Operationalisation of an ecosystem services approach for improving integration in maritime spatial planning

Armoškaitė, Aurelija

DOI (link to publication from Publisher):
10.54337/aau621636264

Publication date:
2023

Document Version
Publisher's PDF, also known as Version of record

OPERATIONALISATION OF AN ECOSYSTEM SERVICES APPROACH FOR IMPROVING INTEGRATION IN MARITIME SPATIAL PLANNING

BY
AURELIJA ARMOSKAITE

DISSERTATION SUBMITTED 2023

AALBORG UNIVERSITY
DENMARK

OPERATIONALISATION OF AN ECOSYSTEM SERVICES APPROACH FOR IMPROVING INTEGRATION IN MARITIME SPATIAL PLANNING

by

Aurelija Armoskaite

AALBORG UNIVERSITY
DENMARK

Dissertation submitted 2023

Dissertation submitted:	September 2023
PhD supervisor::	Associate Professor Lise Schrøder, Department of Sustainability and Planning Aalborg University, Denmark
Assistant PhD supervisors:	Professor Henning Sten Hansen, Department of Sustainability and Planning Aalborg University, Denmark
	Senior researcher Juris Aigars Latvian Institute of Aquatic Ecology, Latvia
PhD committee:	Associate Professor Rikke Becker Jacobsen (chair) Aalborg University, Denmark
	Lecturer Heather Ritchie Queen's University, United Kingdom
	Research Professor Laura Uusitalo Natural Resources Institute Finland, Finland
PhD Series:	Technical Faculty of IT and Design, Aalborg University
Department:	Department of Sustainability and Planning

ISSN (online): 2446-1628
ISBN (online): 978-87-7573-621-8

Published by:
Aalborg University Press
Kroghstræde 3
DK – 9220 Aalborg Ø
Phone: +45 99407140
aauf@forlag.aau.dk
forlag.aau.dk

Printed in Denmark by Stibo Complete, 2023

CV

Aurelija Armoskaite received her B.A in Sociology from the University of Warwick in 2015. Whilst at Warwick, Aurelija spent a year abroad on the Erasmus programme studying at the University of Helsinki, where she first took a course in maritime spatial planning. In 2018, she received her MSc in Marine planning and management from the University of Liverpool. In her MSc thesis, Aurelija investigated the environmental advantages of in-situ decommissioning of offshore oil platforms in the North Sea, the exclusive economic zone of the United Kingdom. She was then employed by the Latvian Institute of Aquatic Ecology as a research assistant to work on projects focused on supporting the marine planning and protected area designation process in Latvia. In October 2019, Aurelija was accepted as a PhD fellow at Aalborg University.

ENGLISH SUMMARY

Human activities are one of the main sources of pressure on the environment leading to global change – biodiversity loss, warming, sea level rise, and acidification – impacting the overall capacity of our 'blue planet' to sustain life, including human populations, the way it has done so far (IPBES 2022; Borja 2023). Maritime spatial planning (MSP) is a public, political decision-making process increasingly employed across coastal countries around the world to address ocean sustainability issues and concerns planning seeks to address on land – increasing demand for resources, adverse impacts of unregulated industrial development, growing levels of pollution and a speedy biodiversity loss (Kid and Ellis 2012; Ehler et al. 2020; Ehler 2021). It is generally accepted that an MSP process must therefore be ecosystem-based, cross-border – translate across land and sea domains and national borders – as well as participatory and inclusive, that is, considers all sectors, interests, and users associated with the place being planned (UNESCO-IOC/European Commission 2021).

Planning is focused on the future and is loaded with uncertainty; therefore, assessment of possible consequences of plans on ecosystems and society is an essential part of the process (Pinarbasi et al., 2017; Quinio et al. 2023). As part of impact outcome analysis, compatibility between different users, and users and the environment must be considered to reduce conflict, support co-existence, and synergistic use of space and resources (Bonnevie et al. 2021). Relatedly, the impacts of drivers of change – human activities and the pressures they create – on the ecosystem and human welfare must be analysed (Duinker and Greig 2007; Hansen 2019; Hammar et al. 2020). Social-ecological system frameworks structure analysis and facilitate the exchange of information and an ecosystem services approach is often discussed as a key concept and framework supporting MSP (Culhane, Robinson, and Lillebø 2020). The term 'services' describes the final outputs of an ecosystem, such as fish for food or a beautiful seascape and waters safe for swimming (Culhane, Robinson, and Lillebø 2020). An ecosystem services approach presents the relationship between the biophysical and the social worlds as an ongoing process of ecosystem service supply and demand for services driven by people seeking to fulfil their needs (Potchin-Young et al. 2018).

However, the integrative and transformative role of MSP has been questioned in research (e.g., Flannery et al. 2020; Saunders et al. 2020). MSP is often found to either be driven by ecosystem protection or sectoral development/economic gains, simultaneously perpetuating existing unsustainable practices, power imbalances, and injustices (Ehler et al. 2021). Conceptual framing to support transformative MSP is missing – there are gaps in conceptualising and systematically addressing social sustainability (Saunders et al. 2020).

Relatedly, while praised for supporting holistic analysis of the links between ecosystem state and human wellbeing and seen as an instrument for estimating social, economic, and environmental consequences of plans (von Thenen et al., 2020; Robinson and Culhane 2020) as it stands, MSP is ill-equipped for supporting analysis of procedural and distributional social sustainability, impacts of decisions from multiple sustainability dimensions (Ntona and Morgera 2018) and in practice often ends up focused on specific and well studies parts of social and ecological systems and their values (Sharpe et al. 2020).

The objective of this PhD project is to contribute to the operationalisation of an ecosystem services approach in a maritime spatial planning context so that MSP can live up to its multi-dimensional sustainability potential. To achieve this, this thesis addresses three research questions focused on ways in which i) social sustainability is conceptualised as part of MSP, ii) ecosystem services can support social sustainability in MSP, and iii) multiple ecosystem service supply can be accessed and communicated across disciplines to improve analysis and tracking of change in social-ecological systems.

Answers to these sub-questions and the discussion chapter addressing the central research aim are based on eleven published papers, each one playing several different roles supporting this thesis. The eleven studies contributing to this thesis study different parts of a social-ecological system and employ different methods for collecting and analysing empirical data (i.e., expert elicitation, geodata analysis, semi-structured interviews, document, and scholarly literature analysis, surveys, tool testing workshops, and case studies). They are brought together under the umbrella of the overall conceptual framework of this thesis grounded in social-ecological systems thinking. Specifically, an ecosystem services-based 'butterfly' framework for analysis of how people benefit from and impact ecosystems, adapted to accommodate conceptual categories for the analysis of social sustainability considerations in MSP (Saunders et al. 2020) and co-location of different maritime uses (Bonnevie et al. 2019).

Answers to the first two research questions are based on studies the normative, institutional MSP set-ups in different countries around the Baltic Sea through documents, research, and experiences based on empirical data from interviews with MSP actors. An academic literature review reveals strategies for advancing social sustainability analysis in an MSP context, one of which is seen as the adoption of an ecosystem services approach. To support the conceptualisation and analysis of social sustainability three tangible outputs are described – a set of principles for assessing coastal community participation in MSP to improve inclusivity in MSP, and an approach for including aspects of spatial co-location in recognition and representation analysis to spot challenges for new, entrepreneurial blue economy sector development. Additionally, MSP-SA – a framework for multi-dimensional ecosystem service-based impact analysis – is presented as an example of how ES impact analysis may support social sustainability considerations in MSP. MSP-SA can be used to structure analysis of plan impacts on the ecosystem and people, that is, explore the flow of ecosystem services and highlight issues of distributional justice through analysis of benefit distribution (distribution of goods and bads) and engage stakeholders that are (un)recognised, and (mis)represented.

To advance approaches for assessing multiple ecosystem service supply, a tool for estimating relative change in the supply of a wide range of services is introduced. A linkage frameworks approach served as the departure point and a context-specific expert knowledge base was created to inform further development and test the tool. As it stands, the tool supports a) analysis of relative species and habitat contribution in ecosystem service supply, b) analysis of change in service supply and ecosystem functioning, and c) graphical representation of the results in maps and linkage web diagrams.

One of the main benefits of the tool designed and tested during this PhD project is that the outputs are visual and spatial therefore can directly support MSP and analysis can be done in various data availability circumstances. However, it is important to keep in mind that social-ecological systems are complex, and while useful for informing policy by highlighting spatial patterns, the model behind the tool does not account for non-linear relationships, i.e., feedback loops or regime shifts, therefore should be interpreted with a pinch of salt. At the same time, the methods and approaches for fostering social sustainability in MSP should not be seen as a replacement for top-down planning processes. Instead, they are complementary and can embedded in any context.

DANSK RESUME

Menneskelig aktivitet er en af de vigtigste kilder til den miljøbelastning, som medfører globale forandringer i form af tab af biodiversitet, opvarmning, havniveaustigninger og forsuring, og som dermed påvirker vores 'blå planets' evne til at opretholde liv, herunder menneskelige populationer på samme måde, som den har gjort hidtil (IPBES 2022, Borja 2023). Havplanlægning eller maritim fysisk planlægning (MSP) er en offentlig, politisk beslutningsproces, som i stigende grad – og over hele verden – vinder indpas i lande med søterritorier for at kunne adressere de problemer og bekymringer angående bæredygtigt hav, som også kendes fra planlægningen på land – det være sig stigende behov for ressourcer, negative konsekvenser af ureguleret industriel udvikling, øget forurening og et hastigt tab af biodiversitet (Kid og Ellis 2012; Ehler et al. 2020; Ehler 2021). Det er generelt accepteret, at en MSP-proces derfor skal være økosystembaseret, skal kunne anvendes på tværs af land- og havområder og nationale grænser samt være deltagerorienteret og inkluderende, således at alle sektorer, interesser og brugere med tilknytning til det sted der planlægges, tages i betragtning (UNESCO-IOC/EU-Kommissionen 2021).

Planlægning fokuserer på fremtiden og er fyldt med usikkerhed, og vurdering af planers mulige konsekvenser for økosystemer og samfund er derfor en afgørende del af processen (Pinarbasi et al. 2017; Quinio et al. 2023). Som del af en påvirkningsanalyse skal kompatibilitet mellem forskellige brugere og miljøet medtænkes for at reducere konflikter, understøtte sameksistens og sikre helhedsorienteret anvendelse af arealer og ressourcer (Bonnevie et al. 2021). I denne sammenhæng skal påvirkningen fra drivkræfterne bag forandringerne analyseres – dvs. menneskelige aktiviteter og den deraf følgende belastning af økosystemet og indvirkning på menneskers velbefindende (Duinker og Greig 2007; Hansen 2019; Hammar et al. 2020). Social-økologiske systemkoncepter kan bidrage til at etablere en fælles analyseramme og facilitere udveksling af information, og en økosystemtjenestetilgang diskuteres ofte som nøglebegreb og forståelsesramme, som understøtter MSP (Culhane, Robinson og Lillebø 2020). Begrebet 'tjeneste' beskriver et økosystems slutprodukter, såsom fisk til fødevarer eller en smuk havudsigt og vand, som er sikkert at svømme i (Culhane, Robinson og Lillebø 2020). En økosystemtjenestetilgang præsenterer forholdet mellem de biofysiske og sociale verdener som en vedvarende proces med levering af økosystemtjenester og efterspørgsel efter tjenester drevet af mennesker, som forsøger at opfylde deres behov (Potchin-Young et al. 2018).

Flere forskere har dog sat spørgsmålstegn ved MSP's integrative og transformative rolle (f.eks. Flannery et al. 2020; Saunders et al. 2020). MSP ses ofte som drevet enten af hensynet til økosystembeskyttelse eller af sektorudvikling og økonomiske interesser, der samtidig opretholder eksisterede ikke-bæredygtige praksisser, magt-ubalancer og uretfærdigheder (Ehler et al. 2020). Der savnes en begrebsramme til understøttelse af transformativ MSP, idet der savnes en yderligere konceptualisering og systematisk adressering af social bæredygtighed (Saunders et al. 2020).

Selvom MSP ligeledes roses for at understøtte en holistisk analyse af forbindelserne mellem økosystemtilstand og menneskers velbefindende og betragtes som et redskab til estimering af sociale, økonomiske og miljømæssige konsekvenser af planer (von Thenen et al. 2020; Robinson and Culhane 2020), savner MSP i sin nuværende form værktøjer til understøttelse af analyser af procedure- og fordelingsmæssig social bæredygtighed, beslutningers virkninger for flere bæredygtighedsdimensioner (Ntona og Morgera 2018) og ender i praksis med at være fokuseret på specifikke og velundersøgte dele af sociale og økologiske systemer og disses værdier (Sharpe et al. 2020).

Målet med dette ph.d.-projekt er at bidrage til operationalisering af en økosystemtjenestetilgang i en marin fysisk planlægningskontekst, så MSP kan leve op til sit multi-dimensionale bæredygtighedspotentiale. Med henblik på at afdække dette er afhandlingen struktureret omkring tre forskningsspørgsmål, som fokuserer på, hvordan i) social bæredygtighed kan konceptualiseres som en del af MSP, ii) økosystemtjenester kan understøtte social bæredygtighed i MSP, og iii) levering af økosystemtjenester kan tilgås og kommunikeres tværfagligt for at forbedre analysen og sporingen af ændringer i social-økologiske systemer.

Svarene på disse underspørgsmål og diskussionen, som adresserer det centrale forskningsformål, er baseret på 11 publicerede artikler, som på forskellig vis og i forskelligt omfang bidrager til de i afhandlingen præsenterede resultater. Forskellige aspekter af et social-økologisk system er således blevet analyseret under anvendelse af en kombination af metoder til indsamling og analyse af empiriske data (ekspertvurderinger, analyse af geodata, semistrukturerede interviews, analyser af dokumenter og videnskabelig litteratur, spørgeundersøgelser, workshops med test af værktøjer og casestudier).

Overordnet tager ph.d.-projektet afsæt i social-økosystemtænkning og en økosystemtjenesteorienteret konceptuel ramme baseret på en viderebearbejdning af sommerfuglemodellen (Gómez et al. 2016) til analyse af, hvordan mennesker har gavn af og påvirker økosystemer, er opstillet og tilpasset, så den kan håndtere begrebsmæssige kategorier vedrørende social bæredygtighed i MSP (Saunders et al. 2020) og samlokalisering af forskellige maritime anvendelser (Bonnevie et al. 2019).

Svarene på de første to forskningsspørgsmål er baseret på undersøgelser af normative, institutionelle MSP-strukturer i forskellige lande omkring Østersøen baseret på dokumenter, undersøgelser og empiriske data fra interviews med MSPaktører. En gennemgang af den akademiske litteratur belyser strategier til fremme af sociale bæredygtighedsanalyser i en MSP-kontekst, herunder én som specifikt har fokus på potentialet i en økosystemtjenestetilgang. Konceptualiseringen og analysen af social bæredygtighed er udmøntet i tre konkrete resultater. For det første har der kunnet opstilles en række principper for bedømmelse af kystnære lokalsamfunds deltagelse i MSP med henblik på at forbedre inklusionen i MSP. Dernæst har der kunnet anvises en fremgangsmåde, hvor forskellige interesser knyttet til fysisk samplacering af aktiviteter og ønsket om en innovativ udvikling af den blå sektor i højere grad kan anerkendes og præsenteres i konsekvensanalyser. Derudover præsenteres MSP-SA i form af en ramme for multi-dimensionel økosystemtjenestebaseret analyse som et eksempel på, hvordan en sådan konsekvensnalyse kan understøtte sociale bæredygtighedsovervejelser i forbindelse med MSP. MSP-SA kan bruges til at strukturere analyser af en plans indvirkning på økosystem og mennesker, hvilket vil sige at undersøge strømmen af økosystemtjenester og belyse problemer med hensyn til fordelingsmæssig retfærdighed gennem analyse af fordeling af goder (fordeling af fordele og ulemper) og inddragelse af interessenter, som er (ikke)anerkendte og (ikke)repræsenterede.

For at videreudvikle tilgange til vurdering af multible økosystemtjenesteydelser præsenteres et værktøj til estimering af relative ændringer i leveringen af en lang række tjenester. Med afsæt i en integreret konceptuel forståelse blev en kontekstspecifik database med ekspertviden etableret med det formål at skabe grundlag for yderligere udvikling og test af værktøjet. I sin nuværende form understøtter værktøjet a) analyse af relative arts- og habitatbidrag til økosystemtjenester, b) analyse af ændringer vedrørende levering af tjenester og økosystemfunktion og c) grafisk præsentation af resultaterne på kort og links til webdiagrammer.

En særlig fordel ved det værktøj, som er udviklet og afprøvet under arbejdet med dette ph.d.-projekt, er at resultaterne kan præsenteres visuelt og i en fysisk-geografisk kontekst, som direkte understøtter MSP, ligesom analyserne kan gennemføres under varierende betingelser i forhold til datatilgængelighed. Imidlertid er det vigtigt at holde sig for øje, at social-økologiske systemer er komplekse, og selvom værktøjet kan bidrage til at belyse spatio-temporale mønstre og dermed understøtte planlægning og politisk beslutningstagning, vil modellen bag ikke tage højde for ikke-lineære sammenhænge som feedback loops eller regimeskift. Tilsvarende skal metoder og tilgange, som understøtter social bæredygtighed i havplanlægningsprocesserne, ikke ses som en erstatning for top-down planlægning. Tværtimod imod understøtter de to tilgange hinanden og kan indgå i enhver sammenhæng.

ACKNOWLEDGEMENTS

Over the last few years, I have had the opportunity to work on several different projects and experience the support of many scientists. I want to thank you all. An especially big thank you to my supervisors Lise Schrøder, Juris Aigars, and Henning Sten Hansen who accepted me as their PhD student. You have provided me with invaluable support as I figure out my path in research. Thank you to my dear colleagues at the institute Solvita, Ingrida, Ieva, and Anda, and lovely Irma and Jamal at AAU Department of Planning for always making me so welcome. Thank you to my co-authors and all-around inspiring people dotted around the Baltic and beyond - Ida, Miriam, Pia, Kira, Fred, Ralph, Jacek, Michael, and Andrea.

Thank you, Malena, Kerstin, Igor, and Harald, for having me in Breda those many years ago. Not only did you help me finalise my MSc thesis, but you also made my move across the channel much less scary. Having met you, I just knew I wanted to be part of the MSP community. And of course, thank you to Stephen Jay and Sue Kidd.

I also want to thank Cosimo, Sia, and Peter for the opportunity to create a beautiful film, visit the Viborg animation festival, and for the beautiful front cover design.

Last but not least, I want to thank my family, and friends and give credit to my dog (and husband) – you are the unlisted co-authors of all this work.

PREFACE

Disciplines are not bodies of knowledge, just like languages are not cultures. Both are systematic ways of moving through a common reality…

Prof. Steve Fuller (twitter)
12.15pm January 31st, 2022

Information on funding

This PhD research was jointly financed by the Latvian Institute of Aquatic Ecology and Aalborg University, as well as the following projects: BONUS BASMATI project (Baltic Sea Maritime Spatial Planning for Sustainable Ecosystem Services) supported by 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 (grant number: 03F0774A); project GRASS (#R097 Growing Algae Sustainably in the Baltic Sea) co-funded by the European Union’s funding Programme Interreg Baltic Sea Region in 2014–2020 (European Regional Development Fund); project LIFE REEF (Research of marine protected habitats in EEZ and determination of the necessary conservation status in Latvia; project number LIFE19 NAT/LV/000973 REEF); project REEF FUN (project number Lzp-2019/1-337); Taking Social Sustainability to the Sea: Strengthening the Social Pillar in MSP (funded by the Foundation for Baltic and East European Studies) and AquaINFRA project funded by the European Commission’s Horizon Europe Research and Innovation program (grant agreement No 101094434).

ABBREVIATIONS

CIA	Cumulative Impacts Assessment
CICES	The Common International Classification of Ecosystem Services
DG MARE	The European Commission's Directorate-General for Maritime Affairs and Fisheries
DPSIR	Driver-Pressure-State-Impact-Response
EBA	Ecosystem-based approach
EBM	Ecosystem-based management
EC	European Commission
ES	Ecosystem services
EU	European Union
HELCOM	The Baltic Marine Environment Protection Commission also known as the Helsinki Commission
IOC-UNESCO	The Intergovernmental Oceanographic Commission of the United Nations Educational, Scientific and Cultural Organization
MPA	Marine protected area
MSP	Maritime Spatial Planning
MSPD	European Union Maritime Spatial Planning Directive
SDST	Spatial decision support tool

DEFINITIONS OF KEY TERMS

Term	Definition
Frameworks	Frameworks or models can be seen as “organisational” network diagrams of variables or elements (Patrício et al. 2016).
Biodiversity	The variability among living organisms and ecological complexes, including diversity within species, between species, and ecosystems (Potschin-Young et al. 2018).
Beneficiary	An individual or a group of actors whose well-being and livelihoods are changed (negatively or positively) by service supply (Potschin-Young et al. 2018).
Benefits	Positive change in human well-being as a result of ecosystem service consumption and fulfilment of human needs and want (Potschin-Young et al. 2018).
Cumulative impacts (of pressures on ecosystem)	Impacts greater than the sum of its parts, which may change the state of an ecosystem immediately or over a long period of time (Reckermann et al. 2022).
Dis-benefits	Negative change in human wellbeing change in human well-being as a result of service consumption (adapted from Potschin-Young et al. 2018).
Decision-support tools	Computer programme applications or non-computer-based techniques developed to support the decision-making process (Pinarbasi et al. 2017; Gee et al. 2019).
Drivers	Demand from society to fulfil basic human needs (Patricio et al. 2016).
Ecosystem-based management	An approach to management of natural resources and human activities aiming to ensure healthy ecosystems and a sustainable supply of ecosystem service s to people (adapted Leenhardt et al. 2015).
Ecosystems’ capacity for an ecosystem service	The ability of a given ecosystem to sustainably generate specific ecosystem services (Potchin – Young et al. 2018).
Ecosystem components	Species, habitats or structures that are contributors to maintaining an ecosystem functioning (Potchin – Young et al. 2018).
Ecosystem functioning	Ecosystem functioning is the operating of an ecosystem or the links between ecosystem components, processes, and biodiversity that underpin services supply (Potchin – Young et al. 2018).
Ecosystem functions	Specific interactions between ecosystem components and ecosystem processes that underpin the capacity of an ecosystem to supply services (Potchin – Young et al. 2018).
Ecosystem services	‘The final output from ecosystems that are directly consumed, used (actively or passively) or enjoyed by people’ (Culhane et al. 2020, p. 107)

Ecosystem service assessment	Analysis of current status and future trends in the capacity of an ecosystem to supply ecosystem services in a specified geographic area. Ecosystem service assessments aim to communicate how services are 'supplied' to society, change in supply and value. They require social and natural scientific knowledge as well as triangulation of methods and approaches from various disciplines (Potchin – Young et al. 2018).
Ecosystem service supply	The availability of a service (irrespective of its actual use) at a specific time at a specific location, for instance in the present, past or future (Potchin – Young et al., 2018).
Ecosystem service flow	The extent to which ecosystem services are accessed and consumed in a specific area and time (Potchin – Young et al., 2018).
Impacts on human welfare	Changes in human livelihoods caused by changes in the ecosystem state. For instance, change in supply of raw resources or food due to decreased abundance of species (Patrício et al. 2016).
Impacts of pressures	Human activities create pressures that alter the state of ecosystems. A single activity may be the cause of multiple different pressures and result in cumulative impacts.
Marine governance	It is the sharing of policy making competences in a system of negotiation between governmental institutions at several levels (international, (supra and sub) national) and multiple actors (state market and civil society) in order to govern activities at sea and their consequences (van Tatenhove 2020).
Stakeholders	'Individuals, groups or representatives of specific groups with an interest or direct involvement in policy development or its direct outcomes' (IOC-UNESCO 2021, p.26).
Value	The worth, usefulness, importance measured by the improvement of 'well-being' (human). Value is measured in willingness of people to give up something to get or enjoy it (Potchin – Young et al. 2018).
Zoning	A commonly used approach in planning whereby uses are allocated a space based on the area's suitability for those uses (Potchin – Young et al. 2018).
Scenarios	'A scenario is a coherent, internally consistent and plausible description of a possible future state of the world. It is not a forecast; rather, each scenario is one alternative image of how the future can unfold' (Intergovernmental Panel on Climate Change 2001 cited in McGowan et al. 2019).

