Output O.T1.1 High-resolution maps on the intensity and extent of ecosystem services supply in the transnational pilot area

Louise Forsblom[1], Marco Nurmi[1], Elina Virtanen[1], Ville Karvinen[1], Jonne Kotta[2], Francisco R. Barboza[2], Anda Ruskule[3], Kristīna Veidemane[3], Agnese Reķe[3], Harri Kuosa[1], Susanna Jernberg[1]

Finnish Environment Institute[1], University of Tartu[2], Baltic Environmental Forum-Latvia[3]

Summary

The aim of Work Package 1 (WP1) output O.T1.1 in the project *from Marine Ecosystem Accounting to Integrated Governance for Sustainable Planning of Marine and Coastal Areas* (MAREA) was to produce high-resolution maps on the intensity and extent of ecosystem services supply in the transnational pilot areas of Estonia, Finland and Latvia. As the mapping was conducted to cover national waters of all partners when applicable, the outputs are presented jointly instead of separately based on two smaller targeted areas. The present output offers answers to the questions stated in the project plan as follows with the corresponding page numbers in this report mentioned:

"*This output consists of a novel framework of the mapping and assessment of ecosystem services by defining relationships between ecosystem structure, functioning and services they provide. The following ecosystem services are considered: potentially interesting biological biomass (4) and biogenic mineral resources (7), regulation services and their magnitude (8), cultural services (11). This framework is then used to identify ecosystem services within pilot study areas and model the intensity and extent of these services. Furthermore, the intensity and extent of ecosystem-service production is assessed within the pilot areas in relation to marine protection areas and various uses of the marine areas (6). Ultimately, the activity develops up-to-date and factual-based knowledge on marine ecosystem structure, functioning and ecosystem service supply in the project area (Listed in deliverable D.T.1.1.)*"

Ecosystem services

Human societies are dependent on viable ecosystems (Millenium ecosystem assessment, 2005). The ecosystems are providing ecosystem services including food, materials and recreational opportunities that are essential for our well-being. The degradation of ecosystems and loss of biodiversity threaten the supply of ecosystem services (Costanza et al. 2014), and effective marine spatial planning and decision-making are needed to guarantee the preservation of the areas vital for ecosystem service production. Identifying the key areas of ecosystem service supply is thus needed and modelling of the areas can help in making better informed decisions (Galparsoro et al. 2021).

Ecosystems are supplying ecosystem services through ecosystem structures, processes and functioning and understanding this flow is essential for both modelling of ecosystem services and for decision-making. Haines-Young and Potschin (2010) have described this flow in the ecosystem service cascade framework that helps understanding the links from ecosystems to human benefits. We apply the framework in the Baltic Sea context and particularly in two case study areas: the Gulf of Finland and Gulf of Riga. We concentrate on the ecosystem side of the cascade and how the structures and functions of ecosystems generate ecosystem services in the marine environment.

One aim of the MAREA project is to produce the next generation of ecosystem service maps. This output will summarise the investigated ecosystem service mapping and modelling approaches and also present examples based on maps produced in D.T.1.1.

Modelling of regulating and provisioning services

Models based on distribution of habitats and species

Species distribution models (SDM) are correlative models used to predict the geographical distribution of species based on the species relationship to the environment (Elith et al. 2008). Typical environmental variables used for predicting the occurrence of aquatic species include water depth, substrate and salinity (Virtanen et al. 2018). Some ecosystem services can justifiably be modelled using species distribution models as the existence of certain species is an indication of the service provision. The species may provide services through their functioning such as carbon sequestration via primary production, or the species may provide the services by just being present in the area, for instance by influencing the passage of water. A review by Czúcz et al. (2020) shows that in the majority of mapping and assessments of ecosystem services, the service is modelled at the source ecosystem.

Using SDMs to represent the ecosystem service supply has its pitfalls and species are unlikely to contribute equally even if they can be seen to have the same functioning. Some functionality can be linked to the efficiency of a species to produce a service (Kremen 2005), such as the size of the species, and it can be expected that a large species, such as the common reed, have a higher carbon content compared to short lived species such as filamentous algae. If relevant data such as biomass are available, the species biomass can be modelled separately and it can be combined with the results of the SDM using a hurdle model approach (eg. Potts and Elith 2006). Whereas it is becoming increasingly possible to accurately model the distribution of many species, information on rates and processes are not as extensive.

The present project produced maps on both the occurrence and biomass of multiple species. Boosted Regression Trees (BRT) and Random Forest (RF) were used to model the distribution of species and habitats. BRT is a machine learning method able to handle nonlinear relationships between occurrence and the environment that has been increasingly used in ecological studies (Elith et al. 2008). RF is another machine learning method capable of handling complex responses and interactive effects of dependent variables (Breiman 2001). As compared to BRT, RF can better handle categorical variables. The data is split for model calibration and validation, and the validation is carried out using metrics such as area under the curve operator (AUC). When species biomasses were modelled, the modelling consisted of a two-stage process. In the first model all studied environmental variables (e.g. coverage of different sediment fractions, ice thickness, oxygen, salinity, slope, water temperature, wave exposure, velocity, chlorophyll a) were regressed to predict the probability of occurrence of species. In the second model only the samples containing the respective species were used to predict the biomass of species. The final map product of realised biomass was calculated as a joint product of the probability of occurrence and biomass. More details on the approaches used for occurence and biomass modelling can be found in Virtanen et al. (2018), Kotta et al. (2015) and in the individual descriptions for each map layer. The species observations used for the modelling of the Finnish waters mainly originate from the Finnish Inventory Programme for Underwater Marine Diversity (VELMU) and from the Hertta database, and the species observations used for the modelling of the Estonian waters originate from multiple national and international seabed mapping campaigns and data is managed centrally in the servers of the Estonian Marine Institute, University of Tartu.

To produce more accurate estimates of the intensity of ecosystem service supply, when biomass data are lacking, one option is to account for traits that could influence functioning, such as the size of the species. Figure 1. illustrates this for two species; the relatively large habitat forming brown algae *Fucus vesiculosus* (fig. 1 a, c, e) and the smaller filamentous green algae *Cladophora glomerata* (fig. 1 b, d, f). Both species have 10 % median cover based on observational data. However if the same model predictions are corrected by the species sizes *F. vesiculosus* is emphasised in the comparison due to its larger size.

