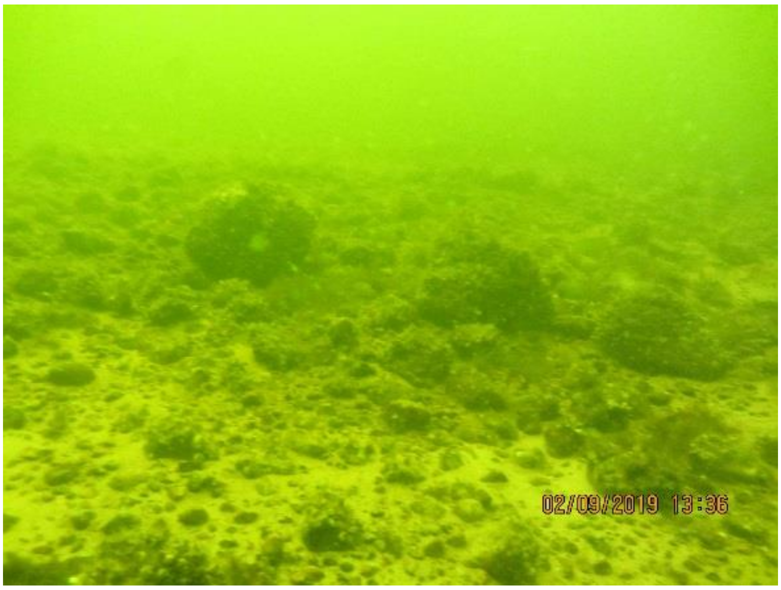
ADRIENNE

Report on Guidelines how to valuate biodiversity elements

Activity Output T1.1.2



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*Estonia-Russia Cross Border Cooperation Programme 2014-2020 aims to foster cross-border cooperation between the Republic of Estonia and the Russian Federation to promote socio-economic development in the regions on both sides of the common borders. The Programme web-site is www.estoniarussia.eu.

Contents

1. Introduction

The sea recognizes no political borders – decisions on economic development and resource use in one Baltic Sea country can affect all countries bordering this already highly-impacted marine region. Increasing maritime activities in the Gulf of Finland area and the uncoordinated use of coastal and marine areas have become problematic for the marine environment and maritime-based economies.

The current EU directives set forth the requirement for unified and transboundary actions in order to address common challenges in these marine environmental issues. Similarly, the trilateral cooperation between Russia, Estonia and Finland has revealed a clear need for a common management approach in the Gulf of Finland region. A fundamental component for the development of efficient policies and effective management actions is knowledge of the spatial distribution of biodiversity, ecosystem functions and related ecosystem services. The entire Gulf of Finland region lacks harmonized biodiversity information. Cross-border methods for mapping ecosystem structure, function and services is clearly fundamental to alleviating the adverse effects of human activities and to improving the status of marine environment. Healthy marine ecosystems and their multiple services, if integrated in planning decisions, can deliver substantial benefits in terms of food production, energy, urban planning, shipping, recreation and tourism, climate change mitigation and disaster prevention.

Adrienne Activity Output 1.2.1 “Report on the harmonizing methods of field sampling, sample analysis and spatial modelling” delivered harmonized methods to map and model various ecosystem indicators (species and habitats) which can be effectively implemented to assess the value of biodiversity in the Gulf of Finland. Here, maps of ecosystem elements provide the core data set to identify ecologically valuable areas, map ecosystem services and assess the spatial impact of sea uses. Transboundary co-operation actions were needed to harmonize mapping and modelling methods, including the exchange of maps of abiotic and biotic environments, joint identification of key habitat types, ecosystem functions and associated services. Synchronized data sets and common approaches to produce maps of ecosystem elements would lead to well-founded decisions in resource management and marine spatial planning (MSP) as well as to support transboundary co-ordination and impact assessment.

The benefits that the marine ecosystem provide to society are diversifying due to the increasing number of human uses in the sea space. In order to maintain richness in ecosystem benefits for future generations, there is a need to quantify the natural capital and evaluate its resilience to change. The concept of natural capital designates the potential and actual benefits that humans derive from ecological processes in the form of ecosystem services.

The current report provides generic guidelines on how to valuate biodiversity elements and thereby support international and local policy efforts to regulate the use of ecosystem services and assure their sustainability in the Gulf of Finland region. This is done by applying the existing concept on how biodiversity elements manifest within ecosystem functions and how ecosystem functioning links to the essential ecosystem services. We then exhibit how to identify and assemble relevant data on biodiversity, ecosystem functions and services in the Gulf of Finland region and offer feasible methods on how to obtain missing data e.g. through spatial modelling. Ultimately, some relationships between biodiversity indicators, associated ecosystem functions and services delivered by e.g. underwater habitats are explored in the Gulf of Finland region.

2. Mapping and modelling nature values in the Gulf of Finland

Modelling background

Describing marine ecosystems is challenging and ecosystem management is often confronted with data deficiency because data on marine nature values are available from a limited number of research sites that are sampled *in situ*. The lack of data lies in the fact that marine environment is difficult, time-consuming, and costly to access. Generally, marine sampling networks are sparse and leave most marine areas unsampled and with no information. Common seabed field sampling methods, such as grab samplers, trawls, scuba diving or underwater videos, provide only point-wise data on the marine nature values, yet spatially continuous seamless maps are needed for adequate management decisions. However, there are methods to alleviate the lack of spatially continuous data on marine nature values. Specifically, the use of remote sensing and mathematical modelling helps to fill information gaps between field sampling sites (Figure 2.1). Remote sensing enables data collection by employing optical or acoustic instruments on ships, airplanes, drones or satellites. Optical or acoustic signals from the seabed or water surface are recorded distantly, enabling more rapid coverage of larger areas than point-wise *in situ* sampling. Remote sensing provides georeferenced spatially continuous data layers of optical or acoustic properties of the marine environment. These properties of the seabed and/or water column can be converted into ecologically meaningful data. However, the conversion from optical or acoustic signal to ecological variables is possible only if on-site samples from the study area have also been collected. Common examples of remote sensing in marine environment include acoustic scanning of seabed using sonars to map seabed habitats and optical satellite imagery to estimate water surface temperature and chlorophyll content. Optical remote sensing (e.g. satellite imagery, aerial photography) can also be used to map seabed habitats and vegetation in shallow waters. In addition to remote sensing, hydrodynamic modelling can be used to produce spatially continuous layers of water parameters such as current speed, temperature, and salinity. Regardless of the origin of spatially continuous environmental variables, *in situ* ecological data are needed in order to produce spatially continuous ecological data layers using mathematical modelling. Models are used to formalize relationships between environmental predictor variables and biotic response variables. Based on these relationships, the model is then used to predict the distribution of the biotic variable (e.g. occurrence of a species) in areas where no biological samples have been collected (Figure 2.1). This kind of modelling approach is called species distribution modelling (SDM) and has gained popularity in tandem with the emergence of novel non-parametric and machine learning modelling methods, such as boosted regression trees (BRT), random forests (RF) and generalized additive models (GAM), which are superior in predictive accuracy than more traditional parametric methods, e.g. linear multiple regression (Elith et al 2006, Elith & Leathwick 2009).

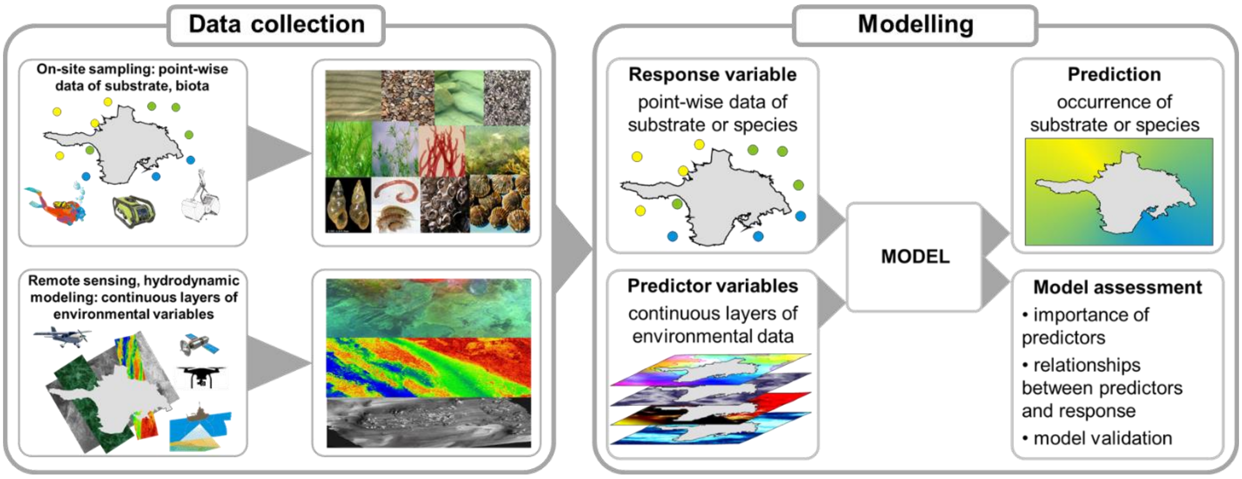


Figure 2.1. Principle of the combined use of *in situ* sampling, remote sensing, and modelling in mapping seabed biota and habitats.