THESIS DETAILS

Publications included in this thesis[1]

Paper 1. Armoškaite, A., Puriņa, I., Aigars, J., Strāķe, S., Pakalniete, K., Frederiksen, P., Schrøder, L., Hansen, H.S. **2020**. Establishing the links between marine ecosystem components, functions, and services: An ecosystem service assessment tool. *Ocean and Coastal Management*. 193. doi.org/10.1016/j.ocecoaman.2020.105229.

Paper 2. Armoškaite, A., Aigars, J., Hansen, H.S., Andersone, I., Schrøder, L., Strāķe, S. **2021a**. Assessing change in habitat composition, ecosystem functioning and service supply in Latvian protected stony reefs. *Journal of Environmental Management*. 298. doi.org/10.1016/j.jenvman.2021.113537.

Paper 3. Armoškaite, A., Aigars, J., Andersone, I., Bonnevie, I.M., Hansen, H.S., Strāķe, S., von Thenen. M., Schrøder, L. **2023**. Setting the scene for a multi-map toolset supporting maritime spatial planning by mapping pressures and relative cumulative effects to ecosystem services. *Frontiers in Marine Science*. doi: 10.3389/fmars.2023.1213119

Paper 4. Armoškaitė, A., Bārda, I., Andersone, I., Bonnevie, I.M., Ikauniece, A., Kotta, J., Kõivupuu, A., Lees, L., Psuty, I., Strāķe, S., Sprukta, S., Szymanek, L., von Thenen, M., Schrøder, L., Hansen, H.S. **2021b**. Considerations of Use-Use Interactions between Macroalgae Cultivation and Other Maritime Sectors: An Eastern Baltic MSP Case Study. *Sustainability*. 13, 13888. doi.org/10.3390/su132413888

Paper 5. Frederiksen, P., Morf, P., von Thenen, M., **Armoskaite, A.,** Luhtala, H., Schiele, K.S., Strake, S., Hansen, H., **2021**. Proposing an ecosystem services-based framework to assess sustainability impacts of maritime spatial plans (MSP-SA). *Ocean and Coastal Management.* 208. doi.org/10.1016/j.oce-coaman.2021.105577

Paper 6. Gilek, M., **Armoskaite, A.,** Gee, K., Saunders, F., Tafon, R., Zaucha, Z. **2021**. In search of social sustainability in marine spatial planning: A review of scientific literature published 2005–2020. *Ocean and Coastal Management.* 208. doi.org/10.1016/j.ocecoaman.2021.105618

Paper 7. von Thenen, **Armoškaitė, A**., Cordero-Penín, V., García-Morales, S., Gottschalk, J.B., Gutierrez, D.; Ripken, M., Thoya, P., Schiele, K.S. **2021**. The Future of Marine Spatial Planning—Perspectives from Early Career Researchers. *Sustainability.* 13, 13879. doi.org/10.3390/su132413879

---

[1] Reference to all papers included in the thesis are henceforth in *italics.*

Paper 8. Tafon, R., **Armoskaite, A**., Gee, K., Gilek, M., Ikauniece, A., Saunders, F. 2023. Mainstreaming coastally just and equitable marine spatial planning: Planner and stakeholder experiences and perspectives on participation in Latvia. *Ocean and Coastal Management.* 242. 10.1016/j.ocecoaman.2023.106681

Paper 9. Koski, C., Rönneberg, M., Kettunen, P., **Armoškaitė, A.,** Strake, S., Oksanen, J. **2021**. User experiences of using a spatial analysis tool in collaborative GIS for maritime spatial planning. *Transactions in GIS*. 24:4. doi.org/10.1111/tgis.12827

Paper 10. Pakalniete, K., Ahtiainen, H., Aigars, J., Andersone, I., **Armoškaite, A.,** Hansen, H.S., Strāķe, S. 2021. Economic Valuation of Ecosystem Service Benefits and Welfare Impacts of Offshore Marine Protected Areas: A Study from the Baltic Sea. Sustainability. 13: 10121. doi.org/10.3390/su131810121

Paper 11. Bonnevie, I.M.; Hansen, H.S.; Schrøder, L.; **Armoškaite, A.** 2022. Utilising MYTILUS for Active Learning to Compare Cumulative Impacts on the Marine Environment in Different Planning Scenarios. *Sustainability*. 14, 12606. https://doi.org/10.3390/su141912606

Other reports and papers not included in this thesis.

Arki, V., Ajanko, J., Luhtala, H., Tolvanen, H. (eds.), BONUS BASMATI – Supporting maritime spatial planning with science. BONUS BASMATI Deliverable 7.7. www.bonusbasmati.eu

Armoskaite, A., Bārda, I., Purina, I., Sprukta, S., Fedorovska, A., Strake, S., 2021. Report on ecological impacts of macroalgae cultivation in the Baltic Sea region. www.submariner-network.eu

Armoskaite, A., Bārda, I., Fedorovska, A., Purina, I., Sprukta, S., Strake, S., 2021. Guidelines for undertaking Environmental Impact Assessments for macroalgae cultivation and harvest projects. www.submariner-network.eu

Kotta, J., Raudsepp, U., Szava-Kovats, R., Aps, R., **Armoskaite, A.,** Bārda, I., Bergström, P., Futter, M., Gröndahl, F., Hargrave, M., Jakubowska, M., Jänes, H., Kaasik, A., Kraufvelin, P., Kovaltchouk, N., Krost, P., Kulikowski, T., Kõivupuu, A., Kotta, I., Lees, L., Loite, S., Maljutenko, I., Nylund, G., Paalme, T., Pavia, H., Purina, I., Rahikainen, M., Sandow, V., Visch, W., Yang, B. and Barboza, F., 2022. Assessing the potential for sea-based macroalgae cultivation and its application for nutrient removal in the Baltic Sea. Science of The Total Environment. 839. doi.org/10.1016/j.scitotenv.2022.156230

Stalmokaitė, S., **Armoškaitė, A.,** Gee., K., Gilek, M., Ikauniece, A., Matczak, M., Saunders, F., Tafon, R., Turski, J., Witkowska, J., Zaucha., J. Social justice in marine spatial planning: Stakeholder perspectives and experiences in the Baltic Sea Region. Journal of Environmental Planning and Management. In review.

Conference participation (presentations and workshop facilitations online and in-person)

Table Facilitator at Sessions on Sustainable Glue Economy and Transboundary cooperation. 2022. *5th International Forum on Marine/Maritime Spatial Planning (MSPforum).* Barcelona, Spain.

Armoškaitė A. 2022. Washed Ashore – a production process from Sci-Vi Ph.D. course. Sci-Vi Conference: Visualisation and animation in science dissemination: symbiosis - imagination and visualization as interdisciplinary field of exploration. *Viborg animation festival*, Viborg, Denmark.

Armoškaite, A., Bonnevie, I.M., Aigars, J.; Andersone, I.; Schrøder, L.; Strāķe, S., Hansen, H.S. 2022. Ecosystem Services for multi-objective maritime spatial planning. *Ecosystem Services Partnership Conference*. Crete, Greece.

Armoškaitė, A., Aigars, J.; Hansen, H.S.; Andersone, I.; Strāķe, S.; Schrøder, L. **2021**. A method for quantifying and graphically representing marine ecosystem service supply using expert judgement and field data. *Baltic Sea Science Congress 2021*. Aarhus. Denmark.

Armoškaitė A., Aigars, J.; Hansen, H.S.; Andersone, I.; Strāķe, S.; Schrøder, L. **2021**. What are we protecting against? Ramifications of the spread of a non-native fish species on protected stony reefs in the eastern Baltic and service supply" Ecosystem Services Partnership Conference. Online

Armoškaitė A., Aigars, J.; Hansen, H.S.; Andersone, I.; Strāķe, S., Schrøder, L.**2021**. Designation of MPAs using the ecosystem service perspective: what and where should be protected and according to whom? Erasmus+ session at the MSP Nature Conference. Online

Armoškaitė, A., Aigars, J.; Hansen, H.S.; Andersone, I.; Strāķe, S., Schrøder, L. **2020**. ESA4MSP tool. The BONUS BASMATI Final online seminar session "Platforms and tools for MSP".

Armoškaitė, A., Puriņa, I., Aigars, J., Strāķe, S., Frederiksen, P., Hansen H.S.**2019**. Establishing the links between ecosystem components, functions, values and benefits: An assessment and communication support tool. Ecosystem Services Partnership Conference. Hannover, Germany.

Animation film project

'Washed ashore' an animation on the ecosystem functions and services provided by macroalgae in the Baltic Sea by the Animation Workshop/VIA University Collage - Centre for Animation, Visualisation and Graphic Storytelling & Latvian Institute of Aquatic Ecology created as part of the Science visualization and dissemination PhD course Online. https://vimeo.com/753832603

TABLE OF CONTENTS

1 Introduction and scope

The driving forces behind a worldwide interest in maritime spatial planning are the need to manage pressures on the ecosystems and the increasing competition and need for resources and space (Ehler et al. 2020). Understanding relationships between human activities driven by needs and wants, and the marine ecosystem state and processes is essential for addressing ocean sustainability problems (Schlüter et al. 2019). These relationships are extremely complex and diverse, their study requires knowledge from different disciplines to come together to collaboratively explore the ways in which people and ecosystems interact (Briggs et al. 2022). An ecosystem service approach is one of many lenses for exploring these relationships, and its conceptualisation in a maritime planning context to ensure multidimensional – social, economic, and environmental – sustainably is the central theme of this thesis.

The following section of this chapter outlines the thesis structure. It is then followed by a more detailed introduction to the research context and concepts, as well as the PhD project aims and objectives.

1.1 Thesis Structure

This thesis consists of five chapters (Figure 1). The introduction provides the research context, a description of the key concepts, as well as an insight into the motivations behind the research aims. The second chapter is focused on research design – and introduces the questions, conceptual framing, and approaches taken to answer the research questions. Chapter three is a summary of the scientific papers. In chapter four, the research questions are answered in a discussion format based on the findings presented in the scientific papers. Chapter five concludes the thesis and is followed by the collection of papers.

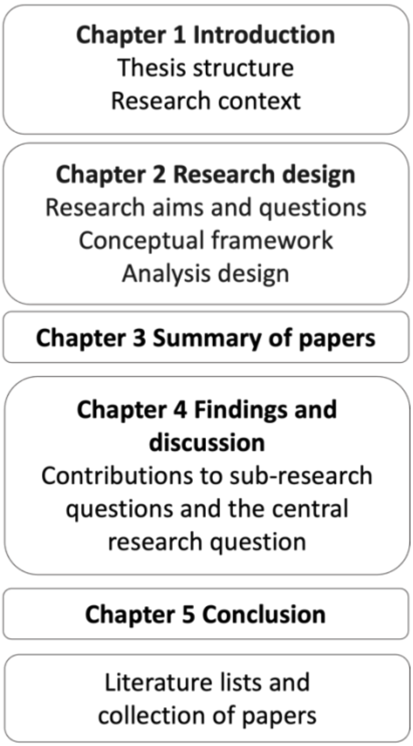

Figure 1 Graphic representation of thesis structure

1.2 Research context

This thesis is concerned with the global advance in the planning of marine and coastal waters under national jurisdiction through maritime/marine spatial planning (henceforth: MSP). The following chapters provide an introduction to MSP, its role in the wider governance system, and a social-ecological systems paradigm, which acknowledges the interconnectedness of people and nature and is at the heart of an ecosystem services approach, the sustainability concept, and MSP.

1.2.1 Maritime boundaries: legally defined division of waters

The United Nations Convention on the Law of the Sea divides the world's oceans and seas into three zones – territorial waters, the exclusive economic zone (EEZ), and sea areas beyond national jurisdiction commonly known as" high seas". Different governance arrangements, legal structures, and management and planning instruments are present to regulate human activities within these zones.

Territorial waters can stretch up to 12nm (22km) away from the shoreline, and from a regulatory point of view are an extension of land territory (Soons 2004). Like land territories, territorial waters are governed by domestic laws as well as regulations negotiated between interests at national and international levels. For instance, domestic strategic interests defined by democratic decision-making within the state as well as requirements laid out at the regional level (i.e., EU-level directives or non-legally binding regulations defined with the remits of sea basins OSPAR, HELCOM-VASAB, and the Mediterranean Action Plan) and global level laws (e.g., the United Nations (UN) Convention on the Law of the Sea, which defines the rights of nations to marine resources and space, and responsibilities for protection of marine ecosystems) or treaties (e.g., Convention on Biological Diversity (treaty dedicated to sustainable development) laid out by international governance institutions such as the UN International Maritime Organisation responsible for regulating shipping and maritime safety. Beyond the territorial waters, there are the Sea Areas under Functional Jurisdiction of a Coastal State, which are commonly referred to as the Exclusive Economic Zone (EEZ; Soons 2004). In the EEZ, the coastal state has the right to resources and can prescribe regulations but has limited power and authority to enforce these rules. Lastly, there are the 'high seas', which are areas governed only at the international level and no single nation has the responsibility for or authority over them (Soons 2004). High seas make up a significant part – approximately two-thirds – of the ocean space. The decreasing level of regulations and management of human activities that comes with the increasing distance from the shoreline leaves the high seas vulnerable to over-exploitation of resources and a space for crime and piracy. While this is an increasingly important topic, it is outside the scope of this research project (for further reading see Zaucha and Jay 2022). Instead, the focus of this thesis is MSP waters under national jurisdiction.

1.2.2 Guiding principles and stages of MSP

One of the most widely used definitions of MSP by IOC-UNESCO/ European Commission states that MSP is a '*public process of analysing and allocating the spatial and temporal distribution of human activities in marine areas to achieve ecological, economic and social objectives that have been specified through a political process*' (Ehler and Douvere 2007). In the European context, MSP is a '*policy tool'* or '*instrument'* for more integrated and cohesive planning (EC 2014). Despite slight variations in the definitions from place to place, there is a shared understanding that MSP should follow a set of principles and stages of an adaptive, cyclical planning process (Ehler and Douvere 2009).

It is widely accepted that MSP must be participatory, ecosystem-based, consider and integrate land and marine planning, and function across borders, boundaries, and leave no stakeholders or interest unseen or behind (UNESCO-IOC/European Commission 2021; see Figure 2).

Guiding principles of maritime spatial planning

- **Supports land and sea interaction** – facilitates a coherent planning system, which considers land to the coast and the marine realm.
- **Supports transboundary and cross-border cooperation** between land and marine planners, institutions involved in the planning process, regional, local, and national level authorities as well as neighbouring countries. Key to preventing inconsistencies across borders, e.g., shipping lanes, that do not align, and for fostering synergies and helping attain common policy goals**.**
- **Follows an ecosystem-based approach (EBA) –** recognises that people are part of the ecosystem and there are environmental limits to be observed in development. The application of EBA is anchored in the use of scientific evidence and knowledge of ecosystem functioning and processes, including human pressures created by human activities and cumulative impacts on ecosystems.
- **Is participatory and inclusive –** considers all sectors connected to the marine space being planned. Identifying stakeholders and engaging with them through appropriate channels meaningfully is a core element of transparent, legitimate, long-lasting, and effective policymaking and a requirement in democratic governance. Stakeholder mapping is an important process to ensure all necessary social groups are recognised and invited to be part of the decision-making process. So an is effort to support representation, especially of less powerful or influential groups. In the MSP context stakeholders often include various government bodies and international organisations (spanning across governance levels i.e., international, national, regional, and local) as well as sectors and action groups. MSP must bring these actors and stakeholders together to create a dialogue and facilitate negotiations between them aiming to resolve existing conflicts and prevent future ones.

Figure 2 Guiding principles of maritime spatial planning based on UNESCO-IOC/European Commission (2021).

Ehler (2018) also argues that on top of being ecosystem-based, participatory, and inclusive, effective MSP must also be place-based - focused on a specific relatable location, adaptive – embody a 'learning by doing' approach to planning, and strategic – focused on the long-term vision.

Broad steps or stages have been defined in guidelines and scholarly studies of MSP processes to structure the planning process at different times (e.g., IOC-UNESCO 2021; Giacometti et al. 2020; Ehler and Douvere 2009). Some of these stages are focused on objective setting (i.e., Scoping, Drafting, and Consulting; Figure 3). Different places have different meanings and purposes to different actors, and through negotiation and discussions, these are formulated into objectives and goals (Ehler et al. 2019).

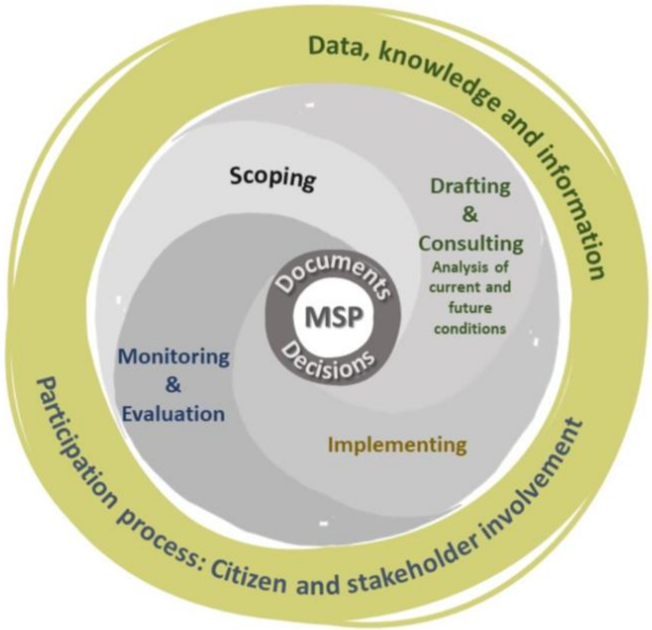

Figure 3 Steps of a cyclical MSP process represented in a loop diagram adapted from Giacometti et al. 2020, Ehler and Douvere 2009 and von Thenen et al. 2020.

The drafting and consulting stage is focused on analysing the potential consequences of plans (Figure 3). This involves analysis of current and future conditions of the ecosystem and society to explore possible futures through what-if scenario building or trade-off analysis (Douvere and Ehler 2011; Gissi et al. 2019; von Thenen et al. 2020). For instance, several scenarios can be built to represent possible alternative futures and be evaluated against each other and desired outcomes to provide an insight into how specific actions or decisions may unfold in a desired or undesired fashion

(McGowan et al., 2019) and may help define more effective measures and actions (Piet et al. 2020; Douvere and Ehler 2011). Assessment of trade-offs between different activities based on expected risks and gains may reveal the most spatially optimal solutions or give an insight into compatibility between sectors (White et al. 2012) and may take place as part of scenario analysis (McGowan et al. 2019).

Throughout the process planners continuously draw on different types of knowledge, data, and involve stakeholders and citizens (Giacometti et al. 2020). In the marine planning context knowledge, and data about ecosystem dynamics are particularly important, as well as the interaction between people and ecosystems which can be described qualitatively and quantitively (IOC-UNESCO 2021; Bednarek et al. 2018).

In the European Union for instance, the Maritime Spatial Planning Directive (MSPD) was adopted in 2014 and made MSP a requirement for every EU coastal state (EC 2014). The implementation of MSPD is obligatory, however, member states are given the freedom to decide on the way MSPD is adopted according to the states' needs, institutional and legal setup, and administrative and cultural practices (Hassler et al. 2019). This means that even within the EU across countries following the same Directive, MSP practices vary to a great degree from country to country as the MSP objectives and processes are shaped by international and national development targets as well as ecosystem protection or conservation goals and planning culture and arrangements.

1.2.3 A promise of multi-dimensional sustainability

Judging by global and EU-level aspirations, the multi-objective, cross-sectoral, participatory nature of MSP makes it a well-rounded tool to support sustainable development – a balance between economic, social, and environmental goals (Ntona and Morgera 2018). Globally, MSP is seen as a mechanism for achieving the United Nations Sustainable Development Goal (SDG) 14 – Life Below Water, and supports the pursuit of social justice and equity i.e., no poverty (SDG 1) and hunger (SDG 2), and improved human health (SDG 3) (Kirkfeldt and Frazão Santos 2021; Ntona and Morgera 2018).