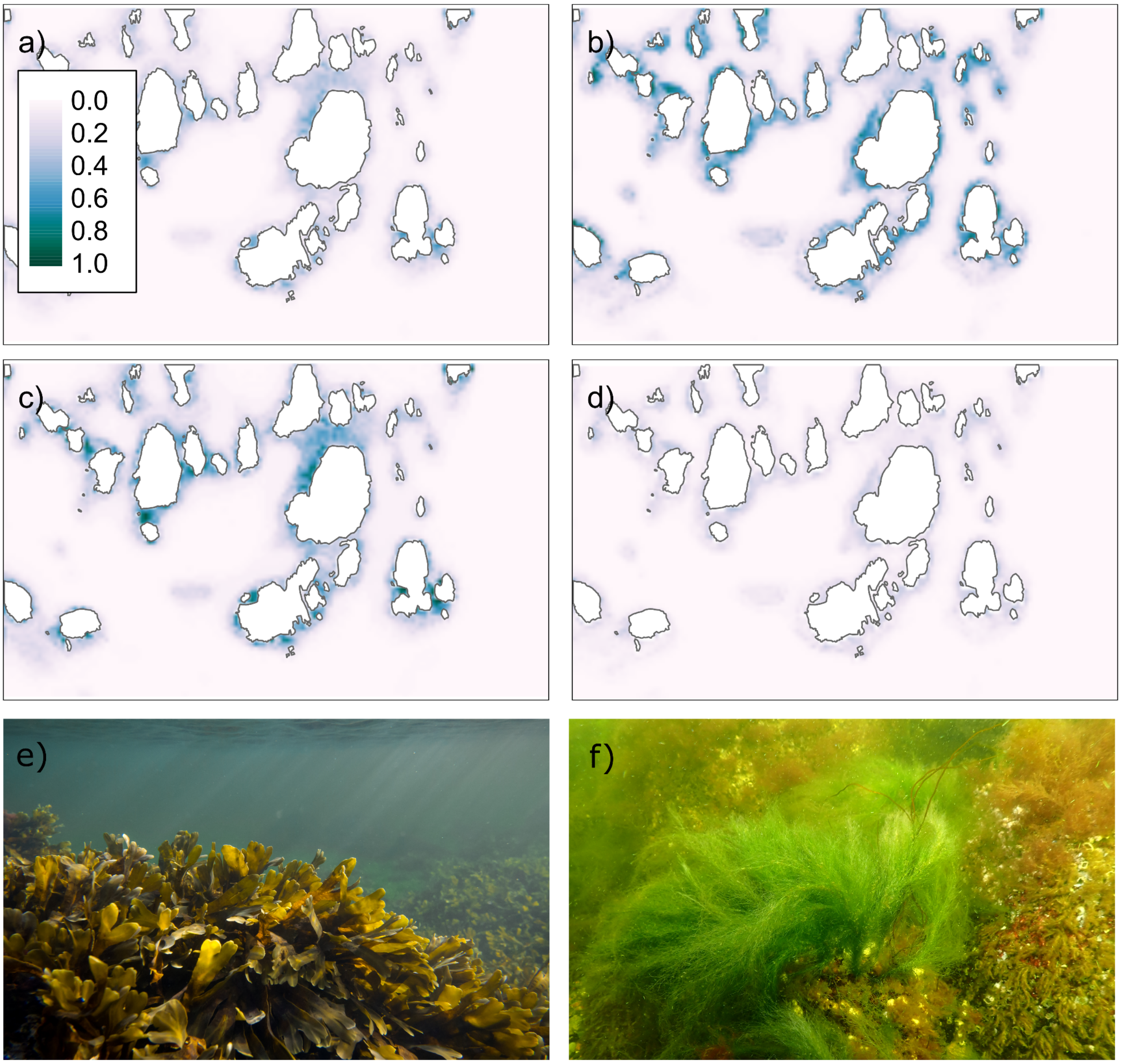


Figure 1. Examples of two algae species *Fucus vesiculosus* (a, c, e) and *Cladophora glomerata* (b, d, f). Panels a and b show the probability of occurrence and panel c and d the same models adjusted by mean cover and median height. Example from the Gulf of Finland. Photos by Juuso Haapaniemi and Jon Ögård Metsähallitus.

Producing maps depicting the distribution of ecosystem service supply enables subsequent analysis to support both the utilisation and protection of the service supply (Galparsoro et al. 2021, Veidemane et al. 2017). The maps provide a planning tool that enables further investigations to see if the location of the ecosystem service capacity matches the sink; where the service is needed (fig. 2). This is also a stepping stone for investigations into the economical use since the economical viability of any venture such as harvesting often is linked to the location (Hein et al. 2006). For more in depth consideration on the valuation of services see OT.2.1.1 by Work Package 2.