Biotic data

The SDM approach was used in ADRIENNE in order to produce species distribution maps. The following sources were used to compile biological input data for modelling:

- Macrobenthos database of the Estonian Marine Institute, University of Tartu
- Dedicated biological fieldwork in the eastern Gulf of Finland during the ADRIENNE project
- Data from earlier studies in the Russian waters of the Gulf of Finland
- Finnish Inventory Programme for the Underwater Marine Environment (VELMU)
- Finnish macrozoobenthos database POHJE
- Data from earlier studies in the Latvian part of the Gulf of Riga and Baltic Proper (stored in the databases of the Estonian Marine Institute, University of Tartu)

The data sources provided both biomass and percentage cover (i.e. visual estimates). Sampling techniques included bottom grab samplers, diver-operated frame samples, and visual estimates by divers or from underwater video recordings. In order to generate presence-absence data of species, only relevant variables (coverage and/or biomass) and sampling techniques were selected. For example, for infaunal bivalves only biomass data from grab samplers could be used, not visual coverage from videos.

Biological input data were aggregated to 1 × 1 km grids to match the resolution of environmental predictor variables. The modelling grid included the full spatial extent of the Estonian marine waters, Finnish and Russian waters in the Gulf of Finland and Latvian waters near the border with Estonia (Figure 2.2). The full extent of the grid was the same as that of the simplified wave exposure model that was specially ordered for the purposes of the ADRIENNE project (see section Environmental variables). Although the ADRIENNE project focuses on the Gulf of Finland, a much larger spatial extent was used to select biological input data. This was needed in order to obtain more data points and to cover wider environmental gradients in the modelling input data, which in turn improved the models. The full modelling grid included 77 495 cells, 6 770 of which provided biotic data (Figure 2.2).

Macrobenthos data from all these sources were transformed to unified table structure and merged. In order to harmonize the names of species and higher taxa and maintain consistency with the most recent taxonomy, an online Google Sheets taxonomy table was established. The taxonomy table was populated with taxon names from all datasets and the AphiaID and an accepted Latin name from the World Register of Marine Species (http://www.marinespecies.org/) was manually added to each taxon. Operational names were also added in order to group some species when needed. The operational name was the lowest harmonized level of taxonomical nomenclature. The taxonomy table included nearly 800 different original names of taxa (incl. synonyms, sp, spp, juv, aggregations, spelling errors etc.) and over 400 operational names. The species and groups of species for distribution modelling were selected based on their occurrence rates and ecological relevance. A total of 57 species/groups were initially selected for distribution modelling. Three levels of groups were generated:

- Group 1 (n = 42): lowest level, mainly species or genus
  Amphibalanus improvisus, Ampullaceana balthica, Battersia arctica, Ceramium, Cerastoderma, Ceratophyllum demersum, charophytes, Chironomidae, Chorda filum, Cladophora glomerata, Cladophora rupestris, Coccotylus truncatus, Dictyosiphon foeniculaceus, Dreissena polymorpha, Fucus, Furcellaria lumbricalis, Gammarus, Halicryptus spinulosus, Hediste diversicolor, Hildenbrandia, Idotea, Jaera, Limecola balthica, Marenzelleria, Monoporeia affinis, Mya arenaria, Myriophyllum, Mytilus trossulus, Najas marina, Oligochaeta, Potamogeton perfoliatus, PylaiellaEctocarpus, Rhodomela confervoides, Ruppia, Saduria entomon, Stictyosiphon tortilis, Stuckenia, Theodoxus, Ulva, Vertebrata fucoides, Zannichellia, Zostera marina
- Group 2 (n = 14): class, life form, freshwater groups
  drifting macrophytes, epifaunal bivalves fresh, filamentous brown algae, filamentous green algae, filamentous red algae, hydrozoa, infaunal bivalves, infaunal bivalves fresh, other *Polychaeta*, snails, snails fresh, thick brown algae, thick red algae, vascular plants
- Group 3 (n = 1): filamentous algae

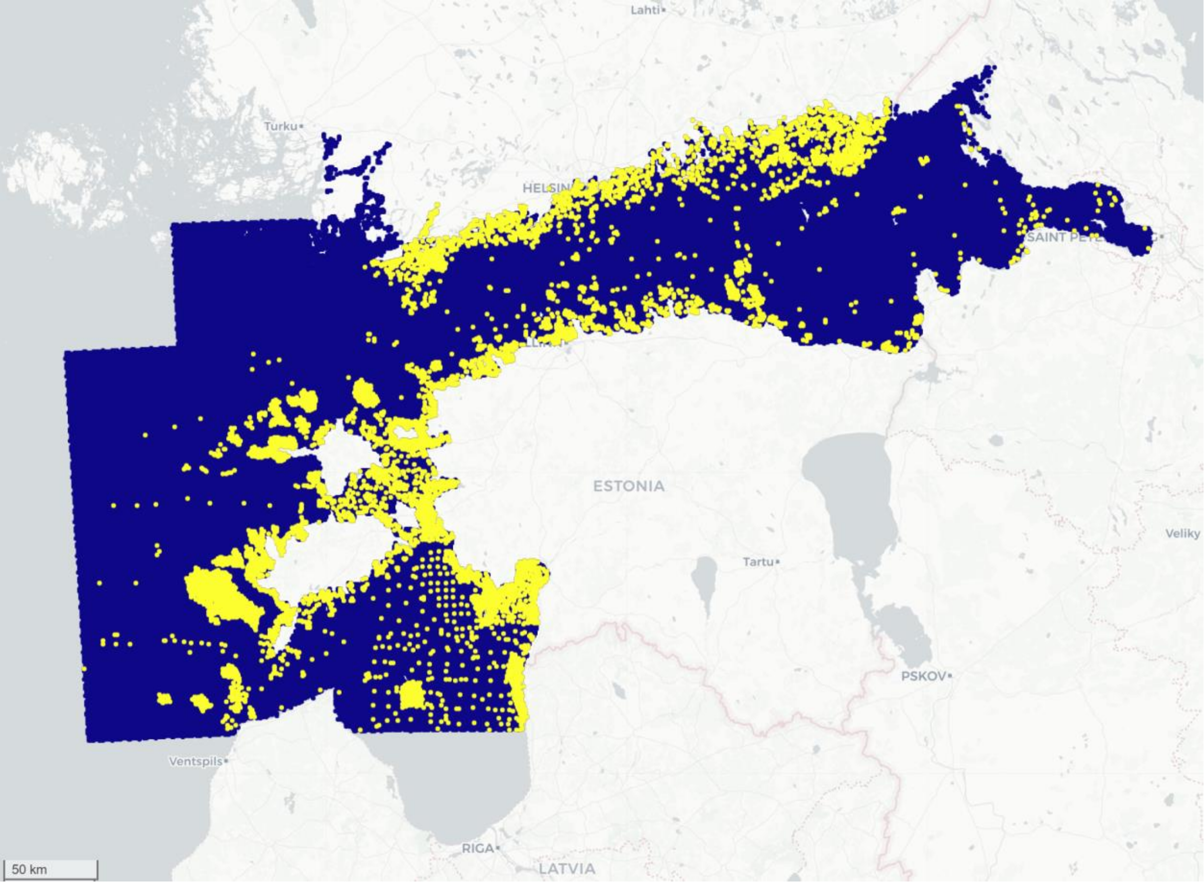


Figure 2.2. Modelling grid (blue) and locations of grid cells with available biotic data (yellow).

