MOSAIC – A tool for ecosystem based spatial management of marine conservation values

Version 1

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MOSAIC – A tool for ecosystem based spatial management of marine conservation values

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Hedvig Hogfors, Frida G. Fyhr and Antonia Nyström Sandman

This report has been developed by the Swedish Agency for Marine and Water Management.
The agency is responsible for the content and conclusions of the report.

Maps; Frida G. Fyhr

Illustrations; Hedvig Hogfors

Translation; Douglas Jones

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Havs- och vattenmyndigheten | Box 11 930 | 404 39 Göteborg | www.havochvatten.se

Preface

The Swedish Agency for Marine and Water Management are responsible for promoting the sustainable management and planning of our marine areas. Part of this includes developing methods for a well-functioning green infrastructure and environmental protection.

The loss of habitats and species is one of humanity's greatest problems and one of the most immediate of threats is the loss of biodiverse and functionally important environments due to human activity. Protecting and conserving biological diversity requires knowledge on the occurrence of species and habitats, their distribution and movements, ecological function and their vulnerabilities. Assessing and prioritizing areas for conservation, or for various forms of physical planning, requires that large amounts of information and knowledge (established and new) are consolidated in such a way as to enable prioritization.

To improve knowledge on the conservation value of marine areas, the Swedish Agency for Marine and Water Management have developed MOSAIC.

MOSAIC (dnr 1592-20) is a tool to identify the conservation value of marine areas, in particular their importance for biodiversity and ecosystem services in coherent (viable and ecologically representative) networks. The tool can be used for spatial management such as marine spatial planning, designation of protected areas, restoration planning and management of fisheries.

MOSAIC is based on ecosystem components that have been identified and developed by researchers and regional experts within the tool's framework. The *list of ecosystem components* and their associated conservation value provides a structure for handling, compiling, evaluating, and prioritizing ecosystem components for spatial management.

This report provides a detailed description of the tool MOSAIC.

It is the Swedish Agency for Marine and Water Management's sincere hope that this report, *list of ecosystem components* and user manual (Swedish Agency for Marine and Water Management report 2020:14) will promote and support an improved and more sustainable management of our marine areas.

MOSAIC's target groups are primarily those involved in the management and physical planning of coastal and marine areas, from national agencies to county administrative boards and municipalities – but even other marine operators and consultancies.

A large debt of gratitude is directed to all the people that have contributed with information and viewpoints during the tool's development. The report has been developed by AquaBiota Water Research and the Swedish Agency for Marine and Water Management, with support from SLU Swedish Species Information Centre and the County Administrative Boards for Västerbotten and Västra Götaland. The project leader from the Swedish Agency for Marine and Water Management is Ingemar Andersson.

Göteborg April 2020,

Mats Svensson Head of the Department of Marine and Water Management

As part of international knowledge sharing, the Swedish version of the report (2020:13) has been translated into English (HaV dnr 1572-22). The translation has been done in collaboration with Douglas Jones (AquaBiota Water Research).

Gothenburg February 2024,

Johan Kling, Head of the Department of Water Management

Summary

Effective ecosystem-based management of marine and coastal environments requires an integrated approach across administrative areas. A standardized approach for the assessment of marine green infrastructure can ensure that the right management measures occur in the right place. MOSAIC is a tool to identify the conservation value of marine areas, in particular their importance for biodiversity and ecosystem services in coherent (viable and ecologically representative) networks. The intention is to provide a standardized and integrated framework for marine management, such as which areas should be prioritized for protection, restoration or other physical planning (including fisheries management and goals set out in the Marine Strategy Framework and Habitat Directives).

MOSAIC's purpose is to promote an ecosystem based, adaptive and functional approach to marine spatial management and conservation. The intention is to provide a structure that, as far as possible, is unbiased in its inclusion of a range of different biological ecosystem components used to assess and identify an areas conservation value. MOSAIC is a diverse tool that can support assessments and management processes that are currently based on a limited number of more general ecosystem components developed for larger areas. MOSAIC provides a structure to incorporate new knowledge, to follow ecosystem change over time and account for spatial variation and complexity – from site-specific details to a seascape perspective.

The purpose of this report is to provide an in-depth description of MOSAIC - the theory behind it, considerations made and discussions that have been held during its development and to describe what the tool can be used for. This report does not need to be read in order to use MOSAIC – a practical guide is provided in the Swedish Agency for Marine and Water Management report 2020:14 *Conservation values from a seascape perspective – user manual for MOSAIC, version 1*.

MOSAIC is divided into two parts (Figure 1) a *preparatory part* and an *implementation part*. The Swedish Agency for Marine and Water Management (SwAM) coordinate the preparatory part and county administration boards, or other users, carry out the implementation part. In the preparatory part, the best available knowledge is gathered and synthesized by experts to provide general (not site-specific) assessments (which are subsequently used for seascape analyses and site-specific assessments in MOSAICS implementation part). In other words, the focus of assessments in the preparatory part is not on spatial variation, but on general patterns and trends. This makes it easier to follow trends and include new knowledge during the recurring revisions.

In MOSAICS's implementation part *core areas*[1] (locations with a high conservation value) and *areas of ecologically coherent networks* are identified. *Areas of ecologically coherent networks* are larger *areas with high conservation values* (aggregations of *core areas*) in viable and ecologically representative networks. The primary focus of assessments in the implementation part is to identify spatial variation using detailed site-specific knowledge and in-depth seascape analyses of where conservation values are likely to occur, where important dispersal/migration routes occur, where viable locations occur and if the locations are part of an ecologically

[1] See chapter 5 (terminology) for definition.

representative network. Viable locations are locations where ecosystem components are less exposed to negative impacts. Following change over time at local scales is challenging and requires resources for intensive field surveys. However, more general changes are possible to follow because the assessments carried out in the implementation part include information from the preparatory part, which is updated regularly to account for natural change or new knowledge.

In order to prioritize areas for management measures (for example through protection, spatial planning or restoration) comparisons need to be possible between areas at regional and local scales. For this, both detailed site-specific and more general seascape knowledge is required.

MOSAIC focuses on biological ecosystem components (populations, species, organism groups and habitats) because biological ecosystem components determine an area’s conservation value and are sensitive to human activities. Furthermore, biological ecosystem components must be represented in areas that are prioritized for spatial management measures. MOSAIC is based on internationally accepted criteria set by the UN Convention on Biological Diversity (Convention on Biological Diversity; CBD; 2008). The criteria have been incorporated into the various parts and steps of MOSAIC to achieve its goals and create a practical working order.

This is the first version of MOSAIC. Detailed guidelines are not yet available for all of MOSAIC´s parts, but by publishing them in their current form we hope the tool will develop as it is used practically and when other parallel processes (within marine management and protection) are completed.

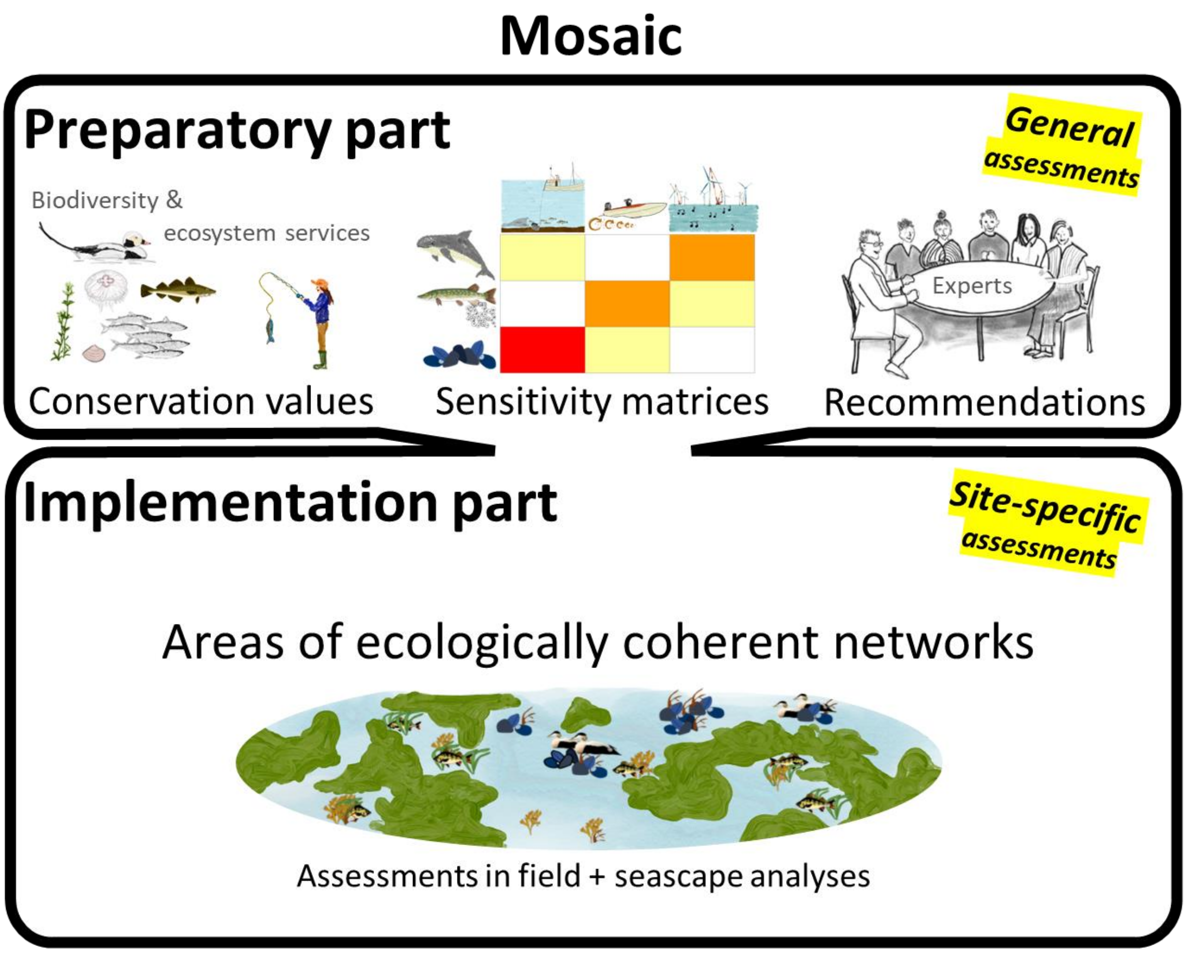

Figure 1. Overview of MOSAIC´s two parts. In the preparatory part, general (not site-specific) assessments are made by experts. The assessments are coordinated by the Swedish Agency for Marine and Water Management and should be able to be used in the implementation part. In the implementation part *core areas* (locations with a high conservation value) and *areas of ecologically coherent networks* (aggregations of *core areas* in viable and ecologically representative networks) are identified using *detailed field surveys* and seascape analyses. The implementation part is coordinated by respective county administration boards or other users.

Contents

Reading guidelines

The purpose of this report is to fully describe all of MOSAIC´s parts - why the tool is constructed as it is (the theory behind MOSAIC), the considerations made and discussions held during its development as well as what the tool can be used for. This report does not have to be read in order to use MOSAIC – practical information can be found in the Swedish Agency for Marine and Water Management report 2020:14[2]. However, if the user is interested in why certain recommendations are given or how the tool was developed, the information can be found here. Because each section should be able to be read independently there is a certain amount of repetition.

Chapter 1 provides an introduction to MOSAIC, its purpose and aims, how it was developed and its limitations.

MOSAIC is described in its entirety in the second chapter of the report. Section 2.1 provides an overview of the tool and section 2.2 describes the workflow. Section 2.3 describes the preparatory part of MOSAIC which contains assessments made by marine experts, coordinated by the Swedish Agency for Marine and Water Management. Section 2.4 describes the implementation part of MOSAIC. A checklist describing the relevant steps that the user should follow to carry out MOSAIC´s implementation part can be found in the Swedish Agency for Marine and Water Management report 2020:14[2].

Throughout the report the trade-offs made in each part are discussed. Criteria applicable to several or all parts of the tool are discussed in more detail in Chapter 3.

Chapter 4 discusses the degree to which MOSAIC achieves its stated aims and Chapter 5 contains a list of terms and their definitions.

[2] Conservation values from a seascape perspective – user manual for MOSAIC, version 1.

1 Introduction

MOSAIC (Methods for spatial, adaptive, ecosystem-based and integrative assessment of offshore and coastal marine conservation values) is a tool to identify marine green infrastructure and provide a common framework for different forms of spatial management such as which areas to prioritize for protection, restoration or other physical planning (including coastal and marine management and fisheries management). MOSAIC enables a wider perspective by providing a structured approach to ecosystem based and adaptive spatial management.

MOSAIC combines several perspectives in order to integrate numerous processes[3] (such as capturing an ecosystems detail and function over time and varying spatial scales - from local to national). For example, by separating large scale analyses from detailed spatial analyses it is easier to follow general changes over time, and vice versa[4]. The tool combines a number of spatial and temporal processes needed for a broad understanding of ecosystems across a range of organizational levels. Guidelines for some parts are not yet complete and the idea is that MOSAIC will be developed and adapted as it is used.

According to the current approach to marine management, the impact of management decisions should be considered for entire ecosystems, not just certain parts of it (Queiros et al. 2016). An adaptive and flexible management that can handle non-linear change is needed to maintain or achieve a desired ecosystem status (Folke et al. 2002, 2004). This ecosystem-based approach is included in several EU directives such as the Water Framework Directive (2000/60/EG), Marine Strategy Framework Directive (2008/56/EC) and Maritime Spatial Planning (2014/89/EU).

By identifying valuable areas – which are especially important for biodiversity and ecosystem services - in ecologically representative networks, MOSAIC provides a solid basis from which national and international environmental objectives can be achieved. Article 13.4 of the EU's Marine Strategy Framework Directive, which is implemented in Sweden via national legislation (Havsmiljöförordningen 2010:1341), states that a marine strategy which aims to achieve or maintain good environmental status must include plans to create a coherent and representative network of marine protected areas. Furthermore, the European Commission have provided guidelines to promote the development of green infrastructure that includes a network of linked Natura-2000 sites (European Commission 2017b). The Swedish government commissioned the Swedish Agency for Marine and Water Management to produce an action plan for marine protection (M2015/711/Nm) to ensure an ecologically representative network of protected areas. According to the action plan (Havs- och vattenmyndigheten 2016) the species and habitats listed in the Habitats Directive do not provide a sufficient basis for an ecologically representative network of protected areas. In addition, representative networks of marine habitats should be protected according to the OSPAR and HELCOM conventions. According to the EU's Maritime Spatial Planning directive, maritime planning should consider the degree that planned actions can

[3] Both linear (simple/general trends) and non-linear (variability and patterns) processes are included

[4] The purpose is to combine simple, linear relationships with more complex site-specific information. The simpler, linear relationships are updated regularly which accounts for non-linear change.

impact an area's environmental status, biodiversity and the provision of ecosystem services. MOSAIC can provide one of several essential platforms to achieve these aims.

Ecosystem components are a central part of MOSAIC and are primarily biological. Examples include eelgrass meadows and pike spawning areas. From a wider seascape perspective the value of an ecosystem component is not dependent on where it is found. As such, all "eelgrass meadows" and all "pike spawning areas" are considered collectively and irrespective of where in a sea area they are located. A detailed description of what we mean by ecosystem component and how they are selected and defined can be found in section 2.3.1.

1.1 Purpose and aims

A number of sub-goals have been established to promote an ecosystem based, adaptive and functional spatial management of marine environments. These have been developed in line with the 12 principles for an ecosystem approach to biodiversity management (the Malawi principles that originate from the UN Convention on Biodiversity; CBD) but are adapted to suit MOSAIC's specific purpose and limitations.

Ecosystem based

MOSAIC should strive to account for a large part of an ecosystem's spectrum of interactions and components (including humans), instead of focusing on certain problems, species, conservation values or ecosystem services separately. It should handle the ecosystem's spatial as well as temporal variation (Christensen et al. 1996) allowing for good management despite this inherent variation. The sub-goals are:

- **The tool should take into account large parts of the ecosystem's spectrum of interactions and components.** The tool should always be grounded in the *ecosystem* and not, for example, in specific regulations. Conservation values related to biodiversity and ecosystem services should be considered. The best available knowledge on current and future scenarios should be included. Knowledge from the whole ecosystem should be able to be applied spatially because the purpose of the tool is spatial management – as such it should be linked to specific locations or to ecosystem components that can be defined spatially (geographically)[5].
- **The tool should be based on the best available knowledge and to the greatest extent possible grounded on scientific facts.** Experts with a global, regional, national and local scientific knowledge should be consulted with a broad ecological competence on a range of organisms dependent on spatial management[6].
- **The tool should include a seascape perspective and in-depth spatial analyses.** To assess an area's overall conservation value, one needs to understand how various ecosystem components vary spatially. An overview of the ecosystem is necessary to reduce the risk of only prioritizing areas where knowledge is available – and risk missing valuable areas where information is lacking. The assessments that are carried out need to be placed in a wider seascape context. Furthermore, to better account for an ecosystem's spatial variation, in-depth spatial analyses are required such as how conservation value and human activity are geographically distributed, which ecosystem components are negatively affected in an area, where important distribution or movement corridors (connectivity) occur and how these are these are likely to be distributed spatially in the future[7].
- **The tool should include detailed site-specific information.** In order for the tool to be truly ecosystem based and account for the complex structures, functions and mechanisms that vary spatially in ecosystems, it needs to include detailed knowledge from geographically separated locations[8].

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[5] Linked to Malawi principles 2, 3, 5, 6, 8 and 10.

[6] Linked to Malawi principles 11 and 12.

[7] Linked to Malawi principles 3, 5, 6 and 8.

[8] Linked to Malawi principles 6 and 11.

- **The tool should include humans as a part of ecological interactions.** This should be done by including ecosystem services and the effect of humans on the environment when prioritizing management areas[9].
- **The tool should be adaptive.** Read the points under “Adaptive” in the text below.
- **The tool should be functional.** Read the points under “Functional” in the text below.

Adaptive

The tool should follow natures change over time. To maintain or achieve a desired ecosystem status requires an adaptive management that is flexible and can handle non-linear change (Folke et al. 2002, 2004). Because our knowledge of marine ecosystems is incomplete or sometimes incorrect, we must be able to incorporate new knowledge as it becomes available. This also includes human interactions such as exploitation and management. In order for the tool to be adaptive it must allow users to evaluate different management strategies (Katsanevakis et al. 2011). The sub-goals are:

- **Assessments should be easy to revise,** for two reasons:
  - × To be able to track natural and human induced changes in the marine environment over time. For example, a common species may become threated over time.
  - × To continually incorporate new knowledge on marine environments[10].
- **Likely future scenarios should be able to be included.** For example, probable future scenarios based on global climate change should be able to be included[10].
- **The tool should be able to be used for evaluations.** One should be able to evaluate the effectiveness of different management strategies.

Functional

The tool should be practical and functional for a range of marine spatial management applications. The sub-goals are:

- **The tool should be based on internationally accepted criteria and foster national harmonization.** By being grounded in internationally accepted criteria it will promote an acceptance of the approach nationally and internationally. Marine areas are used and managed by many different countries. A thorough compilation of current knowledge by a range of experts/researchers is necessary to establish accepted criteria.
- **The tool should minimize subjective assessments and encourage consensus.** The tool should reduce isolated and subjective assessments by including discussions from a larger number of experts (scientific, local, national and, if possible, even international experts) and all available scientific evidence. Assessments should be comparable with each other and should include as much relevant information on the marine environment as possible.
- **The tool should be transparent and allow for clear and comparable assessments.** Assessments should be transparent, clear and comparable to facilitate discussions with a broad group of experts and stakeholders. By making comparisons between assessments easy, it is possible to gain an insight into how trade-offs between assessments have

[9] Linked to Malawi principles 1 and 10.

[10] Linked to Malawi principle 9.

been made. This, in turn, makes it easier to comment on assessments during the next revision of the tool.

- **The tool should be based on transparent analyses that can be carried out by anyone with basic GIS competence** and without the need for specialized software.
- **The tool should support functional and effective field survey methods.** Field surveys are essential to gain knowledge on the marine environment, from acquiring site-specific information to more general patterns. However, field surveys in marine environments are very resource intensive and to be effective they need to be carefully described and comparable with each other whilst still capturing site-specific details that can be difficult to predict[11].
- **The tool's different parts should be arranged at the correct organizational scale.** Assessments should be coordinated by the most suitable authority/agency and decentralized when appropriate[12].

The sub-goals are also in line with other tools, frameworks and reports related to ecosystem-based management and management of marine ecosystems (see Christensens et al. 1996, Borja et al. 2016 and Queiros et al 2016).

A discussion on how well the framework achieves the stated aims can be found in Chapter 4.

[11] This aim is not yet been fully achieved in the first version of MOSAIC.

[12] Linked to Malawi principle 2.

1.2 Marine management's requirements and challenges

Work relating to green infrastructure and conservation value assessments can be structured in a similar way, irrespective of which environment it applies to. But because there are many fundamental differences between terrestrial, freshwater and marine environments the approach should be adapted somewhat to the relevant environment. For example, one aspect that is quite different between these environments, and which can affect the framework used, is connectivity. In freshwater environments the movement of many species is limited by the characteristics of lakes, rivers and streams - how they are linked, the direction the water flows and elevation. Even if many marine species are affected by currents, the effect of physical barriers are generally less important for connectivity than in freshwater. However, factors such as salinity and stratification can strongly influence which species are found in an area.

An ecosystem based and functional approach to marine spatial management includes accounting for the spatial distribution and complexity of marine ecosystems, which requires large amounts of data (Borja et al. 2016). However, we generally know much less about (and have less data on) marine habitats and species distributions compared with terrestrial environments (Hendriks et al. 2006; Verfaillie et al. 2009; Robinson 2011) and survey methods are often expensive (Nyström Sandman et al. 2012). Exploring and understanding the oceans can be compared to exploring land from a hot air balloon in a thick fog. The balloon might descend at certain locations to survey a location but the majority of land remains unexplored over time and space. In other words, it is extremely difficult to know what can be found where and in what quantity, and above all what function and importance species or habitats have in the ecosystem. There is an urgent need to develop a cost-effective method for mapping and monitoring marine habitats (Borja et al. 2016). Although there are several studies that examine the geographic distribution of species and habitats (see Méléder et al. 2007; Bekkby et al. 2008, 2009; Sandman et al. 2008; Florin et al. 2009; Soldal et al. 2009; Sundblad et al. 2009; Bučas et al. 2013 for examples) we seldom understand in detail what it is that limits a species' occurrence and distribution. Could it be salinity, substrate, competition, spawning area, food, a certain life stage or just chance? Even if the marine environment is well connected, local conditions and local impacts can significantly affect the occurrence of a species.

In order to assess which areas should be prioritized for management actions (such as area protection, physical planning, restoration) areas need to be compared with each other on local and regional scales. It is important to identify areas that might contain a high conservation value even where there is a lack of detailed survey data. In other words, the distribution of ecosystem components needs to be mapped. In areas where mapping is insufficient there is a risk high, unknown, conservation value areas will be overlooked whilst well mapped areas are unfairly prioritized.

Different survey methods might be better or worse at collecting information on certain species or organism groups. If information is collected using different survey methods, it is difficult to compare conservation values between the areas surveyed. For example, it is usually inappropriate to compare the conservation value of two bays if one is surveyed using dive transects (which focuses on sessile organisms) and the other is surveyed for occurrence of fish. It can even be difficult to compare bays that are surveyed using dive transects and bays that are surveyed using under water video because the two methods generally don't survey to the same taxonomic level. Even size of the surveyed area generally affects the number of species noted. Other uncertainties that can occur, even using the same survey technique, include the survey effort or taxonomic skill of the surveyor. Standardized methods reduce these problems and are appropriate when comparing different areas (such as bays) with each other.

Despite the current lack of comprehensive field data available in Swedish marine areas, MOSAIC is designed to include this data as it becomes available. The national marine mapping (NMK) project coordinated by the Swedish Agency for Marine and Water Management is designed to provide better data on the occurrence and coverage of ecosystem components in Swedish marine areas. Furthermore, the Marine Strategy Framework Directive requires improved mapping of marine areas with several descriptors for achieving good environmental status to be measured in square kilometer units (km^2; European Commission decision 2017/848, European Commission 2017a).

1.3 Background and development

The Swedish Agency for Marine and Water Management commissioned AquaBiota Water Research to develop a proposal to aid marine green infrastructure and a method to assess conservation values from a seascape perspective. Ingemar Andersson has led the project from the Swedish Agency for Marine and Water Management.

The assignment included a requirement that the work should aim to create a national consensus around marine spatial management and green infrastructure. After an open referral the framework was processed and clarified by the Swedish Agency for Marine and Water Management and AquaBiota Water Research in conjunction with the Swedish Species Information Centre and county administration boards. This is the Swedish Agency for Marine and Water Managements first version of the framework.

Several people have commented on and reviewed MOSAIC under its development including Per Nilsson and Mats Lindegarth from Gothenburg University and the Swedish Institute for the Marine Environment (Per Nilsson is currently a consultant), Christina Halling from the Swedish Species Information Centre at the Swedish University of Agricultural Sciences, Patrik Kraufvelin and Ulf Bergström from the Department of Aquatic Resources at the Swedish University of Agricultural Sciences, Maria Kilnäs and Johnny Berglund from Västra Götaland and Västerbotten County Administration Boards, and Anna Karlsson from the Swedish Agency for Marine and Water Management. Other people have commented various parts of the development of the tool, including Jan Schmidtbauer Crona and Mårten Åström from the Swedish Agency for Marine and Water Management.

About fifty experts have contributed to the work according to guidelines set out in the preparatory part of MOSAIC. They are, in alphabetical order, Markus Ahola, Ingemar Andersson, Sandra Andersson, Johnny Berglund, Per Bergström, Ulf Bergström, Mats Blomkvist, Anja Carlsson, Thomas Dahlgren, Anna Engdahl, Björn Fagerholm, Karl Florén, Ronny Fredriksson, Frida G. Fyhr, Lars Gamfeldt, Bo Gustafsson, Fredrik Haas, Michael Haldin, Christina Halling, Micaela Hellström, Hedvig Hogfors, Per Holliland, Rita Jönsson, Anna Karlsson, Martin Karlsson, Olle Karlsson, Lena Kautsky, Maria Kilnäs, Kjell Larsson, Ewa Lavett, Ulf Lindahl, Lars-Ove Loo, Marina Magnusson, Per-Olav Moksnes, Leif Nilsson, Per Nilsson, Karl Norling, Pia Norling, Antonia Nyström Sandman, Johan Näslund, Angelina Olsson, Jenny Palmkvist, Susanne Qvarfordt, Caroline Raymond, Mattias Sköld, Ola Svensson, Robin Svensson, Stina Tano, Nicklas Wijkmark, Susanne Viker, Ingrid Wänstrand and Matti Åhlund.

1.3.1 Legitimacy and applicibility

Comprehensive groundwork was carried out on the version sent for open referral with regional meetings held in Umeå, Stockholm, Gothenburg, Malmö and Karlskrona (all in 2016) to discuss guidelines for the tool[13]. Recorded lectures were sent to those unable to attend the meeting to increase outreach.

MOSAIC was sent for open referral and received comments from over 50 organizations (local or national authorities, universities, municipalities, country administrative boards and consultants). Many of the responses were positive and over 500 pages of constructive comments were sent in. All comments were grouped and systematically compiled. Comments relating to the version sent for referral have been processed and included in version 1 of MOSAIC, comments relating to further development of the tool will be processed in future versions.

1.3.2 Earlier and parallel work

Several of the criteria used in this report have been set by the UN Convention on Biodiversity (CBD; 2008) and are internationally accepted. There are other analyses of ecologically coherent (sometimes called ecologically functional) networks of marine protected areas (ecological coherence of networks of marine protected areas; see for example Piekäinen and Korpinen 2007; Ardron 2008; Johnson et al. 2014; Deltares 2015 and references therein) such as the Swedish Environmental Protection Agency's guidance on the protection of marine environments with high conservation value (Naturvårdsverket 2007a) and Ekologigruppen's pilot study on methods for the assessment of conservation values in marine areas (Schreiber and Haglund 2013).

Some earlier projects that have been central to MOSAIC's development, and that are relevant to conservation value assessments, are the biological mapping and conservation value assessments of the Swedish High Coast (Isaeus et al. 2007), surveying of offshore sandbanks (Naturvårdsverket 2010), marine modelling in Östragötland (Carlström et al. 2010), SUPERB (Wikström et al. 2013) and MARMONI (Fyhr et al. 2015). The two latter projects applied a points system to ecosystem components, which MOSAIC also does in its preparatory part, but in geographically smaller areas.

Above all, two parallel projects have contributed to the design of MOSAIC, these are:

- the research project IMAGINE (Implications of alternative management strategies on marine green infrastructure, a collaboration between AquaBiota Water Research, Gothenburg University, the Swedish University of Agricultural Sciences and Stockholm University) financed by the Swedish Environmental Protection Agency and the Swedish Agency for Marine and Water Management and
- a project on inter-municipal planning/marine green infrastructure in the sea around Blekinge that AquaBiota Water Research carried out on behalf of the County Administrative Board in Blekinge (in particular work relating to grant 1:12, Swedish Agency for Marine and Water Management dnr 3311-15).

[13] Invitations to the regional meetings were sent out to about 700 recipients representing local county administrative boards, municipalities, universities, local authorities, consultants etc. The meetings were attended by 63 people from 10 county administrative boards, 9 consultancy companies (excluding AquaBiota), 2 universities (Swedish University of Agricultural Sciences and Umeå University), 2 national authorities (Swedish Agency for Marine and Water Management and Geological Survey of Sweden) and a Finnish state-owned enterprise (Metsähallitus).

Pilot studies for MOSAIC have been carried out in conjunction with the county administrative boards in Västra Götaland (Kilnäs 2016) and Västerbotten (Berglund et al. 2016). Further pilot studies to test the tool have been carried out in Hanö bay in the county of Blekinge, as well as in the counties of Stockholm, Södermanland and in Kosterhavet (Swedish west coast). Conservation values have been linked to the majority of ecosystem components that are based on species or species groups reported in the national archive for oceanographic data (Svenskt HavsARKiv or SHARK) coordinated and hosted by Swedish Meteorological and Hydrological Institute.

1.4 Limitations

Despite the fact that many important considerations and trade-offs for MOSAIC's development have been handled in several parallel projects, other aspects can come to light as the tool is used requiring adjustments or modifications. Some parts of MOSAIC currently lack guidelines. The first version of MOSAIC is published by the Swedish Agency for Marine and Water Management with the aim of gathering experience that can further develop the tool.

It is important to underline that MOSAIC is a tool to support the identification and prioritization of ecosystem components and areas for spatial management from a range of conservation values. It does not assess the total conservation value of an area or all of its ecosystem components. For example, MOSAIC cannot estimate the total effect of a loss of one or more ecosystem components from an entire sea area. The assessments in MOSAIC aim to determine which ecosystem components, should be prioritized where based on the conservation values that selected criteria highlight – according to the best available knowledge.

An important aspect is assessment reliability – this should be clear for all of MOSAIC's steps and clearly visible in the final product. Currently, a system for reporting assessment reliability is only complete for the step linking conservation values to ecosystem components in the preparatory part. A method for reporting the reliability of all parts of the tool is something that needs to be developed and tested.

2 The tool

2.1 Overview

This section provides the reader with an overview of MOSAIC's structure through a short presentation of its various parts.

MOSAIC is based on internationally accepted criteria set by the UN Convention on Biodiversity (CBD 2008)[14]. These criteria are there to aid in the identification of areas suitable for protection. MOSAIC uses the same principles in its criteria to identify ecologically and biologically valuable areas in viable and representative networks. However, MOSAIC also aims to highlight valuable green infrastructure as a basis for different forms of spatial management and is not restricted to area protection. For this reason, criteria that are based on ecosystem services are included in the tool. Criteria are processed in particular parts and steps according to a practical workflow to achieve the overall aims.

MOSAIC's assessments are reviewed and revised regularly - how often this will be done has not yet been decided but a six-year cycle could be appropriate.

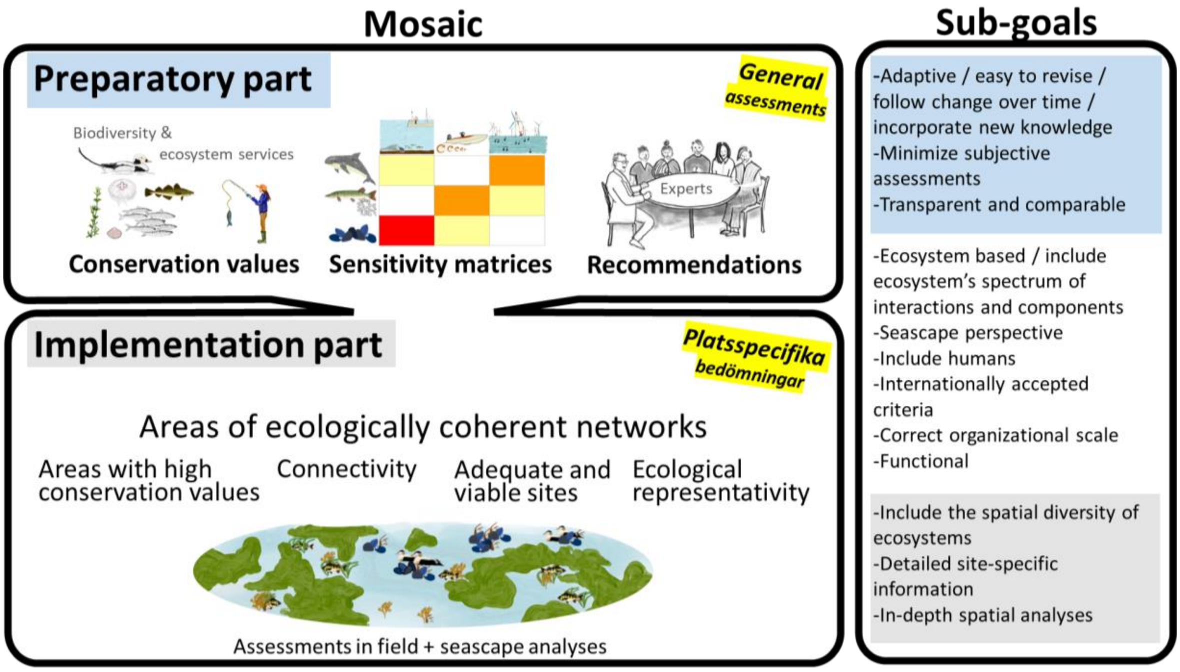


Figure 2. MOSAIC's two parts are illustrated on the left-hand side of the figure. On the right-hand side a list of sub-goals is specified. These sub-goals ensure that the tool achieves its overall aim of being ecosystem based, adaptive and functional (see section 1.1). The sub-goals are ordered according to which part of MOSAIC they relate to. Sub-goals found in the blue box relate to the preparatory part and those in the grey box to the implementation part. Sub-goals that are in white (unmarked) relate to both of MOSAICS's parts.

[14] Criteria set by the UN Convention on Biological Diversity (CBD) for designating so called EBSAs (Ecologically or Biologically Significant Marine Areas) and criteria to establish a representative network of protected marine areas (Appendix 1 and 2, UN Convention of Biodiversity, Decision IX / 20; CBD 2008)

MOSAIC is separated into a preparatory part and an implementation part. Sub-goals can be seen in Figure 2 (and presented in section 1.1), sorted according to the parts of MOSAIC (preparatory or implementation) that they relate to. However, all sub-goals should be attempted to be fulfilled in both parts of MOSAIC.

In the preparatory part more general (not site-specific) assessments are carried out by experts, which are to be used in MOSAIC's implementation part. In the preparatory part experts list and define a range of ecosystem components (*list of ecosystem components*). Assessments are then carried out on these ecosystem components and include: which conservation values each ecosystem component generally contribute to an area (*conservation values linked to ecosystem components*), which human activities or stressors they are sensitive to (*sensitivity matrices*) and what proportion of each ecosystem component should be represented in *areas of ecologically coherent networks* (Figure 3). Even if the assessments are not site-specific in the preparatory part, ecosystem components listed should be able to be geographically defined and it should be possible to link them to a specific area or location. They should also be descriptive enough to separate by degree of cover or abundance, for example if an area has a few occurrences of blue mussels or if it has a high coverage of blue mussel beds.

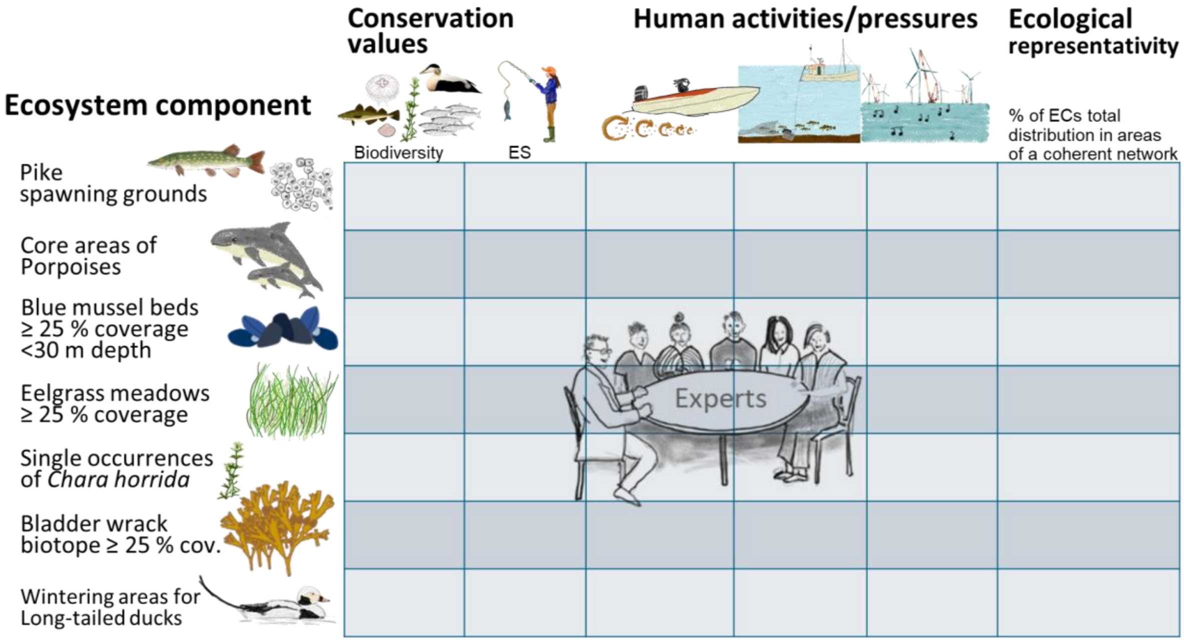


Figure 3. A schematic showing how ecosystem components can be divided so that they are suitable for spatial assessments, and which information that can be linked to them in MOSAIC's preparatory part. The division/selection of ecosystem components and assessments are carried out jointly by scientific and regional experts. It is important that the conservation value linked to ecosystem components is stipulated. In other words, the conservation value they generally contribute to a location (here exemplified by their contribution to biodiversity and ecosystem services). *Furthermore, human activities that ecosystem components are sensitive to should be specified. Finally, recommendations should be given on the proportion of each ecosystem component that should be represented in ecologically coherent networks.*

By carrying out general, not site-specific assessments, the preparatory part does not focus on spatial variation. This increases the ability to follow large-scale and general changes over time. For example, the conservation value that "eelgrass meadows with ≥ 25 % coverage" generally contribute to an area is assessed. It does not assess if a specific eelgrass meadow is more or less valuable than other eelgrass meadows (of the same level of coverage) because of its location or other factors (such as which species are found there or the specific role of a meadow to connectivity). These general – not site-specific – assessments are easier to revise according to temporal change or new knowledge/information. The number or area of eelgrass meadows might decline in the future increasing the importance of the functions provided by those that remain. Similarly, new information or knowledge may come to light that increase or decrease the general conservation value of eelgrass meadows.

To ensure assessments of the conservation value, linked to different ecosystem components, are transparent, easy to compare and revise (as ecosystems change over time or new knowledge comes to light) a points system according to a number of criteria has been implemented. To reduce subjectivity, assessments are first carried out per sea area by an expert group coordinated by the Swedish Agency for Marine and Water Management (phase 1). Following that, relevant county administrative boards coordinate a regional or local assessment (phase 2) to consider whether ecosystem components are more or less important in their region, compared with the whole sea area in question. The assessments are general but the motivation for each assessment should be presented systematically.

In the preparatory part recommendations are taken prior to work that is carried out in the implementation part. This includes questions relating to *ecological representativity* and which ecosystem components presence should automatically qualify an area to be classed as a *core area*[15]. The Swedish Agency for Marine and Water Management coordinate the preparatory part, except for phase 2 where conservation values are adjusted to reflect local importance compared to the wider sea area.

In MOSAIC's implementation part county administration boards or other users identify *core areas* (locations with a high conservation value). They should also identify *areas with high conservation values* (aggregations of *core areas*) in viable and ecologically representative networks with functioning connectivity. Areas that live up to these criteria are designated as *areas of ecologically coherent networks*[16]. Viable locations are those that are less exposed to human activity that affects them negatively.

The sub-goals in the preparatory part (see Figure 2) are indirectly included in the implementation part because assessments carried out in the preparatory part are used in the implementation part. However, the focus in the implementation part is to track an ecosystems spatial complexity (Figure 2). This requires both detailed information and landscape analyses. Identifying locations with a high conservation value, or *core areas*, can for instance be done with the aid of *general conservation value maps* and *site-specific conservation value assessments*. The two approaches should complement each other since one provides a landscape perspective and the other provides important detailed information from specific locations. The *general conservation value*

[15] See chapter 5 (terminology) for definition.

[16] See chapter 5 (terminology) for definition.

maps are based on *ecosystem component spatial distribution maps* and *conservation values linked to ecosystem components* from the preparatory part.

Because *detailed field surveys* are resource intensive it can be difficult to follow temporal change from many locations. However, systematic surveys that follow site-specific change over time are very important, not least as a basis for the general assessments carried out in the preparatory part.

In the first version of MOSAIC the structure (framework) is established. For some parts the structure includes detailed descriptions on methods used, but for other parts guidelines are not complete. Where detailed guidelines are missing the user should decide on appropriate methods to use.

The Swedish Agency for Marine and Water Management report 2020:14[17] contains a checklist of what should be carried out for each step of MOSAIC's implementation part.

[17] Conservation values from a seascape perspective – user manual for MOSAIC, version 1.

2.2 Workflow

In this section MOSAIC's workflow is summarized using flowcharts (Figure 4 and 5). The reason for presenting the workflow at an early stage is to provide an overview that can be referred to when using the tool.

MOSAIC is divided into two parts, a preparatory and an implementation part. In the preparatory part the Swedish Agency for Marine and Water Management are responsible for providing information that can be used by county administration boards (or other users) in the implementation part. In the implementation part users make use of point data (step 1, Figure 5) or detailed field survey data (step 2, Figure 5) to determine where different ecosystem components (species and habitats) occur. If point data in step 1 is of sufficient quality (described in section 2.4.1.1) then *ecosystem component spatial distribution maps* can be produced (step 3, Figure 5).

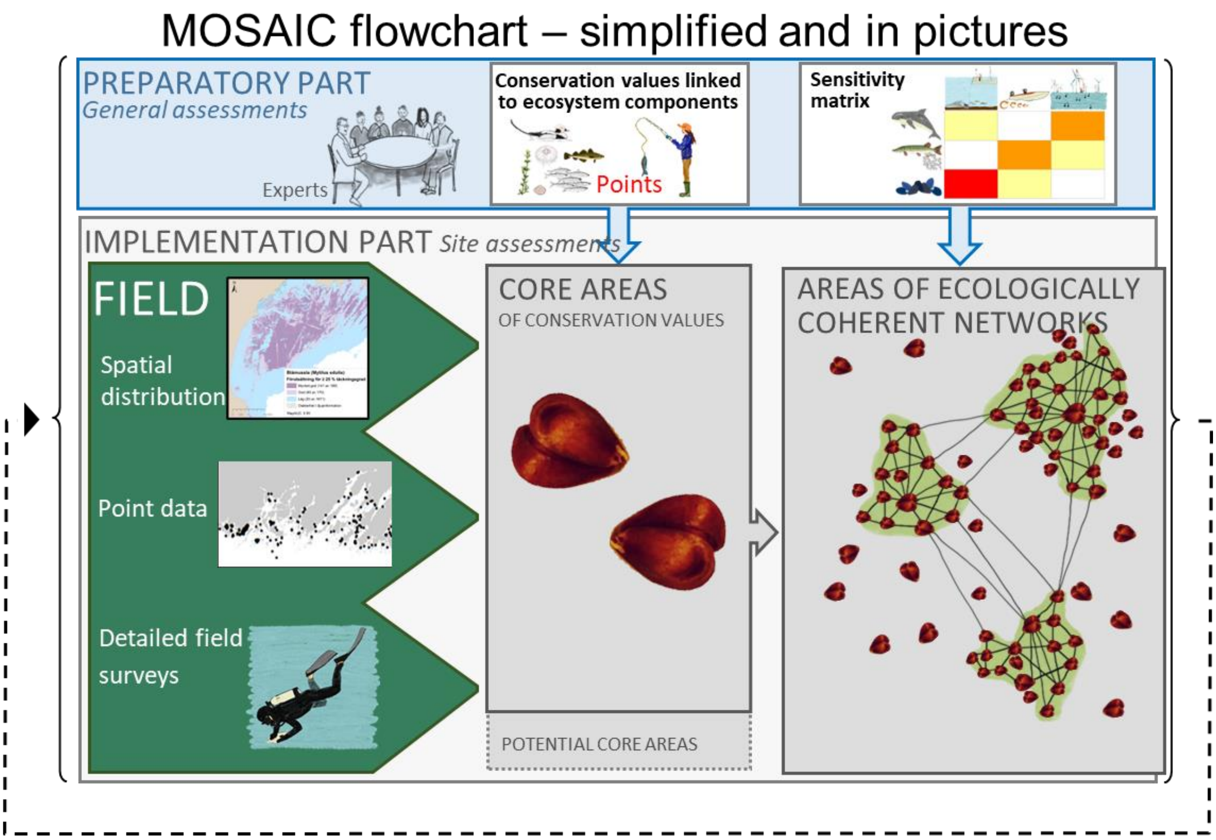


Figure 4. Simplified flowchart showing MOSAIC's workflow. A complete flowchart can be seen in Figure 5.

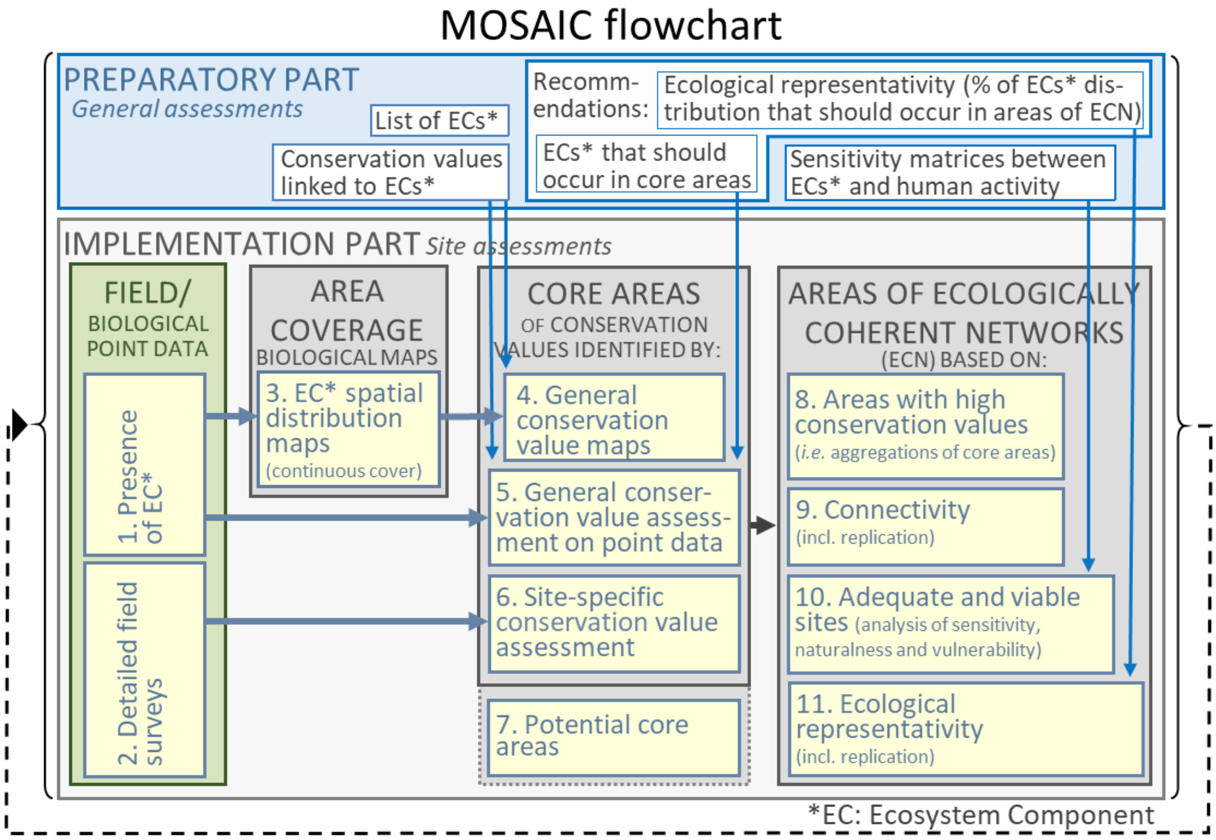


Figure 5. Flowchart showing the different parts and steps that comprise MOSAIC.