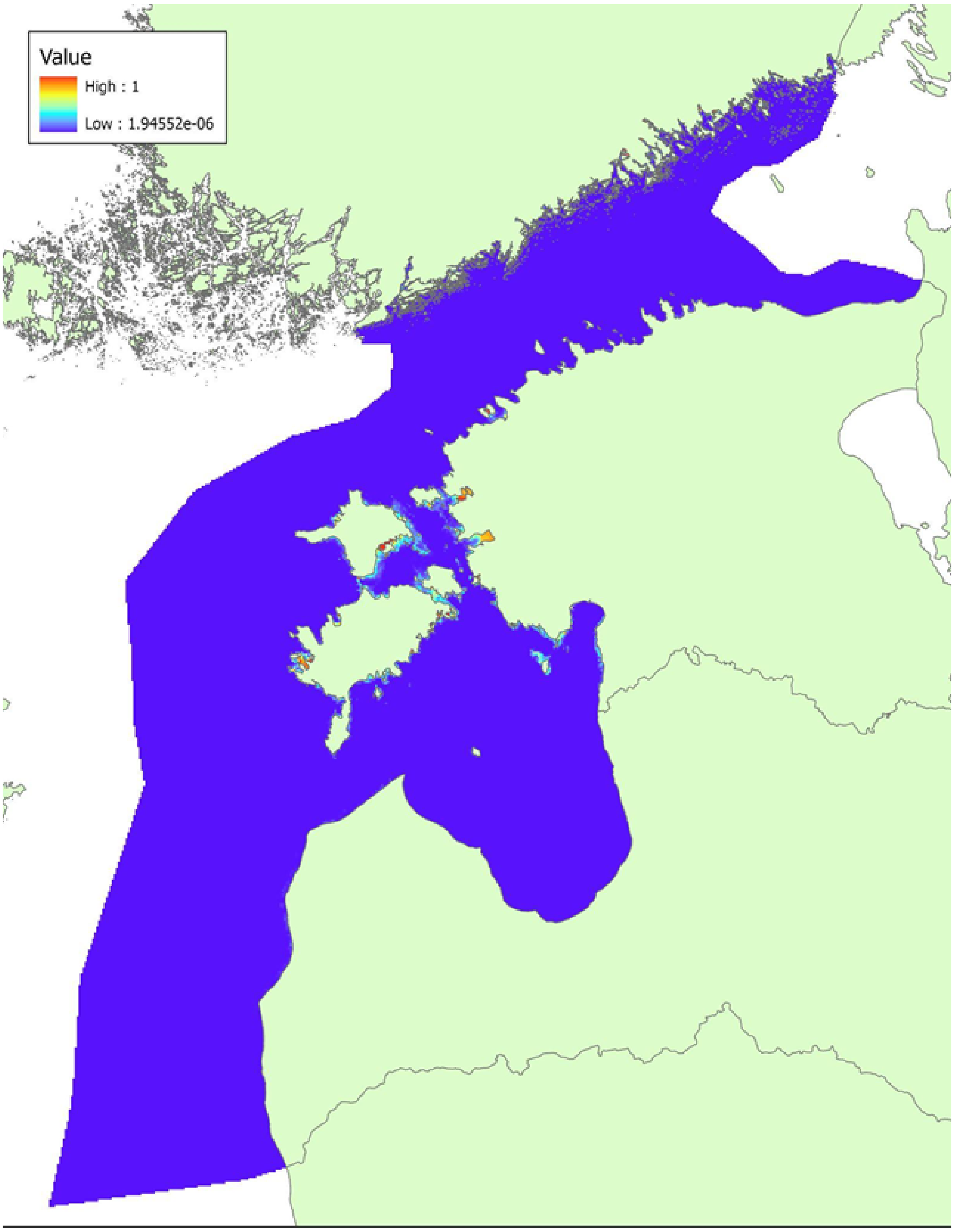


Figure 2. The intensity of erosion protection supply provided by aquatic vegetation on soft substrates.

Ecosystem services in marine protected areas

As marine areas are increasingly used for both recreational and economic activities it is also important to protect the ecosystem service supply. We investigated how well the current marine protected areas conserve the supply of eight provisioning and regulating services. We evaluated the extent and richness of ecosystem services within and outside MPAs. For this, we used the spatial prioritisation approach and a software, Zonation 5.0 rc2 (Moilanen et al. 2022), developed for ecologically-based land use planning. Zonation integrates data on biodiversity, threats, costs and society, such as land ownership or administrative restrictions, and produces spatial priority ranking in which all cells in the seascape are ranked in order of importance for conservation. Here, order is based on the importance of areas providing the supply of ecosystem services. Zonation-technically, we used hierarchical analysis option, where features are forced inside the present MPA network. With the option, one can identify areas for expanding the existing MPA network, based on highest priorities outside areas already protected.

Ecosystem services were classified according to the Common International Classification of Ecosystem Services (CICES, https://cices.eu/):

- 2.2.2.3 maintaining nursery populations and habitats
- 2.1.1.1 bioremediation of wastes by algae and plants
- 2.1.1.2 filtration/sequestration/storage/accumulation by algae and plants for both harmful substances and nutrients
- 2.2.1.1 control of erosion rates
- 2.2.1.3 flood control and coastal protection
- 2.2.5.2 regulation of the chemical condition of salt waters by living processes (only net oxygen production)
- 2.2.6.1 regulation of chemical composition of atmosphere and oceans (i.e. carbon sequestration and storage).

We also evaluated whether the supply of ecosystem services is jeopardised due to human activities. Much of the remaining unprotected supply is located in rather shallow areas close to shore where human activities and consequently pressures are the greatest (fig. 3). In these areas also the demand for ecosystem services is likely high.

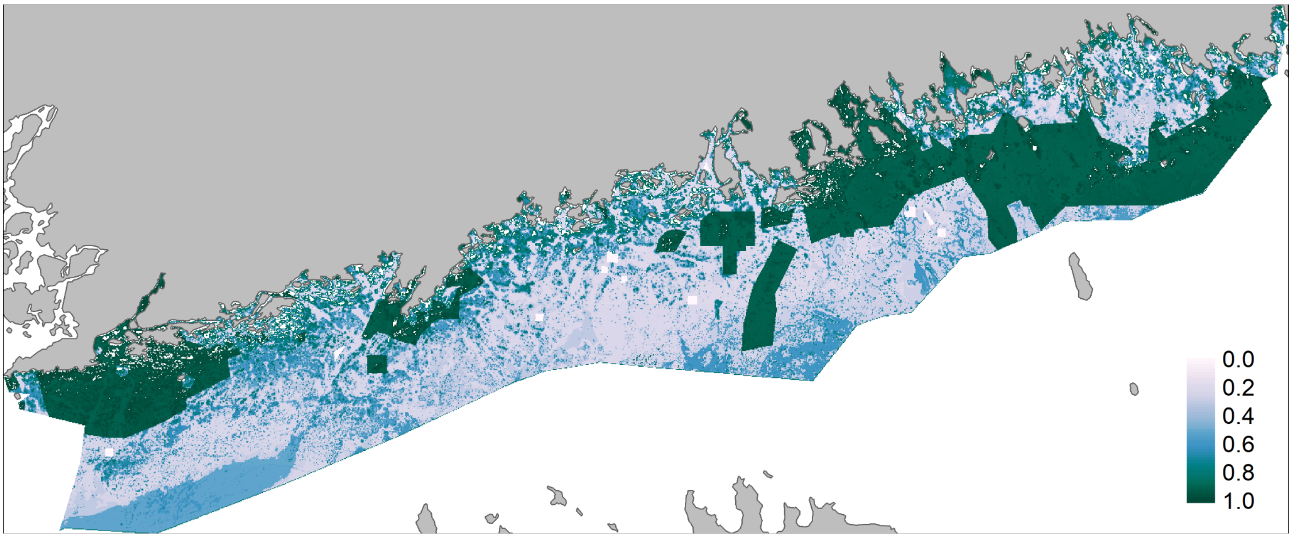


Figure 3. Spatial prioritisation of ecosystem service supply offered by aquatic vegetation showing areas with high priority for protection outside the marine protected areas (MPAs shown in green as they are already protected).

Distribution of mineral deposits

There has been increasing commercial interest in the extraction of ferromanganese nodules (hereafter: concretions), mineral deposits targeted by the mining industry due to high levels of cobalt, nickel, copper and manganese. In the Baltic Sea, the likelihood for extraction activities to take place budged in January 2022, when a Swedish mining company applied for a research permit for the potential extraction of concretions in the Gulf of Bothnia. The ecological role concretions potentially hold needs to be thoroughly estimated, before any commercial activities may take place. Even then, the ecological ramifications and impacts need to be thoroughly assessed, before any permits can be given. The importance of concretions as habitat formers is unclear, but they most likely provide hard substrates for species to attach to in soft sediment areas. They potentially also serve as stepping stones for various species. Concretions are currently classified as “data deficient” habitat type in the national threatened status assessment, highlighting the need for further research (Kontula and Raunio 2018).