Environmental variables

Several key environmental variables including bathymetrical, hydrodynamic, and physico-chemical parameters were designated to be used as predictor variables in species distribution modelling. The data on environmental variables originated from the following sources:

- Baltic Sea Bathymetry Database (Baltic Sea Hydrographic Commission 2013)
- Copernicus Marine Services products: Baltic Sea Physics Reanalysis (https://resources.marine.copernicus.eu/product-detail/BALTICSEA_REANALYSIS_PHY_003_011/), Baltic Sea Biogeochemistry Reanalysis (https://resources.marine.copernicus.eu/product-detail/BALTICSEA_REANALYSIS_BIO_003_012), Baltic Sea Wave Hindcast (https://resources.marine.copernicus.eu/product-detail/BALTICSEA_REANALYSIS_WAV_003_015)
- Wave exposure calculations for the Gulf of Finland (van der Meijs and Isaeus 2020): specially ordered for the purposes of the ADRIENNE project

The final selection of variables used in modelling was as follows (units in brackets; see Figure 2.3 for overview maps):

- Water depth (m)
- Wave exposure based on simplified wave model (m^2 s^{-1}): simplified wave model is calculated based on mean wind speeds and directions and fetch lengths
- Salinity (PSU)
- Water temperature (°C)
- Secchi depth (a measure of water transparency) (m)
- Wave height (m)
- Concentration of nitrates (mmol m^{-3})
- Concentration of phosphates (mmol m^{-3})
- Concentration of chlorophyll a (mg m^{-3})
- Proportion of ice cover (0…1)

The environmental variables were selected based on previous knowledge on the potential relationships with the distribution of the benthic species and data availability. It must be noted that high resolution depth data were not available for Finnish and Russian waters due to national restrictions and publicly available at lower resolution (800 m) depth data (Baltic Sea Bathymetry Database) had to be used. Given the resolution of depth data (800 m) and the original resolution of Copernicus data (4 km), 1 × 1 km grid was chosen to be used as the modelling grid. Copernicus data were interpolated to 1 km grid using inverse distance weighting method.

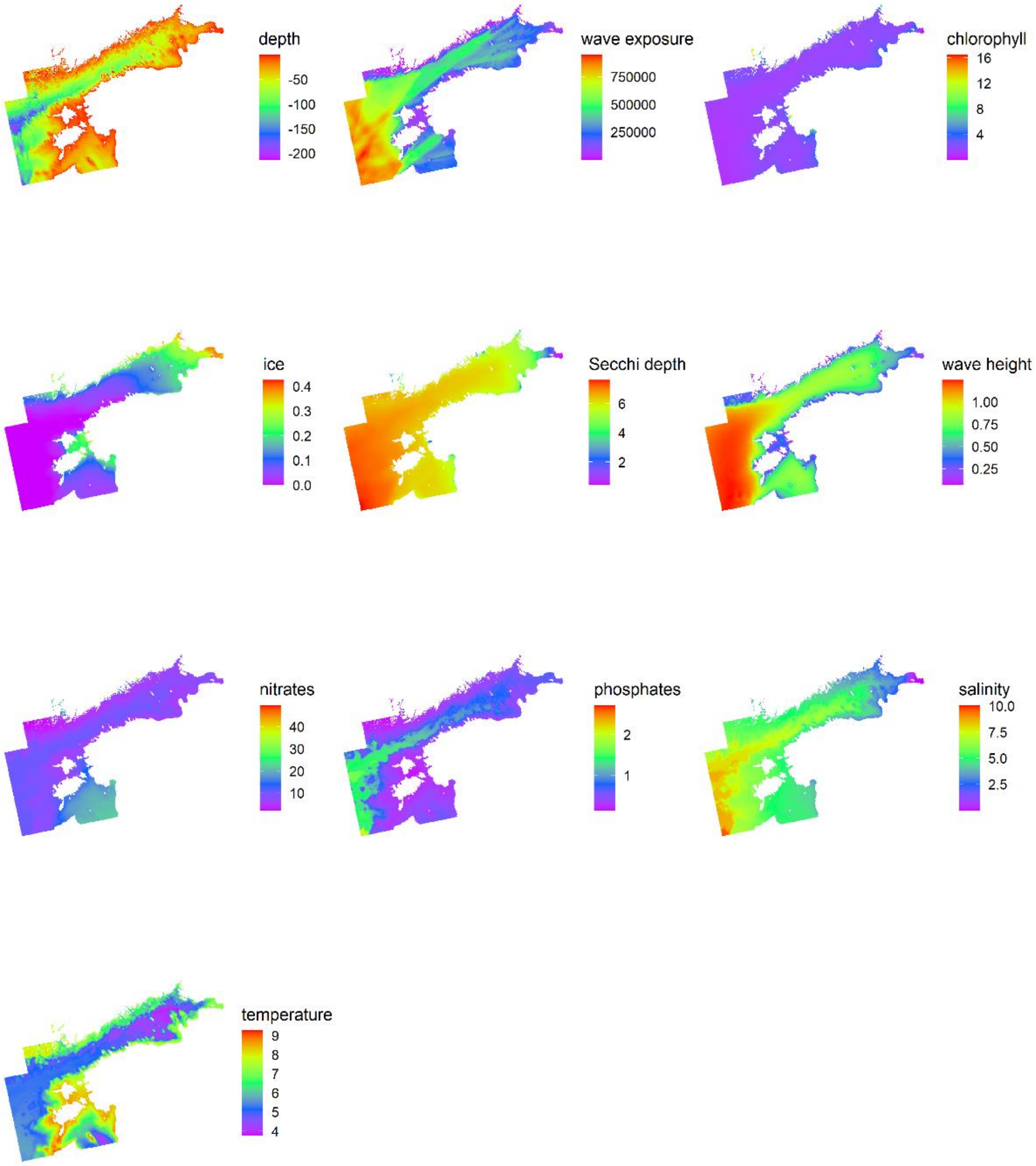


Figure 2.3. Schematic overview maps of environmental variables

Data management and modelling

The central platform of data management, analysis, and modelling was the open source programming language R (R Core Team 2021; Figure 2.4). Macrobenthos database of the Estonian Marine Institute, University of Tartu was based on Microsoft Access database. Finnish, Russian, and Latvian data was received in Microsoft Excel format. Copernicus data were downloaded in NetCDF format and read into R and then processed to generate GeoTIFF raster layers. Shared online Google Sheets in the Google Drive platform was used to facilitate the compilation of the taxonomy table. Species distribution modelling was done in R and the predicted layers exported to GeoTIFF raster files. ArcGIS (ESRI 2020) geographical information system software was used to review and explore spatial data and to produce map layouts (Figure 2.4).

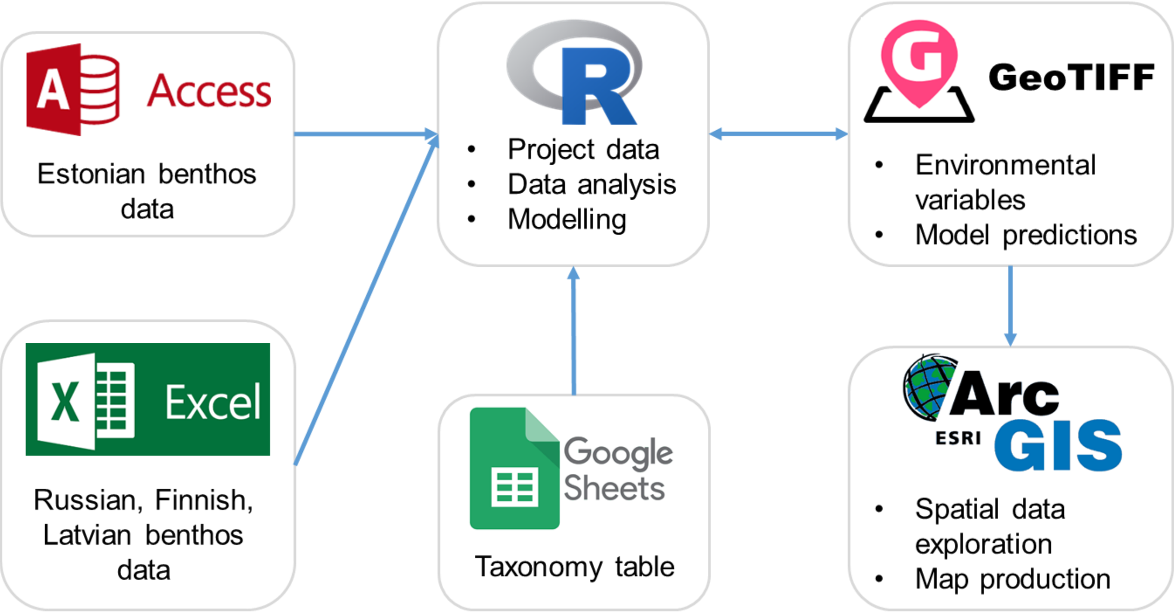


Figure 2.4. General data flow, software platforms, and data formats used in the mapping and modelling tasks in ADRIENNE.