Field data (and the spatial distribution maps) are then used to identify *core areas* (locations with a high conservation value) and *potential core areas*[18] (see Figures 4 and 5). Assessments on the general conservation value of ecosystem components, and ecosystem components that automatically qualify a location as a *core area* (from the preparatory part) are used to identify *core areas*.

Once *core areas* have been established, *areas of ecologically coherent networks* should be identified. *Areas of ecologically coherent networks* are larger *areas with high conservation values* (aggregation of *core areas*) in viable and ecologically representative networks with high connectivity[19]. *Sensitivity matrices* and recommendations relating to *ecological representativity* (from the preparatory part) are used to identify *areas of ecologically coherent networks* (see Figures 4 and 5).

[18] See chapter 5 (terminology) for definition.

[19] See chapter 5 (terminology) for definition.

2.2.1 Division of responsibility

The Swedish Agency for Marine and Water Management coordinate:

- the defining and delimiting of ecosystem components that are suitable for spatial management (*list of ecosystem components*)
- the development of, or reference to, suitable sensitivity matrices for ecosystem components and human activities/pressures
- expert recommendations regarding ecosystem components that automatically qualify a location as a *core area*[20] and the proportion of respective ecosystem components that should be represented in *areas of ecologically coherent networks*, and
- phase 1 assessments in which conservation values are linked to different ecosystem components in respective sea areas.

Local county administrative boards coordinate:

- phase 2 assessments in which conservation values are linked to different ecosystem components in their local region, and
- MOSAIC's implementation part.

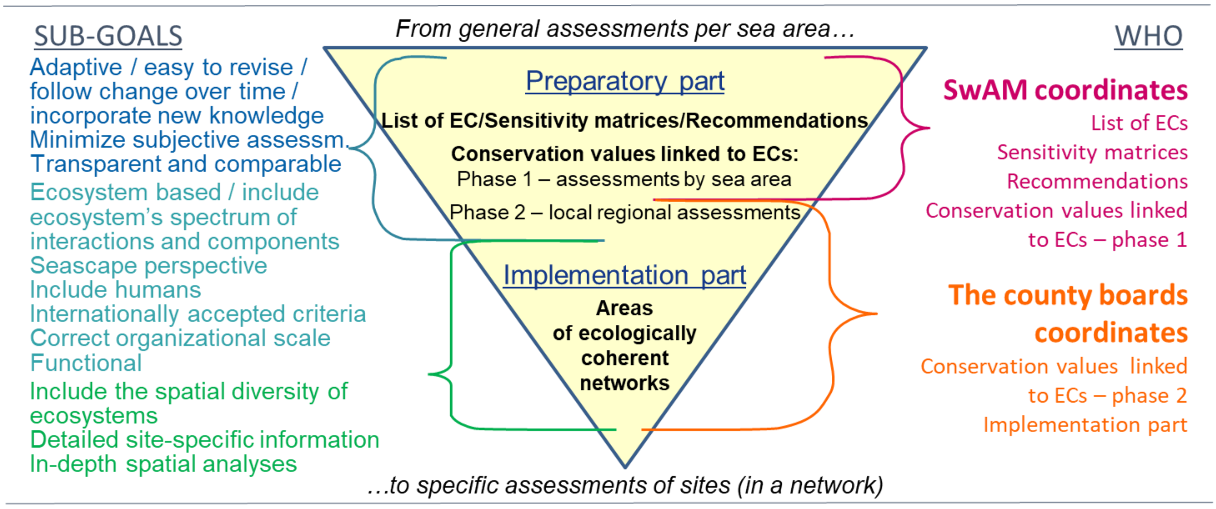


Figure 6. Some of the sub-goals are divided between MOSAIC's two parts. The Swedish Agency for Marine and Water Management (SwAM) coordinate the preparatory part and respective county administrative boards coordinate MOSAIC's implementation part. This division has one exception. Phase 2 local regional assessments linking conservation values to ecosystem components should be coordinated by county administrative boards even if it belongs to the preparatory part. EC = ecosystem component.

[20] See chapter 5 (terminology) for definition.

2.3 MOSAIC's preparatory part

The preparatory part is carried out by experts[21] and coordinated by the Swedish Agency for Marine and Water Management. The work described in this section is not carried out by county administrative boards or other users and contains many detailed descriptions that are not required in order to use the tool.

The preparatory part should aid county administrative boards, and other users, to identify locations with high conservation value and viable and ecologically representative networks. The preparatory part includes:

- ecosystem component selection – specifying and delimiting ecosystem components that are suitable for spatial management
- assessments on the conservation value associated with ecosystem components and that ecosystem components generally contribute to a location
- recommendations regarding ecosystem components that automatically qualify a location as a *core area*[22] and the proportion of the respective ecosystem components that should be represented in coherent networks[23]
- *sensitivity matrices* that indicate how sensitive ecosystem components are to human activities and impacts.

See Figures 4 and 5.

The Swedish Agency for Marine and Water Management coordinate the work carried out in the preparatory part with the exception of phase 2 regional assessments, which are coordinated by country administrative boards (see section 2.3.2.2).

[21] Researchers and other experts with local to national or global knowledge and a variety of ecological expertise (including on a wide range of marine organisms).

[22] See chapter 5 (terminology) for definition.

[23] See chapter 5 (terminology) for definition.

2.3.1 *List of ecosystem components*

How complete are the guidelines for the list of ecosystem components?

Guidelines are available and over 50 experts have defined and delimited a first version of lists with several hundred ecosystem components relevant to Sweden´s marine areas.

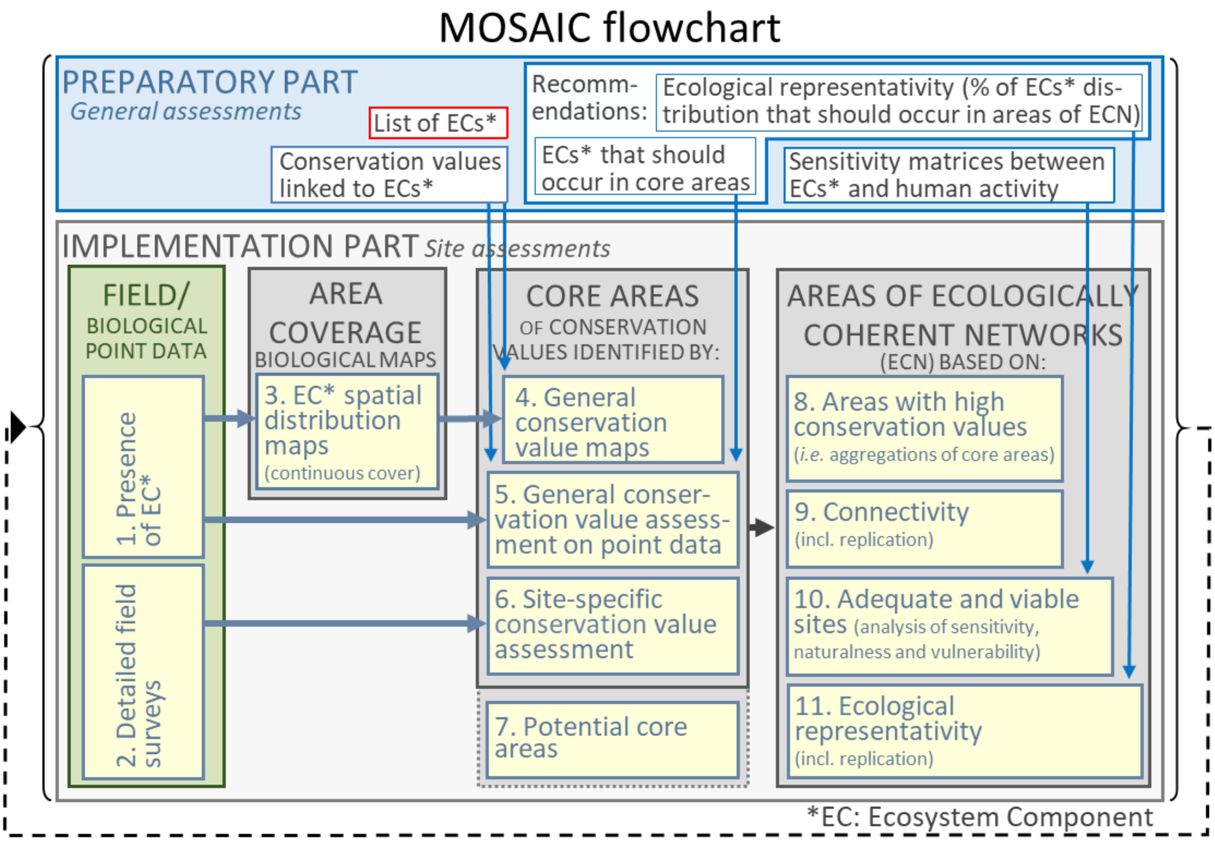


Figure 7. Flowchart showing the different parts and steps that comprise MOSAIC. The relevant section is highlighted in red.

The preparatory part begins with the selection and definition of different ecosystem components (Figure 7). This is an essential part of the tool because it provides a structure for several of the subsequent steps.

We recommend focusing on biological ecosystem components (populations, species, organism groups and habitats) because biological ecosystem components determine an area's conservation value and are sensitive to human activities. It is also the biological ecosystem components we want to ensure are represented in areas prioritized for spatial management. However, abiotic ecosystem components can also be included in the list, especially if they have a clear link to specific biota/biotic ecosystem components. However, since a clear link does not always exist (Näslund 2013), it can be difficult to understand i) which biological ecosystem components that are negatively affected by human activity in an area or ii) which biological ecosystem components that are, or are not, sufficiently protected through area protection.

The ecosystem components that are defined and included in the list should not be influenced by preconceived ideas of conservation value associated with specific components. Ecosystem components *must* be defined so that:

A. it is possible to identify and delineate locations where they occur
B. it is possible to evaluate the general (not site-specific) conservation value they contribute to a location
C. the wide spectrum of marine organisms and habitats are included in the list.

By the term ”ecosystem components” we mean something that has been defined independently of where exactly they are located. For example, the ecosystem component “Bladder wrack habitats 25-100% coverage” does not refer to a bladder wrack habitat in a specific bay, but to all bladder wrack habitats in the sea area (with a 25-100% coverage). However, because the tool is designed for spatial management applications it must be *possible* to identify and delineate it to specific locations (see point A).

Ecosystem components *should try* to include organisms that:

1. are present in and use the same places. This is highly relevant for ecosystem components that include more than one species. Species must have a high degree of spatial overlap if they are included in the same ecosystem component
2. have similar conservation values
3. have similar representativity targets
4. are sensitive to the same human activities/pressures.

Points one to four are ranked according to importance but they are only guidelines. Ecosystem components that comprise several organisms will rarely meet all four criteria.

The first point can be compared to point A above. However, it may be possible to identify and delineate locations for an ecosystem component (point A) even if the organisms in the ecosystem component aren’t always present in the same place (point 1). An example of this is the ecosystem component “Predatory fish: recruitment area”. It is possible to identify and delineate locations that are recruitment areas for predatory fish (follow point A) but recruitment areas for cod and pike are not present at the same places (does not follow point 1). Organisms can use the same location at different times for the same function and it is the cumulative value of the site, all year round, that must be estimated (however, information of what time of year the organisms are present is important when identifying threats and measures). Furthermore, very general ecosystem components such as “Cod” are not appropriate because it is difficult to delineate or define general conservation values to a specific place. More appropriate ecosystem components would be “Cod: Spawning area” and “Cod: Foraging area”. These two ecosystem components are related to the same species but require different management strategies. For example, they probably need to be protected from different impacts and pressures. It is important to ensure that all habitats used by mobile species (birds, fish and mammals) are represented - which is why ecosystem components linked to mobile organisms should be defined by function and not only by species. Other examples of similar ecosystem components are “Eider wintering grounds” and “Grey seal breeding areas”. Ecosystem components that relate to more stationary benthos, those that stay in the same place for most of their lives, are often defined by the presence of an organism and its coverage or abundance.

In order to produce *general conservation value maps* (step 4 in the implementation part) according to the occurrence of ecosystem components, the conservation value associated with ecosystem components needs to be determined. To do this, the definitions of ecosystem components need to be as ecologically relevant as our collective knowledge allows. For example, the habitat quality and sediment binding properties of eelgrass depend on its coverage (Asmus & Asmus 2000). Even if we don't currently know the specific threshold between level of coverage of an organism and conservation value, we can make broad assumptions and rough divisions. For this reason, it might be necessary to define more than one ecosystem component for some organisms (such as biotope building species; i.e. Charophytes at up to 9 % coverage, 10-24 % coverage and 25-100 % coverage).

If several species often occur in the same location, it might be possible to combine them into one ecosystem component. If organisms in the combined ecosystem component have different conservation values, then the conservation value that the ecosystem component normally contributes to an area should be used. Since the conservation values are relative (and not measured in, for instance, monetary value) it is important that their value is not under or over estimated. In other words, the precautionary principle cannot be applied when assigning points because over estimation would be done at the expense of the other ecosystem components.

If multiple species included in an ecosystem component are not always found in the same place, (i.e. does not follow point 1 above), the ecosystem component can still be used to produce *general conservation value maps* (step 4 in the implementation part) if it can be delineated (point A). However, the level of representativity cannot be analyzed and secured for the organisms included in the ecosystem component.

If an organism in a composite ecosystem component has a very different conservation value to the other organisms in the same ecosystem component (if one of them is a threatened species, for example) it might be relevant to define another ecosystem component containing only the species with the higher conservation value. This might be necessary to ensure locations where that species occurs are upgraded and to ensure it is adequately represented in *areas of ecologically coherent networks*[24]. Note, that it does not matter if ecosystem components in the list have overlapping definitions. Read more about how double scoring is avoided when *core areas of conservation values* are identified through for example *general conservation value maps*, section 2.4.3.1.1.

If all four criteria (points 1 – 4 above) are followed, the list of ecosystem components would be extremely long. Experts must therefore decide which criteria are most important on a case-by-case basis and how important it is to keep the lists to a reasonable number of ecosystem components. The need to group species into combined ecosystem components is greater for the Swedish west coast, where species diversity is higher than in the Baltic Sea.

[24] See chapter 5 (terminology) for definition.

2.3.1.1 Biological and abiotic ecosystem components

In this report, biological ecosystem components are specific to and defined by living organisms (populations, species, organism groups) or habitats. Examples of biological ecosystem components include long-tailed duck wintering areas, seal haul-out sites, perch spawning areas, eelgrass meadows, single occurrences of *Chara horrida* and blue mussel beds. Abiotic ecosystem components are defined and delineated by aspects of the physical environment such as depth, substrate type and salinity. Examples of abiotic ecosystem components are deep areas over soft substrates, shallow areas over hard substrates and offshore sandbanks.

Biological ecosystem components can be strongly or weakly associated with specific abiotic ecosystem components. For example, the biological ecosystem components "*Chara tomentosa*" and perch and pike "recruitment area" are all commonly found in abiotic ecosystem components relating to Baltic flads and gloes (shallow water separated from the sea due to land upheaval and or sandbanks, shingle or rocks). Flads and gloes are included in the habitat type, Coastal lagoons, 1150 according to the interpretation manual of European Union habitats (Naturvårdsverket 2011). Lagoons are managed specifically for the conservation value provided by biological ecosystem components that are specific to and often found in those habitats. Another abiotically defined ecosystem component is shallow soft substrates (soft substrates in the photic zone). The exact depth varies but they can extend up to 20-30 meters deep. It is more difficult to predict which biological ecosystem components that can generally be found in shallow soft substrates because the physical attributes differ greatly in these environments, typically due to varying depths.

General conservation value assessments can be carried out on abiotic ecosystem components if they are strongly associated with biota/biological ecosystem components. Abiotic ecosystem components can occasionally be useful when assessing the potential value of an area, regardless of if biological ecosystem components are currently found there or not. However, modelling of biological ecosystem components is often needed to identify potentially valuable locations.

Since management often involves prioritizing between areas, it is important not to overestimate locations of low conservation value or underestimate areas of high value. For example, if all estuaries are valued highly – because a few of them contain a high conservation value – the estuaries with a low conservation value (and low potential) might be prioritized over other areas with a higher (potential) conservation value. The weaker the association between abiotic and biological ecosystem components the less useful the abiotic ecosystem component (Figure 8).

Apart from the fact that it is biological ecosystem components that contain conservation value, it is also these that are most sensitive to negative effects from humans and therefore important to know where they are found or have a high probability of occurring.

For the reasons stated above we recommend using biological ecosystem components as far as possible and abiotic ecosystem components that are strongly associated with specific biological ecosystem components.

A first version of the *list of ecosystem components* (and the conservation value they represent, see the next section 2.3.2) is complete. They can be found in an Excel document, *MOSAIC – ecosystem component lists and conservation values, version 1*, that can be downloaded from the Swedish Agency for Marine and Water Management website. The lists have been compiled by over 50 experts within several working groups and workshops. The lists are divided into the Bothnian Bay, Bothnian Sea, Baltic Proper and Kattegat/Skagerrak sea areas because of broad differences in the species composition and ecosystems between them. The ecosystem components related to bottom substrates in the Bothnian Bay, Bothnian Sea and Baltic Proper are specified according to species listed in the national Swedish maritime archives (Svenskt HavsARKiv; SHARK) and supplemented with species that are verified for these sea areas even if they were absent from the database. Following that, some ecosystem components were excluded so that the number of components were practical for spatial management. For example, bacteria, phytoplankton and zooplankton were excluded.

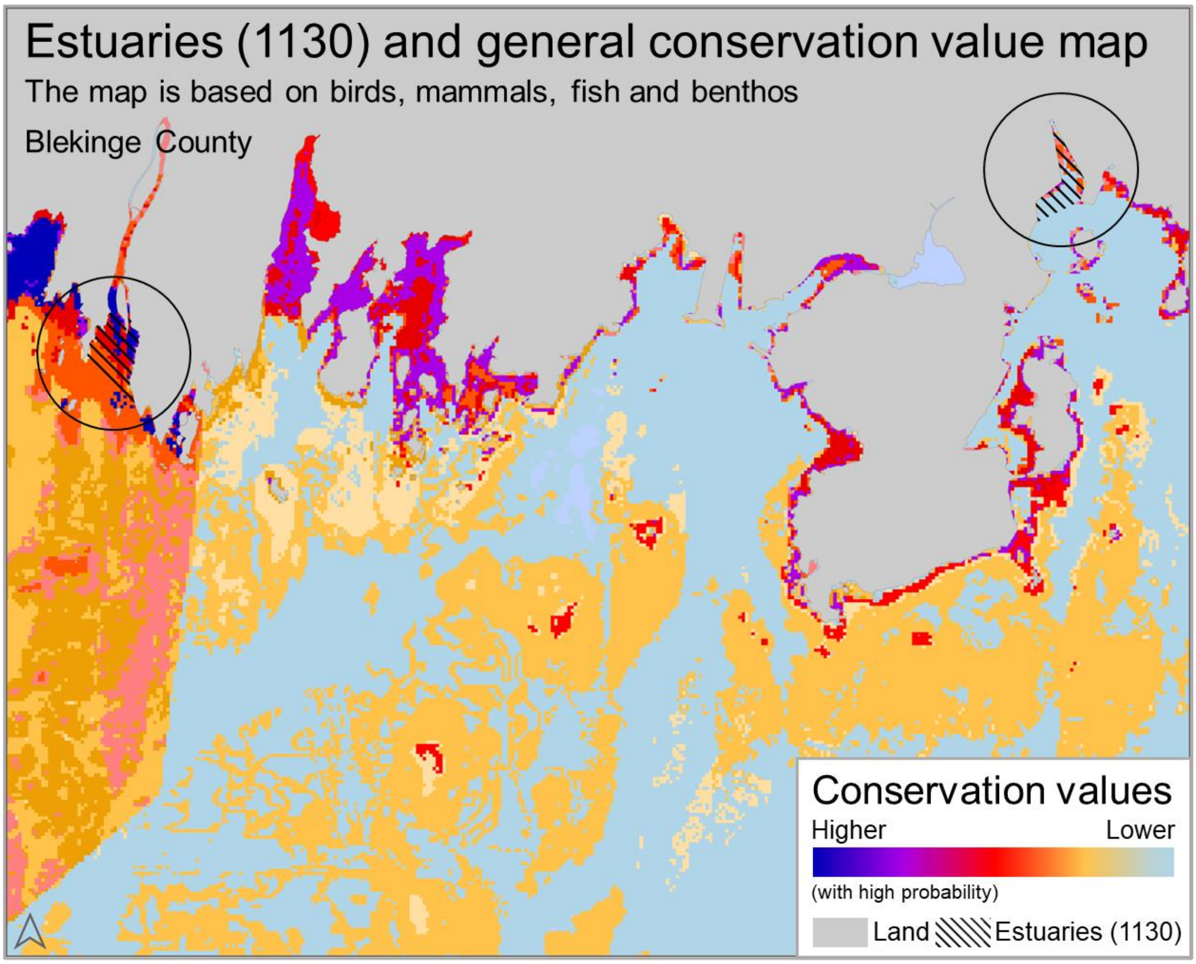


Figure 8. A general conservation value map of an area of southern Sweden (Blekinge) including two estuaries. The map is based on the occurrence of biotic ecosystem components and their assigned conservation value. The western estuary has a higher conservation value than the eastern estuary because of a higher probability of containing extensive areas of bladder wrack, and “meadows of tall underwater vascular plants” as well as providing an overwintering habitat for a range of bird species. The criteria *connectivity* has not been assessed in this map and could modify the values of the two estuaries. More information on how *general conservation value maps* are produced can be found in section 2.4.3.1.

2.3.2 *Conservation values linked to ecosystem components*

How complete are the guidelines for conservation value associated with ecosystem components?

Guidelines are complete and over 50 experts have compiled a first version of assessments made per sea area for several hundred ecosystem components.

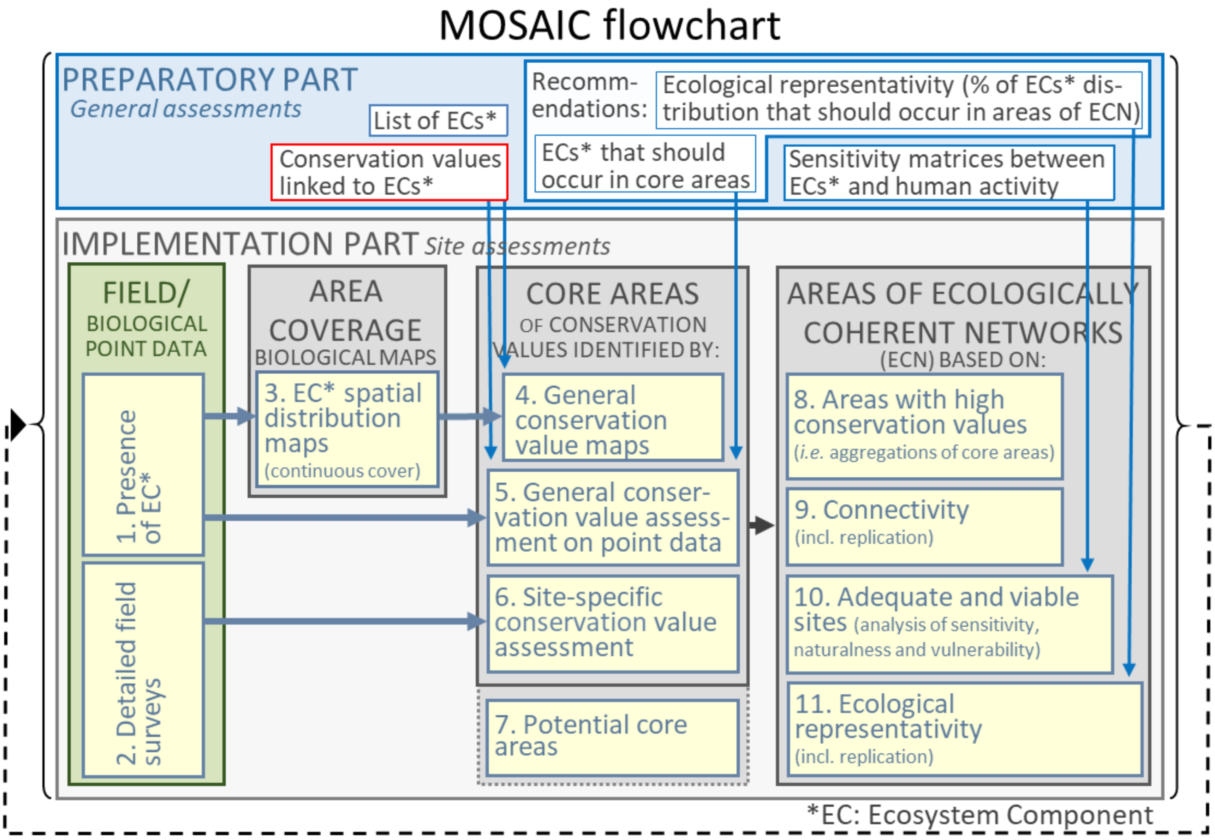


Figure 9. Flowchart showing the different parts and steps that comprise MOSAIC. The relevant section is highlighted in red.

When conservation values are linked to different ecosystem components, experts assess which conservation values different ecosystem component *generally* contribute to a location according to several criteria.

- Throughout MOSAIC, ecosystem components are defined independently from their location and are primarily biological. For example, an ecosystem component can be defined according to its coverage (such as "*Fucus* spp. 25-100 % coverage"). More information on the choice of ecosystem components can be found in section 2.3.1.
- By "*generally*" we mean the conservation value an ecosystem component usually contributes (for example if "*Fucus* spp. 25-100 % coverage" usually contributes to a high or low biodiversity relative to other ecosystem components in the sea area).

A points system is used to make it easier to compare and update assessments as new knowledge becomes available and according to environmental change. The points system also means that *general conservation value maps* are relatively easy to produce and update. Each assessment should be motivated, with references, according to a defined structure.

During phase 1, a group of experts[25], with the aid of scientific literature, assess the conservation value ecosystem components *generally* contribute according to several criteria (Table 1). The Swedish Agency for Marine and Water Management are responsible for coordinating phase 1 (Figure 6).

During phase 2, points are assigned to reflect the ecosystem component's local importance in relation to other parts of the sea area (Table 1). The Swedish Agency for Marine and Water Management suggest that this is coordinated (or carried out) by respective county administrative boards (Figure 6).

Figure 10 shows how the geographical assessments of phases 1 and 2 are separated and Figure 11 shows the division of sea areas.

The criteria focus on ecological/biological value and the value of ecosystem services provided (Table 1).

Table 1. An example of a points table where conservation values are linked to ecosystem components. Points are assigned according to the conservation values an ecosystem component *generally* contributes to a location. The structure and content are described in more detail in this section.

CONSERVATION VALUES LIKED TO ECOSYSTEM COMPONENTS

	Phase 1 – assessment per sea area (Baltic Proper)							Phase 2 – local regional assessment (Blekinge county)		
	Phase 1a – ecological/biological values (incl. indirect ES*)				Phase 1b – direct ecosystem services (ES)					
Ecosystem Component	Biological Diversity	Special importance for life history stages	Ecological function	Threat status	Provisioning ES*	Cultural ES*	Regulating ES*	Local importance (±3)	Total score, without threat status	Total score with threat status
Northern pike (*Esox lucius*): Recruitment area	2	8	8	0	1	4	4	0	27	27
Long-tailed duck (*Clangula hyemalis*): Wintering ground, Oct-Mar	1	8	4	8	0	4	0	2	19	27
Blue mussel bed (*Mytilus edulis*) 25-100% coverage, deeper than 30 m	4	0	4	0	0	1	4	0	13	13
Cladophora glomerata, single occurrences to 9% coverage	1	0	1	0	0	0	0	0	2	2
...	.	.	.	.	.	.	.	.	.	.
...	.	.	.	.	.	.	.	.	.	.

* ES = Ecosystem Services

[25] Researchers and other experts with local to national or global knowledge and a variety of ecological expertise (including on a wide range of marine organisms).

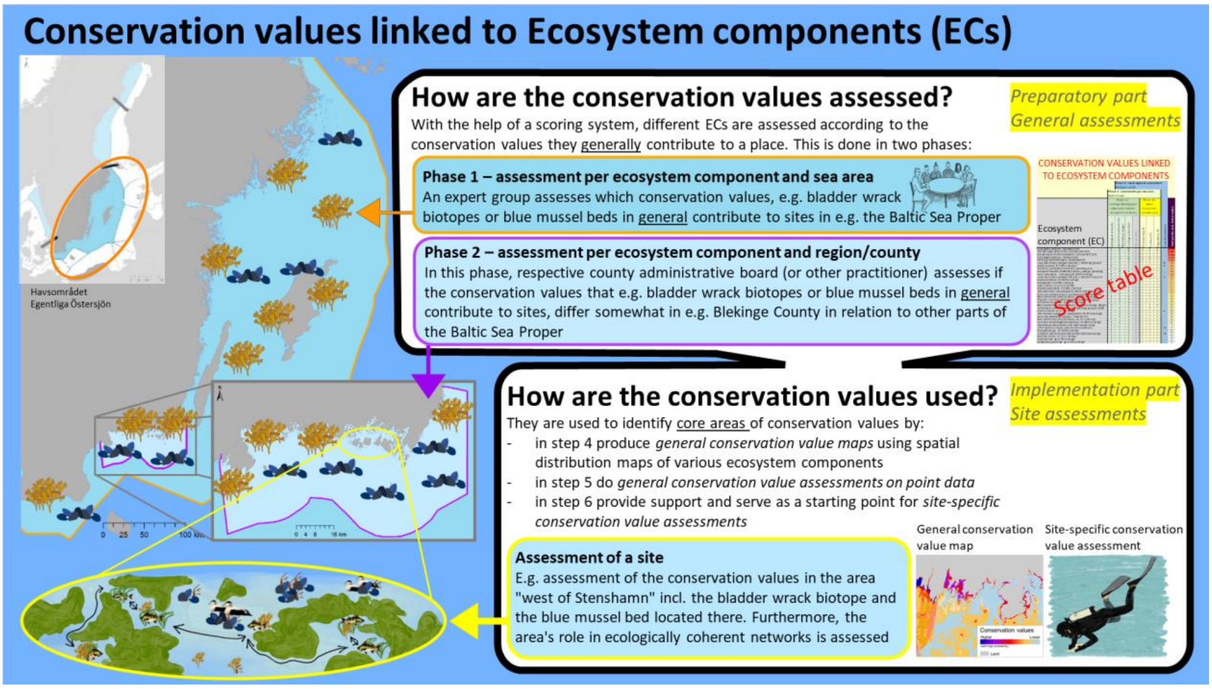


Figure 10. Assessments on the conservation value associated with ecosystem components are carried out in two phases. Phase 1 is a general assessment per sea area and is carried out by a group of experts coordinated by the Swedish Agency for Marine and Water Management. Phase 2 is a local assessment carried out by respective county administrative boards or other users. The assessments can then be used in MOSAIC's implementation part to identify *core areas* (locations with high conservation value; see section 2.4.3).

The purpose of assessing the conservation value ecosystem components *generally* contribute to an area is to systematically gather knowledge on, and prepare for geographical assessments of, conservation values by way of:

- landscape analyses. *General conservation maps* (step 4, section 2.4.3.1) show where high conservation value areas are likely to be found. They are produced using conservation value assessments together with spatial distribution maps on the *presence of ecosystem components*
- *general conservation value assessments on point data*[26] (step 5, section 2.4.3.2)
- *site-specific conservation value assessments* (step 6, section 2.4.3.3). Note, this should be viewed as a support and considered together with other site-specific assessments. The purpose is to minimize subjectivity.

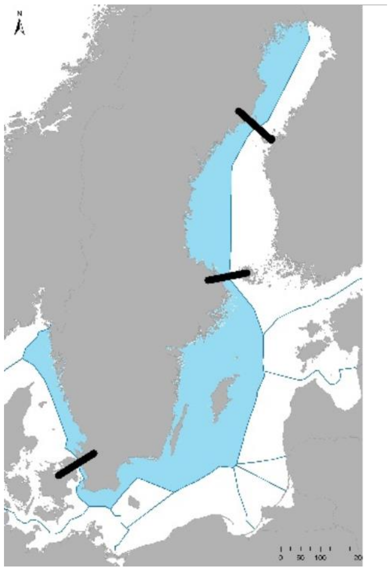


Figure 11. Division of the four sea areas (blue) for phase 1 assessments in MOSAIC. The sea areas are the Bothnian Bay, Bothnian Sea, Baltic Proper and Kattegat/Skagerrak.

[26] In this report point data refers to discrete data points (in contrast to continuous coverage data). Even data from transects, or that is spatially limited (such as from video surveys), are regarded as point data.

A few other examples of how ecosystem components and conservation values can be used (prior to spatial analyses) include:

- prioritizing ecosystem components for regional or national marine mapping
- identifying prioritized ecosystem components or habitats for actions and restoration
- identifying assessment of broad habitat types within the Marine Strategy Framework Directive
- prioritizing ecosystem components for protection according to their conservation value and management needs.

Assessments (ecosystem components and their conservation value points) and motivations should be available digitally (on a website) and allow for user comments in order to:

- increase transparency
- increase accessibility
- allow for comparisons and discussions between experts, users and other stakeholders.

The points system is semi-quantitative and not continuous (divided into categorical intervals 0, 1, 2, 4 and 8). Points should not be interpreted in economic terms and the full value is not assessed since only a few criteria are used.

It is important that assessments are based on the conservation value we currently know – or estimate – an ecosystem *generally* contributes to a location. In addition, it is important that assessments are made from a spatial perspective. For example, blue mussels are very important to ecosystems, but because they are common over sea areas their loss from a particular location only results in a limited loss of conservation value generally. If blue mussels were to decline drastically then the value of locations with blue mussels would increase and assessments would be revised during the next management cycle.

As mentioned previously, it is important that an ecosystem component is not over or under valued because its value is also relative to the other ecosystem components. To avoid over or underestimating an ecosystem component, assessments should be made according to the component in its most commonly found condition and contribution to the ecosystem. By most commonly found condition we mean how the ecosystem component is usually characterized according to its given definition. The most common condition is often unknown and qualified estimates must be made - especially for ecosystem components with highly variable conservation values.

A recurring question is if it is appropriate to compare different types of ecosystem components and their conservation value with each other. For example, is it fair to compare the conservation value of a habitat with the conservation value that a single species contributes to a location by its presence? Comparisons of this sort are appropriate in MOSAIC because the purpose of the tool is to prioritize areas for management. A habitat with a high coverage of *Fucus* receives more points than single/sporadic occurrence/s of *Fucus* because of the higher conservation value associated with *Fucus* biotopes. Spatial management should prioritize areas with a high coverage of *Fucus* over areas with sporadic occurrences (given that the areas are otherwise equal). However, as with all management it is important not to *only* prioritize valuable components – MOSAIC avoids this by including *ecological representativity* in the implementation part (See section 2.4.4.4).

2.3.2.1 Phase 1 – assessments by sea area

For each sea area, a group of experts (coordinated by the Swedish Agency for Marine and Water Management) assess the conservation values that different ecosystem components *generally* contribute (Figure 11) according to a set of criteria. The assessments per sea area can be found in respective tables and are often referred to as ecosystem component lists[27].

Since the assessments are carried out by a group of experts it is not necessary to read this section unless you are part of the expert group or are interested in how the assessments are done.

Criteria in phase 1 are divided into two groups, phase 1a and phase 1b (Table 1). In phase 1a the expert group assesses the conservation value according to criteria related to ecological/biological values (including indirect ecosystem services). In phase 1b assessments are made according to criteria related to direct ecosystem services.

Indirect ecosystem services are primarily supporting, but also include *regulating ecosystem services* (Millennium Ecosystem Assessment 2005; UK National Ecosystem Assessment 2011; Ahtiainen and Öhman 2014). They are often difficult to differentiate from ecological/biological values because they are often one and the same. Biodiversity, for example, can be counted as an indirect ecosystem service and has its own ecological/biological value. For that reason, indirect ecosystem services are included in criteria for phase 1a assessments. Direct ecosystem services are *provisioning*, *cultural* and to some extent *regulating* services (Millenium Ecosystem Assessment 2005; UK National Ecosystem Assessment 2011; Ahtiainen and Öhman 2014) (Figure 12). Direct ecosystem services are often easier to separate and identify than indirect ecosystem services, partly because they are closely associated with ecosystem goods and benefits and partly because indirect ecosystem components are often comprised of several complex interactions (Fisher et al. 2009).

Figure 12. The four categories “supporting, regulating, cultural and provisioning” (Millenium Ecosystem Assessment 2005) of ecosystem services divided into indirect/intermediate and direct/final ecosystem services (Fisher and Turner 2008; UK NEA 2011; Ahtiainen and Ohman 2014). Figure based on Ahtiainen and Öhman (2014).

[27] A first version of the *list of ecosystem components* and the conservation value they represent can be found in an Excel document, *MOSAIC – ecosystem component lists and conservation values, version 1*, that can be downloaded from the Swedish Agency for Marine and Water Management website. The lists have been compiled by over 50 experts within several working groups and workshops. The lists are divided into the Bothnian Bay, Bothnian Sea, Baltic Proper and Kattegat/Skagerrak sea areas because of broad differences in the species composition and ecosystems between them.

By allocating points for ecological/biological values (including indirect ecosystem services) separately from direct ecosystem services it is possible to investigate these on their own. However, we strongly advise against evaluations using only direct ecosystem services because they are entirely reliant on indirect ecosystem services. Spatial management relating to protected areas focusses on ecological/biological value, especially conservation status, whilst work relating to green infrastructure should also include ecosystem services.

Ecosystem services

Similar to Fisher and Turner (2008) and Naturvårdsverket (2014), MOSAIC considers ecosystem services as ecological processes that produce goods and services that benefit humans. “Ecological processes” are processes that contain one or more biological factors – a beautiful sunset over a blue horizon is not an ecosystem service because ecological processes are not needed to produce the phenomenon. However, the occurrence of fish in the sea is an ecosystem service.

Ecosystem services can be categorized in several ways. In the international classification system Millennium Ecosystem Assessment (2005) they are divided into supporting, regulating, cultural and provisioning services. Categorizing is done based on how ecosystem services are used by or benefit humans.

Ecosystem services can also be categorized as indirect (also called intermediate) and direct (also called final) ecosystem services (Fisher and Turner 2008). This division focuses on the link between ecosystems and human well-being. An example: the growth of perch is a direct ecosystem service because it provides goods and benefits directly (angling and food). Chironomids provide food for perch and as such an indirect ecosystem service to humans. Some ecosystem services can be both direct and indirect. For example, perch are food for pike which are prized for angling and therefore perch growth can be considered both as an indirect and a direct ecosystem service.

2.3.2.1.1 Phase 1A – CRITERIA FOR ECOLOGICAL/BIOLOGICAL VALUE (INCLUDING INDIRECT ECOSYSTEM SERVICES)

CBD's scientific criteria for Ecologically or Biologically Significant Marine Areas (EBSA) are:

1) Uniqueness or Rarity
2) Special importance for life-history stages of species
3) Importance for threatened, endangered or declining species and/or habitats
4) Vulnerability, Fragility, Sensitivity, or Slow recovery
5) Biological Productivity
6) Biological diversity
7) Naturalness

Annex 1, decision IX/ 20, CBD 2008

Criteria are used to assess the conservation value ecosystem components generally contribute – by sea area and unrelated to specific locations. The criteria are based on those found in the UN Convention on Biological Diversity (CBD) for determining ecologically and biologically important areas - EBSAs (Ecologically or Biologically Significant Marine Areas) (Annex 1, decision IX/ 20, CBD 2008 (see fact box above).

The EBSA criteria included in MOSAIC's phase 1a assessments of ecological/biological value (including indirect ecosystem services) are *biological diversity* (EBSA criterion nr 6), s*pecial importance for life-history stages* (EBSA criterion nr 2) and *threat status* (EBSA criterion nr 3). *threat status* is a criterion that can be included or excluded as desired (more information in this section under *threat status*).

EBSA criteria are also included in other parts of MOSAIC, especially for *site-specific conservation value assessments*, section 2.4.3.3.

Even if criteria from the CBD are included, methods for assessing them differ slightly because in phase 1a of MOSAIC experts assess the conservation value ecosystem components generally contribute to a place, they do not assess the conservation value of a specific location.

The criterion *Ecological function* is included in MOSAIC's criteria for ecological/biological value (including indirect ecosystem services). This criterion has been used by others when assessing conservation value, see for example Wikström et al. (2013), Schreiber and Haglund (2013) and Fyhr et al. (2015). The criterion assesses the importance of the ecosystem component to the marine environment as a whole and includes qualities not covered by the other criteria in phase 1a.

Criteria in phase 1a for ecological/biological value (including indirect ecosystem services) include:

- *Biological diversity*
- *Special importance for life-history stages*
- *Ecological function*, and
- (*Threat status* - can be included if desired)

Each criterion is awarded 8, 4, 2 or 0 points[28] (Figure 13) per ecosystem component assessed. The exceptions are *Biological diversity* and *Ecological function* which can also be awarded 1 point because all ecosystem components contribute to biodiversity and ecological function – if the ecosystem component does not include an invasive alien species[29].

The points for each criterion are summed for each ecosystem component to give a collective conservation value assessment for phase 1a.

It is our opinion that indirect ecosystem services are adequately assessed using the criteria above. *Biological diversity*, *special importance to life-history* and *ecological function* are all criteria that can be classed as supporting ecosystem services. *Ecological function* can also be classed as a regulatory ecosystem service.

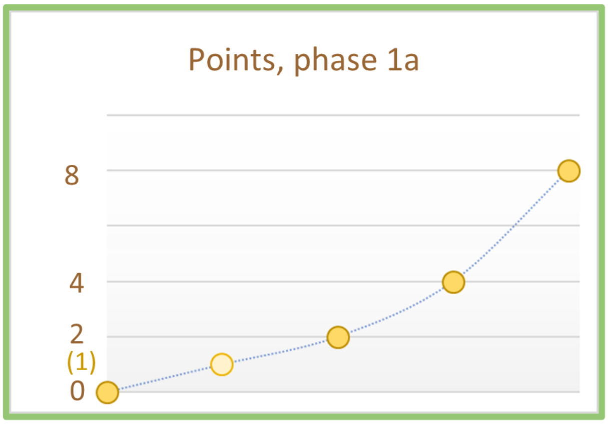


Figure 13. The number of points that can be awarded for each criterion in phase 1a, ecological/biological value (including indirect ecosystem services). In phase 1a, 0, 2, 4 and 8 points can be awarded to all criteria. The criteria *Biological diversity* and *Ecological function* can also be awarded 1 point. The non-linear increase is to account for ecosystem components that contain/contribute a high conservation values.

Biological diversity

The criterion *Biological diversity* is included to assess the value an ecosystem component generally contributes to the diversity of species and populations – or α-diversity (Whittaker 1960, 1972). In order to be awarded high points for this criterion the ecosystem component needs to provide a habitat for organisms. The criterion includes ecological/biological value and indirect (supporting) ecosystem services.

[28] Information on how the points system was developed can be found in section 2.3.2.5.1.

[29] This report defines invasive alien species according to the Regulation (EU) No 1143/2014 of the European Parliament and of the Council of 22 October 2014 on the prevention and management of the introduction and spread of invasive alien species – species that are introduced by human activities and that threaten the biodiversity ecosystem services of the host ecosystem (European Parliament 2014). Species that are alien but not considered invasive may be awarded points on a case-by-case basis.

Points should be awarded based on what is considered high or low biodiversity in the sea area assessed. Different ecosystem components within a sea area are compared with each other to determine which of them should receive high or low points.

The criterion does not account for *Biological diversity* across different habitats or regions (β-diversity) or over larger geographical areas (γ-diversity; Whittaker 1960, 1972). β- and γ-diversity are accounted for by the criterion *ecological representativity* in MOSAIC's implementation part (more information on how MOSAIC includes biodiversity and how it can be further incorporated in future versions can be found in section 3.1).

Guidelines on how the criterion *Biological diversity* can be assessed are found in Table 2, and examples are provided in Table 3.

Table 2. Guidelines for assessing the criterion *Biological diversity* in phase 1a. Assessments are based on an ecosystem components *general* contribution to species and population biodiversity (α-diversity).

Phase 1 - assessment per sea area Phase 1a - criteria for ecological/biological value (including indirect ecosystem services) Biological diversity	
Points	
8	The EC contributes to a **high** biological diversity within the assessed sea area
4	The EC contributes to a **relatively high** biological diverstity within the assessed sea area
2	The EC makes a **limited contribution** to biological diversity within the assessed sea area
1	The EC only contributes to biological diversity through its own presence and does not provide a habitat for other species
0	Invasive alien species

Table 3. Explanations for some of the assessments that have been carried out for the criterion *Biological diversity* in the Baltic Proper. See Table 2 for guidelines on how the criterion should be assessed.

Ecosystem component (EC)	Phase 1 - assessment per sea area (Baltic Proper) Phase 1a - criteria for ecological/biological value (including indirect ecosystem services) Biological diversity Points		Assessment reliability
Zostera marina 25-100% coverage	8	Zostera marina communities in the Baltic have been shown to have a high number of epifaunal species (Möller et al. 2014, Boström and Bonsdorff 1997), and a diverse infauna (Boström and Bonsdorff 1997). Information on species specific biodiversity is largely lacking for the majority of submerged vascular plants and the assessment is based on the fact that soft substrates with vascular plants generally have a higher species diversity (higher species diversity of animals than substrates without vegetation: Heck et al. 1989, Edgar et al 1994, Boström and Bonsdorff 1997). Epifaunal species diversity is positively correlated with algal biomass (Heck and Wetstone 1977; Stone and Lewis 1985) and the highest coverage receives higher points.	Moderate
Fucus vesiculosus 25-100% coverage	8	Studies on epifauna show that diversity does not necessarily differ between Fucus and filamentous algae (such as Cladophera) (Wikström and Kautsky 2006, Kraufvelin and Salovius 2004) - however, Fucus also provides a secondary hard substrate for sessile epifauna and several epiphytic algae.	Moderate
Chara tomentosa 10-24% coverage	4	Chara spp. have a high abundance of invertebrates, mostly herbivores, and are a favoured habitat for many other macro zoobenthos (Orav et al. 2000). Assessments for charophytes are based on this. Epifaunal species diversity have been found to be positively correlated with plant biomass (Heck and Wetstone 1977; Stone and Lewis 1985), and more points are given to components with a higher % coverage.	Moderate
Furcellaria lumbricalis 25-100% coverage	4	Few "meaty" algal species on hard substrates in the area, and thus probably contribute to biodiversity. "Meaty" algal species often have a high diversity of epifauna and epiphytes (Kraufvelin and Salovius 2004; Martin et al. 2013). The reason that these algae receive higher points for biological diversity than other species with a similar coverage is because of their lack of replaceability.	Moderate
Mytilus edulis 25-100% coverage, shallower than 30 m	4	Blue mussel banks have a high biodiversity of associated fauna and flora (Norling and Kautsky 2008). Current assessment is 4 p.	Moderate
Low growing underwater vascular plant meadows 10-24% coverage	2	Species diversity of epifauna has been positively correlated with plant biomass (Heck and Wetstone 1977; Stoner and Lewis 1985), low growing vascular plants achieve higher biomass at higher densities.	Moderate
Fourhorn sculpin (*Myoxocephalus quadricornis*): Spawning area	1	Contributes to some extent to an ecosystem balance in vegetated areas (habitat for a large number of species) by reducing algal growth and increasing visibility. Is more important further north where it is the only commonly occuring benthic predatory fish.	Not assessed
Long-tailed duck (*Clangula hyemalis*): Wintering ground (October - March)	1	Bird components only receive 1 point for biological diversity because they concern single species and not structures beneficial to other species.	Not assessed
European flounder (*Platichthys flesus*): Growth area	1	Can potentially regulate bottom fauna communities. Potential competition with small cod.	Not assessed

Special importance for life-history stages

[This section will be revised in future versions of MOSAIC. For the translation of MOSAIC - version 1 - the changes to come are marked using track changes]

The criterion *special importance for life-history stages* is included to assess if ecosystem components are important for a critical stage of one of more mobile/migratory species[30]. It might include ecosystem components important for the reproduction, growth, foraging or resting of birds, mammals or fish. Experts must determine how limiting the ecosystem component is for one or more mobile/migrating species in order to determine its conservation value. For example, a habitat that is important for fish recruitment receives more points if it is rare and appears to be a limiting factor compared to habitats that are common. In other words, rare ecosystem components – that are important for a critical life-history stage – are more important and should be prioritized within spatial management. Ecosystem components that are important for a critical life-history stage are often indirect (supporting) ecosystem services but can also include direct ecosystem services.

