

Cumulative Impact of Societal Activities on Marine Ecosystems and Their Services

Henning Sten Hansen(✉)

Aalborg University Copenhagen, A.C Meyers Vaenge 15,
2450 Copenhagen, Denmark
hsh@plan.aau.dk

Abstract. Marine space is overall under increasing pressure from human activities and in the way harming the marine ecosystems. Maritime spatial planning is one of the governance elements in the EU Integrated Maritime Policy (2007) that aims to maximise the sustainable use of the seas and oceans. Maritime spatial planning aims to ensure that the increased use of the marine space takes place in a way that are consistent with the sustainable development in the seas and oceans. According to the MSP Directive it is required to follow an ecosystem-based and thus holistic approach. For this to happen, tools are needed, and some tools are available but with various advantages and disadvantages. The aim of the current research has been to develop a comprehensive package of tools to assess the environmental impacts of societal activities under different maritime spatial planning proposals.

Keywords: Maritime spatial planning · Marine environment · Cumulative impact · Decision-support tools · Agenda 2030

1 Introduction

The sea is a scene of a wide range of activities. From nature´s own use to human activities like oil exploration, offshore wind farms, shipping, fishery, aquaculture, and recreation. In the recently launched Blue Growth initiative, the European Commission (EC) identifies a potential for further job-creation and innovative technology development in the sea area, like new offshore renewable energy technologies, sustainable aquaculture, maritime coastal and cruise tourism, marine mineral resources, and biotechnology utilising marine organisms. Human activities are not always compatible with the need of nature, and may lead to several threats like eutrophication, habitat damage, and proliferation of invasive species [1].

In 2015, the United Nations adopted the 2030 Agenda for Sustainable Development and its 17 Sustainable Development Goals (SDG), and they entered into force by 1st January 2016[1]. Number 14 of the 17 SDG's concerns the *conservation and sustainable use of the oceans, seas and maritime resources*. Careful management and regulation of the global marine resources is a key element in obtaining a sustainable future, and to

[1] https://www.un.org/sustainabledevelopment/development-agenda/.

© Springer Nature Switzerland AG 2019
S. Misra et al. (Eds.): ICCSA 2019, LNCS 11621, pp. 577–590, 2019.
https://doi.org/10.1007/978-3-030-24302-9_41

make this operational a set of ten Goal 14 targets with deadlines are defined. Thus, it is expected according to target 14.2 already by 2020 to sustainably manage and protect marine and coastal ecosystems to avoid significant adverse impacts, strengthening their resilience, and act for their restoration in order to achieve healthy and productive oceans.

In the sea, everything is connected. Fish, nutrients, and hazardous substances move from one location to another without barriers. The marine space is characterised not only by a three-dimensional water column supporting multi-functional use (different uses at the same location but at different depths) but is actually strongly four-dimensional (seasonal and diurnal cycles appears in many forms in the marine environment). Hence, Maritime Spatial Planning (MSP) needs to be based on this context different from terrestrial planning which traditionally only needs to address two dimensions – the earth surface. Accordingly, the EC launched a new directive on maritime spatial planning and this directive entered into force in 2014 and required its member states to establish maritime spatial plans by 2021 [2]. According to the MSP Directive it is required to follow an ecosystem-based and thus holistic approach. For this to happen, tools are needed, and some tools are available but with various advantages and disadvantages.

Therefore, the aim of the current research has been to develop a comprehensive package of tools to assess the environmental impacts of societal activities under different maritime spatial planning proposals. After this introduction follows a description of the background and theory behind cumulative impact assessment. Next, follows the design and implementation of the new toolbox, and some examples of its use. The paper ends with a discussion of the proposed approach to tools target towards cumulative impacts assessment on marine ecosystems from anthropogenic activities.

2 Theory

Development of ecosystem-based maritime spatial planning (MSP) comprises a number of tasks including identification of the planning needs, pre-planning and stakeholder engagement, defining and analysing existing and future conditions, preparing and approving the spatial management plan, implementation of the plan, and finally, monitoring and evaluating the performance [3].

Maritime spatial planning is characterised by being a continuing and iterative process adapting over time, and therefore unsuitable to be expressed as a static plan. Practical tools supporting maritime spatial planning and supporting cross-border coordination and participation are still limited.

2.1 Protecting the Marine Environment

The Marine Strategy Framework Directive (MSFD) [4] marks an important step forward in the EU marine environmental policy being the first legal framework specifically aimed at protecting and preserving the marine environment. In addition, it aims at preventing the deterioration of the marine environment and, where feasible, restoring marine ecosystems in areas where they have been adversely affected.