Boosted regression trees (BRT) (Elith et al. 2008) and Shape-constrained additive modelling (SCAM) (Pya & Wood, 2015) were used to fit models and to predict the spatial distribution of the selected species/groups. BRT is an ensemble method that combines the strength of two algorithms: regression trees and boosting (Elith et al. 2008). Regression trees are effective at selecting relevant predictor variables and can model interactions. Boosting enables building of a large number of trees in a way that each successive tree adds small modifications in parts of the model space to fit the data better (Friedman et al. 2000). The algorithm continues to trees until it finds the optimal number of trees that minimizes the predictive deviance of a model. The predictive performance of BRT has been shown to be superior to most other modelling methods (Elith et al. 2006; Revermann et al. 2012). Monotonicity (direction of relationship: increasing, decreasing, arbitrary) was set for each species-environmental variable relationship based on previous knowledge and/or partial dependence plots. Setting monotonicity for known relationships helps to improve prediction accuracy. Like BRT, SCAM allows for the defining of specific monotonic relationships, based on theoretical knowledge or experimental evidence.

3. CICES: a common classification of ecosystem services

Conceptual background

Marine ecosystem services (MES) are generally defined as the direct and indirect contributions of marine ecosystems to human well-being. This definition alone, however, does little to explain the complex task of evaluating and quantifying the value of MES. This task has been a dynamic process, having seen progressive advancement since its onset. This project employs the Common International Classification of Ecosystem Services (CICES) as the basis for classifying MES. The use of CICES has important advantages: firstly, CICES provides a standardized platform, allowing comparison in and among MES; secondly, CICES is recognized internationally, which conforms well to the international nature of this project. Consideration of the direct or indirect nature of MES is crucial to assessing MES (De Groot et al., 2010, Böhnke-Henrichs et al., 2013), and is relevant to maritime spatial planning (MSP), ecosystem-based management (EBM) and decision-making by which the implications of different management measures are evaluated.

A widely-used earlier version of CICES (V.4.3), whose development began in 2009 and was published in 2013 (Potschin & Haines-Young, 2016a), has since been superseded by CICES V5.1 (Haines-Young & Potschin, 2018). SEM under the CICES framework classifies the contributions that ecosystems make to human well-being in three main categories: 1) provisioning includes all nutritional, non-nutritional material and energetic outputs as well as abiotic outputs, 2) regulation and maintenance encompasses those ways in which living organisms can affect the ambient environment with respect to human health, safety or comfort, and 3) the cultural category includes ecosystem output (both biotic and abiotic) that affects the physical and mental states of people. The cascade model (Figure 3.1) provides the conceptual framework in CICES that determine MES.

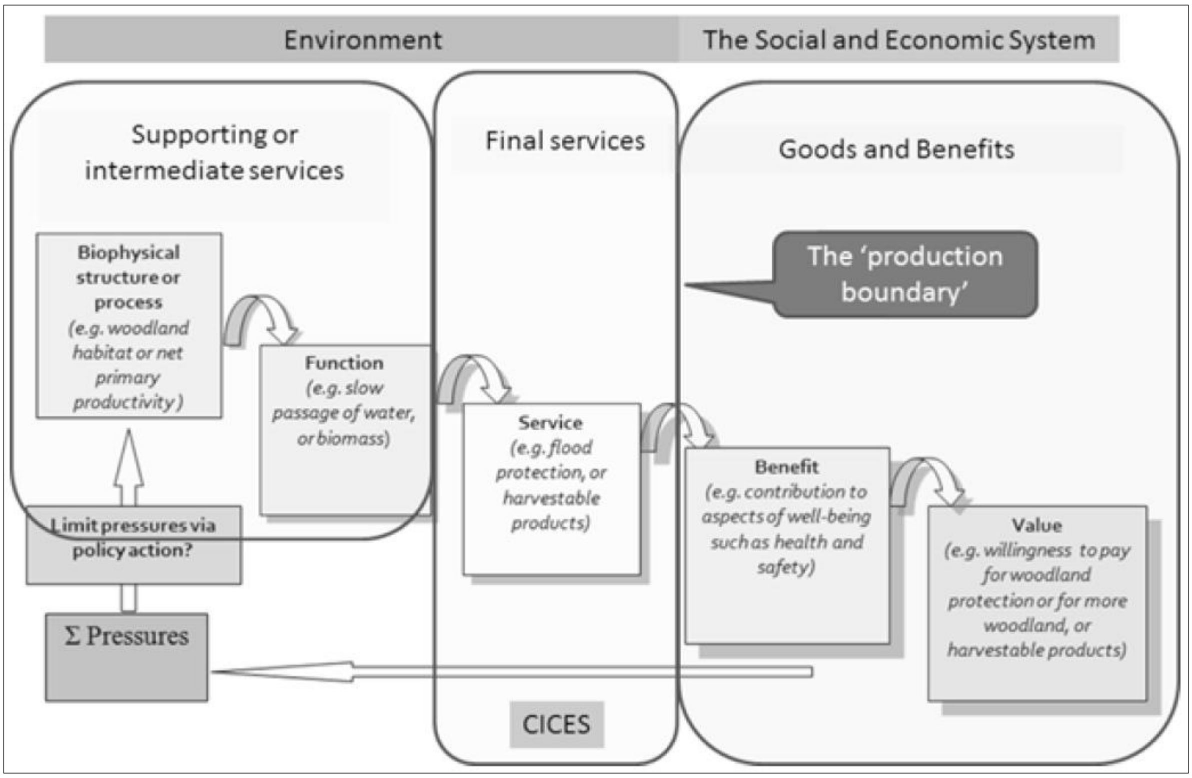


Figure 3.1. The cascade model (Potschin & Haines-Young, 2016b)

CICES V5.1 defines MES as the *contributions* ecosystems make to human well-being, which is distinct from the goods and benefits subsequently delivered to people (Haines-Young & Potschin, 2018). These contributions reflect the idea of 'what ecosystems do' for society. In other words, the new version makes distinct both the purpose or use that society has for of ecosystem service *and* the particular ecosystem attributes that support them. This distinction can be regarded as the "use clause" and the "ecological clause", respectively, of which a concrete example is provided in Section 4 (Filtering potential of suspension-feeding mussels).

Identification and mapping of MES

Ecosystem services exhibit a link between ecosystems economic and social benefits. As such, an assessment of ecosystem service supply is a crucial step in identification and mapping of ecosystem services. Ecosystems are characterised by their biophysical structure and ecological processes. The ecosystem features (structure and functions) which dictate the ability of ecosystems to deliver ecosystem services are 'supporting' or 'intermediate' services. So-called 'final' ecosystem services are those that manifest as direct benefits to society. However, limitations of data and knowledge hinder mapping and assessing ecosystem service supply.

The recently-developed concept of marine green infrastructure (GI) to establish a spatial network of ecologically valuable areas that are important to maintaining health and resilience, biodiversity conservation and the delivery of ecosystem services. GI encompasses both the identification of valuable ecological areas and the potential supply of ecosystem services (Fig. 3.2; Ruskule et al., 2019).

