R. Aps, K. Herkül, R. Cormier, K. Kostamo, J. Kotta, L. Laamanen, J. Lappalainen, K. Lokko, A. Peterson, R. Varjopuro

Deliverable 2.2.1 “The Gulf of Finland marine and coastal environmental risk profile”

ABSTRACT

Title: Deliverable 3.2.1 “The Gulf of Finland marine and coastal environmental risk profile”

Authors: R. Aps, K. Herkül, R. Cormier, K. Kostamo, J. Kotta, L. Laamanen, J. Lappalainen, K. Lokko, A. Peterson, R. Varjopuro

Abstract:

The EU Marine Spatial Planning (MSP) Directive establishes a framework for maritime spatial planning aimed at promoting the sustainable growth of maritime economies, the sustainable development of marine areas and the sustainable use of marine resources. The marine environment is heavily impacted by human activities especially in intensively used sea areas such as the Baltic Sea where the assessments of environmental vulnerabilities and cumulative risks are increasingly demanded in environmental decision and policymaking. In this study we developed the Gulf of Finland marine environmental risk profile (ERP) as a spatial data layer that incorporates the vulnerability of nature values and the HELCOM Baltic Sea Pressure Index (HELCOM BSPI). HELCOM BSPI as a measure of cumulative spatial human pressures and the Gulf of Finland marine environmental vulnerability profile (EVP) were used to identify the likelihood and magnitude of potential environmental effects under pressures of multiple human uses and to develop the Gulf of Finland marine environmental cumulative risk profile to be used in the ecosystem-based adaptive MSP processes in Estonia and Finland including trans-boundary aspects.

The aim of this study was to develop cross-border cumulative ERP of the Gulf of Finland, which, together with EVP, can be used for ecosystem-based MSP processes in Estonia and Finland, in order to find solutions that lead to sustainable use of resources and to improved planning and management of the marine and coastal areas. The main product of this report was the “Environmental cumulative risk profile (ERP)” as a spatial data layer that incorporates the EVP and cumulative human pressures - higher value indicates higher likelihood to damage nature values.

Acknowledgements

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Contents

1 Introduction

1.1 Concept of environmental risk

Humans depend on ocean ecosystems for important and valuable goods and services, but human use has also altered the oceans through direct and indirect influence (Myers and Worm 2003; Lotze et al. 2006). The marine environment is quite frequently heavily impacted by human activities in a multitude of ways, especially in intensively used sea areas like the Baltic Sea (Korpinen et al. 2012), where competition on the access to sea area exceed national borders. However, the cumulative effect of multiple stressors by humans on ecological communities remains largely unknown. Meta-analysis across studies revealed that cumulative effects of multiple stressors will often be worse than expected based on single stressor impacts (Crain et al. 2008).

Politicians and other decision makers are requesting new tools for understanding the state of the environment. Assessing pressures, caused by humans can thus provide an important tool to support blue growth and to preserve the capacity of ecosystems to provide valued services. Thus, pressures or risk assessments are increasingly used and demanded in environmental decision-making and policy-making processes. As part of this trend, both the United States and the European Union have taken the lead in establishing directives to moderate the liability resulting from environmental pollution incidents (Grawford Global Technical Services, 2018).

The multiple competing uses of marine and coastal areas have resulted in a rapid increase of maritime spatial planning (MSP) initiatives to safeguard sustainable use of marine resources as well as to mitigate cross-sectoral and transboundary conflicts over the use of sea space (Douvere and Ehler, 2010; Stelzenmüller et al., 2015). The Maritime Spatial Planning Directive 2014/89/EU establishes a framework for MSP aimed at promoting the sustainable growth of maritime economies, the sustainable development of marine areas and the sustainable use of marine resources. The directive defines the MSP as a process, by which the relevant Member State’s competent authorities analyse and organise human activities in marine areas to achieve ecological, economic and social objectives (EU, 2014).

An understanding of the distribution of the pressures caused by human activities in needed for the successful MSP and integrated assessments (Eastwood et al. 2007). For carrying through a comprehensive assessment of direct physical pressure up-to-date, accurate and high-resolution spatially resolved data for all major offshore human activities and the pressures they cause are required (Defra 2005; Eastwood et al. 2007). An often cited definition states that "MSP is a public process of analyzing and allocating the spatial and temporal distribution of human activities in marine areas to achieve ecological, economic, and social objectives that usually have been specified through a political process" (UNESCO-IOC 2010). MSP is a holistic and cross-sectoral approach that is expected to be based on ecosystem approach (e.g. Douvere and Ehler 2010; Foley et al. 2010; Katsanevakis et al. 2011; Merrie and Olsson 2014).

The need for environmental vulnerability and risk assessments in spatial management is widely recognized and a range of approaches has been described earlier (Villa and McLeod, 2002; Hiddink et al. 2007; Selkoe et al. 2009; Ardron et al. 2014; Stelzenmüller et al. 2015; La Rivière et al. 2016). Comprehensive vulnerability assessment is pressure-driven and includes exposure, sensitivity and recovery of a nature value/ecosystem component to pressures (De Lange et al. 2010), and is based on best available knowledge (La Rivière et al. 2016). Moreover, most vulnerability assessments that aim at contributing directly to a MSP processes are either regional or national (e.g. Foley et al. 2013; La Rivière et al. 2016) and only seldom performed in a transboundary context (Martin et al. 2009).

Risk assessment methods are widely used to assess and grade environmental problems (deFur et al., 2007) but current methods in general are not designed to address the risks of cumulative effects of environmental stressors. However, the U.S. Environmental Protection Agency has developed a general framework for cumulative risk assessment (EPA, 2003). According to this framework, a cumulative risk consists of the combined risks from aggregate exposures to multiple agents or stressors and the cumulative risk assessment means an analysis, characterisation, and possible quantification of the combined risks to health or the environment from multiple agents or stressors. Risk assessment uses science, but itself is not science in the conventional sense. It does not seek to develop new theories or general knowledge, but rather uses scientific knowledge and tools to generate information that is useful for a specific purpose (Suter et al., 2007).

In the assessment of current ecological status and the identification of important ecosystem properties and threats it is important to identify ecosystem components that are structurally and functionally important (Bremner et al. 2003). The key output of risk identification is an environmental vulnerability profile that can be used to prioritize the activities of the risk analysis (Cormier et al. 2013). An inclusion of the characteristic habitat forming and/or functionally important species ensures that the essential spatial proxies of spatially dynamic species are also included. In many coastal regions, several benthic plant and invertebrate species are considered as habitat engineers or habitat-forming species. They are capable of creating a specific local environment that facilitates colonization of other species that otherwise would not be present in the area (Martin et al. 2013; Koivisto and Westerbom 2010, 2012). Also, it is essential to register the type and intensity of factors that influence the ecosystem components, including human activities (de Groot 1996b; Jennings et al. 1999) and understand the way ecosystem features and human activities interact (de Groot 1996a; Kaiser et al. 2002; Breuer et al. 2004). Similar approaches, that were developed to assess and map cumulative human impacts previously applied to marine regions, including e.g. the US EEZ (Halpern et al. 2009), western Canada (Ban et al. 2010) and the Baltic Sea (Korpinen et al. 2012).

The Baltic Sea is the largest brackish-water basin in the world. The catchment area covers over 1,700,000 km^2 and is home for over 84 million inhabitants (HELCOM 2011). The combination of vertical stratification, high population density and well-developed agricultural sector in the catchment area and a small body of water with limited exchange with the North Sea makes the Baltic Sea vulnerable and sensitive to nutrient enrichment and eutrophication (HELCOM 2009).

Because of large freshwater inflow and limited connection to the North Sea, the salinity in the Baltic Sea is much lower than in true oceanic waters, which makes the sea even more sensitive as relatively few species can thrive in such brackish-water conditions (HELCOM 2009). The Gulf of Finland is considered one of the most eutrophicated basins in the Baltic Sea area with the nutrients input and trophic state increasing from west to east (HELCOM 2003; Pitkänen et al. 2007). As compared to other basins in the Baltic Sea, the Gulf of Finland has a relatively large catchment area and the greatest freshwater inflow that results in a strong horizontal salinity gradient. The surface salinity in the gulf varies from 0 in its eastern end to 7 ppt in the western areas of the gulf (Pitkänen et al. 2008).

Data availability plays a major role in developing methodology for pressures and risk assessment (Hinkel 2011), it depend upon improvements in data access and agreed standards for data processing if they are to be used to set future management objectives (Eastwood et al. 2007). The Baltic Sea can provide an interesting possibility to develop the methodology due to the fact that extensive datasets are available for analyses.

1.2 Aim of the study

The aim of this study was to develop transboundary environmental risk profile (ERP) for the Gulf of Finland, which can be used in ecosystem based MSP processes in Estonia and Finland. Developed ERP can facilitate discovering solutions that lead to sustainable use of marine resources and improve planning and management of the marine and coastal areas.

