environmental sciences proceedings

Type of the Paper (Proceedings)

Hydromorphological assessment of coastal waters: is a GIS-based pan-European assessment method feasible? †

Gorazd Urbanič [1,*], Maja Pavlin Urbanič [1] and Monika Peterlin [2]

1 [1]URBANZERO Institute for holistic environmental management, Ltd., Selo pri Mirni 17, 8233 Mirna, Slovenia; gorazd@urbanzeroinstitute.com, maja@urbanzeroinstitute.com
2 European Environment Agency, Kongens Nytorv 6, 1050 Copenhagen K, Denmark; Monika.Peterlin@eea.europa.eu
* Correspondence: gorazd@urbanzeroinstitute.com; Tel.: +386 41509933
† Presented at the 6th International Electronic Conference on Water Sciences (ECWS-6), Online, 15–30 November 2021.

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

Citation: Urbanič, G.; Lastname, F.; Lastname, F. Title. *Environ. Sci. Proc.* **2021**, *3*, x. https://doi.org/10.3390/xxxxx

Published: date

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].

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.

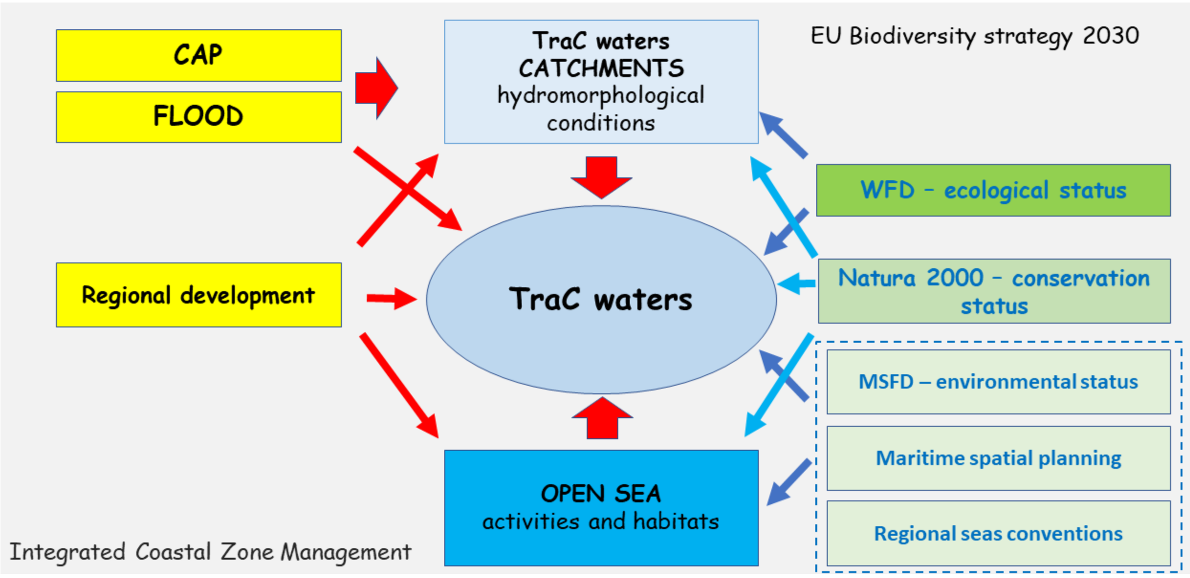

Figure 1. Schematic overview of selected key policies and policy instruments impacting transitional and coastal (TraC) waters hydromorphological conditions through TraC catchments, coastal zones and open sea. CAP – Common agricultural policies, FLOOD – Flood Directive, WFD – Water Framework Directive,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

The 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 [16]. 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 [17-21]. 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) [22] to the North-Atlantic, CMI (MISO-M) [23] to the Adriatic Sea in the Mediterranean, and German GIS based method [24] 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.