~~To provide adequate support for spatial management, an ecosystem component must have a high spatial concurrence with an area that is considered important for a life-history stage (Figure 14). Ecosystem components with a very high spatial overlap are naturally those that are, according to their definition, important for a particular life-history stage (i.e., spawning area for fish or wintering area for birds). An example of an ecosystem component that is important for a life-history stage (perch fry) but which has a spatial overlap that is too diffuse to be useful for spatial management is "areas with chironomid larvae". The ecosystem component occurs even where it is probably less important for perch growth (Figure 15).~~

Table 2 and Figure 14 provide guidelines for how the criterion should be assessed and examples are provided in Table 5.

[30] Mobile/migratory species are primarily birds, mammals and fish – animals that move to a greater extent between areas/habitats.

Table 4. Guidelines for assessment of the criterion *special importance for life-history stages*. The assessment is based ~~partly~~ on the ecosystem component's (EC) importance for critical life-history stages and ~~partly on the degree of spatial overlap an ecosystem component has with the life-history stage it is associated with. The ecosystem component's importance is also based on~~ whether it is limiting to one or more mobile/migratory species. ~~Figure 14 illustrates how these factors are balanced in the assessment of *special importance for life-history stages*~~. [This table will be revised in future versions of MOSAIC. For the translation of MOSAIC - version 1 - the changes to come are marked using track changes]

Phase 1 - assessment per sea area **Phase 1a - criteria for ecological/biological value (including indirect ecosystem services)** Special importance for life history stages			
Points		ECs importance for one or more mobile species* by being important to a critical life history stage or by constitute a critical life history stage in themselves** *Importance is based on whether the availability of the EC limits one or more species*	~~ECs spatial overlap with critical life history stage***~~
8		**High** importance, **probably** limits populations	~~Very high~~
4	~~Alt. 1~~	~~**High** importance, **probably** limits populations~~	~~Relatively high~~
	~~Alt. 2~~	**Relatively high** importance, **possibly** limits populations	~~Very high~~
2		~~**Relatively high**~~ **Moderate** importance, ~~**possibly**~~ **can** limit~~s~~ populations	~~Relatively high~~
~~1~~		1 point cannot be assigned for this criterion	
0	Alt. 2	**No** or **very low** importance, **probably does not** limit populations	~~Does not effect the outcome~~
	Alt. 1	Does not affect the outcome	~~None or low~~

* Primarily birds, mammals and fish - species that often move between areas/habitats.

** Examples of ECs that constitute a critical stage in themselves are spawning areas for fish and wintering areas for birds.

~~*** Very high if the EC is itself a critical life history stage.~~

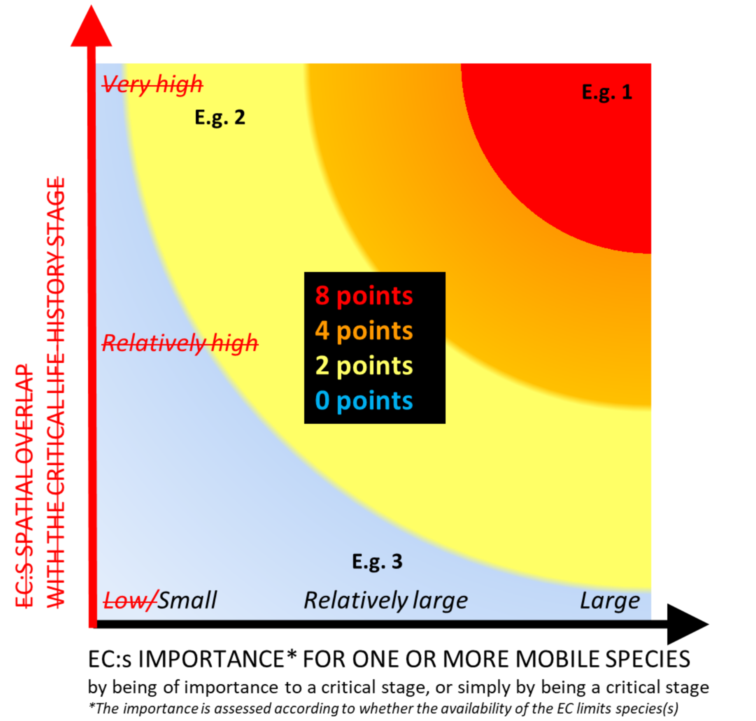


Figure 14. Schematic showing how assessment of the criterion *special important for life-history stages* is carried out. The criterion should assess the importance of an ecosystem component to critical life-history stages in one or more mobile species. The ecosystem component might also be a critical life-history stage (such as spawning are for fish or wintering area for birds). The assessment also considers if the ecosystem component is limiting for one or more mobile/migratory species. The more limiting an ecosystem component is the more valuable locations are that contain it. Because the tool is for spatial management a high spatial overlap is required between the ecosystem component and its associated life-history stage. The following three examples show how assessments can be carried out (note the examples are hypothetical and should only be considered as a guide).

Example 1: The ecosystem component "Cod: spawning area" assessed for the Baltic Proper. Given the assumption that it is – apart from overfishing – a lack of spawning habitat that limits cod populations, the ecosystem component "Cod: spawning area" is considered highly important (far to the right on the x-axis). Because the ecosystem component is itself a critical life-history stage its spatial overlap is 100 percent (high up on the y-axis). The ecosystem component receives 8 points.

Example 2: The ecosystem component "Cod: growth area" assessed for the Baltic Proper. If the assumption is made that there is adequate habitat for cod growth and that it is not limiting to the species, then the assessment is that the ecosystem component is of little importance to a critical life-history stage (on the left side of the x-axis). Because the ecosystem component is itself a life-history stage its spatial overlap is 100 percent (high up on the y-axis). The ecosystem component receives 2 points. This assumption may not be correct and should only be seen as an example of how assessments are carried out.

Example 3: The ecosystem component "Occurrence of chironomid larvae" assessed for the Baltic Proper. If the assumption is made that the "Occurrence of chironomid larvae" is relatively important for perch fry during a critical life-history stage, then the example occurs in the middle of the x-axis. As demonstrated in Figure 15, there is only a small overlap between "Occurrence of chironomid larvae" and "Perch: recruitment area". Chironomid larvae also occur in habitats that are not suitable for perch fry. The spatial overlap is assessed as low (low down on the y-axis). The ecosystem component receives 0 points.

More examples can be found in Table 5.

[NOTE: The analysis of spatial overlap will be removed, and the figure will be revised in future versions. Points will only be awarded according to the horizontal access.]

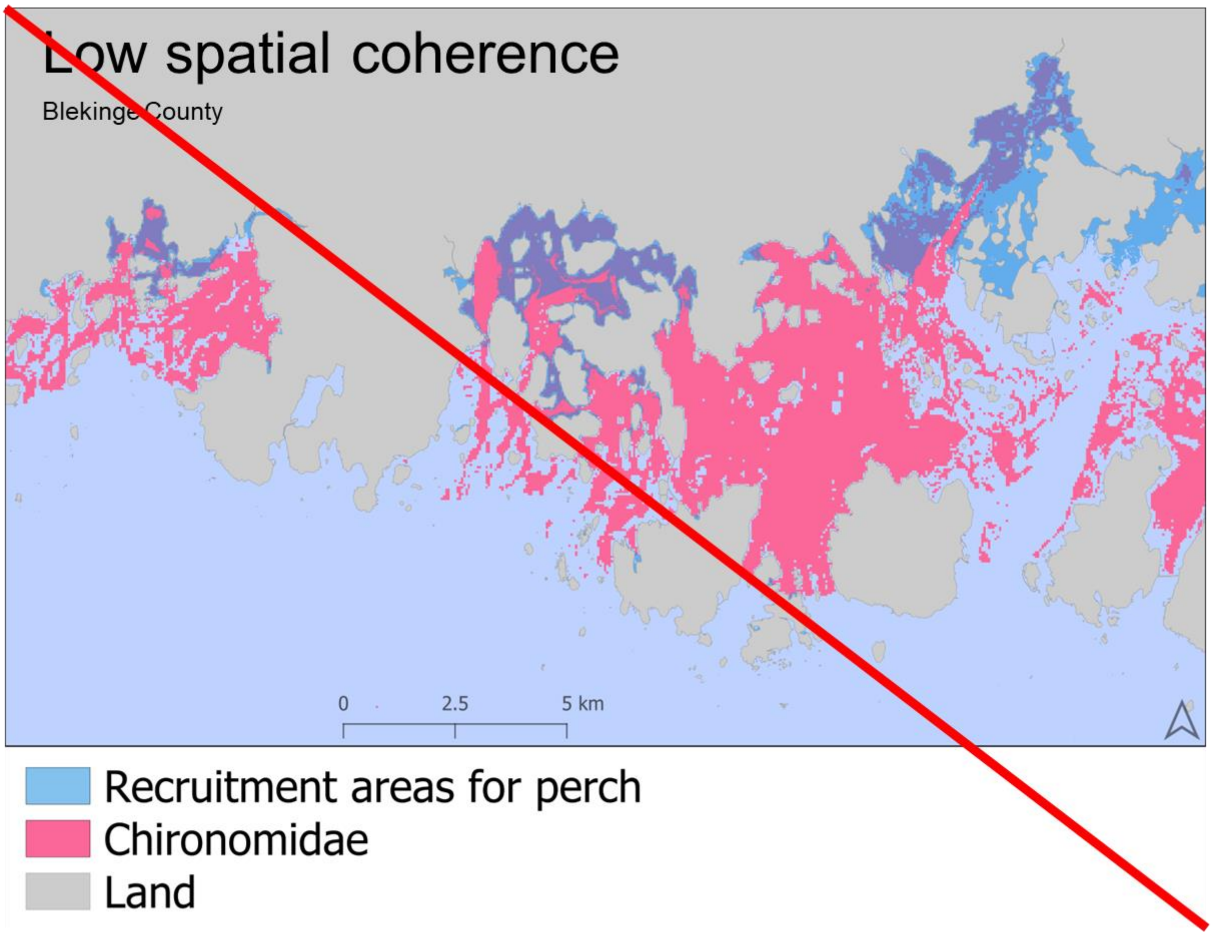


Figure 15. The map indicates a low spatial overlap between occurrence of chironomid larvae and recruitment areas for perch. The purple areas are where chironomid larvae and perch recruitment are found together.

Table 5. Examples of assessments for the criterion *special important for life-history stages* carried out for the Baltic Proper. See Table 4 for information on how assessments are carried out. [This table will be revised in future versions of MOSAIC. For the translation of MOSAIC - version 1 - the changes to come are marked using track changes]

Ecosystem component (EC)	Phase 1 - assessment per sea area (Baltic Proper) Phase 1a - criteria for ecological/biological value (including indirect ecosystem services) Special importance for life history stages Points	ECs importance for one or more mobile species* by being important to a critical life history stage or by constitute a critical life history stage in themselves** *Importance is based on whether the availability of the EC limits one or more species*	~~ECs spatial overlap with critical life history stage***~~	Balanced assessment	Assessment reliability
Cod (*Gadus morhua*): Spawning area	8	Cod spawning is probably only successful in 3 areas of the Baltic Sea where the water is deep enough to provide a salinity of 15 - 16 ppt. The critical stage depends on a salinity that is high enough to prevent fertilized eggs from sinking to the bottom where they die due to hypoxia / anoxia.	~~High~~	8p; Spawning areas are strongly limited and very important for maintaining the population.	High
Long-tailed duck (*Clangula hyemalis*): Wintering ground (October - March)	8	A large part of the global population is found in the Baltic Proper and these wintering areas are particularly important.	~~Very high~~		Not assessed
Chara tomentosa 25-100% coverage	4	The abundance of juvenile fish that favour vegetated areas (such as pike) has been shown to be positively correlated with coverage of Chara tomentosa and Stuckenia pectinate, which can be classified as tall underwater plants (Sandström et al. 2005). The abundance of pike fry has also been shown to be positively correlated with vegetation height (Sandström et al. 2005), and that young of year perch and cyprinids prefer vegetated areas (Sandström och Karås 2002). I brist på specifik artinformation används detta som argumentation för att högre undervattensväxter, samt undervattensdelarna av emergent vegetation, förefaller vara viktiga uppväxtområden för juvenil fisk.	~~Often probably high?~~	Receives a high score because several fish species that use vegetated areas extensively appear to prefer middle to high levels of vegetative coverage (Urho et al. 1990).	Moderate
Zostera marina 25-100% coverage	4	The abundance of juvenile fish that favour vegetated areas (such as pike) has been shown to be positively correlated with coverage of Chara tomentosa and Stuckenia pectinate, which can be classified as tall underwater plants (Sandström et al. 2005). The abundance of pike fry has also been shown to be positively correlated with vegetation height (Sandström et al. 2005), and that young of year perch and cyprinids prefer vegetated areas (Sandström och Karås 2002). I brist på specifik artinformation används detta som argumentation för att högre undervattensväxter, samt undervattensdelarna av emergent vegetation, förefaller vara viktiga uppväxtområden för juvenil fisk.	~~Often probably high?~~	Receives a high score because several fish species that use vegetated areas extensively appear to prefer middle to high levels of vegetative coverage (Urho et al. 1990).	Moderate
Furcellaria lumbricalis 25-100% coverage	2	In Lithuania, Furcellaria is the primary substrate used by herring to attach their roe (Šaškov et al. 2014).	~~Some spatial overlap?~~	2p; the EC has a significance for a critical stage in another species - although it is less likely to limit that species, it has some spatial coherence. Even if sturgeon use Furcellaria as a substrate for their roe (not yet documented in Swedish waters), we assume that not all sites with Furcellaria are used	Moderate
Zostera marina 10-24% coverage	2	The abundance of juvenile fish that favour vegetated areas (such as pike) has been shown to be positively correlated with coverage of Chara tomentosa and Stuckenia pectinate, which can be classified as tall underwater plants (Sandström et al. 2005). The abundance of pike fry has also been shown to be positively correlated with vegetation height (Sandström et al. 2005), and that young of year perch and cyprinids prefer vegetated areas (Sandström och Karås 2002). I brist på specifik artinformation används detta som argumentation för att högre undervattensväxter, samt undervattensdelarna av emergent vegetation, förefaller vara viktiga uppväxtområden för juvenil fisk.	~~Often probably high?~~	Receives points because several fish species that use vegetated areas extensively appear to prefer middle to high levels of vegetative coverage (Urho et al. 1990).	Moderate
Mytilus edulis 25-100% coverage, shallower than 30 m (biogenic reef, subtype of reef 1170 habitat type)	2	Important source of food for critical life stages of eider, Eurasian oystercatcher and long-tailed duck (Varennes et al. 2015; Bustnes 1998; Zydelis och Ruskyte 2005; Öst 2000:, Öst och Kilpi 1997; Custard et al. 1987).	~~Relatively high spatial overlap~~	2p; the EC has a significance for critical stages in other species - but since there is low spatial coherence the EC only receives 2p. However, the assessment is uncertain because, amongst other things, of its important function for wintering birds.	Moderate
Fucus vesiculosus 25-100% coverage	2	Fucus vesiculosus can be used as a substrate for perch spawning as depths greater than 0,5 m (Sickars et al. 2010). Studies from the west coast of Sweden have shown that Fucus vesiculosus on soft sediments is a preferred habitat for juvenile cod (Borg et al. 1997).	~~Relatively high?~~	Points awarded because the species is used as a spawning substrate / area.	Moderate
Fourhorn sculpin (*Myoxocephalus quadricornis*): Spawning area	2	Spawning occurs in shallow areas; males guard the roe for 1-3 months.	~~Low, can spawn over different sediments and probably~~	Low score but little information.	Low
Transport and erosional environment with macroscopic fauna	0	Provide an important resource such as nursery areas for many predators, primarily benthic foraging fish (2p) and spawning habitat for several fish species (2) but are common and so reduced to 0p.	~~Relatively high/ very high spatial overlap with nursery areas for benthic foraging fish.~~		Moderate

* Primarily birds, mammals and fish - species that often move between areas/habitats.
** Examples of ECs that constitute a critical stage in themselves are spawning areas for fish and wintering areas for birds.
~~*** Very high if the EC is itself a critical life history stage.~~

Ecological function

The criterion *Ecological function* is included to assess if an ecosystem component provides important functions (additional to previous criteria) from a holistic ecological perspective. In other words, how important they are for the survival of other species and the resilience of the ecosystem. Within this criterion, many of the indirect ecosystem services (supporting and some regulating ecosystem services) are included. Ecological function can, for example, relate to whether a component contributes food or habitat for other species, provides an important top-down regulation, has a significant water purification or filtering capacity or regulates important water or sediment processes such as oxygenation or sediment binding. An example is the importance of blue mussels to ecosystems through their filtering activities and as an important food source for birds and fish. The assessment also considers whether there are other ecosystem components with a similar potential/function (complementarity species).

The criterion can be compared to the term keystone species. A keystone species is a species that has a disproportionately large importance for the survival of other species in an ecosystem (Paine 1995). When identifying HELCOM MPA's (marine protected areas), keystone species are defined as species important for the maintenance of an ecosystem's resilience[31]. In MOSAIC we also assess the importance of other ecosystem components such as habitats (i.e., not restricted to species).

It is important that the criterion does not include the values already covered under the previous criteria: *biological diversity* and *special importance to life-history stages*[32]. For example, the ecosystem component "Cod: spawning area" has already been awarded points for its role in supporting the reproduction of a species under the criterion *special important for life-history stages* - additional points cannot be given under *ecological function* for the same trait. However, it can receive additional points under *ecological function* for its role in supplying more top predators to the pelagic zone. If we assume that roach do not represent a key function which (at the time of assessment) is vulnerable or limited, then "Roach: spawning area" will not be awarded additional points under *ecological function*.

> *Ecological function* = importance for the ecosystem as a whole – minus points already awarded under the criterion *biological diversity* – minus points already awarded under the criterion *special importance for life-history stages*

Table 6 and Figure 16 provide guidelines for how the criterion should be assessed and Table 7 provides assessment examples.

[31] https://helcom.fi/action-areas/marine-protected-areas/Background%20of%20HELCOM%20MPAs/selection-criteria (2019-11-04)

[32] Note that the "do not assess values contained in previous criteria" rule is only relevant when assessing ecological function. It does not apply to the assessment of direct ecosystem services (described later in the report). If a trait is important from an ecological/biological *and* direct ecosystem service perspective the ecosystem component can be awarded "plus points" under direct ecosystem services.

Table 6. Guidelines for the assessment of the criterion ecological function. Assessments are based on the importance of the ecosystem component's function, its replaceability and its occurrence (potential and actual). Figure 16 illustrates how the criterion is assessed.

Phase 1 - assessment per sea area

Phase 1a - criteria for ecological/biological value (including indirect ecosystem services)

Ecological function

Points		Importance of function provided	Replaceability	Occurence (potential/actual)	
8	Alt. 1	**Large**	Low replaceability	Much lower than potential	
	Alt. 2	**Large**	Low replaceability	Lower than potential	
	Alt. 3	**Large**	Relatively low replaceability	Much lower than potential	
4	Alt. 1	**Large**	Low replaceability	Equal to potential	
	Alt. 2	**Large**	Relatively low replaceability	Lower than potential	
	Alt. 3	**Large**	Relatively low replaceability	Equal to potential	
	Alt. 4	**Relatively large**	Low replaceability	Much lower than potential	
	Alt. 5	**Relatively large**	Low replaceability	Lower than potential	
	Alt. 6	**Relatively large**	Relatively low replaceability	Much lower than potential	
2	Alt. 1	**Large**	Replaceable	Does not affect the outcome	*
	Alt. 2	**Relatively large**	Low replaceability	Equal to potential	
	Alt. 3	**Relatively large**	Relatively low replaceability	Lower than potential	
	Alt. 4	**Relatively large**	Relatively low replaceability	Equal to potential	
	Alt. 5	**Relatively large**	Replaceable	Much lower than potential	*
1	Alt. 1	**Relatively large**	Replaceable	Lower than potential	*
	Alt. 2	**Relatively large**	Replaceable	Equal to potential	*
	Alt. 3	**Small**	Does not affect the outcome	Does not affect the outcome	
0		Invasive alien species			

Comment

If the ecosystem component (EC), by definition, is of *special importance for life history stages* of one or more species - such as spawning or nesting areas - it might be relevant to assess *ecological function* for the species that the EC is important for, and not for the EC itself. However, there must be a strong association between the occurrence of the EC and presence of the species that is assessed. In other words the EC should probably be limiting for the species.

Example: If one assumes that the EC "Cod: spawning area" is limiting for adult cod then the points allocated to the EC can be assessed according to adult cods' *ecological function* . However, the EC "Cod: recruitment area" is not assumed to strongly limit the number of adult cod and the association between the EC and the species is not strong. This EC should not be assessed directly from adult cods' *ecological function* and points should be reduced or not awarded.

* Less likely combination

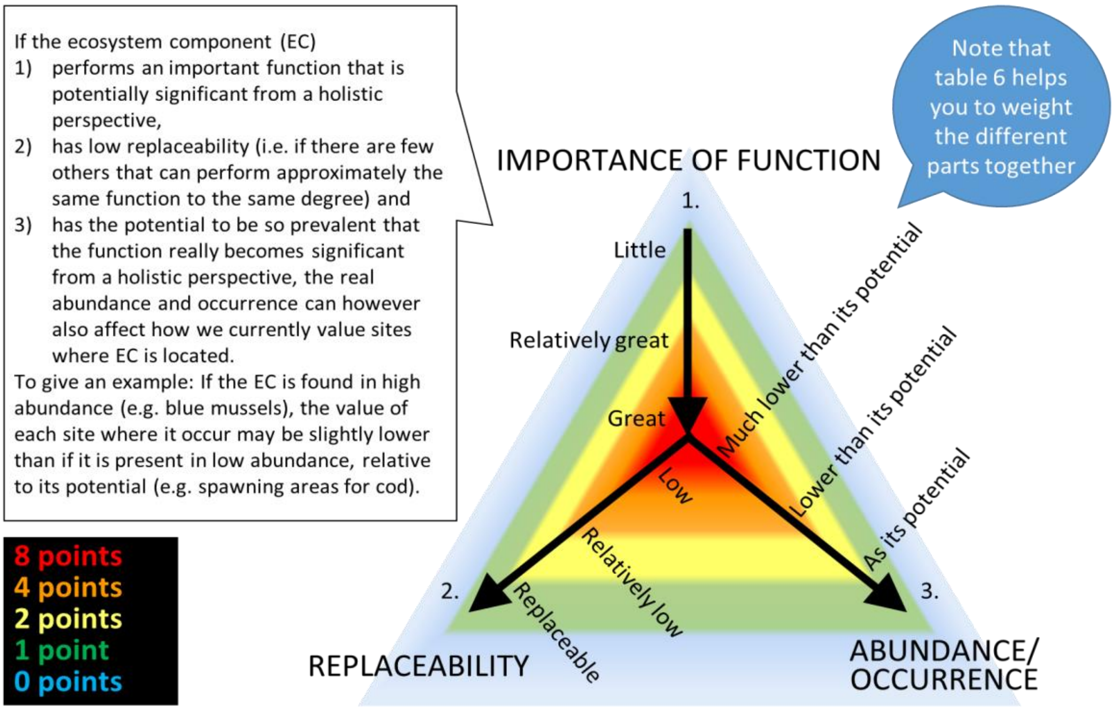


Figure 16. Schematic showing the three criteria on which “ecological function” is assessed: 1) importance of function, 2) replaceability and 3) abundance / occurrence (potential and actual). The following three examples show how assessments can be carried out (note the examples are hypothetical and should only be considered a guide).

Example 1: EC = “Cod: spawning area”, assessed for the Baltic Proper. If we assume that, apart from fishing pressure, it is a lack of functioning spawning areas that limit the number of adult cod, and that adult cod provide a key ecosystem function - then the *ecological function* of cod can be assessed for the ecosystem component “Cod: spawning area”.

1) If cod are assessed as having a very important function as a top predator in the pelagic zone, then the assessment should occur in the red zone of the first axis (importance of function).
2) Because few other ecosystem components can replace cod as a top predator in the Baltic Proper pelagic zone, the assessment on the second axis (replaceability) should occur in the red zone
3) If the assessment is made that cod has the *potential* to be abundant and widespread enough to make their function important in an ecosystem - but the actual abundance is low - then it should also occur in the red zone of the third axis (occurrence).

The ecosystem component “Cod: spawning area is awarded 8 points due to its close association with adult cod that perform a key role in pelagic ecosystems.

Example 2: EC = “Cod: growth area” assessed for the Baltic Proper. If the assessment is done according to cod’s ecological function it should be the same as in example 1, 8 points. However, if we assume that “Cod: growth area” is not as strongly associated with the number of adult cod then the points should not be as high. How many points it should be awarded (4 or 2 points) is uncertain. More literature studies (not available to authors when writing this report) or more research on the role of growth areas for cod are needed. Until then, 2 points are awarded.

Example 3: EC = “*Mytilus edulis* >25-100% coverage, shallower than 30 m” assessed for the Baltic Proper.

1) Blue mussels provide many functions, primarily filtering water, provision of food, biotope building, stabilizing sediment etc. and the assessment should occur in the red zone of the first axis (importance of function).
2) There are probably few other ECs that can, to the same extent, replace the functions provided by blue mussels and the assessment should occur in the red zone of the second axis.
3) Because blue mussels are relatively common, the value is lowered. I.e. the assessment of occurrence should be placed further out on the third axis, occurrence.

Because they are common the assessment for ecological function of blue mussels is reduced from 8 to 4 points. If blue mussels declined, then the assessment would have to be revised.

More examples can be found in Table 7.

Table 7. Explanations for some of the assessments carried out for the criterion “ecological function” for the Baltic Proper. See Table 6 for guidelines and Figure 16 for information on how assessments are carried out.

Ecosystem component (EC)	Phase 1 - assessment per sea area (Baltic Proper) Phase 1a - criteria for ecological/biological value (including indirect ecosystem services) Ecological function					
	Points	Importance of function provided	Replaceability	Abundance/ Occurence (potential/actual)	Balanced assessment	Assessment reliability
Cod (*Gadus morhua*): Spawning area	8	Strong top-down effect on offshore ecosystems when abundant, contribute to improved water quality.	Unique, most important offshore pelagic predator in the Baltic Sea.	Population fluctuates from very common to uncommon. Has high potential.	8p; high importance for ecological function, unique but occurrence lower than potential.	Hög
Fucus vesiculosus 25-100% coverage	8	Biotope-forming primary producer (fauna habitat, biomass production and nutrient uptake), in an area with relatively few “meaty” macroalgae. A higher abundance and biomass of invertebrates in habitats with Fucus than in shallow hardbottom areas with other algae (Wikström och Kautsky 2007).	Generally found more shallow that Fucus serratus, therefore low replaceability.	Very high occurrence.	Strength of the function depends on the degree of coverage. Higher coverages should receive higher points, the component receives 8 p.	Moderate
Furcellaria lumbricalis 25-100% coverage	8	Biotope-forming primary producer (primary production, nutrient uptake, secondary hard substrate). Secondary substrate for blue mussels, for example. Grow relatively deep in comparison to other “meaty” algae, and have a high abundance of epifauna (Orav et al. 2000; Kotta and Orav 2001).	Probably low, limited number of sturdy algae species in deeper habitats. The only coarser red alga on deeper substrates.	High occurrence, probably close to potential. Could justify a lower score.	The strength of the function depends on the degree of coverage. Higher coverages receive more points. Uncertain if score should be reduced due to the assessment that its occurrence fulfills its potential, but no points deducted in the end.	Moderate
Chara tomentosa 25-100% coverage	4	Biotope-forming primary producer on soft sediments (primary production, nutrient uptake, sedimentation). The high abundance of herbivore epifauna on Chara spp. (Orav et al. 2000) illustrates that production is probably used by/beneficial to epifauna.	One of the most common Chara species, probably low/moderate replaceability.	Low occurrence.	Strength of the function depend	Moderate
Zostera marina 25-100% coverage	4	Biotope-forming primary producer (primary production, nutrient uptake, sediment stabilization). The strength of the function depends on the degree of coverage.	Despite the abundance of vascular plant species, only a few are biotope-forming (>10 %), therefore probably relatively low-moderate replaceability.	High occurrence.	High occurrence and relatively low/moderate replaceability. Higher coverages receive more points.	Moderate
Mytilus edulis 25-100% coverage, shallower than 30 m	4	Blue mussels provide many important functions, are extremely important for filtering water and form biotopes (biogenic reefs) that can help stabilize sediments (Young 1983). They contribute important functions to other ecosystem components such as habitat (Tsuchiya & Nishihira 1985, Albrecht and Reise 1994, Yager et al. 1993) and nutrient and food source (Kautsky & Wallentinus 1980, Prins et al. 1998, Norling and Kautsky 2008).	Low - no other species that filters large amounts of water found on hard substrates in the Baltic Proper.	Common.	Despite blue mussels' important function and low replaceability in the Baltic Proper, they receive only receive 4 p because they are common	Moderate
Fourhorn sculpin (*Myoxocephalus quadricornis*): Spawning area	4	Eats benthic invertebrates, roe and occasionally fish.	Replaceable with other benthic fish, such as flat fish and sculpins, but more important further north where it is the only commonly occurring predatory benthic fish.	Common.	4p; relatively high importance for ecological function, less replaceable but commonly occurring.	Low
Transport and erosional environment with macroscopic fauna	2	Important for the turnover of organic material, nutrients, sediment oxygenation via bioturbation. The turnover of organic material is not as large as for depositional environments, but there are more filtering organisms.	Low replaceability (no other group can effectively fill the roll of macroscopic deposit feeders, biomass of meiofauna is too low).	Larger than natural potential.	Ecological function is greater than its potential due to eutrophication =>2p (note anoxic sediments are another EC).	Moderate
Zostera marina 10-24% coverage	2	Biotope-forming primary producer (primary production, nutrient uptake, sediment stabilization). The strength of the function depends on the degree of coverage.	Despite the abundance of vascular plant species, only a few are biotope-forming (>10 %), therefore probably relatively low-moderate replaceability.	High occurrence.	Very high occurrence and relatively low - moderate replaceability. Higher coverages receive more points.	Moderate
Chorda filum up to 9% coverage	1	Limited importance at low coverage.	Replaceable.	Common.	Sporadic occurrences are of limited ecological importance. 1 p for the Baltic Proper.	Moderate

Threat status

The criterion *Threat status* is included to assess if an ecosystem component should be prioritized because it contains a threatened or declining species or habitat. It can also include populations or subspecies.

The criterion is included to gain an overview of some of the central conservation values associated with ecosystem components (in the form of a table). The lists act as a support when making recommendations on how much of an ecosystem component should be represented (section 2.3.3.2) or when prioritizing ecosystem components for mapping. Assessments on threat status can be included when conservation value points are combined and used to produce *general conservation value maps* (section 2.4.3.1), which help determine which areas are awarded high or low conservation status. However, the maps may be more difficult to interpret because other criteria focus on values associated with the ecosystem as a whole. The user should decide whether to include the criterion when producing *general conservation value maps*.

Threatened species or habitats are included in MOSAIC in step 5, *general conservation value assessments on point data* (section 2.4.3.2) and step 6, *site-specific conservation value assessments* (section 2.4.3.3) regardless of whether conservation status is included in the *general conservation value maps* or not. It can be difficult to map the distribution or range of ecosystem components that contain threatened species or habitats because their occurrence might be limited or isolated to a few locations. It is the criterion *ecological representativity* that ensures threatened species or habitats are adequately represented in *areas of ecologically coherent networks*[33] (see section 2.4.4.4).

When assessing the criterion for ecosystem components that are a species, or for the most part comprise one species, we recommend using the latest Swedish Red List (SLU Artdatabanken 2020). The Swedish Red List is the most comprehensive assessment of the conservation status of Swedish aquatic organisms according to the IUCN's criteria. Because there is no equivalent national assessment of Swedish habitats, we recommend using marine habitats found in the EU's Red List of Habitats (European Red List of Habitats; Gubbay et al. 2016), HELCOM's Red List of wintering birds (HELCOM 2012), HELCOM's Red List of Baltic habitats (including Kattegat) ("Red List of Biotopes and Habitats" HELCOM 2013), or OSPAR's list of threatened and/or declining habitats in Region II: The Greater North Sea (OSPAR 2008).

Table 8 provides guidelines for how the criterion should be assessed and Table 9 provides examples of assessments.

[33] See chapter 5 (terminology) for definition.

Table 8. Guidelines for the assessment of the criterion threat status. Assessments are based on several lists over threatened and declining species and habitats.

Phase 1 - assessment per sea area Phase 1a - criteria for ecological/biological value (including indirect ecosystem services) Threat status			
Points	Red listed in Sweden	EUs/Helcoms/ Ospars Red Lists of habitats and biotopes	Balanced assessment
8	Extinct in the wild (EW)/ Critically Endangered (CR)/ Endangered (EN)	Collapsed (CO)/Critically Endangered (CR)/Endangered (EN)/Threatened and/or declining	The Swedish Red list should be used for EC's that comprise, or primarily comprise, a species. Habitats should be assessed using the list that awards the highest points.
4	Vulnerable (VU)	Vulnerable (VU)	
2	Near Threatened (NT)/ Data Deficient (DD)	Near Threatened (NT)	
~~1~~	1 point cannot be assigned for this criterion		
0	Not assessed to be threatened or declining		
Comment			
If the ecosystem component (EC), by definition, is of *special importance for life history stages* of one or more species - such as spawning or nesting areas - it might be relevant to assess *threat status* for the species and not for the EC itself. However, there must be a strong association between the occurrence of the EC and presence of the species that is assessed. In other words the EC should probably be limiting for the species. Example: If one assumes that the EC "Cod: spawning area" is limiting for adult cod then the points allocated to the EC can be assessed according to adult cods' *threat status*. However, the EC "Cod: recruitment area" is not assumed to strongly limit the number of adult cod and the association between the EC and the species is not strong. This EC should not be assessed directly from adult cods' *threat status* and points should be reduced or not awarded.			

Table 9. Explanations for some of the assessments carried out for the criterion threat status for the Baltic Proper. See Table 8 for guidelines on how the criterion should be assessed.

Ecosystem component (EC)	Phase 1 - assessment per sea area (Baltic Proper) Phase 1a - criteria for ecological/biological value (including indirect ecosystem services) Threat status Points	Red listed in Sweden	EUs/Helcoms/ Ospars Red Lists of habitats and biotopes	Balanced assessment	Assessment reliability
Long-tailed duck (*Clangula hyemalis*): Wintering ground (October - March)	8	Endangered (EN) (Swedish species information centre 2020)	HELCOM (wintering population) Endangered (EN)	Wintering populations of long-tailed ducks are Endangered (EN) due to a drastic reduction of the wintering population in the Baltic. 8 p.	High
Cod (*Gadus morhua*): Spawning area	4	Cod: Vulnerable (VU) (Swedish species information centre 2020)		Points are based on the fact that cod are assessed as Vulnurable (VU); the EC gets 4 p because of the strong association between the EC and cod (EC is probably limiting for the species).	High
Chara tomentosa 25-100% coverage	2	Least Concern (LC) (Swedish species information centre 2020)	Helcom's Red List of biotypes and habitats: Charophyte biotypes: Near Threatened (NT) (Helcom 2013)	2 p because charophyte habitats are assessed at Near Threatened (NT) (Helcom)	Moderate
Zostera marina 25-100% coverage	2	Vulnerable (VU) (Swedish species information centre 2020)	Helcom's Red List of biotypes and habitats: Near Threatened (NT) (Helcom 2013)	2 p because biotypes characterized by eelgrass are assessed as Near Threatened (NT) (Helcom)	High
Zostera marina 10-24% coverage	2	Vulnerable (VU) (Swedish species information centre 2020)	Helcom's Red List of biotypes and habitats: Near Threatened (NT) (Helcom 2013)	2 p because biotypes characterized by eelgrass are assessed as Near Threatened (NT) (Helcom)	High
Cod (*Gadus morhua*): Foraging area	0	Cod: Vulnerable (VU) (Swedish species information centre 2020)		Based on the fact that cod are assessed as Vulnerable (VU); the EC could be awarded 4 p. However, foraging areas are not assessed to be limiting for cod in the same way that spawning areas are. The EC is awarded 0 p but it is possible that it should recieve 2 p.	Low
Furcellaria lumbricalis 25-100% coverage	0	Least Concern (LC) (Swedish species information centre 2020)		No points.	High
Mytilus edulis 25-100% coverage, shallower than 30 m	0	Least Concern (LC) (Swedish species information centre 2020)		No points.	High
Fucus vesiculosus 25-100% coverage	0	Least Concern (LC) (Swedish species information centre 2020)		No points.	High
Azoic sediment/ sediment without macroscopic fauna	0	Least Concern (LC) (Swedish species information centre 2020)		No points.	Moderate

Overview of phase 1a

Table 10 provides a summary of guidelines for all of the assessments carried out in phase 1a.

Table 10. Overview of the guidelines for assigning points to ecosystem components according to phase 1a – criteria for ecological/biological value (including indirect ecosystem services).

Phase 1 - assessment per sea area (Baltic Proper) **Phase 1a - criteria for ecological/biological value (including indirect ecosystem services)**				
Points	Biological diversity	Special importance for life history stages	Ecological function	Threat status
8	The EC contributes to a **high** biological diversity within the assessed sea area	**High** importance, **probably** limits populations and has a **very high** spatial overlap with a critical life history stage	The EC provides a function of **very high** importance that **few** other ECs can provide. Occurence is **lower or much lowe**r than potential. Or: The EC provides a function of **very high** importance that **relatively few** other ECs can provide. Occurence is **much lower** than potential	Extinct in the wild (EW)/Collapsed (CO)/Critically Endangered (CR)/Endangered (EN)/Threatened and/or declining
4	The EC contributes to a **relatively high** biological diverstity within the assessed sea area	**High** importance, **probably** limits populations and has a **relatively high** spatial overlap with a critical life history stage Or: **Relatively high** importance, **possibly** limits populations and has a **very high** spatial overlap with a critical life history stage	The EC provides a function of **very high** importance that **few** other ECs can provide. The EC is **common** enough to lower the points awarded. Or: The EC provides a function of **very high** importance that **relatively few** other ECs can provide. The EC is **common** or **lower** than potential Or: The EC provides a function of **high** importance that **few** or **relatively few** other ECs can provide. Occurence is **much lower** than potential	Vulnerable (VU)
2	The EC makes a **limited contribution** to biological diversity within the assessed sea area	**Relatively high** importance, **possibly** limits populations and has a **relatively high** spatial overlap with a critical life history stage	The EC provides a function of **high** importance that **few** other ECs can provide. The EC is **common** enough to lower the points awarded. Or: The EC provides a function of **high** importance that **relatively few** other ECs can provide. The EC is **common** or **lower** than potential Or: The EC provides a function of **relatively high** importance that **few** other ECs can provide. Occurence is **much lower lower** than potential	Near Threatened (NT)/Data Deficient (DD)
(1)	The EC only contributes to biological diversity through its own presence and does not provide a habitat for other species	Cannot be awarded	The EC provides a function of **relatively high** importance that **few** other ECs can provide. The EC is **common** or **lower** than potential. Or: The EC provides a function of **relatively high** importance that **relatively few** or **other** ECs can provide. Or: The EC provides a function of **little** importance	Cannot be awarded
0	Invasive alien species	**No or very low** importance, **probably does not** limit populations or has **no or low** spatial overlap with a critical life history stage	Invasive alien species	The EC is not assessed to be threatened or declining

Comment

If the ecosystem component (EC), by definition, is of *special importance for life history stages* of one or more species - such as spawning or nesting areas - it might be relevant to assess *ecological function* and *threat status* for the species and not for the EC itself. However, there must be a strong association between the occurrence of the EC and presence of the species that is assessed. In other words the EC should probably be limiting for the species.

Example: If one assumes that the EC "Cod: spawning area" is limiting for adult cod then the points allocated to the EC can be assessed according to adult cods' *ecological function* and *threat status*. However, the EC "Cod: recruitment area" is not assumed to strongly limit the number of adult cod and the association between the EC and the species is not strong. This EC should not be assessed directly from adult cods' *ecological function* and *threat status* and points should be reduced or not awarded.

2.3.2.1.2 PHASE 1B – CRITERIA FOR DIRECT ECOSYSTEM SERVICES

Criteria in phase 1b, direct ecosystem services, are:

- *Provisioning ecosystem services*
- *Cultural ecosystem services*
- *Regulating ecosystem services*

In phase 1b, direct ecosystem services, ecosystem components are awarded 4, 1 or 0 points (see Figure 17) – 8 points and 2 points cannot be awarded, in contrast to phase 1a. The number of points awarded to ecosystem components in phase 1b is lower than in phase 1a (ecological/biological value) to reduce the effect of double counting (scoring the same value twice - in phase 1a and phase 1b). Several of the direct ecosystem services are also valued in phase 1a even if the reasons for assigning them points there are different. The points for each criterion are summed for each ecosystem component to give a collective conservation value assessment for phase 1b.

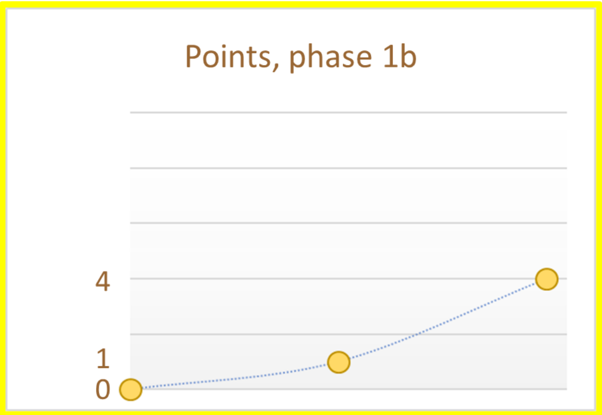


Figure 17. The number of points that can be awarded to each criterion in phase 1b, direct ecosystem services. The number of points awarded increases sharply to prioritize ecosystem components that are important for phase 1b criteria. In contrast to phase 1a (where a maximum of 8 points can be awarded), only 0, 1 or 4 points can be awarded in phase 1b.

Provisioning ecosystem services

The expert group must assess if an ecosystem component provides one or more *provisioning ecosystem services*. Examples of goods and benefits from these services include food, genetic resources, chemical resources, energy production, decorative resources, animal feed, and algae or mussels for fertilizer.

Cultural ecosystem services

The expert group must assess if an ecosystem component provides one or more services that are important for (human) culture. Examples include ecosystem components that provide nature-based activities and recreation (birds for birdwatching or fish for angling) and/or contribute to well-being, tourism, aesthetics, science and education, natural/cultural heritage or inspiration.

Regulating ecosystem services

The expert group must assess if an ecosystem component provides one or more services, via biological processes and/or regulatory functions, that reduce various environmental problems. Examples include services that counteract eutrophication or that bind sediment. For example, mussels that filter water or vascular plants that bind sediment with their roots and thereby reduce erosion.

Table 11 provides guidelines for how the criteria should be assessed and Table 12 provides examples of assessments.

Table 11. Guidelines for assigning points to ecosystem components (EC) according to criteria in phase 1b – direct ecosystem services. Note that only direct ecosystem services are awarded points. Indirect ecosystem services (*supporting* and several *regulatory ecosystem services*) are assessed as part of the ecological/biological value in phase 1a. Examples of assessments can be found in Table 12.

Phase 1 - assessment per sea area **Phase 1b - criteria for direct ecosystem services**			
Points	Provisioning ecosystem services	Cultural ecosystem services	Regulatory ecosystem services
~~8~~	8 points cannot be awarded for this criterion		
4	Biological ecosystem components that **contribute** raw materials that are **very valuable to society** or **used by many**	Biological ecosystem components of cultural **importance** that are **valued highly** or **used by many**	Biological ecosystem components that are **important for regulating** ecosystems that are **very valuable to society** and where few other ECs can provide the same function
~~2~~	2 points cannot be awarded for this criterion		
1	Biological ecosystem components that **potentially contribute** raw materials that are **relatively valuable** to society or **used moderately**	Biological ecosystem components that are **potentially** of cultural importance that are **valued relatively highly** or **used moderately**	Biological ecosystem components that are **regulate** ecosystems that are **relatively valuable** to society
0	Biological ecosystem components that have a **low potential** to contribute raw materials	Biological ecosystem components of **low** cultural importance	Biological ecosystem components with a **low potential** to regulate ecosystems that are valuable to society
Comment If the ecosystem component (EC), by definition, is of *special importance for life history stages* of one or more species - such as spawning or nesting areas - it might be relevant to assess direct ecosystem services for the species and not for the EC itself. However, there must be a strong association between the occurrence of the EC and presence of the species that is assessed. In other words the EC should probably be limiting for the species. Example: If one assumes that the EC "Cod: spawning area" is limiting for adult cod then the points allocated to the EC can be assessed according to adult cods' direct ecosystem services. However, the EC "Cod: recruitment area" is not assumed to strongly limit the number of adult cod and the association between the EC and the species is not strong. This EC should not be assessed directly from adult cods' direct ecosystem services and points should be reduced or not awarded.			

Table 12. Explanations for some of the assessments carried out for criteria in phase 1b – direct ecosystem components – for the Baltic Proper. See Table 11 for information on how points are awarded.

Ecosystem component (EC)	Phase 1 - assessment per sea area (Baltic Proper) Phase 1b - criteria for direct ecosystem services Direct ecosystem services (ES) Points: Propvision ES	Points: Cultural ES	Points: Regulatory ES	Provisioning ecosystem services	Assessment reliability	Cultural ecosystem services	Assessment reliability	Regulatory ecosystem services Only direct regulatory ES are considered here, not indirect ES	Assessment reliability
Cod (*Gadus morhua*): Spawning area	4	4	4	Important fish for consumption.	High	Popular and well-known fish for eating. Recreational fishing and angling.	Low	Contributes to good water quality.	High
Mytilus edulis 25-100% coverage, shallower than 30 m	0	1	4		Not assessed	Decorative shell on beaches.	Not assessed	Extensive water purification.	Not assessed
Long-tailed duck (*Clangula hyemalis*): Wintering ground (October - March)	0	4	0		Not assessed	Outdoor recreation (experience nature, birdwatching) - all bird species considered equally important. 4 points	Not assessed		Not assessed
Fourhorn sculpin (*Myoxocephalus quadricornis*): Spawning area	0	1	1	Unexploited resource. Considered a good fish for consumption with good roe.	High	Some recreational fishing. Sculpin soup.	High	Contributes to some extent to good water quality.	Low
Zostera marina 25-100% coverage	0	0	1		Not assessed		Not assessed	Plants that bind sediment: reeds and submerged plants can bind sediment.	Not assessed
Fucus vesiculosus 25-100% coverage	0	1	0		Not assessed	Bladder wrack as a biotope can be considered to have a cultural value as an indicator of a healthy ecosystem. Very uncertain assessment.	Not assessed		Not assessed
Chara tomentosa 25-100% coverage	0	0	1		Not assessed		Not assessed	Binds sediment: reeds and submerged plants can bind sediment.	Not assessed
Furcellaria lumbricalis 25-100% coverage	0	0	0		Not assessed		Not assessed		Not assessed
Zostera marina, up to 9% coverage	0	0	0		Not assessed		Not assessed		Not assessed
Transport and erosional environment with macroscopic fauna	0	0	1		Not assessed		Not assessed	Nutrient turnover and food source that contribute ecological function/life history importance. Also regulates environmental toxins.	Not assessed

2.3.2.2 Phase 2 – local regional assessments

2.3.2.2.1 LOCAL IMPORTANCE

The expert assessments of ecosystem component's conservation value (phase 1) are supplemented with local regional assessments in phase 2. Under the coordination of respective county administrative boards, or other users, points are awarded to represent the local conservation value of ecosystem components in relation to the rest of the sea area to which it belongs (Figure 10 and Table 1, section 2.3.2). The criterion has the somewhat lengthy title *relative local importance compared with the whole sea area*.

The aim is to carry out assessments by county, but they can also be divided up within a county. For example, assessments can be carried out by municipality or by water district. Assessments can also be divided up within a county if there are large ecological differences between areas, such as between inner and outer archipelago environments.

Assessments should be based on the same criteria as phase 1, but from a regional/local perspective. For example, a species might be less or more common in a county compared with the entire sea area and therefore contain a different value for its ecological function locally. However, in the local regional assessments the changes in value based on the different criteria need to be weighed together to a single assessment of increased or decreased importance.

In the local regional assessments points can be added or deducted from the points awarded in phase 1. A maximum of 3 points can be added or deducted[34].

Note that even if regional/local aspects are accounted for when assessing the criterion, assessments are not site-specific. In other words, assessments are still carried out from a general, but more local/regional, perspective and not on exactly where the ecosystem component is found. For example, the conservation value *Fucus* biotopes generally contribute in Blekinge County irrespective of its exact location (predefined as coverage ≥ 25 percent).

Table 13 provides guidelines for how the criterion should be assessed and Table 14 provides examples of assessments.

[34] With the exception of Öresund where 5 points can be added or deducted. More information on the points system design can be found in section 2.3.2.5.1.