2 Material and methods

2.1 The project area

The tideless Baltic Sea can be characterized by a steep salinity gradient resulting in a variable fauna and flora, which tolerates well the prevailing environmental conditions. The project area and the locations of the toponyms that were used in describing the results are shown in the Figure 2.1.1.

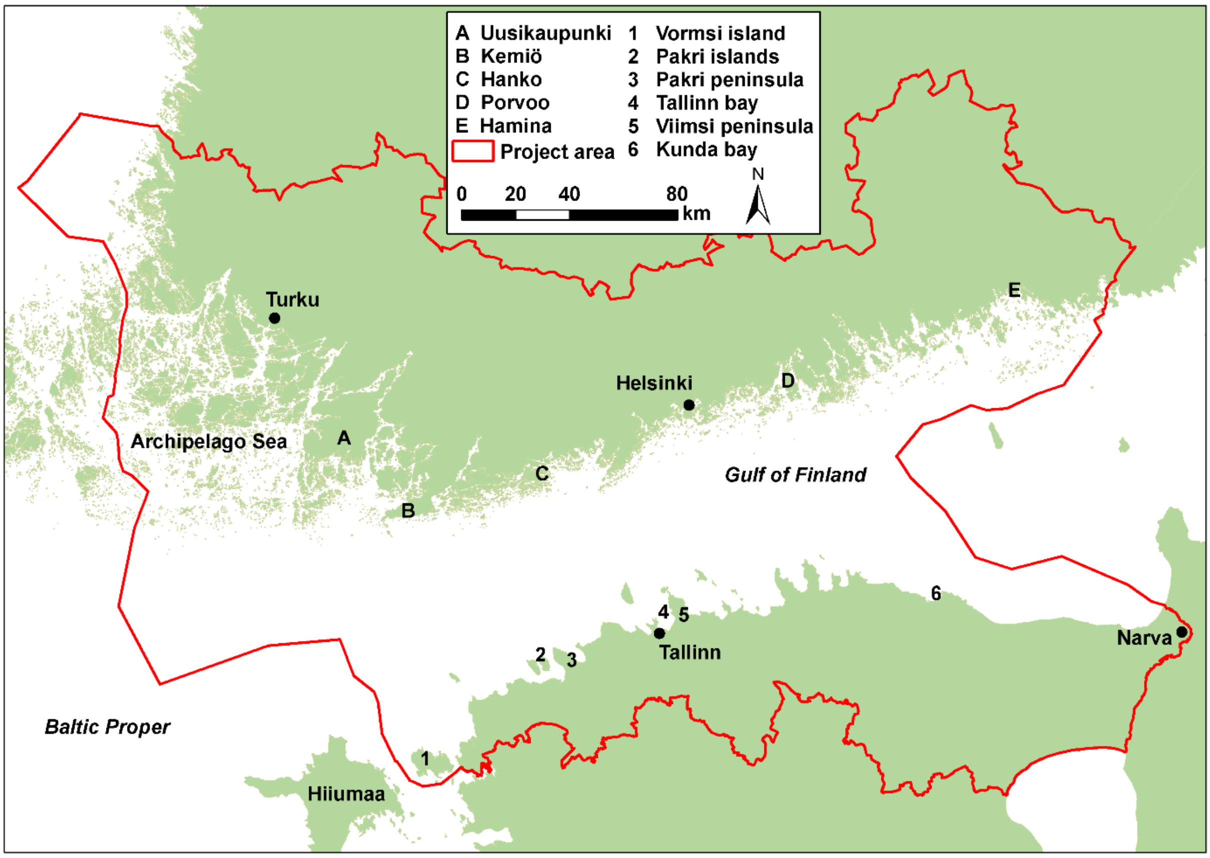

Figure 2.1.1. The project area and the locations of the toponyms that were used in describing the results.

The project area includes three sub-basins of the Baltic Sea: Archipelago Sea, the Northern Baltic Proper and Gulf of Finland. The sea area of Åland was excluded from the area due to lack of field observations (except for the benthos samples that were included). All of the sub-basins exhibit strong gradients of wave exposure, depth, and salinity. The sea areas west of the islands Saaremaa and Hiiumaa and the southwestern outer archipelago are exposed to the open Northern Baltic Proper and have a wave fetch of hundreds of kilometres. In contrast, the inner reaches of the bays of the mainland are very sheltered both by the mainland and by islands. Salinity exceeds 7 PSU in the westernmost study area while it falls to almost 0 PSU in the inner parts of bays with riverine inflow and also in the Bothnian Bay (Kautsky and Kautsky, 2000; Karlson et al., 2002; Zettler et al., 2013, Alenius et al., 2016; Snoeijs-Leijonmalm et al., 2017).

2.2 Environmental vulnerability profile

The environmental vulnerability profile (EVP), which was used in the calculations of risk profile was readily available from previous study of the same project (Aps et al., 2018). EVP represents the single layer, which contains the distribution of all nature values (NVs) and their sensitivity to disturbance (Table 2.2.1). There were ten important benthic species or groups of species with different ecosystem functions and recovery potentials chosen to represent benthic nature values: bladder wrack (*Fucus vesiculosus*), the perennial red seaweed *Furcellaria lumbricalis*, filamentous algae, epibenthic bivalves (*Mytilus trossulus*, *Dreissena polymorpha*), vascular plants (excluding *Zostera marina*), eelgrass (*Zostera marina*), charophytes (*Chara* spp., *Tolypella nidifica*, *Nitella* spp.), infaunal bivalves (*Macoma balthica*, *Cerastoderma glaucum*, *Mya areanaria*), sea birds and seals. In addition, total species richness indices were calculated for each sampling station.

Table 2.2.1. Species or groups of species that were chosen to represent the important nature values in this study with their recovery classes and coefficient in the further calculations according to the recovery class (Aps et al., 2018).

Species/group	**Recovery class (years)**	**Sensitivity Coefficient**
Fucus vesiculosus	2 - 3	2
Furcellaria lumbricalis	5 - 10	4
Filamentous algae	< 2	1
Epibenthic bivalves (*Mytilus trossulus, Dreissena polymorpha*)	3 - 5	3
Vascular plants (excl. *Zostera marina*)	3 - 5	3
Zostera marina	> 10	5
Charophytes (*Chara* spp, *Tolypella nidifica*)	2 - 3	2
Infaunal bivalves (*Limecola balthica*, *Cerastoderma glaucum*, *Mya areanaria*)	2 - 3	2
Seals	> 10	5
Birds	> 10	5

Due to the lack of comparable data on birds in Finnish sea areas the separate index was developed that included only benthic NVs, hereafter termed as the EVP-B. The EVP-B was calculated for both Estonian and Finnish sea areas.

Caused by data limitations of birds and seals data separate layers of EVP were produced and used as the input layer for the calculations of environmental risk profile (Aps et al., 2018):

- EVP-B included only benthos data (Figure 2.2.2).
- EVP-BS included benthos and seal data (Figure 2.2.3).
- EVP-F included all input data (i.e. benthos, birds, and seals). These layers were produced for Estonian area only where the bird data was available (Figure 2.2.4).

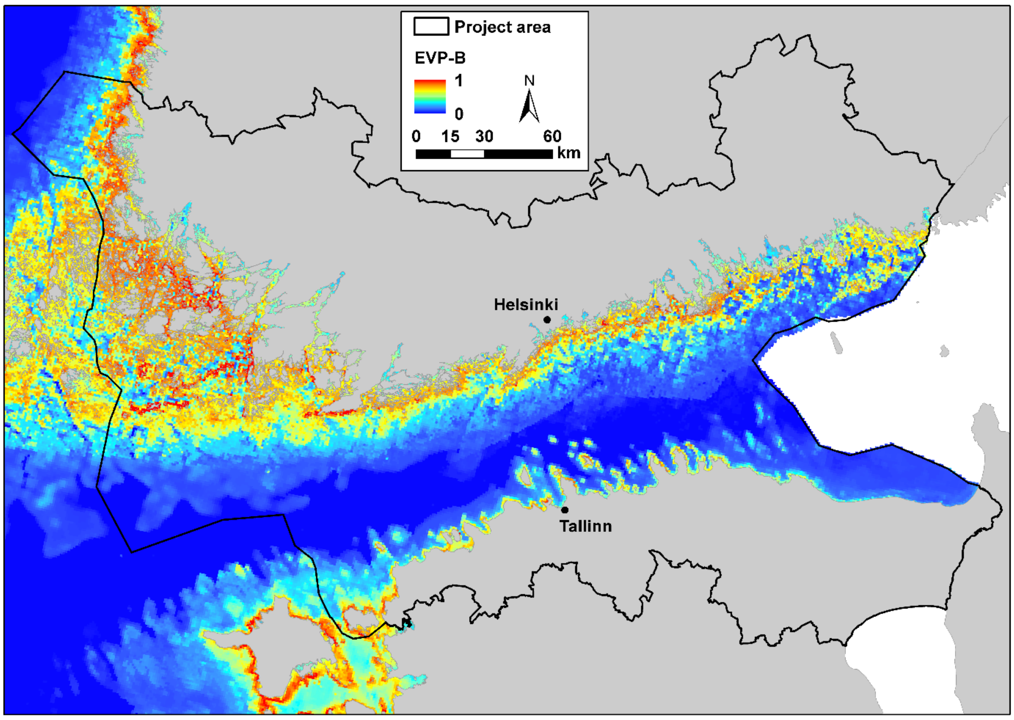

Figure 2.2.2. Environmental vulnerability profile based on benthic nature values (EVP). Values vary between 0 and 1, where 1 expresses the highest vulnerability.