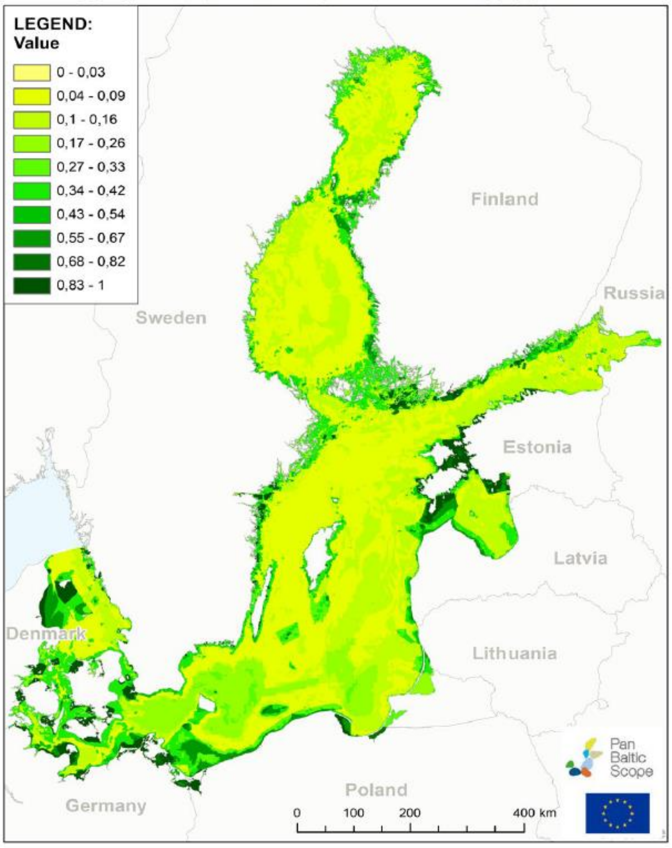


Figure 3.2. An aggregated map of the ecosystem service supply potential in the Baltic Sea (Ruskule et al., 2019). The map indicates the multi-functionality in relation to ecosystem service supply; higher values indicate areas with potential to deliver more ecosystem services.

4. From the modelled maps of nature values to ecosystem services

The Baltic Sea is a region of significant socio-economic importance in the northern hemisphere. A systematic review of the primary literature on ecosystem services in the Baltic Sea region revealed good quantitative information on the ecological foundation of ecosystem services although the associations between ecosystems and their MES are poorly understood (Heckwolf et al., 2020). A recent study on links between marine ecosystem components, functions and services in the Baltic Sea waters revealed high importance of some keystone species (e.g. mussels, annual and perennial algae) in ecosystem service supply and concludes that such highly valuable habitats occupy a relatively small area (Armoškaitė et al. 2020). It is thereby important to identify such valuable ecosystem components or structures and assess their role in maintaining marine ecosystem integrity and service supply (Ruskule et al., 2019).

Moreover, these maps of valuable habitats can be also used to quantify multiple processes and services these habitats are providing. In this section we provide some examples of how the participants of this project have implemented an international effort at establishing a geographic portrayal of different kinds of MES. These efforts integrate a variety of multi-source's inputs (e.g., spatial species inventories, spatial environmental measurements, experimental data), which are subsequently consolidated and analysed and modelled by methods outlined in Section 2. These examples represent a variety of MES application, such as measuring the current state of ecosystem health and mapping ecosystem suitability for particular species, which in turn can be used to establish the degree and extent of species distribution, including non-native species, the potential to improve ecosystem health by selective species introduction, possible locations for new environmentally-sustainable enterprise, and the sound continuation of existing enterprise.

Plankton communities

Quantitative phytoplankton and zooplankton samples are routinely collected in the Gulf of Finland region, which provides information on species abundances (Fig. 4.1). This data makes it possible to calculate different biodiversity indices to value phytoplankton and zooplankton, which in turn can be applied quantitatively to spatial models. Moreover, phytoplankton abundance also serves an indicator of eutrophication and toxic blooms, thereby providing insight on the state of ecosystem health. Importantly, zooplankton in the Gulf of Finland consists of many non-indigenous species (Fig. 4.2), which can be indicative of negative MES – so-called ecosystem disservices – that must be considered in tandem with beneficial services.

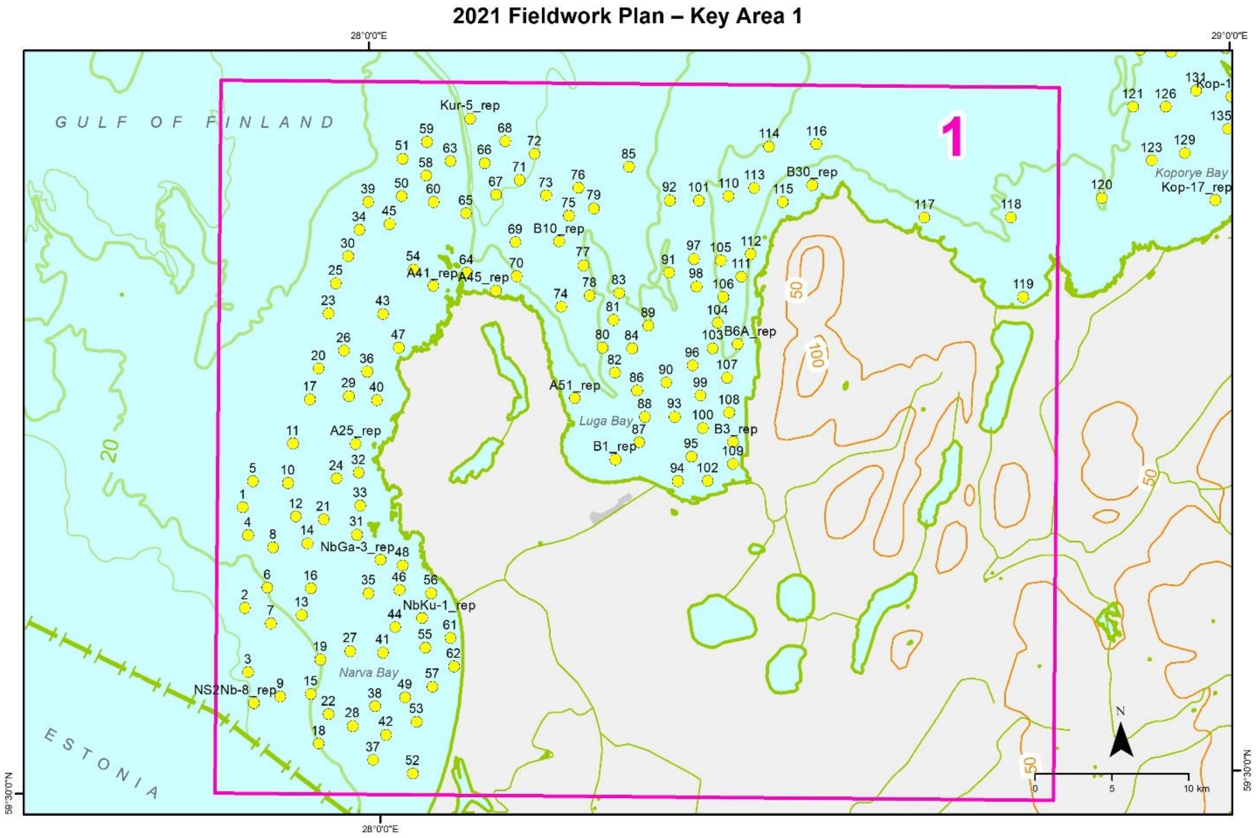
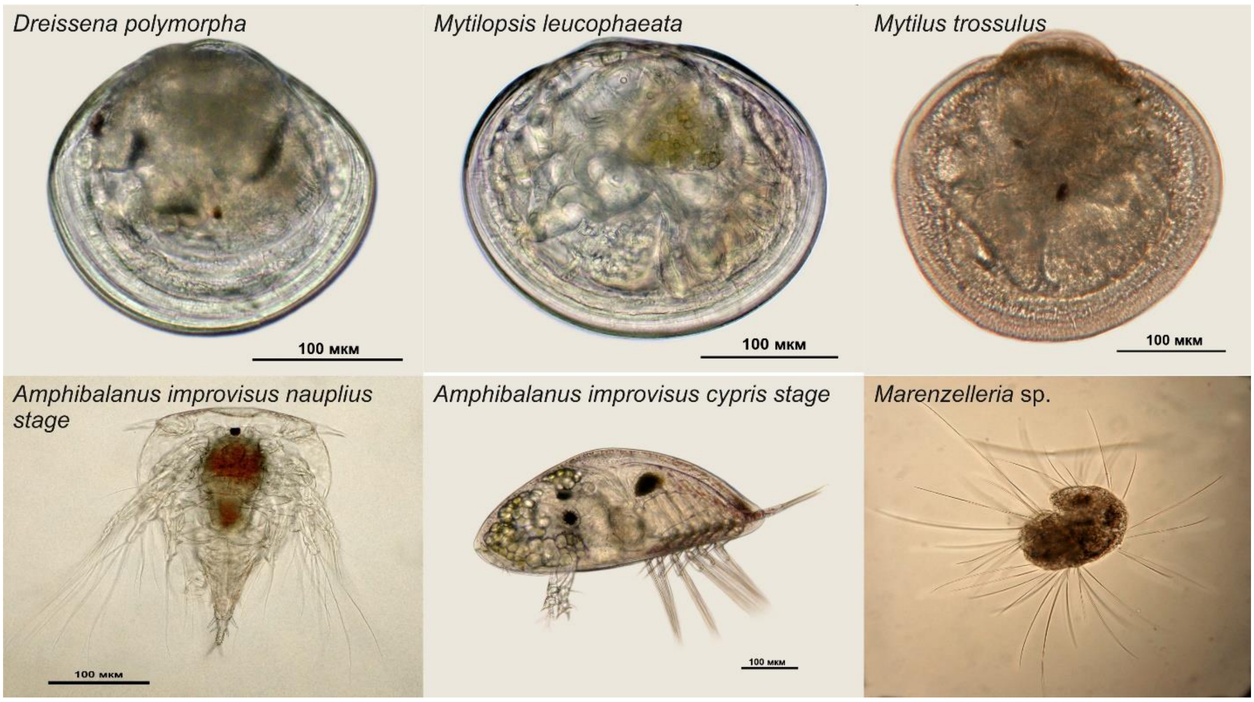


