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AQUACULTURE IN ESTONIAN MARINE WATERS BASIC DATA AND STUDIES

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Contents

Abstract

This analysis summarises the existing data and background knowledge about aquaculture (cultivation fish, mussels and macroalgae) in the Estonian marine waters. In addition, an overview of current research directions in aquaculture is presented. The paper also provides a synopsis on initial procedures that need to be followed in order to start new marine and freshwater fish and algal and mussel farms. This overview is expected to facilitate the first steps for those entering the sector and provide necessary guidance for individuals and companies interested in starting aquaculture business. The plausible future of aquaculture is also briefly discussed, in particular in the context of the forthcoming Agriculture and Fisheries Development Plan up to 2030.

Introduction

The EU Strategy for the Sustainable Development of European Aquaculture, adopted in 2002, sets out policy guidelines to promote the growth of aquaculture. This strategy enabled significant progress to be made in ensuring the environmental sustainability, safety and quality of EU aquaculture production (Communication from the Commission on a Strategy for the Sustainable Development of European Aquaculture, COM(2002) 511). Estonia has good preconditions (incl. fish stocks, water and land resources) for the production of fishery and aquaculture products. Companies operating in the fisheries sector have a long tradition, expertise and experience and they have begun to develop and introduce new processing equipment, employing state-of-the-art technological solutions as well as environmentally friendly farming technologies. At present, the Estonian aquaculture sector is mainly engaged in fish farming, while alternative directions that contribute to the restoration of the natural environment are essentially lacking. New environmentally friendly areas of aquaculture, such as mussel and algae farming, are emerging (Ministry of Agriculture, 2020). While fish farms situated in natural water bodies generally increase the nutrient load on the environment, algae and mussel farming as an area of aquaculture, which remove nutrients from the marine environment, is considered the flagship of the green economy in several EU directives (Kotta et al., 2020).

In 2019, Estonian aquaculture companies sold 1062 tonnes of commercial fish and crustaceans for a total of 3.7 million euros. The quantity of aquaculture production sold in 2019 was the largest in the last twenty-eight years (Statistics Estonia, 2020). According to the 'Agriculture and Fisheries Development Plan up to 2030' (Ministry of Rural Affairs, 2020), Estonia has good preconditions for the production of aquaculture products. The potential production capacity of Estonian aquaculture companies is estimated to exceed 4000 tonnes per year. The demand of EU consumers for fishery products is growing and, given that fishing and aquaculture represent an efficient way of producing animal protein, aquaculture is also a potential solution to the growing demand for animal protein. The sea areas that are potentially suitable for aquaculture and the needs for development of infrastructure were identified in a study conducted by the Estonian University of Life Sciences (2015). Over the last five years, however, the context has changed significantly (legislation, ongoing maritime spatial planning) and a lot of new knowledge has been accumulated about the cultivation of aquaculture species. In order for stakeholders to be better able to navigate in the field of aquaculture, a fresh overview is needed.

With a view to supporting the development of the aquaculture sector and enabling new businesses to enter the sector, this paper has a more general goal to summarise the data on the Estonian marine waters and the knowledge about marine aquaculture (fish, mussels and macroalgae) collected during various projects. In addition, an overview of current research directions in aquaculture is presented. As this paper covers the Estonian marine waters in their entirety, the aggregate analysis represents a generalisation, i.e. it does not address local/site-specific aspects. In addition, the paper provides an overview of the initial procedures that need to be followed to start new marine and freshwater fish and algal and mussel farms. This overview is expected to facilitate the first steps for those entering the sector and provide necessary guidance for individuals and companies interested in starting aquaculture business. The plausible future of aquaculture is also briefly discussed, in particular in the context of the forthcoming Agriculture and Fisheries Development Plan up to 2030.

1. General description of the marine environment

The Estonian marine waters are divided into three parts (in accordance with the Maritime Boundaries Act): the internal sea, the territorial sea and the exclusive economic zone.

The internal sea is the part of marine waters that lies between the baseline of the territorial sea and the shoreline. The baseline of the territorial sea is an imaginary line that connects the points on land, islands, islets, rock formations and single rocks above water level that are the furthest from the shoreline.

The territorial sea is the part of marine waters which is adjacent to the internal sea and the breadth of which is 12 nautical miles. The average water depth of the territorial sea is around 30 m.

The exclusive economic zone is the part of marine waters outside the territorial sea which is adjacent to the latter and the boundaries of which are determined by agreements between the Republic of Estonia and neighbouring countries. The average water depth of the exclusive economic zone is around 80 m.

The total area of the Estonian marine waters is approximately 36,500 km^2 (or almost 10% of the area of the Baltic Sea), of which the exclusive economic zone makes up almost one third, with an area of approximately 11,300 km^2. The length of the coastline of the Estonian marine waters (according to the main map, including islands and islets) is around 4015 km.

The marine waters under Estonian jurisdiction are located in the north-eastern part of the Baltic Sea and consist of parts of several larger basins of the Baltic Sea that are quite different in terms of natural conditions and anthropogenic pressures: the Gulf of Finland, the Baltic main basin near Estonia's western islands, and the Gulf of Riga, including the Väinameri Sea in the region of the West Estonian archipelago. According to the Water Act, coastal waters are divided into 16 coastal water bodies, which are classified into 6 types of coastal water according to certain natural properties (Regulation No. 44 of the Minister of the Environment) (Ministry of the Environment, 2019).

The latest general description of the environment of the Estonian marine waters in the context of various human uses, including aquaculture, is provided in the document "Eesti mereala planeering. Mõjude hindamise aruande eelnõu" (Estonian Maritime Spatial Plan. Draft Impact Assessment Report) compiled by the Ministry of Finance and Hendrikson&KO (Ministry of Finance, Hendrikson & KO, 2020b). *Below we describe the current values and long-term averages of the key environmental indicators of the Estonian marine waters relevant to the aquaculture sector. We have compiled generalised materials (maps and diagrams) that illustrate the spatial and temporal variability of these environmental indicators.*