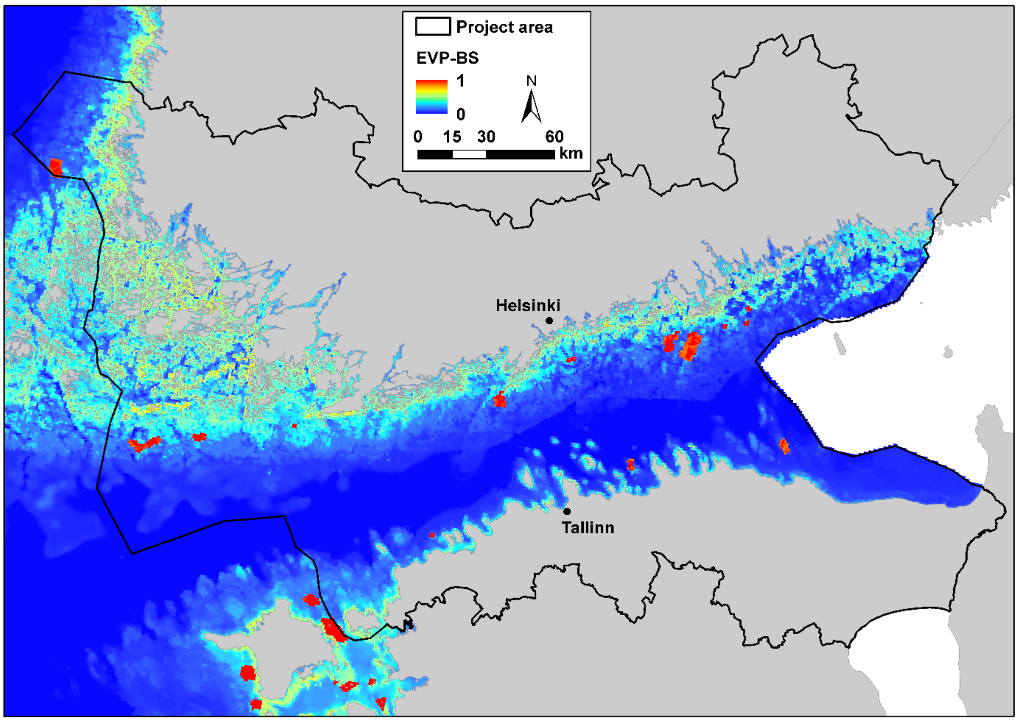

Figure 2.2.3. Environmental vulnerability profile, based on benthic nature values and seals (EVP-BS). Values vary between 0 and 1, where 1 expresses the highest vulnerability.

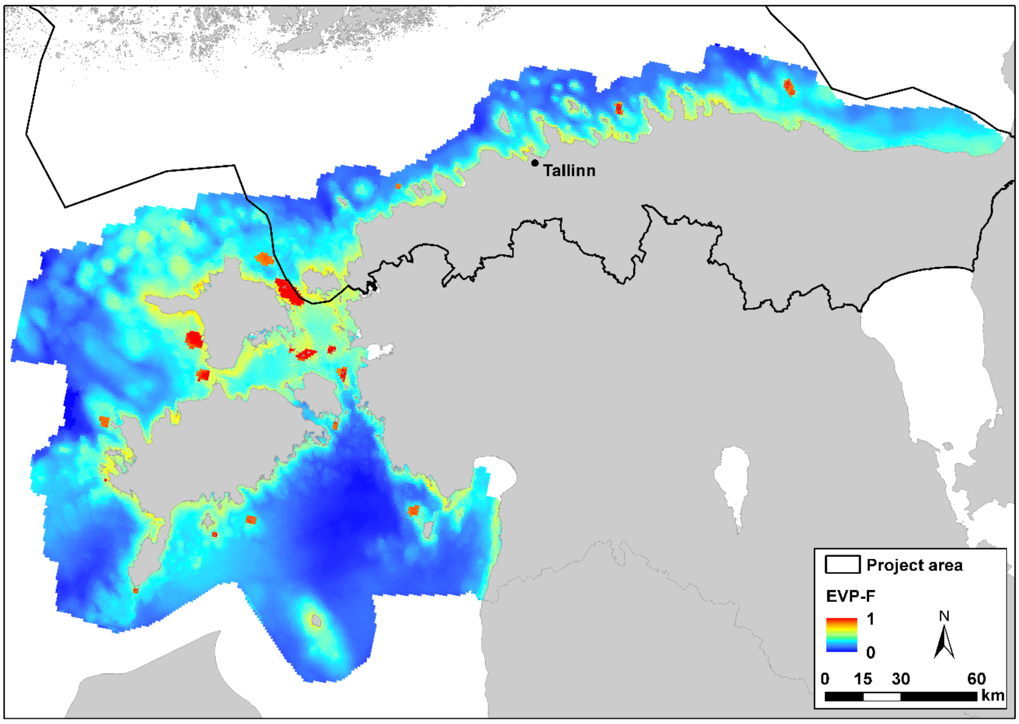

Figure 2.2.4. Environmental vulnerability profile based on benthic nature values, seals and birds (EVP-F). Values vary between 0 and 1, where 1 expresses the highest vulnerability.

2.3 Calculation of environmental risk profiles

2.3.1 HELCOM Baltic Sea Pressure Index (BSPI)

A map of the HELCOM Baltic Sea Pressure Index, BSPI (HELCOM, 2018) represents the intensity of cumulative anthropogenic pressures in a 1 km × 1 km grid in the study area (Figure 2.3.1.1.).

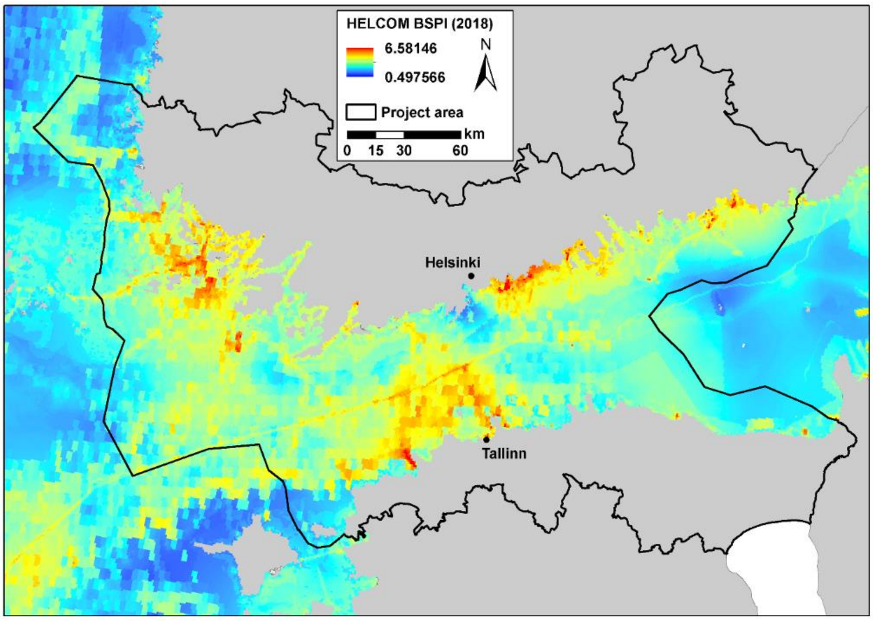

Figure 2.3.1.1. Project area on the backround of HELCOM Baltic Sea pressure index (HELCOM, 2018).

BSPI incorporates multitude of human pressures weighed by their potential impacts on ecosystem. HELCOM Baltic Sea pressure index – BSPI was used to represent the geographical distribution of intensity of cumulative anthropogenic pressures (Figure 2.3.1.1). BSPI is calculated based on multitude of human pressures weighed by their general potential impacts on ecosystem. All datasets and methodologies used in the index calculations are approved by all HELCOM Contracting Parties in review and acceptance processes. This dataset covers the time period 2011-2015 (HELCOM, 2018).