Table 13. Guidelines for assessments carried out in phase 2 – local regional assessment and the criterion *relative local importance compared with the whole sea area*. Examples of assessments can be found in Table 14. EC = ecosystem component.

Points	Phase 2 - local regional assessment Criteria for local importance Relative local importance compared with the whole sea area
+3	The EC's local importance is much greater in the assessed area compared with the larger sea area (based on criteria in phase 1)
+2	The EC's local importance is greater in the assessed area compared with the larger sea area (based on criteria in phase 1)
+1	The EC's local importance is marginally greater in the assessed area compared with the larger sea area (based on criteria in phase 1)
0	The EC's local importance in the assessed area is the same as in the larger sea area (based on criteria in phase 1)
-1	The EC's local importance is smaller in the assessed area compared with the larger sea area (based on criteria in phase 1)
-2	The EC's local importance is marginally smaller in the assessed area compared with the larger sea area (based on criteria in phase 1)
-3	The EC's local importance is much smaller in the assessed area compared with the larger sea area (based on criteria in phase 1)

Table 14. Examples of assessments and justifications carried out in phase 2 – local regional assessment and the criterion *relative local importance compared with the whole sea area* (here exemplified with Blekinge County in the Baltic Proper). Assessments exemplified here are not based on literature studies or carried out by an expert group. The table below only demonstrates how assessments and justifications can be carried out and should not be viewed as definitive local regional assessments. A description of how points are awarded can be found in Table 13.

Example of how assessments can be carried out			
	Phase 2 - local regional assessment, exemplified using Blekinge county Criteria for local importance		
Ecosystem component (EC)	Points	Relative local importance compared with the larger sea area	Assessment reliability
Long-tailed duck (*Clangula hyemalis*): Wintering ground (October - March)	2	Blekinge provides a very important wintering area for long-tailed duck (Hanöbukten)	Not assessed
Zostera marina 25-100% coverage	2	Eelgrass is more common in Blekinge than in the northern parts of the Baltic Proper, but other tall vascular plants are less common here. Therefore functions associated with tall vascular plants on soft substrates are primarily provided by eelgrass in Blekinge and management of these habitas should be prioritized in the county.	Not assessed
Mytilus edulis 25-100% coverage, shallower than 30 m	2	Blue mussels are very important for wintering long-tailed ducks. Hence local importance is higher for Blekinge than the larger sea area (Baltic Proper) and the score increased.	Not assessed
Zostera marina 10-24% coverage	1	Eelgrass is more common in Blekinge than in the northern parts of the Baltic Proper, but other tall vascular plants are less common here. Therefore functions associated with tall vascular plants on soft substrates are primarily provided by eelgrass in Blekinge and management of these habitas should be prioritized in the county. The functions provided by eelgrass with a coverage of 10-24% is considered lower than coverage between 25-100%, therefore only 1 p awarded	Not assessed
Cod (*Gadus morhua*): Spawning area	0		Not assessed
Chara tomentosa 25-100% coverage	0		Not assessed
Furcellaria lumbricalis 25-100% coverage	0		Not assessed
Fucus vesiculosus 25-100% coverage	0		Not assessed
Cod (*Gadus morhua*): Foraging area	0		Not assessed
Transport and erosional environment with macroscopic fauna	0		Not assessed

2.3.2.3 Assessment reliability

Assessment reliability should be indicated for each criterion and ecosystem component. Guidelines and colour coding for assessment reliability can be seen in Table 15. Reliability should be based on the amount of scientific evidence available, how relevant the studies are and the degree of consensus between studies. Assessment reliability is done by the experts that carry out the assessments.

Table 15. Guidelines for assessment reliability. EC = ecosystem component.

Assessment reliability

	Scientific evidence	**Relevance (for specific EC and region)**	**Concensus between studies**
High	Based on reliable studies (peer reviewed or grey literature from established / reputable sources)	Based on relevant studies carried out on specific EC and region	High level of concensus on EC significance
Moderate	Based on a number of reliable studies and expert opinion	Based on relevant studies carried out on similar/comparable EC or region	Majority of studies in agreement on EC significance
Low	Based primarily on expert opinion but also on a few reliable studies	Based on relevant studies carried out on partly similar EC or region	Conflicting studies but a majority for EC significance
Very low	Based on expert opinion	Not based on relevant studies carried out on specific EC or region	No concensus
Not assessed			

2.3.2.4 Overall assessment of ecosystem components' conservation values

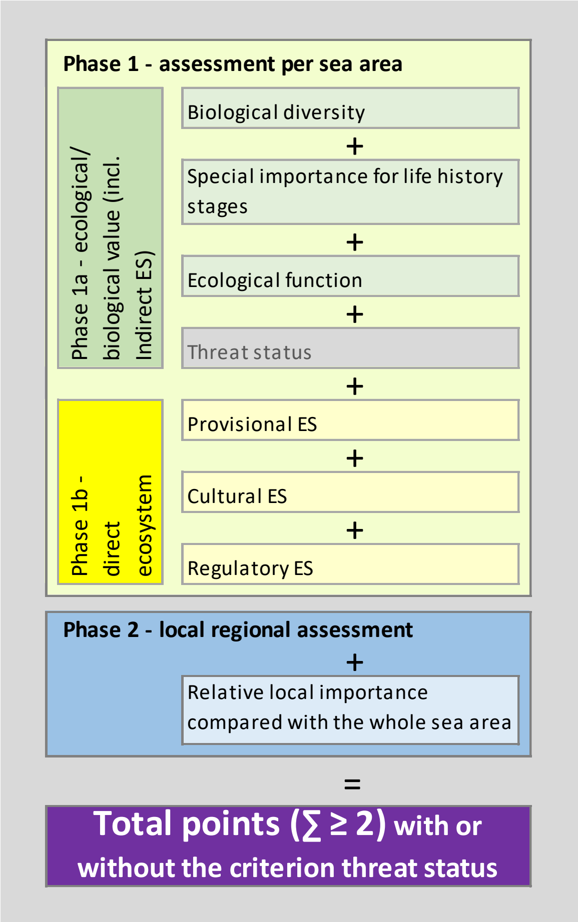
The overall score is calculated by summing points from phase 1a, phase 1b and phase 2. If phase 2 is a negative score it cannot decrease the overall assessment of a native species to less than 2 points because native species must receive at least 1 point for biological diversity and 1 point for ecological function. In other words, if the ecosystem component is not an invasive alien[35] species the regional assessment (phase 2) cannot reduce its overall assessment to less than 2 points. In addition, alien species cannot receive less than 0 points in the overall assessment. Table 16 illustrates how points are combined in the overall assessment.

The final points indicate the conservation value that respective ecosystem components contribute generally to a location in their respective county – from a spatial perspective and according to the best available knowledge and the criteria used. If assessments (and points) are provided in a table on a website, it is relatively easy to compare them and discuss their accuracy (Table 17)[36].

[35] This report defines invasive alien species according to the European parliament and Councils Regulation (EU) No 1143/2014 from the 22 October 2014 on the prevention and management of the introduction and spread of invasive alien species. Specifically, alien species are species that are introduced through human activity and that threaten or adversely impact an areas biological diversity and related ecosystem services. The allocation of points to species that are considered alien but not invasive is done on a case-by-case basis.

[36] More information on how the points system was developed can be found in section 2.3.2.5.1.

Table 16. The total number of points for each ecosystem component is calculated by summing points from phase 1a, phase 1b and phase 2. Ecosystem components comprising native species cannot receive less than 2 points in the overall assessment (1 point each for biological diversity and ecological function). Invasive alien species[37] that can reduce biological diversity or ecological function can receive 0 points.



[37] This report defines invasive alien species according to the European parliament and Councils Regulation (EU) No 1143/2014 from the 22 October 2014 on the prevention and management of the introduction and spread of invasive alien species. Specifically, alien species are species that are introduced through human activity and that threaten or adversely impact an areas biological diversity and related ecosystem services. The allocation of points to species that are considered alien but not invasive is done on a case-by-case basis.

Table 17. An example of a points table used to assess the overall conservation value of ecosystem components. The assessment is based on the conservation value ecosystem components generally contribute to an area, and according to how the ecosystem component is described. An ecosystem component's definition can, for example, be based on coverage or number of individuals per area. Phase 1 (a+b) assessments are carried out per sea area by an expert group coordinated by the Swedish Agency for Marine and Water Management. Phase 2 assessments are specific to smaller areas, such as a county, and reflect the local/regional importance of the ecosystem component compared to the larger sea area. We suggest phase 2 assessments are coordinated by respective county administrative boards. It should be easy to separate points awarded for ecological/biological (including indirect ecosystem services) criteria (marked in green) from points awarded for criteria related to direct ecosystem services (marked in yellow). Whilst points from direct ecosystem services (phase 1b) can be excluded from overall assessments we strongly recommend that overall assessments do not exclude ecological/biological criteria (phase 1a) since direct ecosystem services are dependent on indirect ecosystem services provided. The table provides examples from the Baltic Proper with regional assessments for Blekinge County. The table also shows additional information that is used in MOSAIC´s implementation part (first 4 columns on the left of the table). Specifically, if the ecosystem component's occurrence automatically qualifies a location as a *core area*, how much of the ecosystem component that should be represented in *areas of ecologically coherent networks*, if the ecosystem component contains a priority species and which category the ecosystem component belongs to.

				CONSERVATION VALUES LINKED TO ECOSYSTEM COMPONENTS										
					Phase 2 - local regional assessment *Blekinge county*									
					Phase 1 - assessment per sea area *Baltic Proper*									
					Phase 1a - ecological/biological value (incl. indirect ecosystem services)				**Phase 1b -** direct ecosystem services (ES)					
Occurence = core area (X)*	Representativity in ecological network**	Conservation species***	Mosaic category****	Ecosystem component (EC)	Biological diversity	Special importance for life history stages	Ecological function	Threat status	Provisioning ES	Cultural ES	Regulatory ES	Local importance	**Total points excl. threat status**	**Total points incl. threat status**
X	90%	R; T	F&C	Cod (*Gadus morhua*): Spawning area	2	8	8	4	4	4	4		30	34
	75%	T	F&C	Northern pike (*Esox lucius*): Recruitment area	2	8	8	0	1	4	4		27	27
	75%	T	F&C	European perch (*Perca fluviatilis*): Recruitment area	2	8	4	0	4	4	4		26	26
	5%	R; T	F&C	Cod (*Gadus morhua*): Foraging area	2	4	8	4	4	4	4		26	30
	25%	T	F&C	Herring (*Clupea harengus*): Spawning area	2	4	8	0	4	4	1		23	23
X	90%	D: R; P	B&M	Long-tailed duck (*Clangula hyemalis*): Wintering ground (Oct-Mar)	1	8	4	8	0	4	0	2	19	27
	75%	R; T; NM	Bent	*Zostera marina* 25-100% coverage	8	4	4	4	0	0	1	2	19	23
	75%	D; T; P	F&C	Whitefish (*Coregonus maraena*): Spawning area	2	8	4	0	1	4	0		19	19
	50%	T	F&C	European flounder (*Platichthys flesus*), pelagic: Spawning area	1	8	2	0	4	4	0		19	19
	30%	T	Bent	*Fucus vesiculosus* - free-living 25-100% coverage	8	2	8	0	0	1	0		19	19
	50%	P;D;T	B&M	Long-tailed duck (*Clangula hyemalis*): Spring resting area (April - May)	1	8	4	2	0	4	0	1	18	20
X	75%		Bent	*Chara tomentosa* 25-100% coverage	8	4	4	2	0	0	1		17	19
X	75%		Bent	*Charophytes* 25-100% coverage	8	4	4	2	0	0	1		17	19
X	40%	T	Bent	*Najas marina* 25-100% coverage	8	4	4	2	0	0	1		17	19
	30%	T	Bent	*Stuckenia pectinata* 25-100% coverage	8	4	4	0	0	0	1		17	17
	40%		Bent	Tall underwater vascular plant (>10cm) meadows 25-100% coverage	8	4	4	0	0	0	1		17	17
	75%	D; R; P; T;	B&M	Velvet scoter (*Melanitta fusca*): Breeding ground and foraging area during breeding	1	8	2	2	0	4	0		15	17
	5%	T	Bent	Blue mussel beds (*Mytilus edulis*) 25-100% coverage, shallower than 30 m	4	2	4	0	0	1	4		15	15
X	90%	D; P; R; NM	B&M	Porpoise, core area (*Phocoena phocoena* (Baltic pop.))	1	8	4	8	0	0	1		14	22
	10%	T	Bent	*Furcellaria lumbricalis* 25-100% coverage	4	2	8	0	0	0	0		14	14
	5%	T	Bent	Blue mussel beds (*Mytilus edulis*) 25-100% coverage, deeper than 30 m	4	0	4	0	0	1	4		13	13
X	50%	D;P;	B&M	Tufted duck and common goldeneye: Wintering ground (>1000 individuals)	1	4	2	0	0	4	0		11	11
	25%	R; T; NM	Bent	*Zostera marina* 10-24% coverage	4	2	2	4	0	0	1	1	10	14
	25%		Bent	Tall stoneworts (*Charales, Charophytes*) 10-24% coverage	4	2	2	2	0	0	1		9	11
	25%	D	B&M	Grey seal (*Halichoerus grypus*): Haul-out site	1	4	2	0	0	0	1		8	8
	-	T	Bent	Blue mussel beds (*Mytilus edulis*) 10-24% coverage	4	0	2	0	0	1	1		8	8
	10%		Bent	Common reed (*Phragmites australis*) 75-100% coverage	4	2	2	0	0	0	0		8	8
	-		Bent	Depositional environment with macroscopic fauna	4	0	2	0	0	0	1		7	7
	-		Bent	*Polysiphonia spp*. 25-100% coverage	4	0	2	0	0	0	0		6	6
	-		Bent	Transport and erosional environment with macroscopic fauna	2	0	2	0	0	0	1	-1	4	4
	-		F&C	Three-spined stickback (*Gasterosteus aculeatus*): Recruitment area	1	2	2	0	1	0	0	-3	3	3
	-	T	Bent	*Battersia arctica* 10-24% coverage	2	0	1	0	0	0	0		3	3
X	0.5	R; NM	Bent	*Chara horrida* up to 9% coverage	1	0	1	2	0	0	0		2	4
	-		Bent	*Cladophora glomerata* up to 9% coverage	1	0	1	0	0	0	0		2	2

* Presence of EC which automatically qualifies an area as core area (X). Example, not recommendations.
** Minimum proportion of the EC required in ecological networks to be considered acceptably represented. Example, not recommendations.
***Conservation species: Protected (P); Typical species (T); Red listed (R); Priority (Prio); Indicator (I); with a National program of Measures (NM); Directive species (D).
***Categories: birds and mammals (B&M); fish and large crustaceans (F&C); benthos (Bent).

2.3.2.5 Discussion on the overall assessment of ecosystem component's conservation values

2.3.2.5.1 ALLOCATION OF POINTS

A points system to determine conservation value in marine environments has been used previously in a range of projects (Utsjöbanksinventeringen: U1 och U2, Naturvårdsverket 2010; Marin modellering i Östergötland, Carlström et al. 2010; SUPERB, Wikström et al. 2013; and MARMONI, Fyhr et al. 2015). A points system, guidelines for assessments, and the criteria used have been further developed within MOSAIC, as well as the sequence of assessments – first by sea area and then by local region.

A points system is used to make assessments manageable. The points system in MOSAIC is based on earlier projects where a three-point (0, 1 and 10 points) scaling system is used (see Wikström et al. 2013; Fyhr et al. 2015). A large increase in points between each scale makes it easy to identify the most prioritized ecosystem components. During MOSAIC's development we recognized the need for an increased number of scales in the points system to better differentiate the conservation value of ecosystem components. The number of scales used for assessments is a compromise between simplicity and ease of use, and the ability to differentiate the conservation value of a range of ecosystem components. Several points systems were trialed when developing MOSAIC including a range of scales, the maximum number of points that could be awarded, and if the increase in points should be progressive (0, 1, 2, 4 and 8) or linear (0, 3, 3, 6, 7 and 10).

After testing several points systems, a five-point scale (0, (1), 2, 4, and 8) with a maximum of 8 points was found to be optimal for phase 1a. Only the criteria biological diversity and ecological function can be awarded 1 point (because all ecosystem components contribute to these criteria except for perhaps alien invasive species[38]). Because assessments are based on somewhat vague categories such as "high" and "relatively high" more points did not provide a better differentiation, in fact it often made assessments and interpretations more difficult.

Ecosystem services provide an important basis for prioritization, for example within marine green infrastructure, and extra points can be given to ecosystem components that provide direct ecosystem services. However, criteria for ecological/biological value (including indirect ecosystem services) (phase 1a) are fundamental to conservation value assessments and criteria for direct ecosystem services (phase 1b) are not given the same level of importance. This is ensured by restricting the number of points that can be allocated in phase 1b, when direct ecosystem services are assessed.

Separating phase 1a (criteria for ecological/biological value – including indirect ecosystem services) and phase 1b (criteria for direct ecosystem services) allows one to exclude direct ecosystem services from the overall assessments if desired. However, we do not recommend

[38] This report defines invasive alien species according to the European parliament and Councils Regulation (EU) No 1143/2014 from the 22 October 2014 on the prevention and management of the introduction and spread of invasive alien species. Specifically, alien species are species that are introduced through human activity and that threaten or adversely impact an areas biological diversity and related ecosystem services. The allocation of points to species that are considered alien but not invasive is done on a case-by-case basis.

carrying out assessments using only phase 1b (criteria for direct ecosystem services) because indirect ecosystem services (that are assessed in phase 1a) are central ecosystem services.

In phase 2, local regional assessments are carried out according to criteria found in phase 1 (assessment by sea area) and points are added or subtracted according to the *relative local importance compared with the whole sea area* (Table 13). The reason for this is that different parts of a sea area provide different conditions for marine life, such as the salinity gradient found in Swedish sea areas (Figure 18). For example, some ecosystem components might be more common or provide a function that is more important in some locations compared to others. This can result in a different conservation value from one location to another within the sea area. When assessing local regional importance, a maximum of 3 points can be added or subtracted from the phase 1 score. The exception is Öresund where 5 points can be added or removed from the phase 1 score. This is due to the strong salinity gradient found there (Cameron and Askew 2011, Figure 18) that can require greater adjustment in phase 2.

The number of points that can be added or removed during phase 2 assessments has been discussed during MOSAIC'S development. Phase 1 assessments - that are based on consensus within the expert group and are supported by scientific evidence as far as possible – are the most important and should provide the basis of the overall assessment. For this reason, it was decided that ±3 points (5 for Öresund) were reasonable to account for local variability. We also tried to weight the local assessments using a scaling factor, but this would require the use of incremental scaling factors (fractions above and below 1) so that the increase or decrease in points would not be too great. We decided this would make the points system less intuitive and the assessments appear more mathematically exact than they are.

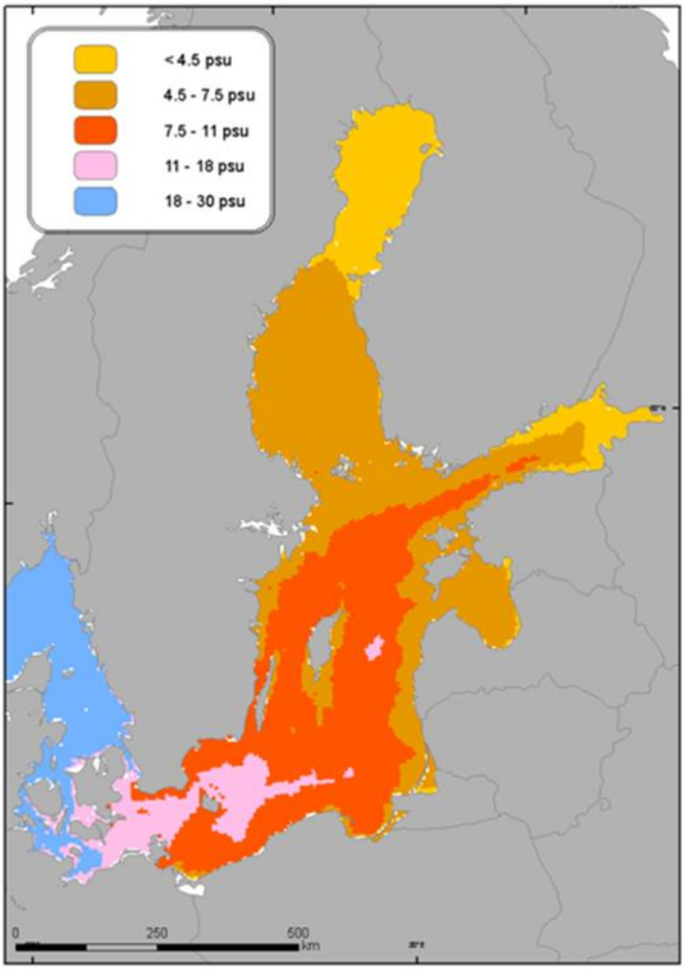


Figure 18. Salinity gradient (average over 9 years, Cameron and Askew 2011) in the Baltic and part of the North Sea.

2.3.3 Recommendations

2.3.3.1 Ecosystem components that should occur in core areas

How complete are the guidelines?

Guidelines are in place. However, expert recommendations are not yet available.

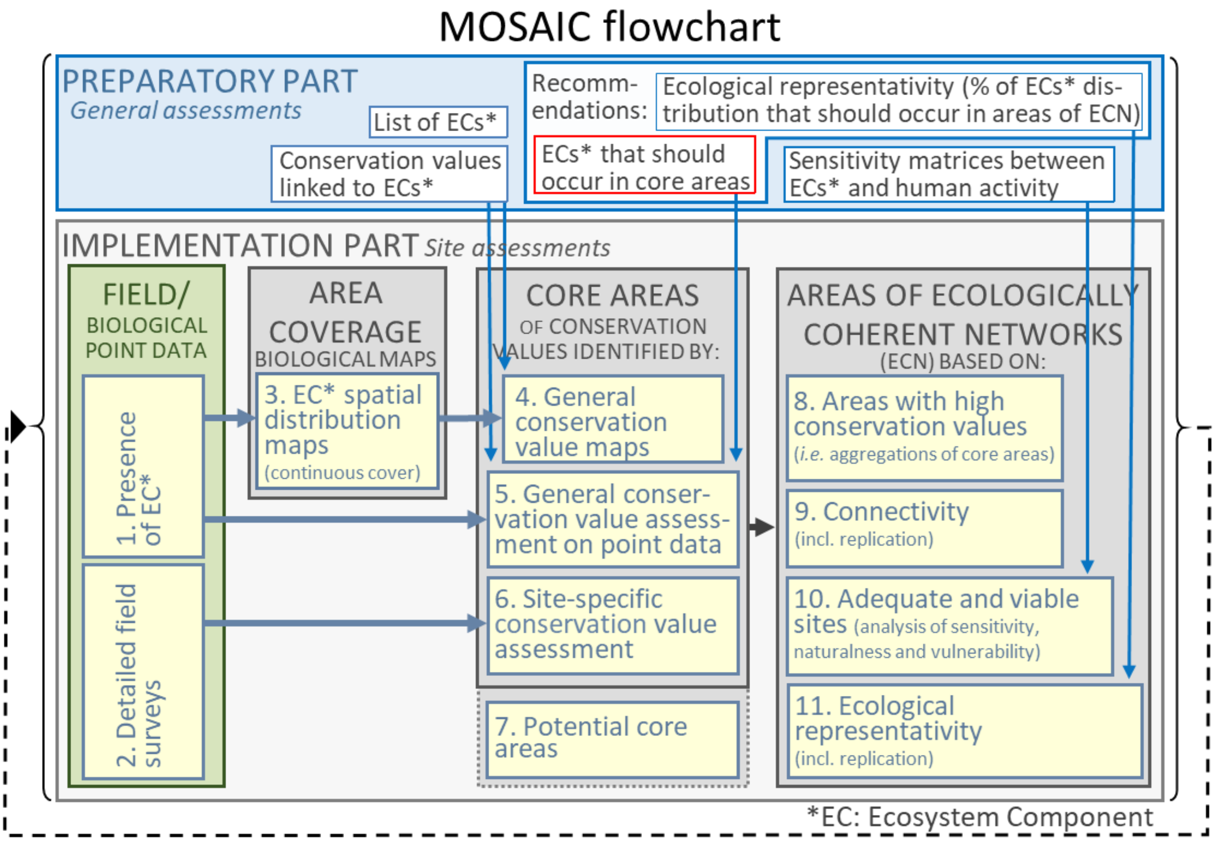


Figure 19. Flowchart showing the different parts and steps that comprise MOSAIC. The relevant section is highlighted in red.

The presence of some ecosystem components containing rare species or habitats can justify the direct designation of a *core area*[39] (Figure 19). Experts that define and delimit ecosystem components and their associated conservation value should also recommend which ecosystem components directly qualify an area as a *core area*.

In step 5 *general conservation value assessment on point data*, county administrative boards can decide which ecosystem components automatically qualify an area as a *core area* according to the expert recommendations.

[39] See chapter 5 (terminology) for definition.

Areas that should always be considered as *core areas* are those that contain ecosystem components with endangered (EN) or critically endangered (CR) species or habitats according to the Swedish Red List (SLU Artdatabanken 2020), the Red List of Habitats (European Red List of Habitats; Gubbay et al. 2016), HELCOM's Red List of wintering birds (HELCOM 2012), HELCOM's Red List of Baltic habitats (including Kattegat) ("Red List of Biotopes and Habitats" HELCOM 2013), or OSPAR's list of threatened and/or declining habitats in Region II: The Greater North Sea (OSPAR 2008). Only areas that have a large potential to limit the species should be considered for mobile/migratory species (for example, core area for Baltic porpoise). Mobile/migratory species are primarily birds, mammals and fish – animals that move to a greater extent between areas/habitats.

We do not recommend using HELCOM´s Red List of Biotope Complexes (HELCOM 2013) as the sole basis for deciding on a *core area*. However, it should be used as one of several sources for pointing out *potential core areas*[40], in step 7. More information can be found in section 2.4.3.4.

Ecosystem components whose presence automatically qualify an area as a *core area* can be indicated as shown in the first column of Table 17 (section 2.3.2.4).

[40] See chapter 5 (terminology) for definition.

2.3.3.2 Recommendation for ecological representativity

How complete are the guidelines?

Guidelines are in place. However, expert recommendations are not yet available.

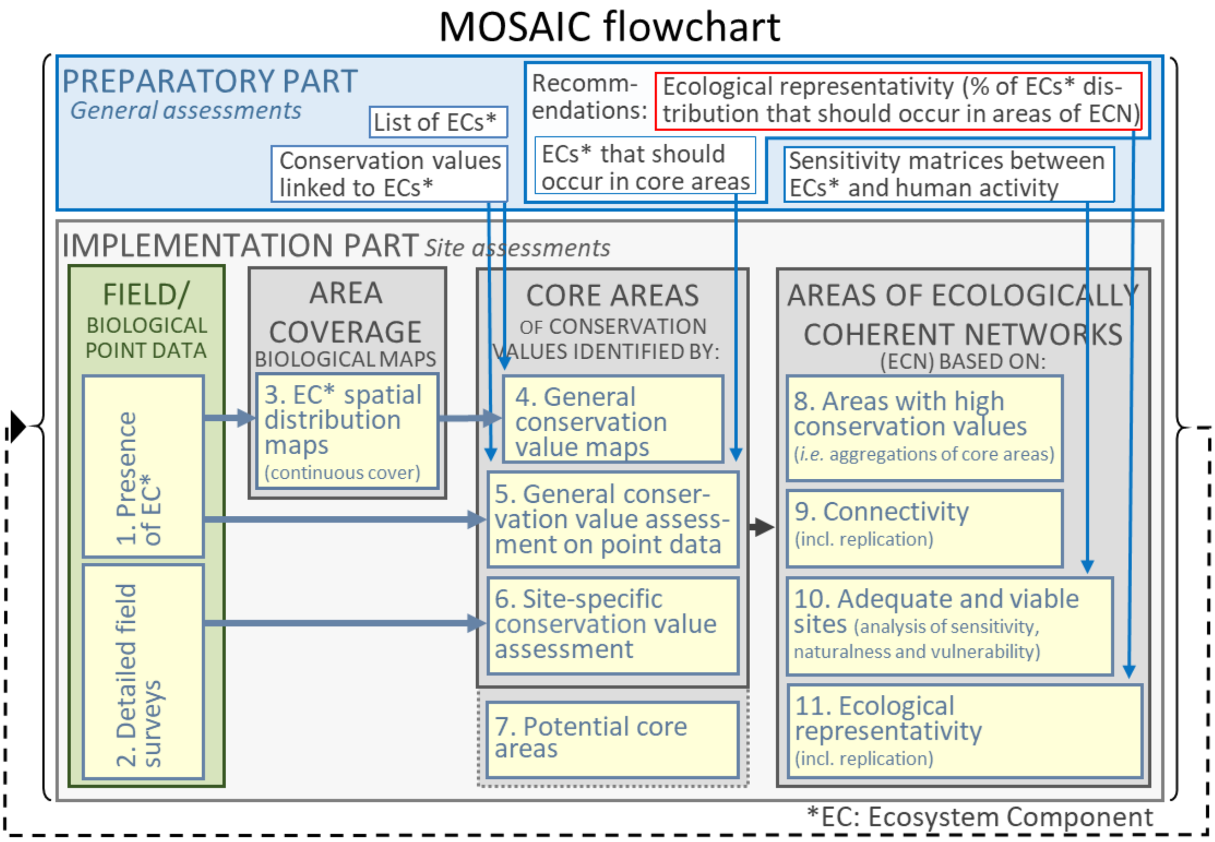


Figure 20. Flowchart showing the different parts and steps that comprise MOSAIC. The relevant section is highlighted in red.

In this report *ecological representativity* is considered to have been achieved when an *area of ecologically coherent networks*[41] contains a broad range of the diversity of species and habitats that are found in the region's marine ecosystem. As many ecosystem components as possible should be sufficiently represented for their spatial management which is assessed regionally in step 11 of MOSAIC's implementation part and the criterion *ecological representativity* (see section 2.4.4.4). Prior to the implementation part, experts should provide recommendations for the proportion of an ecosystem component's distribution that should be represented in *areas of ecologically coherent networks* (Figure 20). Recommendations should be based on:

- the conservation value an ecosystem component generally contributes to a location (assessed in phase 1, conservation value associated with ecosystem components)

[41] See chapter 5 (terminology) for definition.

- the degree to which the ecosystem component is exposed to human activities that have a known negative effect, and in which case
  - × how much of an ecosystem component is required for its long-term existence and for the survival of species associated with it.
- If the ecosystem component contains a priority species, the reason/s for this designation should be included in the assessment of its required distribution in *areas of ecologically coherent networks*. Examples of priority species are species with dedicated action plans, typical species, species of principal importance, red listed species or protected species (legislation for the protection of species 2007:845, Hallingbäck 2013).

Details and recommendations should be noted as shown in Table 17 (second column from left), section 2.3.2.4, with justifications for the evaluations given. The final decision on the proportion of an ecosystem component that should be represented in *areas of ecologically coherent networks* is made in MOSAIC's implementation part when regional knowledge and analyses on exposure to negative human activities is considered under the criterion *ecological representativity*. More information on this criterion can be found in section 2.4.4.4.

The expert recommendations have not been finalized. However, within regional plans for marine protected areas, the Swedish Agency for Marine and Water Management and representatives from all coastal county administrative boards have specified the area needed to adequately preserve specific ecosystem components for the Gulf of Bothnia and Baltic Proper (Länsstyrelserna 2021a and b). The specific conservation values referred to above are a collection of ecosystem components that are considered particularly valuable and their representativity targets are called "protection objectives". These protection objectives can provide a basis for representativity assessments for common/shared ecosystem components.

2.3.4 *Sensitivity matrices* between ecosystem components and human activity

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How complete are the guidelines?

Guidelines for sensitivity matrices are not yet complete for the first version of MOSAIC. For the time being, county administration boards, or other users, need to choose which matrices to use for their assessments.

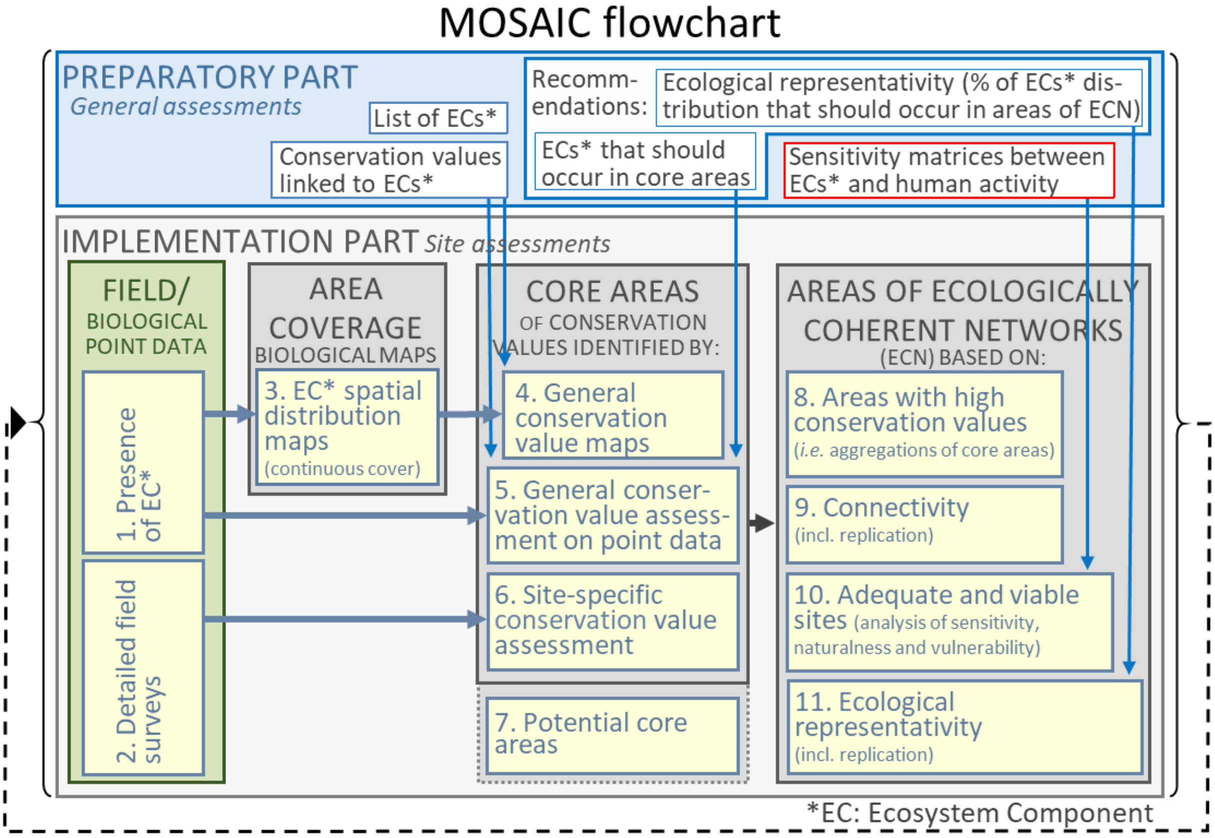

Figure 21. Flowchart showing the different parts and steps that comprise MOSAIC. The relevant section is highlighted in red.

In the preparatory part, suitable matrices to assess the sensitivity of ecosystem components to human activity should be developed or referred to (Figure 21). However, guidelines for this have not been developed and county administrative boards, or other users, should themselves find/develop suitable matrices. These matrices should contain general assessments on how sensitive ecosystem components are to different human activities and impacts (Halpern et al. 2008). In addition to the sensitivity assessments, an estimated safe distance from relevant impacts should be provided. This will form the basis for later landscape analyses showing areas sensitive to human activities/impacts and areas that are most likely suffering from negative human activities (more information in section 2.4.4.3).

The assessments will most likely be very general and not based on site-specific conditions or synergistic effects from several impacts. Additional information should be collected if possible, such as if impacts vary seasonally. It should be highlighted that this is an imprecise/general tool that should be used for landscape analyses to indicate where negative human impacts occur.

Examples of sensitivity matrices can be found in the national marine planning project SYMPHONY (Swedish Agency for Marine and Water Management 2018), in HELCOM Holas II (HELCOM 2018), in Kraufvelin et al. (2020) and in MarLIN/MarESA (Tyler-Walters et al. 2018) (more information in can be found in section 2.4.4.3). Guidelines in MOSAIC should be based on these examples for harmonization.

2.4 Implementation part

The intention is that respective county administrative boards coordinate MOSAIC's implementation part. With the exception of step 4, where assessments are carried out using stricter guidelines (*general conservation value maps* to identify *core areas*), assessments are carried out using expert judgement[42]. When *core areas* or *areas of ecologically coherent networks*[43] do not correspond with those in *general conservation maps* justification needs to be provided for the sake of transparency.

Guidelines for some of the steps are not complete in the first version of MOSAIC, but the structure/framework is in place.

In MOSAIC's implementation part site-specific assessments are carried out with the help of *detailed field surveys* and landscape analyses including:

- field studies (or data from previous field studies)
- spatial distribution maps if possible, i.e. maps with continuous coverage of biological information for the whole area
- identification of *core areas* (places with a high conservation value)
- identification of *areas of ecologically coherent networks* (aggregations of *core areas* in viable and ecologically representative networks with functional connectivity).

See the flowchart (Figure 4 and 5, section 2.2)

2.4.1 Field/biological point data[44]

The "field/biological point data" section is made up of two steps. Step 1 *presence of ecosystem components* aims to provide information on where different ecosystem components occur, step 2 *detailed field surveys* provide more detailed and additional site-specific conservation value information. The two steps overlap each other. For example, both steps provide information on which type of biotope occurs at a location. However, information that can be used to calculate a biodiversity index, for example, can only be obtained from step 2, *detailed field surveys*.

[42] By expert judgement we mean a assessments carried out according to the best available knowledge and where standardized methods cannot be applied (in accordance with Naturvårdsverket 2007a).

[43] See chapter 5 (terminology) for definition.

[44] In this report point data refers to discrete data points (in contrast to continuous coverage data). Even data from transects, or that is spatially limited (such as from video surveys), are regarded as point data.

2.4.1.1 Step 1: Presence of ecosystem components

How complete are the guidelines for step 1?

There is a general description for this step, but recommendations for a gap analysis are lacking. The gap analysis should include information on, for example, which ecosystem components lack presence data. Recommendations on possible gap analyses in step 1 may fall outside of the scope of MOSAIC.

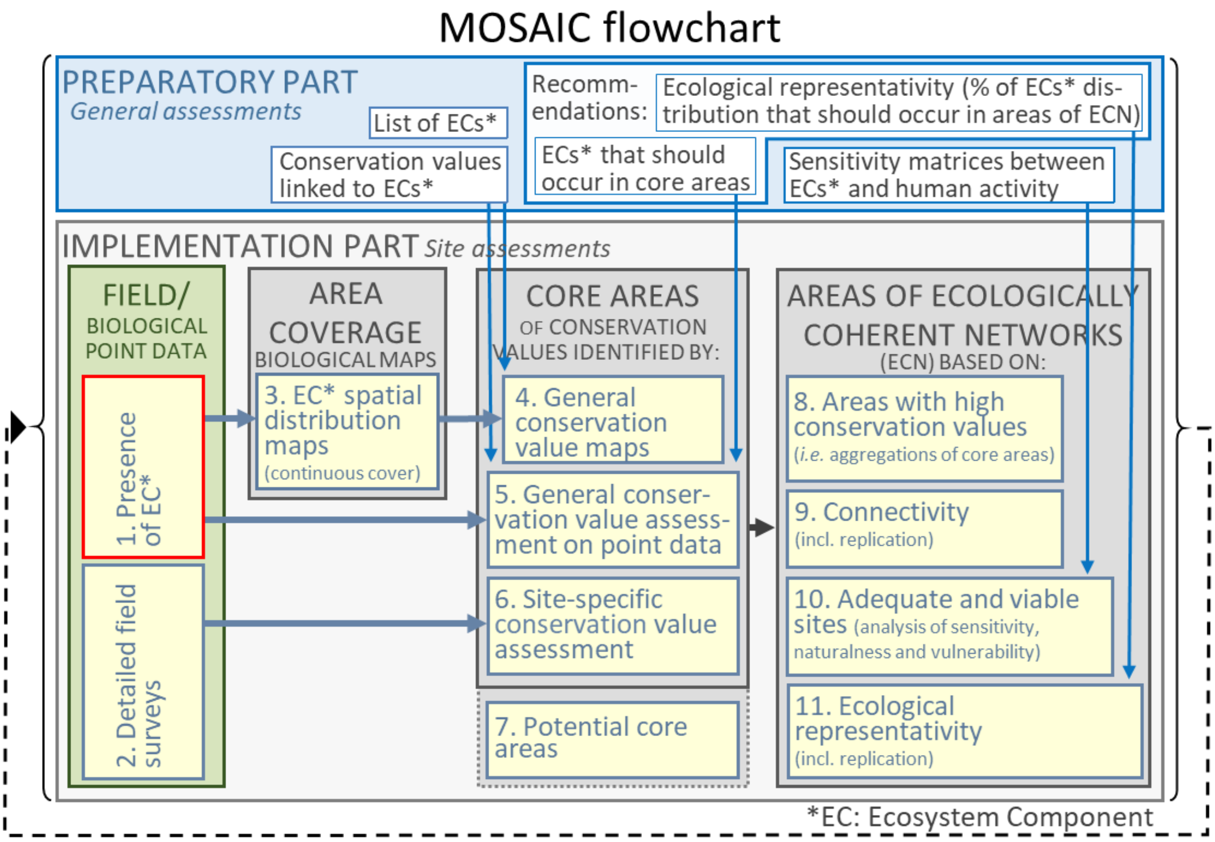

Figure 22. Flowchart showing the different parts and steps that comprise MOSAIC. The relevant section is highlighted in red.

The first step of MOSAIC's implementation part involves collecting data on where different ecosystem components can be found in the area of interest (Figure 10). The quality of the information dictates how it can be used. It can be used to model *ecosystem component spatial distribution maps* (step 3) which are then used to create *general conservation value maps* (step 4). Information can also be used directly to estimate the conservation value associated with sampling locations (points) (step 5).

In order to prioritize areas with the greatest need for management (to avoid negative human impacts) comparisons between areas must be possible. For spatial management (from a landscape perspective) we recommend that point data[45] fulfill the following quality requirements:

- Survey positions should be accurately documented
- Survey area should be documented
- The ecosystem components (species, habitats etc.) that were surveyed and not surveyed should be documented. What ecosystem components are possible to document using the survey method chosen? Are there species not documented that could have been using the survey method chosen?
- The time period for the survey should be documented. Especially for species whose distribution changes greatly over time, an inventory that is too old or done at wrong time of the year will most probably give an incorrect picture of the distribution.
- Survey data should be well balanced (certain habitat types should not be overrepresented in the survey design).

If point data is to be used for spatial distribution modelling (with continuous cover), we also recommend:

- The full gradient of environmental variables (such as salinity, depth, wave exposure) are represented in the surveys (i.e. the shallowest and deepest occurrences of an ecosystem component). Even data from outside the natural gradient of an ecosystem component is valuable in order to record its absence.

[45] In this report point data refers to discrete data points (in contrast to continuous coverage data). Even data from transects, or that is spatially limited (such as from video surveys), are regarded as point data.

2.4.1.2 Step 2: Detailed field surveys

How complete are the guidelines for step 2?

Guidelines for biodiversity surveys have not been developed. These should be developed in combination with step 6, site-specific conservation value assessments*.*

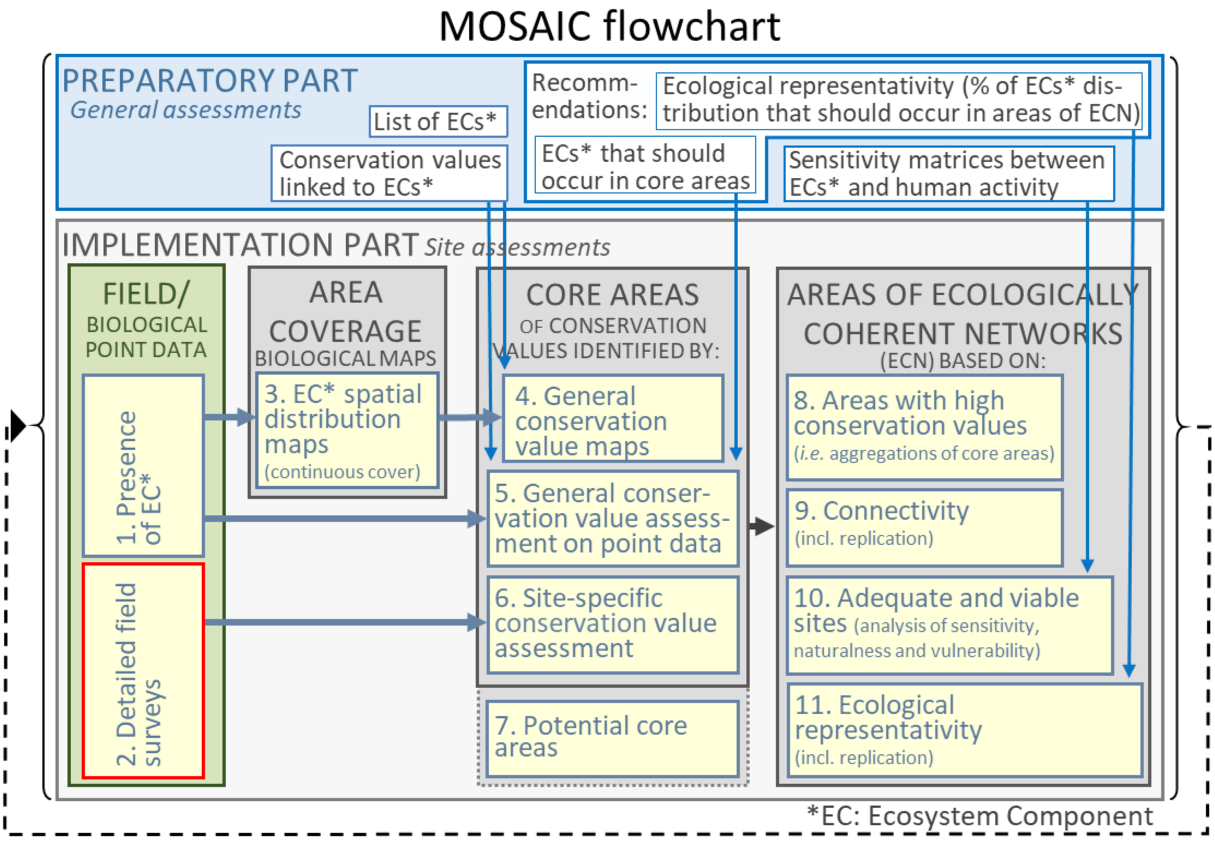

Figure 23. Flowchart showing the different parts and steps that comprise MOSAIC. The relevant section is highlighted in red.

The purpose of the second step, *detailed field surveys* (Figure 23), of MOSAIC's implementation part is to obtain detailed information on a location's conservation value. Guidelines for this step have not been developed. The guidelines for this step depend on the criteria that are used for assessments in step 6, *site-specific conservation value assessments*. Because the two steps are interdependent, guidelines should be developed in combination with each other. In this report we discuss both steps in section 2.4.3.3.

2.4.2 Area coverage maps

2.4.2.1 Step 3: Ecosystem component spatial distribution maps

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How complete are the guidelines for step 3?

A brief description of how ecosystem component spatial distribution maps can be produced is available. More detailed recommendations are not currently planned within MOSAIC and for the time being it is considered outside the scope of the tool. However, gap analysis guidelines need to be produced for spatial distribution maps (for example specify the minimum number of maps needed or a list of mandatory ecosystem components).