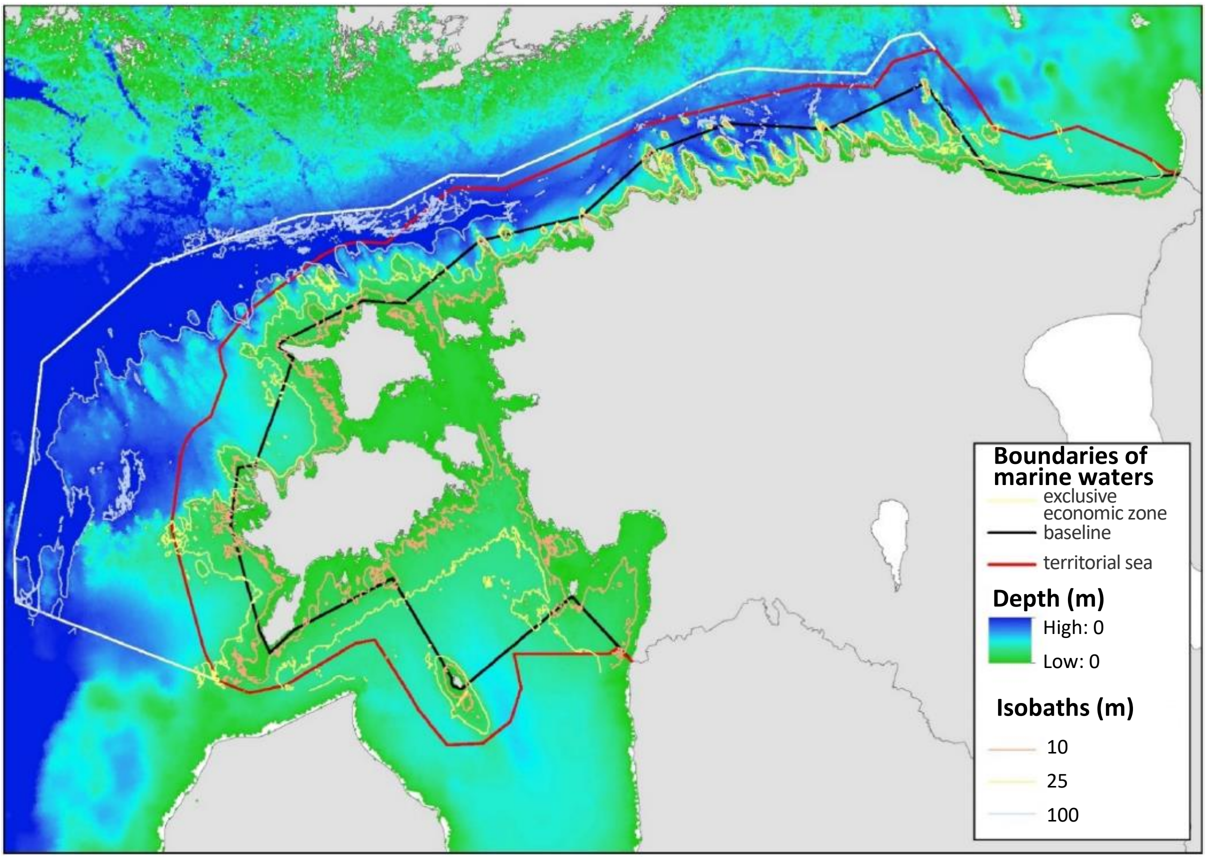


Figure 1.1. Estonian marine waters and depth (m) thereof. Depth data were provided by the Estonian Maritime Administration.

The **temperature and salinity** of the water largely determine the characteristics of the ecosystem in the given region – the boundaries of the range of species, including the distribution potential of aquaculture species and the relative abundance of different species in their habitats. The salinity of the Estonian marine waters varies significantly between different regions. In the Baltic main basin, salinity can reach 10 g/kg, while the salinity of water in the arms of smaller bays is essentially negligible. However, the temporal variability of salinity in a particular region of the sea is relatively small, generally no more than a few salinity units. Water temperature values in the Estonian coastal sea are usually highest at the end of July and in August. In calm and sunny weather, shallow coastal water warms rapidly and in some places water temperatures can reach 25 degrees, but as the wind strengthens, coastal water mixes with cool offshore water or is completely replaced by offshore water. In autumn, when the sea loses heat to the atmosphere, the situation is reversed: calm and cool weather cools the coastal water faster, but over time, currents carry warmer water back to the coast. In the coldest month, coastal water temperatures are generally below 5 degrees.

The Baltic Sea is characterised by a phenomenon that is extremely important for aquaculture. Namely, the water of the Baltic main basin is stratified, with both seasonal (temperature-related) and permanent (due to the density i.e. salinity of seawater) stratification occurring there. Seasonal stratification occurs during the summer period, when the surface water layer of some 10-20 m warms to as much as 20-25 degrees. However, beneath this layer, the water is still close to 4-5 degrees. This stratification of seawater lasts for a few months and the layers are broken apart during autumn storms. By contrast, the stratification caused by different salinity levels of water masses is permanent. This is reflected in changes in the levels of several physico-chemical parameters of water at a depth of approximately 50-60 m. In particular, the salinity (and therefore the density) of seawater rises sharply at this depth. The decrease in **oxygen concentration** associated with this change in salinity is of particular relevance to aquaculture and has an ecological significance, as well. The oxygen concentration in the near-bottom water layer is one of the indicators of the overall 'health' of the Baltic Sea. There are regions in Estonian marine waters where the oxygen concentration of the near-bottom water layer fluctuates quite a lot, as well as regions where it remains low for an extended period of time. In general, oxygen concentrations in the seawater below the halocline are extremely low, and in exceptional cases the environment may be even oxygen deficient. Vertical oxygen and salinity measurements performed in the course of the Estonian national marine monitoring conducted in July 2019 showed that at that time the halocline was at a depth of > 50 m, and a sharp decrease in oxygen concentrations also occurred at that depth. Therefore, it should be taken into account that aquaculture cannot be planned at a depth of more than 50 m in the Baltic main basin. When planning aquaculture, one should also consider the possibility of upwelling, i.e. the rise of deep seawater layers towards the sea surface due to certain hydrological and climatic conditions. This may result in a temporary sharp drop in the oxygen concentration of the surface water layers.