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2.3.2 Calculation process

The general scheme of calculations is shown in figure (Figure 2.3.2.1). Environmental vulnerability profile (EVP) was calculated as a sum aggregation of all NVs that were first rescaled from 0 to 1 (by dividing with maximum value) and then weighed by NV-specific sensitivity coefficient (see Table 2.2.1). The environmental risk profile (ERP) was a multiplication product of EVP and BSPI.

In order to calculate the environmental risk profile in the study area, BSPI was divided by its maximum value over all cells to make the values vary between 0 and 1. Then the rescaled BSPI was multiplied with EVP and divided by the maximum value of such multiplication term over all grid cells to make the values vary between 0 and 1(Formula 1).

(EVP × BSPI/max(BSPI))/max(EVP × BSPI/max(BSPI)) (Formula 1)

Similar to the EVP, when calculations were based on EVP-F the index was termed ERP-F and in case calculations were based on EVP-B or EVP-BS, the index was termed ERP-B or ERP-BS accordingly.

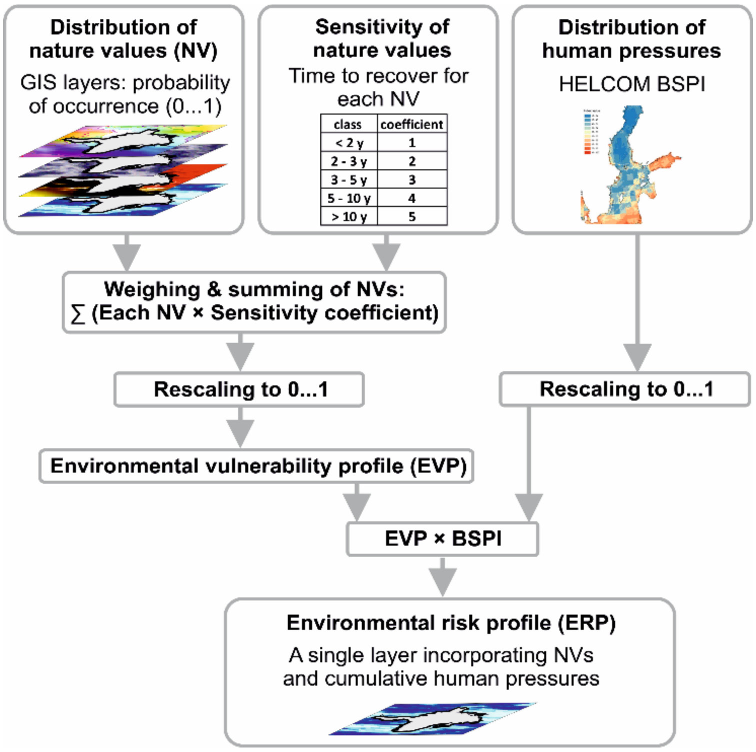

Figure 2.3.2.1. The general scheme of calculations of environmental vulnerability profile (EVP) and environmental risk profile (ERP).

It is important to add that ERP-B is developed as the main product that cover the whole project sea area of the Gulf of Finland.

3 Results

3.1 Environmental risk profile (ERP)

3.1.1 ERP-B

Environmental risk profile, including only benthic species (ERP-B), has the highest risk areas in Archipelago Sea, near the Kemiö peninsula and Hanko, in the coast of Helsinki and close to Hamina, in the Finnish side of the project area (Figure 3.1.1.1). At the Estonian coast of the project area, areas with highest risk situate around Pakri islands and peninsula, close to Tallinn bay and city, and Viimsi peninsula. Medium risk values can be faound across all the coast area of Estonia and Finland. Lowest values of risk values cover most of the open sea areas across the Gulf of Finland and northern Baltic Proper.

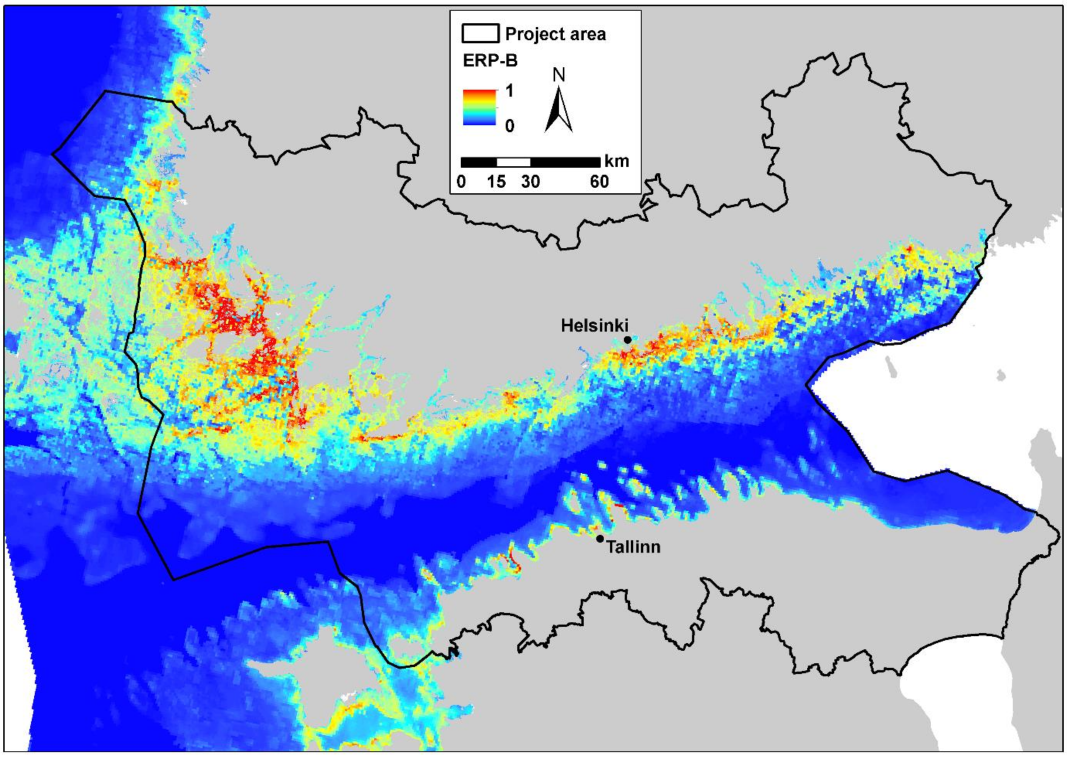

Figure 3.1.1.1. Environmental risk profile, based only on benthic nature values (ERP-B). Values vary between 0 and 1, where 1 expresses the highest risk.

3.1.2 ERP-BS

ERP-BS include environmental risk profile that consists of benthic data accompanied with seal data. When the seals and benthic nature values are considered together, highest risk occurs around the seals protection areas (Figure 3.1.2.1). High values are also in the Archipelago Sea, close to Kemiö, Helsinki, Pakri and Viimsi peninsula. Medium values of risk cover near the coast areas around all the coast of Estonia and Finland. Lowest values are located farther from the coast and in the open sea area.

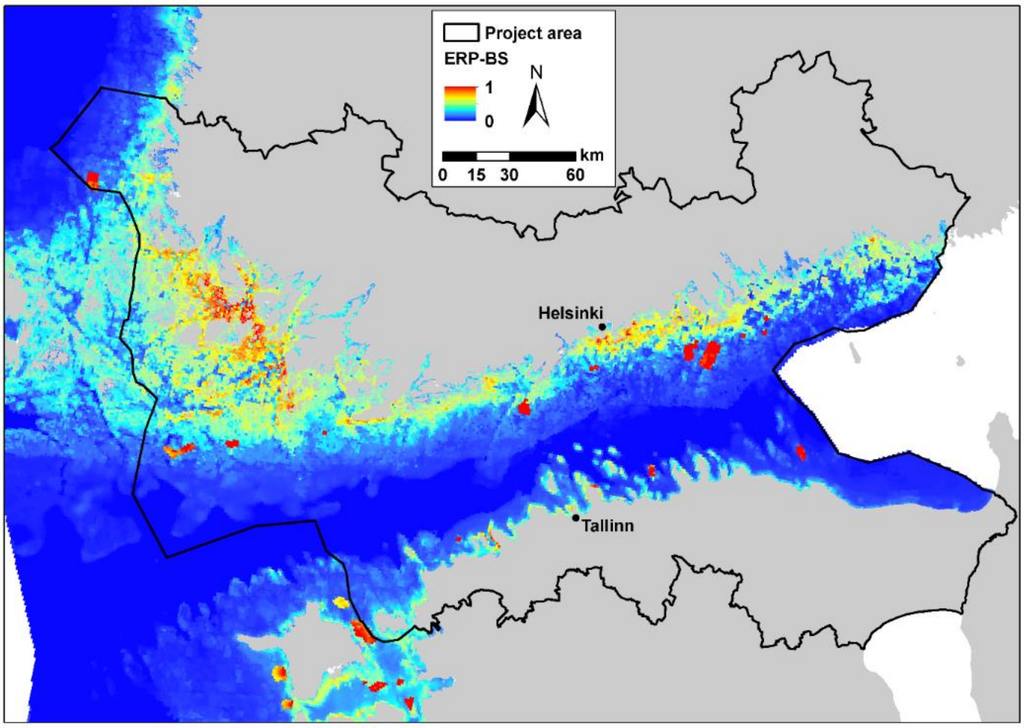

Figure 3.1.2.1. Environmental risk profile, based on benthic nature values and seals (ERP-BS). Values vary between 0 and 1, where 1 expresses the highest risk.