At the EU level, the MSPD is a key instrument for the implementation of the Integrated Maritime Policy (2007) framework focused on supporting blue, economic growth in the region and the Marine Strategy Framework Directive (MSFD; EC 2008) aimed at protecting the marine environment. When implementing the MSPD, planning authorities must therefore find ways to address challenges and enhance synergies between different users of marine space competing for resources, as well as users and the environment as a result of increasing pressures on ecosystems due to human activities (EC 2022). The possibility of addressing use-use and use-environment conflicts as part of the same process is one of MSP's key characteristics that makes it a beacon of hope for multi-dimensional sustainability (Ntona and Morgera 2018).

However, there is a growing concern that much of the focus in MSP is on economic growth or/and addressing environmental issues, whilst alarmingly little attention is paid towards social sustainability (SS), that is, social justice (Saunders et al., 2020). Research suggest that in most cases MSPs end up being focused on either:

a) takes an ecosystem based-approach focused on the conservation of the environment and ecosystem (Ehler et al. 2020), thereby subscribing to a ‘hard sustainability approach’ and a view that development is limited by the planetary boundaries (Rockström et al. 2009); or
b) is driven to find solutions to conflicts between users and support the development of a maritime economy (Rockström et al. 2009) thereby taking on a “soft sustainability” approach – viewing human and natural capital on a par with each other, and at times assuming that technological progress will eventually resolve environmental problems (Pelenc, Ballet and Dedeurwaerdere 2015).

National MSP experiences suggest that social sustainability is assumed to follow economic growth and good environmental status (Saunders et al. 2020; Ramirez-Monsalve and Van Tatenhove 2020). Further, when considered as part of the MSP process and engaged with by scholars, social sustainability is often limited to stakeholder participation – questions of which social actors, why and when should be engaged, and the format of participation is often restricted to a consultative rather than dialogue-focused ways of engagement (Flannery et al. 2018; Tafon et al. 2022).

Strategic Environmental Assessments are a compulsory part of MSP and used evaluate the environmental consequences of plans, yet do not consider social impacts for the most part (Pinkau and Schiele 2021). Part of the challenge of engaging with matters of social sustainability in MSP, Saunders et al. (2020) and others (e.g., McKinley et al. 2019) believe, is a lack of common, systematic ways of conceptualising social sustainability in the marine context. To tackle sustainability issues, there is a need for cross-sectoral and transdisciplinary approaches and methods to strengthen and highlight the links between human activities and ecosystem state as a single, interconnected system (Ntona and Morgera 2018).

1.2.4 A social-ecological systems approach to planning

The notion of ‘systems’ and ‘systems thinking’ is at the heart of the sustainability discourse, and has played a significant role in shaping the current-day planning process (Healey 2007). Central to systems thinking is an understanding that problems can be solved through the analysis of interconnections between elements that constitute a defined ‘system’, which are affected by each other, elements external to the system, and can create feedback loops (Healey 2007). One of the central roles of systems thinking is to break down complex systems into bite-size pieces, their component parts, and the interactions between them (Patricio et al., 2016; Healey 2007). Systems thinking, mainstreaming of the policy concept of 'sustainable development' and the discourse around it in the late 80s that drew attention to the shortcomings of traditional, narrowly focused resource management practices (Healey 2007; Schlüter et al. 2012), resulted in a shift from an understanding that planning primarily focused on physical design of spaces, to a view places and people as interconnected, interdependent systems nested within and made of interactions between actors and their environments (Healey 2007). The reimagining of the nature and role of planning in society meant that planners and decision-makers began engaging in analysis of how different 'parts' of systems are connected and interact, analysing impacts of and trade-offs between decisions based on constructs representing a version of an 'objective reality' (Healey 2007) and employing systems thinking as an instrument '*to dissect and harness complexity, rather than eliminate it'* (Ostrom 2009).

A social-ecological systems (SES) approach specifically implies that people are part of the natural environment, and focuses on the complex and dynamic interactions between people and ecosystems (Schlüter et al. 2019; Biggs et al. 2022). SES and the wider systems worldview draw attention to the relational qualities and processes between objects as key elements of reality (Preiser et al. 2022). Since the 1990s, the SES approach has been important for understanding and addressing many sustainability challenges that have no straightforward solutions, so-called 'wicked problems' (Potchin-Young et al. 2018; Schlüter et al. 2019). Common frameworks have been developed to organise and guide SES analysis of social and ecological element interaction with varying degrees of emphasis on non-linearity, feedback loops, and scales, such as an ecosystem services approach and the ecosystem services cascade framework (Briggs et al. 2022; Binder et al. 2013; Schlüter et al. 2019). The *DPSIR* model was one of the first developed and used for the analysis of pressures and impacts of human activities on ecosystems in the context of decision-making (Binder et al. 2013; Gómez et al. 2016). DPSIR–type models, an ecosystem service approach, and combinations of the two frameworks provide the theoretical foundations for this project (further described in Chapter 2.2 Conceptual Framing) and are unpacked next.

1.2.4.1 The DPSIR – type models

Over the years, many different variations of the DPSIR model have been developed and used in environmental risk assessment and management contexts including the marine (see Patrício et al. 2016 for a detailed description of the model development timeline). The defining characteristic of DPSIR – type models their focus on pressures and analysis of impact pathways, that is, how people affect the ecosystems (Sharpe et al. 2020).

In an in-depth study of the evolution of the DPSIR model, Patrício et al. (2016) present that the most recent version of the DPSIR model applied in the marine context is the *Drivers-Activities-Pressures-State-Impact (on human Welfare)-Response (as Measures)* model or the *DAPSI(W)R(M)* (Figure 4).

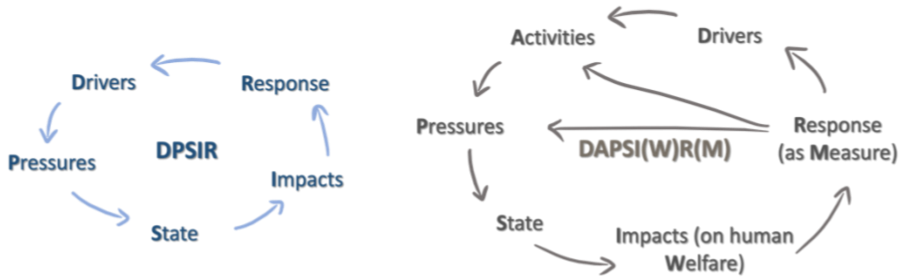

Figure 4 Visualisation of the original DPSIR and its more recent adaptation – the DAPSI(W)R(M) models.

Drivers are the basic human needs underlying human *Activities*, which result in *Pressures* and a change in the *state* of the ecosystem (e.g., habitat composition) (Patrício et al. 2016). A single activity can be a source of multiple pressures generating stressors and in turn – cumulative impacts, which are greater than the sum of individual parts – resulting in an immediate change in the ecosystem state or changes that manifest over time (Reckermann et al. 2022; Directive 2008 /56/EC). Change in the ecosystem *impacts human welfare* (Patrício et al., 2016), for instance, a decrease in the abundance of some fish populations may have an effect on fish landings directly impacting fishers' wellbeing and others who may depend on fish as a food source. *Impacts* are in many cases met by people with a management *response,* which may be a *measure* or an action targeted at managing the *drivers*, *activities,* and *impacts* on *human welfare* (Elliott and O'Higgins 2020).

1.2.4.2 An ecosystem services approach

In contrast to DPSIR, an ecosystem services approach shifts the focus from how people affect ecosystems to also explore how society benefits from them aiming to make the value of these benefits and the ecosystem more tangible (Sharpe et al., 2020). Ecosystem services are the contribution of the ecosystem to human wellbeing and livelihoods, or "*the final output from ecosystems that are directly consumed, used (actively or passively) or enjoyed by people*" (Culhane et al. 2020, p. 107). The ecosystem services cascade is one of the most widely used models to represent an ecosystem service approach (Figure 5; La Notte et al. 2017).

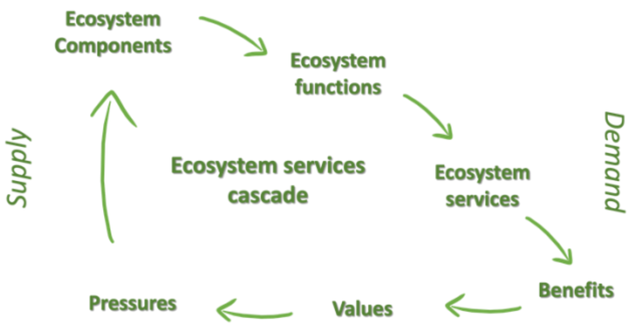

Figure 5 The ecosystem Services cascade model based on Potchin-Young 2018.

The cascade depicts the link between ecosystem components, species, and structures, ecosystem functions that represent interconnections between ecosystem components and ecosystem processes, and underpin the capacity of an ecosystem to supply services (Potchin-Young 2018). Services are obtained by economic, social, and cultural activities and provide benefits to people, which can be defined and measured as changes in human wellbeing as a result of service consumption or experience and fulfilment of needs and wants (Potchin-Young 2018). The value of a service or benefits comes from a socially ascribed worth or importance of the change in wellbeing (Potchin-Young 2018). The *supply* of ecosystem services, irrespective of their use, is maintained by a well-functioning ecosystem through the interaction of its ecosystem components more often than not under pressure as a result of various human activities (Potchin-Young 2018).

A number of classification systems have been developed to support the analysis of SES from an ecosystem services perspective (La Notte et al. 2017). Classification systems serve an important role in facilitating service and benefit valuation studies. One of the most widely used is the Common International Classification of Ecosystem Services (CICES), which groups services into three main categories – provisioning, cultural, regulating and maintenance. Some services have a much more direct link to benefits than others, for instance, the connection between wild fish for food and increased human wellbeing due to a supply of nutritious food and health benefits is relatively obvious (Hyytiäinen et al. 2014), while others are more closely related to ecosystem functions and processes, and require a much deeper understanding of ecological processes. Services such as retention of pollutants and nutrient regulation are examples of regulating and maintenance services, which at times may be confused with functions (Hyytiäinen et al. 2014).

To increase the reliability of economic studies of benefits and benefit distribution and lower the risk of mismanagement of natural resources, service supply assessment, availability and value of benefits, and drivers of change rooted in human needs should go hand in hand with biophysical assessments of pressure impacts, change in ecosystems and service supply (Bateman et al. 2011; Figure 5). Linking the two sides – supply and demand – is a complex and resource-demanding process of bridging social and natural sciences (Sharpe et al. 2020) and requires triangulation of methods and approaches from various disciplines (Potchin – Young et al. 2018). Analysis that stretches the two sides requires geospatial and biological information about ecosystem component distribution or abundance, and knowledge of which functions they perform. On top of this, a description of benefits and services includes an analysis of their value, and distribution of costs and benefits often through engagement with the beneficiaries and communities (Sharpe et al. 2020). Most ecosystem service assessments, therefore, focus on either the supply or demand side, interconnections between a select few elements say services supplied by one or two species at a time (Sharpe et al. 2020), and even fewer assess the link between ecosystems services supply and pressures (Heckwolf et al. 2021).

1.2.5 Ecosystem services in maritime spatial planning

This might be self-evident, but studying different parts of the cascade provides insights into different parts of the systems, gives rise to different types of knowledge and therefore inform the decision-making process differently. For instance, qualitative supply assessments can depict contribution of ecosystems in service supply and are useful in understanding service origins (Veidemane et al. 2017) say to determine areas of high value and inform conservation measures. While analysis of benefits, disbenefits, benefit distribution, socio-ecological consequences of trade-offs, as well as labour or social costs involved in transforming services into benefits or goods can create an better understanding of the social and economic consequences of decisions (Berbés-Blázquez et al. 2016; Schröter et al. 2017) Consideration of the distributional aspect of benefits is particularly important as they can reveal issues of access, fairness, and inequity in society (Bateman et al. 2011). However, Ntona and Morgera (2018) suggest that the links between ES and justice need further study.

The ES cascade can be linked directly to MSP at each analysis step (see Figure 5), and importantly structure the evidence-gathering and analysis stages of the MSP process (von Thenen et al. 2020). von Thenen argues that the different stages of an integrated ecosystem service assessment (capacity, ecosystem service, benefits, and value assessments) can have a role to play in the stock-taking and scenario analysis spectrum of activities as current and future conditions (social, environmental and, economic) are analysed during the MSP process.

1.2.6 Decision-support tools for MSP

Various spatial and non-spatial decision support tools, that is, computer programme applications or non-computer-based techniques have been developed to support the

MSP process, most of which support a single, specific type of analysis and MSP task (Pinarbasi et al. 2017; Gee et al. 2019).

Digital tools have been developed to support participatory knowledge co-creation and a collaborative decisions-making process. Participatory mapping techniques and tools can help highlight problem areas and capture socio-culturally important spaces and knowledge (Ntona and Morgera 2018). The Baltic Explorer (http://balticexplorer.eu/) is an example of an open-source collaborative GIS online tool developed as part of the BONUS BASMATI project (Koski et al. 2021b) for drawing shapes, and editing maps loaded through a Web Map Service from a range of sources real-time on a shared platform. The MSP challenge game is an example of spatial 'serious game' (digital and as a board game) created to engage stakeholders and build a common understanding of an MSP process (Abspoel et al. 2021).

Considerable efforts have also been made in the recent years to compute cumulative impacts of pressures generated by human activities on ecosystems (Menegon et al. 2018). The Symphony tool for cumulative impact assessment and the MYTILUS toolset for cumulative impact and co-location analysis have been developed for and tested in a decision-making setting (Hansen 2019; Hammar et al. 2020). Both tools have built in scenario analysis components, which allow adaptation of pressure levels to assess changes in pressures and cumulative impacts for a specific area following the Halpern et al. (2008) approach.

InVest (Integrated Valuation of Ecosystem Services and Trade-offs) is a widely used ES supply assessment and mapping tool, that in some cases can be used to also identify and value the benefits and compare alternative plans and trade-offs (Guerry et al. 2012). The AquaLinks tool is for analysing ecosystem services in the form of weighted linkage web diagrams and linkage chains (see AQUACROSS project).

The interconnections between different elements of social-ecological systems can be represented in linkage diagrams following a linkage framework approach (Ostrom 2009). Populated with indicators and data to reflect a SES at a specific time and place, linkage web diagrams can be used as a tool for graphically representing multiple linkage chains or pathways sustaining ecosystem service supply and giving an overview of a SES as a whole – the elements and processes between them (Robinson and Culhane 2020). The importance of a link between elements can be described numerically and represented graphically through varying widths (Robinson and Culhane 2020). Ultimately aiding communication between social and natural scientists, as well as decision-makers involved in ecosystem service analysis (Robinson and Culhane 2020).

Participatory, expert scoring has often been used to describe the links between ecosystem components, functions, and services qualitatively and quantitatively (Robinson and Culhane 2020; Campagne et al. 2017). One of the main advantages of an expert knowledge-based linkage framework approach is that it essentially accommodates various types of data (Campagne et al. 2017). That is, while not 'data driven', expert-filled matrices describing links between elements may be based on field studies or modelling results. Therefore, certain downsides come with using expert knowledge (e.g., poor transparency and reproducibility and no systematic way of acknowledging uncertainties), an elicitation process can bring various data and evidence sources together under one roof thereby enabling fuller social-ecological system assessments where some element may be well studied while other areas – not as data-rich (Robinson and Culhane 2020).

2 Research design

The design of this research project was guided by an interest to embrace methodological pluralism, and interdisciplinarity and explore the untapped potential of ecosystem services in supporting MSP. While the central objective of this project remained constant throughout, the formulation of sub-research questions and the development of the analysis design was an iterative process different research strands informed each other and shaped the understanding presented in this thesis. This chapter is divided into three sections focused on the three key aspects of research design – i) research aims driving the project, ii) conceptual framing, and, iii) analysis design.

2.1 Research aims and the role of papers

The overarching aim of this thesis is to contribute to the way an ecosystem services approach is conceptualised and employed in MSP, and answer the central research question – *How can an ecosystem services approach be operationalised to improve integration in MSP?* To answer this question, the following three sub-research questions (SRQs) are investigated:

1. What are the gaps in the current conceptualisation of social sustainability in MSP and how can they be addressed?
2. What is the potential role of an ecosystem services approach in supporting social sustainability conceptualisation in MSP?
3. How can multiple ecosystem service supply change be assessed to support MSP?

SQR1 highlights some shortcomings of how social sustainability is currently studied in MSP and provides some analytical approaches to support social sustainability conceptualisation in a more systematic and place-based manner. SRQ2 is focused on exploring the untapped potential of ES in supporting social sustainability conceptualisation in MSP, specifically multidimensional impact analysis. To answer SRQ3, a spatial decision-support tool, which supports quantitative, geospatial analysis of multiple ecosystem service supply change following a linkage framework approach is designed and tested.

Each question is answered separately and Chapter 4, and the discussion rounds up the findings from all studies presented in this thesis to discuss how the findings may improve operationalisation of an ecosystem services approach in MSP.

The findings presented in this thesis are published in authored and co-authored papers (as illustrated in Figure 6. A schematic representation of the paper contribution). All papers written during the project have varying degrees of empirical and theoretical focus and play different – key or supplementary – roles in answering the research questions.

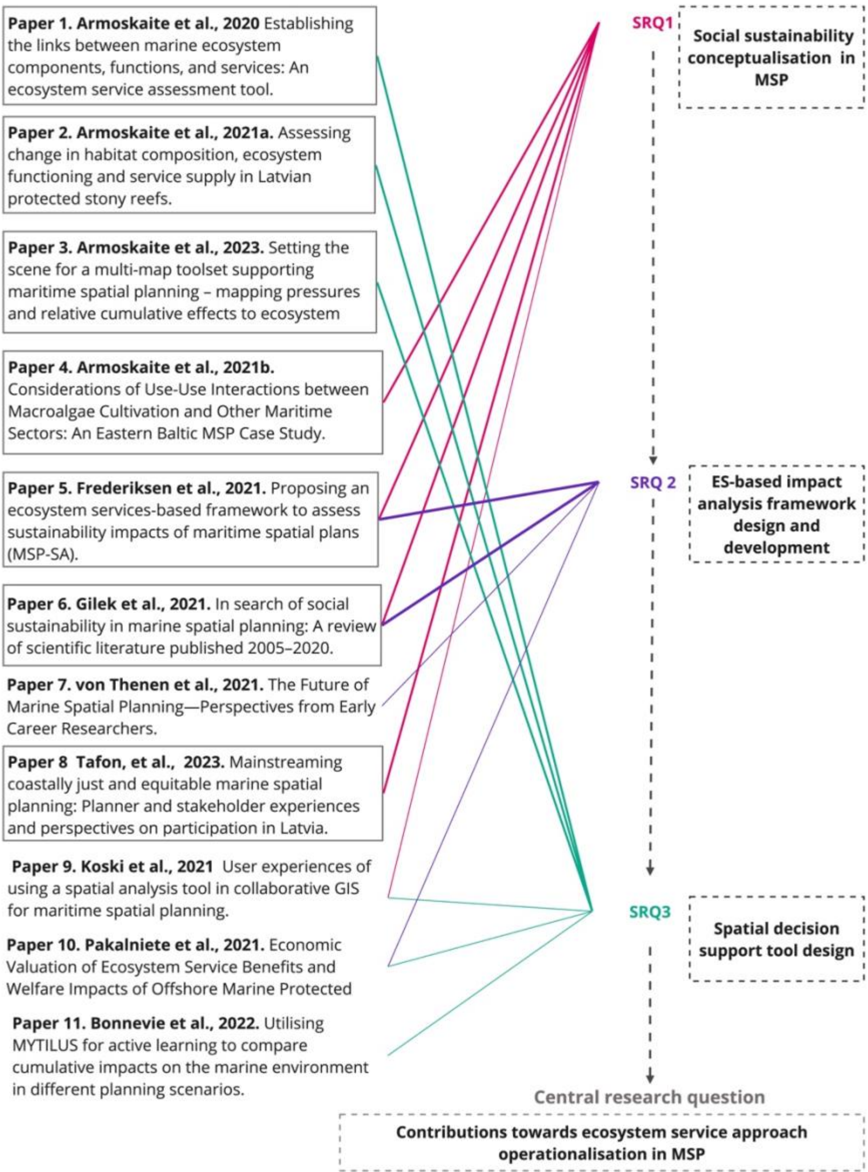

Figure 6 Contributions from the papers to answering sub-research question (SRQs), including key contributions to the thesis (in boxes; papers 1-7, and 8) as well as supplementary papers (papers 7, 9-11). Strength of contribution is represented by the thickness of the line.

2.2 Conceptual framing

To manage human activities in a way that tackles ocean sustainability issues, adaptative, ecosystem-based MSP requires an overview of social-ecological systems and the possibility of tracking change in the system (Culhane and Robinson 2020; Briggs et al. 2022). This entails a relational understanding of the connections between multiple different elements of systems simultaneously, which in an ideal world, recognises the dynamic, adaptive, and ever-changing nature of systems that are affected by external forces outside the artificial system boundaries, place and time and, non-linearity within systems - cumulative impacts, feedback loops – that may emerge as systems change and elements interact (Briggs et al. 2022; Potchin and Young 2018).

Species and habitats perform various different ecosystem functions and contribute to the supply of a wide range of services (Sharpe et al. 2020). However, literature suggests that few ecosystem service studies embrace complexity and have so far attempted to take on a more 'holistic' approach, that is, explore the links between more than one or two ecosystem services and ecosystem components in the marine context (Sharpe et al. 2020) and those that do follow a linkage frameworks approach and assess interactions qualitatively (Robinson and Culhane 2020; Campagne et al. 2017). Numerical descriptions of multiple interactions between a whole range of elements in a linkage diagram would advance the application of ecosystem services in MSP by supporting analysis of change in the environment and human wellbeing (Robinson and Culhane 2020). The effects of cumulative impacts on marine ecosystem service supply have also been explored in a handful of studies using the Halpern et al. (2008) approach (Hammar et al. 2020; Singh et al. 2020). Hammar et al. (2020), for instance, assessed relative change in impact index values to explore the consequences of different activities considered by the Swedish MSP. However, comprehensive methods for analysing cumulative impacts on service supply remain to be developed.

Requirements for SES analysis to consider cumulative impacts, assess the links between multiple ecosystem components and services, and be communicated numerically and visually – through linkage web diagrams and maps – to foster communication with decision-makers, stakeholders, and across disciplines (Bateman et al. 2011) set the foundations for the design of a spatial decision support tool to assess multiple ecosystem service supply. The design of the tool further evolved through interaction with experts and decision-makers throughout the project.