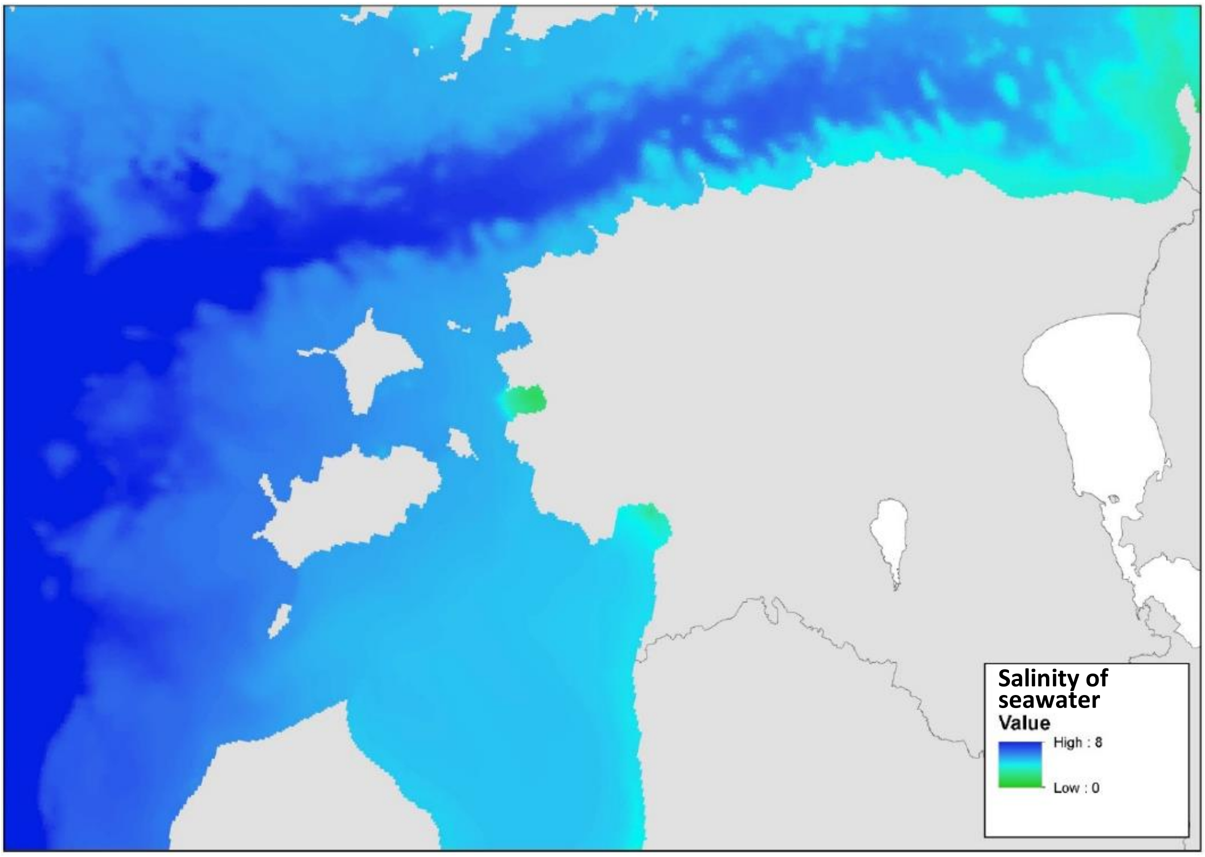


Figure 1.2. Average salinity of surface water layers in Estonian marine waters. The basic salinity data are from the Copernicus portal (BALTICSEA_ANALYSIS_FORECAST_PHY_003_006).

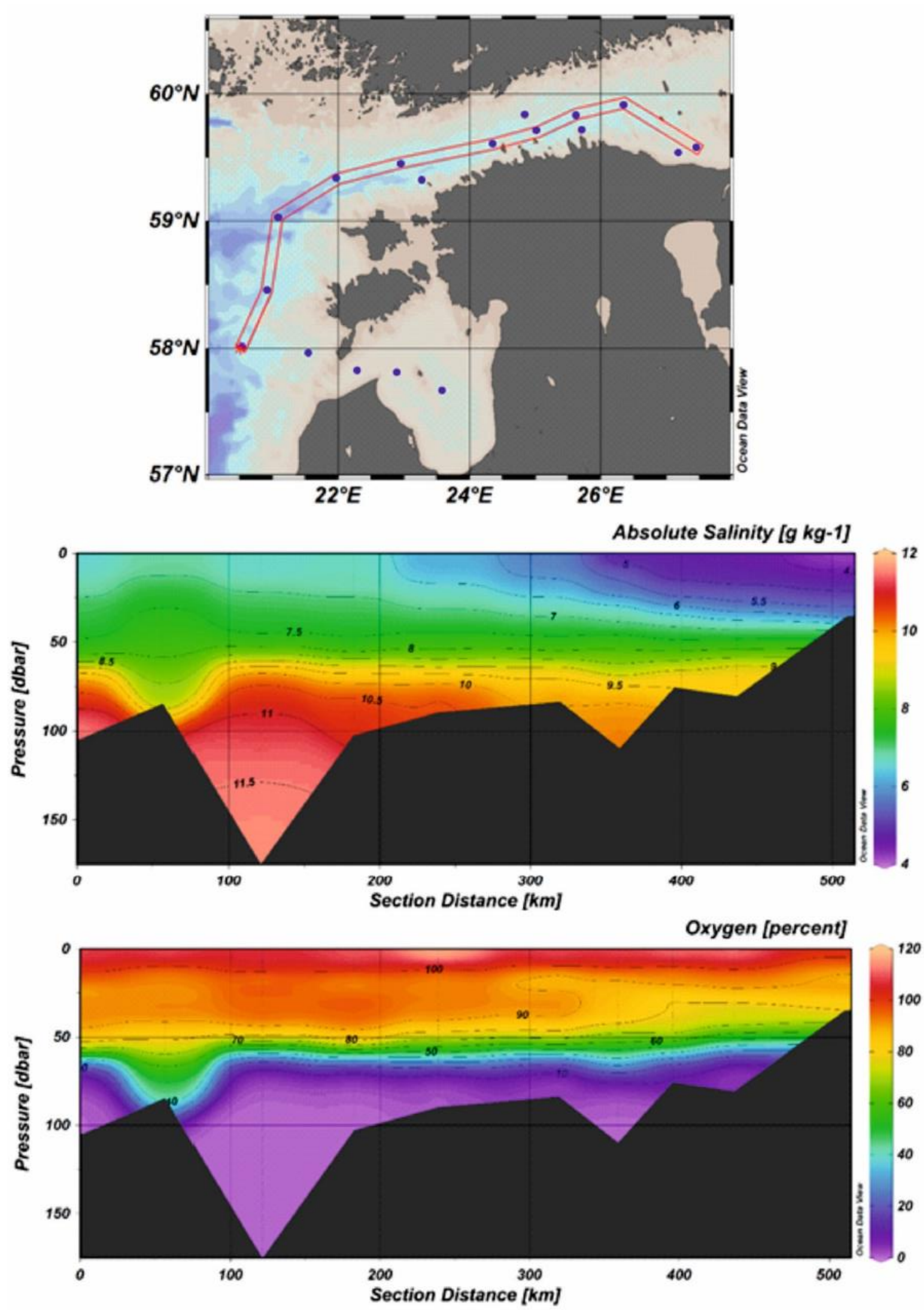


Figure 1.3. Distribution of salinity (g kg^{-1}; middle panel) and oxygen concentration (%; bottom panel) in the section from the East Gotland Basin to Narva Bay based on the data of the Estonian national marine monitoring conducted in July 2019. The location of the section is shown on the map in the top panel (Estonian Marine Institute of the University of Tartu, Department of Marine Systems of Tallinn University of Technology, 2020).