3.1.3 ERP-F

ERP-F results describes the risk where all nature values (birds, seals and benthic nature values) are considered and presented only for Estonian waters (Figure 3.1.3.1).

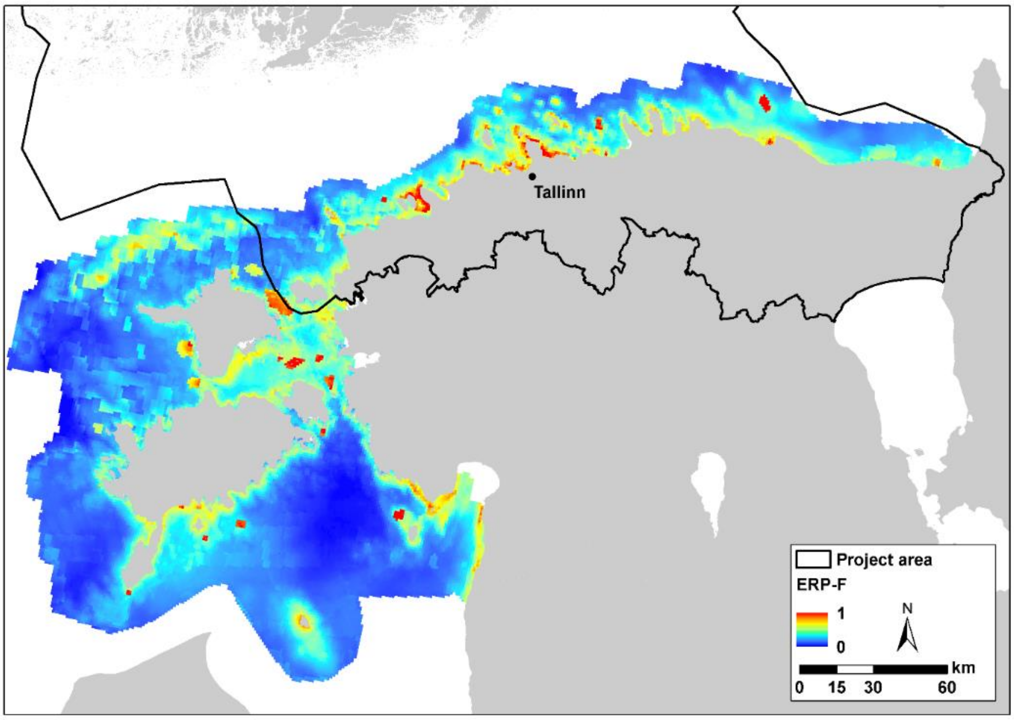

Figure 3.1.3.1. Environmental risk profile, based on benthic nature values, seals, birds (ERP-F.) Values vary between 0 and 1, where 1 expresses the highest risk.

The highest risk is estimated to occur around seals protection areas (ERP-F max 1.0) as shown in Figure 3.1.3.1. Other high risk areas (>0.9) are located around Pakri islands and peninsula, near the city of Tallinn and Viimsi peninsula and in the Kunda bay. Medium risk values, ERP-F above 0.5, cover almost most of the coast from Vormsi Island to the eastern part of the project area. Close to the city of Narva coast has also ERP-F around 0.5 which is due to important bird areas taken into account. Values decrease towards open sea, especially in the western Gulf of Finland and in the open sea.

A map layers of environmental vulnerability and risk profiles can be used as argumentation maps for MSP processes with multiple stakeholders. According to Rinner (2006) the argumentation maps can support the communication process among the involved groups during geospatial planning, and allows the specific arguments and related geographical features to be linked and analysed. The content of such argumentation maps can be easily communicated to maritime spatial planning experts and other interested stakeholders to jointly analyse and compare the potential environmental risk levels resulting from different planning related marine space allocations.

3.2 Environmental cumulative risk analysis and evaluation

3.2.1 Cumulative risk analysis

The issue is exemplified by environmental cumulative risk analysis for potential development area of offshore renewable energy installations (OREI) off the Saaremaa Island in the Baltic Sea. Based on methodology presented above the average value of environmental vulnerability and environmental cumulative risk was calculated for Saare OREI potential marine area (Figure 3.2.1.1).

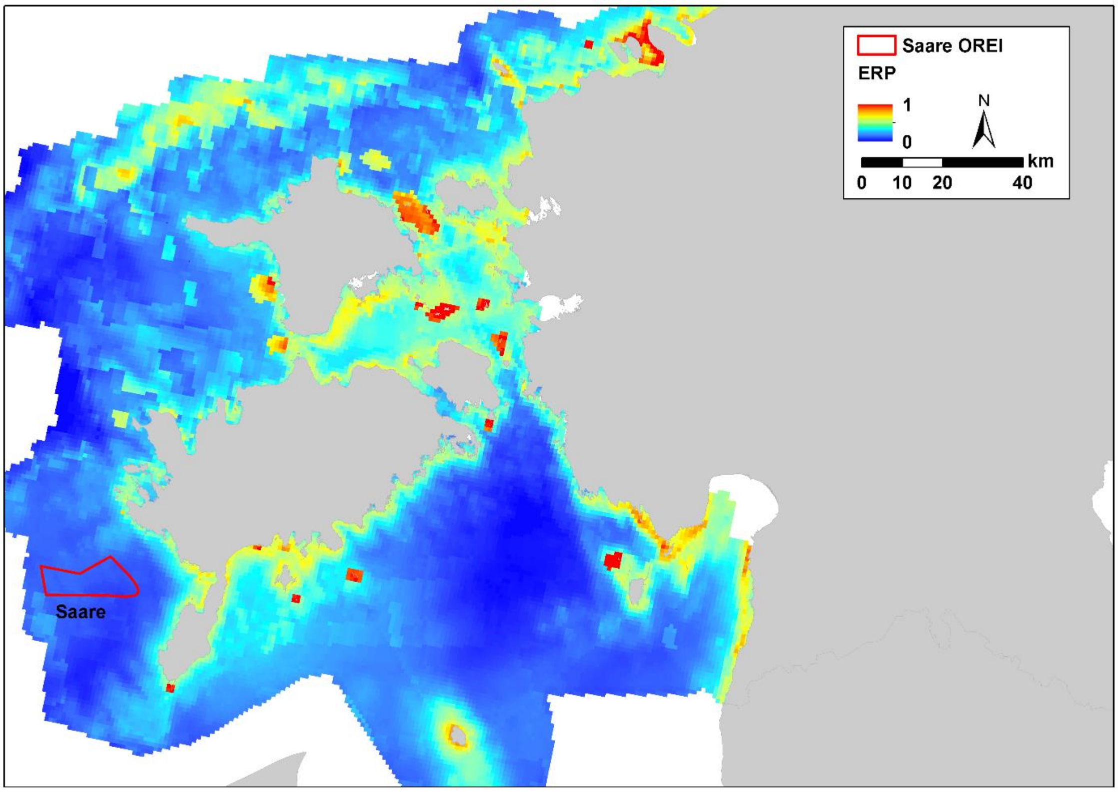

Figure 3.2.1.1. Possible marine area for potential development of offshore renewable energy installations (Saare OREI) off the Saaremaa Island in the Baltic Sea. Environmental cumulative risk profile (ERP) values are shown in the background.

The remaining Estonian sea area from the same depth range (hereafter no-OREI) was also assigned with the average environmental vulnerability values. The depth filtering was necessary to ensure adequate comparison between OREI and "no-OREI" areas as depth is a major driver of both abiotic and biotic characteristics. Two-dimensional scatterplots between environmental vulnerability and BSPI were used to visualize the differences between possible OREI and no-OREI sea areas (Figure 3.2.1.2).

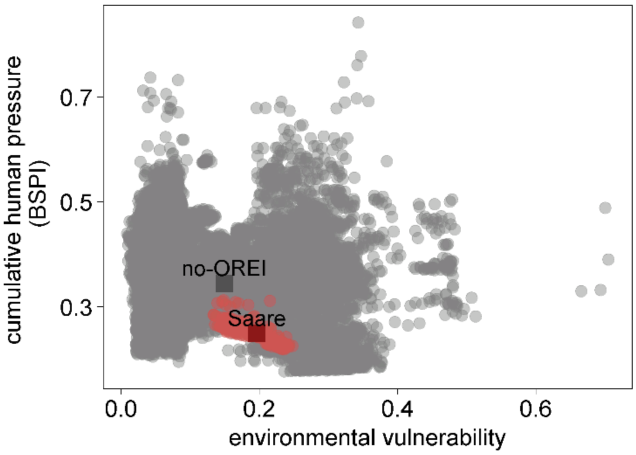

Figure 3.2.1.2. Scatterplot of area-specific pixel values (circles) of environmental vulnerability (EVP) on the horizontal axis and of cumulative human pressures (BSPI) on the vertical axis. The mean values of inside and outside of possible Saare OREI area are shown with rectangles.