The MSFD requires that the EU member states, that share the same marine region (i.e., Baltic Sea, the Mediterranean Sea, and the Black Sea) should collaborate to develop marine strategies in order to ensure coherence in the assessment, setting environmental targets and monitoring efforts. The regional platforms for developing coherent marine strategies are the Regional Sea Conventions, which are the required regional coordination structures. Furthermore, the MSFD states that the marine strategies shall apply an ecosystem - based approach to the management of human activities.

Achieving a Good Environmental Status in the European marine regions require appropriate planning decisions which furthermore requires the comprehensive knowledge of the impacts induced by different anthropogenic activities and natural changes. Therefore, methods and techniques are required in to efficiently estimate the cumulative impacts from multiple and interactive human activities and their pressures enabling planners and decision makers to apply science-based information to assess different efforts in marine management by using scenarios.

An ecosystem oriented maritime planning support tool needs to respond to a number of challenges to integrated planning and management, including to consider effects of various and/or alternative economic and other activities in the maritime space – and to communicate benefits and trade-offs of different alternatives with stakeholders in the planning phases. This requires a framework for assessment of effects that can: (a) integrate effects of multiple human activities, (b) integrate the impacts of spatially explicit maritime human activities on multiple ecosystem services related to the sea and coastal ecosystems, (c) address ecosystem services related to waters, sea bed, sub sea bed, as well as to coastal ecosystem services, (d) economic and social impacts related to involved and affected stakeholders, (e) ensure conservation of biologically and ecologically sensitive marine areas, (f) support governance of maritime activities at various governance levels and between horizontal authorities and stakeholders. A large number of impact assessment frameworks for terrestrial activities exist along lines of EIA, SEA or sustainable development criteria [5].

The DPSIR (Drivers-Pressures-States-Impacts-Responses) framework from the European Environment Agency is used to act as an integrated approach to their State of the Environment Reporting and is the basic concept behind the many tools for cumulative impact on ecosystems from anthropogenic activities and pressures. The MYTILUS toolbox, which is the aim of this research is such a tool.

At the top level of the framework you find the Driving forces representing different kind of needs for humans [6]. Examples are need for food, water, shelter, transport, culture, etc. In addition, the number of people including their age structure, and education levels is an important driver, affecting the strength of the other drivers.

The driving forces lead to human activities like transportation (e.g. sailing) or food production (e.g. fishery). These human activities exert pressures on the environment – often trough emission of substances, noise, radiation, etc. The pressures subsequently change the State of the environment – e.g. reduced biodiversity in the seas and oceans, or fewer fish due to overfishing.

If the impact on the ecosystem goes beyond what is acceptable by the societies, some response is required in order reduce the pressure on the ecosystems. This may be done by regulation – e.g. through higher taxation of the human activities being the

reason to the adverse effects, or by maritime spatial planning dictation what is allowed and what is forbidden in specific sea areas.

To take the right decisions, knowledge about cause-effect links must be provided, but most often the impact on marine ecosystems is not only the result of a single human activity but cumulative effects of several human activities.

2.2 Cumulative Impact Assessment

The concept of cumulative impact assessment (CIA) on the marine environments originally defined by Halpern et al. [7] was the first effort in this direction and has served as inspiration for further research into that direction. He developed an index to assess the cumulative impact on the marine environment at a rather high spatial resolution in a global perspective.

According to Halpern [7] the cumulative impact is determined from three components: maps of pressures from different human activities; maps over different ecosystems, and a matrix describing the sensitivity of each ecosystem to each pressure. Thus, the cumulative impact (I_a) on the environment within a square pixel can be estimated by multiplying the values for each pressure (P) with the values for each ecosystem component (E) and its specific sensitivity μ. Finally, these impacts are summarised over all pressures and ecosystems:

$$I_a = \sum_{i=1}^{n} \sum_{j=1}^{m} P_i \times E_j \times \mu_{i,j} \tag{1}$$

Here n is the number of pressure layers and m is the number of ecosystems. The sensitivity variable μ represents the sensitivity of ecosystem j to pressure i and are most often derived by expert judgment in a rather complicated process – see for example the way this is done in the assessment of the cumulative impact in the Baltic Sea [8].

Equation (1) has led to other indices describing the impact on the environment but underlining different aspects. The subscript a in I_a refers to the calculation principle of just adding the impact on all ecosystems for all pressure layers.

Closely related to the two equations above is the so-called cumulative pressure index (PI), which form the dynamic part of Eq. (1), and is calculated similarly but without considering the ecosystem component:

$$PI = \sum_{i=1}^{n} \left(P_i \frac{1}{m} \sum_{j=1}^{m} \mu_{i,j}\right) \tag{2}$$

Focusing on the ecosystems part of Eq. (1) will provide an index of the ecological diversity/complexity E_{Div} ending up with an expression like:

$$E_{Div} = \sum_{j=1}^{m} E_j \tag{3}$$

It has been argued that the additive principle in Eq. (1) is too simple, and can be improved by averaging over the ecosystems to estimate the so-called I_{Mean} index:

$$I_{Mean} = \sum_{i=1}^{n} \sum_{j=1}^{m} \frac{1}{E_{Div}} 1P_i \times E_j \times \mu_{i,j} \quad (4)$$

This set of equations build the foundation for cumulative impact assessment on marine ecosystems from human activities and pressures.