Kaikkonen et al. (2019) quantified the potential area where concretions most likely occur along the coast of Finland, and estimated that at least 11 % of the seafloors are suitable for concretions to form. Concretions have been abundantly observed within the VELMU programme, but mainly with visual methods, such as drop videos (N > 6000). This suggests the number of concretions to be higher than reported, as concretions get easily buried in the sediment where there is enough oxygen. In anoxic areas, concretions dissolve releasing high levels of phosphorous. In the MAREA project, the aim was to make predictions on the probability of finding concretions from the whole Gulf of Finland. Models were trained with the Finnish data, and model predictions were done also for Estonian waters.

Observations with at least 70% concretion cover were used to train a simplified version of the BRT model described in Kaikkonen et al. (2019). The model performed well based on standard model evaluating techniques, with an AUC value of 0.97 (area under the curve operator) calculated for the independent validation data. More data would be required for validating the concretion model on the Estonian side. Concretions occur widely in the Gulf of Finland, but any estimates of the thickness of commercially feasible concretion fields is impossible with the existing data (fig. 4).

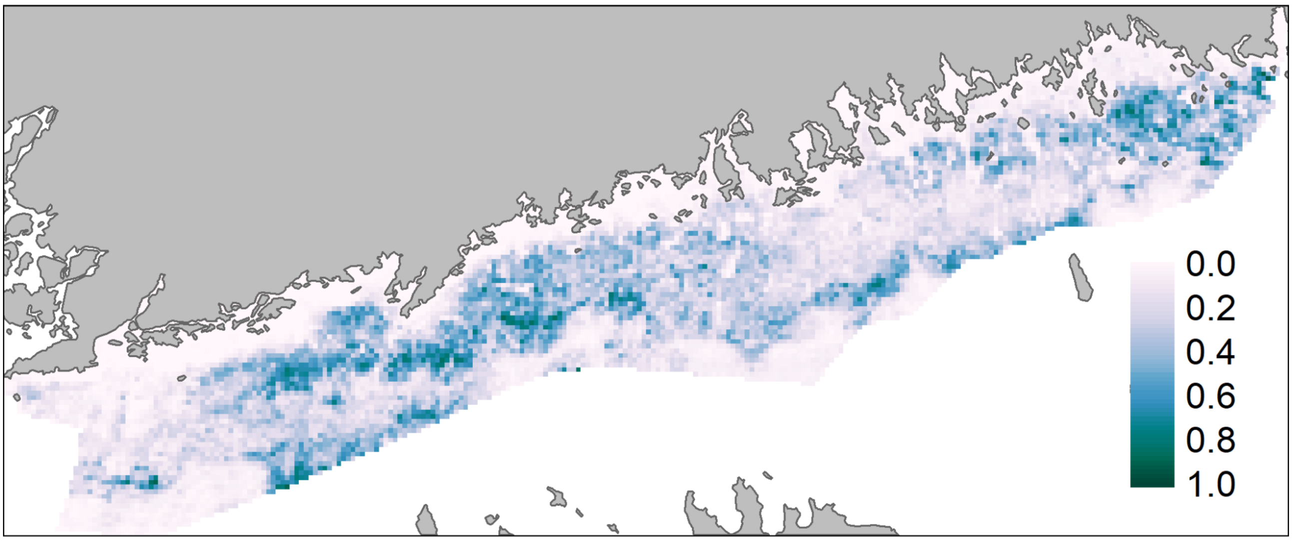


Figure 4. Predicted occurrences of concretions in the Gulf of Finland.

Process-based modelling approaches

Natural systems are very complex. Currently, there are no clear rules on how to relate the patterns of marine life to the processes they generate, and how to infer the values of ecosystem services from marine processes and quantify the intensity of such services. The majority of earlier evidence on ecosystem services in the Baltic Sea have mainly focused on marine habitats and have only estimated the occurrence of ecosystem services from habitat distribution maps (e.g. http://www.panbalticscope.eu/; https://bonusbasmati.eu/). However, such an approach is too simplistic, as the occurrence of a species alone does not really provide information on the intensity of such services. For example, the seabed may be covered by mussels, but whether such an assemblage provides a service of coastal filter to an extent that it actually affects the coastal water quality, depends on the biomass of mussel population, the amount of food in the water column, and many physical properties of the water (fig. 5). By bringing together in a coherent analytical framework the biomasses of species together with the process-based model of intensity of ecosystem services they provide, it is possible to generate realistic and accurate maps of ecosystem services (fig. 6).