Further, the standard three-level environmental cumulative risk analysis matrix (Figure 3.2.1.3) was outlined based on the following basic assumptions: a) the level of cumulative human pressure (BSPI) is proportional to the likelihood of potential environmental cumulative effect events, and b) the level of environmental vulnerability is proportional to potential consequences of environmental cumulative effect events.

Suggested potential Saare OREI sea area was characterized by relatively low environmental vulnerability and relatively low cumulative human pressure levels (Figure 3.2.1.3). No-OREI area in the same depths as Saare OREI was also characterized by relatively low environmental vulnerability and low to medium cumulative human pressure levels.

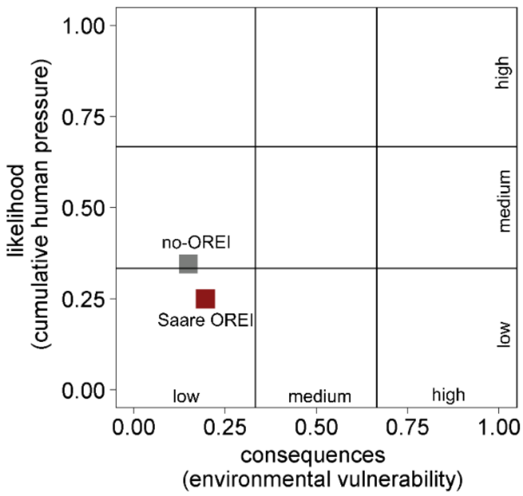

Figure 3.2.1.3. Risk analysis: the mean pixel values of environmental cumulative risk characteristic inside and outside of the potential offshore renewable energy installations (Saare OREI) off the Saaremaa Island in the Baltic Sea.

3.2.2 Cumulative risk evaluation

According to ISO 10000 2018 (ISO, 2018) the risk is the “effect of uncertainty on objectives” and the risk analysis is a process that is used to understand the nature, sources, and causes of the risks that are identified and to estimate the level of risk as well as to study impacts and consequences and to examine the controls that currently exist.

In environmental cumulative risk management, risk matrices (Figure 3.2.2.1) do not make decisions (ICES, 2014) as they only provide a set of criteria to express tolerances of risk in relation to achieving the policy objectives.

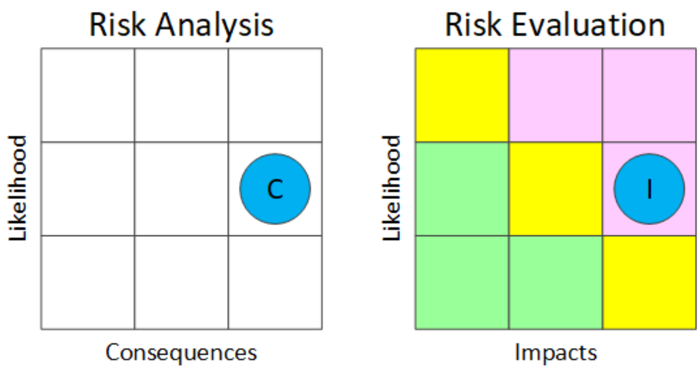

Figure 3.2.2.1. Risk matrices and tolerance overlay.

Risk matrix is used to classify a tolerance of the risk based on the combination of likelihood and consequences to achieve a policy objective and is not an extension of an x-y function plot (Cox, 2009). Given the need for an independence of the scientific research and policy advice, the scientific value free estimates of risk are not considered within a tolerance context (Figure 3.2.2.1. left side matrix). They are basically mapped to a blank matrix.

Given the policy context of management and stakeholder, the likelihood and consequences are converted into the level of impacts that are not tolerated by management and stakeholders in terms of achieving a policy objective set by the planning process (Figure 3.2.2.1. right side matrix). The values of value neutral scientific consequences (C) are technically converted into an impact statement (I) within the policy context. A likelihood and consequence in the pink area becomes an intolerable situation from a policy perspective.

Referring to ISO 10000 2018 (ISO, 2018) the likelihood is the chance that something might happen and it is defined, determined, or measured objectively or subjectively and can be expressed either qualitatively or quantitatively while a consequence is the outcome of an event and has an effect on objectives. It is stated further that a single event can generate a range of consequences which can have both positive and negative effects on objectives.

Differences in the ERP mean values for different marine areas enable maritime spatial planners and stakeholders to compare the environmental cumulative risk level of different planning solutions and thereby to overcome the major environmental challenges faced by any highly impacted marine ecosystem (Aps et al., 2018).

However, establishment of environmental cumulative risk-related tolerability levels require extensive consultations with regulators, stakeholders, and the public in order to determine the level of risk that is acceptable to all stakeholders. “Given that a scientific assessment is objective and is based on facts, it would simply reflect likelihood and magnitude leaving the severity, tolerability or values to the governance decision-making processes and stakeholder constituency” (ICES, 2014).

3.2.3 Bow-tie analysis

It is stated (ICES, 2014) that the Bow-tie is a diagrammatic representation of the complex relations between the risks and management that can lead to better communication and understanding of the risks with third parties. It is added further that the Bow-tie analysis can help to integrate knowledge and science from disparate sources and thus aid in structuring the questions that arise during the marine planning activities and efficiently communicating the logic or reasoning behind the decisions that have to be taken in order to prevent an undesired ecological event.

The unifying framework for marine environmental management DAPSI(W)R(M) (pronounced dap-see-worm) is suggested (Elliott et al., 2017) to link the natural and social systems with aim to deliver the Ecosystem Approach, i.e. to protect and maintain the natural system while supporting ecosystem services which then can help to deliver societal goods and benefits. It is further explained that in DAPSI(W)R(M) 1) the Drivers of basic human needs require Activities which lead to Pressures, 2) the Pressures are the mechanisms of State change on the natural system which then leads to Impacts (on human Welfare), and the Impacts then require Responses (as Measures).

Referring to the MSP outcome solutions for spatial and temporal management of the activities of the drivers that introduces pressures within the marine ecosystem, an event is described in terms of having the potential of not achieving an ecosystem management objectives as they relate to ecosystem components or ecosystem services (cultural, social or economic consequences due to the loss of a valued ecosystem services).

It is stated (Cormier et al., 2015) that the MSP process has to identify all relevant *risk sources* and related *events* resulting from the planned solutions to accommodate the activities of the drivers operating in the management area in terms of ecological, cultural, social, economic *consequences* and legal repercussions referring to achieving the environmental, economic and social objectives of the Maritime Spatial Plan concerned. It is stated further that Bow-tie analysis can be used as a means of organizing and visualizing all of the elements of risk to primarily map and evaluate the system of management controls. It is added that in MSP context the Bow-tie analysis would be used to evaluate the various spatial and temporal management measures that could be implemented to prevent the undesired events or to mitigate their consequences (Figure 3.2.3.1).

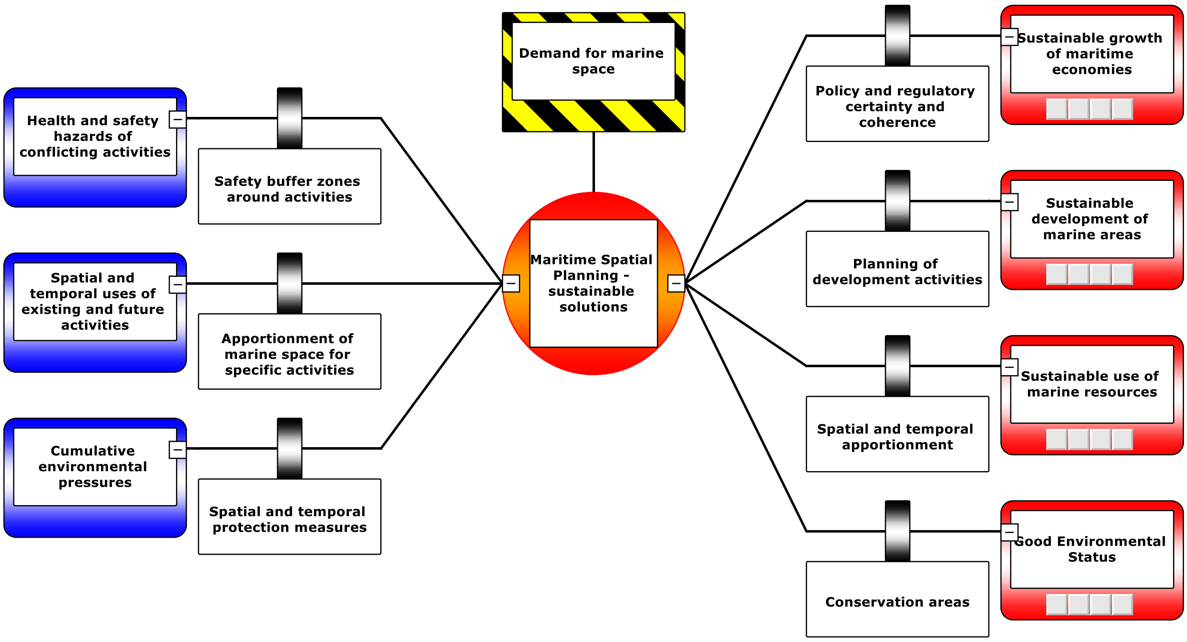

Figure 3.2.3.1. Bow-tie diagrammatic representation of the Maritime Spatial Planning related prevention and mitigation management measures to achieve the environmental, economic and social sustainability objectives (modified from Cormier et al., 2015).