The overall conceptual framing of this thesis is based on the butterfly model (Gómez et al. 2016; Elliot and O'Higgins 2020), which combines elements of the ecosystems services cascade and the DAPSI(W)R(M) model. The butterfly has two interconnected sides representing the supply/ecological the demand/social relationships of the social-ecological system, and the 'impacts' of the

DAPSI(W)R(M) are seen synonymous with 'ecosystem services' of the ecosystem services cascade (Gómez et al. 2016; Elliot and O'Higgins 2020; Atkins et al. 2021).

Figure 7 is a graphical re-interpretation of the further adapted butterfly model to highlight central elements and focus areas of this thesis, and their interconnections. Four elements have been added to the model (Figure 7; text in red). Firstly, 'cumulative impacts of pressures' on the ecosystem state have been added to the supply/ ecological system side of the butterfly to elevate the importance of considering multiple pressures and cumulative impacts in the analysis of ecosystem service supply. The yellow arrows and text on the supply side indicate elements and processes studied to develop a method and design a tool for assessing multiple ecosystem service supply.

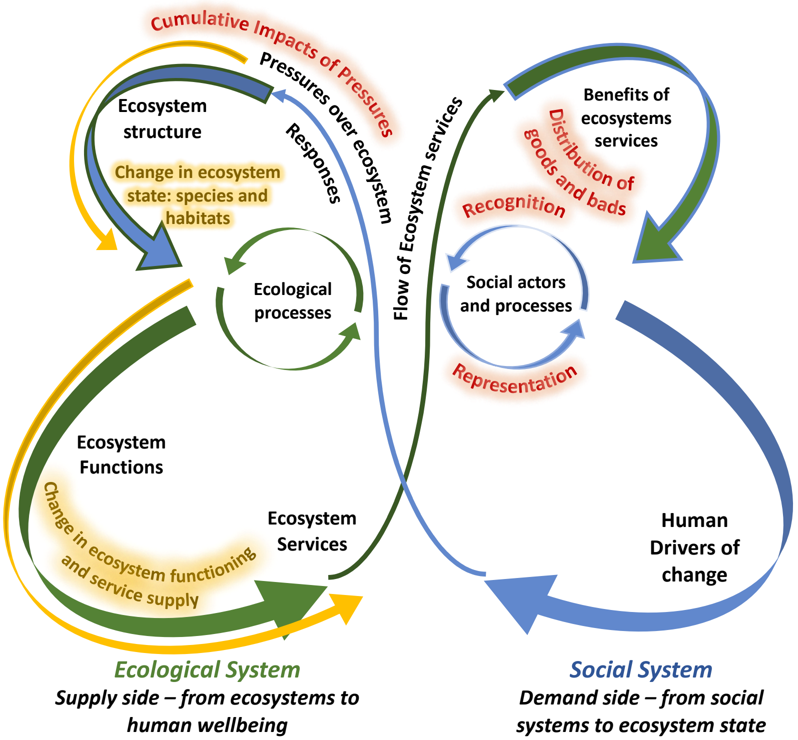

Figure 7 A graphical representation of the conceptual framing of this project based on the butterfly model (Gómez et al. 2016). Labels in red highlight new additions to the model. Yellow arrows and labels indicate elements considered in the design and testing of the tool for ecosystem service supply change analysis.

Three additional elements have also been introduced to the social system side of the butterfly to emphasise the significance of distributional and procedural justice as part of the benefit and social actors and process analysis (Figure 7). Literature suggests that the links between ES and justice need further study (e.g., Ntona and Morgera 2018), and the development of systematic approaches for analysis would be advantageous for improved social sustainability and considerations in MSP (e.g., Saunders et al. 2020). To this end, three analytical categories are added to the butterfly to cover aspects of distributional and procedural justice, as presented by Saunders et al. (2020) based on Fraser's (2008) theory of social justice:

- *Recognition* of the legitimacy of diverse identities and rights, needs, livelihoods, lifestyles, and types of knowledge
- *Representation* – determinants participation, inclusion/exclusion in decision-making.
- *Distribution of goods and bads* – sharing of impacts, risks, (dis)benefits, and resources in MSP.

All three categories are interconnected, and together provide an insightful overview of justice when applied in the evaluation or analysis of MSPs (Saunders et al. 2020). Analysis of the spatial distribution of goods and bads over time and space may reveal issues of environmental injustice (Bennet et al. 2023). At the same time, a claim to space and a designated spot on the map is a direct consequence of being at least to some extent part of the process of deliberation (Gimpel et al., 2018), therefore is not only an indicator of access to resources, but also a manifestation of procedural considerations recognition and representation. Spatial visibility on maps is increasingly important for sector development as seas, especially coastal areas, become more and more crowded (Przedrzymirska et al. 2019; Gimpel et al. 2018). At the same time, traditional uses with existing claims over space may have an upper hand making it challenging for new sectors to establish (Schultz-Zehden et al. 2018). Co-location is a concept that has become increasingly popular in MSP and describes an ambition to find synergies between uses and uses and the environment (Bonnevie et al. 2019; Przedrzymirska et al. 2019). For establishing sustainable blue economy sectors, such as low trophic aquaculture, spatial representation, and consideration as part of the use-use combability, co-location analysis is a step in the right direction and a start to streamlining regulations, licensing procedures and attracting attention from investors (Stelzenmuüller et al. 2017). Therefore, in the context of spatial planning, spatial dimensions of all three categories need to be evaluated, and the spatial distribution of benefits also needs to be addressed (Ntona and Morgera 2018).

Saunders et al., (2020) categories shaped the conceptual framing and the analysis of empirical data in papers 4, 6, and 8 focused on social sustainability conceptualisation and provided the conceptual understanding of the links between papers 4, 6, 8, and 5. In paper 4, Bonnevie (2019) categories applied by Bonnevie in spatially explicit MSP use-use, use-environment, and co-location and multi-use analysis (e.g., Bonnevie et al. 2020) are introduced to complement the Saunders et al. (2020) analytical approach.

2.3 Analysis design

Analysis of social-ecological systems, including ecosystem service supply and demand, involves the study of the physical world governed by the laws of nature which speak the language of mathematics, and the social world defined by continuous processes of interaction, sensemaking, and discourses created at the individual and broader system level (Andriessen 2008). SES research is therefore a space where different disciplines and types of knowledge come together to collaboratively describe various parts of SES, which also means that SES research accepts and embraces methodological and epistemological pluralism – different ways of understanding what constitutes knowledge, how it is produced and applied (Miller et al., 2008; Preiser et al. 2022). In SES research, various methods may be employed to gather and analyse data that is not only scientifically robust but also a meaningful interpretation of SES made accessible to others to facilitate collaboration between researchers and engage relevant stakeholders (Preiser et al. 2022).

The process-relational systems worldview focused on exploring interactions and changing nature of social and ecological elements of the system, is on par with a critical realism theoretical worldview which integrates ontological realism – says that a ‘real’ objective world exists – and epistemological relativism – recognises the significance of time, space and discourse created at an individual level (Preiser et al. 2022). This project too is rooted in critical realism and attempts to endorse epistemological agility by combining different scientific fields of research and methodological approaches for collecting and interpreting empirical evidence (Figure 8). The focus on improving the operationalisation of an ecosystem services framework in a decision-making context set the precedent for a series of solution-based investigations with an underlying intention to provide solutions to social and management problems by creating knowledge and practical products, such as maps and tools, through for instance collaborative design and action research (Baard et al. 2010; Arnott and Pervan 2005; Hevner et al. 2004; Figure 8).

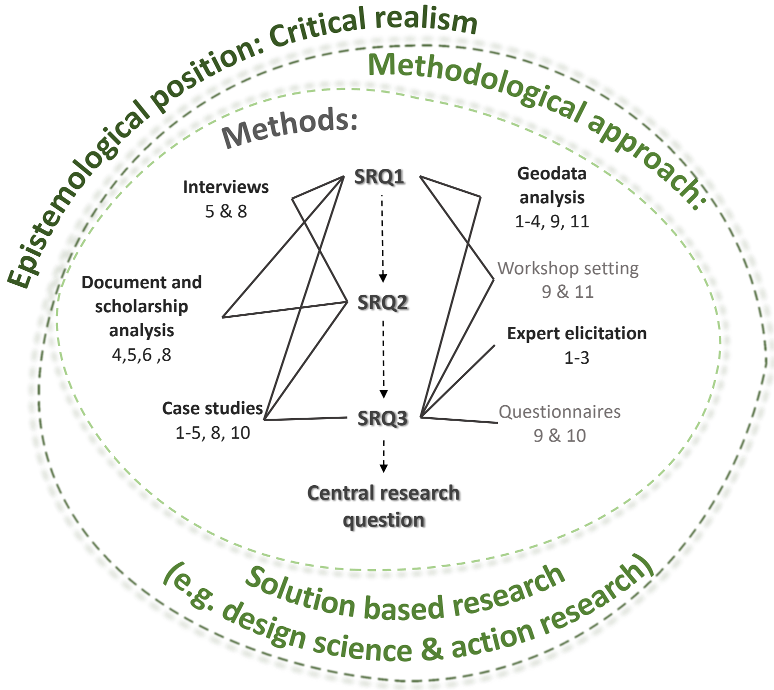

Figure 8 A graphical representation of the methodological framing and different sources of knowledge contributing to each sub-research question. Numbers underneath methods indicate the paper number and light grey colour, non-bold text – indirect input. Paper 7 is not included as it is a commentary

To answer the research questions, this thesis engages with eleven studies that explore different parts of the adapted butterfly, and follow different methodological approaches but can be categorised into two groups of methods responding largely to SRQ1 and 2, and SRQ3.

Firstly, the first two sub-research questions are focused on identifying and addressing some of the gaps in conceptualising and analysing social sustainability (**SQR1**) and ES (**SQR2**). SQR1 and SQR2 are answered with reference to papers 4 – 8 based on studies of the normative, institutional MSP set-ups in different countries around the Baltic Sea through documents, literature, geospatial analysis of marine spatial plans and theories of social sustainability in research. Interview responses provided insight into stakeholder/social actor experiences of planning processes (papers 5 & 8) and experiences of researchers as insider participants of MSP (papers 4 & 7).

Secondly, to develop a method and design a spatial decision support tool for analysing change in ecosystem service supply in response to **SRQ3**, on the other hand, a context-specific expert knowledge base was developed to inform tool development (presented in paper 1), adapted and re-used as a secondary data source through the process for the development of new functionalities and testing (papers 2 & 3). Ecological geospatial data was also gathered from open sources, produced in collaboration with experts, and informed the knowledge base and the case studies analysed to demonstrate the tool.

The following sections of this chapter describe the key methods and materials – case studies, the expert elicitation process, interviews, geodata sources, documents, and analysis methods – in more detail. Empirical data was also collected through observations at interactive workshops (paper 9), and through written feedback (paper 11) in quantitative surveys (10) in studies which indirectly contribute to answering the research question. These methods are described in Chapter 3 Summary of papers alongside the specific paper summaries.

2.3.1 Case studies

Case studies provide a form of empirical research to explore relationships (Yin 2003). In several papers (1-5, 8, and 10) presented in this project, case studies with a geographical location (all within the Baltic Sea region) complement other methods based on the pragmatic need for context-specific knowledge. In papers 1-3 case studies facilitate close-up analysis of various parts of SES in great detail and relationships between tools and users, which define tool requirements central to the design, testing, and demonstrating tool functionalities, and the results. In papers 4, 5, 8, and 10 case studies composed of gathering and analysis of empirical data ranging from document analysis, interviews, participant observer knowledge, and geospatial data, a nationally representative questionnaire, workshops, and ecosystem service supply analysis.

2.3.2 Expert elicitation

As described previously, the use of various types of knowledge bases for the development of linkage web diagrams and analysis of SES (Robinson and Culhane 2020; Campagne et al. 2017). Expert knowledge, however, is central to the process and underpins the identification of elements of the SES and descriptions of most connections (Robinson and Culhane 2020; Campagne et al. 2017) and was collected through workshops and individual consultations to create a knowledge base for an ecosystem service supply SDT design and testing (papers 1, 2 and 3).

To gather expert knowledge and develop a knowledge base for the spatial decision support tool design and testing, five scientists with backgrounds in marine biology, ecology, biogeochemistry, sociology, and economics participated in a total of three semi-structured, iterative workshops and carried out independent reflective work evaluating the links between species, habitats, the functions they perform, and function importance to society. Regional experience, technical knowledge, and an understanding of an ecosystem services approach were the criteria used to select participants (as proposed in Singh et al. 2017; Jacobs et al. 2015; Figure 9).

Sampling criteria

- Regional experience - experience in researching the territory of interest in the field of social or environmental sciences.
- Technical knowledge – environmental scientists were to have an overall understanding of ecosystem functioning, some more specific technical knowledge, and complement each other.
- Understanding or a level of familiarity with an ecosystem services approach and the ecosystem services cascade.

Figure 9 Sampling criteria based on Singh et al. 2017 and Jacobs et al. 2015.

During the expert elicitation process, the experts were asked to complete three tasks and check the results several times (Figure 10). The first task was to list the context-specific ecosystem components, functions, and services (Step 1 Figure 10). A common international classification system for ecosystem service (CICES v.5.1) and a widely used Baltic Sea, macroregional habitat (HELCOM HUB 2013) classification systems, and maps depicting ecosystem components (HELCOM Map and data service), as well national datasets such as national fisheries data (Latvian Fisheries Yearbook, 2014) and monitoring observations from the Latvian National Monitoring program (Latvian Institute of Aquatic Ecology, 2018) were consulted by the experts and provided a reference point for listing habitats, ecosystem functions and services. Habitats and species were listed to describe the ecosystem at different levels of detail, and widen the range of geodata compatible with the analysis results so that they are mappable and can support MSP.

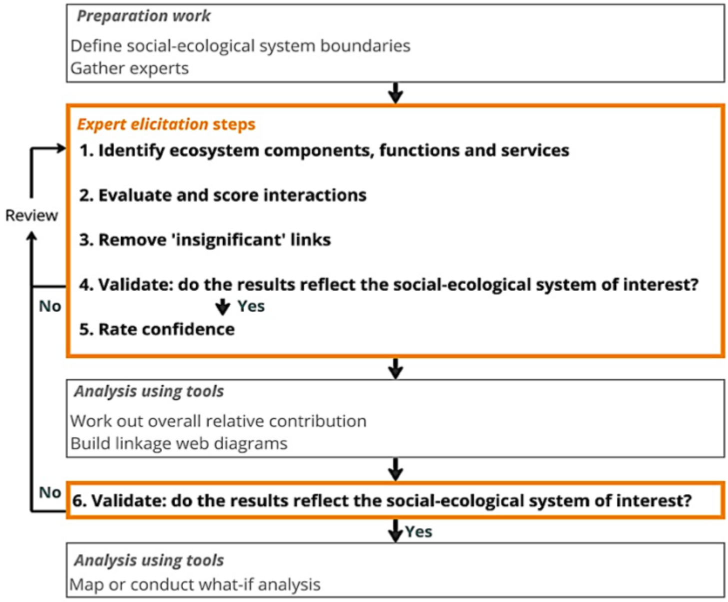

Figure 10 A flow chart depicting steps of expert elicitation taken as part of the decision-support tool development process.

The identified elements were added to a matrix and scoring took place (Step 2, Figure 10), which was followed by the identification of 'insignificant' links – links ascribed values under a specific threshold (Step 3, Figure 10) – and an overall result validity check (Step 4, Figure 10). The experts were asked to reflect whether the results represented the social-ecological system fairly, and if so, to describe their confidence in scores on a scale of 1 (very low) to 5 (very high) based on a) the evidence or data behind each score and b) consensus within the group (Step 5, Figure 10). Once the scores were gathered and analysis was performed, the results of the assessment were once again discussed with the experts to see if the final products of the analysis reflect the experts' understanding of the social-ecological system (Step 6 Figure 10).

2.3.3 Geodata sources and analysis methods

Papers 1- 4, 9, and 11 primarily sourced freely accessible geodata from the HELCOM Map and Data service (with few acceptations) and employed open-source tools for the analysis.

Geodata depicting maritime uses for Latvia, Estonia, and Poland were downloaded from the HELCOM Map and Data and gathered from national authorities responsible for developing the marine spatial plans to map the results of the co-location analysis in paper 4. Various ecological component maps from the HELCOM Map and Data

Service as well as national databases informed the expert-driven linkage web diagram development process. LIAE in-house sediment and habitat maps classified according to HELCOM HUB (2013) based on video observations informed papers 1 and 2.

Two tools were used in geospatial analysis in papers 1,2 and 3. MYTILUS – an open-source cumulative impact assessment tool (Hansen 2019) and QGIS (an open-source GIS software) for further analysis (e.g., overlay). The Halpern et al. (2008) CIA method at the heart of MYTILUS CIA requires spatial data on ecosystem pressures from human activities, ecosystem components, and non-spatial, expert-assigned sensitivity scores of components to pressures. By design, MYTILUS runs Baltic Sea scale CIA based on spatial data from the HELCOM Map and Data Service, and sensitivity scores derived by HELCOM (more info HELCOM 2017). MYTILUS was used to run the CIA in papers 3 and 11. In paper 3, the results depict per-cell cumulative impact values and were exported in raster format for further analysis. QGIS was used to work out the per-cell change in cumulative impact index values and ecosystem service supply. In paper 11, MYTILUS was used in a teaching context by students to do the following exercises for a selected area: i. view maps and data, ii. calculate cumulative impacts and view the results (maps and statistics), iii. create an alternative scenario by copying reference scenarios and adapting human activity levels to see change cumulative impacts, and iv. explore spatial patterns in conflicts and synergies between activities.

For paper 9, a spatial multi-criteria assessment function to analyse the presence of habitats and species on the seafloor, and an interface to accompany the analysis – select and view data, and parameters – were added to the Baltic Explorer (Koski et al. 2021b). The data for the multi-criteria analysis was point data on species presence pre-processed for the users using inverse distance-weighted interpolation.

2.3.4 Documents and research analysis

Iterative content analysis is a systematic reading of a text to identify key themes, which are further categorised or analysed for patterns, and used as empirical data (Hall and Steiner 2019). In papers 4, 5, 6, and 8 documents were analysed to gather main empirical evidence.

In paper 5, reports and records of the MSP process in Latvia, Sweden, Germany, and Finland, MSP sustainability appraisals from Sweden and England, and frameworks, (i.e., MSFD socio-economic analysis and the First Global Integrated Marine Assessments) were reviewed to compare the sustainability criteria used in MSP practice and theoretical sustainability principles found in literature. In paper 4, Latvian, Polish, and Estonian MSPs and associated documents (e.g., consultation protocols, pilot MSPs, aquaculture sector development strategies; 18 in total) were reviewed for acknowledgments of macroalgae cultivation sector legitimacy and instances of representation in formal and informal capacity by stakeholders or the planning authorities.

Paper 6 is a systematic review of 310 scholarly papers published between 2005- 2020, which address at least one dimension of social sustainability in an MSP context and were identified using a search string that included terms such as social, cultural, societal, social inclusion, diversity, equity, justice, quality of life. In paper 8, critical blue justice in MSP research was analysed to derive analytical principles for equity in MSP participation analysis.

2.3.5 Semi-structured interviews

Semi-structured interviews were carried out as part of studies 5 and 9. In paper 5, planners in the Baltic Sea region (Finland, Sweden, Denmark, Germany, and Latvia) were interviewed by the authors to see if alternative outcome and impact analysis if are part of the MSP process, and if and how are social sustainability aspects considered.

In paper 8, 12 semi-structured interviews were carried out with 15 different Latvian MSP stakeholders (a local planner, consultants involved in the MSP process, as well as the Latvian MSP authority, Maritime Administration (responsible for navigation, shipping, and safety), Cultural Heritage authority and nature conservation organisation representatives, and a coastal fisher, resident and tourism entrepreneur, and two environmental scientists). The interviews were a gateway into the experiences of and opinions on the Latvian MSP process, especially with regard to participation. They were conducted in 2020-2021, mostly online due to COVID-19 restrictions.

3 Summary of papers

This section provides a brief paper-by-paper summary of the eleven papers contributing towards this thesis. The summary describes key research aims, methods, and a brief outline of the findings contributing towards this thesis.

Paper 1. Establishing the links between marine ecosystem components, functions, and services: An ecosystem service assessment tool (Armoskaite et al. 2020)

Research aim: to design and test an ecosystem service supply assessment tool for estimating the relative i) contribution of ecosystem components in service supply following the ecosystem service cascade and ii) change in service supply. Represent the results in weighted linkage web diagrams**.**

Methods: several rounds of expert elicitation workshops and individual consultations to define elements of a case study SES and describe interactions through scoring. The information provided by the experts was used to develop the tool using Microsoft Office Excel to do the calculations and the Plotly module (Plotly technologies Inc. 2015) in a Jupyter notebook web-based environment using Python to visualise the results in a Sankey diagram.

Result contribution to this thesis: introduces a Microsoft Office Excel-based tool to work out the relative overall contribution of ecosystem components in multiple ecosystem service supply and estimate change in service supply based on changes in the ecosystem. An explorative example illustrates the effects of mussel cover decrease on ecosystem functioning and service supply.

Paper 2. Assessing change in habitat composition, ecosystem functioning and service supply in Latvian protected stony reefs (Armoskaite et al. 2021a)

Research aim: to assess the change in protected stony reef habitat composition, ecosystem functioning, and service supply.

Methods: a combination of geospatial analysis to develop benthic habitat cover maps and relative ecosystem service supply change employing the ES supply assessment tool and the assessment results published in *Armoskaite et al. (2020).*

Result contribution to this thesis: a method for preparing and utilising geospatial information– detailed habitat maps based on underwater video data – as a basis for place-based, relative ecosystem service supply change analysis using the tool introduced in *Armoskaite et al. (2020).* The findings of this paper advance the development of the decision support tool for estimating multiple ecosystem service supply change to support MSP (SRQ3).

Paper 3. Setting the scene for a multi-map toolset supporting maritime spatial planning – mapping pressures and relative cumulative effects on ecosystem services (Armoskaite et al. 2023)

Research aims: to design a conceptual framework for a multi-map decision-support toolset that facilitates geospatial, relative ecosystem service supply analysis informed by results of cumulative impact assessments, and manually test the model behind the toolset.