2.3 Tools for Cumulative Impact Assessment

Based on the original ideas by Halpern et al. [7] several tools have been developed to calculate the cumulative impact on ecosystems and their services. Generally, all the data layers are created in "standard" GIS software like ArcGIS or QGIS. Therefore, the most straight forward approach to calculate cumulative impact is to apply the selected GIS tool. This can be done, but the calculations will take rather long time, which is often the case using general purpose tools compared to dedicated tools. For stakeholder meetings this is not appropriate, if the calculations have to be repeated several times with different options. In addition, the learning curves for ArcGIS or QGIS are rather steep putting emphasis among the users on learning a GIS tool instead of focusing on the actual topic – estimating the cumulative impact on the ecosystems from various anthropogenic activities and pressures. Therefore, several efforts to develop dedicated tools for cumulative impact assessments have been done.

The EcoImpactMapper tool developed by Stock [9] is probably the most well-known approach and has been used in many contexts [10, 11]). The EcoImpactMapper is a stand-alone desktop tool with a simple user interface which is straight to use. It applies CSV files to represent the pressure and ecosystem layers. This is one of the main challenges using EcoImpactMapper, that it cannot use 'standard' raster and shape files, but data needs to be transformed to and from CSV files when moving between GIS software packages and EcoImpactMapper. This, is perhaps the main disadvantage using EcoImpactMapper.

Tools4MSP is a set of tools aiming to support ecosystem-based maritime spatial planning [12]. The software package consists of three parts: Maritime Use Conflict Analysis, Cumulative Effects Assessments, and Marine Ecosystem Services Threat Assessment. Focusing on the tool for Cumulative Effects Assessments it is based on an open source geo-python library. It is very flexible but not straightforward to use.

Finally, Symphony is developed as a dedicated tool to the Swedish Agency for Marine and Water Management [13] and it is based on SeaSketch, which is commercial product with a starting price of 3000$ per year for the simplest version. It is web based and more a collaborative planning system supporting stakeholder involvement than just a tool for cumulative impact assessment. Thus, the system is comprehensive, but the licensing price is an important obstacle for its wider use.

Altogether, the existing tools for cumulative impact assessment have various challenges of being used in practical maritime spatial planning – and particularly during stakeholder involvements, where all the calculation processes need to be carried out fast and smoothly.

2.4 Marine Spatial Data Infrastructure

One of the main challenges regarding decision support systems for maritime spatial planning hereunder assessing the cumulative impact on the marine ecosystems is the accessibility to up-to-data good quality data covering the whole study area. A Spatial Data Infrastructure is about facilitation and coordination of the exchange and sharing of spatial data. It is described as the underlying infrastructure, often in the form of policies, standards and access networks that allows data to be shared between people within organisations, states or countries. The fundamental interaction between people and data is governed by the technological components of SDI represented by the access network, policies and standards [14]. The INSPIRE Directive which was adopted by the European Council and Parliament in spring 2007 and entered into force May 2007 [15] aims to make more and better spatial information available for Community policy-making and implementation in a wide range of sectors – including the marine environment. Considering the large number of data sets, they prioritised and put into three annexes with different time frames. Unfortunately for maritime spatial planning, the data sets connected to this topic is allocated to annex three of the INSPIRE Directive with a rather long time horizon.

Kocur-Bera and Dudzińska [16] examine geoportals of interest for the Baltic Sea region, and they similarly conclude that current environmental data unfortunately are not available from one single entry and that the resolution of the data is sometimes inadequate for marine planning. Two of their examples are INSPIRE geoportal, which links the user to terrestrial and marine environmental data at various European institutions' homepages, and HELCOM Data & Map Service, which hosts many marine datasets from the Baltic Sea region that can be viewed, and some of them downloaded through ArcGIS rest service or WMS [16]. The main advantage of the data at the HELCOM data portal is, that the data are coherent and harmonised, and available for the whole Baltic Sea from just one data portal. The main challenge concerning the HELCOM data concerns the temporal dimension, where data are of different age and sometimes not even the newest available data. This is clearly a major challenge if data are being used in real decision making on maritime spatial plans. During the last three years, the Baltic Lines project has developed a new data portal BASEMAPS (Baltic Sea Map Service) based on a modern distributes architecture, where data are retrieved from the original sources among associated data providers but identified from the BASEMAPS data portal [17]. However, although the data represents the most recent edition, they are not harmonised across national borders and represent challenges concerning the different languages present in the Baltic Sea Region. Thus, there is at the moment no straight forward solution easily to feed data into different tools for cumulative impact assessment.