Figure 4.1. Sampling sites for benthos and plankton in the Russian part of the Gulf of Finland in 2021.


Dreissena polymorpha

Mytilopsis leucophaeata

Mytilus trossulus

Amphibalanus improvisus nauplius stage

Amphibalanus improvisus cypris stage

Marenzelleria sp.

Figure 4.2. Native and non-indigenous meroplankton in the eastern Gulf of Finland.

Filtering potential of the suspension-feeding mussels

The regional suspension-feeding mussels are brackish water or marine organisms that attach themselves to suitably hard substrata. As filter feeders, they rely on currents to supply them with food, which they filter from the water. This action causes the removal of potentially excess nutrients from the water column, thereby improving water quality. These mussels can also serve as a food supply for both humans and domesticated animals. Establishing mussel farms creates dual ecosystem services: a cleaner marine environment (ecological clause) and a useable harvestable product (use clause).

We used environmental data, experimental data and modelling methods described in section 2 to determine areas in the Gulf of Finland that are environmentally suitable to host natural populations and farms for two species, *Mytilus trossulus* (Fig. 4.3) and *Dreissena polymorpha* (Fig. 4.4). Relevant environmental variables included water salinity, chlorophyll content, current velocity and temperature. Because *Mytilus* prefers higher salinity than *Dreissena*, the two species exhibit little spatial overlap, with *Dreissena* potential greatest in areas of low salinity.

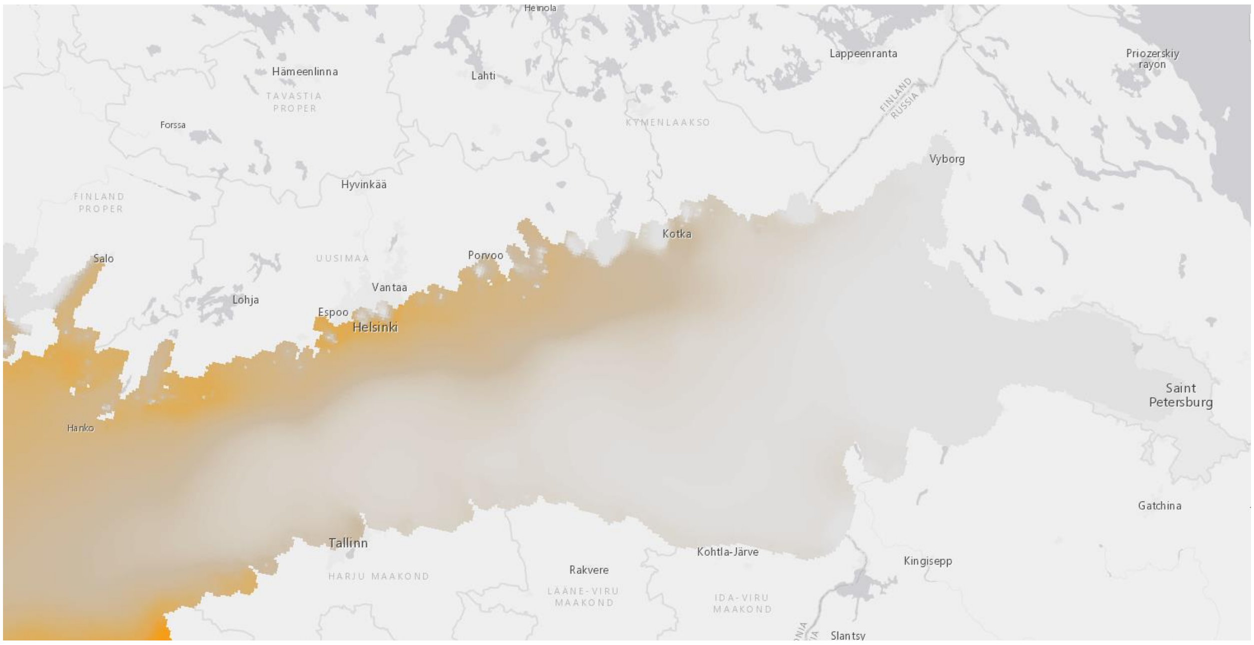


Figure 4.3. Spatial pattern of the filter-feeding potential of the native *Mytilus trossulus* in the Gulf of Finland area. Dark red areas indicate higher filtration potential.

Figure 4.4. Spatial pattern of the filter-feeding potential of the non-indigenous *Dreissena polymorpha* in the Gulf of Finland area. Dark red areas indicate higher filtration potential.

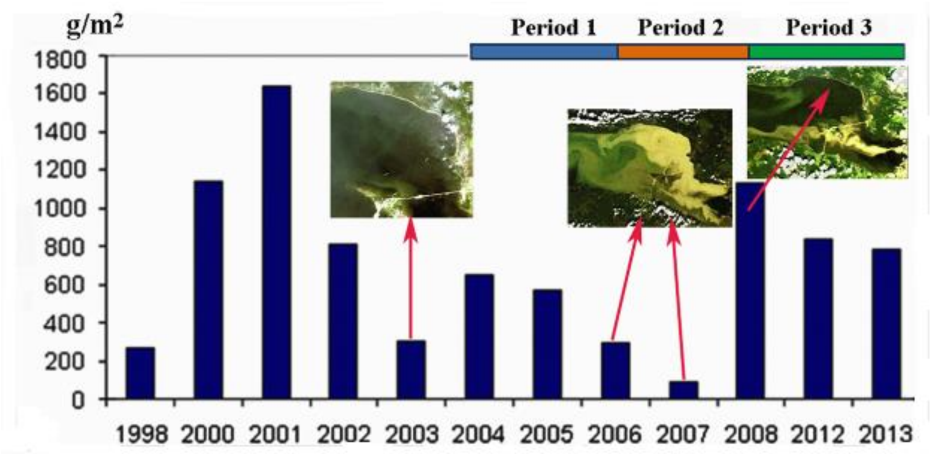


Figure 4.5. Remote sensing and quantitative (biomass) of *Dreissena polymorpha*.

Operation of hydraulic work leads to pollution of the water column by turbid sediments and causes variability of the biomass of *Dreissena polymorpha* for several years in the Kurortny district of St. Petersburg (Fig. 4.5). In 2003, there was a decline in the operation of hydrotechnical works; a noticeable decrease in the bottom population of *D. polymorpha* can be attributed to the impact of natural phenomena - upwelling and inflows, which coincided in time with the reproduction period of the relatively thermophilic and oxyphilic *D. polymorpha*. The population of *D. polymorpha* quickly attained its earlier values during periods of relatively clear water, when the trail of drifts, even during work, passes from the side of the settlement.