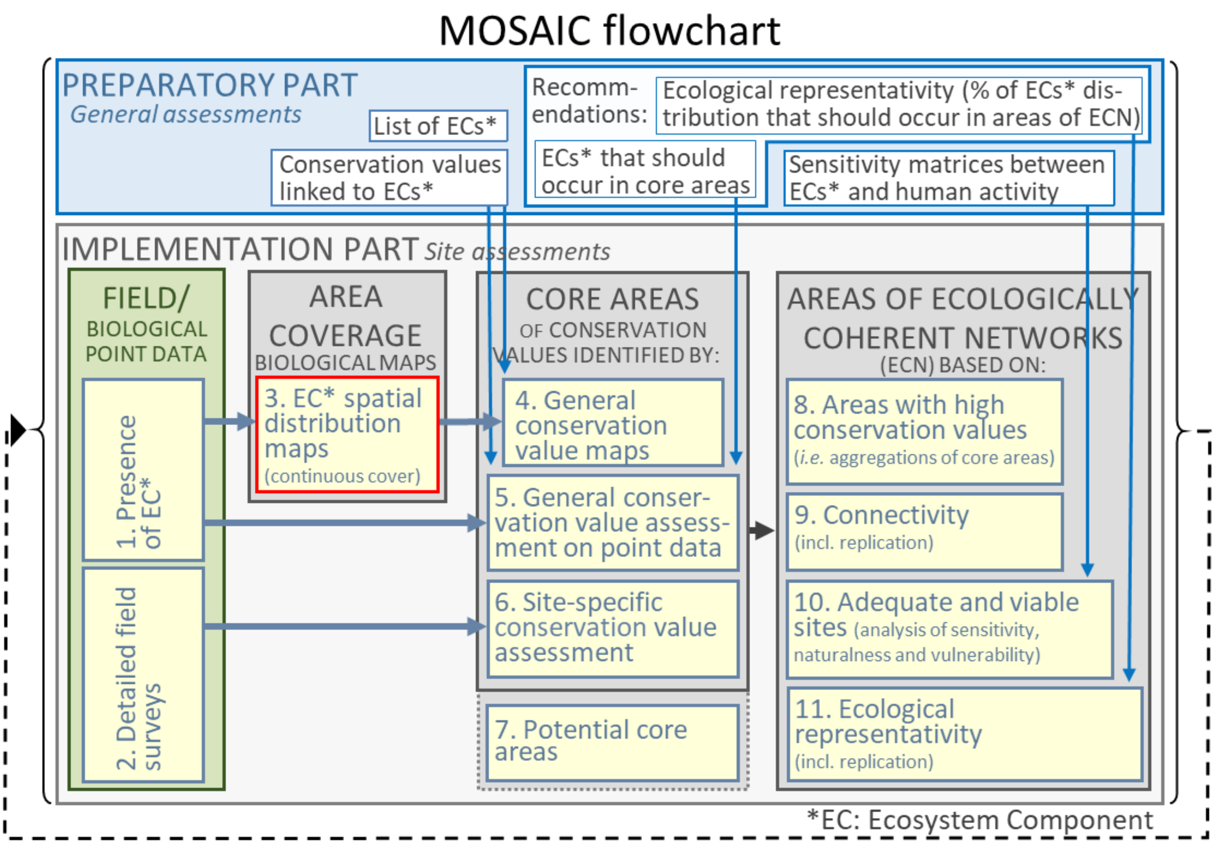

Figure 24. Flowchart showing the different parts and steps that comprise MOSAIC. The relevant section is highlighted in red.

In the third step of MOSAIC's implementation part, *ecosystem component spatial distribution maps* (Figure 24), maps are obtained or created that show where an ecosystem component occurs in an area. The purpose is to gain an overview of the ecosystem components from a landscape perspective. The maps provide an important basis for later analyses on which areas have a high collective conservation value and where the risk for a variety of negative human impacts is high or low.

To account for probable future scenarios – not least those associated with climate change – maps of changing distributions should also be modelled in this step.

2.4.2.1.1 SPATIAL MODELLING OF BIOLOGICAL ECOSYSTEM COMPONENTS

Ecosystem component spatial distribution maps can be produced using different methods. For example, information from point data[46] can be used to find spatial relationships between the occurrence and abundance of an ecosystem component and different environmental variables such as depth, wave exposure, salinity and substrate (see Nyström Sandman et al. 2013; Wijkmark et al. 2015). This kind of predictive spatial modelling measures the variation in occurrence or abundance of an ecosystem component as a function of the different environmental variables influencing its distribution. This relationship is then used to extrapolate and map the probable distribution and abundance of ecosystem components in the entire area.

How well the predictive model performs depends on the amount and quality of the input data. Part of the data should be excluded from the model and used to evaluate model performance – a process known as external validation. This validation method uses data that is unbiased and provides the best opportunity for detecting inaccurate modelling and predictions. Where there is too little data to carry out external validation, modelling can be carried out on the data available but in the knowledge that there is a greater chance that the resulting map will contain inaccuracies.

The modelled *ecosystem component spatial distribution maps* are not as reliable as full-scale surveys of every square meter of an area, but since this is practically impossible, modelled maps provide the best possible alternative. In addition, the models/maps can indicate locations that are worth surveying more closely to investigate their conservation value – locations that might otherwise be missed.

Another advantage with modelled spatial distribution maps is that they can indicate potential locations for an ecosystem component and its conservation value. Modelled maps can even show locations of potential niches for an ecosystem component. Field surveys of these areas can verify or refute the modelled data. During the verification process reasons for the absence of an ecosystem component from a potentially suitable location can be documented. In particular, if absence of an ecosystem component is due to human impacts, the location could be a potential area for restoration or *potential core area*[47] (see step 7). One problem with modelled data is that it is based on occurrences recorded from field surveys. If occurrence/abundance at the survey sites is already impacted by human activity, the model will not be able to identify all potential niches. An example might be if an ecosystem component, that is sensitive to eutrophication, occurs in an area where there is a strong positive correlation between eutrophication and wave exposure. A model based on data from this area would not point out suitable niches in sheltered areas for the ecosystem component because, due to eutrophication, they don't occur in these areas. The

[46] In this report point data refers to discrete data points (in contrast to continuous coverage data). Even data from transects, or that is spatially limited (such as from video surveys), are regarded as point data.

[47] See chapter 5 (terminology) for definition.

model would, however, correctly predict the absence of the ecosystem component in that area. Provided that the input data is of good quality and relevant to the distribution of the ecosystem component, modelled maps are very useful for identifying potential ecosystem component niches.

Since modelled maps also contain information on where an ecosystem component is less likely to be found (which point data usually does not) they can be used to determine how common ecosystem components are – information that is important when deciding on the level of protection needed for species and habitats. However, rare ecosystem components can be more difficult to model. Spatial distribution maps (together with *detailed field surveys*) can also be used to plan where protection should be provided because one can visualize areas of continuous cover where one or more ecosystem components are common (Figure 25).

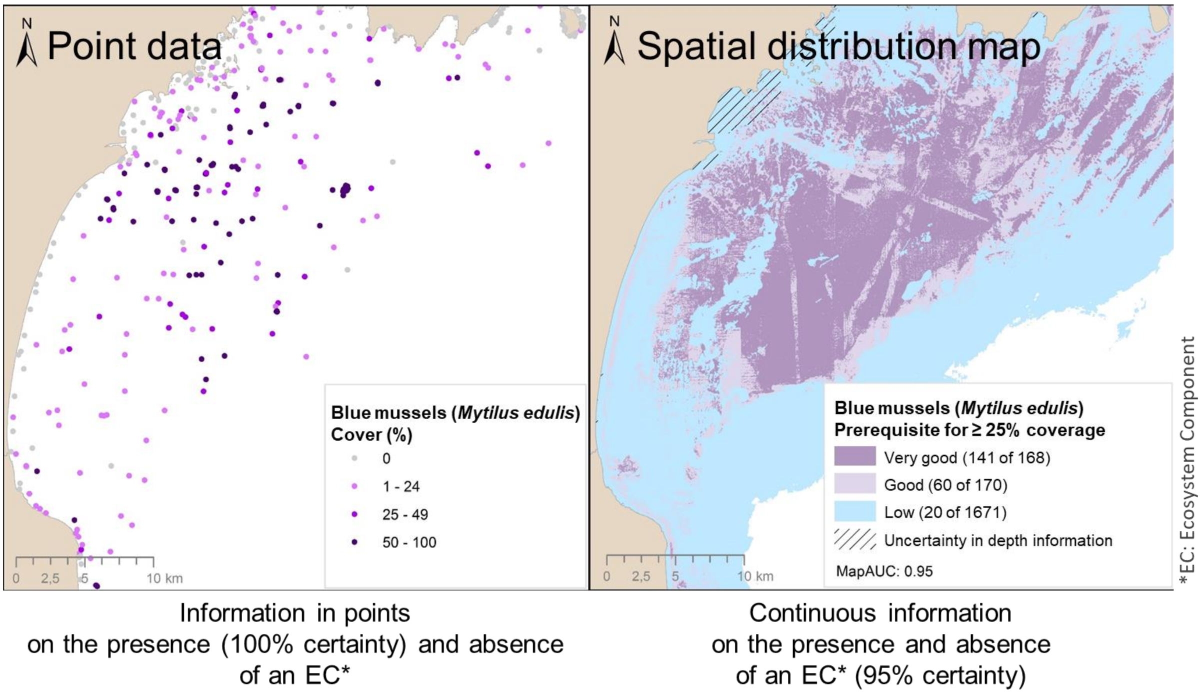

Figure 25. Two maps of blue mussels in western Hanö bay. The map on the left shows point data from transects carried out with underwater cameras or by divers. The map on the right shows a modelled spatial distribution map of the probability of finding mussel beds (at a coverage >25 %). The map on the right is based on the same point data shown in the map on the left but statistical modelling and information on relevant environmental variables (such as depth, salinity, level of exposure and substrate) provide more information on the likely distribution of blue mussels in that part of the bay. The map on the right has been externally validated.

The modelling is only as good as the data it is based on. Producing high quality and reliable ecosystem component distribution maps requires the data from point surveys (field data) to be of sufficient quality for predictive spatial modelling. Data requirements are covered in step 1, *presence of ecosystem components* (section 2.4.1.1).

There is variability in how well biological ecosystem components can be modelled. For example, the magnitude of response of different ecosystem components might differ for a given environmental variable. It is also possible that the environmental variables that best explain an ecosystem components distribution are not included in the modelling. Rare species often have occurrences that are too low for associations to be made between its occurrence and relevant environmental variables. A model based on a dataset with too few occurrences will most likely be able to predict where an ecosystem component does *not* occur with great certainty, but at the same time provide maps that poorly predict their occurrences. Uncommon ecosystem components often require targeted surveys to get enough occurrences for modelling. Due to the higher species diversity (and competition between species) found on Sweden's west coast, distribution models for individual species are likely to be weaker than for the Baltic Sea. However, modelling of organism groups and habitats can be carried out in species rich environments as well, and there are good examples of this being done successfully (see Bekkby et al. 2009; Florin et al. 2009; Soldal et al. 2009).

If spatial distribution maps of biological ecosystem components are unavailable, it might be necessary to use ecosystem components defined by abiotic traits, such as shallow bays with low wave exposure or other habitat types. Conservation value is primarily associated with biological ecosystem components, and it is this conservation value we want to ensure is represented in areas prioritized for spatial management and protected from negative human impacts. Abiotic ecosystem components used for mapping must then have a clear link to specific biological ecosystem components (Näslund 2013) otherwise it is difficult to know what conservation value is at threat from human impacts. For this reason, we recommend using biological ecosystem components as far as possible.

More information on mapping marine green infrastructure (requirements, data collection and limitations) can be found in the AquaBiota Report 2015:05 (Enhus and Hogfors 2015).

By including scenarios of changes in environmental variables (such as changes in salinity or nutrient loading due to climate change), possible future distributions of ecosystem components can be predicted.

2.4.2.1.2 MEASURING UNCERTAINTY IN SPATIAL DISTRIBUTION MAPS

Uncertainty should be assessed for every ecosystem component included in spatial distribution maps. In this section we present a preliminary approach, but this suggestion requires more work before it can be considered complete.

The example includes a standard scoring system based on a five-point scale:

- 0 = data obtained in the cell
- 0.25 = very good model, validated
- 0.50 = good model
- 0.75 = poor model/extrapolated
- 1 = no data, extrapolation not possible[48]

[48] The 5 point-scale follows the scale developed within SYMPHONY – a tool for ecosystem-based marine spatial planning to calculate marine cumulative impacts (Havs- och vattenmyndighets rapport 2018:1). However, in MOSAIC we evaluate uncertainty in the map and not the reliability of the map, because we want to be able to add uncertainties on top of each other.

The uncertainty in maps based on point data is assumed to be 0 for the cells where the ecosystem component is known to occur and 1 for all other cells. This can vary somewhat according to the age of the data (time since the survey was undertaken) since the accuracy of survey positions are generally better in more recent surveys. It is important that the size of the cell (mapping) is not so large that it increases uncertainty (i.e. point data is no longer relevant for the entire cell area).

The uncertainty for modelled surface distribution maps is assumed to be 0.25 for good and validated models. Models have an inherent uncertainty that affects how well the binary occurrence:non-occurrence can be predicted. This uncertainty is described spatially by using the confidence interval for occurrence to calculate an area of uncertainty around the occurrence and non-occurrence border. The cells in the map where predictions are within this area are considered uncertain and receive the value 0.50.

Uncertainty can be summed to obtain a combined uncertainty map (Figure 26). It is important to use this in parallel with the map showing all ecosystem components, because it helps to differentiate areas that have overlapping ecosystem components due to prediction uncertainty from areas that have overlapping ecosystem components due to favourable environmental conditions. The uncertainty maps should probably also provide information on how many categories (birds and mammals, fish and large crustaceans, benthos) and ecosystem components the collective uncertainty is based on.

The exact points-scale and performance of the uncertainty analysis should be tested on real data before a decision is made on its final form.

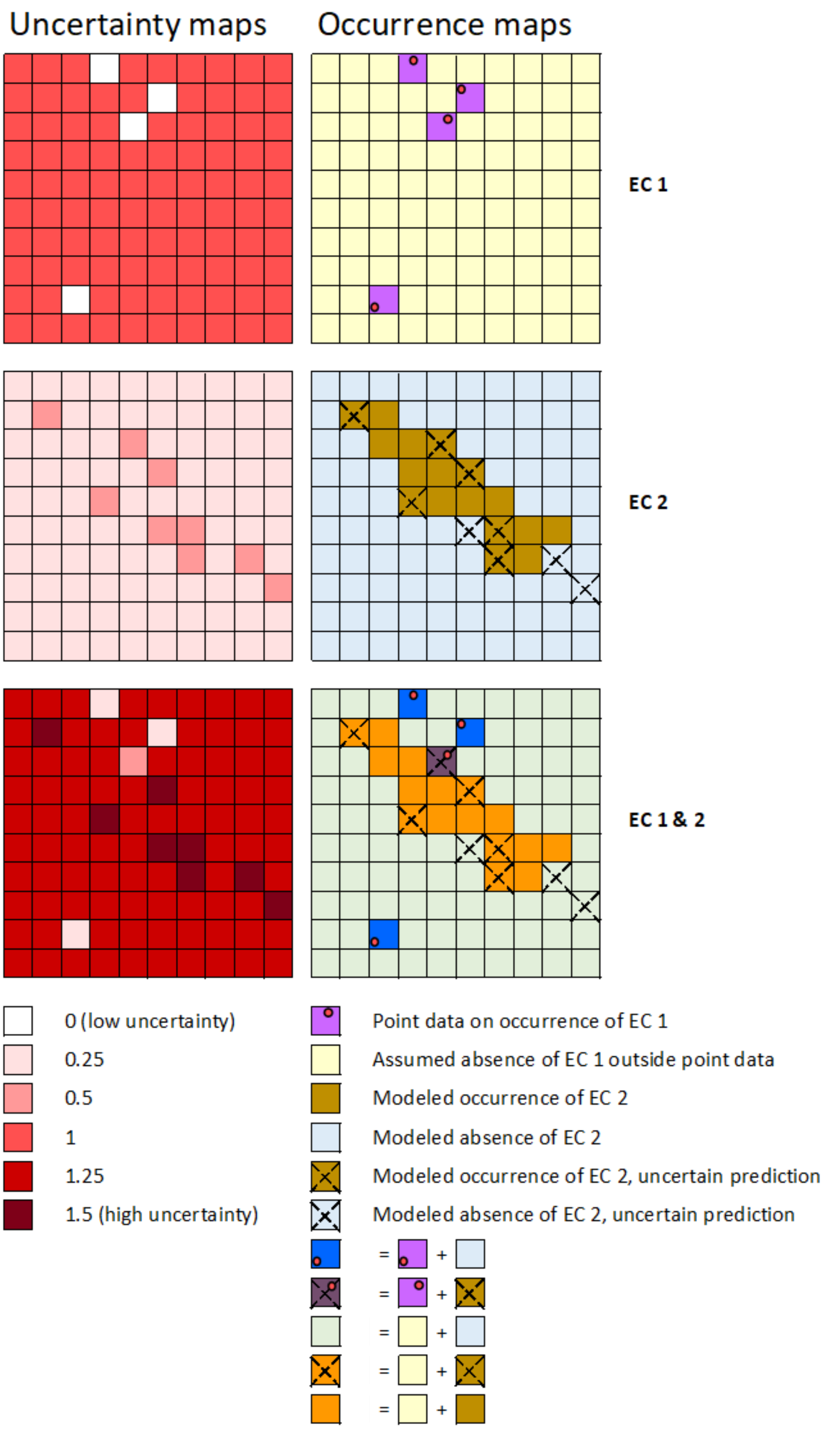

Figure 26. The "map" on the top left illustrates how uncertainty might be represented for the occurrence of an ecosystem component (EC 1) based on point data (top right). Uncertainty for this method is high in cells that have not been surveyed (because EC 1 is assumed to be absent). The "map" on the middle left illustrates how uncertainty can be represented after modelling of another ecosystem component (EC 2). This map shows where predicted occurrence and absence are less or more certain based on known physical/environmental conditions. The "map" on the bottom left illustrates how the maps for EC 1 and EC 2 can be combined to produce a combined uncertainty map.

Prior to its use for mapping, one should ensure that spatial distribution data:

- covers the entire area that is to be assessed
- contains sufficient detail (i.e. resolution should not be too low)
- is collected in the relevant season and represents current distributions (data should not be too old)
- contains relevant information (for example, provides information on a degree of coverage that is relevant for a species).

2.4.3 Identifying *core areas*

The definition of a marine *core area* is: An area with a high conservation value with respect to biodiversity and the provision of ecosystem services.

Core areas can be identified directly using point data from *presence of ecosystem components* (step 1), from *detailed field surveys* (step 2) and from *ecosystem component spatial distribution maps* (step 3). The different methods should support each other by combining important detailed information on specific locations with a landscape perspective over areas with a higher conservation value.

The criteria used to identify *core areas* are based on those found in the UN Convention on Biological Diversity (CBD) for determining ecologically and biologically important areas - EBSAs (Ecologically or Biologically Significant Marine Areas) (Annex 1, decision IX/ 20, CBD 2008). The EBSA criteria are used on two occasions in MOSAIC (Figure 27). Firstly, when conservation value is assigned to ecosystem components, specifically the conservation value an ecosystem component generally contributes to a location. Because this is not a site-specific conservation assessment, we have chosen to include criteria that are best suited for this purpose (see Figure 27). Several other criteria (not from the CBD) are also included when conservation value is linked to ecosystem components, notably criteria for direct ecosystem components. More information can be found in section 2.3.2.

The second time EBSA-criteria should be used in MOSAIC is during *site-specific conservation value assessments* (see Figure 27) in step 6 (section 2.4.3.3). During this step, criteria should be assessed according to site-specific data. However, guidelines for *site-specific conservation value assessments* have not yet been developed for Mosaic.

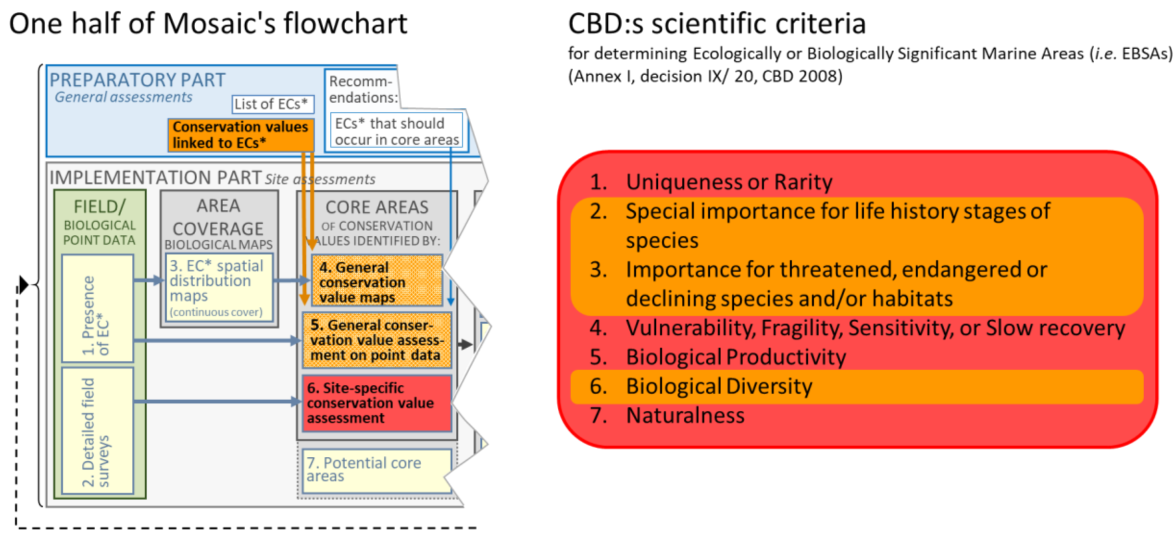

Figure 27. The UN Convention on Biological Diversity's (CBD) criteria for determining Ecologically or Biologically Significant Marine Areas – EBSAs (Annex 1, decision IX/ 20, CBD 2008) are central to identifying *core areas* in MOSAIC. The criteria are used on two occasions in MOSAIC (see flowchart). Firstly, when conservation values are linked to ecosystem components (which are subsequently used in steps 4 and 5 of the implementation part; marked in orange in the flowchart) and secondly during step 6 where *site-specific conservation value assessments* are carried out (marked in red in the flowchart). Guidelines for step 6 have not yet been developed but we recommend that all the EBSA-criteria are used for this step. Because assessments in the preparatory part (*conservation values linked to ECs*) are not site-specific, but an assessment of the conservation value an ecosystem component generally contributes to a location, specific and relevant EBSA-criteria have been selected. These are *biological diversity*, *special importance for life-history stages* and *threat status*. The latter two are abbreviations of CBD's second and third criteria. In MOSAIC ecosystem services can be included in the assessments if desired.

2.4.3.1 Step 4: General conservation value maps

How complete are the guidelines for step 4?

Guidelines are available in version 1 of MOSAIC. However, guidelines on how to report deficiencies in the data are lacking.

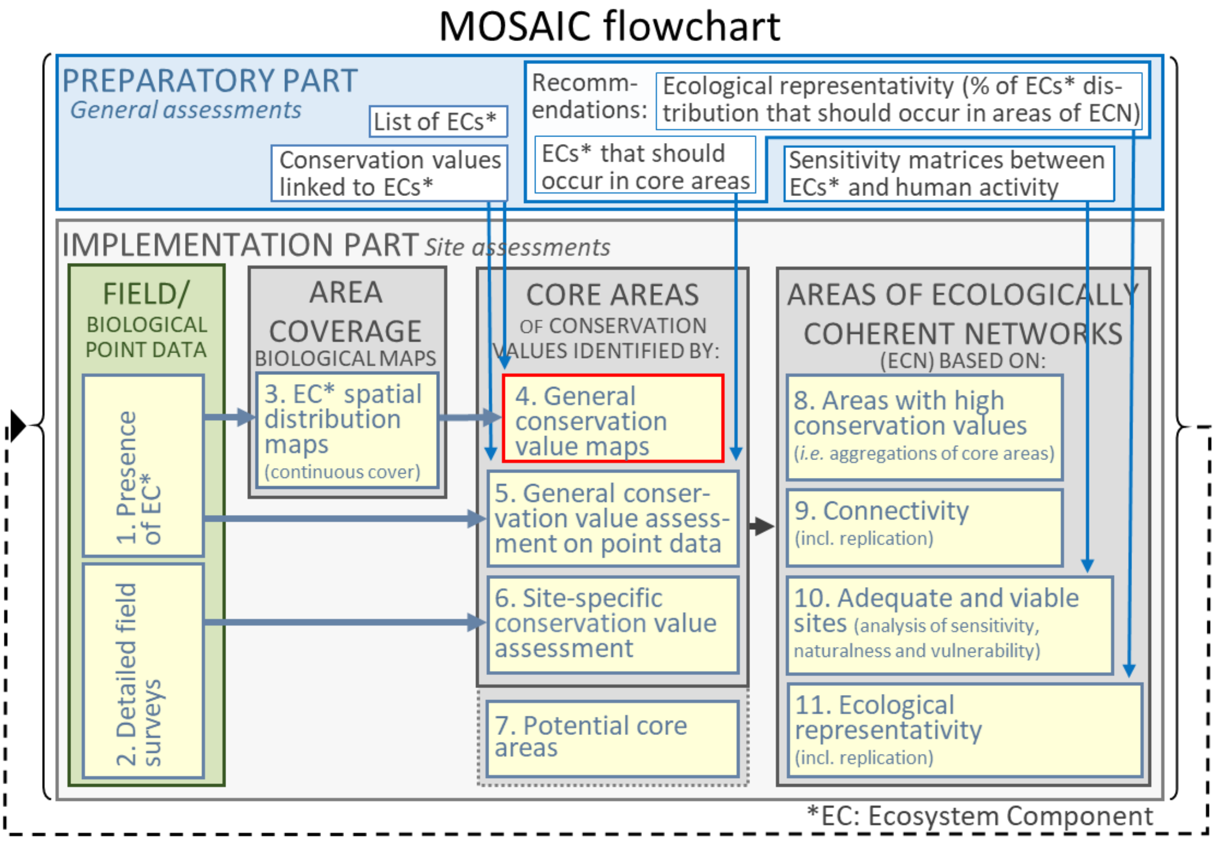

Figure 28. Flowchart showing the different parts and steps that comprise MOSAIC. The relevant section is highlighted in red.

In the fourth step of MOSAIC's implementation part, *core areas*[49] are identified using *general conservation value maps* (Figure 28). This is done by carrying out general conservation value assessments on *ecosystem component spatial distribution maps*. The purpose of *general conservation value maps* is to identify where conservation value aggregates in a landscape. Maps can be produced in different ways with pros and cons to each method used – the following text describes a method that we found suitable. In section 2.4.3.1.1 we discuss our suggested method.

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[49] See chapter 5 (terminology) for definition.

The data used to produce a *general conservation value map* in MOSAIC comes partly from the conservation value points assigned to ecosystem components in the preparatory part[50] and partly from *ecosystem component spatial distribution maps* (Figure 29).

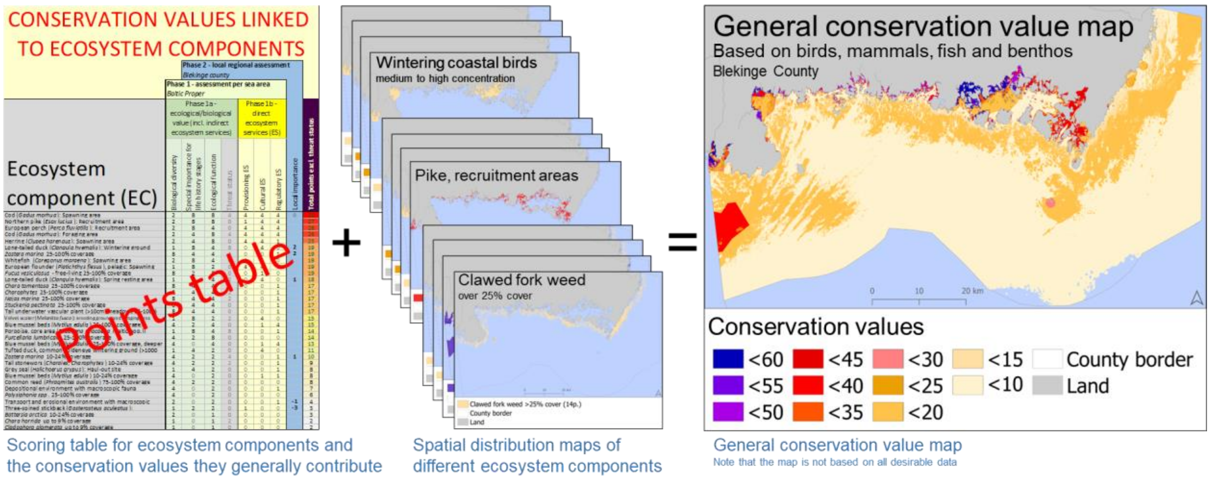

Figure 29. The conservation value points assigned to ecosystem components in the preparatory part (conservation value that an ecosystem component generally contributes to a location) are combined with *ecosystem component spatial distribution maps* to produce *general conservation value maps*.

Points associated with respective ecosystem components can be based on criteria for ecological/biological value (including indirect ecosystem services) alone or include points for direct ecosystem services. Points for direct ecosystem services should be included for spatial management relating to, for example, green infrastructure. Note that maps produced using only direct ecosystem services are highly unsuitable because they exclude the essential indirect ecosystem services (included in criteria for ecological/biological value).

Because several ecosystem components can occur on the same point on a map (Figure 30 a-b), which is inevitable when summarizing a three-dimensional[51] world onto a two-dimensional map, the area is divided into a raster or grid (Figure 30 c). The water column in each cell is called the "minimum assessment unit" (Figure 30 d). Points for ecosystem components that occur in each "minimum assessment unit" (regardless of where in the water column they occur) are assigned.

[50] A first version of the *list of ecosystem components* and the conservation value they represent can be found in an Excel document, *MOSAIC – ecosystem component lists and conservation values, version 1*, that can be downloaded from the Swedish Agency for Marine and Water Management website. The lists have been compiled by ~50 experts within several working groups and workshops. The lists are divided into the Bothnian Bay, Bothnian Sea, Baltic Proper and Kattegat/Skagerrak sea areas because of broad differences in the species composition and ecosystems between them.

[51] The "fourth dimension" – time – is handled in MOSAIC through reoccurring revisions. Seasonal variations are not accounted for in version 1 of Mosaic (an area will be pointed out as having high conservation value even if it is only for a limited time over the course of a year). It is possible that future versions of Mosaic will better account for season variation.

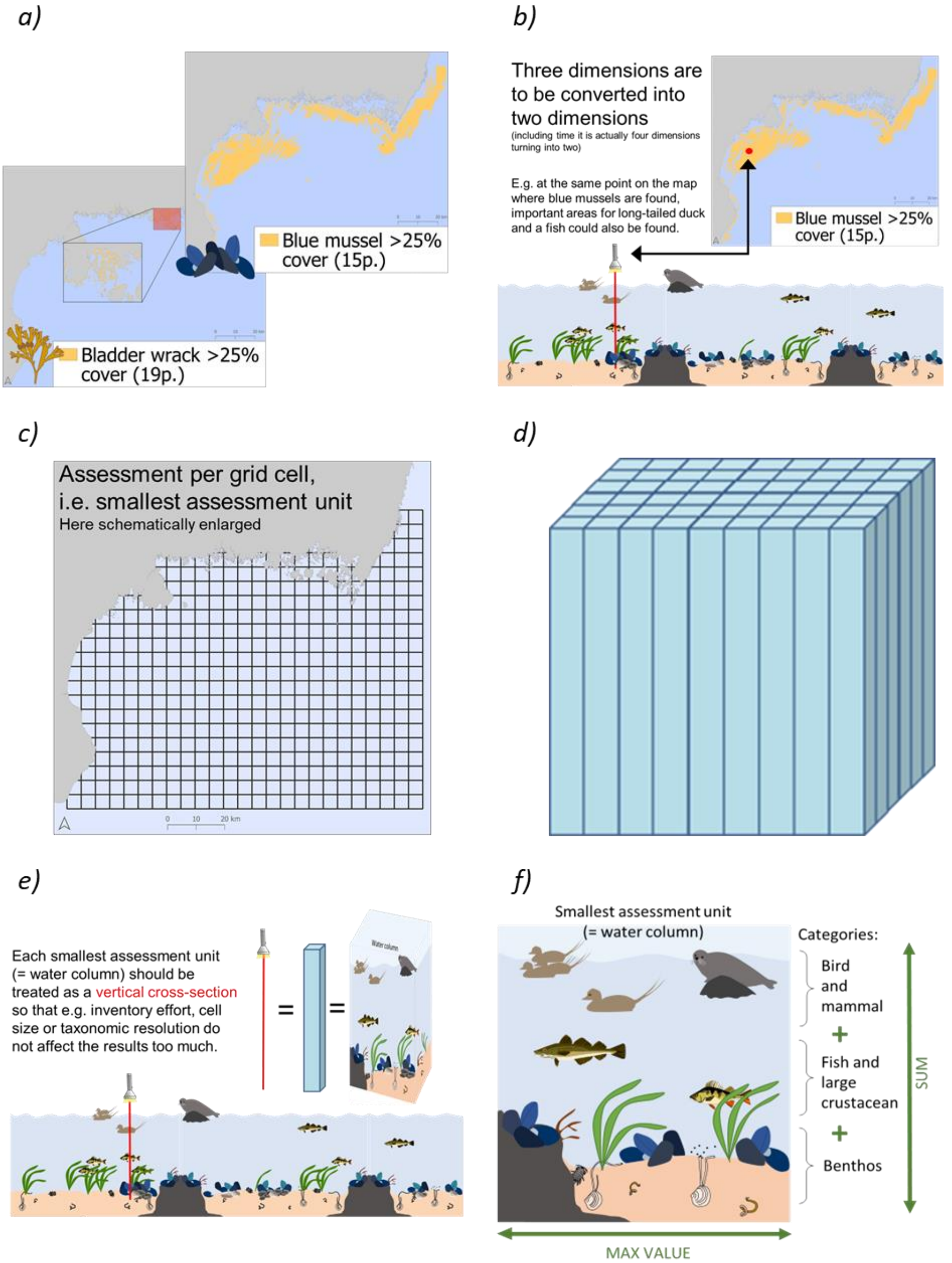

Figure 30. (a) Example of a surface coverage map of two different ecosystem components. Because a two-dimensional map is created from a three-dimensional reality several ecosystem components can occur on the same point on a map (b). To account for this, the sea area is divided into a raster of cells (c) (here schematically enlarged; in reality the maps are based on 25 x 25 m cells). The water column within each cell is the "minimum assessment unit" (d) and should be treated as a vertical transect through the water to enable comparisons between areas with different cell sizes ("minimum assessment units"). By treating the water column as a vertical transect, bias arising from varying sampling frequency is reduced. Biological ecosystem components have been divided into categories that can be found in different layers of a water column (f). The points from these categories are combined when assigning conservation value points to produce *general conservation value maps*. If several ecosystem components from the same category occur in the same cell, the highest value should be used (i.e. the maximum value within a category; f and see Figure 31). Each category should only provide points from one ecosystem component per vertical transect. The total points assigned to each "minimum assessment unit" are the summed value of each of the categories' maximum value (f; and see Figure 32). This is a simplification of reality, but necessary to avoid problems associated with scale and methods.

We recommend that “minimum assessment unit” cells are between 10 x 10 m (100 m^2) to 50 x 50 m (2500 m^2) along the coast. “Minimum assessment units” offshore can be up to several km^2, depending on how homogenous the environment is. Because the method simplifies the heterogenous environments found in each water column transect it is important that the cells are not too large in variable environments. Environmental differences between areas are reduced when using larger assessment units decreasing the suitability for spatial management.

Every “minimum assessment unit” should be assessed as a vertical cross-section through the water (Figure 30 e), even if conservation value is found horizontally in cells adjacent to each other. This is done to reduce the effect of variable cell size, variable survey/mapping/modelling efforts, differences in taxonomic resolution of ecosystem components and the risk of double scoring. More information on treating the “minimum assessment unit” as a vertical cross-section can be found in section 2.4.3.1.1.

In order to assess the “minimum assessment units” as a cross-section, biological ecosystem components are divided into categories that are roughly separated vertically in a water column (Figure 30 f). The categories are:

- birds and mammals
- fish and large crustaceans and
- benthos

Large crustaceans include large decapods, with a certain mobility, that are often valuable for commercial and recreational fisheries: species include European lobster (*Homarus gammarus*), langoustine (*Nephrops norvegicus*), prawns (*Pandalus borealis*) and edible crab (*Cancer pagurus*).

To create a *general conservation value map*, the points that are assigned to occurring ecosystem components a “minimum assessment unit” and its water column, are to be compiled in its grid cell of the map. This is done by taking the highest value, <u>the maximum value,</u> within each category (birds and mammals, fish and large crustaceans and benthos). Maps showing the maximum value per category could be saved and used for analyses later on. The maximum values, from each category are then <u>summed</u> together (Figure 30 f, 31 and 32). In other words, only one ecosystem component should be represented per category in each cell (giving three ecosystem components per cell). *General conservation value maps* will be subsequently used to identify *core areas*[52].

[52] See chapter 5 (terminology) for definition.

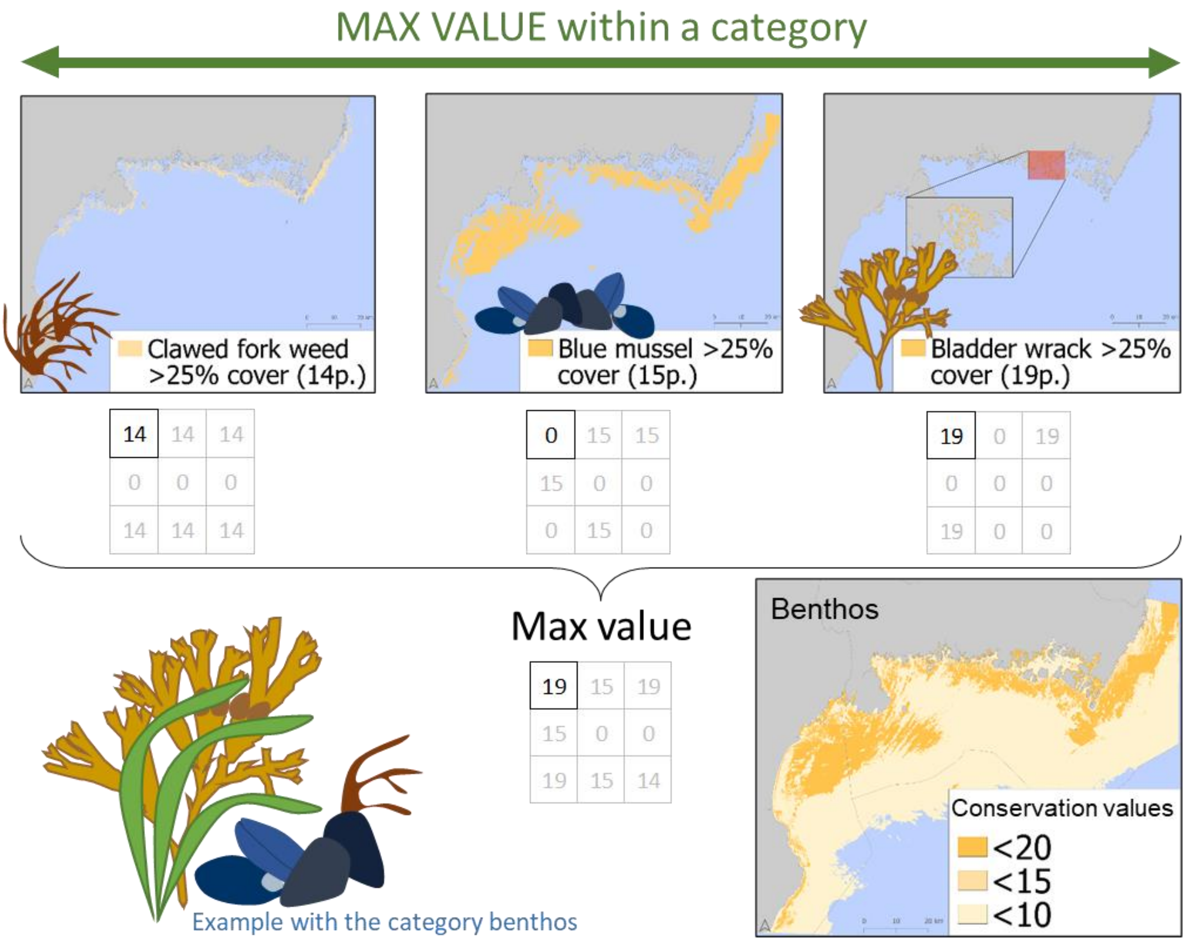

Figure 31. The three uppermost maps show ecosystem components belonging to the same category (benthos): *Furcellaria* with 25-100 % coverage, blue mussel beds with 25-100 % coverage and bladder wrack with 25-100 % coverage. From Table 17 we can see that each ecosystem component has been awarded 14, 15[53] and 19 points respectively. To compile points within a category (here benthos) the ecosystem component with the highest points (maximum value) is selected in each cell (”minimum assessment unit”). See also Figure 30 f. The maps shown in this example have been produced following extensive field surveys which were used to model the occurrence and conservation value in 25 x 25 m grid cells. The maps were then verified in the field. The lower map showing the conservation value of benthos is based on more ecosystem components than the three uppermost maps.

[53] Note that when comparing with Table 6, criteria accounting for local importance (blue column in Table 6) are not used because the maps represent the whole of Hanobukten bay, not just Blekinge county. Blue mussel beds with a coverage > 25% are therefore scored 15 and not 17 points.

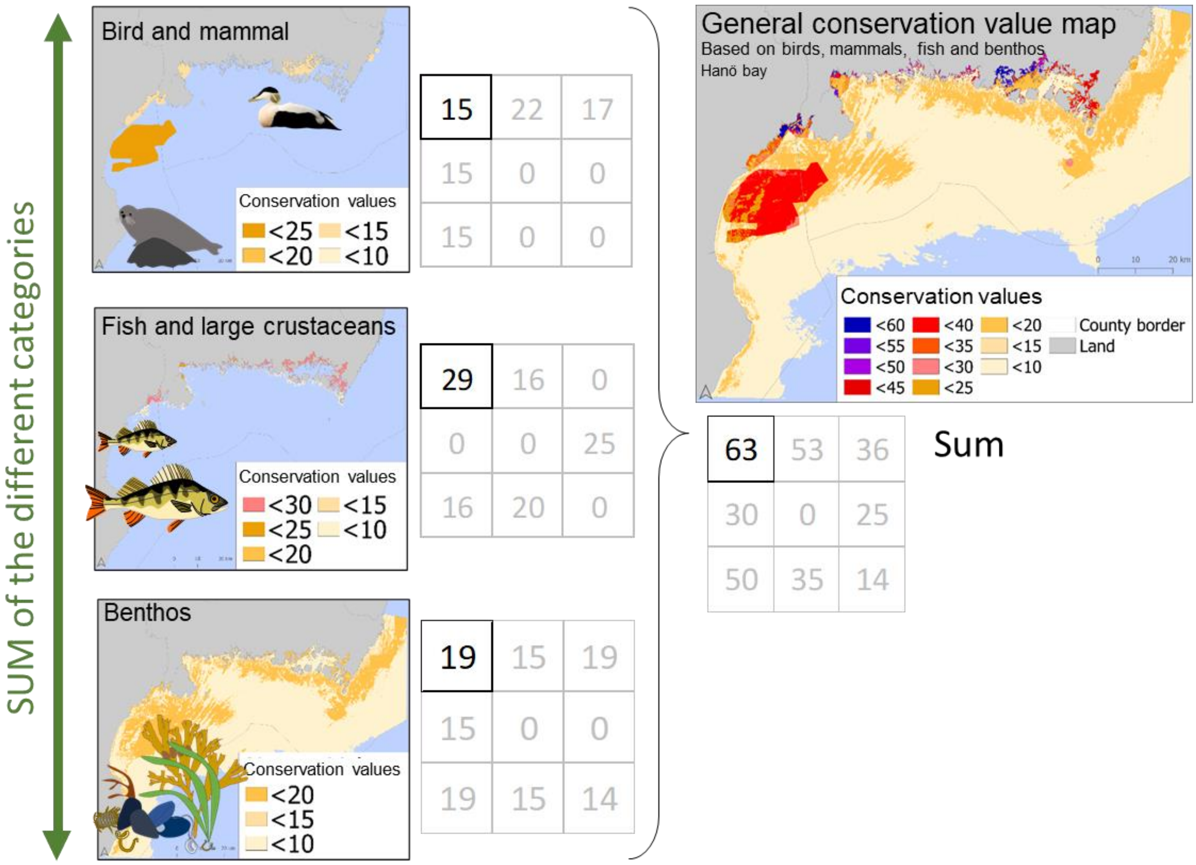

Figure 32. The three maps on the left show the conservation value points for birds and mammals, fish and large crustaceans and benthos for the area. The maximum values from each category are summed in each cell or minimum assessment unit to produce *general conservation value maps* (map on the right; see also Figure 30 f). The maps shown in this example have been produced following extensive field surveys which were used to model the occurrence and conservation value in 25 x 25 m grid cells. The maps were then verified in the field. This example does not, however, contain data on all possible ecosystem components and should not be considered as the final map of conservation values. The general conservation value map on the right is the primary distribution map used to identify *core areas*, but maps for each respective category can also be used independently.

We have found that the combined map of the conservation value including all of the categories was the most suitable for identifying areas with a high conservation value and good *ecological representativity*. However, no method that attempts to systematically produce maps of conservation values is flawless and it is important to remain critical when analyzing the maps. And, as always, the results depend on the amount and quality of data available.

An alternative method is to use maps created for each category (birds and mammals, fish and large crustaceans and benthos; Figure 31) separately. However, when analyzing these maps, be aware that the value of each cell only reflects the value of one ecosystem component (the one with highest points) since points from different categories are not summed. Areas indicating high conservation values will then give a lower representation or spread of different ecosystem components, compared to *general conservation value maps* that have been made based on all categories.

By identifying areas with a high concentration of points in a *general conservation value map* (preferably made using all categories) one can demarcate *core areas*[54] (Figure 33). The demarcation of *core areas* can be adapted according to specific management purposes. For example, ten percent of the area (with the highest points) in a map can be identified as *core areas*.

The ten percent suggested above is influenced by the national Swedish environmental protection goal of protecting at least ten percent of marine areas by 2020 to meet national and international targets relating to the protection of biodiversity. Protected areas should be important for biological diversity or ecosystem services whilst simultaneously accounting for *ecological representativity* and *connectivity*. Ten percent should be regarded as a minimum example that can be increased. *Core areas* that have been identified from *general conservation value maps*, should be prioritized for *detailed field surveys* in the next management cycle, if these have not already been carried out. A checklist for the relevant steps that should be carried out by county administrative boards, or other users, can be found in the Swedish Agency for Marine and Water Management report 2020:14[55].

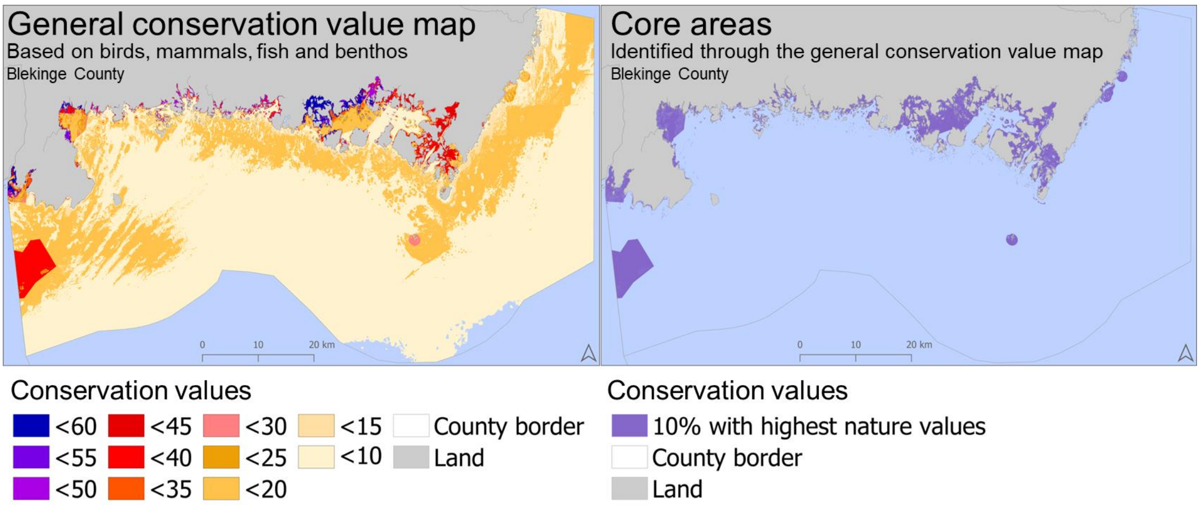

Figure 33. The map on the left is a *general conservation value map* for Blekinge County. The map on the right shows the 10 % of marine area that contain the highest conservation value points according to the *general conservation value map*. These areas are demarcated as *core areas*.

2.4.3.1.1 DISCUSSION AROUND GENERAL CONSERVATION VALUE MAPS

This section takes a closer look at *general conservation value maps* and can be ignored if the reader is not interested in detailed information relating to their production.

Even though coastal "minimum assessment units" should be small (100 m^2 to 2500 m^2), every cell will still be large enough to contain several biotic ecosystem components adjacent to, or

[54] See chapter 5 (terminology) for definition.