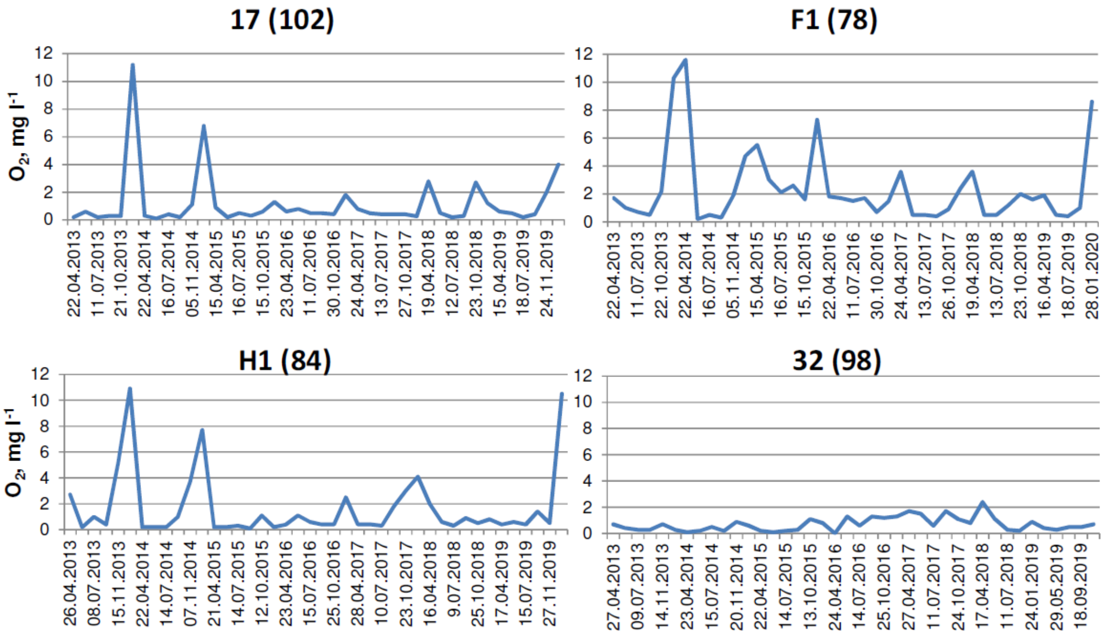


Figure 1.4. Dynamics of oxygen concentrations in near-bottom water layers (O_2, mg l^{-1}) in different offshore monitoring stations, 2013-2020. The average sampling depths in metres are presented in brackets (University of Tartu, Tallinn University of Technology, 2020).

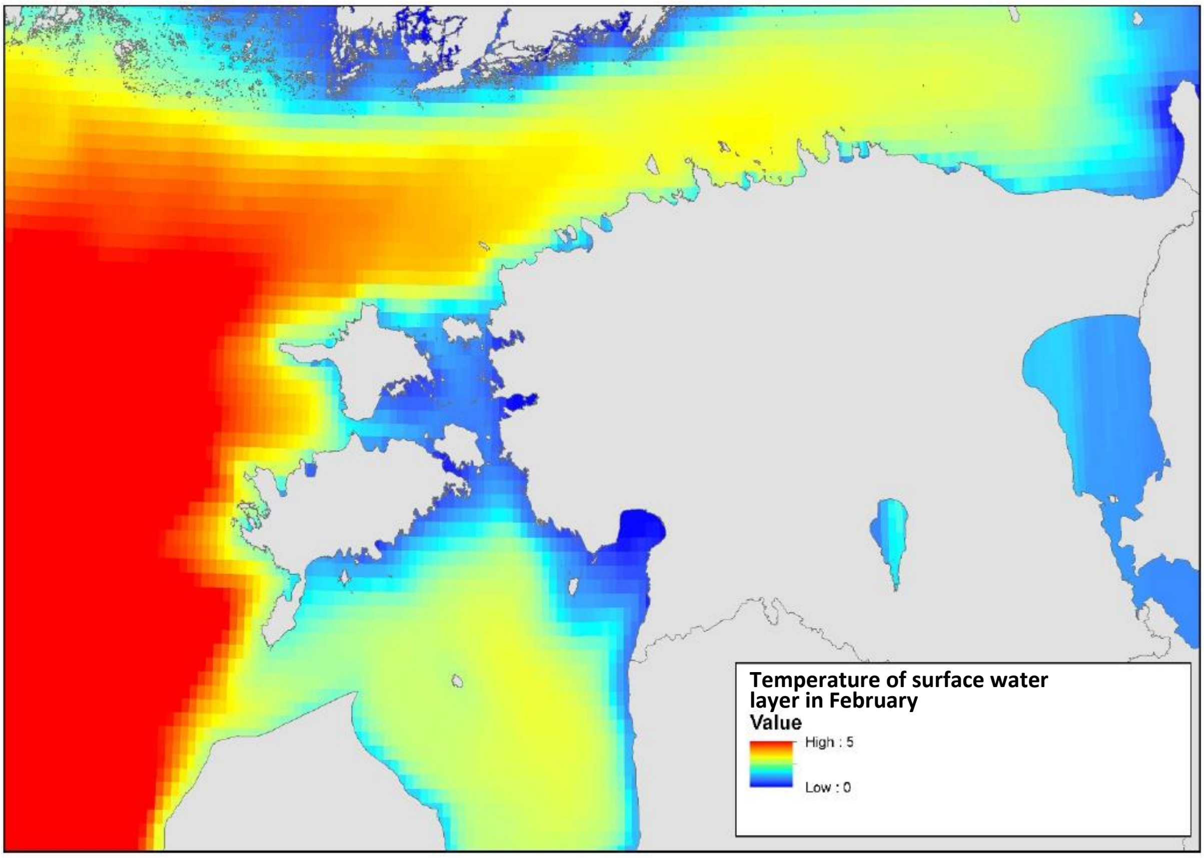


Figure 1.5. Average surface water temperature in Estonian marine waters in February. The basic temperature data are from the Copernicus portal (BALTICSEA_ANALYSIS_FORECAST_PHY_003_006).