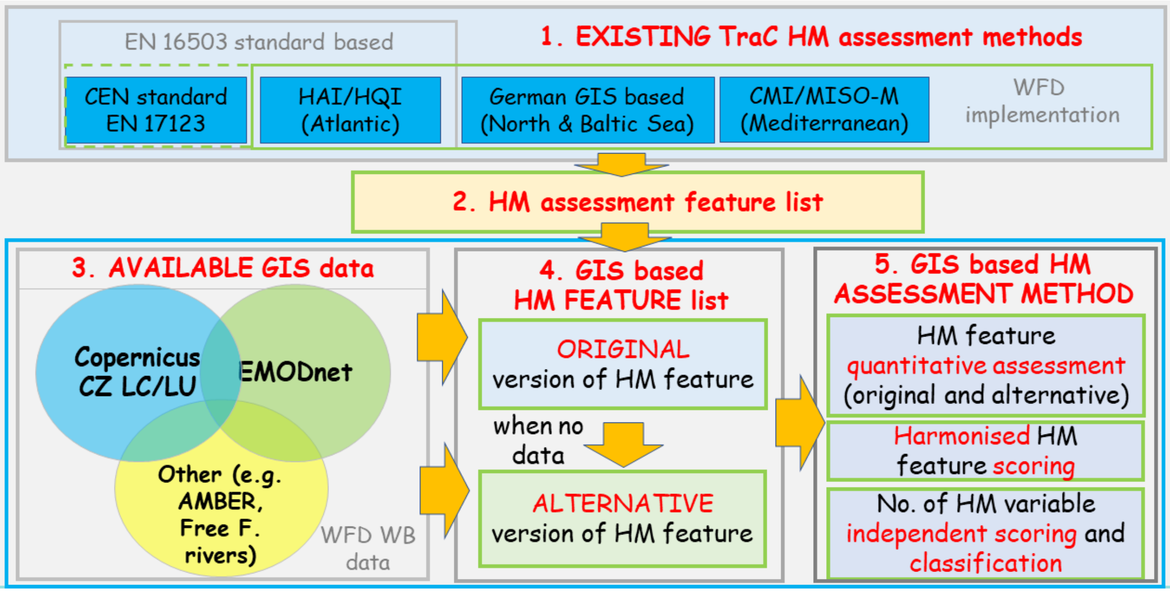

Figure 2. Schematic flow chart of the analytical procedure for development of the transitional and coastal (TraC) water GIS-based hydromorphological (HM) assessment method. Hydromorphological Scoring Index (HSI). HAI – hydromorphological alteration index, HQI – hydromorphological quality index, CMI/MISO-M – 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).