Moving the study area outside the Baltic Sea makes the data challenges even bigger although the North Sea Commission (OSPAR) has a data service called ODIMS (OSPAR's Data and Information Management System)[2], which contain 45 pre-processed maps and 233 Data Layers. Other important sources of marine data are the

[2] https://odims.ospar.org.

European Marine Observation and Data Network (EMODnet)[3] and the International Council for the Exploration of the Sea (ICES)[4] with access to huge amount of marine data. However, although the availability of data seems overwhelming, you are not sure, that the *right* data are available. To estimate the cumulative impact on ecosystems from anthropogenic activities requires many data layers for a specific area, and quite often you cannot find the same data for even two neighbouring seas making comparisons difficult.

3 Implementation

The overall aim of developing the MYTILUS toolbox is first of all to avoid some of the main challenges of the tools described above.

The MYTILUS Toolbox contains several building blocks and the overall structure is presented in Fig. 1. The core part is the cumulative impact assessment tool, which calculates the cumulative impact on different ecosystems from a range of human activities and their pressures.

3.1 Systems Design

The modelling system applies native ESRI ASCII raster data. This facilitates an easier exchange of data between MYTILUS and GIS software like ArcGIS and QGIS. In this way, MYTILUS can be used as a decision-support tool while doing data preparation and advanced visualisation in general purpose GIS- packages (Fig. 1).

The design of MYTILUS has focus on three aspects: (a) user friendliness, (b) analytical capacity, and (c) processing speed:

(a) Generally, large GIS software systems like ArcGIS and QGIS are rather complicated systems with a steep learning curve, and potential users working with maritime spatial planning are not necessarily GIS experts. Therefore, building a stand-alone application focusing on a logical and easy to learn user interface has been given high priority. Everything is organised into projects – typically representing different geographical areas (sea basins). Under each project the user can define various scenarios – typically as baseline scenario describing the impact on the environment today followed by a set of alternative scenarios describing various spatial planning options as well as changing human activities. The user can visualise the different pressure and ecosystem layers and edit the values in the sensitivity matrix if needed. All calculations are carried out using dedicated easy-to-use dialog boxes, and results are shown within a short time frame.

(b) The main aim of MYTILUS toolbox is to provide knowledge about the expected impact on the marine environment from various human activities under various maritime spatial planning proposals. This requires a flexible approach in the calculation process, where all combinations of pressures and ecosystems can by

[3] http://www.emodnet.eu.

[4] https://www.ices.dk/Pages/default.aspx.