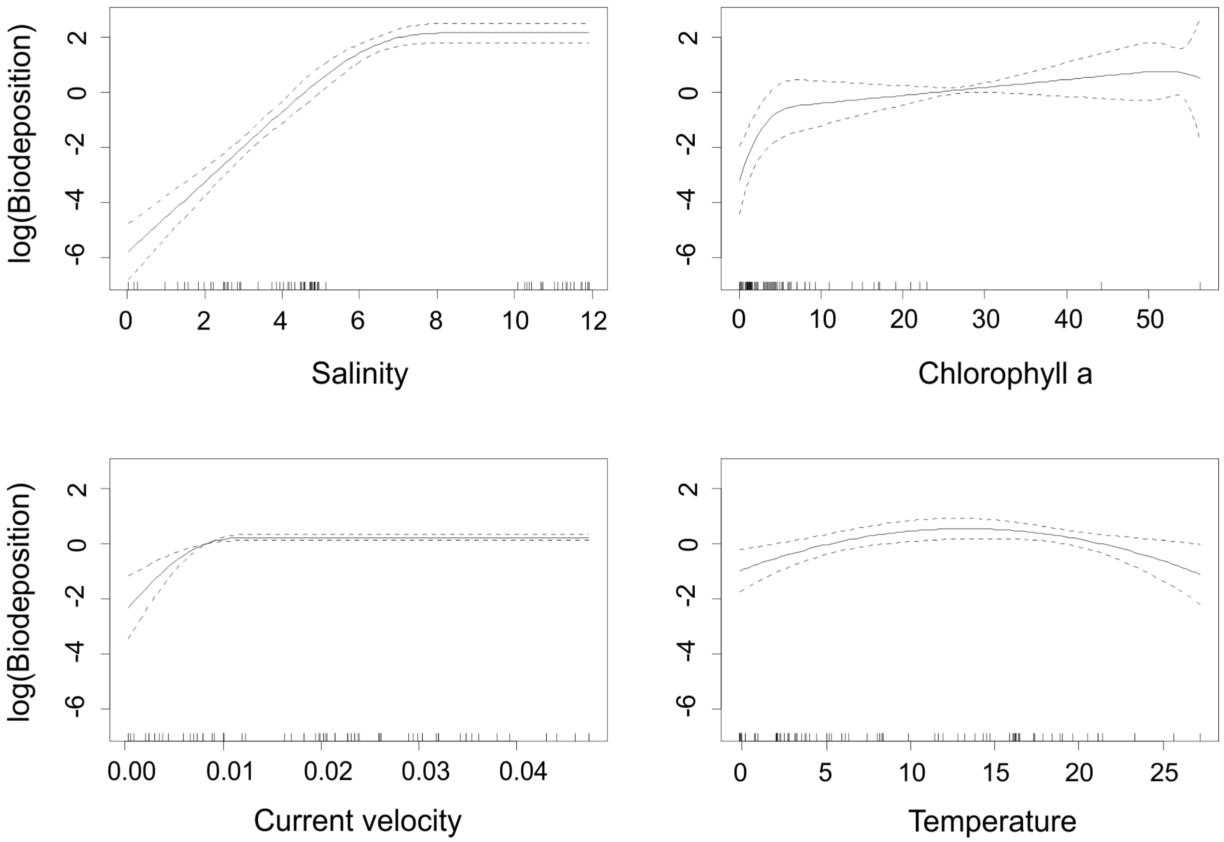


Figure 5. Response of the biodeposition of *Mytilus trossulus* to the studied environmental variables in the MAREA study area. Biodeposition is an indicator that relates to the efficiency of *M. trossulus* to act as a coastal filter.

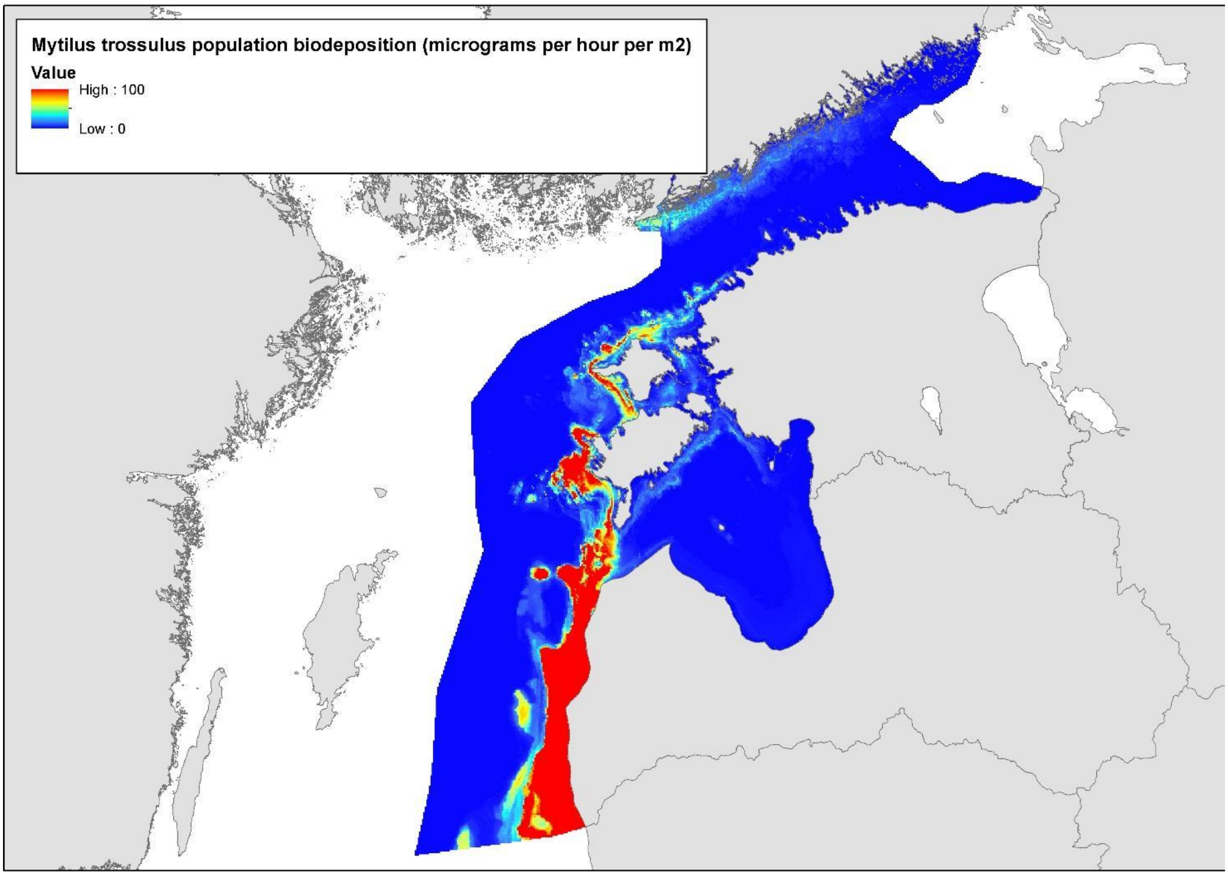


Figure 6. The predicted biodeposition rate of the mussel *Mytilus trossulus* in the MAREA study area based on the above response curves. Biodeposition is an indicator that relates to the efficiency of *M. trossulus* to act as a coastal filter.

For a large number of ecosystem services, it is still not known how these services are delivered and which species are behind the delivery. However, an increasing number of experimental studies have been carried out for some key species of the Baltic Sea, and this makes it possible to analytically infer relationships between the structure of communities, the associated ecosystem processes, and the ecosystem services delivered by these processes. Here, we used an approach, where the availability of data and knowledge determined the ecosystem services to be modelled. At the same time, our second important selection criterion was to cover the widest possible range of different ecosystem services of public importance and to include the most important key species in the MAREA project area (fig. 7).