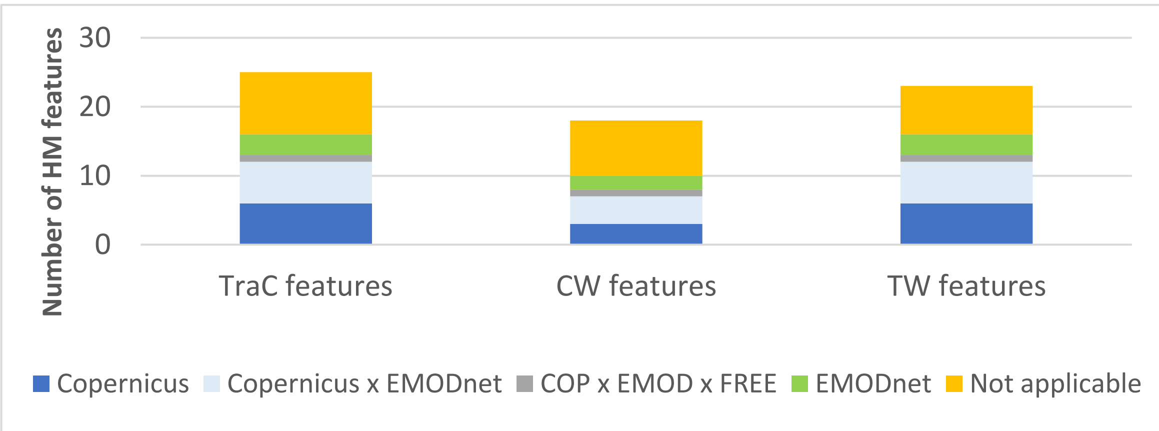

Figure 3. Distribution of hydromorphological (HM) features applicable for use in GIS based hydromorphological (HM) assessment based on data source for transitional and coastal (TraC) waters, coastal waters (CW), transitional waters (TW). x – denotes a combination of data sources. Copernicus (COP) – coastal 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.

Author Contributions: "Conceptualization, G.U., M.P.U. and M.P.; methodology, G.U.; validation, G.U., M.P.U.; formal analysis, G.U; resources, G.U., M.P.U.; data curation, G.U.; writing—original draft preparation, G.U, M.P. and M.P.; visualization, G.U.; supervision, M.P.; project administration, G.U., M.P.U.; funding acquisition, G.U. All authors have read and agreed to the published version of the manuscript."

Funding: This study was funded by European Environment Agency, contract number 3416/B2020/EEA.58107. The opinions expressed in the paper are those of the authors only and do not necessarily reflect the official opinion of the EEA or other European Communities bodies and institutions.

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

Acknowledgments: The authors would like to thank all those who contributed positively during the project with their critical and constructive comments and observations, in particular Matteo Mattiuzzi, Mohamed Azlak and Cécile Roddier-Quefelec.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Korpinen, S.; Klančnik, K.; Peterlin, M.; Nurmi, M.; Laamanen, L.; Zupančič, G.; Murray, C.; Harvey, T.; Andersen, J.H.; Zenetos, A.; Stein, U.; Tunesi, L.; Abhold, K.; Piet, G.; Kallenbach, E.; Agnesi, S.; Bolman, B.; Vaughan, D.; Reker, J.; Royo Gelabert, E.