Methods: a four-step analysis process – i. analysis of the Halpern et al. (2008) CIA approach, ii. analysis of linkage framework-based ecosystem service analysis methods and tools, iii. development of a conceptual framework for integrating CIA and ES assessments, and iv. test case analysis using QGIS and MYTILUS.

Result contribution to this thesis: directly contribute to the development of a decision support tool for the relative estimating ecosystem service supply change (SRQ3) by introducing a method for calculating place-based, geospatial, relative change in service supply as a result of change in cumulative impacts.

Paper 4. Considerations of Use-Use Interactions between Macroalgae Cultivation and Other Maritime Sectors: An Eastern Baltic MSP Case Study (Armoskaite et al. 2021b)

Research aim: to explore the ways in which MSP enables and restricts the development of a new blue economy sector – macroalgae cultivation – in Latvia, Estonia, and Poland. Incorporate spatially explicit analysis of use-use interactions as part of social sustainability and justice analysis in MSP.

Methods: MSP and related planning documents analysis, author observer/ participant knowledge, and geospatial analysis.

Result contribution to this thesis: presents an approach to integrating co-location analysis as part of SS analysis by combining Saunders et al. (2020) analytical categories and the Bonnevie et al. (2019) co-location analysis methodology, and directly contributes to answering SRQ1.

Paper 5. Proposing an ecosystem services-based framework to assess sustainability impacts of maritime spatial plans (MSP-SA) (Frederiksen et al. 2021)

Research aim: to develop a framework that facilitates MSP impact assessments, which include all three sustainability dimensions – social, economic, and environmental – with an emphasis on sociocultural dimensions.

Methods: iterative analysis of planning documents followed by semi-structured interviews with MSP planners in Germany, Finland, Latvia, Sweden, and the UK were carried out to see if and how a) alternative outcomes and impacts were analysed and b) social sustainability aspects considered as part of the MSP process.

Result contribution to this thesis: offers an ecosystem service and DPSIR model based framework (MSP-SA) to broaden the scope of MSP sustainability analysis, therefore is a key contribution to SRQ2.

Paper 6. In search of social sustainability in marine spatial planning: A review of scientific literature published 2005–2020 (Gilek et al. 2021)

Research aim: provide an overview and critically evaluate how social sustainability is conceptualised in MSP literature.

Methods: A systematic review of 310 peer-reviewed papers to answer the following three key research questions – i) what key arguments are made for including social sustainability in MSP? ii) how is social sustainability described? and iii) what strategies are proposed to address challenges and/or promote social sustainability in MSP?

Result contribution to this thesis: The results of this literature review identify gaps in and ways to address conceptualisation of social suitability in MSP (SRQ1) and the current, and potential role of an ecosystem services approach in supporting SS analysis in MSP (SRQ2).

Paper 7. The Future of Marine Spatial Planning—Perspectives from Early Career Researchers (von Thenen et al. 2021).

Research aim: to highlight some of the missing, focal themes to be addressed in the future, for MSP to become truly effective.

Methods: von Thenen et al. (2021) is a commentary based on the observation, experiences, and opinions of the authors, early-career researchers who took part in a transdisciplinary early-career research focused session at the IOW MSP NATURE 2021 conference.

Result contribution to this thesis: stresses the importance of addressing climate change, ecological sustainability, blue justice, ecosystem services, and blue governance and suggests ways these topics could play a greater role in future MSP. The discussion of these themes side by side contributed to formulating the research questions and answers to all research questions in this thesis.

Paper 8. Mainstreaming coastally just and equitable marine spatial planning: Planner and stakeholder experiences and perspectives on participation in Latvia (Tafon et al. 2023)

Research aim: to develop equity-based principles to assess participation and influence, and analyse Latvian first MSP coastal community participatory processes.

Methods: Scholarly literature analysis and a retrospective, exploratory study of Latvian MSP through inductive content analysis of Latvian MSP documents, and semi-structured interviews with various MSP stakeholders.

*Result contribution to this thesis***:** this study contributes to the conceptualisation of social sustainability in MSP (SRQ1) by introducing six principles (i.e., timely, inclusive, collaborative, supportive and localized, methodical, and impactful) to assess the planning process and outcomes. The analysis of the Latvian MSP process draws attention to the challenges of equity-based, inclusive, and localised coastal community engagement and illustrates how the principles can be used to comprehensively evaluate the MSP participation process.

Paper 9. User experiences of using a spatial analysis tool in collaborative GIS for maritime spatial planning (Koski et al. 2021)

Research aim: to understand i) the purpose of spatial decision support tools (how they are used by MSP stakeholders in a real-life, collaborative planning context) and ii) the benefits of integrating tools for performing spatial multi-criteria analysis (elements of SDSTs) and creating spatial objects, and adding datasets from third-party sources (elements of collaborative Geographic Information Systems) for same-time, same-place collaborative problem-solving.

Methods: an interactive workshop with 24 Latvian MSP stakeholders (representatives from ministries, public authorities, and non-governmental organisation) working in teams to find a location for an offshore wind farm task using the ‘Baltic Explorer’, a collaborative GIS-based SDST. Empirical data was gathered through non-participant observations and a questionnaire (21 responses).

*Result contribution to this thesis***:** This study unpacks the topic of collaborative SDTS in a planning context for the purpose of engagement, which touches upon several aspects of this thesis. This study informed the development of the spatial aspect of the ecosystem service supply assessment tool (SRQ3). Also contributes indirectly to answering SRQ1 by highlighting the ways in which collaborative SDTSs may increase meaningful participation in MSP.

Paper 10. Economic Valuation of Ecosystem Service Benefits and Welfare Impacts of Offshore Marine Protected Areas: A Study from the Baltic Sea (Pakalniete et al. 2021)

Research aim: to elicit values for a wide array of marine ES benefits provided by protected stony reef habitats and human welfare change as a result of the designation of new offshore, marine protected areas.

Methods: analysis of change in service supply as a result of varying spatial protection levels of stony reef habitats, based on the estimated contribution of reefs in service supply presented in paper 1, and citizen willingness-to-pay for ES benefits collected through a discrete choice experiment in a survey.

Result contribution to this thesis: the method for monetary benefit analysis presented in this study illustrates how the ecosystems service supply change analysis tool designed during this project may be used to link analysis of social and ecological parts of a SES following and ES approach, thereby indirectly contributes to answering SRQ3.

Paper 11. Utilising MYTILUS for Active Learning to Compare Cumulative Impacts on the Marine Environment in Different Planning Scenarios (Bonnevie et al. 2022)

Research aim: present a training set to familiarise students in higher education with the concept of spatial decision support tools, cumulative impact assessments, and their role in an MSP process.

Methods: used MYTILUS, a spatial decision-support tool for cumulative impacts and user co-location analysis, in the development of the training-set made up of four exercises. The training set was tested on two planners in a workshop setting, and by PhD students as part of an online PhD course by 7 PhD students. The students provided written feedback on the training set design, challenges, and strengths of MYTILUS.

Result contribution to this thesis: the training set and specific exercises presented in this study demonstrates the functionalities of MYTILUS and directly informed the design of CIA-related functionalities of the ecosystem service supply assessment SDST introduced in paper 4.

4 Findings and discussion

This chapter presents answers to the sub-research questions based on the findings of the published key and supplementary papers and reflects on how they contribute to answering the central research question – How can an ecosystem services approach be operationalised to improve integration in MSP? This chapter is split into six sections. The first two sections unpack findings related to conceptualisation of social sustainability in ES and MSP. The third section introduces a spatial decision support tool for exploring multiple ecosystem service supply and discusses the role it plays in supporting social-ecological system analysis. The fourth chapter provides an answer to the central research questions – synthesises the contribution to the operationalisation of an ecosystem services approach in MSP and science. Section five outlines some key methodological considerations and recommendations related to the application of an ecosystem services approach in analysis (i.e., expert elicitation and terminology challenges). The sixth and final section outlines the next steps and topics for future research, including, possible routes for the development of the ecosystem service supply tool, which is followed by a conclusion.

4.1 Conceptualising social sustainability in MSP

A diverse set of definitions of and motivations for why social sustainability matters can be found in research, including acknowledgement of participation and collaboration, socio-cultural values, preferences, and benefits, knowledge and knowledge production, considering conflicts, wellbeing and livelihoods, justice, rights, and equity as well as trade-offs and power dynamics (*Gilek et al. 2021*). However, most studies focus on the representation and recognition of social actors and their links to procedural justice, and far fewer explore the links between inclusion, influence, and distributional justice dimensions *(Gilek et al. 2021*). Further, despite diverse descriptions and motivations, not many tend to dig in deeper, analytically frame, conceptualise and theorise social sustainability in MSP (*Gilek et al. 2021*).

Participation is a central aspect of MSP – highlighted in the IOC-UNSECO principles and Article 9 of the MSPD, and one of the most commonly discussed SS topics in scholarly literature, yet in most cases the understanding and justification of participation are quite narrow, largely concentrated on reduction of conflicts and increased support for MSP *(Gilek et al. 2021).* In response, *Tafon et al. (2023)* offer six, interconnected, equity-based principles to conceptualise representations thereby supporting the evaluation of participation and inclusion in MSP to counter a tokenistic approach, which results in plans and processes that are unresponsive to directly affected, at times vulnerable and already marginalised groups of stakeholders, such as coastal communities. The principles include timely, inclusive, supportive and localise, deliberative, methodological, and impactful devised to reflect different dimensions of what participation ought to look like if it is to promote just (supportive of actors prevented from engaging by additional barriers), efficient (embedded in the socio-cultural context and fuelled by co-design), and effective (words put into action) decision-making and action *(Tafon et al. 2023).*

Unpacking of community participation in a study of Latvian MSP *(Tafon et al., 2023)* revealed that the process had two well-defined phases – a pluralistic approach in the build-up to version 1, and a participation process greatly skewed towards specific sectoral interest during the development of the 2nd version, which is the now adopted version of the plan. Localised, regional seminars were held to engage coastal actors, however only in the early stages, and were not re-introduced in the second half of the planning process (*Tafon et al. 2023*; Figure 11).

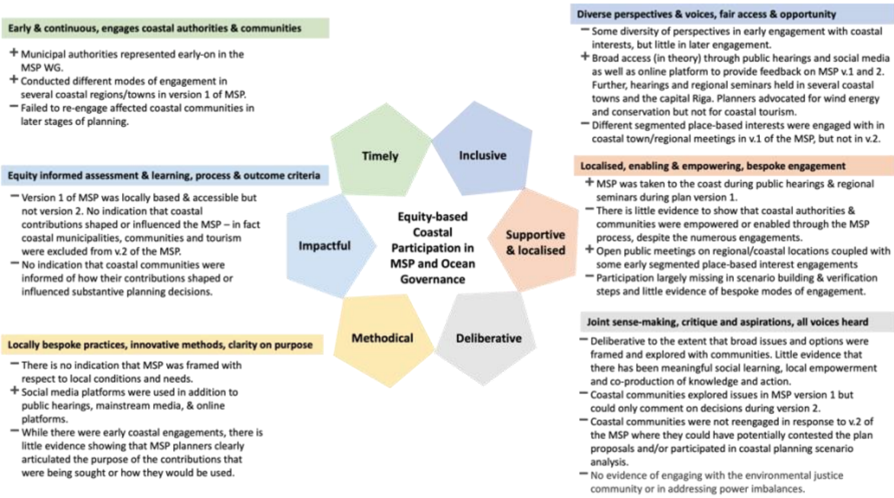

Figure 11 Key findings from an evaluative analysis of the first Latvia MSP development process against the *Tafon et al. (2023)* principles (in pentagons) and key, qualitative indicators (in rectangular boxes). -/+ indicate whether the indicators are reached (+) or not (-). Source: adapted from *Tafon et al. (2023).*

There is little indication that coastal authorities were empowered to participate and supported in developing a common, clear understanding of the objectives of MSP through bespoke methodological practices at the regional seminars or that they had an impact on the planning decisions (*Tafon et al. 2023*). There was also little sense of collaboration, co-design, or room for deliberation, and an interviewed coastal municipality planner expressed they felt more like a participant, and not a co-creator of the plan (*Tafon et al. 2023*). During the second/final phase of the planning process, co-development of scenarios took place in a much more closed environment. Planners advocated voices of the offshore wind energy sector, and targeted workshops with offshore wind, shipping, and nature conservation sectors (*Tafon et al. 2023*). The wider public and coastal communities were only invited to provide written feedback at the final stages of the decision-making process, suggesting the narrowing of the

MSP participatory process and challenges in maintaining open and inclusive participation (*Tafon et al. 2023*).

Analysis of the Latvian MSP participation process through the lens of the six equity principles, suggests that the Latvian MSP authorities struggled to engage coastal actors and maintain a level of engagement as the MSP focus rotated from knowledge base development, awareness raising (scoping) to analysis of possible futures (drafting and consulting).

Analysis of the perceived legitimacy of sector needs and stakes by the planning authorities (recognition), and degree of meaningful engagement, and deliberation (representation) can reveal challenges for sector development related to social and political dynamics *(Armoskaite et al. 2021b).* Geospatial use-use interaction and co-location analysis can also be investigated as an additional dimension of recognition and representation in MSP to give an overview of opportunities available for sectors and specific barriers to overcome, that may not be explicit in the final plan itself (*Armoskaite et al. 2021b).* User interactions can be classified into 'conflicting', 'synergetic', and 'with potential for co-location under certain conditions' as a result of environmental, location, user attraction, and technical spatial-temporal links (Bonnevie et al. 2019).

Analysis of a gradually emerging blue economy macroalgae cultivation sector in the Baltic Sea and the Latvia, Estonia, and Poland MSPs following this analytical approach, showed that the sector is formally recognised as a 'future use', however, is seen lacking technological solutions, and a knowledge base of environmental suitability, risks, and socio-economic benefits (*Armoskaite et al. 2021b*). Recognition, therefore translates into very weak (Estonia) or no representation in MSPs (*Armoskaite et al. 2021b*). Use-use analysis also showed few synergistic, or potentially compatible combinations of uses with macroalgae cultivation, notably other aquaculture, offshore wind farms, and marine tourism (Estonia) (*Armoskaite et al. 2021b*). At the same time, analysis and mapping of the use-use interaction showed pockets of space, which could be considered areas for future development to be discussed during the next planning cycle (*Armoskaite et al. 2021b*). The case study analysis results highlight the importance of considering co-location and multi-use as part of MSP to gain a deeper understanding of the hurdles faced by emerging sectors with little to no pre-existing claims over marine space and resources (*Armoskaite et al. 2021b*).

4.2 Ecosystem services to support social sustainability in MSP

A review of blue justice research showed that ecosystem services (ES) is perceived as one of the key tools (alongside public participation GIS) for generating (often spatial) information on social and cultural values, and method for integration of intangible values, socio-cultural preferences (*Gilek et al. 2021*). ES is also seen as a way of engaging social actors in conversations of what constitutes an ecosystem service and highlight the dependence of people on the environment (*Gilek et al. 2021*). At the same time, it also the potential support exploration of understudied links distributional justice *(Frederiksen et al. 2021).*

MSP-SA is a framework developed to primarily broaden the scope of MSP impact analysis to explicitly highlight the impacts of decisions on human welfare through changes in benefits (*Frederiksen et al. 2021*). In MSP-SA impacts are broken down into three categories – a) ecosystem capacity, b) ecosystem services (provisioning, regulating and maintenance, cultural), and c) human wellbeing – (dis)benefits, losses, and values as well as distribution of beneficiaries over time and space *(Frederiksen et al. 2021).* The framework builds on the DPSIR framework and extends it with elements of the ecosystem services cascade to draw attention to the social impacts of MSP – 'the distribution of risks, benefits, capacities or resources in MSP, especially in relation to disadvantaged groups' *(Gilek et al. 2021, p. 9).* Specifically, to the distributional aspects of social justice through analysis of distribution benefits and disbenefits – who gets what and where. At the same time, issues of recognition and power imbalance, facilitate a much-needed critical discussion of the transformative role of MSP if used as a tool in a collaborative, knowledge co-creation context (*Frederiksen et al. 2021*).

MSP-SA follows the ecosystem services cascade, therefore here too ecosystem capacity (impacts a) determines ecosystem service supply (b) and availability and distribution of benefits (c). Changing ecosystem state and capacity will have a trickle-down effect on impacts directly related to human wellbeing – service and benefit supply. In practice, assessment of impacts a. involves place-based biophysical analysis of change in the interconnections between pressures, ecosystem components, and ecosystem functions and therefore state or capacity of the ecosystem to supply services as a result of decisions. Assessment of impacts b) involves analysis of the context-specific supply of cultural, provisioning, and regulating and maintenance services and change in supply as a result of change in ecosystem capacity. Assessment of impacts c) is largely concerned with assessing the direct effects of supply change on human welfare, including livelihood and health (physical and psychological).

MSP is a political process, and case studies of coastal actor participation in Latvian MSP *(Tafon et al. 2023)* and recognition and representation of a new aquaculture sector in Latvia, Poland, and Estonia *(Armoskaite et al. 2021b*) exemplify how some sectors and interests may be overshadowed by others. The role of the MSP-SA framework would be to tip the scales and balance power asymmetries under such circumstances. For instance, MSP-SA could help synthesise information on the impacts of macroalgae cultivation from various sources and reveal the wide range of ecosystem functions, services, and benefits the activity could be linked to, thereby supporting the development of an evidence base describing its social, environmental and economic impacts, potentially leading to increased recognition. Moreover, facilitate dialogues between different stakeholders, who may be affected by the introduction of new activities.

In society, the distribution of both ‘goods’ and 'bads' is unequal - those who consume the bads do not always even have the opportunity to consume the goods resulting in injustice (p.93; De Shalit 2006). The MSP-SA framework draws attention to the beneficiaries and the understudied distributional justice in MSP *(Gilek et al. 2021*). *Tafon et al. (2023)* principles for evaluating participation in MSP and the *Armoskaite et al (2021b)* approach for including elements of use-use and co-location in the analysis of recognition/representation of social actors complement MSP-SA by facilitating analysis of procedural aspects of justice. The addition of these two approaches to MSP-SA could support an ecosystem services-based, comprehensive assessment of social sustainability that stretches across all three Saunders et al. (2020) analytical categories.

4.3 A tool for assessing multiple ecosystem service supply

A linkage framework approach served as the departure point for the design of a spatial decision support tool (SDST), that supports relative, multiple ecosystem service supply analysis (*Armoskaite et al. 2020*). The tool calculates weighted, numerical descriptions of the overall relative contribution of ecosystem components in ecosystem functioning and service supply and can be used to analyse change as a result of ecosystem change (*Armoskaite et al. 2020*). The results of the supply analysis are graphically represented in maps depicting several or single service supply mapped using marine species distribution data (*Armoskaite et al. 2023*); and Sankey linkage web diagrams depicting the flow of service supply represented by varied width links to communicate the significance of connections between elements *(Armoskaite et al. 2020).*

The tool has so far been used to explore the effects of ecosystem change on service supply using three different types of evidence – expert knowledge (*Armoskaite et al. 2020),* geospatial empirical observations (*Armoskaite et al., 2021a),* and relative change in Halpern et al. (2008) cumulative impact index values (*Armoskaite et al. 2023*) – suggesting it can be used in a variety of data availability contexts, and integrating cumulative impact analysis as part of service supply assessments.

The next section presents data needs and a more detailed overview of the functionalities of the tool with real-world examples.

4.3.1 Tool design and application

A conceptual framework to streamline the approach illustrates the overall design of the tool (Figure 11). The framework gives an overview of the links between the inputs for (1-3) and outputs of the reference assessments (i and ii) and change analysis (iii-v) and between ecosystem service supply and cumulative impacts analysis.

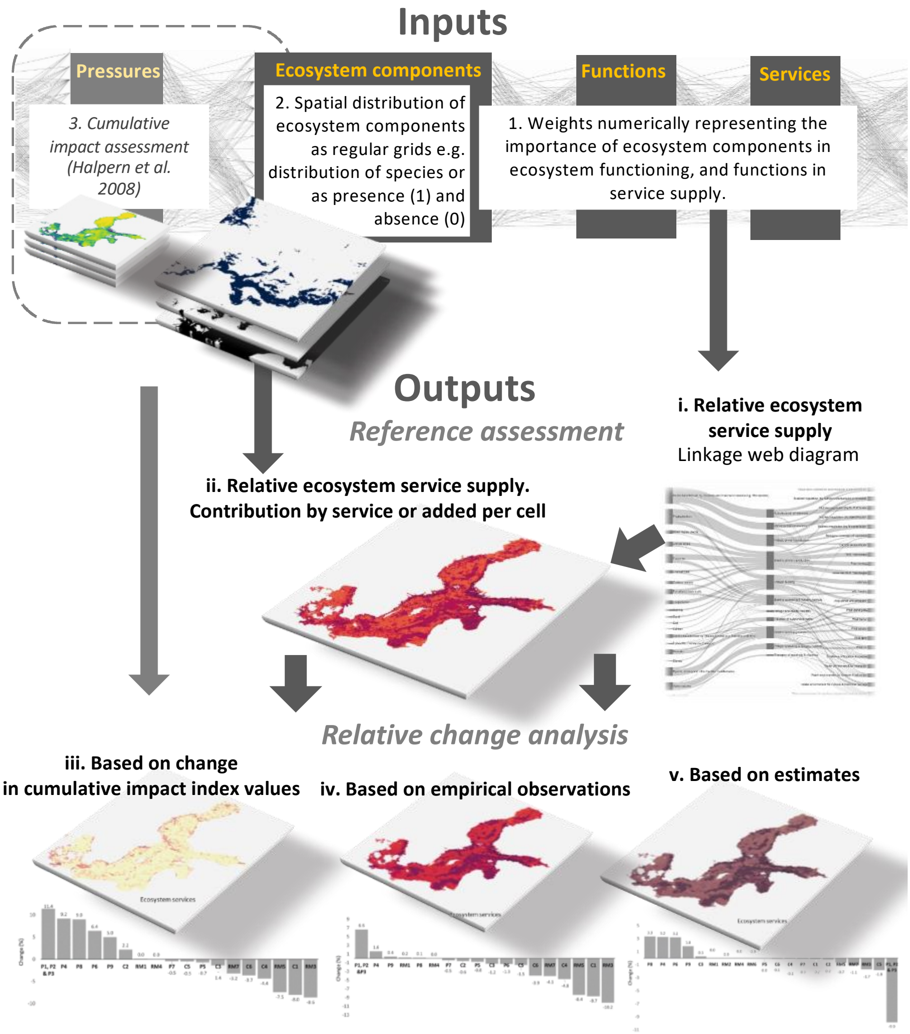

Figure 12. A graphical illustration depicting the inputs and outputs of the linkage framework-based ecosystem service supply assessment tool developed as part of this project. Outputs ii, iii, iv, and v are graphically represented in maps and graphs, and output i is a linkage web diagram. Image source: adapted from *Armoskaite et al. 2023.*

Weights numerically representing the importance of ecosystem components in the ecosystem functioning in a good environmental state, and functions in service supply a lay the foundations for developing linkage chains and linkage web diagrams starting from ecosystem components, through to functions and services. Weights alone provide the empirical data required for calculating the **overall relative contribution of each ecosystem component in service supply (output i; Figure 12)**. One way of deriving weights is through expert elicitation as done to perform a full assessment of service supply for the Latvian waters where experts identified and described the links between a total of 17 different species, 24 habitat types, 10 ecosystem functions, and 22 ecosystem services (7 regulating and maintenance, 9 provisioning and 6 cultural) (*Armoskaite et al. 2020*). Spatial data is not essential for the initial assessment represented in linkage web diagrams, although it can inform experts' opinions during weighting of element importance (see *Armoskaite et al. 2020).*

To estimate the overall relative contribution of ecosystem components in service supply (henceforth: contribution values), inverse weights need to be worked out for each element with respect to all incoming and outgoing links starting at the service level with the assumption that each service is supplied at 100%. The contribution values can be graphically represented in a linkage web diagram to depict the flow of ecosystem service supply, for instance using a Sankey diagram adopted in linkage framework-based ES analysis (e.g., AQUACROSS project results) used to visualise the results of the Latvian marine waters-wide ES study (*Armoskaite et al. 2020*; Figure 13).