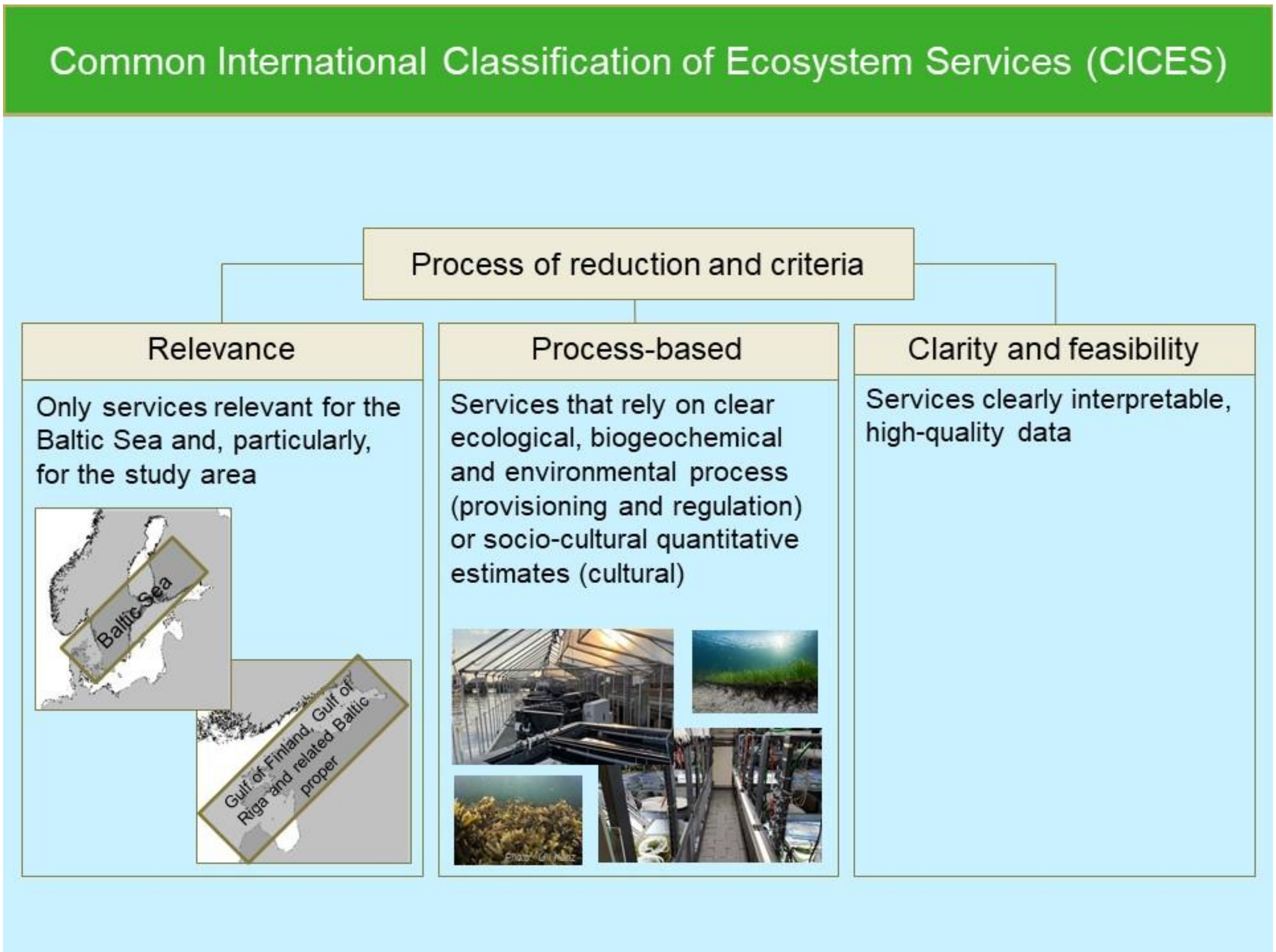


Figure 7. Conceptual diagram on the selection of process-based services in the MAREA study area.

Modelling of cultural services

Mapping of recreational services

Using survey data to support mapping of recreational services

In order to describe and characterise the spatial distribution of cultural activities and their associated benefits across the coasts of Estonia and Latvia and to support mapping and modelling of cultural ecosystem services in MAREA WP1, a public survey was conducted.

The main aims of the survey were:

- To generate an overview of the supply and use of cultural ecosystem services in the study area;
- To describe the spatial distribution of use of cultural ecosystem services, identifying hotspots for different activities and investigate potential interactions;
- To determine the factors (environment and infrastructure) that shape coastal suitability for cultural ecosystem service supply for suitability modelling;
- To describe relevant socio-economic dimensions associated with different cultural ecosystem services.

The survey was conducted using a targeted survey method. The target group of the survey was users of the coastal areas in Latvia and Estonia. We distributed the survey by a mixed approach - surveying was done both online and face-to-face in order to reach as wide an audience as possible, including those seaside users who might not be active on the Internet. We also used diverse survey distribution channels, including social media, local municipalities, NGOs, state organisations, leaflets with QR codes in various public events and stakeholder events and other. In each country the survey was conducted in three languages: the national language (Latvian, Estonian), English and Russian. The online version was developed in the ArcGIS Survey123 application.

The survey was conducted from July 2021 to November 2021 in Latvia and from July 2021 to December 2021. During this period we collected 810 responses in Latvia and 618 responses in Estonia.

Collected responses nicely covered the coastlines of Estonia and Latvia. Descriptive results showed, beyond some differences between countries, that hiking/walking, swimming and enjoying the landscape were the preferred activities performed by respondents along the coast of the Baltic Sea (fig. 8). The fact that enjoying the landscape was listed among the most relevant activities suggests the relevance that coastal natural features have for the respondents when developing recreational activities in coastal areas.

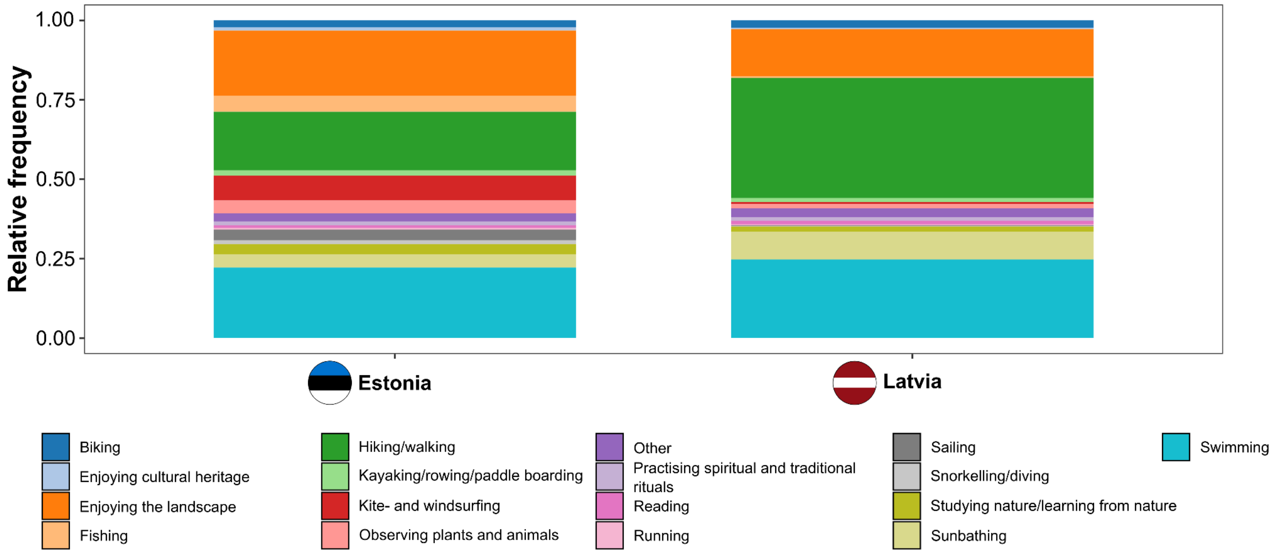


Figure 8. Relative frequency of respondents per cultural/recreational activity. The presented data only refer to the favourite cultural/recreational activity practised by respondents along the coasts of Estonia and Latvia.