It is concluded (ICES, 2014) that the Bow-tie approach helps to structure information and, thus, helps to gain joint understanding and facilitate joint problem framing among a group of MSP experts, stake-holders and policy makers. It is added further that “At the same time a Bow-tie is a conceptual integrator bridging information from science and policy. While the assessment of any area or problem can be seen as a product of scientific research, the management of the risks identified in assessments requires an evaluation of management options that would include rules of management, regulatory regimes or economic incentives as a suite of management tools”.

4 Executive summary

The marine environment is heavily impacted by human activities especially in intensively used sea areas such as the Baltic Sea where the assessments of environmental vulnerabilities and cumulative risks are increasingly demanded in environmental decision and policymaking.

Politicians and other decision makers are requesting new tools for under-standing the state of the environment. Assessing pressures, caused by humans can thus provide an important tool to support blue growth and to preserve the capacity of ecosystems to provide valued services. Thus, pressures or risk assessments are increasingly used and demanded in environmental decision-making and policy-making processes.

In this study the Gulf of Finland marine environmental risk profile (ERP) was developed as a spatial data layer that incorporates the vulnerability of nature values and the HELCOM Baltic Sea Pressure Index (HELCOM BSPI). HELCOM BSPI as a measure of cumulative spatial human pressures and the Gulf of Finland marine environmental vulnerability profile (EVP) were used to identify the likelihood and magnitude of potential environmental effects under pressures of multiple human uses and to develop the Gulf of Finland marine environmental cumulative risk profile to be used in the ecosystem-based adaptive MSP processes in Estonia and Finland including trans-boundary aspects.

The aim of this study was to develop cross-border cumulative ERP of the Gulf of Finland, which, together with EVP, can be used for ecosystem-based MSP processes in Estonia and Finland, in order to find solutions that lead to sustainable use of resources and to improved planning and management of the marine and coastal areas. The main product of this studyt is the “Environmental cumulative risk profile (ERP)” as a spatial data layer that incorporates the EVP and cumulative human pressures; higher value indicates higher likelihood to damage nature values.

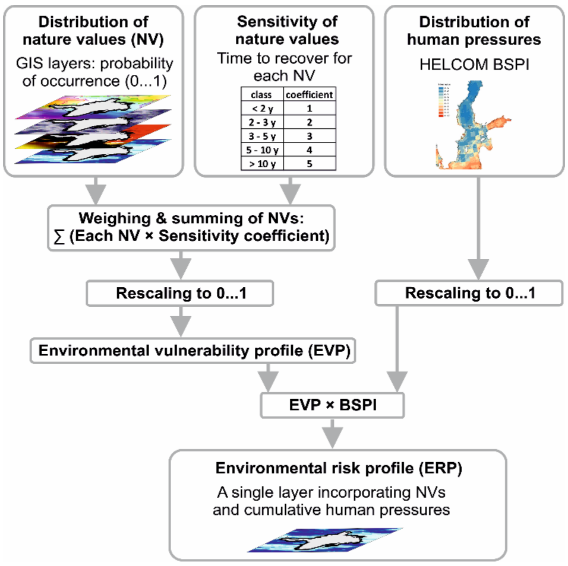

Figure 4.1. The general scheme of calculations of environmental risk profile (ERP).

Caused by data limitations of birds and seals data, separate layers of EVP were produced and used as the input layer for the calculations of environmental risk profile (Aps et al., 2018):

- ERP-B included only benthos data as input biological data
- ERP-BS included benthos and seal data as input biological data
- ERP-F included all biological input data (i.e. benthos, birds, and seals). These layers were produced for Estonian area only where the bird data was available

It is important to add that ERP-B (Figure 4.2) is developed as the main product that cover the whole project sea area of the Gulf of Finland.

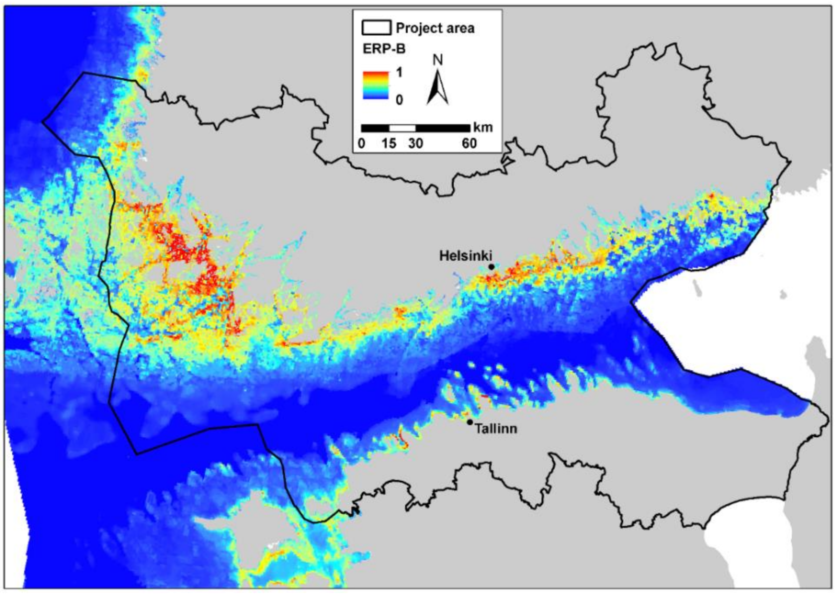

Figure 4.2. Environmental risk profile, based only on benthic nature values (ERP-B). Values vary between 0 and 1, where 1 expresses the highest risk.

4.1 Cumulative risk analysis

The issue was exemplified by environmental cumulative risk analysis for potential development area of offshore renewable energy installations (OREI) off the Saaremaa Island in the Baltic Sea.

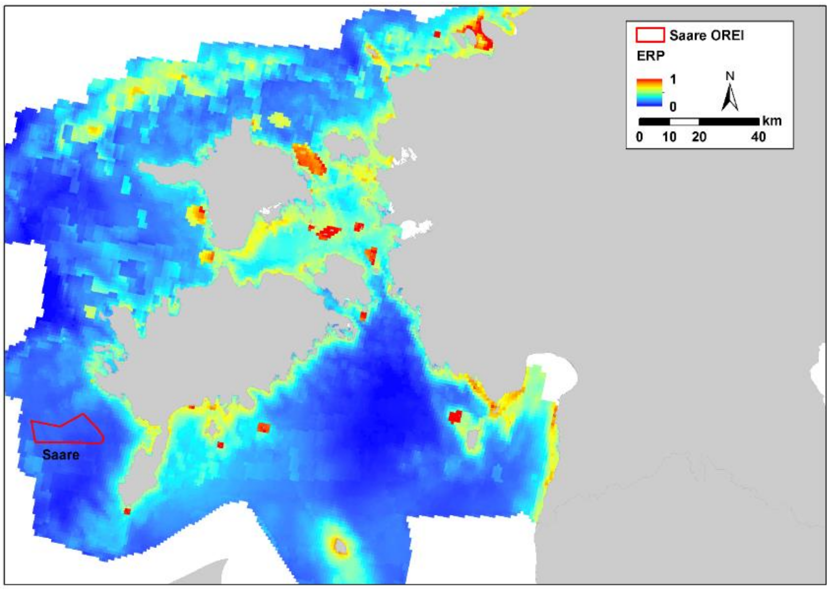

Figure 4.1.1. Possible marine area for potential development of offshore renewable energy installations (Saare OREI) off the Saaremaa Island in the Baltic Sea. Environmental cumulative risk profile (ERP) values are shown in the background.