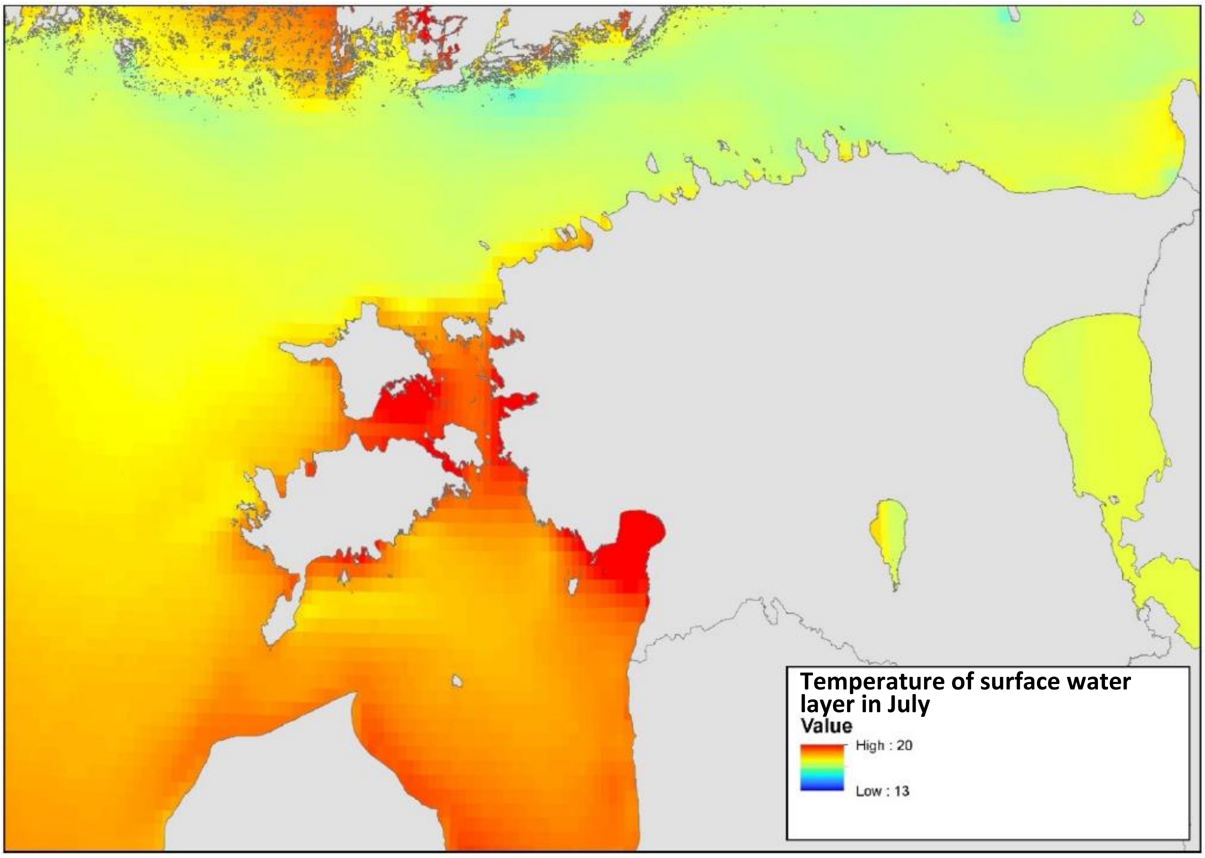


Figure 1.6. Average surface water temperature in Estonian marine waters in July. The basic temperature data are from the Copernicus portal (BALTICSEA_ANALYSIS_FORECAST_PHY_003_006).

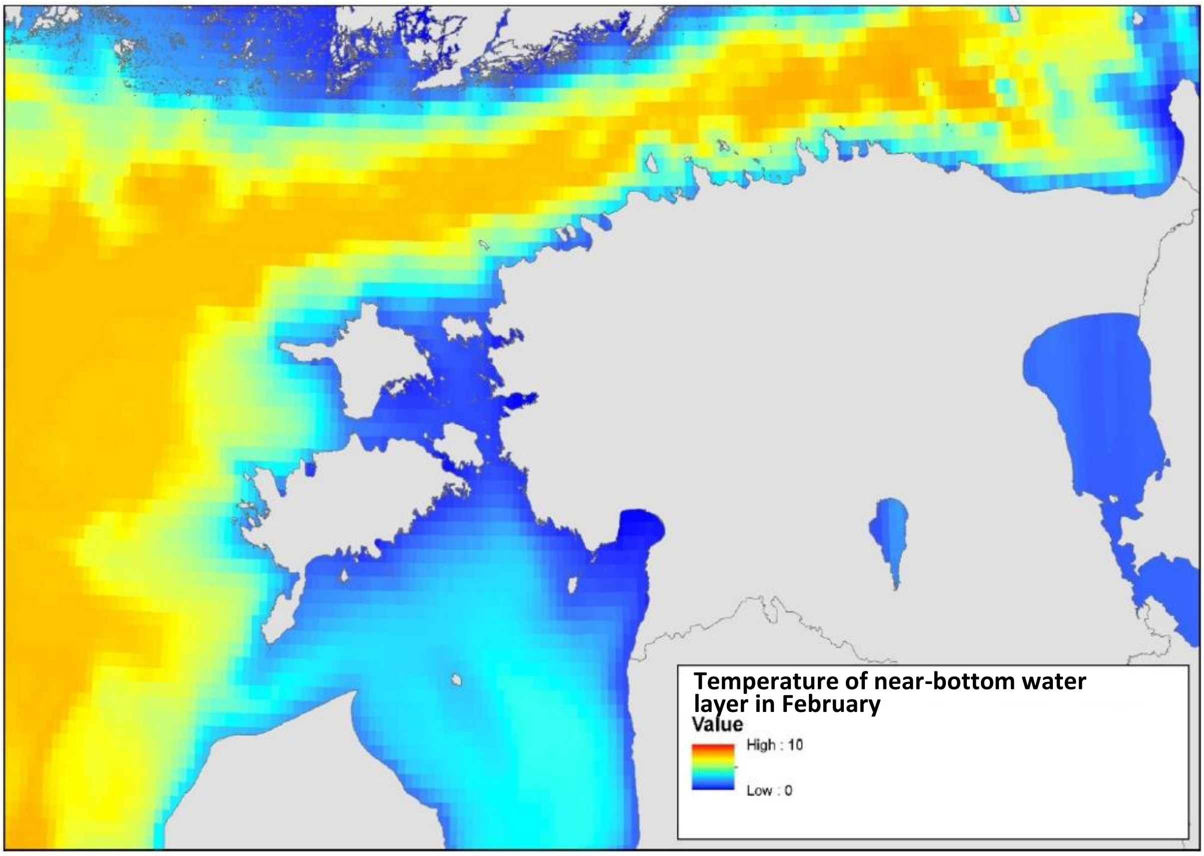


Figure 1.7. Average near-bottom water temperature in Estonian marine waters in February. The basic temperature data are from the Copernicus portal (BALTICSEA_ANALYSIS_FORECAST_PHY_003_006).