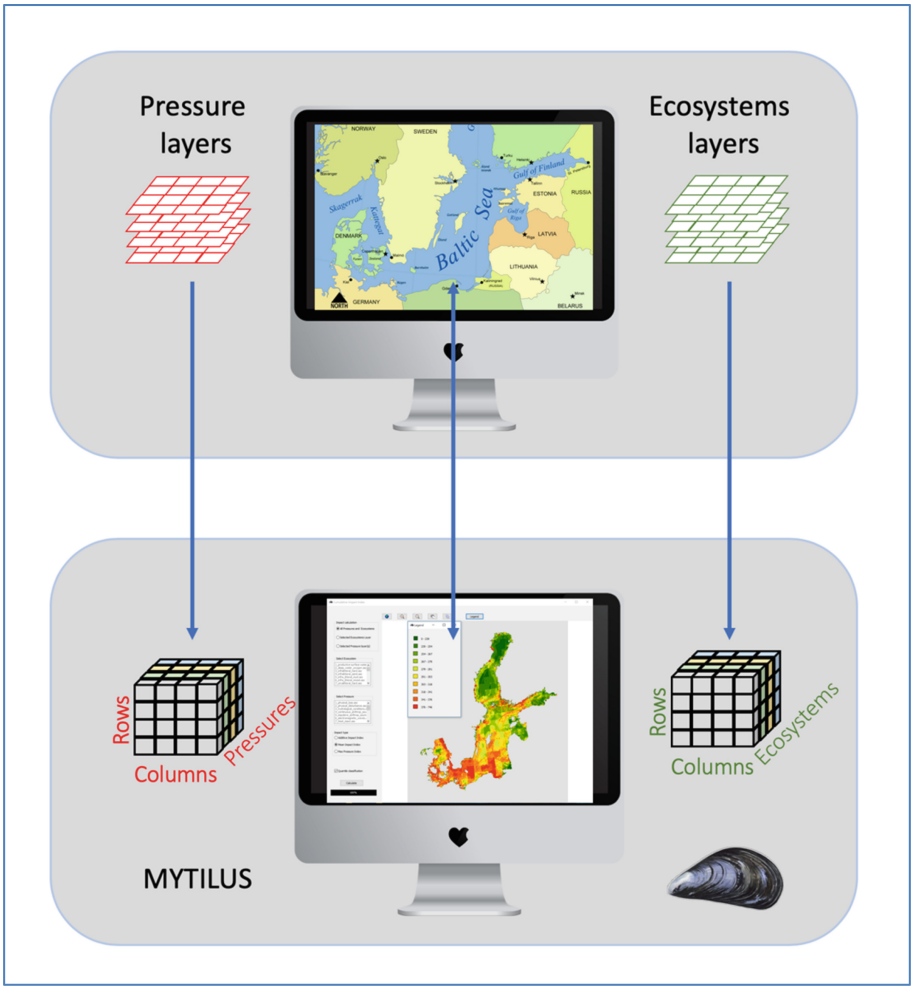

Fig. 1. MYTILUS systems architecture.

analysed numerically and visually based on Eqs. (1)–(4). Also, a direct comparison of the results from two scenarios can be made to identify interesting spatial patterns and differences. Finally, the out from the calculations can be imported directly into ArcGIS or QGIS if more analysis or professional map production is required.

(c) The calculations can be time consuming for large data sets, and this has been an issue in some existing tools. Therefore, there has been put a lot of efforts in the design and implementation of MYTILUS to support very fast calculations. This is done in several ways. First, the input data are preferably using integer values, which are generally faster than floating points. Second, the input data layers are organised in two data cubes – one for each of the two groups of layers

representing pressures, and ecosystems (Fig. 1). This is for efficiency in data retrieval by substantially reduction in reading data files from the disk. Finally, the calculations are carried out with extensive use of parallel processing, utilising the full power of today's computers with at least four CPU cores – but even with 6, 8, 10 and more cores. In practice the calculations on the raster cells are done row by row in traditional serial processing but using parallel processing the calculations can be done for several rows of cells simultaneously dependant on the number of CPU cores – but speeding up the processing time significantly.

The MYTILUS software is developed using the Delphi 10.1 Integrated Development Environment from Embarcadero[5], without using software libraries requiring royalties. Accordingly, the software is freeware with full accessibility to the source code. The software is easy to install on every computer running Windows 10 – also Mac computer under BootCamp or with virtualisation software.

The next paragraph demonstrates the use of MYTILUS with some examples from the Baltic Sea. The examples are by no means exhaustive but provides an idea of the possibilities with the MYTILUS toolbox.

4 Examples

Currently, the MYTILUS toolbox is being tested in the Baltic Sea, where HELCOM[6] provides freely available Baltic Sea wide data on human activities, pressures, and ecosystems. The pressure layers available from HELCOM's data portal are used for their own assessment of the Baltic Sea Environment [18] and follows the pressure layers mentioned in the Marine Strategy Framework Directive (MSFD) (European Commission, 2008).

The data used for testing the MYTILUS software comes from the HELCOM data portal mentioned earlier. Originally, Halpern et al. [7] recommended to log(x + 1) transform the pressure data in order to reduce the extreme outliers. Afterwards the pressure data are re-scaled to values between 0 and 100 in opposite to Halpern et al. [7] rescaling into the interval 0–1. As mentioned above, MYTILUS primarily makes use of integer values of performance reasons. Most of the data on ecosystems are binary (1 or 0) meaning that an ecosystem can exists in a particular raster cell or not. If this is not the case, they ecosystem layers are log(1 + x) transformed and rescaled similar to the pressure layers. All data on pressures and ecosystems from HELCOMS data portal are in raster format with 1 km cell size and using the INSPIRE EEA Reference Grid using ETRS89/LAEA Europe as projected reference system [15].

Figure 2 illustrate the flexibility and analytical capacity of cumulative impact assessment toolbox in MYTILUS. The user has the flexibility to calculate the so-called additive cumulative impact index I_a on the environment according to Eq. (1) as well as the I_{Mean} index according to Eq. (2). The map in Fig. 2 shows the spatial distribution of

[5] https://www.embarcadero.com/products/delphi.

[6] HELCOM (Helsinki Convention).