Identifying recreational services using a biophysical approach

The quantification of different recreation services was based on the coastal suitability index (CSI) that summarises the environment that make coastal areas suitable for the development of different recreational activities (kite-surf, wind-surf, sea-kayaking, swimming, snorkelling, sunbathing). The respective importances (i.e. preferences) of these different environmental variables were obtained from surveys conducted in Estonia and Latvia (see above subsection). For further details on the method applied and variables considered see D.T.1.1.

The current maps show the potential of these services in terms of environmental variability as seen in figure 9 that shows the predicted suitability for kayaking. The maps do not necessarily reflect people’s preferences as preferences are a product of multiple factors including e.g. infrastructure, cultural background, etc. which were not taken into account in the current modelling exercise. Moreover, as weighing factors were obtained from the Estonian and Latvian surveys described in the previous section, these may not accurately reflect Finnish conditions. Nevertheless, these maps can be viewed as an important input when starting developing the recreation services’ sites in yet underdeveloped areas, i.e. areas indicated with high CSI values show a high potential for these services in terms of natural environment.

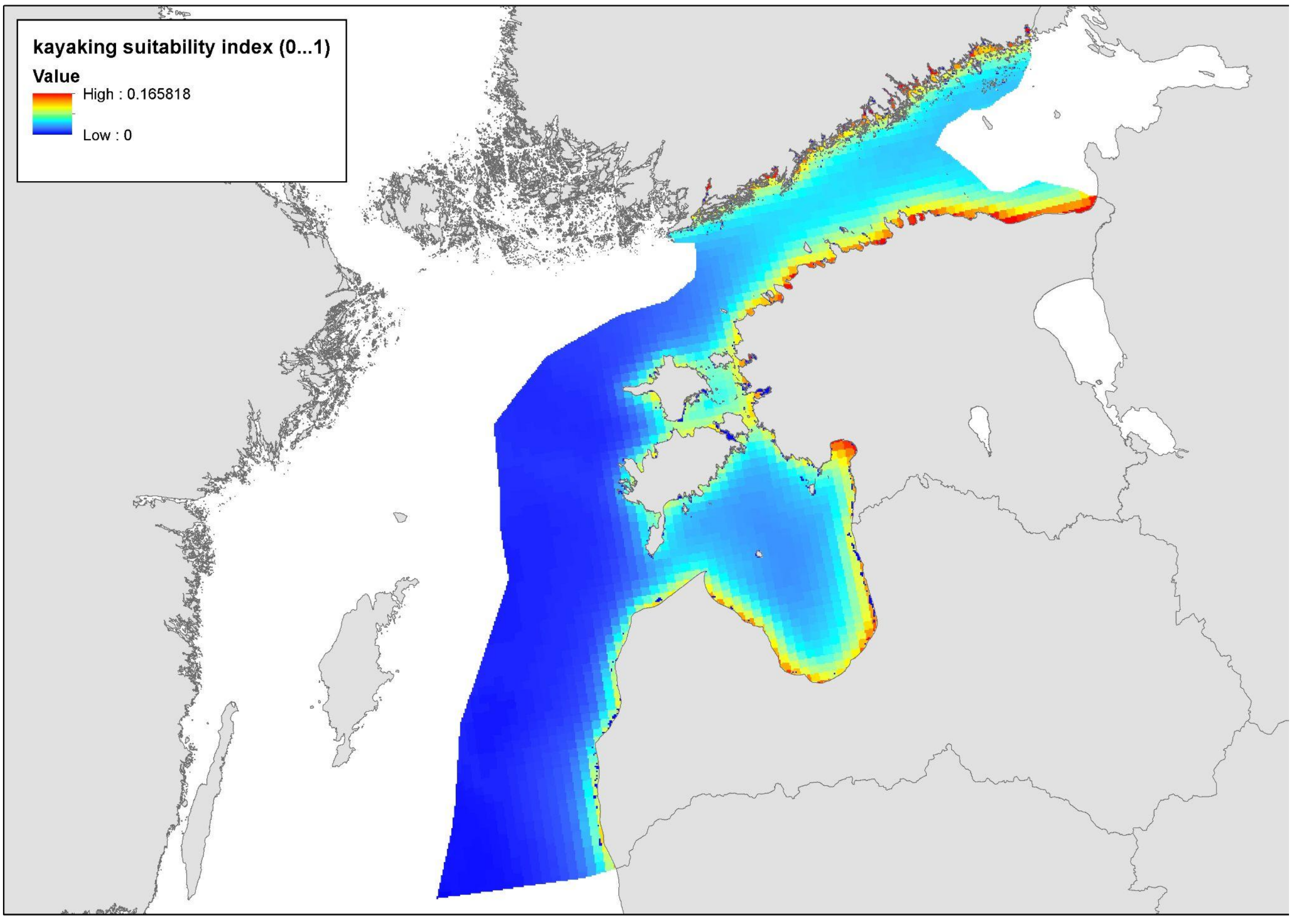
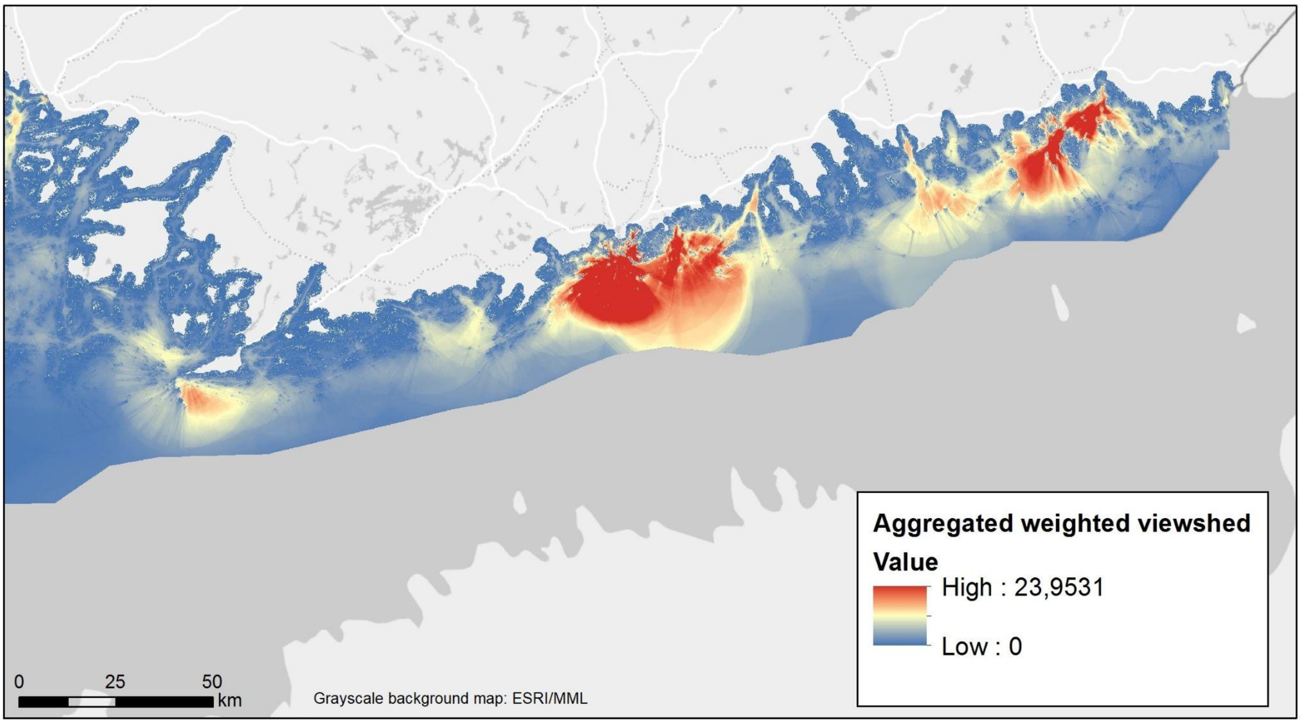