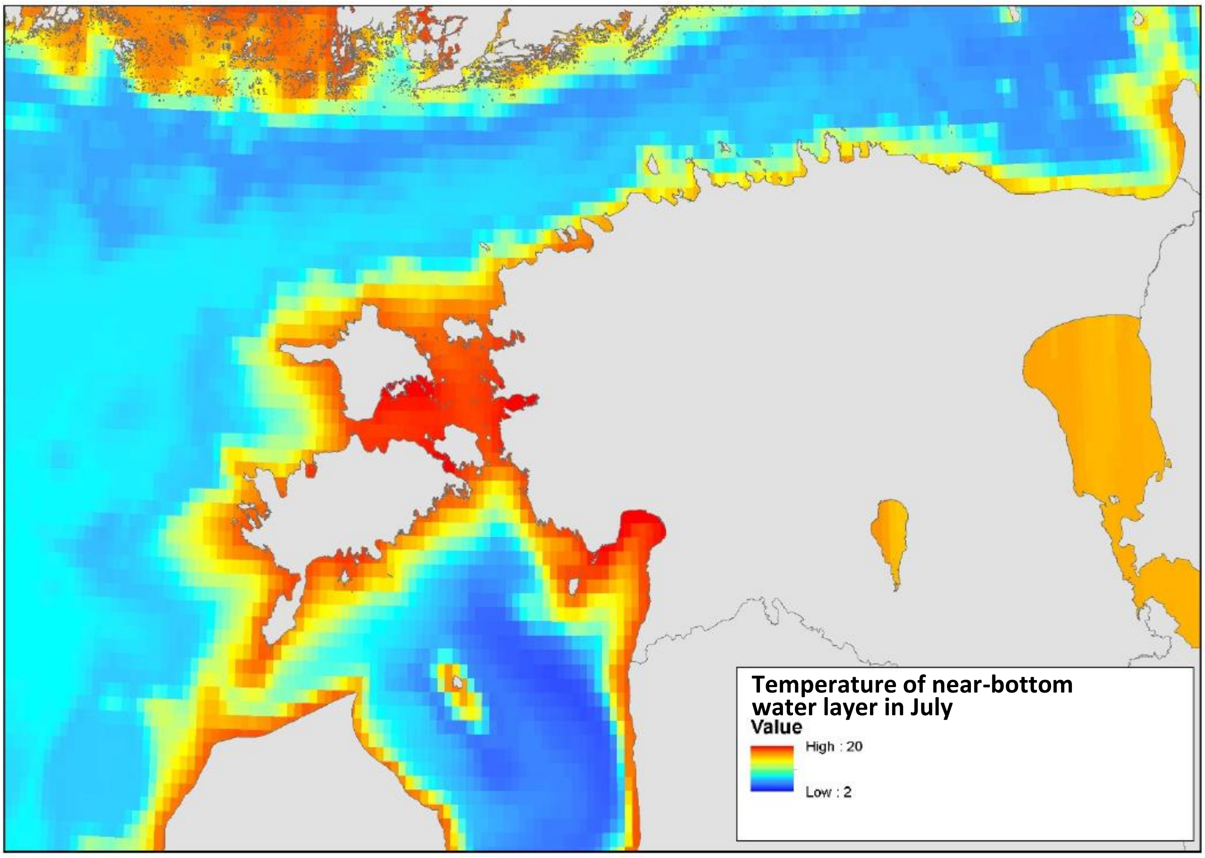


Figure 1.8. Average near-bottom water temperature in Estonian marine waters in July. The basic temperature data are from the Copernicus portal (BALTICSEA_ANALYSIS_FORECAST_PHY_003_006).

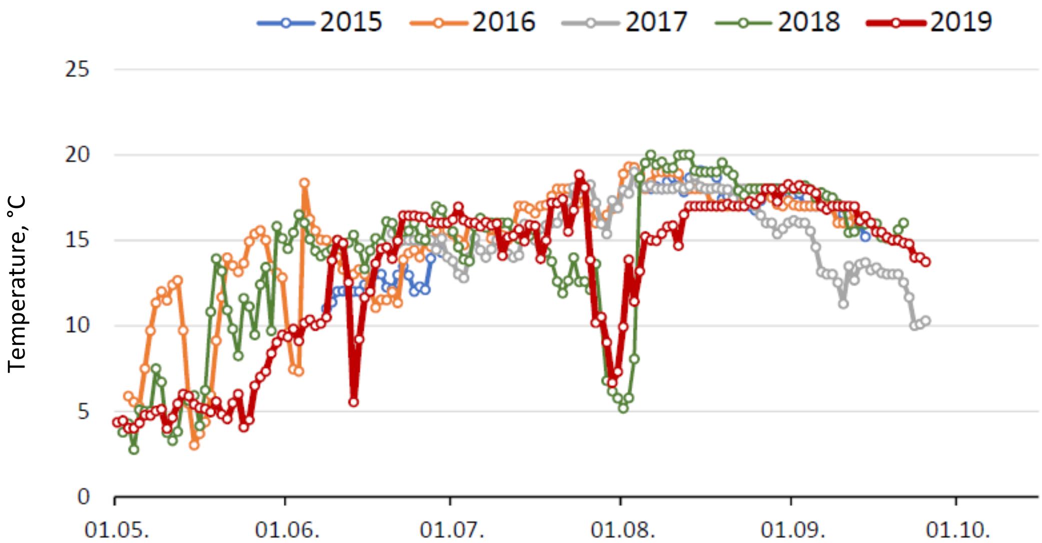


Figure 1.9. Seasonal changes in daily average values of seawater temperature at a depth of 5 m near Narva-Jõesuu during the period 2015-2019 (University of Tartu, Tallinn University of Technology, 2020).

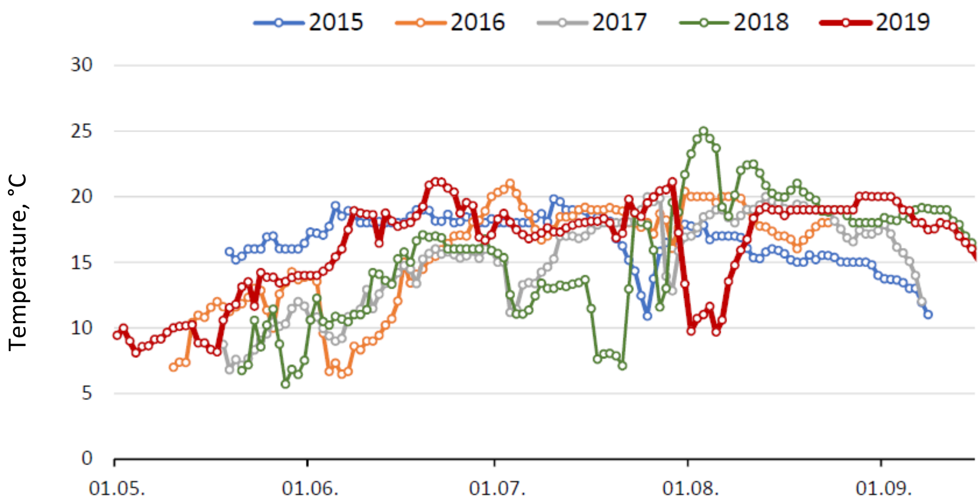


Figure 1.10. Seasonal changes in daily average values of seawater temperature in the Väinameri Sea (Pasilaid monitoring transect) during the period 2015-2019 (University of Tartu, Tallinn University of Technology, 2020).

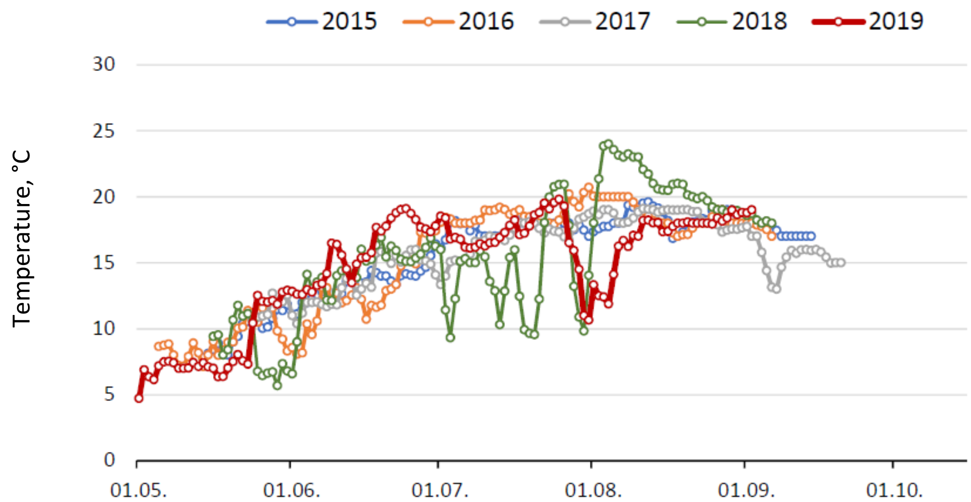


Figure 1.11. Seasonal changes in daily average values of seawater temperature in Küdema Bay (at a depth of 5 m) during the period 2015-2019 (University of Tartu, Tallinn University of Technology, 2020).