Multiple pressures and their combined effects in Europe's seas. ETC/ICM Technical Report 4/2019: European Topic Centre on Inland, Coastal and Marine waters, Helmholtz Centre for Environmental Research – UFZ, Magdeburg, Germany; 2019, 164pp.
2. CEN. Water quality – Guidance standard on assessing the hydromorphological features of transitional and coastal waters. EN 16503; European Committee for Standardisation, Brussels, Belgium, 2014; p. 24.
3. Orlando-Bonaca, M.; Mavrič, B.; Urbanič, G., 2012. Development of a new index for the assessment of hydromorphological alterations of the Mediterranean rocky shore°. *Ecological indicators* **2012**, 12, 26–36, doi: 10.1016/j.ecolind.2011.05.010.
4. EEA. Roadmap for the evolution of Copernicus marine and land services to better serve coastal users. European Environment Agency: Copenhagen, Denmark, 2018; 27 pp. Available online: https://land.copernicus.eu/user-corner/technical-library/roadmap-for-coastal-zone-monitoring-activities (accessed on 10.8.2020).
5. EEA. Local Component: Coastal Zones Monitoring Nomenclature and Mapping Guideline. Version 1.1.; European Environment Agency: Copenhagen, Denmark, 2020; 266 pp. Available online: https://land.copernicus.eu/local/coastal-zones (accessed on 10.11.2020).
6. EU. Directive 2000/60/EC of the European Parliament and of the Council Establishing a Framework for the Community Action in the Field of Water Policy; Brussels, Belgium, 2000; p. 72. Available online: https://eur- lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32000L0060 (accessed on 25 November 2020)
7. EU. Directive 2008/56/EC of the European Parliament and the Council of 17 June 2008 establishing a framework for community action in the field of marine environmental policy (Marine Strategy Framework Directive). *Official Journal of the European Union* **2008**, L164, 19-40.
8. EU. Directive 2014/89/EU of the European parliament and of the council of 23 July 2014 establishing a framework for maritime spatial planning. *Official Journal of the European Union* 2014, L257, 135–145.
9. EU. EU Biodiversity Strategy for 2030. Bringing nature back into our lives, Brussels, Belgium, 2020, 22 pp. Available online: https://eur-lex.europa.eu/resource.html?uri=cellar:a3c806a6-9ab3-11ea-9d2d-01aa75ed71a1.0001.02/DOC_1&format=PDF (accessed on 15 September 2020)
10. EU. Directive 2009/147/EC of the European Parliament and of the Council of 30 November 2009 on the conservation of wild birds *Official Journal of the European Union* 2009, L20, 7–25. Available online: http://data.europa.eu/eli/dir/2009/147/oj (accessed on 25 October 2020)
11. Salas Herrero, F. Hydromorphological assessment and monitoring methodologies in coastal and transitional report. Summary of European country questionnaires, EUR 29597 EN, Publications Office of the European Union, Luxembourg; 2018, 69pp. doi:10.2760/973493.
12. UKTAG, 2013. TraC MImAS. Technical Report e Version A (4) Development and Review of a TraC Hydromorphology Decision Support Tool for (A) Screening Proposed New or Altered Activities/Structures for Compliance with WFD Water Body Status and (B) Classifying TraC Waters Under the WFD. UKTAG Report, 90 pp. Available online: https://www.sepa.org.uk/media/163212/transitional-coastal-waters-morphology-tool.pdf (accessed on 19.7.2020).
13. EEA. European Waters—Assessment of Status and Pressures 2018; EEA Report No 7/2018; European Environment Agency: Copenhagen, Denmark, 2018; p. 85.
14. CEN. Water quality – Guidance on determining the degree of modification of the hydromorphological features of transitional and coastal waters. EN 17123; European Committee for Standardisation, Brussels, Belgium, 2018; p. 39.
15. EEA, 2016. WFD Water bodies. Available online: https://www.eea.europa.eu/data-and-maps/data/wise-wfd-spatial/surface-water-body (accessed on 10.9.2020).
16. EMODnet, Central Portal. Available online: https://emodnet.eu/en/portals (accessed on 25.11.2020).
17. Amber project. Available online: https://amber.international/ (accessed on 21.10.2020).
18. Global large dams. Available online: http://globaldamwatch.org/data/#core_global (accessed on 21.10.2020.)
19. EEA. Copernicus Climate Change Services: River discharges. European Environment Agency: Copenhagen, Denmark, 2020; Available online: https://climate.copernicus.eu/ (accessed on 23.11.2020).
20. Free flowing rivers. Based on the reviewed product. Available online: https://hydrolab.io/ffr (accessed on 19.10.2020).
21. Grill, G.; Lehner, B.; Thieme, M. et al. Mapping the world's free-flowing rivers. *Nature* **2019**, 569, 215–221. doi.org/10.1038/s41586-019-1111-9.
22. Keogh, J.; Wilkesa, R.; O'Boyle, S. A new index for the assessment of hydromorphology in transitional and coastal waters around Ireland. *Marine Pollution Bulletin* **2020**, 151, 110802.
23. Peterlin, M.; Urbanič, G.; Kramar, M. Pressure and impact index - Morphological alterations of the sea coast. Institute for water of the Republic of Slovenia, Ljubljana, Slovenia, 2013; 26 pp. (in Slovenian) Available online: http://www.statika.evode.gov.si/fileadmin/direktive/MSFD_P/2013/2013_I_3_06_P_01.pdf (accessed on 19.7.2020).
24. Sari, A.I. GIS based assessment of hydromorphological quality elements in coastal waters in the scope of the EU Water Framework Directive. Master Thesis, Christian Albrechts University Kiel, Germany, 2011; 97 pp.