[55] Swedish Agency for Marine and Water Management report 2020:14 *Conservation values from a seascape perspective – user manual for MOSAIC, version 1*.

overlapping, each other. These should be assessed as a vertical cross-section of the water column (including the water and sediment surfaces). To achieve this, ecosystem components are grouped into general categories that can be found in the different vertical layers of the cross-section. The categories are “birds and mammals”, “fish and large crustaceans”, and “benthos” which represent a very rough vertical division of ecosystem components in a water column. The “minimum assessment units” are further treated as a vertical cross-section by selecting the ecosystem component present that contains the highest conservation value within each category. Simply put, each category is only represented by one ecosystem component per “minimum assessment unit”. Soft and hard substrate biotypes are seldom found vertically in the exact same vertical cross-section (Figure 34). The maximum value from each category is summed (Figure 30 – 32) to provide a final conservation value score for the respective “minimum assessment unit”. This method was developed after considering the following aspects:

- If the “minimum assessment unit” summed the value of all the ecosystem components instead of the maximum values of each category in a vertical cross section, it would have been crucial to account for the area of the assessment cells because large areas often contain more ecosystem components than small areas. This would complicate the assessment. Using larger assessment units also increases the chance that a highly valuable ecosystem component will occur and thereby also affects the outcome when treating the “minimum assessment unit” as a vertical cross section. However, the effect is reduced when treating the “minimum assessment unit” as a vertical cross section than if the sum of all ecosystem components is used. Nevertheless, it is important that the size of “minimum assessment units” is not too large.

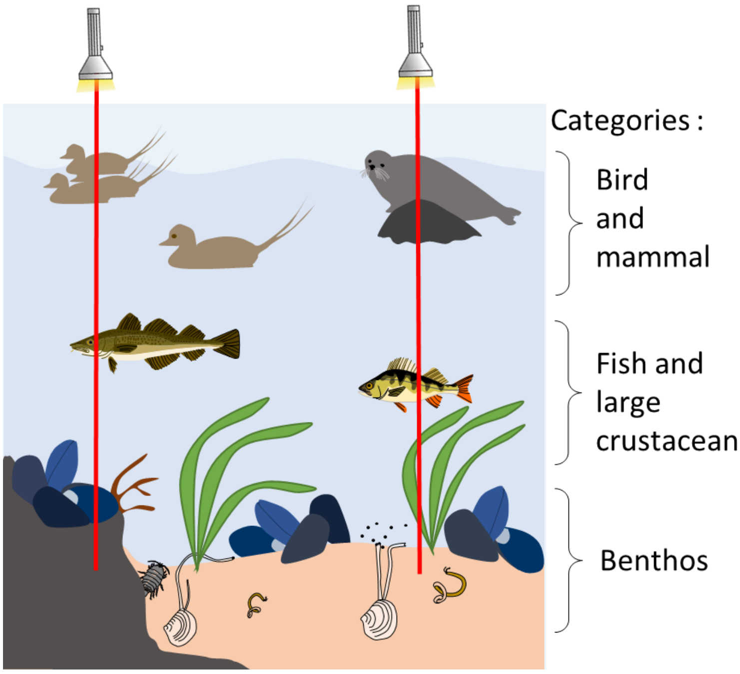

Figure 34. In a vertical cross-section, benthos ecosystem components are either on soft or hard substrates. If every “minimum assessment unit”/water column/cell is assessed as a vertical cross-section, then soft and hard substrates are not summed together. Instead, the maximum value should instead be used.

- If the value of all ecosystem components within each category were summed (instead of taking the maximum value) a location would increase in value with increasing numbers of surveys/mapping/modelling which would give an incorrect (sampling bias) representation of where conservation values occur. This can even be a problem when selecting a single maximum value per category because the chance of finding a valuable ecosystem component increases with increasing survey effort. However, the effect is not as great as it would be if ecosystem components are summed within categories.

- If the value of ecosystem components within each category were summed (instead of taking the maximum value) the taxonomic resolution of the biological ecosystem components would have a large effect on the conservation value identified. For example, if “wintering area for seabirds” were divided up into several biotic ecosystem component (one for each species) it would result in a much higher conservation value for an area than the collective “wintering area for seabirds” ecosystem component (a comparative example for vegetation can be seen in Table 18).
- The definition of ecosystem components can overlap each other (“tall underwater vascular plants” and “eelgrass” for example). If the maximum value is not used in each category there is a risk for double counting the scoring of the same ecosystem component.

Table 18. The table shows how the sum of ecosystem components calculated for a category (benthos) result in a conservation value that is highly sensitive to taxonomic resolution compared to using a maximum value. Differences in taxonomic resolution between categories (birds and mammals, fish and large crustaceans and benthos) in the same assessment area can also result in highly variable general conservation maps if the sum of the ecosystem components is used.

Taxonomic resolution example 1: grouped by species	**Points**
Ceratophyllum demersum 10-24% coverage	9
Myriophyllum spicatum 10-24% coverage	9
Potamogeton perfoliatus 10-24% coverage	9
Stuckenia pectinata , single occurrences and up to 9% coverage	2
Fucus serratus , single occurrences and up to 9% coverage	**2**
Fucus vesiculosus , single occurrences and up to 9% coverage	**2**
Chorda filum , single occurrences and up to 9% coverage	2
MAXIMUM VALUE	**9**
SUM	**35**

Taxonomic resolution example 2: grouped by broader taxa	**Points**
Tall underwater vascular plant (>10cm) meadows 10-24% coverage	**9**
Tall underwater vascular plants (>10cm), single occurrences and up to 9% coverage	**2**
Large perennial brown algae, single occurrences and up to 9% coverage	**2**
Large annual brown algae, single occurrences and up to 9% coverage	**2**
MAXIMUM VALUE	**9**
SUM	**15**

Due to the reasons stated above, the summed value of points within a category should not be used when making *general conservation value maps*. However, use of a maximum value within each category will not represent the conservation value of an area with a high diversity of (many) ecosystem components (species). This is partly overcome because there is a greater chance that a high scoring ecosystem component will occur in areas where there are many ecosystem components (high diversity). A deeper analysis is required to ensure that diversity is adequately accounted for using a maximum value per category.

By modelling the “diversity of ecosystem components” biological diversity can be incorporated into *general conservation value maps* even more. However, it is not easy to find a method that effectively integrates ecosystem component diversity and maximum values in this step.

Accounting for the conservation value provided by a high diversity of ecosystem components would be more suitable as part of step 11, *ecological representativity*. More information on how MOSAIC incorporates biodiversity in its assessments can be found in section 3.1.

The general assumption that areas with a high diversity of biotopes are more valuable than areas with few biotopes is not always correct. For example, an area with many overlapping biotopes might represent suboptimal environmental conditions for all biotopes. This *could* mean that none of the biotopes achieve their full conservation value potential and may not function well as habitat for their associated species. Negative edge effects can occur where biotopes overlap in their outer zones. However, locations with many ecosystem components within the same category are usually a reflection of a higher biodiversity and therefore a higher conservation value (Figure 35).

In HELCOM's Underwater Biotopes (HUB; HELCOM 2013), biotope classification is strictly hierarchical and according to predefined conservation values. For example, sessile, perennial, epibenthic organisms are deemed more valuable than non-sessile, perennial algae which in turn are deemed more valuable than annual algae. When assessing the conservation of a site, such as over a soft substrate, one first looks for the presence of perennial, epibenthic and sessile organisms (at 10 % coverage, for example), and if this is not present then one looks for the presence of non-sessile, perennial algae (10 % coverage) and so on. This is analogous to the method used in MOSAIC where the maximum points per category are used to create *general conservation value maps*.

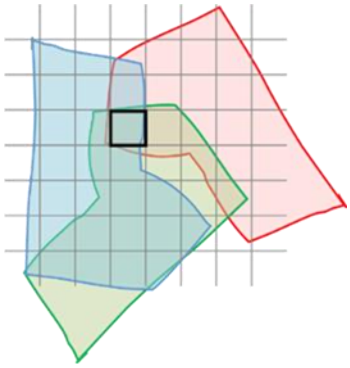

Figure 35. The square surrounded by a black border represents a minimum assessment unit/water column/cell where three different ecosystem components from the same category overlap (biotypes, for example). This cell might contain the highest conservation value because of the diversity of ecosystem components found there. But it doesn´t have to be the case; because the cell is on the border of each of the biotypes, environmental conditions might be suboptimal for each of the biotypes and it is possible that the full conservation value potential of each is not realized.

When mapping conservation values, trade-offs are made on transparency, objectivity, standardization, flexibility (to ecological mechanisms) and current relevance/conditions. No method that handles complex ecological systems will be faultless and the results should be assessed critically. However, these guidelines should be followed when creating *general conservation value* maps.

Several different maps related to a *general conservation value map* can be seen in Figure 36. The *general conservation map* (a) is primarily determined by the occurrence of ecosystem components with a high conservation value (map b) and how many categories are represented at a given location (map c). In this case the general conservation value map is not unlike the map showing the sum of all the ecosystem component points in each "minimum assessment unit" (map d). As explained earlier in this section, we strongly advise against using this map because it can vary according to several factors such as the taxonomic resolution used in ecosystem components and in categories (see earlier text and Table 18).

When comparing locations that have been surveyed and assessed using the same methods conservation value can be calculated by summing points from all the ecosystem components in each category. At the end of section 2.4.3.2 (step 5, *general conservation value assessments on point data*) we describe several quality-control factors that should be met if this is to be carried out. However, this method should be used with caution, and not when creating spatial distribution maps.

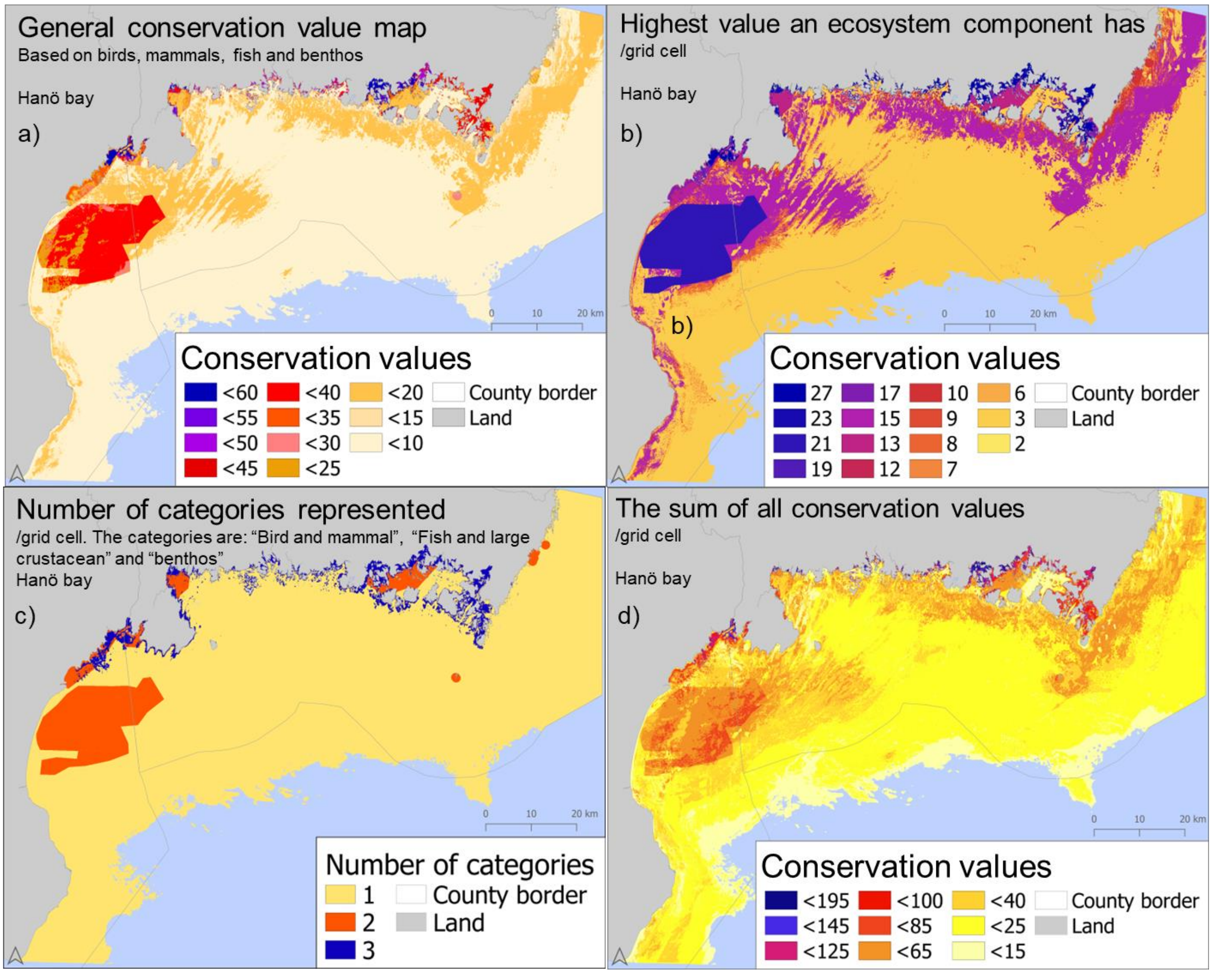

Figure 36. Some of the factors that determine a *general conservation value map* (a). The general conservation map is primarily determined by the occurrence of ecosystem components with a high conservation value (map b) and how many categories are represented at a given location (map c). The map on the lower right-hand side (d) shows the sum of all the ecosystem components found in each "minimum assessment unit". A map created using this method can be misleading because, for example, it is heavily influenced by the taxonomic resolution used when dividing species into ecosystem components. For example, large differences occur if ecosystem components are represented by single species or grouped to represent several species (such as a habitat, see Table 18). Note that the scale and colours representing conservation value differ between the maps.

If an ecosystem component or category dominates the conservation value of an area to the degree that the conservation value of other ecosystem components is masked, then the conservation value of the dominant ecosystem component should be reassessed. In addition, the quality of the maps on which the *general conservation value map* is based should also be investigated. By comparing maps for the three categories, it should be possible to determine if one of the categories strongly influences the conservation value assessments. In a pilot study conducted by Västra Götaland County, it was found that the methods presented in MOSAIC resulted in an unrealistically high conservation value around small islands and peninsulas due to breeding birds (Kilnäs 2016). It is also possible to designate *core areas* based on maps from each category respectively. Note that maps for respective categories are based on a maximum value for a single ecosystem component in each grid cell, which means that there is an increased risk that subsequent *core areas* will consist of the same ecosystem components. When several categories are used in the same map there is a greater chance that *core areas* will include a wider range of ecosystem components. In other words, *core areas* that are designated according to *general conservation value maps* using all categories will better achieve *ecological representativity*.

Another way to create a conservation value map is to sum all the conservation value points (irrespective of category) adjacent to an assessment unit (Figure 37). For every cell (minimum assessment unit), points from each unique ecosystem component that occurs in a larger area around it are summed. Figure 38 shows how a map of this sort can be produced schematically. This sort of map will be highly influenced by how many *different* ecosystem components occur in adjacent areas and will not accurately represent the actual conservation value points of the ecosystem components present.

The map in Figure 37 shows clearly how many more ecosystem components there are in coastal areas (even if this map is also affected by ecosystem component taxonomic resolution) and why it is important to manage them.

It is worth comparing the map showing the sum of adjacent conservation values (Figure 37) with the map showing the sum of all conservation values in a minimum assessment unit (Figure 36 d). Both maps are based on the same data and division of ecosystem components.

What Figure 37 does not show is where the most valuable ecosystem components occur and where several categories are represented together on the map. This makes it difficult to determine where management should be prioritized. It also highlights the difficulties associated with including models of ecosystem component diversity in *general conservation value maps* (see discussion earlier in this section).

In conclusion, studies using different methods to create *general conservation value maps* in three test areas (Blekinge, Stockholm and Södermanland Counties) have shown that our preferred method (the sum of the maximum value from three categories) provides the best results for identifying valuable areas in *ecologically representative* networks. However, the method needs to be evaluated in more places and using various kinds of data (type, quality, amount). The goal – to identify locations with a high conservation value in viable and ecologically representative networks - is the most important aspect, and not the specific method used to achieve it.

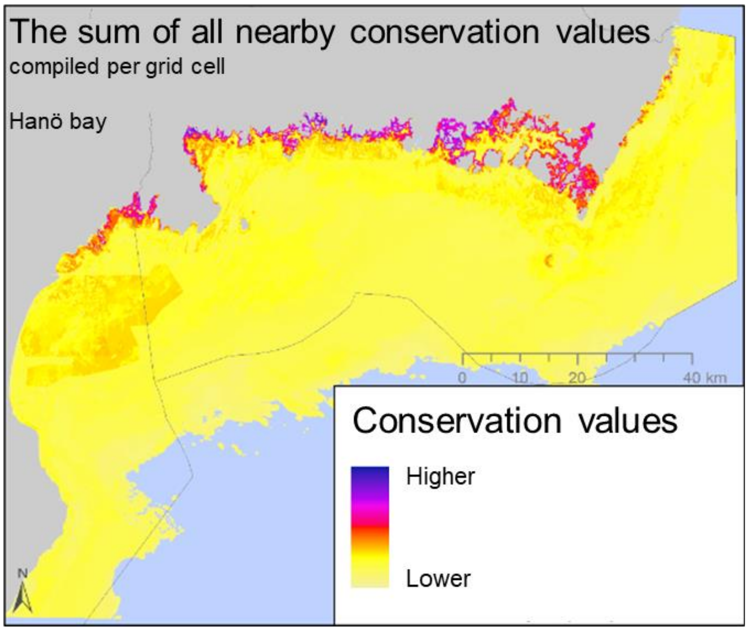

Figure 37. The sum of all the conservation value points surrounding an assessment unit is another way to produce a conservation value map. Above all, this map shows where the highest number of unique ecosystem components are found (in this example the sum of all conservation value points in an area of 250 x 250 m around assessment units, see Figure 38 for more information on how this is done). The map clearly shows that there is a higher number of ecosystem components in coastal areas. However, the map should be viewed cautiously because it is highly influenced by the taxonomic resolution of the individual ecosystem components. The map is difficult to use within spatial management, and the most valuable information that can be extracted from it is that many different ecosystem components contribute to a high conservation value of coastal areas - which underlines the importance of, for example, restricted coastal development.

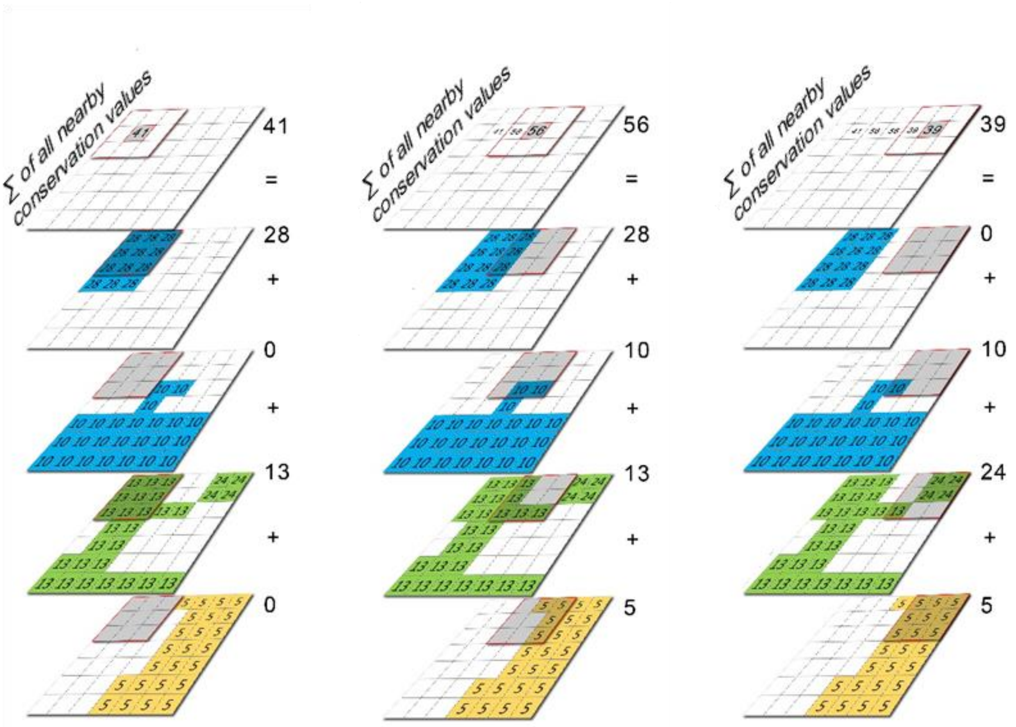

Figure 38. Illustration showing how maps of "the sum of adjacent conservation value points" can be produced. The maps primarily show where the diversity of ecosystem components (ECs) are high or low. Every "minimum assessment unit" is assessed by summing the conservation value points of each unique ecosystem component found in adjacent areas. In the map in Figure 37 the "minimum assessment units" are 25 x 25 m and the value of ecosystem components are taken from a 250 x 250 m area surrounding the assessment unit. Where several ecosystem components of the same biotope building organism are found in the area (i.e. the same component at different levels of coverage) the ecosystem component with the highest conservation value is used. This is shown for EC 3 in the figure. For example, a habitat with a coverage of 10-25 percent (13 points) and the same habitat with a coverage of ≥50 percent (24 points). Note that maps produced using this method (sum of all ecosystem component points) should be viewed with caution because they are highly influenced by the taxonomic resolution of the ecosystem components used.

2.4.3.2 Step 5: General conservation value assessments from point data

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How complete are the guidelines for step 5?

Guidelines are available for general conservation value assessments on point data*. However, a method to establish how valuable an area should be, to be classified as a* core area*, has not yet been specified. Until more detailed guidelines are available, assigning* core areas *from* general conservation value assessments on point data *should be overseen by respective county administrative boards.*

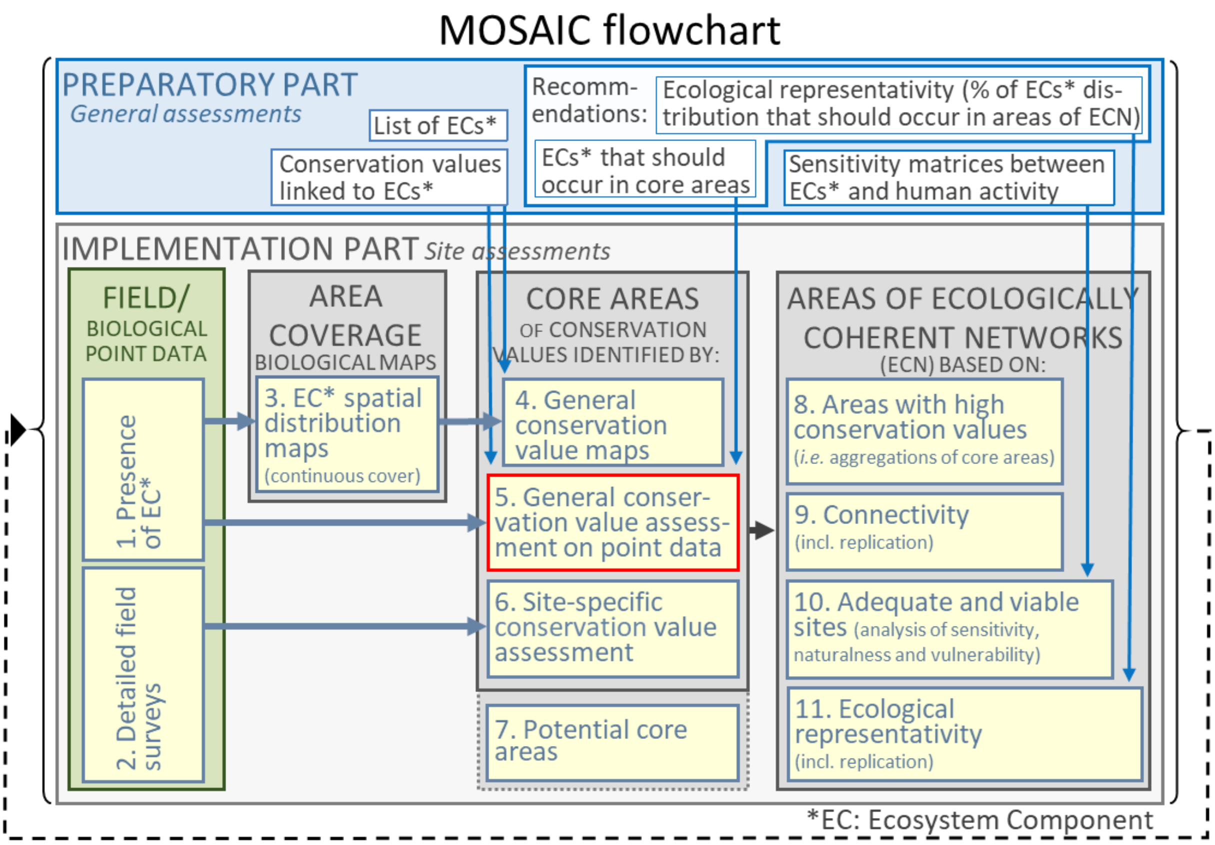


Figure 39. Flowchart showing the different parts and steps that comprise MOSAIC. The relevant section is highlighted in red.

The fifth step of MOSAIC's implementation part identifies *core areas*[56] from general conservation value assessments carried out on point data (Figure 39 and 40). In the report the term point data is used to describe data that is discrete (not related to coverage). Point data includes transects or data from confined areas (such as data generated from drop video surveys).

In this step, locations containing ecosystem components that automatically qualify an area as a *core area* are identified. Recommendations are made by an expert group in the preparatory part,

[56] See chapter 5 (terminology) for definition.

(see section 2.3.3.1) but in step 5 county administrative boards decide on which of these ecosystem components are relevant for the area of interest.

Point data can be used to create *ecosystem component spatial distribution maps* (step 3) and *general conservation value maps* (step 4) or, as in step 5, used directly together with *conservation values linked to ecosystem components*. Point data might also contain additional and detailed information on a location. This information should not be analyzed in this step. Instead it should be included in the next step, step 6, *site-specific conservation value assessments*. Occasionally just the occurrence of a known ecosystem component will need to be investigated on a case-by-case basis. In other words, specific data may need to be considered which is especially true for sites:

- with rarities[57],
- with a unique conservation value (species or habitats),
- with threatened species lacking their own designated ecosystem component,
- containing essential passage[58] for one or more species
- with unusual combinations of species/habitats
- whose geographical location adds extra value to one or more ecosystem components[59].

More information on why these should be handled on a case-by-case basis can be found in step 6, *site-specific conservation value assessments*, section 2.4.3.3. Even if the data is limited in comparison to a detailed survey, information on occurrence can sometimes suffice for a case-by-case assessment. These locations should be noted and treated in step 6, *site-specific conservation value assessments*.

Point data used to demarcate *core areas* should be treated in the same way as point data used to produce *general conservation value maps* (step 4, section 2.4.3.1). Assessment of a location should be linked to different ecosystem components and the conservation value they generally contribute (from the preparatory part)[60]. The conservation value points of a location's ecosystem components should be combined. This should be carried out as it is in step 4 when producing *general conservation value maps*, by dividing ecosystem components into the following categories:

- birds and mammals
- fish and large crustaceans
- benthos

[57] More information on rarities can be found in section 3.2.

[58] An area or distance very important for connectivity of one or more species. For example, river deltas and important resting places for migration birds are often essential passages. For mobile species that are only able to travel short distances (restricted spread / movement), essential passages might include habitats that allow for movement between areas.

[59] Examples are provided in step 6, *site-specific conservation value assessments*, section 2.4.3.3.

[60] A first version of the *list of ecosystem components* and the conservation value they represent can be found in an Excel document, *MOSAIC – ecosystem component lists and conservation values, version 1*, that can be downloaded from the Swedish Agency for Marine and Water Management website. The lists have been compiled by ~50 experts within several working groups and workshops. The lists are divided into the Bothnian Bay, Bothnian Sea, Baltic Proper and Kattegat/Skagerrak sea areas because of broad differences in the species composition and ecosystems between them.

The points from the highest scoring ecosystem component (maximum value) from each category are summed. These points can be used to identify *core areas* and prioritization during subsequent management decisions. See Figure 40.

The reason that a maximum value, and not the summed value, from each category is used:

- different survey methods can have been used that, by their design, record different ecosystem components
- potential differences in the survey area between locations; larger areas increase the chance of finding more ecosystem components
- the length of the surveys might differ; a longer survey period increases the chance of finding more ecosystem components
- the taxonomic resolution of ecosystem components can differ which will strongly influence the assessment.

More information on assessing conservation value in this way can be found in step 4, section 2.4.3.1.1.

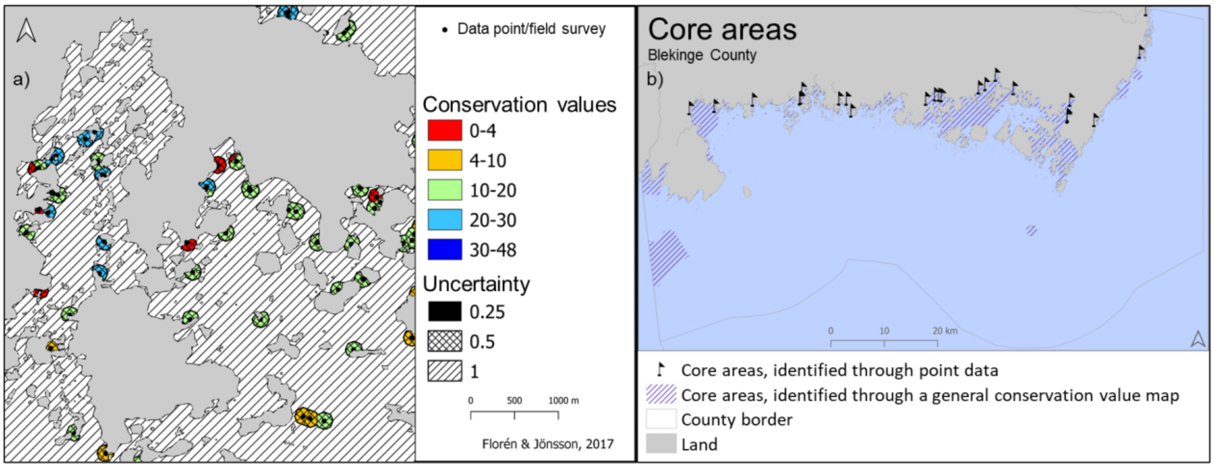


Figure 40. An example of conservation values based on point data can be seen in map a). The *presence of ecosystem components* from point data is combined with their associated conservation value to produce the map. Note that the conservation value uncertainty is 100 % in areas with parallel hatching (Florén and Jönsson 2017). Map b) shows *core areas* demarcated using *general conservation value assessments on point data*, step 5 (this section) or by *site-specific conservation value assessments*, step 6, section 2.4.3.3 (locations shown with flags) or *general conservation value maps*, step 4 (purple hatched areas).

If the county administrative board, or other user, has data that fulfill the following requirements then the sum of all conservation values can be used - instead of the maximum value associated with one ecosystem component from each category. If the point data do not meet the following requirements we strongly advise against this method, the requirements are:

- The same survey techniques should be used for each data point
- What should and should not be surveyed must be specified
  - × For example, it should be explicit if something is not present (despite targeted surveys) or not recorded.
  - × Division of ecosystem components is important to avoid double scoring. For example, “eelgrass” can also be included in “underwater vascular plants” resulting in points for both ecosystem components for the same species. This inflates the score and leads to an incorrect assessment of conservation value. The ecosystem component resolution is also important and can affect the result (points). For example, should “resting place for seabirds” be used or should it be more specific, by species? The groups that have a higher resolution determine the result.
- The size of the survey area should be known and recorded
- The date of the survey should be recorded.
- All survey sites should be selected randomly using the same procedure; for example, sites can be selected using a random stratified approach.
- Those carrying out the surveys must have a similar level of taxonomical knowledge and experience.

2.4.3.3 Step 6: Site-specific conservation value assessments

How complete are the guidelines for step 6?

As for step 2 (biodiversity surveys), guidelines for site-specific conservation value assessments *have not been established. These two steps should be developed together. However, we recommend several aspects that should be considered in step 6.*

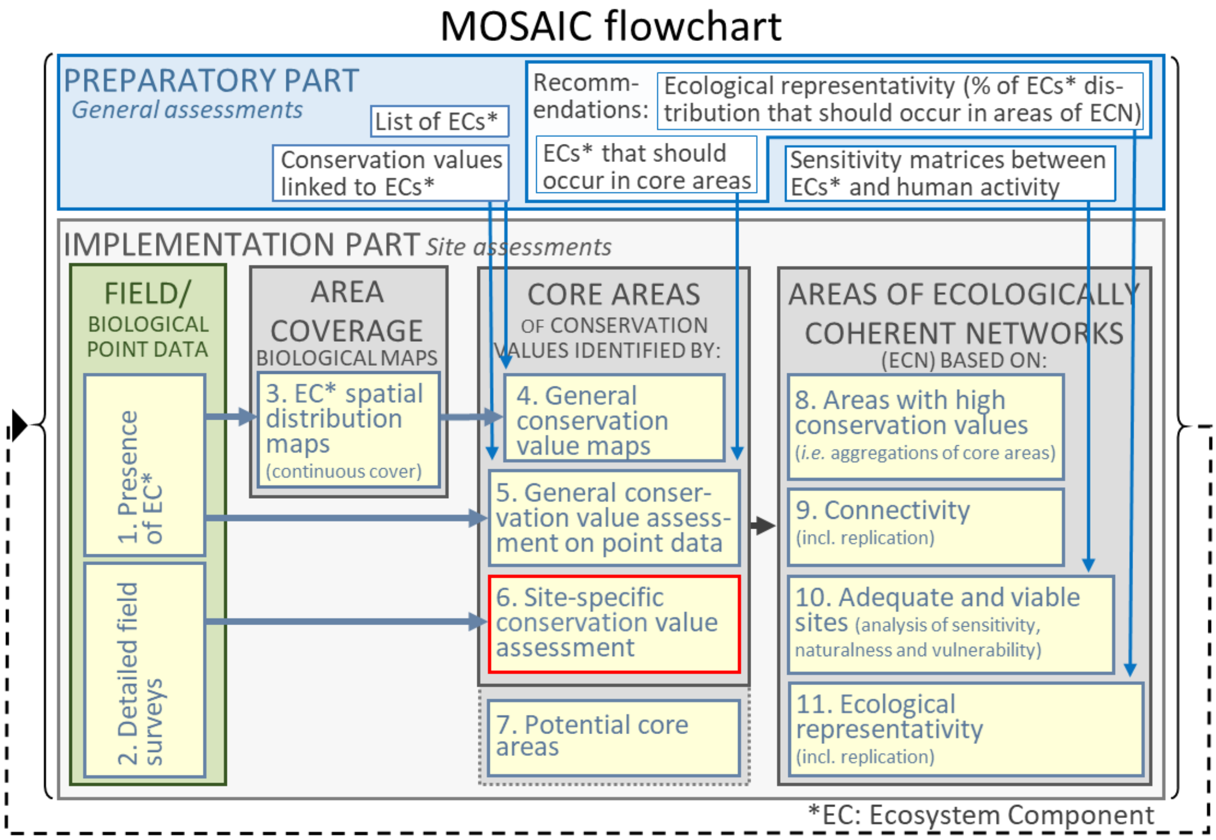


Figure 41. Flowchart showing the different parts and steps that comprise MOSAIC. The relevant section is highlighted in red.

In the sixth step of MOSAIC's implementation part, *site-specific conservation value assessments* (Figure 41), *core areas*[61] are identified by carrying out in-depth assessments of individual sites (Figure 40 b). This should be done primarily using *detailed field surveys*, step 2. However, other data can also be used. Sites with a known and high conservation value can be included here, such as a well-studied breeding area for a bird or an area known for its high biodiversity.

In this step, assessments from the preparatory part (where conservation values are assigned to ecosystem components; section 2.3.2)[62] should provide the basis for site-specific assessments of

[61] See chapter 5 (terminology) for definition.

[62] A first version of the *list of ecosystem components* and the conservation value they represent can be found in an Excel document, *MOSAIC – ecosystem component lists and conservation values, version 1*, that can be downloaded from the

the conservation value of ecosystem components. The assessments from the preparatory part provide structure and reduce subjectivity when assessing a site. However, the final assessments should be based on detailed site-specific information. Here, the motivation for assigning a higher or lower conservation value (compared to that based on the sites ecosystem components alone) must be given.

Occasionally, even quite limited information on a location's conservation value will be included in the assessment in this step. This can occur when a separate assessment is needed on a location's rarities[63], unique values, threatened species lacking their own designated ecosystem component, essential passage[64] for one or more species, unusual combination of species/habitats or geographical location that adds extra value to one or more ecosystem components. Examples might include: a feeding area that is close to a breeding location, a mussel bank close to aquaculture (that leaks nutrients) and an area that is frequently used for birdwatching because of its proximity to a town or city (ease of access). This site-specific information cannot be accounted for in the general conservation value of ecosystem components and must be included in this stage.

This step can include criteria for both ecological/biological value (including indirect ecosystem components) and for direct ecosystem services.

We recommend using methods that meet the internationally accepted criteria set by the UN Convention on Biological Diversity (CBD) for designating EBSAs (Ecologically or Biologically Significant Marine Areas) (Appendix 1, Decision IX / 20, 2008) (see the fact box). These criteria are also used in the preparatory part when conservation values are assigned to ecosystem components (see Figure 27, section 2.4.3). There the specific criteria used are chosen according to how well suited they are for general (not site-specific) assessments. Because *site-specific conservation value assessments* are specific to a location all the CBD's EBSA criteria are relevant (which does not mean that all must be included). The criteria *biological productivity* can be replaced by *ecological function* (which is included in the preparatory part).

Swedish Agency for Marine and Water Management website. The lists have been compiled by ~50 experts within several working groups and workshops. The lists are divided into the Bothnian Bay, Bothnian Sea, Baltic Proper and Kattegat/Skagerrak sea areas because of broad differences in the species composition and ecosystems between them.

[63] More information on rarities in section 3.2

[64] An area important for connectivity of one or more species. For example, river deltas are often essential passages, as are important resting places for migrating birds. For mobile species that are only able to travel short distances (restricted spread / movement), essential passages might include habitats that allow for movement between areas.

CBD's scientific criteria for Ecologically or Biologically Significant Marine Areas (EBSA) are:

1) Uniqueness or Rarity
2) Special importance for life-history stages of species
3) Importance for threatened, endangered or declining species and/or habitats
4) Vulnerability, Fragility, Sensitivity, or Slow recovery
5) Biological Productivity
6) Biological diversity
7) Naturalness

Annex 1, decision IX/ 20, CBD 2008

The assessment should also determine if a location is known to be important for connectivity[65], for example if it is an essential passage[66]. *Connectivity* is also accounted for when identifying *areas of ecologically coherent networks*[67] (see section 2.4.4.2), but well-known locations should be included at this earlier stage.

Site-specific conservation value assessments are complex and require detailed knowledge of a location. Guidelines should be flexible to be able to capture unique and detailed information from locations but, on the other hand, if the methods are not standardized it is difficult to compare the conservation value of locations. This is a difficult trade-off that that should be carefully balanced.

There is a risk that the designation of *core areas* from point data (steps 5 and 6) will lead to well surveyed areas being prioritized over areas that have not been surveyed. For this reason, steps 5 and 6 should be carried out together with step 4, *general conservation value maps* - which are based on modelled *ecosystem component spatial distribution maps*. However, steps 5 and 6 are necessary to increase the diversity of conservation values included in assessments.

[65] By connectivity we mean the degree to which a landscape supports or hinders individuals or species from moving between suitable habitats. Movement might be daily, seasonal, small or large scale, or dependent on life-history traits (the need for different habitats at different life stages) and allow for the transfer of genetic material between populations (gene flow). The aim of good connectivity is to maintain an areas conservation value with respect to, for example, biodiversity and ecological function. Because many marine species disperse over long distances using currents, we suggest using dispersal routes as a term to describe connectivity in marine environments. Dispersal routes are areas that facilitate the movement of one or several species between habitats.

[66] An area important for connectivity of one or more species. For example, river deltas are often essential passages, as are important resting places for migrating birds. For mobile species that are only able to travel short distances (restricted spread / movement), essential passages might include habitats that allow for movement between areas.

[67] See chapter 5 (terminology) for definition.

2.4.3.4 Step 7: Potential core areas

How complete are the guidelines for step 7?

This step has not been developed.

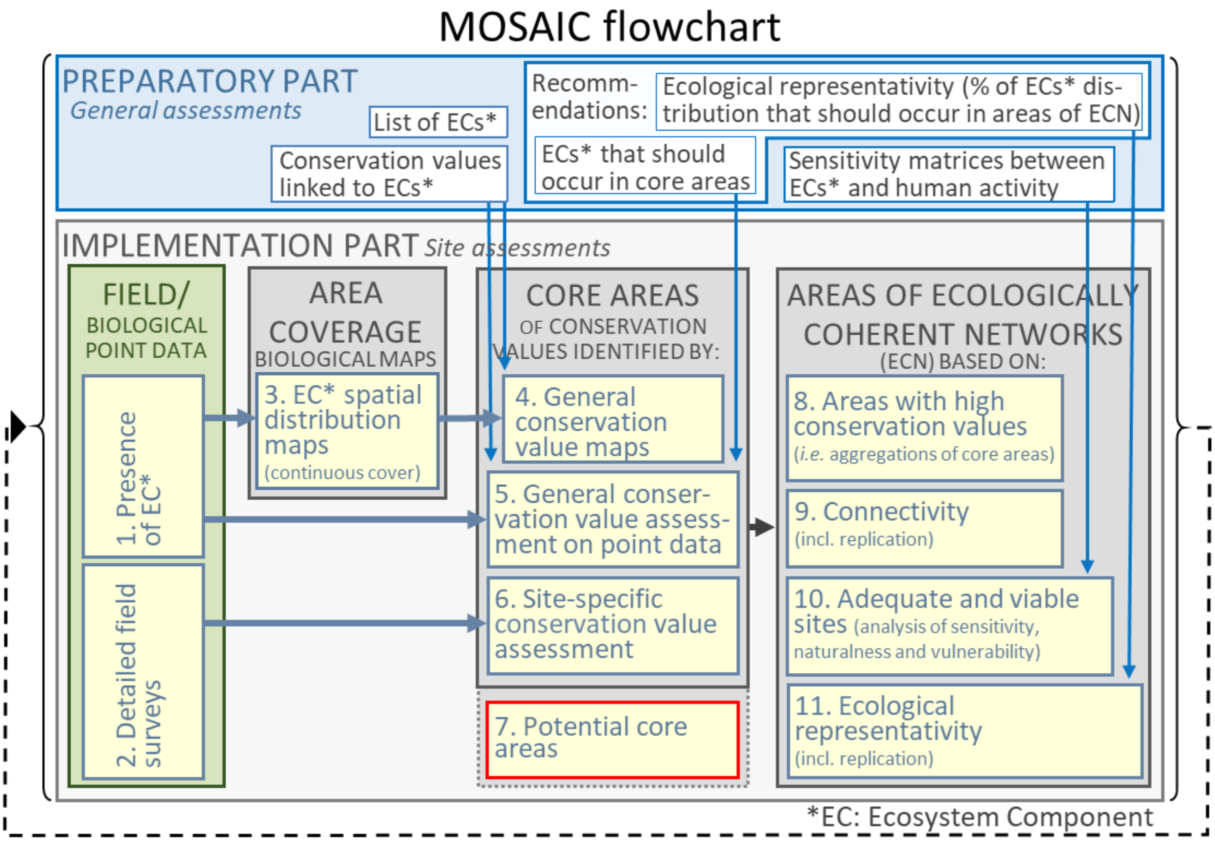


Figure 42. Flowchart showing the different parts and steps that comprise MOSAIC. The relevant section is highlighted in red.

In the seventh step of MOSAIC's implementation part, *potential core areas* are identified (Figure 42). *Potential core areas* are places that, if restored or remediated, could increase their conservation value and become *core areas*. This step has, however, not been developed.

Potential core areas can be identified based on their historical conservation value or, in some cases, through modelling. Modelled maps can indicate where there are suitable conditions, or potential niches, for an ecosystem component (see step 3, *ecosystem component spatial distribution maps*). If historical or modelled conservation values are missing because of human activity, then it might be a suitable site for restoration. Areas that are particularly interesting are those that are important for the dispersal, measured according to the criteria *connectivity*, of one or more species (such as a poorly functioning essential passage).

There are also examples of biological ecosystem components that vary/fluctuate naturally over time. If occurrence is known to vary naturally, and not due to human activity, then one should assess if the location is indeed a *core area*[68].

HELCOM's Red list of Biotope Complexes (HELCOM 2013) often highlight threatened abiotic ecosystem components and can possibly be used to identify *potential core areas*. For example, estuaries (Natural 2000 habitat type 1130) are assessed as *critically endangered* (CR) because many of them have the potential for high conservation value, but their conservation value might be absent due to human activities. It would be appropriate to identify several estuaries as *potential core areas*, so they are prioritized for restoration.

[68] See chapter 5 (terminology) for definition.

2.4.4 Identifying *areas of ecologically coherent networks*

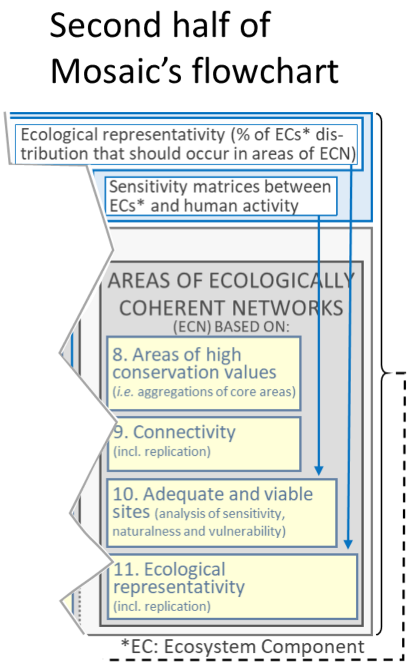
In this report, a marine *area of ecologically coherent networks* is: A viable marine area with high conservation values (i.e. aggregations of *core areas*) in ecologically representative networks with well-functioning connectivity.

The criteria used to identify *areas of ecologically coherent networks* are based on those used in the UN Convention on Biological Diversity to establish a representative network of marine protected areas (CBD; 2008) (see Figure 43 and Table 19; Annex 2, decision IX/20 CBD 2008). The identification of ecologically coherent networks in MOSAIC can be used to identify areas suitable for protection. They can also be used for other purposes, such as identifying green infrastructure and for spatial planning (sea and coastal zone planning).

The network of protected areas that are identified according to (or similar to) the CBD criteria are often referred to as ecologically contiguous or ecologically functional (ecological coherence of networks of marine protected areas, see Piekäinen & Korpinen 2007; Ardron 2008; Johnson et al. 2014; Deltares 2015 and references therein).

The criteria for identifying *areas of ecologically coherent networks* are:

- *areas with high conservation values*
- *(aggregations of core areas)*
- *connectivity*
- *(sub-criterion: replication)*
- *adequate and viable sites*
- *(sub-criterion: sensitivity, naturalness and vulnerability)*
- *ecological representativity*
- *(sub-criterion: replication)*



CBD:s scientific guidance

for selecting areas to establish a representative network of marine protected areas
(Annex II, decision IX/ 20, CBD 2008)

1. Ecologically and biologically significant areas (*i.e.* EBSAs)
2. Representativity
3. Connectivity
4. Replicated ecological features
5. Adequate and viable sites

Figure 43. MOSAIC's criteria for identifying *areas of ecologically coherent networks* can be compared to the criteria in the UN Convention on Biological Diversity (CBD) to establish representative networks of marine protected areas (2008). The criteria are practically identical, but some differences occur. The order in which they are applied differs, in MOSAIC replication is a sub-criterion in steps 9 and 11, and some criteria have slightly different names. *Core areas* in MOSAIC are equivalent to the CBD's EBSAs (more information in section 2.4.3 and see Figure 27).

Even if MOSAIC's criteria are very similar to the CBD's (to establish representative networks of marine protected areas), some differences occur. For example, in the CBD replication is a stand-alone criterion (criterion nr 4) but in MOSAIC it is included as a sub-criterion under steps 9 and 11.

The criteria follow a practical working order, but they can be analyzed in the users own preferred order. The degree to which an area fulfills the criteria above (to be designated an *area of ecologically coherent networks*) should be assessed using expert assessments where specific guidelines are missing[69].

For good spatial management, the four criteria given should primarily be met in the *core areas* found in *areas of ecologically coherent networks*. Knowing where high conservation values occur (*core areas*) and which human activities should be avoided in these areas are prerequisites for the sustainable use of marine areas.

A practical approach to identifying ecological networks is to identify preliminary areas based on one criterion, then adapt the boundaries of areas according to the next criterion – until all the criteria are fulfilled. A description of how this can be done is found below, starting with the first

[69] By expert assessments we mean assessments based on the best available knowledge, used in cases where standard assessment criteria or procedures cannot be applied (Naturvårdsverket 2007b).

criterion. During the process the areas are called *preliminary areas of ecologically coherent networks*.

Table 19. The UN Convention on Biological Diversity's (CBD) guidelines for establishing representative networks of marine protected areas, annex 2, decision IX/20 CBD 2008, CBD 2008.