The Estonian **wind climate** is shaped by the frequent alternation of cyclones and anticyclones characteristic of the northern part of the temperate zone, i.e. cyclonal activity, which causes windy weather. The strongest winds and frequent storms occur during the period from October to January, while the period from May to August is characterised by weaker winds and calmer days. The mean annual wind speed in the marine waters west of the islands is 8.5-9 m/s, with gusts reaching over 30 m/s. In the open central part of the Gulf of Riga, the mean annual wind speed is 8-8.5 m/s with gusts reaching 26-28 m/s. In the Väinameri Sea, winds are considerably weakened by the islands and the mainland, with the mean annual wind speed being less than 8 m/s, but gusts can still exceed 29 m/s. In the Gulf of Finland, both the wind speed and the strength of the gusts decrease clearly in the west-east direction: in the open western part of the gulf, the mean wind speed is 8-8.8 m/s, while in the eastern part it is only 7-7.5 m/s, and gusts reach > 30 m/s and up to 28 m/s, respectively. The wind climate also determines the nature of **waves and currents**. More often than not, seawater flows along the Estonian coast towards the east. The characteristic current speed is 10-20 cm/s in the surface layer of the Estonian marine waters. Maximum current speeds exceeding 1 m/s have been recorded in straits (e.g. the Suur Strait) and along the coast (e.g. in the Gulf of Finland) where occasional strong jet currents occur. Intense currents with a speed of 40-50 cm/s can also occur in the deeper layers of the sea (including near the seabed). The wave height is usually 1-2 m; on the high seas the wave height is 5-6 m during storms and up to 10 m during exceptional western storms. The wave height reaches 6 metres in the Gulf of Finland and 3-4 metres in the Gulf of Riga.

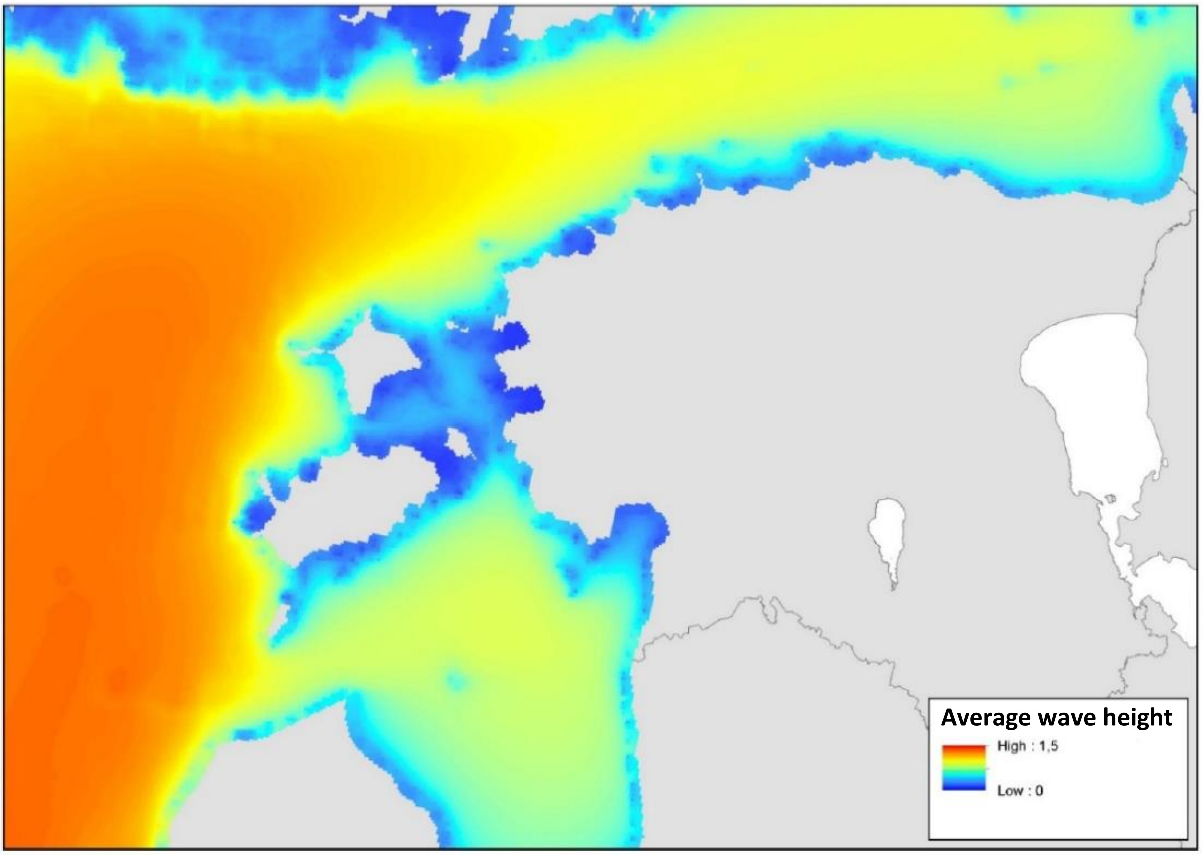


Figure 1.12. Average wave height in Estonian marine waters (m). The basic wave data are from the Copernicus portal (BALTICSEA_ANALYSIS_FORECAST_WAV_003_010).

In the Estonian marine waters, **ice cover** occurs every year at least in Pärnu Bay and the Väinameri Sea. However, there has been essentially no ice cover in extremely mild winters such as 2019/2020. In severe winters (like in 2010/2011) all the Estonian marine waters are covered with ice, and ice cover persists for 30 days even on the west coast of Hiiumaa and Saaremaa. On average, Pärnu Bay, Väinameri Sea and Narva Bay are covered with ice 50% of the time (from 15 December to 1 May), but in severe winters this figure can reach 85%. In the western and central parts of the Gulf of Finland, the ice period is shorter – on average 30% and in severe winters 60% of the time. However, in the western and central parts of the Gulf of Finland, ice drift and the potential damage it causes to offshore and coastal facilities represent an important obstacle to maritime activities. Drift ice occurs mainly in areas where the duration of ice cover is shorter on average – in the western and central parts of the Gulf of Finland, in the open central part of the Gulf of Riga and on the west coast of Saaremaa.