Figure 9. The predicted suitability of the MAREA study area for kayaking activity.

Identifying pristine landscapes

Studies have shown that people value nature highly as a destination for recreational visits and nature can have a beneficial impact on wellbeing (Ahtiainen et al. 2019, Russell et al. 2013). As the type of habitat and species people find aesthetically appealing is likely to vary, we approach this by identifying areas where human made structures are least visible. We used a viewshed approach that accounts for how many human made objects or activities such as boating one can see from a specific cell on the map and consider areas with low number of visible structures to imply more pristine conditions. Among the structures considered are buildings, bridges, harbours, piers etc. For further details on summation and weighting of layers see D.T.1.1.

According to the map (figure 10) most of the pristine areas are located further offshore, and areas with a high number of visible structures are located close to densely populated or industrial areas, such as the Helsinki metropolitan area. Comparing the pristine areas to the reported locations of summer cottages and summer houses along the Finnish coast of the Gulf of Finland shows that many of them are located with few human made structures in sight (fig. 10).



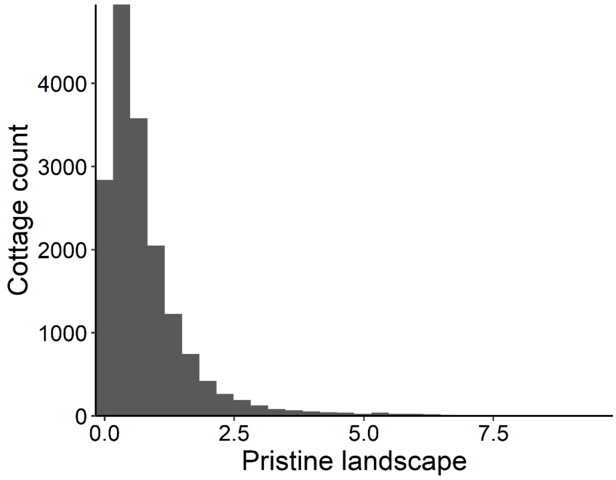


Figure 10. Map of landscape values with higher number of observed artificial structures in red (top). Number of cottages in relation to the number of observed artificial structures.

Using social media data for cultural service mapping

Background

Social media platforms enable their users to post information such as photos and videos with textual explanations and hashtags which are essentially keywords denominated with the # symbol. In social media posts the hashtags can be used to designate things or actions, such as #boat or #boating. This data contained in the posts can be downloaded by automated scripts accessing the platforms in a process called e.g. data mining, data scraping or web scraping. The data acquired can be analysed in several ways, from simple keyword analysis using the hashtags or text content to sentiment analysis of the text and visual analysis of the photo or video contents. If the data is georeferenced, it can be used to map things found in the posts. Thus, it is possible to estimate in which areas cultural ecosystem services are present and utilised by people. In recent years a growing amount of research has been done on cultural ecosystem services using these methods (Havinga et al. 2020).

Work was done in WP1 to investigate what the current situation of data mining on social media platforms is like, and to see whether it would be possible to produce a test case using social media data for cultural service mapping. It was found out that considering the legal framework of copyright, especially the status of national implementation of the DSM directive, and data privacy issues to ensure both user privacy and copyrights are key areas to consider.

To produce high-resolution maps on the intensity and extent of ecosystem services supply in the project's transnational pilot area one would need to define a smaller test-case area considering available social media data coverage and data sources used to verify it such as national park visitor data or mobile operator data, depending on their availability

Challenges

Access to data

Some social media platforms, especially those owned by Meta (Instagram, Facebook) prohibit automated access to their platform in their Terms of Reference, preventing the use of automated scripts, which is the most feasible way of data scraping. This prohibition is being actively enforced by blocking access of users who are thought to be behaving suspiciously, e.g. downloading large amounts of data or otherwise behaving in a pattern that is algorithmically determined to be non-typical for regular use of the platform.

Other platforms have varying access policies, e.g. researchers can apply for access to Twitter data, allowing data scraping through an API. The photo sharing platform Flickr as well has an API that can be used.

Despite the restrictions imposed by the Instagram ToR commercial actors such as Apify exist to provide access to Instagram data by using decentralised scraping which evades the blocking measures. Another existing possibility is so-called manual scraping where the target web pages are manually clicked open using a regular web browser, from which the content can then be saved to files for analysis. Compared to automated data scraping this manual work is very time consuming.

Copyright and user privacy issues

The Article 3 of the Directive on Copyright in the Digital Single Market (Directive (EU) 2019) allows "research organisations and cultural heritage institutions to carry out, for the purposes of scientific research, text and data mining of works or other subject matter to which they have lawful access". The directive was passed in 2019 and Member States had two years to nationally implement it into their legislation, but so far at least Finland is still lagging on the implementation schedule, meaning that data mining is not explicitly allowed yet. As both the users and the platform hold copyrights to the content, this makes the legal situation of data mining still unclear, until national implementation of the directive is completed.

The directive also states that Terms of Reference can't prohibit data mining for research purposes, so it remains to be seen how e.g. Instagram will allow research access in the future. On other platforms such as Twitter with their research API and Flickr, on which users can define the copyright details of their photos with precision, data scraping for research is already less problematic regarding copyright issues.

When performing data mining for research purposes user privacy is of utmost importance. This means that the methods of acquiring and storing data, and publishing research results must all address data privacy concerns. Recommendations on how to take these issues into account have been produced by e.g. Di Minin et al (2021).

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