Photosynthetic production of macrophytes

Marcophytes, also macroalgae or edible seaweed, are in terms of ecosystem services similar to suspension-feeding mussels in that they exhibit both “ecological clause” and “use clause” services. In addition to providing a terrestrial food source, macrophytes enhance ecosystems by sequestering CO_2 and by protecting shores from erosion. We used environmental data, experimental data and modelling methods described in section 2 to determine areas in the Gulf of Finland that are environmentally suitable to host farms for macrophytes, an example being the edible seaweed *Ulva intestinalis* (Fig. 4.6). Environmental variables in the models included water salinity, temperature, nutrient content (nitrate and phosphate), radiance and wave height. Temperature and salinity tended to dictate spatial suitability the most, although environmental variables were often species-specific.

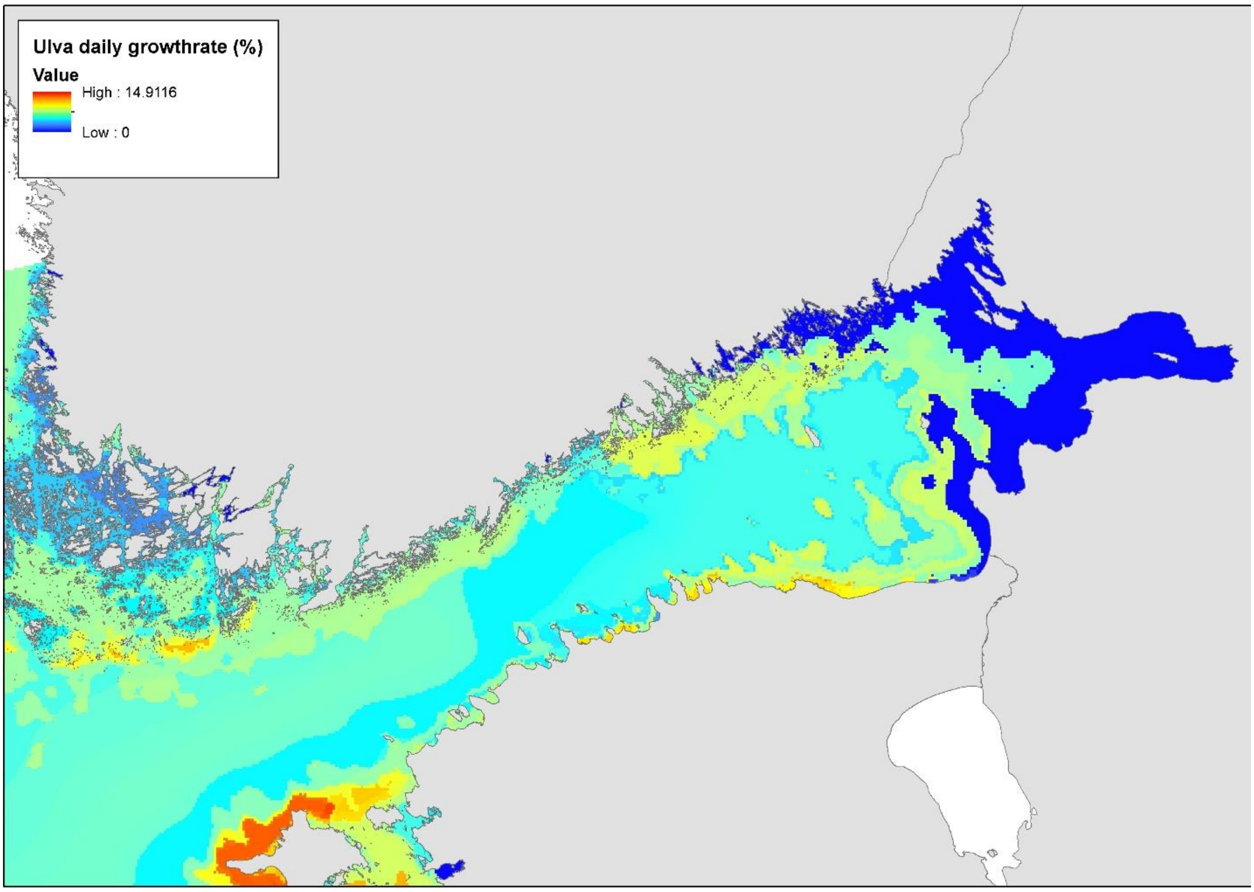


Figure 4.6. Spatial pattern of the growth rate (daily increment, %) of *Ulva intestinalis* in the Gulf of Finland area.

The case of large-scale trawl fishery: Estonian example

Internationally-regulated fisheries in the Baltic Sea are managed under the EU’s Common Fisheries Policy (CFP) by using the Total Allowable Catches (TACs) and including the input from Regional Baltic Sea Fisheries Forum (BALTFISH) and the Baltic Sea Advisory Council (BSAC).

As a first step, the fishing mortalities and spawning stock sizes are evaluated by International Council for the Exploration of the Sea (ICES) against maximum sustainable yield (MSY) and precautionary approach

(PA) reference points. The Baltic Sea ecoregion (highlighted in yellow) and ICES subdivisions are presented in Figure 4.7.

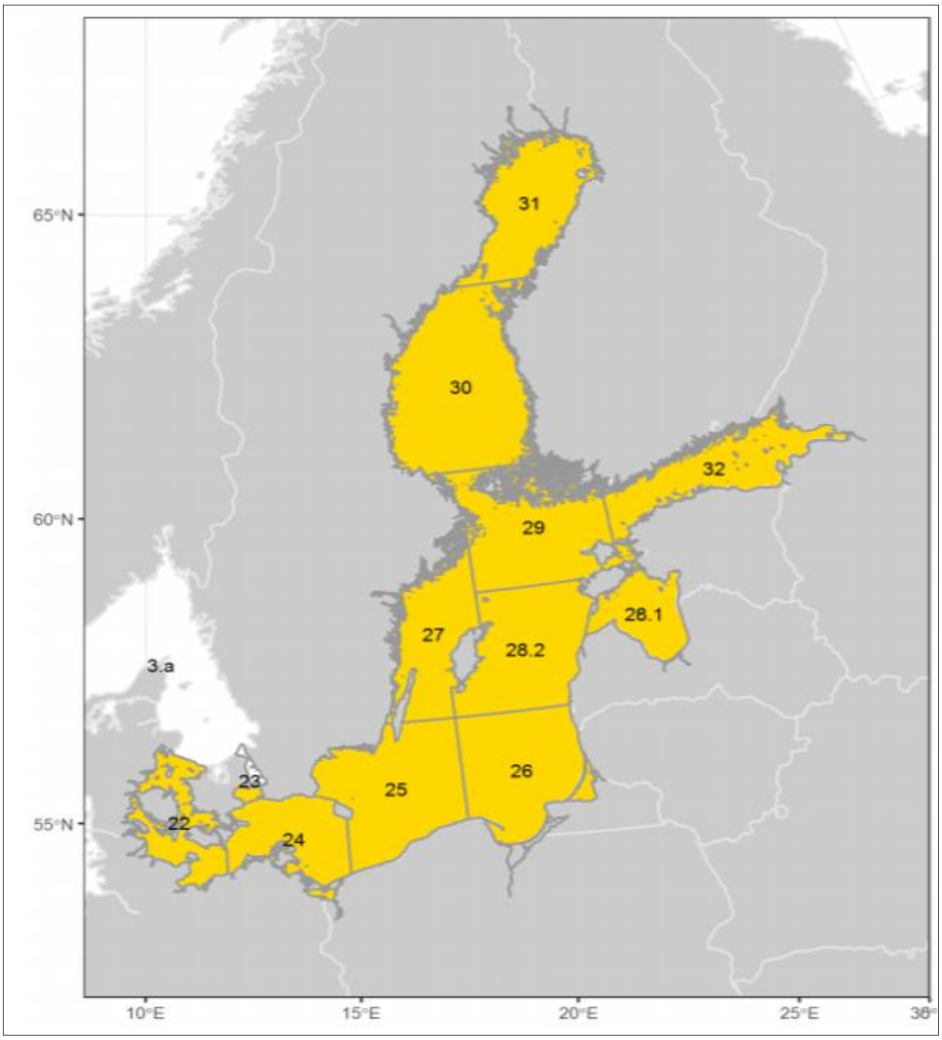
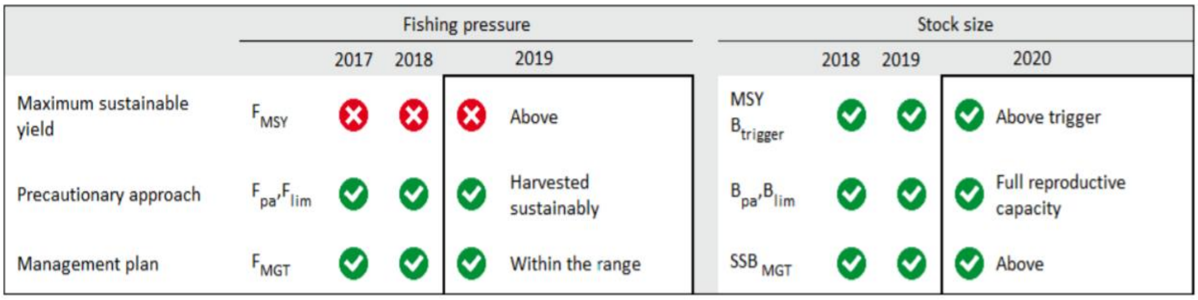