Required network properties and components	**Definition**	**Applicable site specific considerations (*inter alia*)**
Ecologically and biologically significant areas	Ecologically and biologically significant areas are geographically or oceanographically discrete areas that provide important services to one or more species/populations of an ecosystem or to the ecosystem as a whole, compared to other surrounding areas or areas of similar ecological characteristics, or otherwise meet the criteria as identified in annex I to decision IX/20.	• Uniqueness or rarity • Special importance for life history stages of species • Importance for endangered or declining species and/or habitats • Vulnerability, fragility, sensitivity or slow recovery • Biological productivity • Biological diversity • Naturalness
Representativity	Representativity is captured in a network when it consists of areas representing the different biogeographical subdivisions of the global oceans and regional seas that reasonably reflect the full range of ecosystems, including the biotic and habitat diversity of those marine ecosystems.	A full range of examples across a biogeographic habitat, or community classification; relative health of species and communities; relative intactness of habitat(s); naturalness
Connectivity	Connectivity in the design of a network allows for linkages whereby protected sites benefit from larval and/or species exchanges, and functional linkages from other network sites. In a connected network individual sites benefit one another.	Currents; gyres; physical bottlenecks; migration routes; species dispersal; detritus; functional linkages. Isolated sites, such as isolated seamount communities, may also be included.
Replicated ecological features	Replication of ecological features means that more than one site shall contain examples of a given feature in the given biogeographic area. The term "features" means "species, habitats and ecological processes" that naturally occur in the given biogeographic area.	Accounting for uncertainty, natural variation and the possibility of catastrophic events. Features that exhibit less natural variation or are precisely defined may require less replication than features that are inherently highly variable or are only very generally defined.
Adequate and viable sites	Adequate and viable sites indicate that all sites within a network should have size and protection sufficient to ensure the ecological viability and integrity of the feature(s) for which they were selected.	Adequacy and viability will depend on size; shape; buffers; persistence of features; threats; surrounding environment (context); physical constraints; scale of features/processes; spillover/compactness.

2.4.4.1 Step 8: Areas with high conservation values

How complete are the guidelines for step 8?

A simple suggestion has been developed.

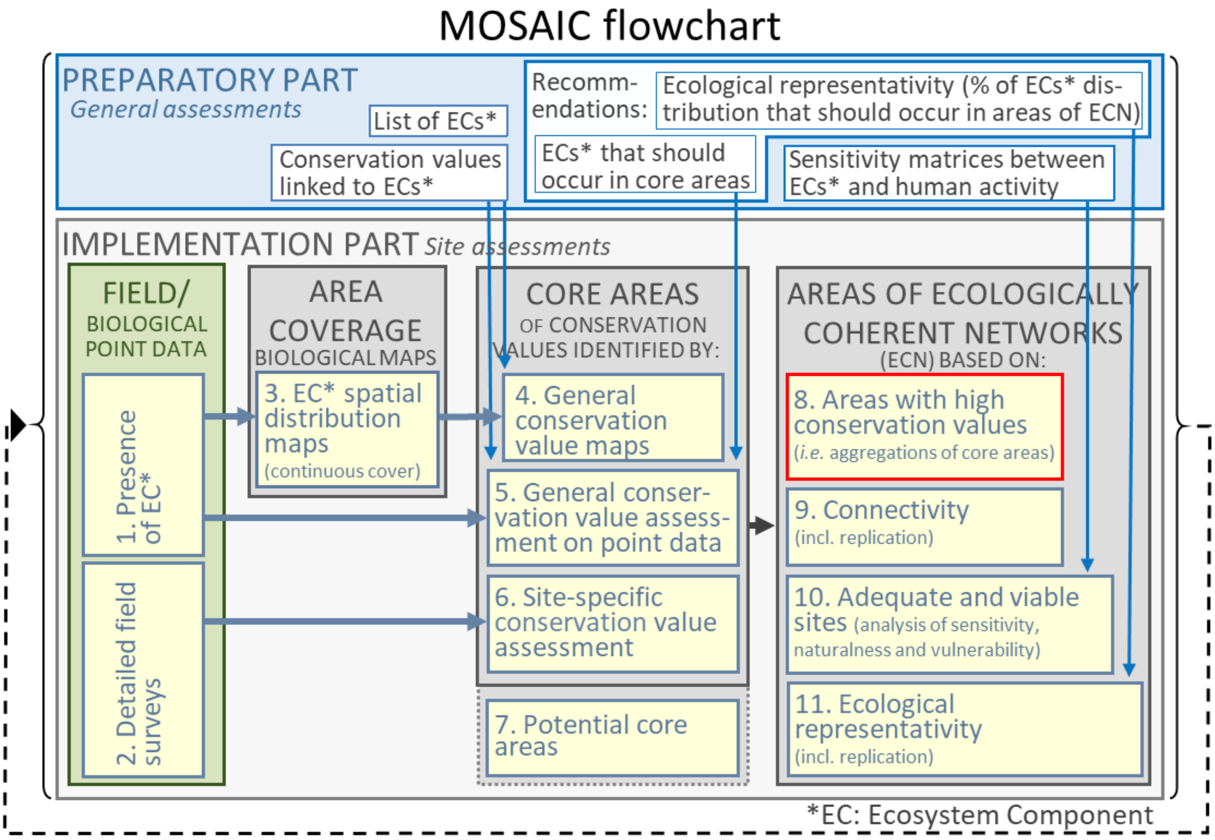


Figure 44. Flowchart showing the different parts and steps that comprise MOSAIC. The relevant section is highlighted in red.

In the eighth step of MOSAIC's implementation part, *areas with high conservation values* are identified and included in *areas of ecologically coherent networks* (Figure 44). This is done by identifying aggregations of *core areas*[70]. Geographic information systems (GIS) can be used to identify areas with a high proportion of *core areas* or with many small *core areas*. These areas can be grouped according to their sea distance from each other (Figure 45).

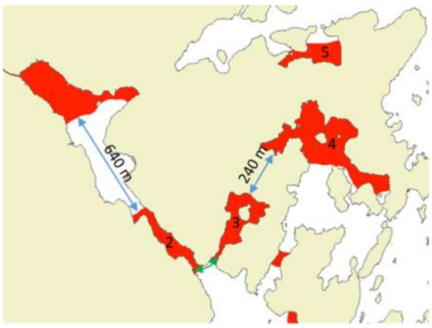


Figure 45. The map shows how *core areas* can be grouped according to the sea distance between them. *Core areas* two and three are grouped because the sea distance between them is small. The actual distances in the map are an example and should not be used as a guideline when grouping *core areas*.

[70] See chapter 5 (terminology) for definition.

Areas with high conservation values (aggregations of *core areas*) can be mapped for use in subsequent analyses (Figure 46). The boundaries can be adjusted according to the other criteria (*connectivity*, *adequate and viable sites*, *ecological representativity*).

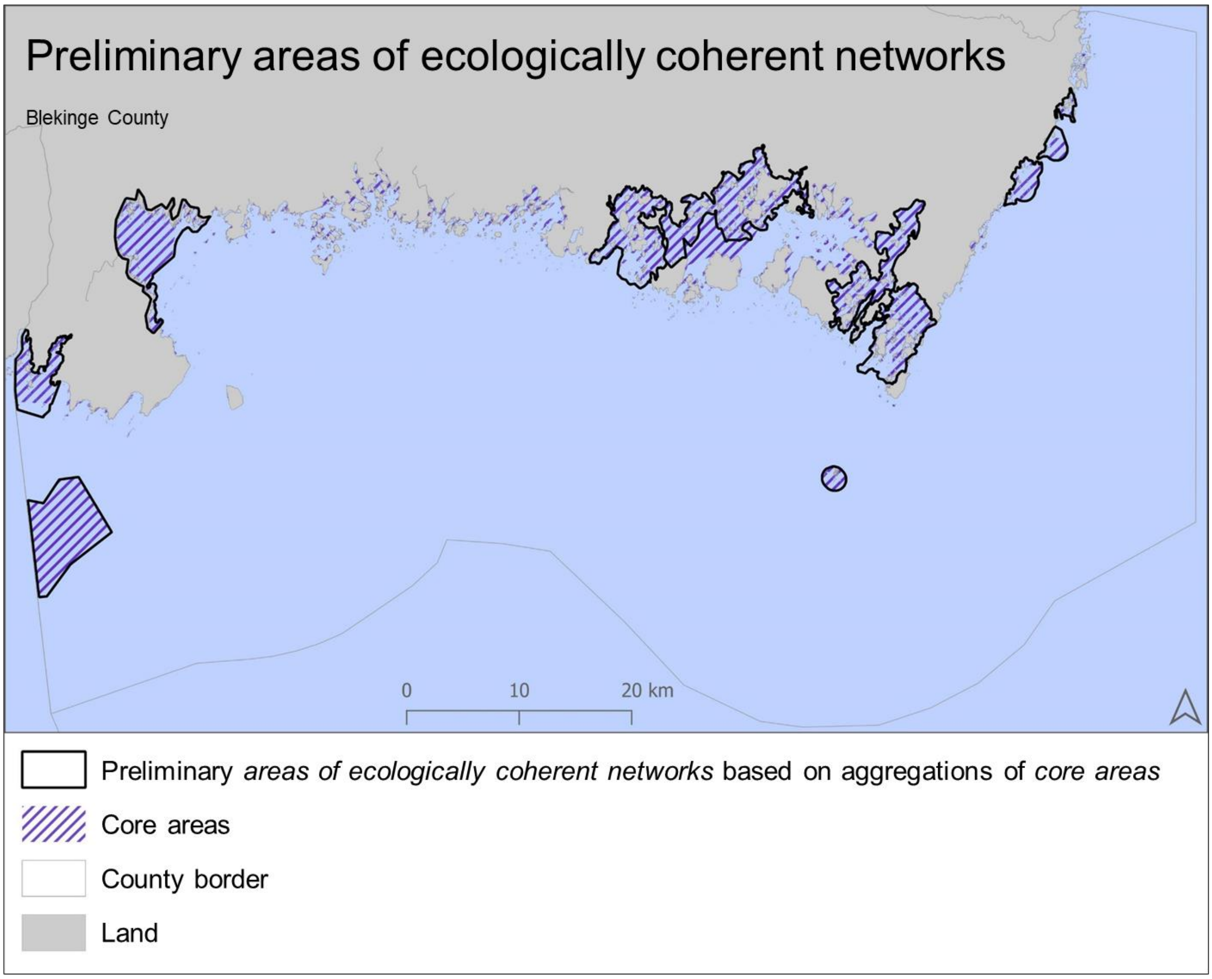


Figure 46. Preliminary *areas of ecologically coherent networks* based on aggregations of *core areas*. Note that the preliminary areas shown in the map have been produced without a deeper analysis or local knowledge. They should only be seen as an example.

2.4.4.2 Step 9: Connectivity

How complete are the guidelines for step 9?

Recommendations and suggestions for analyses in step 9 have not yet been developed. Even when guidelines are available, users will likely have to use their own initiative to account for the movement patterns of multiple species, and to include new and updated methods. Guidelines should not limit the methods chosen by users.

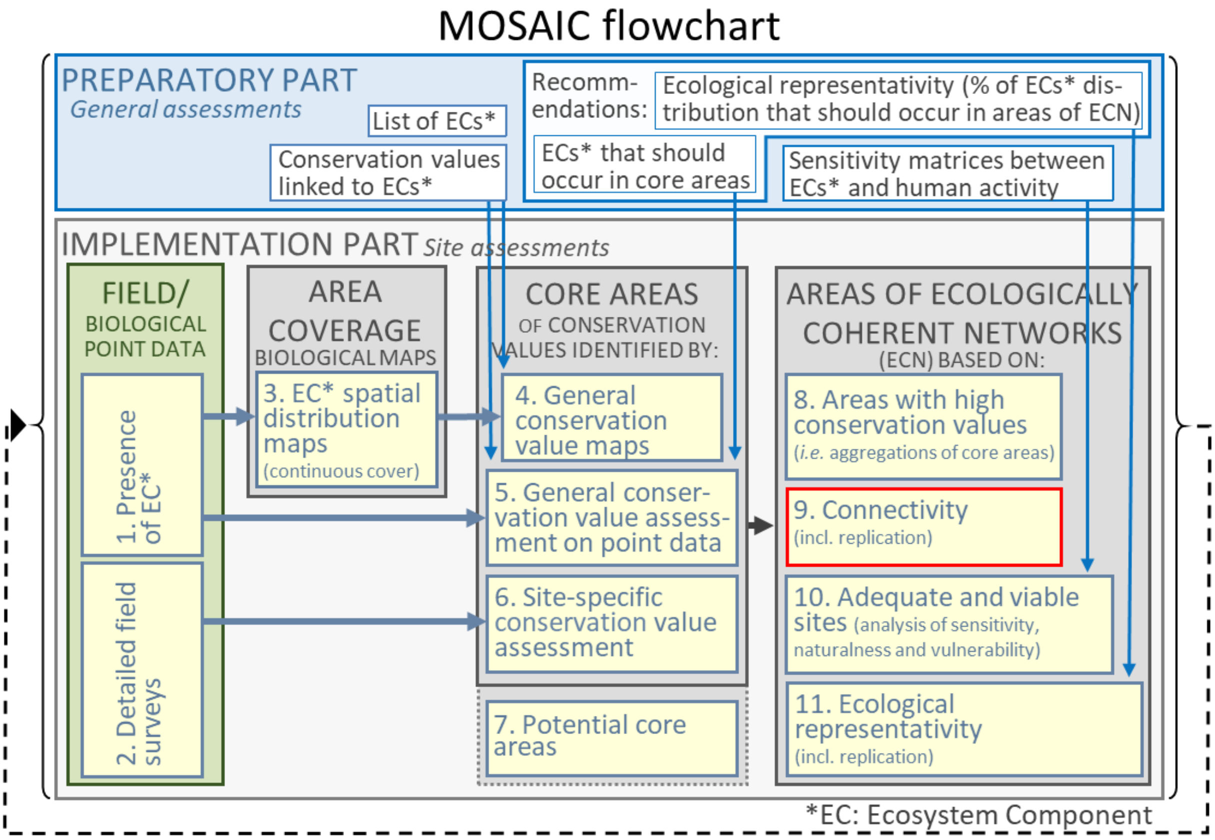


Figure 47. Flowchart showing the different parts and steps that comprise MOSAIC. The relevant section is highlighted in red.

In the ninth step of MOSAIC's implementation part, areas that are important for species' connectivity are identified (Figure 47). These areas are very important for spatial management and are an integral part of *areas of ecologically coherent networks*[71]. Guidelines have not yet been developed for this step.

To identify important distribution, dispersal, migration and movement areas, connectivity analyses should be carried out. If possible, the analyses should be carried out with and without negative human impacts (which can be done in conjunction with step 10, *adequate and viable sites*,

[71] See chapter 5 (terminology) for definition.

section 2.4.4.3). These kinds of analyses indicate which locations or areas are (potentially) important for connectivity and should be prioritized for management.

Replication is a sub-criterion in step 9. When carrying out connectivity analyses one must consider if species in an ecosystem component benefit from its replication or if its occurrence in a limited number of locations is sufficient to ensure a functioning connectivity. The size of an area of ecologically coherent networks is also important when assessing connectivity because large areas have a greater potential to support viable populations and their recruitment (Carr et al. 2017). More information on this can be found in step 10 *adequate and viable sites*, section 2.4.4.3.

There is currently a lack of knowledge and accepted methods for carrying out connectivity analyses for active migration and passive dispersal in marine environments. We hope that a more detailed description of how this criterion can be analyzed will be available soon. Until such time county administrative boards, or other users, should find or develop methods they deem suitable. The analyses could include simple measurements of the distance between *areas of ecologically coherent networks* or more complex *connectivity* analyses for different organisms. For example, it might be necessary to designate one or more *areas of ecologically coherent networks* over the stretch of coastline in Figure 46 where there are currently none found (because the number or *core areas* were too few according to step 8). A recent report (Berkström et al. 2019) provides information on the migration and dispersal distances of Swedish marine organisms (as far as this information is known) including 1) macrophytes 2) invertebrates and 3) fish. This report can be used in step 9 as part of the *connectivity* analyses.

2.4.4.3 Step 10: Adequate and viable sites

How complete are the guidelines for step 10?

A general structure for step 10 has been specified, but details are lacking. To provide detailed guidelines in this step requires recommendations on which sensitivity matrices to use in MOSAIC's preparatory part. Sensitivity matrices *provide the basis for analyses in step 10 because they contain general assessments on how sensitive ecosystem components are to different types of human activities and pressure.*

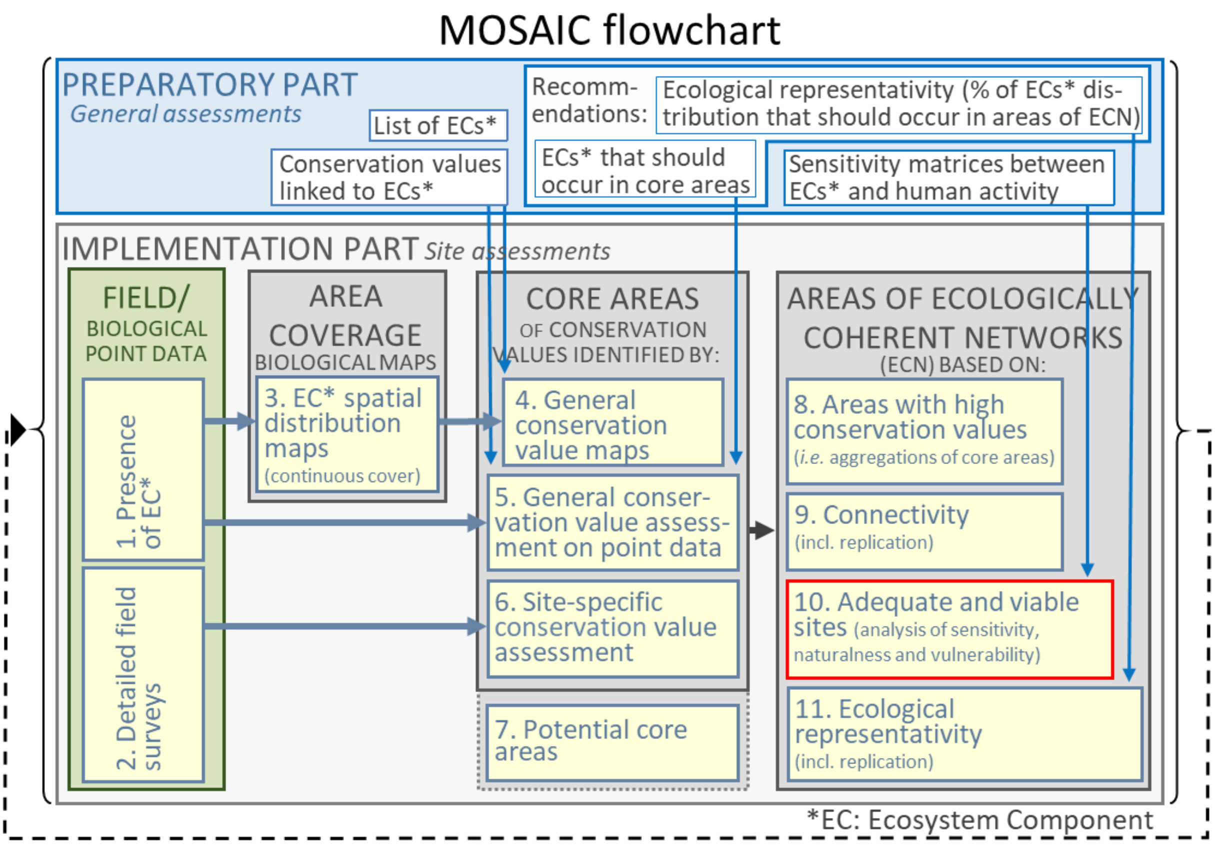


Figure 48. Flowchart showing the different parts and steps that comprise MOSAIC. The relevant section is highlighted in red.

In the tenth step of MOSAIC's implementation part, *areas of ecologically coherent networks*[72] are assessed according to *adequacy and viability* (Figure 48). This is primarily carried out by analyzing the *sensitivity, naturalness and vulnerability* of a location. The locations *size* should also be considered, partly because larger areas provide a buffer against negative human activities and partly because they support more recruitment and viable populations (Carr et al. 2017; also mentioned in step 9, *connectivity*, section 2.4.4.2).

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[72] See chapter 5 (terminology) for definition.

To analyze an area's *sensitivity* to human impacts requires knowledge on which human activities/pressures different ecosystem components are *sensitive* to. These general assessments should be a part of MOSAIC's preparatory part and shown in *sensitivity matrices* (Table 20) but have not yet been developed. Until guidelines for this are complete, county administration boards, or other users, should decide on details surrounding the analyses used. The information in a sensitivity matrix is often very general with simplified linear relationships and without specific context. Despite the lack of detail, they are useful when many ecosystem components are analyzed over a larger geographic area. Examples of sensitivity matrices can be found in the national marine spatial planning project SYMPHONY (Havs- och vattenmyndigheten 2018), HELCOM Holas II (HELCOM 2018), Kraufvelin et al. (2020) and MarLIN/MarESA (Tyler-Walters et al. 2018). Guidelines in MOSAIC should follow these examples to ensure national and international harmonization of methods.

Information from the *sensitivity matrices* can be combined with ecosystem component maps (steps 1-3) using GIS. The resulting sensitivity maps should show areas in the landscape that are *known* to be sensitive to different human activity/pressure. Note, absence of sensitivity from an area does not mean they are *not* sensitive to pressure. Comprehensive surveys and environmental impact assessments are needed to be certain that an area is not sensitive to human activity/pressure. However, the maps will provide information on areas that have a lower *chance* of being sensitive to exploitation. In other words, the maps should not be used to decide where certain human activities can occur (only where they should not occur).

Information on where human activities should not occur is still valuable for designating protected areas and spatial planning (sea and coastal zone planning).

Table 20. A simplified sensitivity matrix showing the effect of different human pressure on biological ecosystem components. Porpoises are sensitive to underwater noise, pike spawning areas are probably sensitive to suspended sediments (Hansen et al. 2019) and blue mussels are sensitive to demersal trawling. *Sensitivity matrices* should also contain information on how distance from an activity can affect ecosystem components.

SENSITIVITY MATRIX					
Driver (D in DPSIR):	**Recreation**	**Food**	**Trade**	**Trade**	**...**
Activity (D in DPSIR):	**Boat traffic**	**Trawl fishing**	**Shipping**	**Shipping**	**...**
Pressure (P in DPSIR):	**Suspended sediment**	**Plowing/scraping seabottom**	**Noise**	**Erosion**	**...**
Porpoise: Breeding/calving area			Negative effect	...	...
Pike: Recruitment area	Negative effect		Small negative effect		...
Blue mussel >25% coverage	Small negative effect	Large negative effect			...
...	...	...	...	...	...

Assessments of locations where ecosystem components are not exposed to activities/pressures they are sensitive to should also be carried out. In this report, *naturalness* refers to locations where biological ecosystem components are not exposed to human pressure. This can be done by combining sensitivity maps with geographic information on where human activities/pressures occur in a landscape (Figure 49 and 50). The resulting impact maps show where negative human activities likely occur. This information can be used to localize areas with the highest amount of naturalness/least impact (information that can be used to maintain an areas conservation values, i.e. through protection) and to localize where impacts occur and which kind of management/restoration is most suitable. It is also possible to calculate the cumulative effects occurring in a location or on its ecosystem components.

The maps can indicate where *potential core areas*[73] could occur if the right management or restoration is put in place (*potential core areas*) (see step 7).

Calculations of the cumulative effects of human activities on 32 ecosystem components (see the fact box) are available from the national marine spatial planning project SYMPHONY (Havs- och vattenmyndigheten 2018). Information is bound to 250 x 250 meter cells and is available for Sweden's entire marine area. This resolution is low for regional and communal planning and for work relating to protected areas. In the future it will be possible for users to upload their own layer of ecosystem components (and impacts/effects) to use the tool with more detailed data (higher resolution). However, this requires the user to develop their own sensitivity matrix.

SYMPHONY's 32 ecosystem components:

Plankton community
Shallow area
Hard substrate, photic
Hard substrate, aphotic
Hard substrate, deep
Erosional environment, photic
Erosional environment, aphotic
Erosional environment, deep
Soft substrate, photic
Soft substrate, aphotic
Soft substrate, deep
Mussel reef
Deep reef
Haploops reef
Artificial reef
Vegetation with long shoots
Cod
Herring
Sprat
Vendace
Fish spawning
Estuarine fish
Eel migration
Grey seal
Harbour seal
Ringed seal
North Sea porpoise
Danish straights porpoise
Baltic Sea porpoise
Coastal bird
Seabird coast
Seabird offshore

[73] See chapter 5 (terminology) for definition.

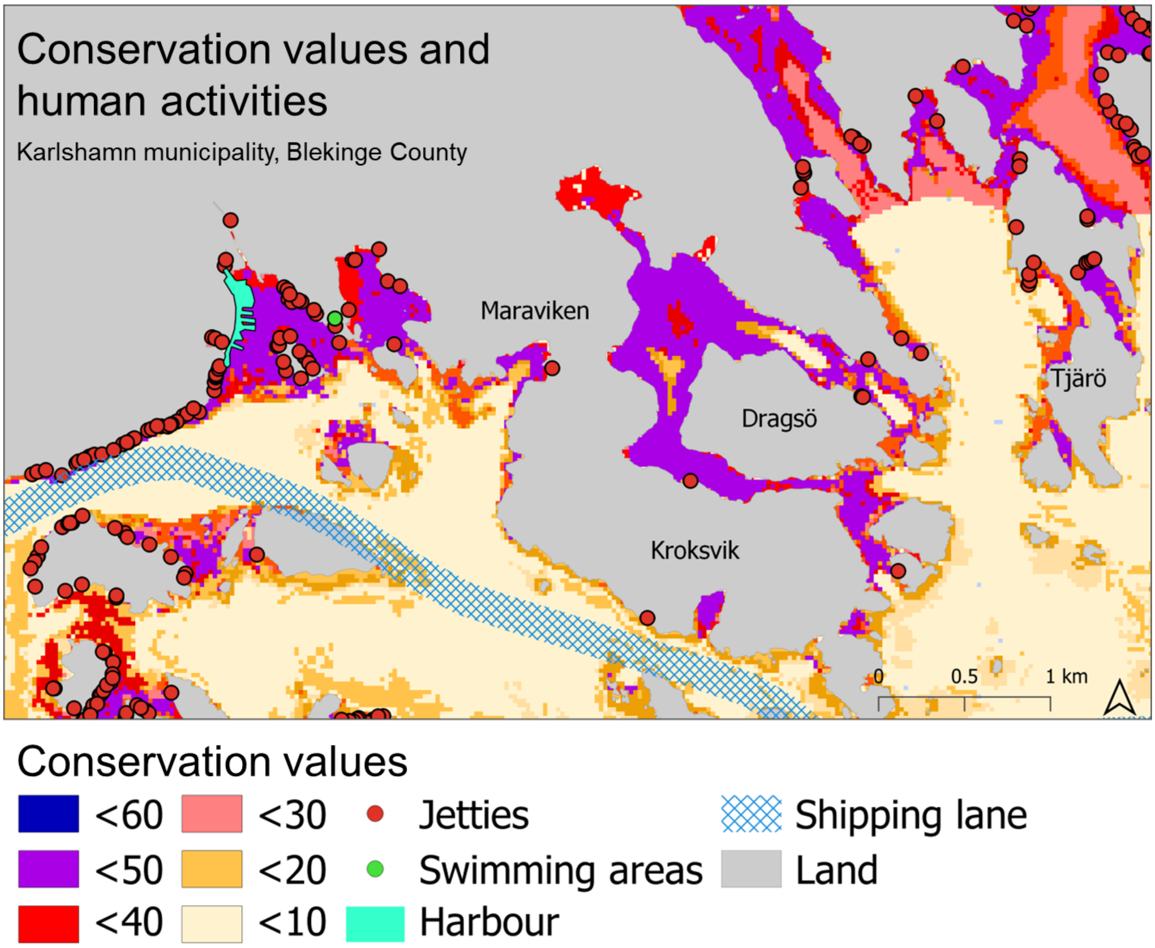

Figure 49. A surface area map showing a *general conservation value map* and some of the human impacts/pressures present. However, it is the ecosystem components that are sensitive to impacts that are relevant and analyses should be carried out on them, not indirectly on an area's conservation value.

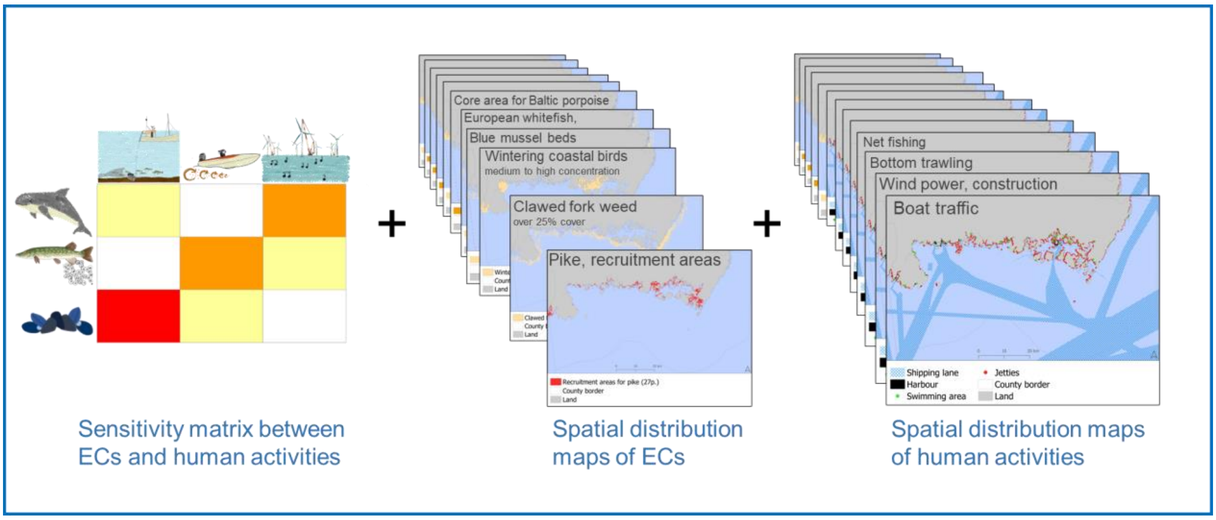

Figure 50. *Sensitivity matrices* can be used with spatial distribution information on ecosystem components and human activities/pressures to analyze where negative human impacts occur. The analyses can also indicate where there is a lower risk of negative impacts from human activity, but thorough environmental impact assessments must be carried out to evaluate this adequately.

An important part of the analyses is determining how *vulnerable* biological ecosystem components are to human impacts in an area. This, together with other information, is important for assessments relating to how much of an ecosystem component should be represented in *areas of ecologically coherent networks* (step 11, *ecological representativity*, section 2.4.4.4). If an ecosystem component is often negatively affected by human activity, then it is important to prioritize the protection of areas where it is not exposed to negative human impacts.

Likely future scenarios should be considered when identifying *adequate and viable sites*, not least with respect to climate change. Modelled maps on the likely future distribution of ecosystem components (step 3, *ecosystem component spatial distribution maps*, section 2.4.2.1) should help to determine *areas of ecologically coherent networks*. Potential climate refuges are especially important to include in *areas of ecologically coherent networks*. More information can be found in section 2.5.

The UN Convention on Biological Diversity (CBD; 2008) define *adequate and viable sites* as: "Adequate and viable sites indicate that all sites within a network should have size and protection sufficient to ensure the ecological viability and integrity of the feature(s) for which they were selected." (see Table 19, section 2.4.4). An areas size and level of protection are also important sub-criteria when considering ecologically coherent (sometimes referred to as ecologically functional) networks of marine protected areas (see Piekäinen and Korpinen 2007; Ardron 2008; Johnson et al. 2014; Deltares 2015 and references therein). The type of protection is central to work relating to protected areas, but it is not discussed further in MOSAIC - which has a more general approach to spatial management. This could be expanded on in later editions of MOSAIC, but it is expected that work relating specifically to area protection will occur at the national level over the next few years. The current focus in MOSAIC is assessing if a location is negatively affected, regardless of whether it is protected or not.

When carrying out an overlap analysis on the occurrence of ecosystem components and presence of human activities/pressures it is our intention that *sensitivity matrices* include information on the size of suitable buffer zones. The size of the area and distance from negative human impacts should be considered to ensure sufficient ecological integrity and viability. The size of an area (that is free from negative impacts) is related to its ability to support viable populations and recruitment (Carr et al. 2017).

MOSAIC's approach is similar to the CBD's guidelines for "applicable site-specific considerations" for *adequate and viable sites*: "Adequacy and viability will depend on size; shape; buffers; persistence of features; threats; surrounding environment (context); physical constraints; scale of features/processes; spillover/compactness." (see Table 19, section 2.4.4) (UN Convention on Biological Diversity 2008).

2.4.4.4 Step 11: Ecological representativity

How complete are the guidelines for step 11?

The workflow is complete for version 1. However, parts that are dependent on previous steps that lack guidelines (i.e. steps 9 and 10) have not been specified in detail. Furthermore, recommendations on the ecological representativity *of ecosystem components in the* preparatory part *have not yet been carried out. Approaches used in this step can be developed in updated versions of MOSAIC.*

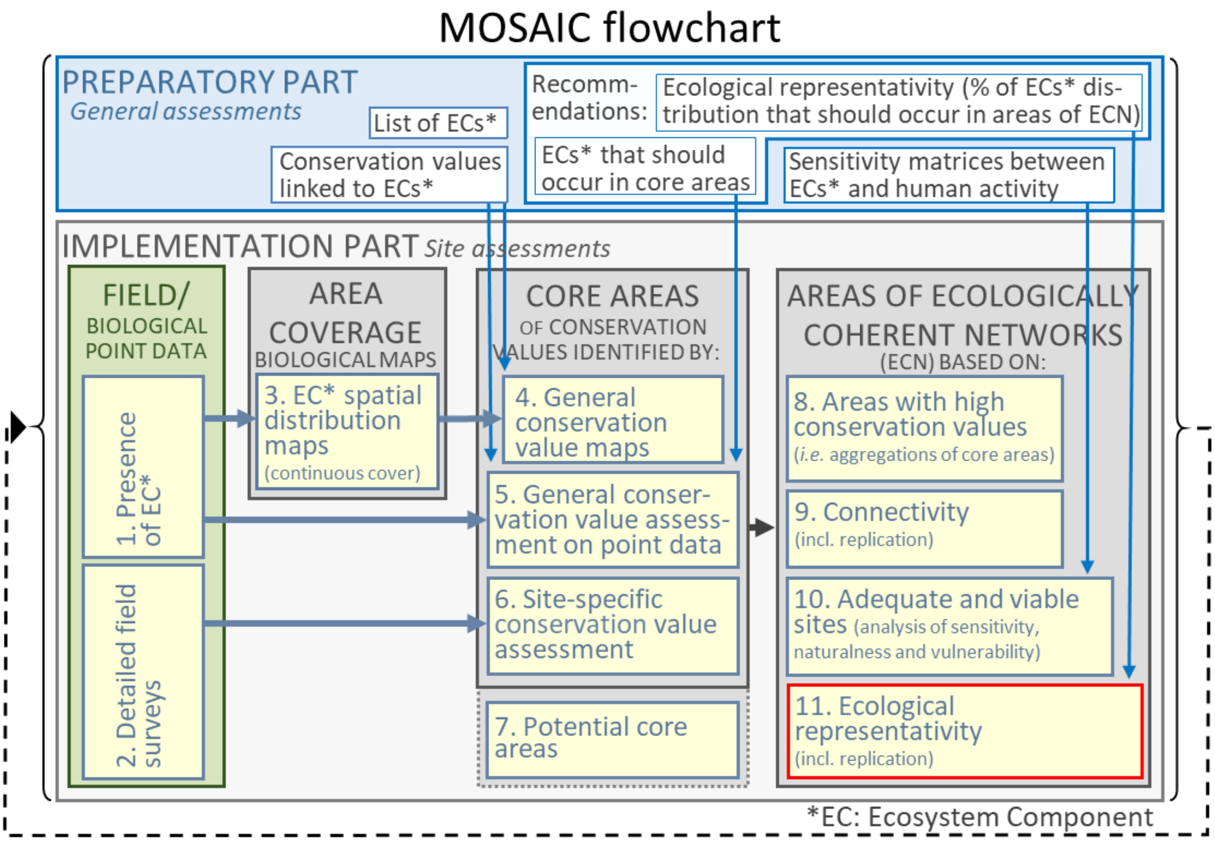

Figure 51. Flowchart showing the different parts and steps that comprise MOSAIC. The relevant section is highlighted in red.

In the eleventh step of MOSAIC's implementation part, the *ecological representativity* of *areas of ecologically coherent networks*[74] is established (Figure 30). In this report *ecological representativity* is considered to have been achieved when an *area of ecologically coherent networks* contains a broad range of the diversity of species and habitats that are found in the region's marine ecosystem. To ensure *ecological representativity* the assessments should be based on biological ecosystem components. In MOSAIC, the focus is not only on ensuring that as

[74] See chapter 5 (terminology) for definition.

many ecosystem components as possible are represented but also that those most in need of protection/management are well represented (i.e., a high proportion of their occurrence is found in *areas of ecologically coherent networks*). Because the focus is on *biological* ecosystem components it is not necessary to analyze the proportion of abiotic ecosystem components such as deep zones or hard or soft substrates represented - unless more detailed information on specific biological ecosystem components is not available.

The criterion *ecological representativity* should primarily be met in *core areas* that are included in *areas of ecologically coherent networks*[75] to provide information for planning and management (Figures 52 and 53). However, it is not always possible to fully achieve *representativity* within *core areas* alone. In this case, representation outside the *core areas*, but within an *area of ecologically coherent networks*, can suffice (Figure 52).

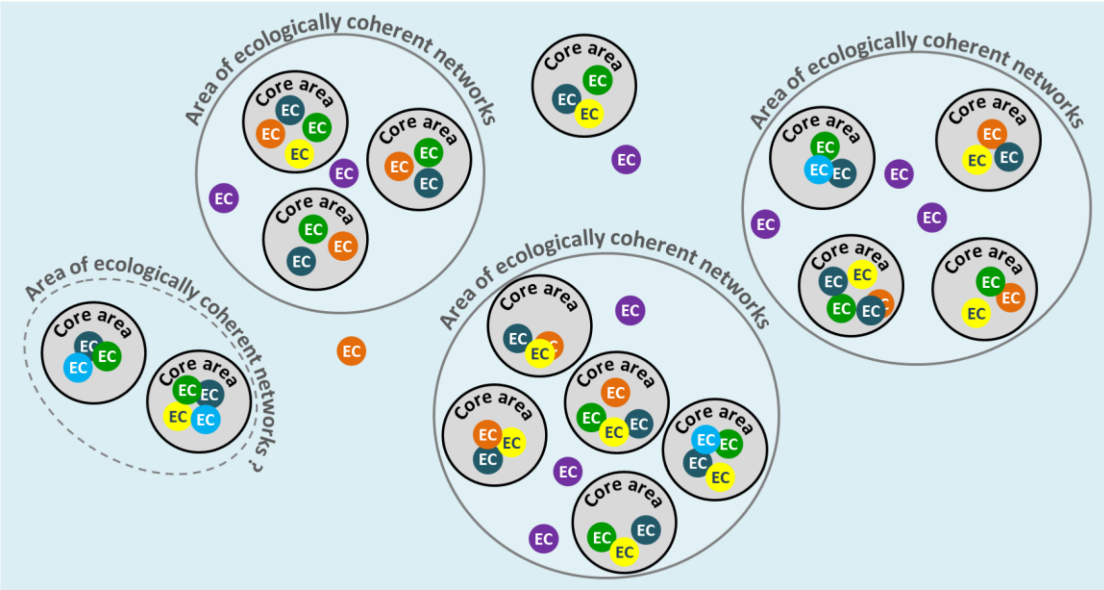

Figure 52. The aim is to achieve *ecological representativity* of ecosystem components within *core areas*, but the *presence of ecosystem components* outside of *core areas* but within an area of ecologically coherent networks can suffice.

The coloured circles symbolize different ecosystem components, grey circles symbolize *core areas* and the larger, colourless circles symbolize *areas of ecologically coherent networks*. To achieve full representativity of ecosystem components, an *area of ecologically coherent networks* should be formed comprising the two *core areas* on the left of the figure (dashed line). The purple ecosystem components fall outside of *core areas* but are represented within *areas of ecologically coherent networks*.

[75] See chapter 5 (terminology) for definition.

One of the primary reasons for focusing on *core areas* within *areas of ecologically coherent networks* (e.g. protected areas) can be found in the report *Skydd av marina miljöer med höga naturvärden* (*The protection of marine environments with high conservation values*; Naturvårdsverket 2007a, freely translated from the original) which states:

> *It is not always possible or justifiable to protect large coastal/archipelago areas. Instead, protection can be established in zones such as core areas, with surrounding areas afforded less stringent or short-term protection. … For example, an activity (i.e. dredging or building a new jetty) might be forbidden inside a core area but allowed, after seeking permission, outside of core areas.*

Furthermore, the report suggests that buffer zones around *core areas* should be sufficient to protect the species, habitats or functions for which the *core area* is designated (Figure 53).

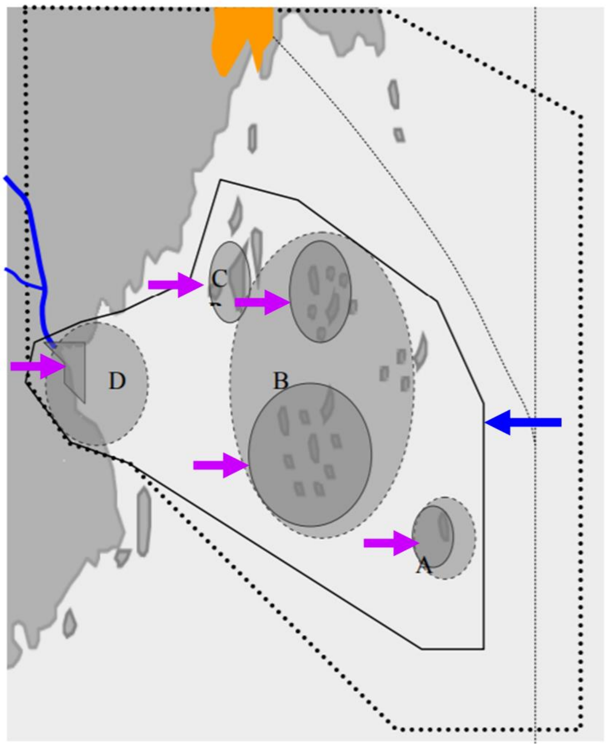

Figure 53. A figure modified from the Swedish Environmental Protection Agency's report "Skydd av marina miljöer med höga naturvärden" (2007). The purple arrows point to *core areas*, the blue arrow to a nature reserve and A, B, C and D represent zones with different levels of protection. The report suggests that different regulations can apply to the different zones within the reserve - depending on the specific needs of the *core areas*. For example, A=boat traffic and disembarkation / landing forbidden. B=exploitation and physical disturbance forbidden. C=restricted outdoor / leisure activities. D=nature reserve regulations are supplemented with angling / fisheries regulations.

When following the guidelines provided in MOSAIC, some *core areas* will not be included in *areas of ecologically coherent networks* (see example in Figure 52). These are *core areas* with conservation values that are not prioritized for *viable and representative ecological networks*. There may also be examples of *core areas* that are not prioritized for *viable and representative ecological networks* that are included in *areas of ecologically coherent networks* simply because of their geographic position (by chance) close to other important *core areas*. Occasionally a larger coastal area can be classified as a core area, but because it is rarely possible to enforce restrictions over large areas it is better to apply them to smaller *core areas* that significantly contribute to *viable and ecologically representative networks*.

To ensure *ecological representativity* one should specify both the *proportion* or *amount* of an ecosystem component's distribution that should be represented and *where* this representativeness is best suited.

When specifying the *proportion* or *amount* of an ecosystem component's distribution needed for *ecological representativity* one should consider:

- the conservation value points assigned to an ecosystem component from the preparatory part (section 2.3.2)
- expert recommendations from the preparatory part (section 2.3.3.2)
- how exposed the ecosystem component is to negative human impacts (information from step 10, section 2.4.4.3). If exposure is high:
    - try to estimate the proportion of its distribution needed to ensure the ecosystem component is viable for itself, associated species, the ecosystem as a whole and for the provision of ecosystem services
- if the ecosystem component is associated with a priority species (i.e. protected or red listed; Hallingbäck 2013), also noted in Table 17 (third column) section 2.3.2.4.

Examples can be found in the second column of Table 17, section 2.3.2.4. Specifications on the proportion of an ecosystem component's distribution needed to achieve *ecological representativity* should be motivated.

When specifying *where* ecosystem components should be represented one should consider:

- the proportion of an ecosystem component's distribution that should be represented (see previous points)
- where ecosystem components are most valuable. Choose:
    - places where an ecosystem components presence is important for *connectivity* (step 9, section 2.4.4.2)
    - places where the conservation value of an ecosystem component is especially high (often identified in *site-specific conservation value assessments*, step 6, section 2.4.3.3)
    - *adequate and viable sites*, step 10, for an ecosystem component
    - places where other valuable ecosystem components occur
- how often an ecosystem component should be replicated
    - how often an ecosystem component should be replicated is primarily determined by aspects relating to distribution, dispersal and movement (which are assessed in step 9, *connectivity*) but the precautionary principle should also be considered. An ecosystem component should be found (replicated) in several places in an area to minimize the risk of its disappearance due to a local accident or environmental change.
- if climate change is likely to affect the distribution of an ecosystem component

In our example (Blekinge) many ecosystem components were acceptably represented with regard to proportion of distribution in the *core areas* (found in preliminary *areas of ecologically coherent networks*). Figure 54 shows different ecosystem components and their occurrence in relation to *core areas* and preliminary *areas of ecologically coherent networks*. The occurrence of whitefish spawning areas (Figure 54 a) exceeds the specification for the ecosystem component (Table 17, section 2.3.2.4). The proportion of pike recruitment areas occurring in *core areas* (Figure 54 b) was lower than the specified target (75 %). The target can be reached by designating more *core areas*, where pike recruitment occurs, as *areas of ecologically coherent networks* (Figure 54 c). The ecosystem component *Furcellaria* at a coverage of more than 25 percent is also not adequately represented (only 7 percent). Because most of the areas with *Furcellaria* at a coverage over 25 percent are found outside of *core areas* it is difficult to achieve the representativity target (10 percent of its distribution in *areas of ecologically coherent networks*, see Table 17, section 2.3.2.4) by including more *core areas* into *areas of ecologically coherent networks* (as it did for pike recruitment). The reason it is scarce in *core areas* is that the conservation value of *Furcellaria* is not assessed to be high (from preparatory part) and it doesn't often occur with other ecosystem components with a high conservation value. However, *Furcellaria* with a coverage over 25 percent is sufficiently represented in *areas of ecologically coherent networks*, but outside of *core areas*. Note the examples shown have not been analyzed according to all criteria and should only be seen as an example to discuss representativity.

