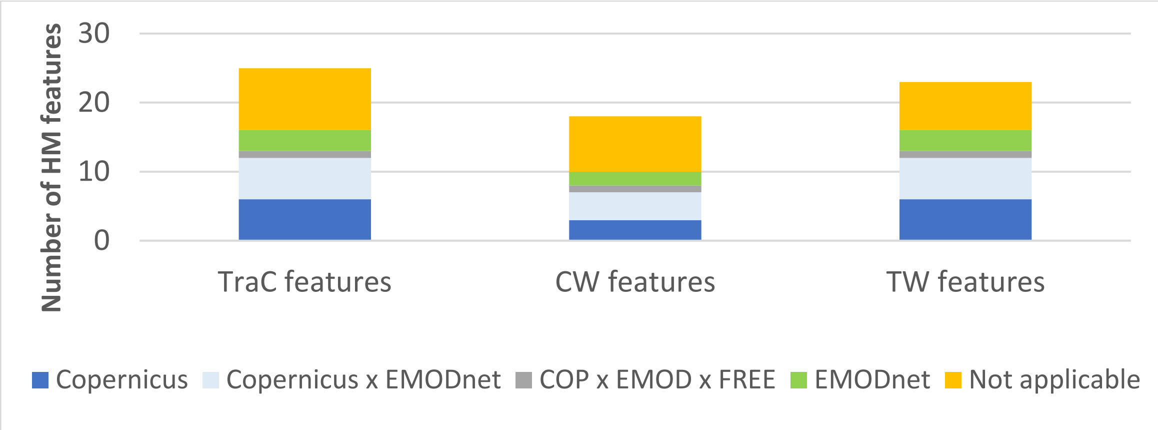

Figure 3. Distribution of hydromorphological (HM) features applicable for use in GIS based hydromorphological (HM) assessment based on data source for transitional and coastal (TraC) waters, coastal waters (CW), transitional waters (TW). x — denotes a combination of data sources. Copernicus (COP) — coastal zone Land cover/land use, EMOD — EMODnet, FREE — free flowing rivers.

5. Conclusions

1. Coastal areas are exposed to increasingly intense pressures related to human use that cause various physical alterations to hydromorphological features of coastal ecosystems. To maintain coastal areas healthy and productive also for future generations, changes caused by human activities need to be measured and assessed in a harmonised way at the pan-European level.
2. EU and regional level regulations allow economic prosperity along with sustainable activities in coastal areas, which need to be regularly monitored and status assessed. Assessment of hydromorphological conditions of transitional and coastal waters is relevant for Water Framework Directive, Marine Strategy Framework Directive, Maritime Spatial Planning and Regional Seas Conventions and supports objectives of the EU Biodiversity Strategy to 2030.
3. Review of available knowledge and hydromorphological assessment methods is a basis for the development of a GIS-based pan-European assessment method. However, assessment methods are applicable when harmonised data and GIS-based products are available.
4. All reviewed coastal HM assessment methods include the baseline conditions approach, meaning that present conditions need to be compared with the baseline conditions. However, defining the baseline conditions for varied HM features is a challenge as appropriate data from the past are limited.
5. Copernicus Coastal zone land cover/land use (LC/LU) products are a good basis to assess coastal zone HM features, but some cross-service activities with EMODnet (e.g., bathymetry data, human activities) and some other platforms (river basins specific data; e.g., Free flowing rivers database) are needed to assess hydromorphological conditions of TraC waters at large scale.

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Data Availability Statement: The data presented in this study are available on request from the corresponding author.

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