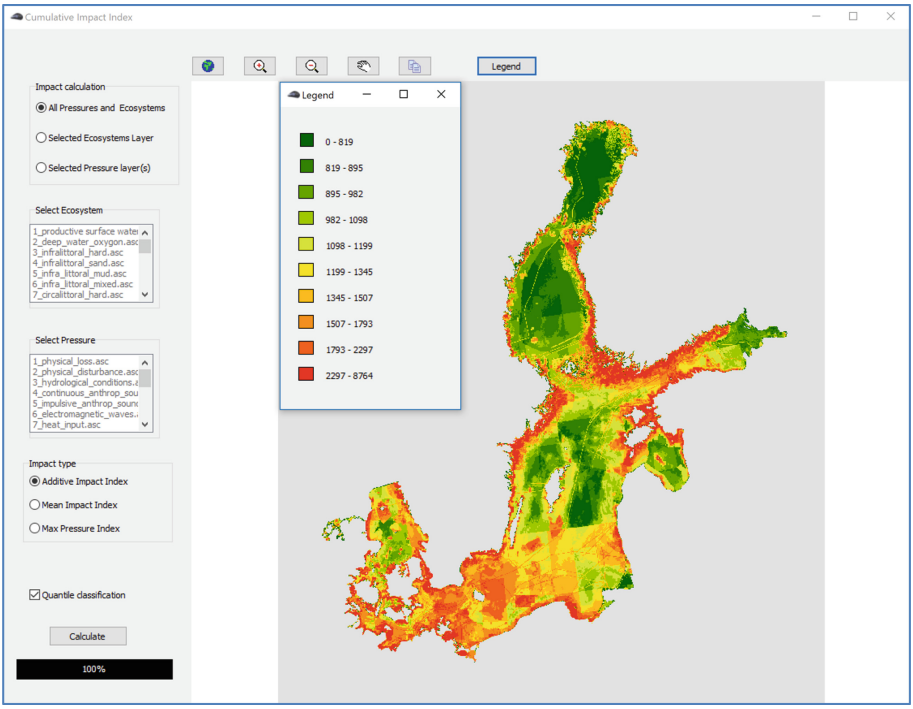

Fig. 2. Cumulative impact assessment dialog in MYTILUS

index I_a, with a strong impact on the environment in the South-western Baltic Sea and along the coast around Stockholm and Helsinki.

In addition, the user can also select a single or groups of pressure layers and combine with a single or groups of ecosystems thus getting possibilities for better understanding of cause-effect relationships. In order to enhance the visual analytical capacity, the user can choose between the traditional equal interval in the definition of class intervals, and the equal-area classification enhancing the visual differences.

Finally, the user can calculate the max-pressure index – i.e. the pressure in each grid cell providing the highest impact. This is important in identifying needed actions regarding reducing pressures from human activities in certain areas – and this has to be reflected in maritime spatial plan. The user can also identify the second highest and third highest important pressure in each cell – again to assess the

For Cumulative Impact Assessment to support environmental management in an area it is necessary to establish a fixed baseline against which to evaluate the effects of new spatial planning options, new technological development trends, or future changes due to for example climate changes. Establishing such a baseline for the cumulative impact assessment can be developed from historical conditions or from the present conditions. Alternative spatial scenarios are important steps for analysing and visualizing how specifics goals and objectives may result in re-location of human activities within the planning area.

The figure below shows an example, where the left map illustrates the impact on the ecosystems according to the baseline scenario, while the right-side map shows the impact for the same area but for an alternative scenario after adding 8 new fish farms (Fig. 3). The adverse effect on the environment from fish farms is related to the emission of primarily nitrogen but also phosphorous leading to eutrophication and later on oxygen depletion in the water. The spreading of nitrogen kernel is off-course dependent on many several physical characteristics not at least sea currents, but currently the contribution of additional nitrogen from fish farms is modelled isotopically applying a kernel density function. The impact from the enhanced nitrogen emission is a little higher around the new fish farms compared to the baseline scenario, but not significant higher (both maps is based on an equal interval classification). Thus, it may be appropriate to allocate space to new fish farms in the proposed area unless other challenges – like the general high pressure from nitrogen emissions in the whole Baltic Sea Basin.

The user can test different effects of new human activities compared the current situation illustrated by the baseline scenario, and in this way facilitate an optimum location of new activities, or identifying areas, where existing activities needs to be reduced or even closed down in order to requirements of a good ecological status of the marine waters according the EU Marine Strategy Framework Directive.