Two-dimensional scatterplots between environmental vulnerability and BSPI were used to visualize the differences between possible OREI and no-OREI sea areas (Figure 4.1.2, left side). Also, the standard three-level environmental cumulative risk analysis matrix (Figure 4.1.2, right side) was outlined based on the following basic assumptions: a) the level of cumulative human pressure (BSPI) is proportional to the likelihood of potential environmental cumulative effect events, and b) the level of environmental vulnerability is proportional to potential consequences of environmental cumulative effect events.

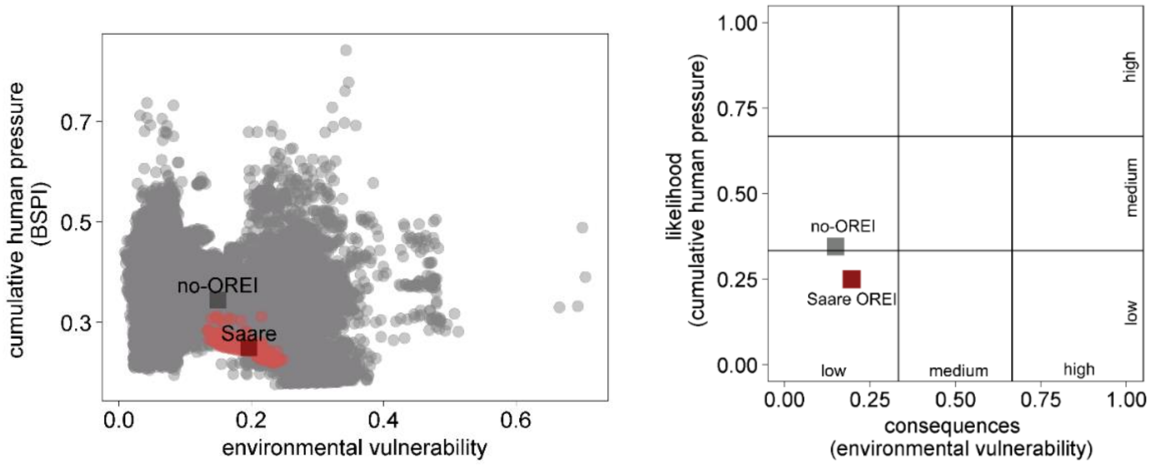

Figure 4.1.2. Scatterplot of area-specific pixel values (circles) of environmental vulnerability (EVP) on the horizontal axis and of cumulative human pressures (BSPI) on the vertical axis (left figure). The mean values of inside and outside of possible Saare OREI area are shown with rectangles. Risk analysis on the right figure: the mean pixel values of environmental cumulative risk characteristic inside and outside of the potential offshore renewable energy installations (Saare OREI) off the Saaremaa Island in the Baltic Sea.

4.2 Cumulative risk evaluation

In environmental cumulative risk management, risk matrices (Figure 4.2.1.) do not make decisions as they only provide a set of criteria to express tolerances of risk in relation to policy objectives.

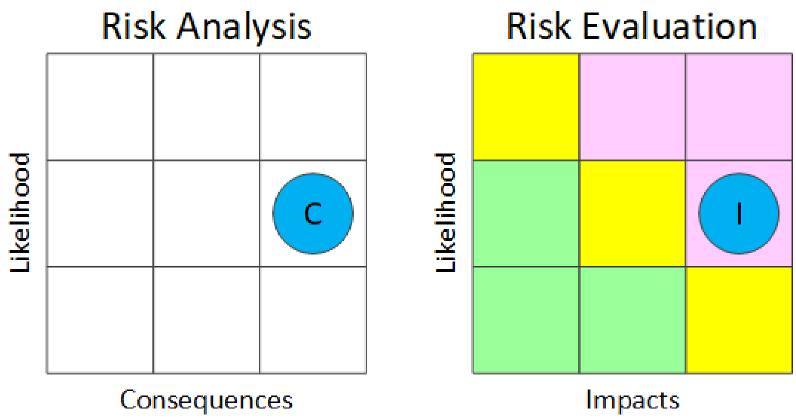

Figure 4.2.1. Risk matrices and tolerance overlay.

Risk matrix is used to classify a tolerance of the risk based on the combination of likelihood and consequences to achieve a policy objective and is not an extension of an x-y function plot. Given the need for an independence of the scientific research and policy advice, the scientific estimates of risk are not considered within a tolerance context (Figure 4.2.1. left side matrix). They are basically mapped to a blank matrix. Given the policy context of management and stakeholder, the likelihood and consequences are converted into the level of impacts that are not tolerated by management and stakeholders in terms of achieving a policy objective set by the planning process (Figure 4.2.1. right side matrix). The values of value neutral scientific consequences (C) are technically converted into an impact statement (I) within the policy context. A likelihood and consequence in the pink area becomes an intolerable situation from a policy perspective.

4.3 Bow-tie analysis

Referring to ICES (2014) the Bow-tie is a diagrammatic representation of the complex relations between the risks and management that can lead to better communication and understanding of the risks with third parties. It is added further that the Bow-tie analysis can help to integrate knowledge and science from disparate sources and thus aid in structuring the questions that arise during the marine planning activities and efficiently communicating the logic or reasoning behind the decisions that have to be taken in order to prevent an undesired ecological event.

It is argued (Cormier et al., 2015) that the MSP process has to identify all relevant *risk sources* and related *events* resulting from the planned solutions to accommodate the activities of the drivers operating in the management area in terms of ecological, cultural, social, economic *consequences* and legal repercussions referring to achieving the environmental, economic and social objectives of the Maritime Spatial Plan concerned. It is stated further that Bow-tie analysis can be used as a means of organizing and visualizing all of the elements of risk to primarily map and evaluate the system of management controls. It is added that in MSP context the Bow-tie analysis would be used to evaluate the various spatial and temporal management measures that could be implemented to prevent the undesired events or to mitigate their consequences (Figure 4.3.1).

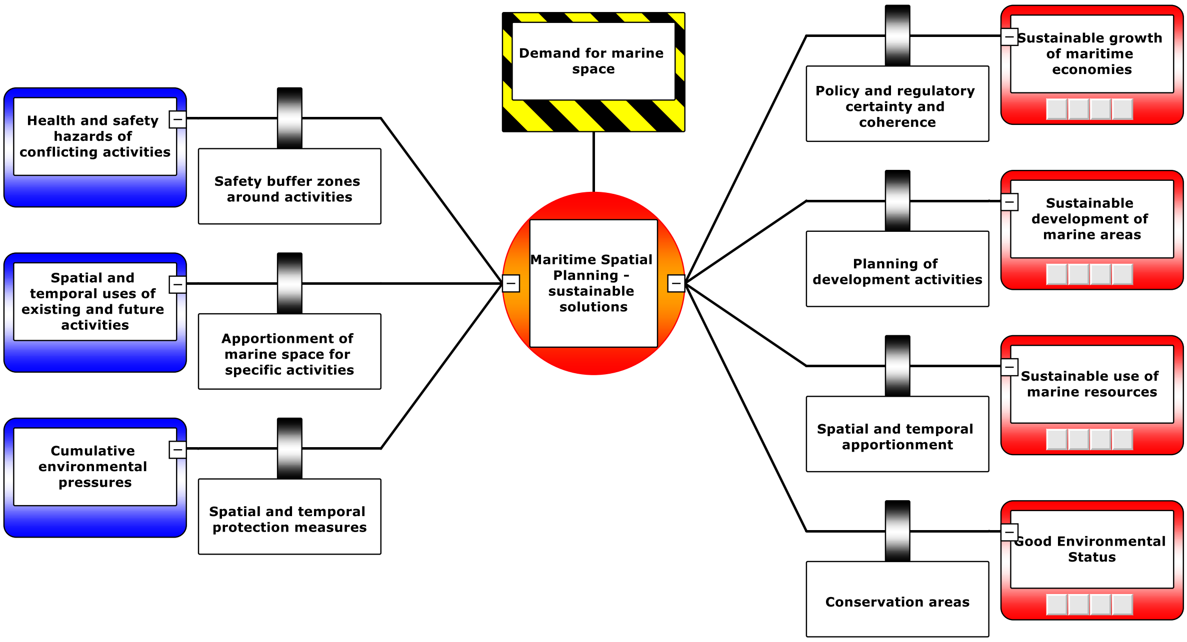

Figure 4.3.1. Bow-tie diagrammatic representation of the Maritime Spatial Planning related prevention and mitigation management measures to achieve the environmental, economic and social sustainability objectives (modified from Cormier et al., 2015).

It is concluded (ICES, 2014) that the Bow-tie approach helps to structure information and, thus, helps to gain joint understanding and facilitate joint problem framing among a group of MSP experts, stake-holders and policy makers. It is added further that “At the same time a Bow-tie is a conceptual integrator bridging information from science and policy. While the assessment of any area or problem can be seen as a product of scientific research, the management of the risks identified in assessments requires an evaluation of management options that would include rules of management, regulatory regimes or economic incentives as a suite of management tools”.

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