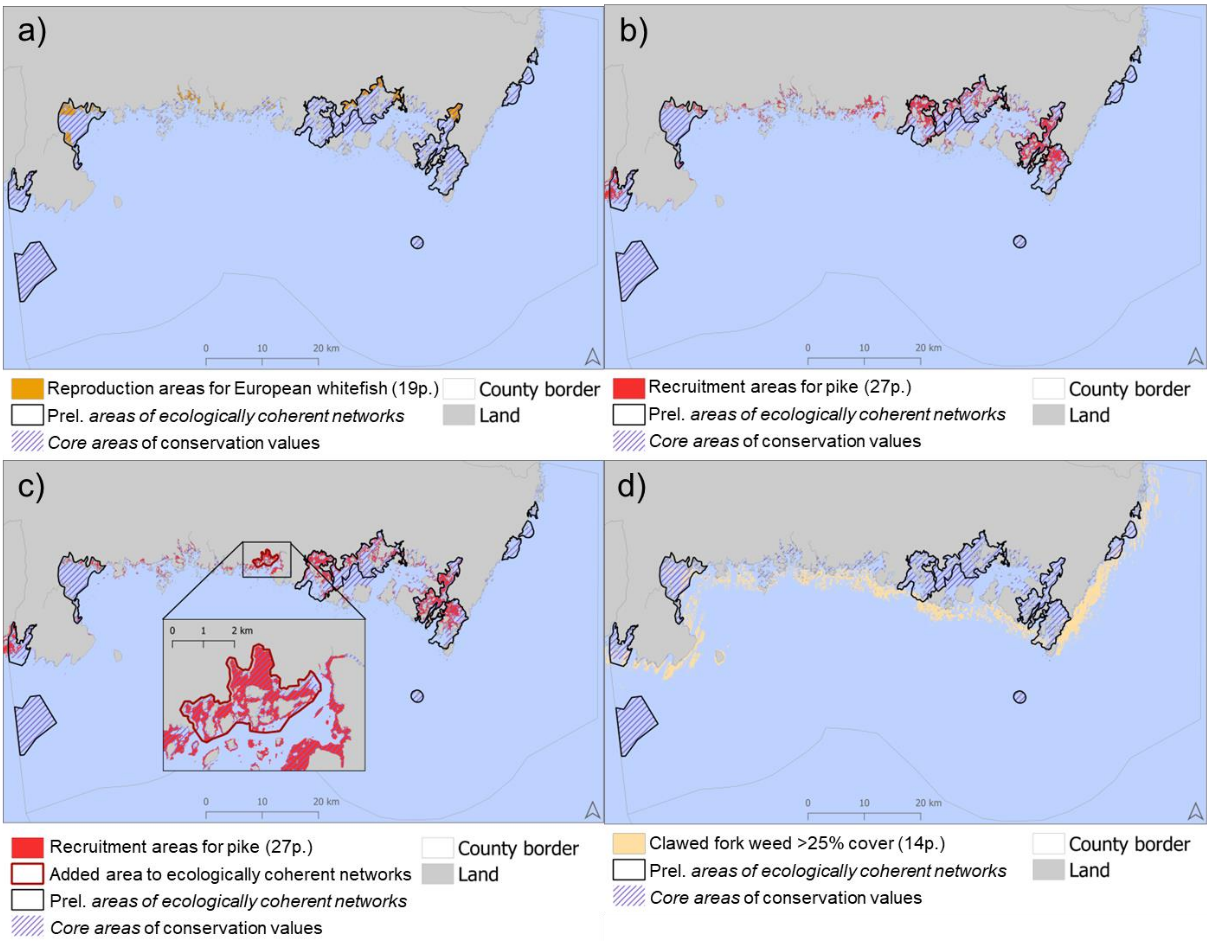

Figure 54. The maps show the distribution of different ecosystem components in relation to *core areas* and the preliminary *areas of ecologically coherent networks*. This can be used to investigate if they are sufficiently represented according to the targets set in the preparatory part. The representativity targets should primarily be met in *core areas* within *areas of ecologically coherent networks*. Whitefish spawning areas (map a) are well represented with ~79 percent of the total spawning area occurring in *core areas* within preliminary *areas of ecologically coherent networks*. This exceeds the target set as an example in Table 17, section 2.3.2.4. Pike recruitment areas (map b) are not sufficiently represented in *core areas* within preliminary *areas of ecologically coherent networks* (the example target from Table 17, section 2.3.2.4, is 75 percent and the actual value is 72 percent). Additional *core areas* that contain pike recruitment can be designated as *areas of ecologically coherent networks* and added to the existing ones. Map c shows how a new *area of ecologically coherent networks* can be added to achieve the representativity target by including *core areas* containing the ecosystem component pike recruitment. The ecosystem component *Furcellaria* at a coverage of more than 25 percent is also not adequately represented (only 7 percent; map d). Because most of the areas with *Furcellaria* at a coverage over 25 percent are found outside of *core areas* it is difficult to achieve the representativity target (10 percent, see Table 17, section 2.3.2.4) by including more *core areas* into *areas of ecologically coherent networks*. However, *Furcellaria* with a coverage over 25 percent is sufficiently represented in *areas of ecologically coherent networks*, outside of *core areas*, which may be considered acceptable. Please note that the maps of *core areas* and *areas of ecologically coherent networks*, as well as the goals for *ecological representativeness*, should only be seen as examples to illustrate the work process.

Because *ecological representativity* focusses on:

- maximizing the number of ecosystem components (populations, species, organism groups, habitats) represented and
- ensuring the ecosystem components most in need of management/protection are sufficiently represented,

the diversity locally (α-diversity), regionally (β-diversity) and over regions (γ-diversity; Whittaker 1960, 1972) is accounted for. Future versions of MOSAIC would benefit from a suitable method for identifying areas with many ecosystem components weighted according to their representativity requirements. More information on how biological diversity is accounted for in MOSAIC can be found in section 3.1.

2.4.4.5 Final assessment

When all 11 steps are complete, *core areas* (and *potential core areas*) and *areas of ecologically coherent networks*[76] should be identified. If a high conservation value has been identified for a location in any of steps 4-6, then the location can be designated a *core area*. However, *areas of ecologically coherent networks* are designated according to a combined assessment based on all the criteria in steps 8-11 (i.e. if they are viable marine *areas with high conservation values* (i.e. aggregations of *core areas*) in ecologically representative networks with well-functioning connectivity). These criteria should primarily be met in *core areas* within *areas of ecologically coherent network*s.

There is a greater risk that assessments in the implementation part are biased, non-comparable, more subjective and less transparent compared with assessments in the preparatory part. Assessments are on the other hand more general in the preparatory part, whilst the implementation part provides details on natures spatial variation. On the whole, guidelines in MOSAIC's implementation part are less stringent than those in the preparatory part when, for example, conservation value is linked to ecosystem components[77]. To increase transparency in the implementation part, deviations should be documented and motivated based on differences to the *general conservation value maps* (step 4). In addition to information on the occurrence of ecosystem components, these maps are based on nationally harmonized assessments of conservation values linked to ecosystem components.

[76] See chapter 5 (terminology) for definition.

[77] By expert judgement we mean an assessment carried out according to the best available knowledge and where standardized methods cannot be applied (in accordance with Naturvårdsverket 2007a).

2.5 Including future scenarios in MOSAIC

To include and account for likely future scenarios – not least those caused by global climate change – maps of the likely future distribution of ecosystem components should be modelled. Maps showing likely future scenarios can be modelled in step 3, *ecosystem spatial distribution maps* (section 2.4.2.1), by including likely changes in environmental variables such as salinity or nutrient concentrations. These maps can be used in step 10 when *adequate and viable sites* are assessed (section 2.4.4.3).

These maps could perhaps be used already in step 4, *general conservation value maps* (section 2.4.3.1) to influence where cores areas are identified and in step 6, *site-specific conservation value assessments* (section 2.4.3.3) to increase the control over which sites are designated as *core areas* based on, amongst other things, the location of future climate refugia.

2.6 Evaluating management strategies

To structure the many interactions between socioeconomic activities and the environment the European Environment Agency (EEA) developed the DPSIR (*Drivers – Pressures – States – Impacts – Responses*) framework. Anthropogenic drivers (D) create pressures (P) that result in a change of state (S) and subsequent impacts (I) on an ecosystem. These impacts can result in a response (R) such as measures to stop drivers (strong response), ameliorate pressures (medium response) or in other ways try to improve the status of ecosystems, or negative impact on ecosystem services (weak response) (EEA 2003; Berg et al. 2015) (Figure 55). It has been suggested that the DPSIR framework should be applied to the Marine Strategy Framework Directive (Borja et al 2010; Berg et al. 2015) and we use some of its terms when discussing how MOSAIC can be used to evaluate management strategies.

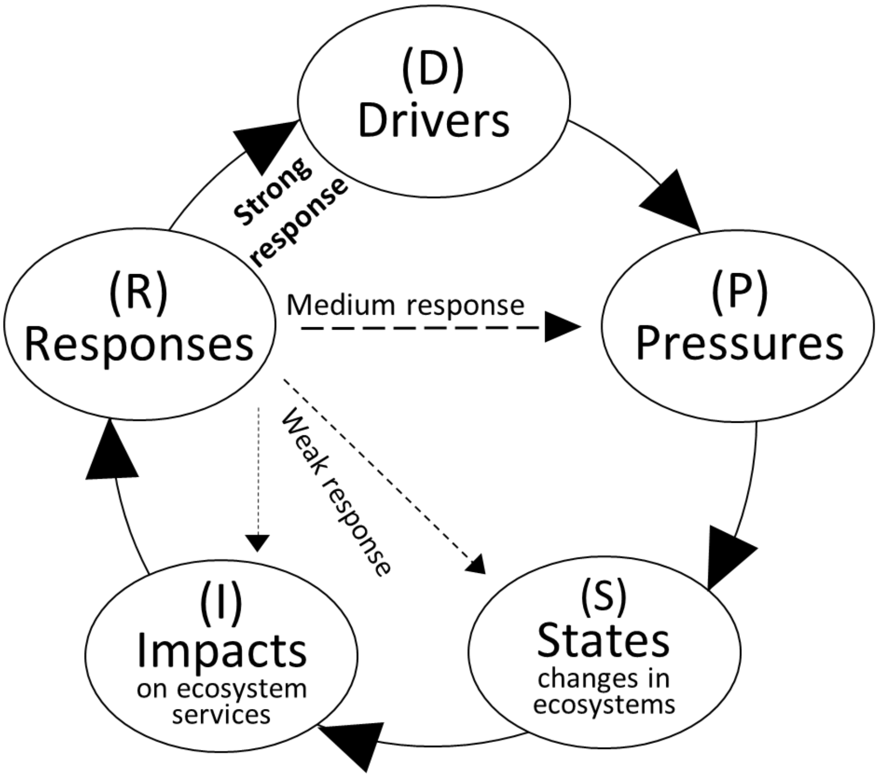

Figure 55. The European Environment Agency (EEA) developed the DPSIR framework to structure the interactions between socioeconomic activities and the environment. This figure is modified from Gari et al. (2015).

MOSAIC and DPSIR have several common features and the two tools/frameworks can be used to support each other. In sensitivity matrices, the drivers (D) and pressures (P) resulting from human activities should be listed. These can include environmental contaminants, noise, habitat loss or alien species (Figure 56).

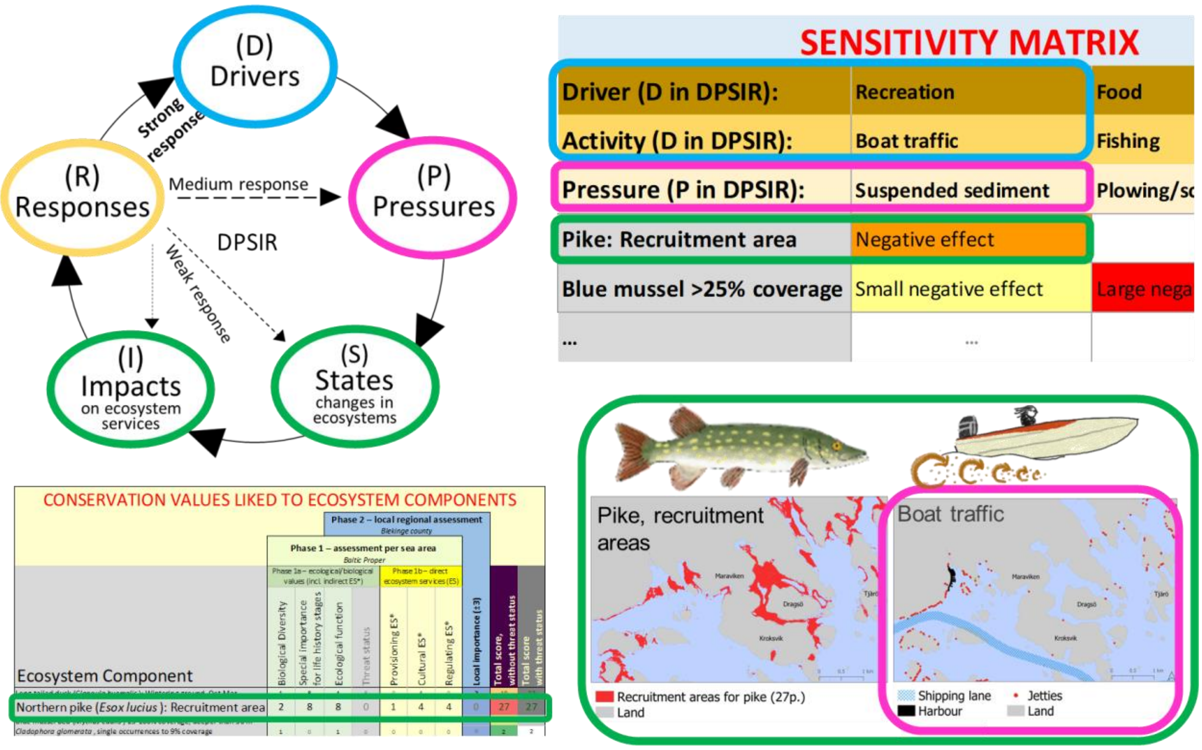

Figure 56. The figure shows how MOSAIC can be used together with the DPSIR framework. The table in the upper right corner is an example of a sensitivity matrix. This matrix contains information on the effect of drivers (D, marked in blue) and pressures (P, marked in pink) on different ecosystem components (marked in green). When combined with maps on human activities/pressures and maps of ecosystem component distribution the extent of the impact can be estimated. In this example, the probable negative effect of boat traffic on pike recruitment (Hansen et al. 2019) is shown. Because assessments in MOSAIC's preparatory part stipulate which conservation value and ecosystem services each biological ecosystem component represents, it is possible to roughly estimate the change in environmental state (S) and impacts (I) on ecosystem services. A relevant question might be how many pike recruitment areas are impacted by boat traffic. By looking at different management strategies for boat traffic one can investigate the quantitative and geographic effects of each management strategy. Step by step it is possible to evaluate how a change in boat traffic might impact the ecosystem components that are sensitive to it.

Sensitivity matrices should also list secondary drivers, which are human activities that trigger an pressure. Primary drivers are the underlying socio-economic reasons behind observed environmental pressure. Sensitivity matrices should specify if, and how strongly, the human pressures impact different biotic ecosystem components. This information can be combined with *ecosystem component surface area maps* and maps of the presence of human pressures/activities to quantify the exposure of biological ecosystem components in a defined area. By providing details on which conservation value and ecosystem services are linked to which ecosystem components in MOSAIC's preparatory part, changes in state (S) of the ecosystem, and impacts (I) on ecosystem services can be summarized and decisions made on whether a change of strategy is required (response, R).

The research project IMAGINE[78] has explored how MOSIAC and DPSIR can be used together to study the possible effects on marine areas under likely scenarios of future human activities, including possible effects from different management strategies and legislation. The project included study areas from both the east and west coasts of Sweden.

The DPSIR framework is often criticized for promoting a simplistic, one-way and linear causal relationship between its categories (Gari et al. 2015 and references therein) – which is also true for sensitivity matrices. The EEA (1999) recognized this and warned that relationships were more complex than can be described by simple cause-effect relationships. The framework does not account for synergistic effects that are common in nature. Despite these weaknesses, DPSIR is a powerful tool for communication and for dealing with a large number of influencing factors simultaneously. It is important to develop tools, such as sensitivity matrices, to increase environmental awareness as much as possible during spatial planning (such as marine and coastal planning). Using a simplified method to assess conflicts and compatibilities can provide a sound foundation for analyses of more complex interactions with multiple variables at a later stage.

[78] IMAGINE (Implications of alternative management strategies on marine green infrastructure) was a collaboration between AquaBiota Water Research, Gothenburg University, the Swedish University of Agricultural Sciences and Stockholm University and financed by the Swedish Environmental Protection Agency and the Swedish Agency for Marine and Water Management.

3 Discussion

3.1 Biological diversity

Biological diversity is essential to identifying valuable areas in viable and ecologically representative networks and is a central part of MOSAIC. Biological diversity can be separated into α-, β- and γ-diversity (see below) (Whittaker 1960, 1972).

Biological diversity is one of the criteria used when conservation value is linked to ecosystem components (phase 1, assessments by sea area). Ecosystem components are assessed according to their relative contribution to an area's *biological diversity*, especially their capacity to provide habitats for other species or populations – or α-diversity (Whittaker 1960, 1972). Furthermore, biodiversity is indirectly accounted for at global and large regional scales (γ-diversity) through the criterion *threat status*.

Biological diversity is also included in the *site-specific conservation value assessments* (step 6, section 2.4.3.3). Guidelines or not yet complete for this step, but we recommend using the CBD's criteria for "Ecological or Biological Significant Marine Areas" (EBSAs) (UN Convention on Biological Diversity 2008). If this is done, α-diversity will be further accounted for under the EBSA criterion "biological diversity". Global and regional diversity (γ-diversity) is also accounted for by the criterion "importance for threatened, endangered or declining species and/or habitats" (which is roughly equivalent to the *threat status* criterion when linking conservation values and ecosystem components).

The aim of the criterion *ecological representativity*, is to make sure that as many ecosystem components as possible are represented in *areas of ecologically coherent networks* by considering:

- the local diversity of species and populations (α-diversity),
- habitat diversity (proxy for β-diversity) and
- the diversity of populations and species at a larger, regional level (γ-diversity, Whittaker 1960,1970).

Biological diversity could be further incorporated in the tool by modelling the diversity of ecosystem components (species and habitats). The decision on whether this should be carried out in MOSAIC should be addressed in a later version of the tool.

This sort of analysis could be included in step 4, *general conservation value maps*, to influence the designation of *core areas*[79]. However, there are difficulties associated with analyzing β-diversity (here habitat diversity) in order to identify *core areas* in a landscape. There is also a high probability that this sort of analysis would not find areas that aren't already designated as *core areas* according to other criteria. A modelled map of ecosystem component diversity is probably most useful to determine *core areas* that should be included in *areas of ecologically coherent*

[79] See chapter 5 (terminology) for definition.

networks[80] and could be included in step 11, *ecological representativity*. This step already attempts to prioritize areas where many ecosystem components are represented, and modelling of ecosystem component diversity could ensure that *areas of ecologically coherent networks* are not always based on the same combination of ecosystem components. However, as mentioned previously, later versions of MOSAIC should consider if and how analyses on “diversity of ecosystem components” should be included.

[80] See chapter 5 (terminology) for definition.

3.2 Rarities, species at the limit of their natural distribution and responsibility species

Careful considerations were made on whether to include the criteria *rarity*, *species at the limit of their natural distribution* and *responsibility species* when conservation values are linked to ecosystem components in MOSAIC's preparatory part. It was decided not to include the criteria because:

- Spatial distribution maps (with continuous cover) for uncommon species are difficult to produce.
- Data on rarities, unique conservation value, unusual combinations or unusual occurrences are often assessed on a case-by-case basis. In other words, this information is included in step 6, *site-specific conservation value assessments* and does not have to be included in the preparatory part. Even if information is limited, occurrence data can suffice for individual assessments.
- Unnatural abnormalities or changes in an ecosystem component's distribution due to e.g. climate change are assessed under the criterion *threat status*.
- Biotopes that benefit rare species are assessed under the criteria *biological diversity* or *ecological function*.
- Ecosystem components that are locally rare are assessed in phase 2 (regional assessments).
- Rarities that are not covered by any of the criteria in the preparatory part or steps in the implementation part are not thought to have a conservation value equivalent to those included in phase 1a.
- Rare ecosystem components that are exposed to human impacts should be included when analyzing "sensitivity, naturalness and vulnerability" in the criteria *adequate and viable sites*

Responsibility species are not included as a separate criterion because:

- They should be stipulated in the lists of ecosystem component (see the third column in Table 17, section 2.3.2.4) and are part of the assessment on the *proportion* of an ecosystem component that should be represented in *areas of ecologically coherent networks* (under the criterion *ecological representativity*).
- If they are rare in an area, they will often have to be assessed on a case-by-case basis. This information is handled in step 6, *site-specific conservation value assessments* (section 2.4.3.3).

3.3 Occurrence

How common a biological ecosystem component is effects conservation value assessments in an intricate way. Rare ecosystem components receive more points for the criteria *threat status* and *special importance for life-history stages* (see Figure 14 in section 2.3.2.1.1). However, more common species are often awarded more points for the criterion *ecological function* and for criteria linked to direct ecosystem services because species with a high abundance usually provide important ecological functions in marine environments. The criterion *ecological function* is assessed according to an ecosystem component's potential and actual occurrence - as seen in Table 6 and as stated in Figure 16 (section 2.3.2.1.1):

> *"If the ecosystem component […] has the potential to be common enough for it to provide one or more important ecological functions, its actual occurrence will also affect the conservation value of the areas where it is found. If it is widespread (such as for blue mussels) the value of each place it is found will be slightly lower than if occurrence was low in relation to its potential (such as for cod spawning areas)."*

It may have been preferable to first assess the conservation value of ecosystem components regardless of how common they are and account for the effect of occurrence/abundance on assessment criteria in a separate step. However, we found this approach to complicate the assessments more than the chosen method.

4 Does the tool achieve its aims?

It is impossible to create a perfect assessment tool that can account for all of nature's variability and produce objective and comparable assessments in an environment that is difficult to survey. All assessments have to be evaluated critically to determine if they are reasonable. In other words, the tool will not always achieve its objectives. We discuss how MOSAIC is structured to achieve its aims, as far as is possible, below.

The purpose of MOSAIC is to promote an ecosystem-based and functional management of our marine areas. The tool is in line with the ecosystem approach and broadly follows the Malawi principles. However, it is limited to provide a framework for prioritizing based on biodiversity, ecosystem services and other conservation values in a spatial perspective. Furthermore, it does not directly include Malawi principle 4, "*Recognizing potential gains from management there is a need to understand the ecosystem in an economic context*". By providing a framework for assessing conservation values and prioritizing areas for management, the tool could support the economic assessment of ecosystems. However, there are a lot of problems associated with assigning an economic value to nature and we have chosen not to attempt it in MOSAIC.

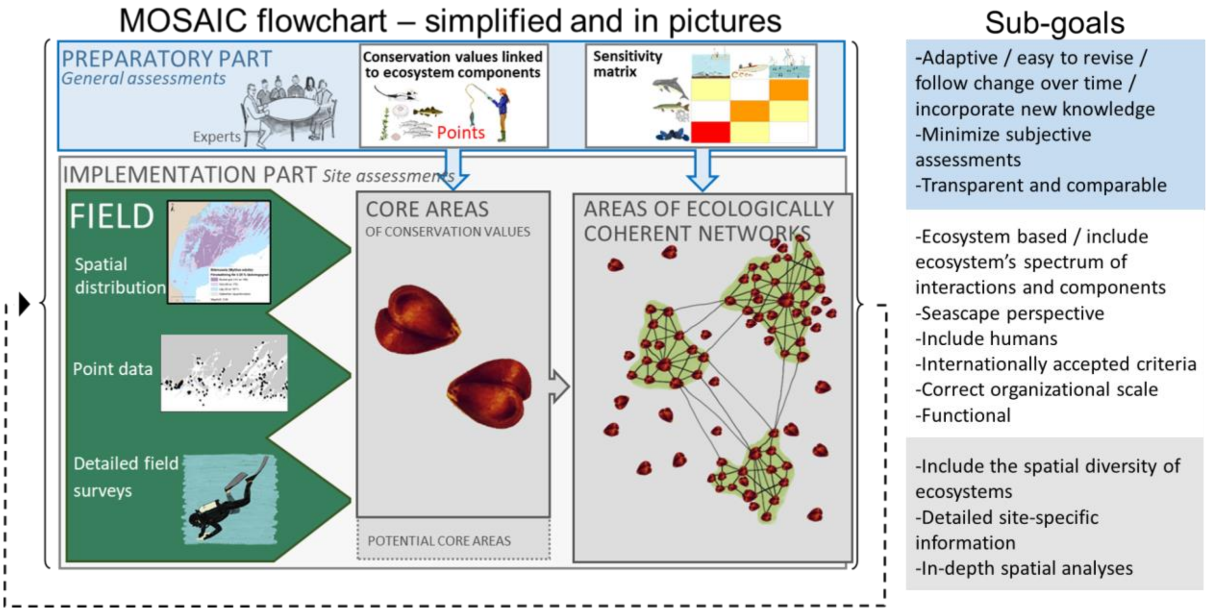

Figure 57. Illustration of MOSAIC's two parts. On the right-hand side a list of sub-goals are specified. These sub-goals ensure that the tool achieves its overall aim of being ecosystem based, adaptive and functional (see section 1.1). The sub-goals are ordered according to which part of MOSAIC they relate to. Sub-goals found in the blue box relate to the preparatory part and those in the grey box to the implementation part. Sub-goals that are in white (unmarked) relate to both of MOSAIC's parts. However, one should attempt to achieve all the sub-goals in both the preparatory and the implementation parts.

The following framework has been developed to ensure that MOSAIC achieves the sub-goals set out in section 1.1:

Ecosystem based

- **The tool should take into account large parts of the ecosystem's spectrum of interactions and components.**
  - × To account for complex (non-linear) ecosystem interactions (such as food web interactions) relevant to spatial management, ecosystem components are assessed by a group of experts and based on the best available scientific evidence – this is done to ensure the maximum amount of knowledge on marine environments currently, and in likely future scenarios, is included in an accessible way (see the preparatory part, section 2.3)[81].
  - × All ecosystem components (see section 2.3.1, *list of ecosystem components*) should be assessed according to all the criteria in the preparatory part. There are advantages and disadvantages to this approach. The advantage is that all ecosystem components are treated equally and can contribute to conservation value assessments according to the best available knowledge. The downside is that many assessments are based on inadequate information. It is important that this is noted and used to prioritize investigations/studies (see section 2.3.2.3 assessment reliability).
  - × The tool contains many criteria that highlight different conservation values and ecosystem services. This will be reinforced in future versions if the CBD's EBSA-criteria are included in step 6, *site-specific conservation value assessments* (currently only a suggestion, see section 2.4.3.3).[82]
  - × The tool provides a holistic approach by including various methods to identify valuable areas (*core areas*[83]) based on a range of criteria.

- **The tool should be based on the best available knowledge and to the greatest extent possible grounded on scientific facts.**
  - × Ecosystem components are assessed by a group of researchers and experts, with local, national and regional/global experience and a wide range of ecological expertise – this ensures the maximum amount of relevant information on marine environments currently and in likely future scenarios is included in an accessible way (see the preparatory part, section 2.3.2)[84].
  - × The assessments carried out in the preparatory part should be available via a digital platform (website). It should be easy to include comments and references to this material (see section 4.1) for consideration during the next revision. This is a strategy to efficiently gather more relevant information. However, this is not yet operational and cannot be considered fulfilled[85].
- **The tool should include a landscape perspective and in-depth spatial analyses.**
  - × When conservation values are linked to ecosystem components, a more comprehensive assessment by sea area is carried out (phase 1). Even if points

[81] Linked to Malawi principles 2, 3, 5, 6, 8 and 10.

[82] Linked to Malawi principles 5 and 10.

[83] See chapter 5 (terminology) for definition.

[84] Linked to Malawi principles 11 and 12.

[85] Linked to Malawi principles 2, 11 and 12.

can be added or deducted in the next phase to account for local importance, the score still reflects their conservation value from a landscape perspective.
  - × One of the methods for identifying *core areas* uses *ecosystem component spatial distribution maps* to show where conservation value is high in a landscape (according to available data; step 4, section 2.4.3.1).
  - × We encourage the use of maps showing likely future scenarios of ecosystem component distribution and human activities when identifying *adequate and viable sites*, step 10.
  - × All the criteria used to identify *areas of ecologically coherent networks*[86] should be assessed according to landscape analyses (*areas with high conservation values*, *connectivity*, *adequate and viable sites* and *ecological representativity*; steps 8-11, section 2.4.4)[87].
- **The tool should include detailed site-specific information.**
  - × Site-specific knowledge should be included for all steps in MOSAIC's implementation part. Site-specific knowledge is especially important in steps 2 (*detailed field surveys*, section 2.4.1.2) and 6 (*site-specific conservation value assessments*, section 2.4.3.3)[88]. However, these steps are not yet fully developed.
- **The tool should include humans as a part of ecological interactions.**
  - × Assessments on which ecosystem services different ecosystem components generally contribute to an area are carried out in the preparatory part when conservation value is linked to ecosystem components (information is then used to identify *core areas* in steps 4 and 5 of the implementation part, see sections 2.3.2.1.2, 2.4.3.1 and 2.4.3.1). The intention is that ecosystem services will be considered in *site-specific conservation value assessments* (step 6, section 2.4.3.3) but the guidelines are not yet complete.
  - × When identifying *areas of ecologically coherent networks*, negative human activities should be analyzed during step 10, *adequate and viable sites* (section 2.4.4.3). Analyses are carried out with the aid of *sensitivity matrices* developed (or referred to) in the preparatory part (section 2.3.4). Detailed guidelines are not yet complete.
  - × MOSAIC can be used in conjunction with other tools when assessing marine management strategies (see section 2.6)[89].
- **The tool should be adaptive.** Read the points under "Adaptive" in the text below.
- **The tool should be functional.** Read the points under "Functional" in the text below.

[86] See chapter 5 (terminology) for definition.
[87] Linked to Malawi principles 3, 5, 6 and 8.
[88] Linked to Malawi principles 6 and 11.
[89] Linked to Malawi principles 1 and 10.

Adaptive

- **Assessments should be easy to revise**
    - × It is easy to change individual assessments when conservation values are linked to ecosystem components in the preparatory part because a simple points system is used (see section 2.3.2).
    - × By assessing ecosystem components without taking site-specific characteristics into account, it is practically possible to carry out recurring revisions to account for nature's complex (non-linear) changes over time (see section 2.3.2.1, phase 1, assessments by sea area where conservation values are linked to ecosystem components in the preparatory part).
    - × The assessments in phase 1 are revised periodically by a group of experts (when conservation values are linked to ecosystem components in the preparatory part) allowing for the inclusion of new knowledge and to follow change (e.g. non-linear change) in the environment (see section 2.3.2.1).
    - × *General conservation value maps*, step 4 (section 2.4.2.1), are relatively easy to revise if the *conservation values linked to ecosystem components* are adjusted (it is not as easy to remodel *ecosystem component spatial distribution maps* after environmental change because new field surveys are often required)[90].
    - × Revisions should not be carried out continuously but with a certain cyclical periodicity to provide stability to management.
    - × MOSAIC's implementation part is not as easy to revise as the preparatory part because more complex spatial adjustments have to be accounted for.
- **Likely future scenarios should be able to be included.**
    - × Modelled maps showing the likely future distribution of ecosystem components can, and should, be included when identifying *adequate and viable sites* and, indirectly, when identifying *areas of ecologically coherent networks*.
- **The tool should be able to be used for evaluations.** MOSAIC can be used in conjunction with other information and tools when evaluating marine management strategies (see section 2.6).
    - × For example, spatial distribution maps of future scenarios of human pressures and of ecosystem components can be combined to evaluate effects on an area's conservation value.

Functional

- **The tool should be based on internationally accepted criteria and foster national harmonization.**
    - × MOSAIC is based on internationally accepted criteria set by the UN Convention for Biological Diversity (CBD; 2008). In addition, other criteria relating to ecosystem services have been included. Read more in sections 2.1, 2.3.2.1, 2.4.3.3 and 2.4.4. If the tool becomes widely used it can contribute to national harmonization of marine spatial management. Its use depends primarily on its applicability and secondly on its presentation in text and via lectures (recorded video lectures are available).
- **The tool should minimize subjective assessments and encourage consensus.**
    - × Repetition from an earlier point: All ecosystem components (see section 2.3.1, *list of ecosystem components*) should be assessed according to all the criteria in the

[90] Linked to Malawi principle 9.

preparatory part. There are advantages and disadvantages to this approach. The advantage is that all ecosystem components are treated equally and can contribute to conservation value assessments according to the best available knowledge. The downside is that many assessments are based on inadequate information. It is important that this is noted and used to prioritize investigations (see section 2.3.2.3 assessment reliability).

- × In preparation for conservation value assessments of locations, an expert group (with the aid of scientific literature) assess the conservation values linked to ecosystem components by sea area. This ensures the maximum amount of relevant information on marine environments currently, and in likely future scenarios, is included in an accessible way (see the preparatory part, section 2.3.2).
- × The amount of knowledge on specific ecosystem components, processes and geographic areas analyzed in MOSAIC will differ. For example, *connectivity* analyses might be possible for some species but not for others. We have to accept a certain amount of subjectivity in order to best account for spatial variation and complexity found in natural systems. Because MOSAIC's implementation part is more subjective than the preparatory part it is practical that they are carried out separately. However, if the *ecosystem component spatial distribution maps* are based on reliable data the *general conservation maps* will be less subjective. Transparency is given to the assessments by motivating the reasons *core areas* and *areas of ecologically coherent networks* (in steps 5-11) have been placed in areas other than those that the *general conservation value map* points out as valuable,
- × Repetition from an earlier point: The assessments carried out in the preparatory part should be available via a digital platform (website). It should be easy to include comments and references to this material (see section 4.1) for consideration during the next revision. This is a strategy to efficiently gather more relevant information. However, this is not yet operational and cannot be considered fulfilled.

- **The tool should be transparent and allow for clear and comparable assessments.**
  - × Using a points table for assessments makes them intuitive and easy to compare. Complimenting this with explanations (including references) improves transparency (see section 2.3.2).
  - × A digital platform should allow users to easily compare assessments by including simple filtering functions.
  - × Comparisons are made easier by allocating general points according to sea areas (phase 1 assessments) and more specific points locally in a sea area (phase 2 assessments). The general points assigned in phase 1 are more comprehensive and assessed according to several criteria.
  - × If the *core areas* or *areas of ecologically coherent networks* are designated outside of those expected according to *general conservation value maps*, full explanations must be given for the sake of transparency.
- **The tool should be based on transparent analyses that can be carried out by anyone with basic GIS competence** and without the need for specialized software.
  - × All analyses in the first version can be carried out by users with basic GIS knowledge.

- **The tool should support functional and effective field survey methods.**
  - × Guidelines for *detailed field surveys* (step 2, section 2.4.1.2) have not been developed. This needs to be prioritized because it is a central part of the tool. Until this has been done the sub-goal cannot be fully achieved.
  - × However, the sub-goal is partly achieved because MOSAIC provides a structure for conservation value assessments by identifying its biological ecosystem components. Step 1, *presence of ecosystem components*, section 2.4.1.1, provides guidelines to ensure the maximum amount of relevant information is collected during field surveys. A location's general conservation value is assessed with the aid of information from the preparatory part (when conservation value is linked to ecosystem components) in either step 4 (*general conservation value maps*, section 2.4.3.1) or step 5 (*general conservation value assessments on point data*, section 2.4.3.2) of the implementation part.
- **The tool's different parts should be arranged at the correct organizational scale.**
  - × Coordination of MOSAIC's different parts is shared between a central agency (Swedish Agency for Marine and Water Management) and respective county administrative boards to maximize accuracy and workflow efficiency. County administrative boards can further decentralize their work to municipalities or water districts (section 2.2.1)[91]. In addition, the maps produced should be able to be used by municipalities for coastal zone planning.
  - × Local perspectives are important and the preparatory part can be criticized because it is coordinated nationally. However, it is essential to have a simple and unified framework as a starting point for local assessments and the framework developed in MOSAIC is a trade-off.
  - × Even if the preparatory part is coordinated nationally, experts that assign conservation values to ecosystem components have local, national and global expertise on a wide range of organisms which are dependent on spatial management (see section 2.3.2)[92].
  - × In the future it should be possible to comment on the assessments via a digital platform. The comments should be taken into consideration during the next revision cycle[93].

[91] Linked to Malawi principle 2.

[92] Linked to Malawi principle 2.

[93] Linked to Malawi principle 2.

4.1 MOSAIC's development areas

MOSAIC should evolve and adapt continuously to improve its versatility as a tool for the spatial management of marine conservation values. The parts that are particularly interesting to develop (but not necessary to be able to start using the tool) are:

- Web based IT support.
- Suggestions for handling mapping uncertainty.
- Guidelines for reporting which ecosystem components are and are not included in *general conservation value maps*. In other words, a gap analysis of elements missing from conservation value maps.
- Guidelines on how the criteria *connectivity*[94] should be assessed and analyzed.
- Detailed methods for creating sensitivity matrices of human activities/pressures and biological ecosystem components – such as design of the matrix structure, what should be specified in the matrix and how the information should be compiled and applied to spatial analyses. Alternatively, recommend suitable matrices that already exist.
- Assessments of the sensitivity of ecosystem components to human activities/pressures (i.e. apply *sensitivity matrices* to ecosystem components). Alternatively, information from existing matrices.
- Guidelines for the spatial analysis of *adequate and viable sites* (i.e. how *sensitivity matrices* should be applied to landscape analyses).
- Summary and description of suitable field survey methods.
- Guidelines for *site-specific conservation value assessments*.

[94] See chapter 5 (terminology) for definition.

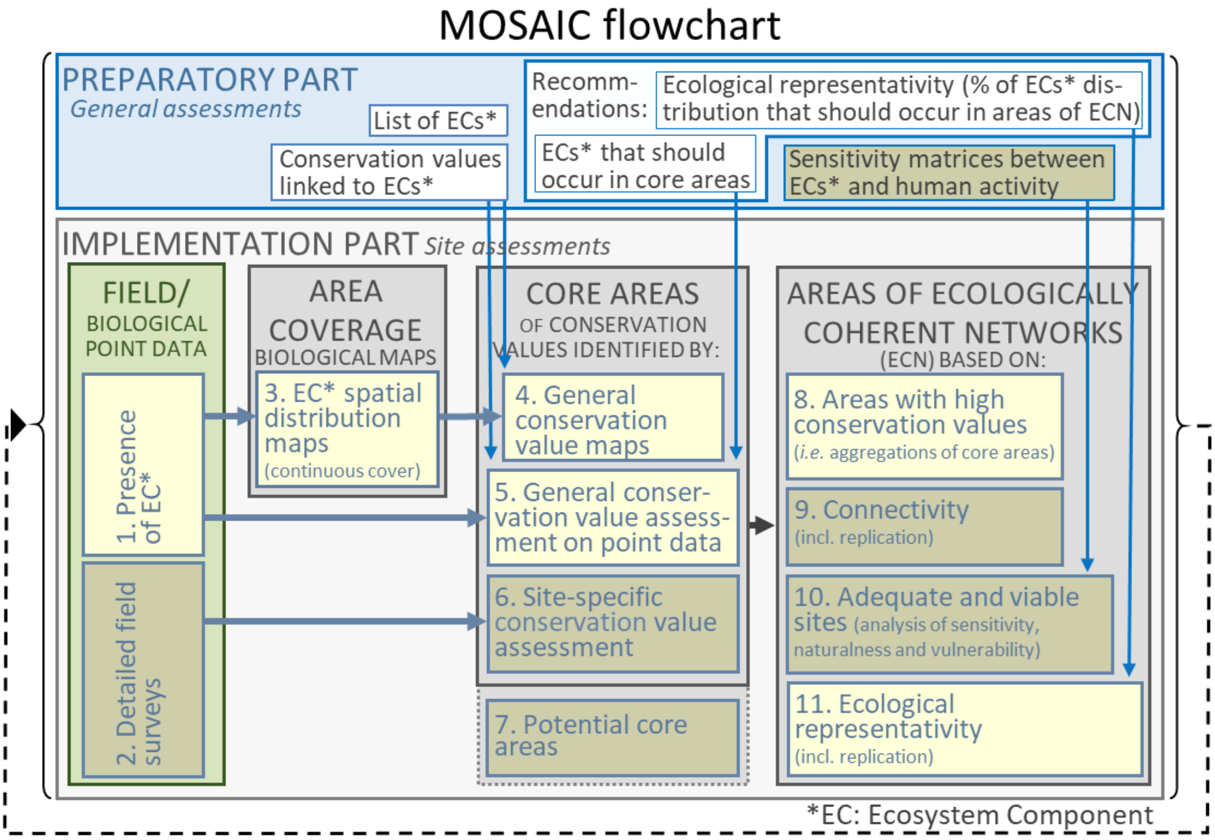

Figure 58. The toned areas in the flow chart are the parts of MOSAIC that are not fully complete.

5 Terminology

MOSAIC uses several terms and phrases. This section provides a list of these terms and their definition with respect to MOSAIC and this report. The text is not designed to be read from start to finish but to be referred to by the reader as and when guidance on terms is needed.

Area of ecologically coherent networks: A viable marine area with high conservation values (i.e. aggregations of *core areas*) in ecologically representative networks with well-functioning connectivity.

Connectivity: The degree to which a seascape supports or hinders individuals or species from moving between suitable habitats. Movement might be daily, seasonal, small or large scale, or dependent on life history traits (the need for different habitats at different life stages) and allow for the transfer of genetic material between populations (gene flow). *Connectivity* is a criterion used when identifying *areas of ecologically coherent networks*. The aim of good connectivity is to maintain an areas conservation value with respect to, for example, *biological diversity* and *ecological function*.

Because many marine species can travel over long distances using currents, we suggest using **dispersal/migration routes** as a term to describe connectivity in marine environments. Migration routes are areas that facilitate the movement of one or several species between habitats.

Conservation value: The term conservation value is often primarily related to biodiversity. For conservation values relating to biodiversity MOSAIC uses internationally accepted criteria included in the UN Convention for Biological Diversity (CBD; 2008) for ecologically or biologically significant areas (EBSAs). However, in MOSAIC the term *conservation value* may also include ecosystem services. Because ESS can be included in the evaluation, *nature value* is an alternative term (in future versions this may be favoured over *conservation value*).

Conservation value assessment: The assessment of a location or area according to its conservation value (see previous term). In MOSAIC there are three ways to do this:

- *In step 4, general conservation value maps* are produced by combining *conservation values linked to ecosystem components* (assessed in the preparatory part) with *ecosystem component spatial distribution maps* (step 3).
- In step 5, *general conservation value assessments on point data* are assessed by combining *conservation values linked to ecosystem components* (assessed in the *preparatory part*), with the *presence of ecosystem components* (step 1) from point data.
- In step 6, *site-specific conservation value assessments* are carried out based on *detailed field surveys* (step 2). Guidelines for this have, however, not yet been developed.

Core area: An area with a high conservation value with respect to biodiversity and the provision of ecosystem services.

Direct ecosystem services: Direct ecosystem services are closely linked to ecosystem goods and benefits used by humans (Fisher et al. 2009). The difference between direct and indirect ecosystem services can be difficult to define and the same ecosystem service might provide goods or benefits directly and indirectly. Direct ecosystem services include *provisioning*, *cultural* and certain *regulatory services* (according to the Millennium Ecosystem Assessment (2005)).

Dispersal/migration routes: see *connectivity*

Ecological function: A criterion that assesses how ecosystem components contribute to the functioning of the entire ecosystem such as importance for the survival of other species and resilience of the ecosystem. *Ecological function* is a part of larger ecosystem processes. This criterion includes many of the indirect ecosystem services (i.e. supporting and most regulatory ecosystem services). The ecological functions might, for example, be related to the provision of food or habitat for other species, "top-down" regulation, significant water purifying or filtering ability or significant water or sediment chemical functions such as oxygenation of bottoms or sediment binding characteristics. For example, mussels are very important from an ecological perspective because they filter the water and are an important food source for fish and birds.

The criterion can be compared with the keystone species concept. A keystone species is a species that is of important for the survival of other species in an ecosystem (Paine 1995). Keystone species is a selection criterion for HELCOM MPAs (marine protected areas). Keystone species are defined as species which are important for maintaining the resilience of the ecosystem. In MOSAIC, however, we intend to assess the significance of species as well as other ecosystem components such as habitats.

Ecological representativity: *Ecological representativity* is achieved in a network when the *areas of ecologically coherent networks* contain the diversity of biota and habitats that occur in that region's marine ecosystem. *Ecological representativity* is achieved by 1) maximizing the number of biotic ecosystem components in the network and 2) ensuring an appropriate proportion of each ecosystem component is included. See section 2.4.4.4 on how this should be evaluated.

Ecosystem component (EC): A central term in MOSAIC. Ecosystem components are primarily biological in the MOSAIC tool, but some abiotic ecosystem components are included. Biological ecosystem components are defined by and bound to living organisms, such as populations, species, organism groups or habitats. Examples include wintering grounds for long-tailed ducks, seal haul out points, perch spawning areas, seagrass meadows, mussel beds and single occurrences of the charophyte *Chara horrida*. Abiotic ecosystem components are defined by and bound to the physical environment, such as depth, bottom substrate, salinity and coastal topography. Examples of abiotic ecosystem components include deep areas with soft sediments, shallow areas over hard substrates and submerged offshore sandbanks.

Throughout MOSAIC, ecosystem components are defined independently of their exact geographical position. An ecosystem component may be a habitat defined by how dense its coverage is (for example, mussel beds with a coverage over 50 percent). However, even if the definition should be independent of location, it should be specific enough to allow one to easily identify locations where the ecosystem component occurs. For example, places with the ecosystem component "Cod" are vague. Does it refer to places where cod sometimes occur or to spawning grounds for cod? Places with occurrences of cod and spawning areas for cod need different considerations and management; vaguely defined ecosystem components are inappropriate for spatial management.

When linking conservation values to ecosystem components it is important that assessments are based on the value an ecosystem component generally contributes to a site. For example, not all places where there are blue mussels can be valued according to the full value that the sea area has blue mussels at all. The final conservation values are partly determined by its occurrence/distribution in the whole sea area. If the ecosystem component is common and its ecological function is not limited, the value of each site where it is present is lower than if it is rare or its ecological function is impaired. The relative semi-quantitative evaluation must reflect the conservation value loss of blue mussels disappearing from a site (through exploitation, for example) according to the current state of knowledge about mussels, and their general occurrence and distribution in a sea area. If blue mussels were to decrease substantially in the Baltic Proper, for example, the conservation value of each site with blue mussels there would change (increase) and would have to be adjusted during the next management cycle.

Ecosystem component spatial distribution maps: Maps with information on the presence or absence of ecosystem components in each grid cell or minimum assessment unit.

Essential passage: An area important for connectivity of one or more species.

Expert assessment: Assessments based on the best available knowledge, used in cases where standard assessments or procedures cannot be applied (Naturvårdsverket 2007b).

General conservation value maps: Maps produced by combining the conservation value points associated with ecosystem components (from MOSAIC's preparatory part) and their presence in an area (from ecosystem component spatial distribution maps).

Importance for life history stages: A criterion used to assess if an ecosystem component is important for critical life history stages for one or several mobile/migratory species (see term below). Examples include reproduction, growth, resting or foraging.

Indirect ecosystem services: Also called intermediate services. Services that do not directly produce goods or benefits used by humans, but which are a prerequisite for the existence and function of direct ecosystem services. Indirect ecosystem services often consist of complex interactions (Fisher et al. 2009). The difference between direct and indirect ecosystem services can be difficult to define and the same ecosystem service might provide goods or benefits directly and indirectly. Indirect ecosystem services include supporting and certain regulatory services (according to the Millennium Ecosystem Assessment (2005)).

Marine green infrastructure: An ecologically functional network of habitats. The network supports the preservation of biodiversity and ecosystem services.

Minimum assessment unit: The smallest area on a map (grid cell) containing conservation values. Conservation values in the assessment unit include the entire water column in the grid cell. In this manual the smallest assessment unit is 25 x 25 meters, and we recommend an area between 10 x 10 meters to 50 x 50 meters in coastal areas. The minimum assessment unit of offshore areas can be a few km^2 depending on how homogenous the area is. Furthermore, we recommend that the water column in the minimum assessment unit is treated as a vertical cross-section as far as possible to reduce problems of scale (see section 2.4.3.1.1).

Mobile / migratory species: Species with individuals that move between areas or habitats (often large distances). Primarily birds, mammals and fish.

Point data: Information relating to discrete data points (in contrast to spatial distribution maps with information on continuous cover; see *ecosystem component spatial distribution maps* above). Even data from transects, or that is spatially limited (such as from video surveys), are regarded as point data in this manual.

Potential core area: A location or area that, with remediation or restoration, has the potential to be categorized as a *core area*.

Preliminary area(s) of ecologically coherent networks: A practical approach to identifying *areas of ecologically coherent networks*, according to steps 8-11, is to delineate areas based on one criterion, then adapt the boundaries of areas according to the next criterion. Until all the criteria are fulfilled the areas are called *preliminary area(s) of ecologically coherent networks*.

Sea area: Swedish marine territory divided into four large areas, the Bothnian Bay, Bothnian Sea, Baltic Proper and Kattegat/Skagerrak. Divisions follow those used for national maritime spatial planning, except for the Gulf of Bothnia which is divided into the Bothnian Bay and Bothnian Sea because of the large differences in species between the two areas. Sea areas extend to and include shorelines.

Sensitivity, naturalness and exposure to pressure: Analysis of “sensitivity, naturalness and exposure to pressure” is used to assess where conservation values are, and are not, affected negatively by human activity. It combines an assessment of biological ecosystem components “naturalness” with their “exposure” to activities that they are known to be “sensitive” to.

Threat status: A criterion in MOSAIC. This criterion aims to assess conservation values according to if a species, sub-species, population, habitat or biotope in an ecosystem component is threatened or declining. The criterion is primarily assessed using national and international red lists.

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MOSAIC – A tool for ecosystem based spatial management of marine conservation values

Version 1

Effective ecosystem-based management of marine and coastal environments requires an integrated approach across administrative areas. A standardized approach for the assessment of marine green infrastructure can ensure that the right management measures occur in the right place. MOSAIC is a tool to identify the conservation value of marine areas, in particular their importance for biodiversity and ecosystem services in coherent (viable and ecologically representative) networks. The intention is to provide a standardized and integrated framework for marine management, such as which areas should be prioritized for protection, restoration or other physical planning (including fisheries management and goals set out in the Marine Strategy Framework and Habitat Directives). The purpose of this report is to fully describe all of MOSAIC´s parts - why the tool is constructed as it is (the theory behind MOSAIC), the considerations made and discussions held during its development and what the tool can be used for. This report does not have to be read in order to use MOSAIC – practical information can be found in the Swedish Agency for Marine and Water Management report 2020:14

Vi arbetar för levande hav och vatten

Havs- och vattenmyndigheten, HaV, är en statlig förvaltningsmyndighet inom miljöområdet. Vi arbetar på regeringens uppdrag för bevarande, restaurering och hållbart nyttjande av sjöar, vattendrag, hav och fiskresurserna

Havs och Vatten myndigheten