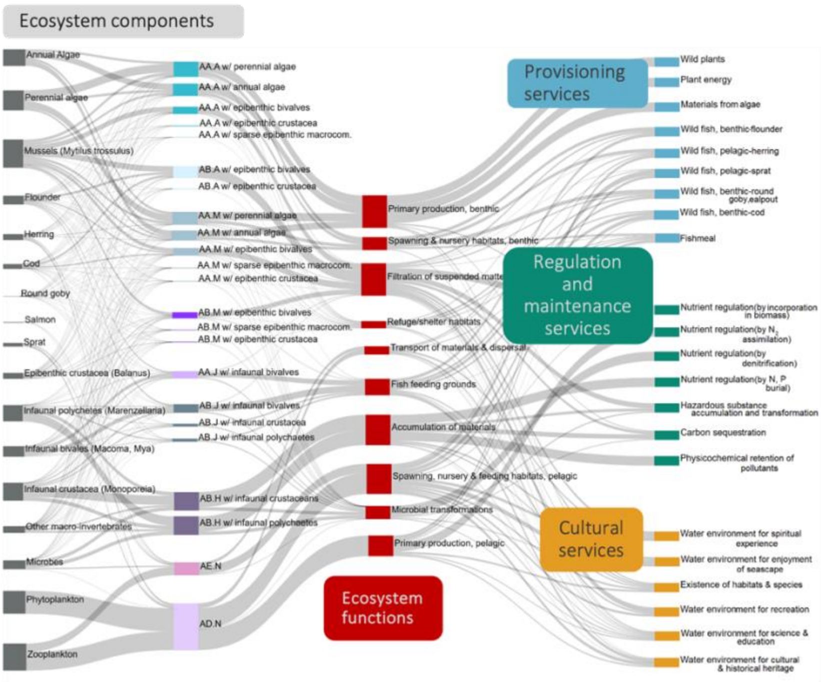

Figure 13 Results of the Latvian marine ecosystem service supply assessment represented in a Sankey diagram, adapted from *Armoskaite et al. 2020*.

To analyse change, the contribution values for each component can be altered to mirror a new state of the ecosystem. In the Latvian marine waters-wide study, marine ecologist observations of drastic mussel cover decrease in the real world motivated the exploration of dramatic **ecosystem change effects on service supply based on estimates (output iv; Figure 12;** *Armoskaite et al. 2020***).** To test the effects of ecosystem change, the previously derived mussel contribution value was decreased by 90%, which affected several ecosystem functions, most significantly the capacity of the ecosystem to filtrate suspended matter (Table 1).

Table 1 Relative change in the capacity of the Latvian marine ecosystem to perform ecosystem functions as a result of a 90% decrease in mussel cover. Analysis based on the results of the ES assessment published in *Armoskaite et al. 2020*.

Ecosystem Functions	**Relative change**
Spawning & nursery habitats, benthic	-25.40
Spawning, nursery & feeding habitats, pelagic	0.00
Refuge/shelter habitats	-17.58
Primary production, benthic	-63.94
Primary production, pelagic	0.00
Fish feeding grounds	-8.98
Filtration of suspended matter	-154.25
Transport of materials & dispersal	0.00
Accumulation of materials	0.00
Microbial transformations	-2.00

A lowered capacity function translated also into a decreased capacity to supply all three categories of services, most significantly affecting Nutrient regulation (by nutrient incorporation in biomass) hazardous substances accumulation and transformation services, and the water environment for recreation (Table 2).

Table 2 Relative change in ecosystem service supply by the Latvian marine habitats as a result of a 90% mussel cover decrease. Based on the results of the ES assessment in *Armoskaite et al. 2020*.

	Ecosystem services	**Relative change in supply**
Regulation and maintenance	Nutrient regulation (by denitrification)	-1.4
	Nutrient regulation (by N, P burial)	0.0
	Nutrient regulation (by nutrient incorporation in biomass)	-34.2
	Nutrient regulation (by N assimilation)	0.0
	Hazardous substances accumulation & transformation	-25.6
	Physicochemical retention of pollutants	0.0
	Carbon sequestration	-15.3
Provisioning	Wild plants	-18.0
	Plant energy	-18.0
	Materials from algae	-18.0
	Wild fish, pelagic- herring	-8.5
	Wild fish, pelagic- sprat	-2.2
	Wild fish, benthic-flounder	-19.2
	Wild fish, benthic- cod	-5.1
	Wild fish, benthic-round goby, eelpout	-19.6
	Fishmeal	-9.3
Cultural	Water environment for recreation	-24.5
	Water environment for science & education	-11.4
	Water environment for cultural & historical heritage	-3.5
	Water environment for spiritual experience	-13.4
	Existence of habitats & species	-13.5
	Water environment for enjoyment of seascape	-11.3

A critical aspect of change analysis is that it can only be done within the boundaries of the reference assessment, meaning that it can only include the elements already considered during weighing of importance in the system. To perform change analysis with fewer elements than initially considered in the reference assessment, the linkage chains associated with the ecosystem component or service supply of interest need to be identified and isolated from the wider system along with the numerical descriptions.

Pakalniete et al. (2021) valued a wide array of marine ES benefits provided by protected stony reef habitats and change in human as a result of new offshore, marine protected area designation illustrates this. The study used protected stony reef habitat contribution values estimated in *Armoskaite et al. (2020)* to estimate habitat contribution at different spatial extents. It demonstrates how the relative overall contribution values and weighted linkage web diagrams can inform socio-economic, monetary benefits valuation studies and the graphical outputs (diagrams and maps) aid communication across disciplines.

Geospatial ecosystem component data (e.g., regular grids of species or habitat distribution) is needed **to map overall ecosystem contribution values to represent ecosystem service supply (output ii; Figure 12).** Service supply/contribution values can be mapped by ecosystem component, or summed up per cell to show hot and cold spots of total service supply.

Change in service supply in three case study sites in marine protected areas in Latvia was assessed taking advantage of readily available input information from paper 1 (*Armoskaite et al. 2021a).* It involved analysis of geospatial habitat composition change based on field observations before and after the spread of the non-native fish species – round goby (*Neogobius melanostomus,* Pallas 1814) and service supply analysis **based on empirical observations (output iv.; Figure 12**). The first step was to analyse geospatial, and environmental data – classify habitats at the sites (Jūrmalciems, Pape, and Ragaciems) and determine proportional habitat cover change (Table 3).

Table 3 Proportional habitat composition change. The habitats have been classified according the HELCOM HUB (2013) classification system based on underwater video observations. *Armoskaite et al., 2021a*

	Habitat type	Cover sq. km	Portion of area	Cover sq. km	Portion of area	
	Year	**2006**		**2019**		
Baltic Proper (Jūrmalciems)	Perennial macroalgae on hard substrate (AA.A1C)	1.3	0.1	4.0	0.4	↑
	Mussels on hard substrate (AA.A1E)	4.5	0.5	0.5	0.1	↓
	Barnacles on hard substrate (AA.A1I)	0.0	0.0	0.8	0.1	↑
	Perennial macroalgae on mixed substrate (AA.M1C)	0.0	0.0	1.3	0.1	↑
	Mussels on mixed substrate (AA.M1EI)	4.0	0.4	0.3	0.0	↓
	Barnacles on mixed substrate (AA.M1I)	0.0	0.0	3.0	0.3	↑
	Infaunal bivalves on sand (AA.J3L)	0.3	0.0	0.3	0.0	→
Baltic Proper (Pape)	Perennial macroalgae on hard substrate (AA.A1C)	0.0	0.0	2.0	0.2	↑
	Mussels on hard substrate (AA.A1E)	3.8	0.4	0.8	0.1	↓
	Barnacles on hard substrate (AA.A1I)	0.0	0.0	1.5	0.2	↑
	Perennial macroalgae on mixed substrate (AA.M1C)	0.0	0.0	0.3	0.0	↑
	Mussels on mixed substrate (AA.M1EI)	6.0	0.6	0.8	0.1	↓
	Barnacles on mixed substrate (AA.M1I)	0.0	0.0	4.3	0.4	↑
	Infaunal bivalves on sand (AA.J3L)	0.3	0.0	0.5	0.1	↑
	Year	**2016**		**2019**		
Gulf of Riga (Ragaciems)	Perennial macroalgae on hard substrate (AA.A1C)	5.5	0.6	4.0	0.4	↓
	Barnacles on hard substrate (AA.A1I)	0.0	0.0	3.3	0.4	↑
	Perennial macroalgae on mixed substrate (AA.M1C)	3.0	0.3	0.8	0.1	↓
	Sparse epibenthic macrocommunity on mixed substrate (AA.M2T)	0.3	0.0	0.0	0.0	↓
	Annual macroalgae on mixed substrate (AA.M1S)	0.0	0.0	0.5	0.1	↑
	Infaunal bivalves on sand (AA.J3L)	0.5	0.1	0.8	0.1	↑

Then, the linkage chains associated with each habitat found at each study site were selected from the wider Latvian assessment to perform a supply assessment tailored to reflect the composition of the seabed at each site. In total six separate ecosystem service supply assessments were performed – two for each site – to show the difference in ecosystem functioning and service supply between them *(Armoskaite et al., 2021a).*

The habitat change assessment revealed a significant change in all case study sites (Table 3) and the types of changes that have occurred suggest possible pressures impacting the protected ecosystems could be the spread of the round goby in the Baltic Proper and the effects of eutrophication in the coastal areas in the Gulf of Riga (*Armoskaite et al. 2021a*). Fluctuations in ecosystem functioning and service supply as a result of changing benthic habitats at each site were also evident – there was a drop in regulating and maintenance, and cultural services, and increased provisioning service supply (*Armoskaite et al. 2021a*; Figure 14).

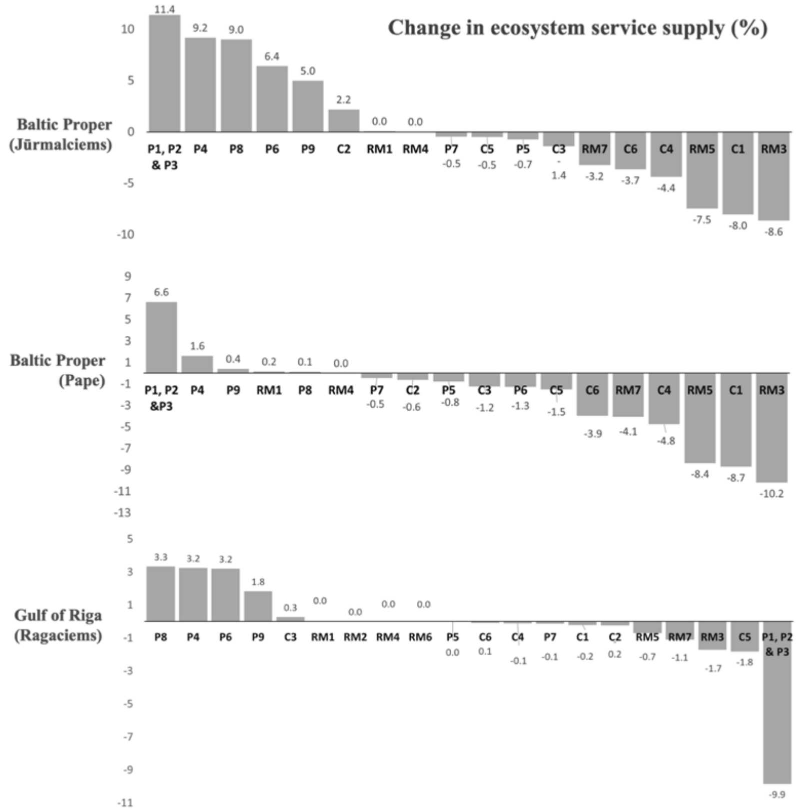

Figure 14 Change in ecosystem service supply in three sites within marine protected areas in Latvia. P – provisioning services, RM – regulation and maintenance, and C – cultural. *Armoskaite et al. 2021a*

One benefit of mapping relative ecosystems service supply (output ii), is that the output can then be used for the **analysis of service supply change based on the relative change in cumulative impact index values following the Halpern et al., 2008 approach (output iii; Figure 12;** *Armoskaite et al. 2023*). To run the analysis, it is necessary to work out per-cell change in cumulative impact index values by running two assessments – a reference and a new scenario – and dividing the new scenario by the reference scenario. In a case study assessing the change in cumulative impacts on the benthic habitats in the Gulf of Riga as a result of reduced herring fishing (*Armoskaite et al. 2023*; figure 15) this part of the analysis was done using MYTILUS (following *Bonnevie et al. 2022* exercises from the training set) and QGIS.

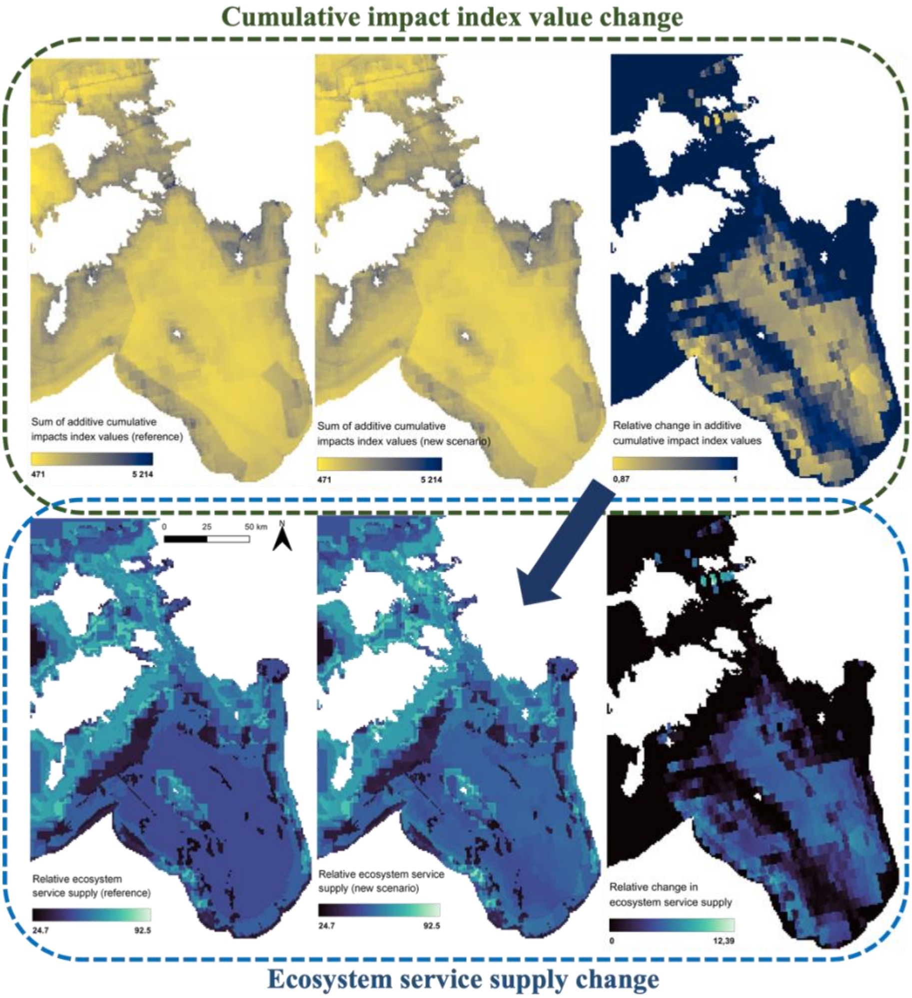

Figure 15 Maps displaying the results of the cumulative impact and relative ecosystem service supply analysis for the Gulf of Riga as a result of reduced fishing. Adapted from *Armoskaite et al. 2023*.

Central to the method is that the exact same ecosystem geodata is used in the service supply analysis and mapping, and the CIA. Therefore, the following step is to make sure the service supply (ecosystem component contribution values) is mapped using ecosystem maps used in CIA. To map the ecosystem service supply with impact index values applied, maps of the ecosystem service supply for the area are divided by the change in cumulative impact index values. Finally, change in ecosystem service supply, that is, per-cell relative change can be worked out by subtracting the reference supply scenario from the new supply scenario.

This approach to analysing cumulative impacts on service supply builds on the Hammar et al. (2020) approach used to inform Swedish MSP. A key advantage of the Halpern et al. (2008) additive cumulative impact index is that it considers ecosystem component distribution as part of the calculation. This makes it compatible with the ecosystems service supply SDST designed during this project. At the same time, in reality, cumulative impacts can be synergistic, or antagonistic (Robinson and Culhane 2020) and this is not reflected in the Halpern et al. (2008) approach. Nonetheless, including cumulative impacts of pressures on the ecosystem is an important step towards considering different interactions taking place simultaneously, analysing multiple pressure – impact scenarios (Patrício et al. 2016).

4.4 Operationalising an ecosystem services approach to improve integration in MSP

The tool designed during this PhD project can be used to gain an insight into the ways ecosystem state change due to pressures can potentially affect ecosystem functioning, and human wellbeing through fluctuations in ecosystem service supply. The tool supports a holistic approach by facilitating the analysis of multiple services. It also attempts to promote more integrated supply-demand analysis by describing the relationship between people and the ecosystem numerically, graphically, and spatially to lay the foundations for service and benefits valuation studies, scenario and trade-off analysis (Pandeya et al. 2016; Braat et al. 2014). The results of *Armoskaite et al. (2020)* have already been employed in a benefits valuation study (*Pakalniete et al. 2021*) thereby demonstrating at least to some extent that the tool supports communication between social and environmental scientists working in SES research. Mapping relative change in service supply, especially due to cumulative impacts, could give planners an overview of areas most at risk (Menegon et al. 2018; Singh et al. 2020). Further, supply maps can be overlayed with activity requirement maps to find the most suitable and unsuitable locations from a use-environment perspective (*Armoskaite et al. 2023*).

The intention of the MSP-SA framework is to guide systematic analysis of the impacts of MSP proposals on the ecosystem state, services, and benefits as part of the MSP sustainability appraisal process (*Frederiksen et al. 2021)* thereby addressing a shortage of theoretical, analytical, and methodological approaches to support social sustainability considerations in ecosystem services and MSP. MSP-SA advances conceptualisation of social in ES, and MSP, importantly, highlights the significance of distributional justice (distribution of benefits across time and space).

MSP-SA can also be an instrument for MSP stakeholder involvement and serve as a departure point for discussions to support analysis of benefits and values, cultivate a common understanding of the MSP process and its objectives among stakeholders from different backgrounds, support stakeholders in formulating their interests and needs, and empower marginalised, (un)recognised, and (mis)represented groups (*Frederiksen et al. 2021*). The SDST for ecosystem service supply analysis presented in this thesis also facilitates the deconstruction of social-ecological systems, analysis of the links between ecosystems and human wellbeing and could be a useful communication support tool during discussions among scientists, as well as between experts and decision-makers, and stakeholders on the connections between ecosystem state and human actions and vice versa (*Armoskaite et al. 2020*).

Transdisciplinary, MSP education has a big role to play in creating an international community of researchers and practitioners equipped with the skills to analyses SES, use tools for CIA and co-location analysis, and tackle 'wicked problems' (*von Thenen et al. 2021*). To really operationalise ecosystem services in MSP, marine ecosystem services could be one of many topics taught as part of higher education programs as an approach for exploring SES, analysing and tracking change and communicating information.

4.5 Challenges of employing an ecosystem services approach in practice

Using an ecosystem services approach, specifically following the cascade terminology, adapting a classification system to do place-based assessment and employing ecosystem services terminology during expert workshops presented its challenges. Some lessons learnt and recommendations can be highlighted.

Some of the studies presented in this thesis (1-3, 5, and 10) used the Common International Classification of Ecosystem Services (CICES) to identify and analyse services and functions and several lessons can be drawn from the experience. Firstly, it would be advantageous if CICES also included a separate class for and a description of benefits and beneficiaries, in addition to provisioning, cultural, and maintaining and regulating ecosystem services *(Frederiksen et al. (2021)* and *a* clearer distinction between ecosystem functions and regulating and maintenance services is needed *(Armoskaite et al. 2020).* During expert discussions, definitions of 'ecosystem function' and 'regulation and maintenance services' were frequently revisited as the list of services and functions evolved, eventually resulting in the addition of extra regulating and maintenance services detailing nutrient assimilation at an extra level of detail *(Armoskaite et al. 2020).*

Open discussions among experts and a collaborative set-up with a goal of consensus (*Armoskaite et al. 2020*) were seen as a good way of achieving a common understanding of the concepts. The concept of 'intermediate services', whilst an important part of monetary valuation, was dropped as it caused confusion between ecosystem functions and regulation and maintenance services during discussions between experts (*Armoskaite et al. 2020).*

Expert elicitation to develop a knowledge base for service supply analysis presented its own set of challenges. The expert elicitation approach employed to create a knowledge base for the development of the SDST was a collaborative set-up, and the goal of reaching a consensus was seen as a good way of achieving a common understanding of the concepts and reasoning behind each decision. It was accepted that a consensus approach as such, does not increase the certainty of results nor does it reduce data needs (Jacobs et al. 2015), however, it did increase transparency. At the same time, it was an emotive exercise, filled with disagreements and opposing opinions. While space and time was given to explaining positions and were to a certain extent reflected in certainty scores, power dynamics among the expert involved may have also influenced the end results.