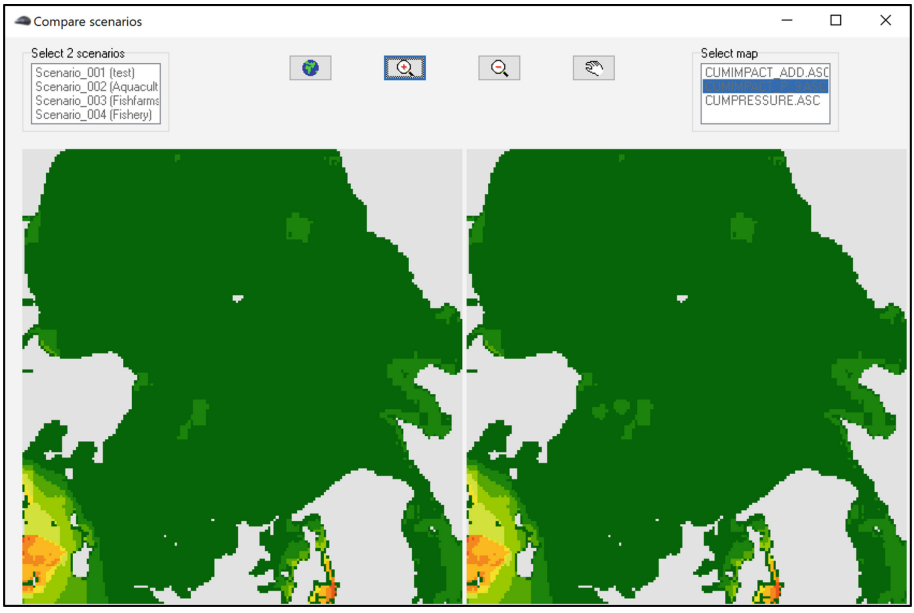

Fig. 3. Comparison of two different scenarios demonstrating the effect on the cumulative impact from new fish farms (right map)

5 Discussion

Since the approval of the Maritime Spatial Planning Directive by the European Union in 2014 [2] with a strong encouragement to adopting an ecosystem-based approach, the interests for cumulative impact assessment of marine ecosystems due to pressures from human activities has increased heavily. Particularly, the assessment of cumulative effect on global marine waters by Halpern et al. [7] has provided interest in developing tools to carry out the assessments. The tools being developed like EcoImpactMapper [9], Tools4MSP [12] and Symphony [13] are all fine examples on tools to support the ecological assessment in the MSP process. However, they all have their advantages and disadvantages, and that was the main reason behind developing the MYTILUS toolbox for cumulative assessment of the impact on marine ecosystems from human activities and pressures. Additionally, the advantage of having our own system with easy possibility to further development was a second reason.

Working with CSV files were not found appropriate when exchanging data with 'standard' GIS software like ArcGIS and QGIS, and the costs of using the Seasketch-based Symphony was out of scope for our financial capabilities.

As stated in Sect. 3.1 the ambition was to build a new cumulative impact tool with three priorities: user friendliness, high analytical capacity, and high-performance calculations. The MYTILUS toolbox was tested during a recent PhD course on decision support systems in maritime spatial planning, and the user interface could be used with only few instructions – even exchanging data between MYTILUS and GIS software due the de common data format for raster data and the use of shapefiles for vector data.

The high analytical capacity is provided via several toolboxes, where the user has the flexibility to do calculations on all combinations of pressure layers and ecosystems. The analytical capacity is furthermore enhanced by many possibilities to visualise the resulting maps. Finally, the MYTILUS toolbox applies a scenario-based approach facilitating the inclusion of an unlimited number of different scenarios, where the user has made step-by-step changes in the human activities and pressures and afterwards make visual comparisons two-by-two. The toolbox can also calculate several statistics to compare scenarios.

The last point in the requirement list was the high-performance calculations. It is annoying the wait long time to see the results of a calculation. By using data cubes to organise the input data and make use of parallel-processing the calculations of for example cumulative impact for the whole Baltic Sea can be calculated in seconds instead of other systems where you have to wait in minutes. Especially, at stakeholder events it is critical to provide results of alternative scenarios quickly.

6 Conclusion

Marine space is increasingly used for many human activities, and the recently announced Blue Growth initiatives will contribute to a continuous growth of maritime activities. This will inevitably lead to enhanced – and perhaps even irreversible – pressure and impact on the marine ecosystems, which is a prerequisite for obtaining benefits like food, transport, energy, etc. by ecosystem services.

Therefore, there is a need for a well organised allocation of marine space, and that is the background for the EU Directive on Maritime Spatial Planning from 2014 [2]. This planning needs to be performed based on information and knowledge.

The so-called index on cumulative impact assessment originally developed by Halpern et al. [7] was pioneering for this work and inspired several researchers working with the impact on the ecosystems from human activities and pressures. The various tools like EcoImpactMapper, Tools4MSP, and Symphony are good examples on tools for cumulative impact assessments – but with their advantages and disadvantages.

The current paper has described the development of a new tool for cumulative impact aiming at user friendliness, high analytical capacity, and high-performance calculations. The success of the applied approach is demonstrated be a set of examples, and the current version is just a first version of the MYTILUS toolbox. It is expected that tools like MYTILUS can contribute to make more knowledge based maritime spatial plans among the EU Member States, as well as contributing to the process of reaching the targets set by the UN SDG goal 14 on the marine environment.