Figure 4.7. The Baltic Sea ecoregion (highlighted in yellow) and ICES subdivisions (Source: https://www.ices.dk/sites/pub/Publication%20Reports/Advice/2020/2020/FisheriesOverviews_BalticSea_2020.pdf

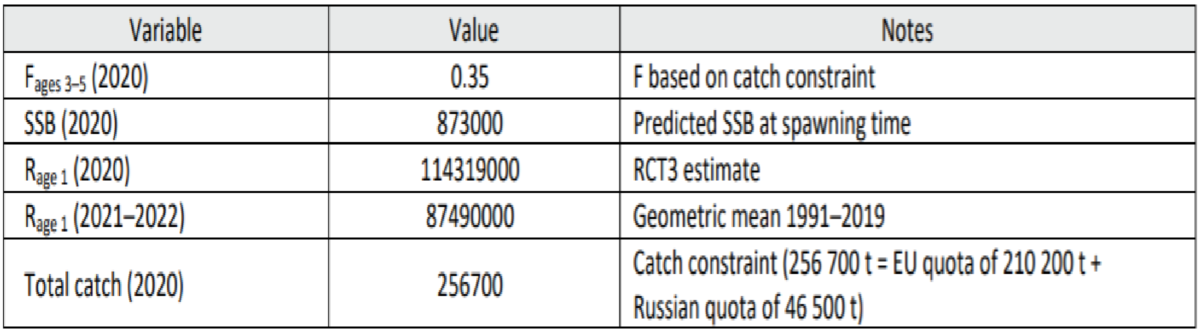
As an example, the state of the fish stock and the fishery relative to reference points of Baltic sprat ICES Subdivisions 22–32 is presented in Figure 4.8.



	Fishing pressure					Stock size				
		2017	2018	2019			2018	2019	2020	
Maximum sustainable yield	F_{MSY}	✗	✗	✗	Above	MSY $B_{trigger}$	✓	✓	✓	Above trigger
Precautionary approach	F_{pa},F_{lim}	✓	✓	✓	Harvested sustainably	B_{pa},B_{lim}	✓	✓	✓	Full reproductive capacity
Management plan	F_{MGT}	✓	✓	✓	Within the range	SSB $_{MGT}$	✓	✓	✓	Above

Figure 4.8. Baltic sprat in ICES Subdivision 22-32 (Source: https://www.ices.dk/sites/pub/Publication%20Reports/Advice/2020/2020/spr.27.22-32.pdf)

ICES assesses that fishing pressure on the stock is above FMSY, below Fpa, and below Flim, and spawning-stock size is above MSY Btrigger, Bpa, and Blim. in 2020 in ICES subdivisions 22–32 the spawning stock biomass (SSB) of Baltic sprat was 873 000 tonnes, and final ecosystem service, total catch 256 700 tonnes as presented in Figure 4.9.



Variable	Value	Notes
$F_{\text{ages 3–5}}$ (2020)	0.35	F based on catch constraint
SSB (2020)	873000	Predicted SSB at spawning time
$R_{\text{age 1}}$ (2020)	114319000	RCT3 estimate
$R_{\text{age 1}}$ (2021–2022)	87490000	Geometric mean 1991–2019
Total catch (2020)	256700	Catch constraint (256 700 t = EU quota of 210 200 t + Russian quota of 46 500 t)

Figure 4.9. Baltic sprat in ICES Subdivisions 22-32. (Source: https://www.ices.dk/sites/pub/Publication%20Reports/Advice/2020/2020/spr.27.22-32.pdf)

Fishing in Estonia takes place throughout its territorial waters, except in areas with statutory fishing restrictions. Areas that are more heavily used for fishing are well-established and, to a large extent, are preserved by the combined use of the marine area. The catches of the Estonian Baltic Sea large-scale trawling fleet consists mostly of herring and sprat, which are subject to quotas agreed at EU level and allocated as individual fishing rights to companies based on their 3-year historical fishing rights. This kind of management ensures that companies themselves maintain optimal capacity for utilization of their fishing opportunities.

The Estonian Baltic Sea large-scale trawl fleet operates outside the coastal zone using pelagic trawls. The live weight landed by the large-scale fleet in 2018 was 56 500 tonnes of fish, with a landed value of EUR 9.2 million, thereby realizing a profit. Most of the fish landed by trawlers is owned by producer organisations in charge of the whole chain from catch to processing to exports, therefore their profits are generated at the export stage and not at the moment of landing.

As an example, the marine ecosystem service 'Sea Food' relevant indicators are: (1) the amount of fish landed, (2) capital investment required (gear, vessel, fuel etc.), and (3) return on investment (ROI). Return on investment is a simple ratio that divides the net profit (or loss) from an investment by its cost (https://www.forbes.com/advisor/investing/roi-return-on-investment). Because it is expressed as a percentage, the effectiveness or profitability of different investment choices can be compared.

In our case, ROI as a *balance capacity indicator* is calculated as: Net profit / (fleet depreciated replacement value + estimated value of fishing rights) where, Net profit = (Income from landings + other income + income from fishing rights) - (crew wage + unpaid labour + energy + repair + other variable costs + non variable costs + fishing rights costs + annual depreciation). Source: STECF 19-13 - Balance capacity - indicators table.xlsx (Version 1.3) https://stecf.jrc.ec.europa.eu/reports/balance/-/asset_publisher/3rBi/document/id/2635863?inheritRedirect=false

As an example, the value of ROI as a *balance capacity indicator* for Estonian large-scale trawlers of length classes VL1824 (18-24 m) and VL2440 (24-40 m) clustered together was 15.3% in 2018.

The quantification of ecosystem services provision is an important step in the consideration of MES in EBM and MSP because it can provide an initial indication of the service importance in an area and because it constitutes an important reference point for the monetary value of MES that can be affected by planning and management. MES are inherently economic in nature as changes in the ecological delivery of the MESs affects the benefits (i.e., welfare) received by society.

5. Conclusions

The fate and fortune of the Baltic Sea are shared by all nations along its shores. As these nations continue to exploit the sea, so continues the responsibility of these nations to protect it. The efforts made by the participants of the Adrienne project as presented in this report show the systematic framework for this protection. Data from diverse sources is compiled and consolidated into a single consistent database. Mathematical modelling and remote sensing is used to extrapolate to areas where marine monitoring and sampling are too difficult or too costly to cover. Established knowledge and experimental data provide the means for ascertaining ecosystem response to environmental conditions and changes. Through state-of-the-art modelling these responses are mapped over the Gulf of Finland. Finally, potential future actions can be assessed against a quantifiable and standardized system of ecosystem services to assure the continued sustainable use of the Gulf of Finland. This framework is well-aimed at addressing the ongoing environmental challenges, but just as the Baltic Sea recognizes no border, so must Baltic scientists aim for trans-border cooperation and partnership.

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