Relatedly, mediating conflicts and facilitating discussions requires skills and experience, which have also had an effect on the outcomes. Additionally, while a group of five scientists may be considered too small by some (Campagne and Roche 2018), in a real-world expert assessment of the impacts of pressures on ecosystems held in Sweden the average number of experts has so far been 5.3 (Pålsson 2020, personal communication). To avoid some of the biases that come with collecting data via workshops, surveys could be carried out instead. Surveying would also mean that a greater number of participants could be reached, potentially increasing the sample.

To streamline the knowledge base development process, a more efficient method for expert elicitation identification and scoring process needs to be developed. One approach could be to adapt tools for Analytic Hierarchy Process (AHP) information organisation and decision-making based on relative preference (e.g., Goepel 2018) and invite experts on an individual or group basis to respond to a two-part survey to describe the components and interaction of a SES by entering comparing different variables and validating the results at a later stage.

4.6 Next steps

Collaborative, participatory processes are central to an MSP process and analysis of SES (Preiser et al. 2022) and in addition to being an analytical instrument revealing spatial patterns (Burgess et al. 2016), maps are also a useful tool in a collaborative, participatory planning context as they can contribute to creating a common understanding, a sense of shared interest (*Koski et al. 2021*). In addition to the analysis of impacts and change, the ecosystem service supply maps created using the SDST designed as part of this project may also be useful to prompt discussions in a stakeholder workshop context, or in an MSP-focused education environment (*Bonnevie et al. 2022*). The collaborative, ES supply assessment process facilitated by the tool also promotes collaboration and co-creation of knowledge during expert elicitation. However, currently, assessments are performed manually, require know-how, and are a laborious process, which means that they do not support on-the spot analysis and have limited application in a collaborative planning context.

In the future, the tool should be made operational as part of a toolset accessible to novice users, support collaboration and co-creation of knowledge (*Armoskaite et al. 2023),* Potentially, it could be integrated with the open-source CIA and co-location analysis tool MYTILUS to create a multi-map toolset equipped with the functions for on the spot, geospatial cumulative impacts, co-location and ecosystems service supply analysis (*Bonnevie et al. 2022; Armoskaite et al. 2023*).

Furthermore, guidelines or procedural recommendations to improve the operationalisation of ES and support a more coherent assessment of social sustainability in MSP could developed based on these findings and form a procedural framework for employing ES in MSP.

5 Conclusion

An ecosystem services approach holds the potential to support various MSP tasks at different stages of the planning process. Importantly it also holds the potential to better integrate multidimensional sustainability considerations in maritime spatial planning (MSP), including considerations of often overlooked social justice. However, an ecosystem services approach is still applied to a limited degree in MSP due to various conceptualisation and practical application challenges, and the approaches, and methods to strengthen the link between ecosystem services and notions of social justice still need to be advanced. To contribute to the operationalisation of an ecosystem services approach in MSP, this thesis explores how social sustainability is conceptualised in MSP and ecosystem services. It conceptualises social sustainability in an MSP context and describes an ecosystem services-based framework to support multidimensional impact analysis, and in turn, promote more justice-oriented MSP. Secondly, this thesis looks at how ES supply assessments can be advanced methodologically to provide a broader representation of social-ecological systems, support analysis of change in numerical terms, and improve cross-discipline communication needed for integrated analysis of the social and environmental sides of social-ecological systems, and benefit analysis. In response, a tool for multiple ecosystem service supply analysis based on the linkage frameworks approach and expert knowledge is designed and tested. The outputs of the ecosystem service supply assessment using the tool are graphically represented in maps of service supply to directly inform MSP, and linkage web diagram to support cross-discipline communication and knowledge exchange.

The tool takes the first steps in linking cumulative impact analysis and service supply assessments and this will be further explored in the future as the tool is operationalised into a fully functional collaborative, spatial decision support tool and is integrated into a multi-map toolset consisting of tools for ecosystem service supply, synergy and conflict, and cumulative impact analysis. Alongside further investigations of the pressures-service supply links, relationships between services and benefits will be investigated with the objective of supporting spatially explicit analysis of (dis) benefits and shed light on distributive (in)justices.

LITERATURE LIST

Andriessen, D. 2008. Combining design-based research and action research to test management solutions. Conference paper. 7th World Congress Action Learning, Action Research and process Management, Groningen. Available online: https://www.researchgate.net/profile/Daniel-Andriessen/publication/242695924_Combining_design-based_research_and_action_research_to_test_management_solutions/links/0a85e5341353c4c185000000/Combining-design-based-research-and-action-research-to-test-management-solutions.pdf

Albrechts, L., Healey, P., Kunzmann, K.R., 2003. Strategic Spatial Planning and Regional Governance in Europe, Journal of the American Planning Association. 69:2, 113-129. doi.org/10.1080/01944360308976301

Atkins, J. P., Burdon, D., Elliot, M., and Gregory, A. J. 2011. Management of the marine environment: integrating ecosystem services and societal benefits with the DPSIR framework in a systems approach. Mar. pollut. Bulletin. 62, 2015–2226. doi: 10.1016/j.marpolbul.2010.12.012

Arnott, D., & Pervan, G. 2005. A Critical Analysis of Decision Support Systems Research. Journal of Information Technology, 20. 2, 67–87. doi.org/10.1057/palgrave.jit.2000035

Armoškaite, A.; Puriņa, I.; Aigars, J.; Strāķe, S.; Pakalniete, K.; Frederiksen, P.; Schrøder, L., Hansen, H.S.2020. Establishing the links between marine ecosystem components, functions, and services: An ecosystem service assessment tool. Ocean and Coastal Management. 193. doi.org/10.1016/j.ocecoaman.2020.105229.

Armoškaite, A.; Aigars, J.; Hansen, H.S.; Andersone, I.; Schrøder, L.; Strāķe, S. 2021a. Assessing change in habitat composition, ecosystem functioning and service supply in Latvian protected stony reefs. Journal of Environmental Management. 298. doi.org/10.1016/j.jenvman.2021.113537.

Armoškaitė, A., Bārda, I., Andersone, I., Bonnevie, I.M., Ikauniece, A., Kotta, J., Kõivupuu, A., Lees, L., Psuty, I., Strāķe, S., Sprukta, S., Szymanek, L., von Thenen, M., Schrøder, L., Hansen, H.S. 2021b. Considerations of Use-Use Interactions between Macroalgae Cultivation and Other Maritime Sectors: An Eastern Baltic MSP Case Study. Sustainability. 13, 13888. doi.org/10.3390/su132413888

Armoskaite, A., Barda, I., Purina, I., Sprukta, S., Fedorovska, A., Strake, S., 2021c. Report on ecological impacts of macroalgae cultivation in the Baltic Sea region (GoA 2.3.). https://www.submariner-network.eu/images/grass/outputs/GoA_23_Report_on_ecological_impacts_of_macroalgae_cultivation_in_the_Baltic_Sea_region_final3.pdf

Armoškaite, A.; Aigars, J.; Andersone, I.; Bonnevie, I.M., Schrøder, L.; Strāķe, S., von Thenen., Hansen, H.S. Setting the scene for a multi-map toolset supporting maritime spatial planning – mapping pressures and relative cumulative effects to ecosystem services. Frontiers in Marine science. 10:1213119. doi.org/10.3389/fmars.2023.1213119

Aquacross, 2019. https://aquacross.eu/.

Abspoel, L., Mayer, I., Keijser, X., Warmelink, H., Fairgrieve, R., Ripken, M., Abramic, A., Kannen, A., Cormier, R., Kidd, S. 2021. Communicating Maritime Spatial Planning: The MSP Challenge approach. Marine Policy. 132. 103486, doi.org/10.1016/j.marpol.2019.02.057

Baard, V. 2010. A critical review of interventionist research. Qualitative Research in Accounting & Management, 7.1, 13–45.

Bateman, I.J., Mace, G.M., Fezzi, C., Atkinson, G., Turner, K. 2011. Economic analysis for ecosystem service assessments. Environmental and Resource Economics. 48:2, 177-218. https://10.1007/s10640-010-9418-x

Berbés-Blázquez M., González J.A and Pascual U. 2016. Towards an ecosystem services approach that addresses social power relations, Current Opinion in Environmental Sustainability. 19. 134-143. doi.org/10.1016/j.cosust.2016.02.003

Bednarek, A. T., Wyborn, C., Cvitanovic, C., Meyer, R., Colvin, R. M., Addison, P. F. E., et al. (2018). Boundary spanning at the science–policy interface: the practitioners' perspectives. Sustainability Science. 13, 1175–1183. doi: 10.1007/s11625-018-0550-9

Bennett, N. J., Alava, J. J., Ferguson, C. E., Blythe, J., Morgera, E., Boyd, D., Côté, I. M. 2023. Environmental (in)justice in the Anthropocene Ocean. Marine Policy, 147, 105383. doi.org/10.1016/j.marpol.2022.105383

Binder, C. R., Hinkel, J., Bots, P. W. G., and Pahl-Wostl, C. 2013. Comparison of frameworks for analyzing social-ecological systems. Ecol. Soc. 18, 4, 26. doi: 10.5751/ES- 05551-180426

Bonnevie, I.M.; Hansen, H.S.; Schrøder, L.; Armoškaite, A. 2022. Utilising MYTILUS for Active Learning to Compare Cumulative Impacts on the Marine Environment in Different Planning Scenarios. Sustainability. 14, 12606. doi.org/10.3390/su141912606

Bonnevie, I., Hansen, H. S., and Schrøder, L. 2021. Supporting integrative maritime spatial planning by operationalising SEANERGY – a tool to study cross-sectoral synergies and conflicts. Int. J. Digital Earth. 14, 678–695. doi: 10.1080/ 17538947.2020.1865467

Bonnevie, I. M., Hansen, H. S., & Schrøder, L. 2020. SEANERGY - a spatial tool to facilitate the increase of synergies and to minimise conflicts between human uses at sea. Environmental Modelling & Software, 132, 104808. doi.org/10.1016/j.envsoft.2020.104808

Bonnevie, I.M.; Hansen, H.S.; Schrøder, L. 2019. Assessing use-use interactions at sea: A theoretical framework for spatial decision support tools facilitating co-location in maritime spatial planning. Marine Policy 106, 103533. doi.org/10.1016/j.marpol.2019.103533

Borja A. 2023. Grand challenges in ocean sustainability. Frontiers in Ocean Sustainability. 1:1050165. doi:10.3389/focsu.2023.1050165

Braat, L.C., 2018. Five reasons why the Science publication “Assessing nature’s contributions to people” (Diaz, et al. 2018) would not have been accepted in Ecosystem Services. Ecosystem Services. 30. doi.org/10.1016/j. ecoser.2018.02.002. A1–A2.

Biggs, R., Clements, H., de Vos, A., Folke, C., Manyani, A., Maciejewski, K., Martín-López, B., Preiser, R., Selomane, O., Schlüter, M. 2022. What are social-ecological systems and social-ecological systems research? In: Biggs, R., de Vos, A., Preiser, R., Clements, H., Maciejewski, K., Schlüter, M. (eds) The Routledge Handbook of Research Methods for Social-Ecological Systems. (pp.

Campagne, C.S., Roche, P., Gosselin, F., Tschanz, L., Tatoni, T., 2017. Expert-based ecosystem services capacity matrices: Dealing with scoring variability. Ecological Indicators. 79, 63-72. doi.org/10.1016/j.ecolind.2017.03.043

Culhane, F. E., Robinson, L. A., and Lillebø, A. I. 2020. Approaches for estimating the supply of ecosystem services: concepts for ecosystem-based management in coastal and marine environments. In Ecosystem-based management, ecosystem services and aquatic biodiversity. Eds. T. O’Higgins, M. Lago and T. DeWitt (Cham: Springer) (pp.105–126). doi: 10.1007/978-3-030-45843-0_6

Cuba, N. 2015. Research note: Sankey diagrams for visualizing land cover dynamics. Landscape and Urban Planning. 139, 163–167. doi.org/10.1016/j.landurbplan.2015.03.010

Depellegrin, D., Hansen, H. S., Schrøder, L., Bergström, L., Romagnoni, G., Steenbeek, J., et al. (2021). Current status, advancements and development needs of geospatial decision support tools for marine spatial planning in European seas. Ocean Coast. Management. 209, 105644. doi: 10.1016/j.ocecoaman.2021.105644

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). Available at: http://data.europa.eu/eli/dir/2008/56/oj.

Douvere, F., Ehler, C.N. 2011. The importance of monitoring and evaluation in adaptive maritime spatial planning. Journal of Coast Conservation. 15, 305–311. doi.org/10.1007/s11852-010-0100-9

Duinker, P. N., and Greig, L. A. 2007. Scenario analysis in environmental impact assessment: improving explorations of the future. Environ. Impact Assess. Rev. 27, 206– 219. doi: 10.1016/j.eiar.2006.11.001

Ehler, C., 2021. Two decades of progress in Marine Spatial Planning. Marine Policy. 132. 104134. doi.org/10.1016/j.marpol.2020.104134

Ehler, C., Zaucha, J., and Gee, K. 2019. Maritime/Marine spatial planning at the interface of research and practice. In Maritime spatial planning past, present, future. Eds. J. Zaucha and K. Gee (pp.1–21). doi: 10.1007/978-3-319-98696-8_1

Ehler, C., 2018. Marine spatial planning an idea whose time has come. In: Yates, K.L., Bradshaw, C.J.A., Offshore Energy and Marine Spatial Planning (pp.1-12). doi.org/10.4324/9781315666877

Ehler, C.L., Douvere, F., 2009. Marine Spatial Planning: A Step-by-step Approach toward Ecosystem-Based Management. Intergovernmental Oceanographic Commission and Man and the Biosphere Programme. IOC Manual and Guides No. 53, ICAM Dossier No. 6. UNESCO. 2009, Paris.

Ehler, C., Douvere F., 2007. Visions for a Sea Change. Report of the First International Workshop on Marine Spatial Planning. Intergovernmental Oceanographic Commission and Man and the Biosphere Programme. IOC Manual and Guides, 46: ICAM Dossier, 3. Paris: UNESCO. doi.org/10.25607/OBP-1415

Elliott, M., and O'Higgins, T. G. (2020). "From DPSIR the DAPSI(W)R(M) emerges… a butterfly – 'protecting the natural stuff and delivering the human stuff," in Ecosystem- based management, ecosystem services and aquatic biodiversity. Eds. T. O'Higgins, M. Lago and T. DeWitt (Cham: Springer), 61–86. doi: 10.1007/978-3-030-45843-0_4

European Commission .2022. Integrated Maritime Policy of the European Union. https://www.europarl.europa.eu/factsheets/en/sheet/121/integrated-maritime-policy-of-the-european-union

European Commission 2008. 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). http://data.europa.eu/eli/dir/2008/56/oj

European Commission .2022. Communication from the commission to the European parliament, the council, the European economic and social committee and the committee of the regions towards a strong and sustainable EU algae sector. https://oceans-and-fisheries.ec.europa.eu/system/files/2022-11/COM-2022-592_en.pdf

European Commission Guidance Note for ethical social sciences and humanities research .2021. https://ec.europa.eu/info/funding-tenders/opportunities/docs/2021-2027/horizon/guidance/ethics-in-social-science-and-humanities_he_en.pdf

European Commission .2014. Directive 2014/89/EU of the European Parliament and of the Council of 23 July 2014 establishing a framework for maritime spatial planning. http://data.europa.eu/eli/dir/2014/89/oj.

European Commission .2008a. Guidelines for an Integrated Approach to Maritime policy: Towards best practice in integrated maritime governance and stakeholder consultation, Brussels

European Commission .2008b. Roadmap for Maritime Spatial Planning: Achieving Common Principles in the EU, vol. 2008 COM, Brussels 791 final.

Food and Agriculture organisation of the United Nations. 2023. https://www.fao.org/land-water/land/land-governance/land-resources-planning-toolbox/category/details/en/c/1026561/

Frederiksen, P., Morf, P., von Thenen, M., Armoskaite, A., Luhtala, H., Schiele, K.S., Strake, S., Hansen, H., 2021. Proposing an ecosystem services-based framework to assess sustainability impacts of maritime spatial plans (MSP-SA). Ocean and Coastal Management. 208. doi.org/10.1016/j.ocecoaman.2021.105577

Flannery, W., Healy, N., Luna, M., 2018. Exclusion and non-participation in marine spatial planning. Mar. Pol. 88, 32–40. doi.org/10.1016/j. marpol.2017.11.001.

Giacometti, A., Morf, A., Gee, K., Kull, M., Luhtala, H., Eliasen S.Q., Cedegren, E., 2020. Handbook: Process, Methods and Tools for Stakeholder Involvement in Maritime Spatial Planning. BONUS BASMATI Deliverable 2.3

Gilek, M., Armoskaite, A., Gee, K., Saunders, F., Tafon, R., Zaucha, Z., 2021. In search of social sustainability in marine spatial planning: A review of scientific literature published 2005–2020. Ocean and Coastal Management. 208. doi.org/10.1016/j.ocecoaman.2021.105618

Gimpel, A., Stelzenmüller, V., Töpsch, S., Galparsoro, I., Gubbins, M., Miller, D. et al. 2018. A GIS-based tool for an integrated assessment of spatial planning trade-offs with aquaculture. Sci. Total Environ. 627, 1644–1655. doi.org/10.1016/j.scitotenv.2018.01.133

Gissi, E., Fraschetti, S., and Micheli, F. 2019. Incorporating change in marine spatial planning: a review. Environ. Sci. Policy 92. 191–200. doi: 10.1016/j.envsci.2018.12.002

Gee, K., Blazauskas, N., Dahl, K., Göke, C., Hassler, B., Kannen, A., Leposa, N., Morf, A., Strand, H., Weig, B., Zaucha, J. 2019. Can tools contribute to integration in MSP? a comparative review of selected tools and approaches. Ocean Coast. Manage. 179, 104834. doi: 10.1016/j.ocecoaman.2019.104834

Goepel, K. D. 2018. Implementation of an Online Software Tool for the Analytic Hierarchy Process (AHP-OS). International Journal of the Analytic Hierarchy Process, 10(3). doi.org/10.13033/ijahp.v10i3.590

Gómez, C. M., Delacámara, G., Arévalo-Torres, J., Barbière, J., Barbosa, A. L., Boteler, B., et al. 2016. The AQUACROSS innovative concept. deliverable 3.1 (European Union's Horizon 2020 Framework Programme for Research and Innovation grant agreement No. 642317). Available at: https://aquacross.eu/sites/ default/files/D3.1%20Innovative%20Concept.pdf.

Guerry A.D, Ruckelshaus M.H, Arkema K.K., Bernhardt J.R., Guannel G., Kim C.K., et al.2012. Modeling benefits from nature: using ecosystem services to inform coastal and marine spatial planning, International Journal of Biodiversity Science, Ecosystem Services & Management. 8, 107-121, 10.1080/21513732.2011.647835

Haines-Young, R. and M.B. Potschin. 2018: Common International Classification of Ecosystem Services (CICES) V5.1 and Guidance on the Application of the Revised Structure. www.cices.eu

Hall, D.M., Steiner, R., 2019. Insect pollinator conservation policy innovations at subnational level: Lessons for lawmakers. Environmental Science and Policy. 93, 118-128. doi.org/10.1016/j.envsci.2018.12.026

Halpern, B. S., Walbridge, S., Selkoe, K. A., Kappel, C. V., Micheli, F., D'Agrosa, C., et al. 2008. A global map of human impact on marine ecosystems. Science 319, 5865, 948–952. doi: 10.1126/science.1149345

Hammar, L., Molander, S., Pålsson, J., Schmidtbauer Crona, J., Carneiro, G., Johansson, T., et al. 2020. Cumulative impact assessment for ecosystem-based marine spatial planning. Science of The Total Environment. 734, 139024. doi:10.1016/j.scitotenv.2020.139024

Hansen, H. S. 2019. "Cumulative impact of societal activities on marine ecosystems and their services," in Computational science and its applications – ICCSA 2019. ICCSA 2019. lecture notes in computer science (Cham: Springer) 11621, 521–534. doi: 10.1007/978-3-030-24302-9_41

Hassler B., Blažauskas N., Gee, K., Luttmann A., Morf A., Piwowarczyk J., Saunders F., Stalmokaitė I., Strand H., Zaucha J. 2019. New Generation EU directives, sustainability, and the role of transnational coordination in Baltic Sea maritime spatial planning. Ocean and Coastal Management. 169, 254-263. doi.org/10.1016/j.ocecoaman.2018.12.025

Healey, P. 2007. Re-thinking Key Dimensions of Strategic Spatial Planning: Sustainability and Complexity. In: Gert de Roo and Geoff Porter. (eds.) Fuzzy Planning The role of actors in a fuzzy governance environment. (pp. 21-43). Ashgate

Heckwolf, M.J., Peterson, A., Jänes, H., Horne, P., Künne, J., Liversage, K., Sajeva, M., Reusch, T.B.H., Kotta, J. 2021. From ecosystems to socio-economic benefits: A systematic review of coastal ecosystem services in the Baltic Sea. Science of The Total Environment. 55. 142565. doi.org/10.1016/j.scitotenv.2020.142565

HELCOM 2020 Indicator Manual. Version 1. Baltic Sea Environment Proceedings n°175. HELCOM https://helcom.fi/wp-content/uploads/2021/01/BSEP175.pdf

HELCOM Hub 2013 https://helcom.fi/baltic-sea-trends/biodiversity/helcom-hub/

HELCOM Map and data service https://helcom.fi/baltic-sea-trends/data-maps/

HELCOM 2017 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. Available at: http://stateofthebalticsea.helcom.fi/about-helcom-and-the-assessment/downloads-and-data/

Hevner, A.R., March, S.T., Park, J., Ram, S. 2004. Design Science in Information Systems Research. MIS Quarterly. 28. 75-105. https://www.jstor.org/stable/25148625

Hyytiäinen, K., Blyh, K., Hasler, B., Ahlvik, L., Ahtiainen, H., Artell, J., Ericsdotter, S. 2014. Environmental economic research as a tool in the protection of the Baltic Sea – Costs and benefits of reducing eutrophication. Nordic Council of Ministers. http://norden.diva-portal.org/smash/get/diva2:707748/FULLTEXT01.pdf

Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES). 2022. Methodological assessment report on the diverse values and valuation of nature of the intergovernmental science-policy platform on biodiversity and ecosystem services. Eds. P. Balvanera, U. Pascual, M. Christie, B. Baptiste and D. González-Jiménez (Bonn, Germany: IPBES secretariat). 10.5281/zenodo.6522522

Jabareen, Y., 2009. Building a Conceptual Framework: Philosophy, Definitions, and Procedure. International Journal of Qualitative Methods, 8:4, 49–62. doi.org/10.1177/160940690900800406

Jacobs, S., Burkhard, B., Van Daele, t., Staes, J., Schneiders, A., 2015. The Matrix Reloaded': a review of expert knowledge use for mapping ecosystem services. Ecol. Model. 295, 21–30. doi.org/10.1016/j.ecolmodel.2014.08.024.