Currently, the next step in the development with focus on adding dynamics (time-series) into the impact calculations is under implementation and will be finished Autumn 2019. In addition, the calculation of conflict and synergy scores in connection with multi-use of marine space.

Acknowledgement. The current research has been supported by the NorthSEE project[7] funded by North Sea Programme of the European Regional Development Fund of the European Union, and the BONUS BASMATI project[8], which has received funding from BONUS (art. 185), funded jointly by the EU, Innovation Fund Denmark, Swedish Research Council Formas, Academy of Finland, Latvian Ministry of Education and Science, and Forschungszentrum Jülich GmbH (Germany).

References

1. Blaesbjerg et al.: Marine Spatial Planning in the Nordic Region. TemaNord, 2009:525. Nordic Council of Ministers (2009)
2. European Commission. Directive 2014/89/EU of the European Parliament and of the Council of 23 July 2014 establishing a framework for maritime spatial planning. The Official Journal of the European Union, L 257/135 (2014)
3. Ehler, C., Douvere, F.: Marine Spatial Planning: a step-by-step approach toward ecosystem-based management. Intergovernmental Oceanographic Commission and Man and the Biosphere Programme. In: OC Manual and Guides No. 53 IDNPU, editor (2009)
4. European Commission. Directive 2008/56/EC of the European Parliament and of the Council of 17 June 2008 establishing a framework for community action in the field of marine environmental policy (Marine Strategy Framework Directive). The Official Journal of the European Union, L 164/19 (2008)
5. Hacking, T., Guthrie, P.: A framework for classifying the meaning of Triple Bottom-Line, Integrated, and Sustainability Assessment. Environ. Impact Assess. Rev. **28**, 73–89 (2008)

[7] https://northsearegion.eu/northsee/.

[8] https://bonusbasmati.eu.

6. Kristensen, P.: The DPSIR framework. Paper presented at the 27–29 September 2004 Workshop on a Comprehensive/Detailed Assessment of the Vulnerability of Water Resources to Environmental Change in Africa Using River Basin Approach. UNEP Headquarters, Nairobi, Kenya (2004)
7. Halpern, B.S., et al.: A global map of human impact on marine ecosystems. Science **319**, 948–952 (2008)
8. HELCOM: The assessment of cumulative impacts using the Baltic Sea Pressure Index and the Baltic Sea Impact Index - supplementary report to the first version of the HELCOM 'State of the Baltic Sea' report (2017). http://stateofthebalticsea.helcom.fi/about-helcom-and-the-assessment/downloads-and-data/
9. Stock, A.: Open source software for mapping human impacts on marine ecosystems with an additive model. J. Open Res. Softw. **4**, 1–7 (2016)
10. Korpinen, S., Meski, L., Andersen, J.H., Laamanen, M.: Human pressures and their potential impact on the Baltic Sea ecosystem. Ecol. Indic. **15**(1), 105–114 (2012)
11. Micheli, F., et al.: Cumulative human impacts on mediterranean and black sea marine ecosystems: assessing current pressures and opportunities. PLoS ONE **8**(12), e79889 (2013)
12. Menegon, S., Sarretta, A., Depellegrin, D., Farella, G., Venier, C., Barbante, A.: Tools4MSP: an open source software package to support Maritime Spatial Planning. PeerJ Computer Science (2018). https://doi.org/10.7717/peerj-cs.165
13. Swedish Agency for Marine and Water Management: Symphony - Integrated planning support for national maritime planning from an ecosystem approach. Gothenburg (2018). (in Swedish)
14. Rajabifard, A., Feeney, M.E.F., Williamson, I.: Spatial data infrastructures: concept, nature and SDI Hierarchi. In: Williamson, I.P., Rajabifard, A., Feeney, M.E.F. (eds.) Developing Spatial Data Infrastructures: From Concept to Reality, pp. 17–40. Taylor and Francis, London, New York (2003)
15. European Commission. Directive 2007/2/EC of the European Parliament and of the Council of 14 March 2007 establishing an Infrastructure for Spatial Information in the European Community (INSPIRE). Official Journal of the European Union (2007)
16. Kocur-Bera, K., Dudzińska, M.: Information and database range used for maritime spatial planning and for integrated management of the coastal zone – case study in Poland. Baltic Sea. Acta Adriatica **55**(2), 179–194 (2014)
17. Hansen, H.S., Reiter, I.M., Schrøder, L.: A system architecture for a transnational data infrastructure supporting maritime spatial planning. In: Kő, A., Francesconi, E. (eds.) EGOVIS 2017. LNCS, vol. 10441, pp. 158–172. Springer, Cham (2017). https://doi.org/10.1007/978-3-319-64248-2_12
18. HELCOM: First version of the 'State of the Baltic Sea' report – June 2017 – to be updated in 2018 (2017). http://stateofthebalticsea.helcom.fi