Kidd, S, Jones H., Jay, S. 2019. Taking Account of Land-Sea Interactions in Marine Spatial Planning. In: Zaucha, J. and Gee, K., Maritime Spatial Planning past, present, future (pp.245-270). https://link.springer.com/chapter/10.1007/978-3-319-98696-8_11

Kid, S and Shaw D., 2014. The social and political realities of marine spatial planning: some land-based reflections. ICES Journal of Marine Science. 71:7, 1535 – 1541. doi:10.1093/icesjms/fsu006

Kid, S and Ellis, G., 2012. From the Land to Sea and Back Again? Using Terrestrial Planning to Understand the Process of Marine Spatial Planning. Journal of Environmental Policy & Planning. 14. doi.org/10.1080/1523908X.2012.662382

Kirkfeldt, T.S. and Frazão Santos, C. 2021. A Review of Sustainability Concepts in Marine Spatial Planning and the Potential to Supporting the UN Sustainable Development Goal 14. Frontiers in Marine Science. 8:713980. doi: 10.3389/fmars.2021.713980

Koski, C., Rönneberg, M., Kettunen, P, Armoškaitė, A., Strake, S., Oksanen, J. 2021. User experiences of using a spatial analysis tool in collaborative GIS for maritime spatial planning. Transactions in GIS. 24:4. doi.org/10.1111/tgis.12827

Koski, C., Rönneberg, M., Kettunen, P, Eliasen, S., Hansen, H.S., Oksanen, J.2021b. Utility of collaborative GIS for maritime spatial planning: Design and evaluation of Baltic Explorer. Transactions in GIS. 25:3. 1347-1365. https://doi.org/10.1111/tgis.12732

La Notte, A., D'Amato, D., Mäkinen, H., Paracchini, M.L., Liquete, C., Egoh, B., Geneletti, D., Crossman, N.D. 2017. Ecosystem services classification: A systems ecology perspective of the cascade framework. Ecological Indicators. 74, 392-402. doi.org/10.1016/j.ecolind.2016.11.030

Latvian Fisheries Yearbook, 2014. The Latvian Rural Advisory and training centre. In: Latvian. http://www.laukutikls.lv/sites/laukutikls.lv/files/informativie_materiali/zivsaimniecibas_gadagramata_2014.pdf.

Latvian Institute of Aquatic Ecology, 2018. Jūras vides stāvokļa novērtējums. In: Latvian. https://www.lhei.lv/attachments/article/573/Juras_vides_novertejums_2018.pdf.

Leenhardt, P., Teneva, L., Kininmonth, S., Darling, E., Cooley, S., Claudet, J. 2015 Challenges, insights and perspectives associated with using social-ecological science for marine conservation. Ocean and Coastal management. 115, 49-60. doi.org/10.1016/j.ocecoaman.2015.04.018

Levin, S., Xepapadeas, T., Crépin, A.S., Norberg, J., de Zeeuw, A., Folke, C. et al. 2013. Social-ecological systems as complex adaptive systems: modelling and policy implications. Environment and Development Economics. 18, 111132. doi:10.1017/S1355770X12000460

McGowan, L., Jay, S., and Kidd, S. 2019. Scenario-building for marine spatial planning. In Maritime spatial planning. Eds. J. Zaucha and K. Gee (Cham: Palgrave Macmillan) (pp.327–351). doi: 10.1007/978-3-319-98696-8_14

Menegon, S., Depellegrin, D., Farella, G., Sarretta, A., Venier, C., and Barbanti, A. 2018. Addressing cumulative effects, maritime conflicts and ecosystem services threats through MSP-oriented geospatial webtools. Ocean and Coastal Management. 163, 417– 436. doi: 10.1016/j.ocecoaman.2018.07.009

Miller, T. R., Baird, T. D., Littlefield, C. M., Kofinas, G., Chapin, F. S., & Redman, C. L. 2008. Epistemological Pluralism: Reorganizing Interdisciplinary Research. Ecology and Society, 13:2. http://www.jstor.org/stable/26268006

Ntona, M and Morgera, E. 2018. Connecting SDG 14 with the other Sustainable Development Goals through marine spatial planning. Marine Policy. 93, 214-222. doi.org/10.1016/j.marpol.2017.06.020

O'Hagan, M. A., 2020. Ecosystem-based management and ecosystems services in EU Law, Policy and Governance. In O'Higgins et al., Ecosystem-based management, Ecosystem services and Aquatic biodiversity. Theory, Tools, and Applications (pp.353-372). https://link.springer.com/chapter/10.1007/978-3-030-45843-0_18

Ostrom, E. 2009. A general framework for analyzing sustainability of social- ecological systems. Science 325, 419–422. doi: 10.1126/science.1172133

Pålsson, Jonas. 2020. Swedish agency for Marine and Water management. Personal communication

Pakalniete, K., Ahtiainen, H., Aigars, J., Andersone, I., Armoškaite, A., Hansen, H.S., Strāķe, S. 2021. Economic Valuation of Ecosystem Service Benefits and Welfare Impacts of Offshore Marine Protected Areas: A Study from the Baltic Sea. Sustainability. 13: 10121. doi.org/10.3390/su131810121

Patricio, J., Elliot, M., Mazik, K., Padopoulou, K.N., Smith, C.J., 2016. DPSIR—Two Decades of Trying to Develop a Unifying Framework for Marine Environmental Management? Frontiers in Marine Science. 3. doi.org/10.3389/fmars.2016.00177

Pelenc, J., Ballet J., and Dedeurwaerdere T. 2015. Weak Sustainability versus Strong Sustainability. Brief for GSDR. https://sustainabledevelopment.un.org/content/documents/6569122-Pelenc-Weak%20Sustainability%20versus%20Strong%20Sustainability.pdf

Piet, G., Delacámara, G., Kraan, M., Röckmann, C., Lago, M., 2020. Advancing Aquatic Ecosystem-Based Management with Full Consideration of the Social-Ecological System. In: O'Higgins, T., Lago, M., DeWitt, T. (eds) Ecosystem-based management, Ecosystem services and Aquatic biodiversity. Theory, Tools, and Applications(pp.18-38). doi.org/10.1007/978-3-030-45843-0

Pinarbasi, K., Galparsoro, I., Borja, A., Stelzenmüller, V., Ehler, C. H., and Gimpel, A. (2017). Decision support tools in marine spatial planning: present applications, gaps and future perspectives. Mar. Policy 83, 83–91. doi: 10.1016/j.marpol.2017.05.031

Pinkau, A and Schiele, S.K. 2021. Strategic Environmental Assessment in marine spatial planning of the North Sea and the Baltic Sea – An implementation tool for an ecosystem-based approach? Marine Policy. 130: 104547. doi.org/10.1016/j.marpol.2021.104547

Plotly Technologies Inc, 2015. Collaborative data science. Plotly Technologies Inc, Montreal, QC. https://plot.ly.

Potschin-Young, M., Burkhard, B., Czúcz, B., and Santos-Martín, F., 2018. Glossary of ecosystem services mapping and assessment terminology. One Ecosystem 3: e27110. doi.org/10.1051/shsconf/20185801025

Preiser, R., Schlüter, M., Biggs, R., García, M.M., Haider, J., Hertz, T., and Klein, L. 2022. Complexity-based social- ecological systems research: philosophical foundations and practical implications. In: Biggs, R., de Vos, A., Preiser, R., Clements, H., Maciejewski, K., Schlüter, M. (eds) The Routledge Handbook of Research Methods for Social-Ecological Systems. (pp.27-46). doi.org/10.4324/9781003021339-2

Przedrzymirska, J., Zaucha, J., Depellgrin, D., Fairgrieve, R., Kafas, A., Calado, H.M.G.P., et al. 2018. Multi-use of the sea: From research to practice. SHS Web Conf. 58, 01025. doi.org/10.1051/shsconf/20185801025

Quinio, L., Ripken, M., Klenke, T., Trouillet, B., Hansen, H. S., and Schrøder, L. 2023. Exploring ecosystem-based approaches in MSP through actor-driven perceptual mapping. Mar. Policy 152, 105604. doi: 10.1016/j.marpol.2023.105604

Ramirez-Monsalve, P., and Van Tatenhove, J.P.M., 2020. Mechanisms of power in maritime spatial planning processes in Denmark. Ocean and Coastal Management. 198. doi.org/10.1016/j.ocecoaman.2020.105367

Reckermann, M., Omstedt, A., Soomere, T., Aigars, J., Akhtar, N., Bełdowska, M., et al. (2022). Human impacts and their interactions in the Baltic Sea region, earth syst. Dynam 13, 1–80. doi: 10.5194/esd-13-1-2022

Robinson, L.A., Culhane, F.E., 2020. Linkage Frameworks: An Exploration Tool for Complex Systems in Ecosystem-Based Management. In: O'Higgins, T., Lago, M., DeWitt, T. (eds) Ecosystem-based management, Ecosystem services and Aquatic biodiversity. Theory, Tools, and Applications (pp. 213- 233). doi.org/10.1007/978-3-030-45843-0_11

Rockström, J., Steffen, W., Noone, K., Persson, Å., Chapin, F.S., Lambin, E., et al. 2009. Planetary boundaries: exploring the safe operating space for humanity. Ecology and Society. 14:2, 32. http://www.ecologyandsociety.org/vol14/iss2/art32/

Santos, F. C., Domingos, T., Ferreira, M.A., Orbach, M., Andrade, F., 2014. How sustainable is sustainable marine spatial planning? Part I—Linking the concepts. Marine Policy.49, 59-65. https://doi.org/10.1016/j.marpol.2014.04.004.

Saunders, F., Gilek, M., Ikauniece. A., Tafon, V.R., Gee, K., Zaucha, J., 2020. Theorizing Social Sustainability and Justice in Marine Spatial Planning: Democracy, Diversity, and Equity. Sustainability. 12:6, 2560. doi.org/10.3390/su12062560

Saunders, P.F., Gilek, M., Tafon, R., 2019a. Adding people to the sea: conceptualizing social sustainability in maritime spatial planning. In: Zaucha, J., Gee, K. (Eds.), Maritime Spatial Planning: Past, Present, Future. Palgrave McMillan, Cham, pp. 175–199.

Schlüter, M., McAllister, R. R. J., Arlinghaus, R., Bunnefeld, N., Eisenack, K., Hölker, F., Milner-Gulland, E. J., Müller, B., Nicholson, E., Quaas, M., Stöven, M., 2012. New horizons for managing the environment: a review of coupled social-ecological systems modeling. Natural Resource Modeling. 25:1, 219-272. http://dx.doi.org/10.1111/j.1939-7445.2011.00108.x

Schlüter, M., Müller, B., and Frank., K. 2019. The potential of models and modelling for social-ecological systems research: the reference frame ModSES. Ecol. Soc. 24, 1, 31. doi: 10.5751/ES-10716-240131

Schmidt, M., 2008. The Sankey diagram in energy and material flow management - Part II: methodology and current applications. J. Ind. Ecol. 12, 173–185. https://doi.org/ 10.1111/j.1530-9290.2008.00015.x.

Schultz-Zehden, A., Lukic, I., Ansong, O. J., Altvater, S., Bamlett, R., Barbanti, A., et al. 2018. Ocean Multi-Use Action Plan; MUSES Project; Multi-Use in European Seas: Edinburgh, UK, 2018.

Schröter M., Stumpf K.H., Loos J., van Oudenhoven A.P.E., Böhnke-Henrichs A and Abson D.J. 2017. Refocusing ecosystem services towards sustainability, Ecosystem Services. 25. 35-43 doi.org/10.1016/j.ecoser.2017.03.019

Singh, G. G., Eddy, I. M. S., Halpern, B. S., Neslo, R., Satterfield, T., and Chan, K. M. 2020. Mapping cumulative impacts to coastal ecosystem services in British Columbia. PloS One 15, e0220092. doi: 10.1371/journal.pone.0220092

Singh, G.G., Sinner, J., Ellis, J., Kandlikar, M., Halpern, B.S., Satterfield, T., Chan, K. 2017. Group elicitations yield more consistent, yet more uncertain experts in understanding risks to ecosystem services in New Zealand bays. PloS One 12, 8. hdoi.org/10.1371/journal.pone.0182233.

Sharpe, L. M., Hernandez, C. L., and Jackson, C. A. (2020). "Prioritizing stakeholders, beneficiaries, and environmental attributes: a tool for ecosystem-based management," in Ecosystem-based management, ecosystem services and aquatic biodiversity. theory, tools, and applications. Eds. T. O'Higgins, M. Lago and T. DeWitt (Springer), 189–211. Available at: https://link.springer.com/chapter/10.1007/ 978-3-030-45843-0_10.

Soons, A.H. Alfred., 2004. Law enforcement in the ocean. WMU Journal of Maritime Affairs. 3, 3–16. doi.org/10.1007/BF03195046

Stalmokaitė, S., Armoškaitė, A., Gee, K., Gilek, M., Ikauniece, A., Matczak, M., Saunders, F., Tafon, R., Turski ,J., Witkowska, J., Zaucha., J. Social justice in marine spatial planning: Stakeholder perspectives and experiences in the Baltic Sea Region. Accepted. Journal of Environmental Planning and Management.

Stelzenmuüller, V., Gimpel, A., Gopnik, M., Gee, K. 2017. Aquaculture Site-Selection and Marine Spatial Planning: The Roles of GIS-Based Tools and Models. In Aquaculture Perspective of Multi-Use Sites in the Open Ocean; Buck, B., Langan, R., Eds.; Springer International Publishing: New York, NY, USA, *Tafon, R., Armoskaite, A., Gee, K., Gilek, M., Ikauniece, A., Saunders, F. 2023. Mainstreaming coastally just and equitable marine spatial planning: Planner and stakeholder experiences and perspectives on participation in Latvia. Ocean and Coastal Management. 242. 10.1016/j.ocecoaman.2023.106681*

Tafon, R., Glavovic, B., Saunders, F., Gilek, M., 2022. Oceans of conflict: pathways to an ocean sustainability PACT. Planning Practice and Planning 37 (2), 213–230. doi.org/10.1080/02697459.2021.1918880

Tengö, Maria., and Andersson, Erik. 2022. Solutions-oriented research for sustainability: Turning knowledge into action. Ambio. 51, 25–30. doi.org/10.1007/s13280-020-01492-9

van Tatenhove, J.P.M. 2017. Transboundary Marine Spatial Planning: A Reflexive Marine Governance Experiment? Journal of Environmental Policy and Planning. 19:6, 783–794. doi.org/10.1080/1523908x.2017.1292120.

von Thenen, M., Armoškaitė, A., Cordero-Penín, V., García-Morales, S., Gottschalk, J.B., Gutierrez, D.; Ripken, M., Thoya, P., Schiele, K.S. 2021. The Future of Marine Spatial Planning—Perspectives from Early Career Researchers. Sustainability. 13, 13879. doi.org/10.3390/su132413879

von Thenen, M., Frederiksen, P., Hansen, H.S., Schiele, K.S., 2020. A structured indicator pool to operationalize expert based ecosystem service assessments for marine spatial planning. Marine Policy. 187. doi.org/10.1016/j.ocecoaman.2019.105071

UNESCO-IOC/European Commission. 2021. MSPglobal International Guide on Marine/Maritime Spatial Planning. Paris, UNESCO. (IOC Manuals and Guides no 89). https://unesdoc.unesco.org/ark:/48223/pf0000379196

Veidemane, K., Ruskule, A., Strake, S., Purina, I., Aigars, J., Sprukta, S., Ustups, D., Putnis, I., Klepers, A. 2017. Application of the marine ecosystem services approach in the development of the maritime spatial plan of Latvia. International Journal of Biodiversity Science, Ecosystem Services & Management. 13, 398-411. doi.org/10.1080/21513732.2017.1398185

Zaucha, J., and Jay, S., 2022. The extension of marine spatial planning to the management of the world ocean, especially areas beyond national jurisdiction. Marine Policy. 144. doi.org/10.1016/j.marpol.2022.105218

Zaucha, J., 2014. The key to governing the fragile Baltic Sea Maritime spatial planning in the Baltic Sea region and way forward. https://vasab.org/vasab-presents-comprehensive-book-about-msp-in-the-baltic-sea-region/

White, C., Halpern, S.H., Kappel, C.V. 2012. Ecosystem service trade-off analysis reveals the value of marine spatial planning for multiple ocean uses. PNAS. 109 (12) 4696-4701. doi.org/10.1073/pnas.1114215109

Yin, R. 2003. Case Study Research and Applications. Design and Methods. Third Edition. SAGE Publications, Inc

APPENDICES

Appendix A. Paper 1

Establishing the links between marine ecosystem components, functions, and services: An ecosystem service assessment tool.

Published in Ocean and Coastal Management. 193. 105229

Armoškaite, A.; Puriņa, I.; Aigars, J.; Strāķe, S.; Pakalniete, K.; Frederiksen, P.; Schrøder, L., Hansen, H.S. 2020.

doi.org/10.1016/j.ocecoaman.2020.105229.

Appendix B. Paper 2

Assessing change in habitat composition, ecosystem functioning and service supply in Latvian protected stony reefs.

Published in Journal of Environmental Management. 298.

Armoškaite, A.; Aigars, J.; Hansen, H.S.; Andersone, I.; Schrøder, L.; Strāķe, S. 2021.

doi.org/10.1016/j.jenvman.2021.113537.

Appendix C. Paper 3

Setting the scene for a multimap toolset supporting maritime spatial planning by mapping relative cumulative impacts on ecosystem service supply.

Published Frontiers in Marine Science. 10:1213119

Armoškaite, A.; Bonnevie, I.M.; Aigars, J.; Andersone, I.; Schrøder, L.; Strāķe, S., von Thenen., Hansen, H.S. 2023

doi: 10.3389/fmars.2023.1213119

Appendix D. Paper 4

Considerations of Use-Use Interactions between Macroalgae Cultivation and Other Maritime Sectors: An Eastern Baltic MSP Case Study.

Published in Sustainability. 13, 13888.

Armoškaitė, A., Bārda, I., Andersone, I., Bonnevie, I.M., Ikauniece, A., Kotta, J., Kõivupuu, A., Lees, L., Psuty, I., Strāķe, S., Sprukta, S., Szymanek, L., von Thenen, M., Schrøder, L., Hansen, H.S. 2021.

doi.org/10.3390/su132413888

Appendix E. Paper 5

Proposing an ecosystem services-based framework to assess sustainability impacts of maritime spatial plans (MSP-SA).

Published in Ocean and Coastal Management. 208. 105577

Frederiksen, P., Morf, P., von Thenen, M., Armoskaite, A., Luhtala, H., Schiele, K.S., Strake, S., Hansen, H., 2021.

doi.org/10.1016/j.oce-coaman.2021.105577

Appendix F. Paper 6

In search of social sustainability in marine spatial planning: A review of scientific literature published 2005–2020

Published in Ocean and Coastal Management. 208.

Gilek, M.; Armoskaite, A.; Gee, K.; Saunders, F.; Tafon, R.; Zaucha, Z. 2021.

doi.org/10.1016/j.ocecoaman.2021.105618

Appendix G. Paper 7

The Future of Marine Spatial Planning—Perspectives from Early Career Researchers.

Published in *Sustainability*. 13, 13879.

von Thenen,; Armoškaitė, A.; Cordero-Penín, V.; García-Morales, S.; Gottschalk, J.B.; Gutierrez, D.; Ripken, M.; Thoya, P.; Schiele, K.S. 2021.

doi.org/10.3390/su132413879

Appendix H. Paper 8

Mainstreaming coastally just and equitable marine spatial planning: Planner and stakeholder experiences and perspectives on participation in Latvia.

Published in Ocean and Coastal Management. 242.

Tafon, R.; Armoskaite, A.; Gee, K.; Gilek, M.; Ikauniece, A.; Saunders, F. 2023.

10.1016/j.ocecoaman.2023.106681

Appendix I. Paper 9

User experiences of using a spatial analysis tool in collaborative GIS for maritime spatial planning.

Published in Transactions in GIS. 24:4.

Koski, C.; Rönneberg, M.; Kettunen, P.; Armoškaitė, A.; Strake, S.; Oksanen, J.
2021.

doi.org/10.1111/tgis.12827

Appendix J. Paper 10

Economic Valuation of Ecosystem Service Benefits and Welfare Impacts of Offshore Marine Protected Areas: A Study from the Baltic Sea.

Published in Sustainability. 13: 10121.

Pakalniete, K.; Ahtiainen, H.; Aigars, J.; Andersone, I.; Armoškaite, A.; Hansen, H.S.; Strāķe, S. 2021.

doi.org/10.3390/su131810121

Appendix K. Paper 11

Utilising MYTILUS for Active Learning to Compare Cumulative Impacts on the Marine Environment in Different Planning Scenarios.

Published in Sustainability. 14, 12606.

Bonnevie, I.M.; Hansen, H.S.; Schrøder, L.; Armoškaite, A. 2022.

doi.org/10.3390/su141912606

ISSN (online): 2446-1628
ISBN (online): 978-87-7573-621-8

AALBORG UNIVERSITY PRESS