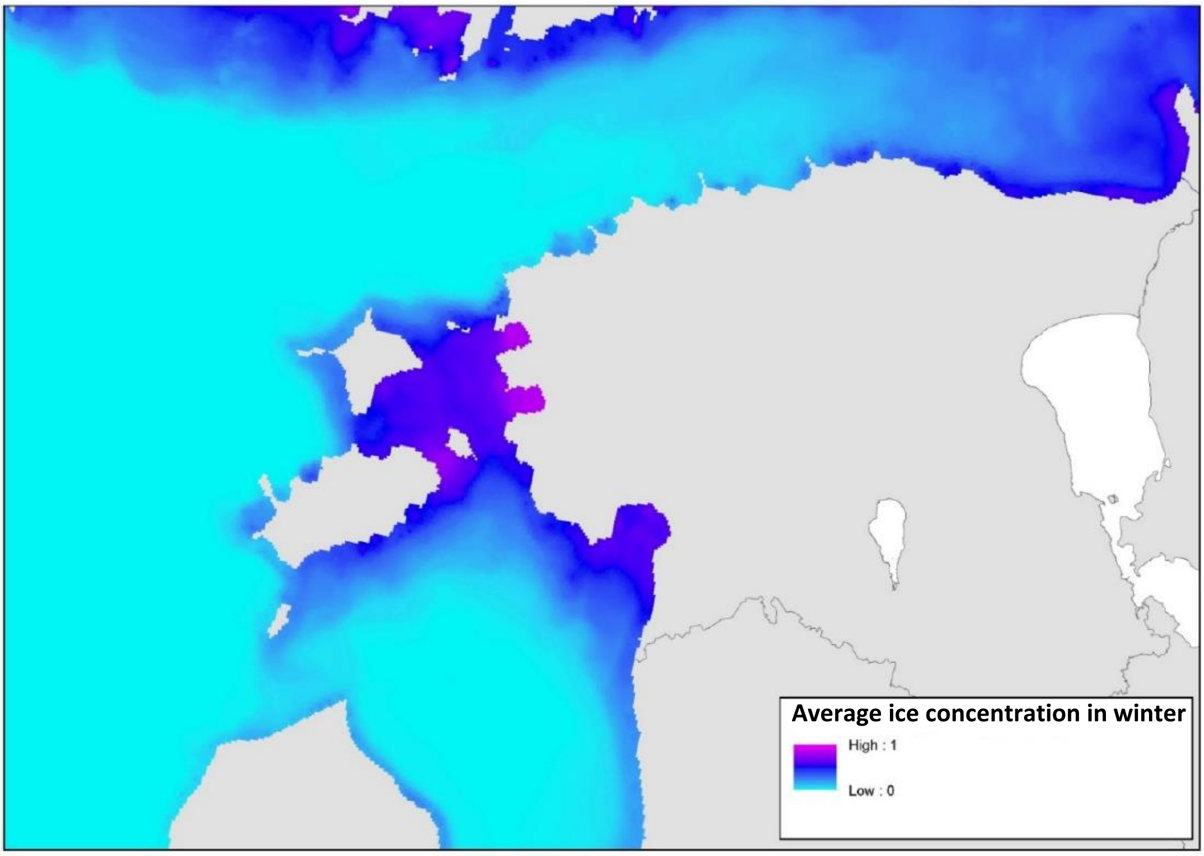


Figure 1.13. Average ice concentration in Estonian marine waters in winter (0 = no ice, 1 = 100% ice cover). The basic ice cover data are from the Copernicus portal (BALTIC_ANALYSIS_FORECAST_PHY_003_006).

Eutrophication is one of the biggest environmental issues in the Baltic Sea. Eutrophication is caused by the accumulation of nutrients (especially nitrogen and phosphorus compounds) in the marine environment. Eutrophication is manifested by a number of simple and complex symptoms, both across individual ecosystem components and at the level of the whole ecosystem, including phenomena that can be positive for human society (high secondary production, including high biomass of plankton-feeding fish such as herring and sprat) and numerous negative phenomena (increased primary production – algal blooms, oxygen in near-bottom water layers, impoverishment of species diversity).

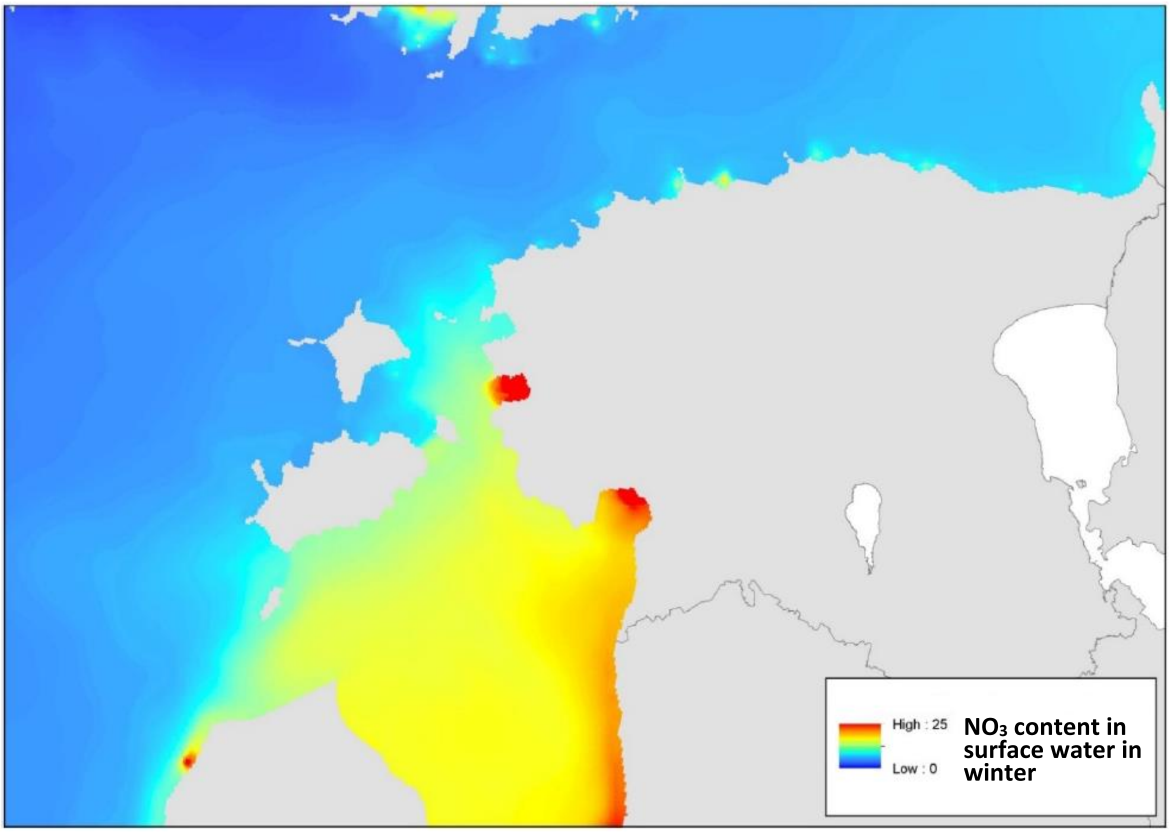


Figure 1.14. Average NO_3 content in surface water in Estonian marine waters in winter (mmol m^{-3}). The basic NO_3 data are from the Copernicus portal (BALTIC_ANALYSIS_FORECAST_BIO_003_007).

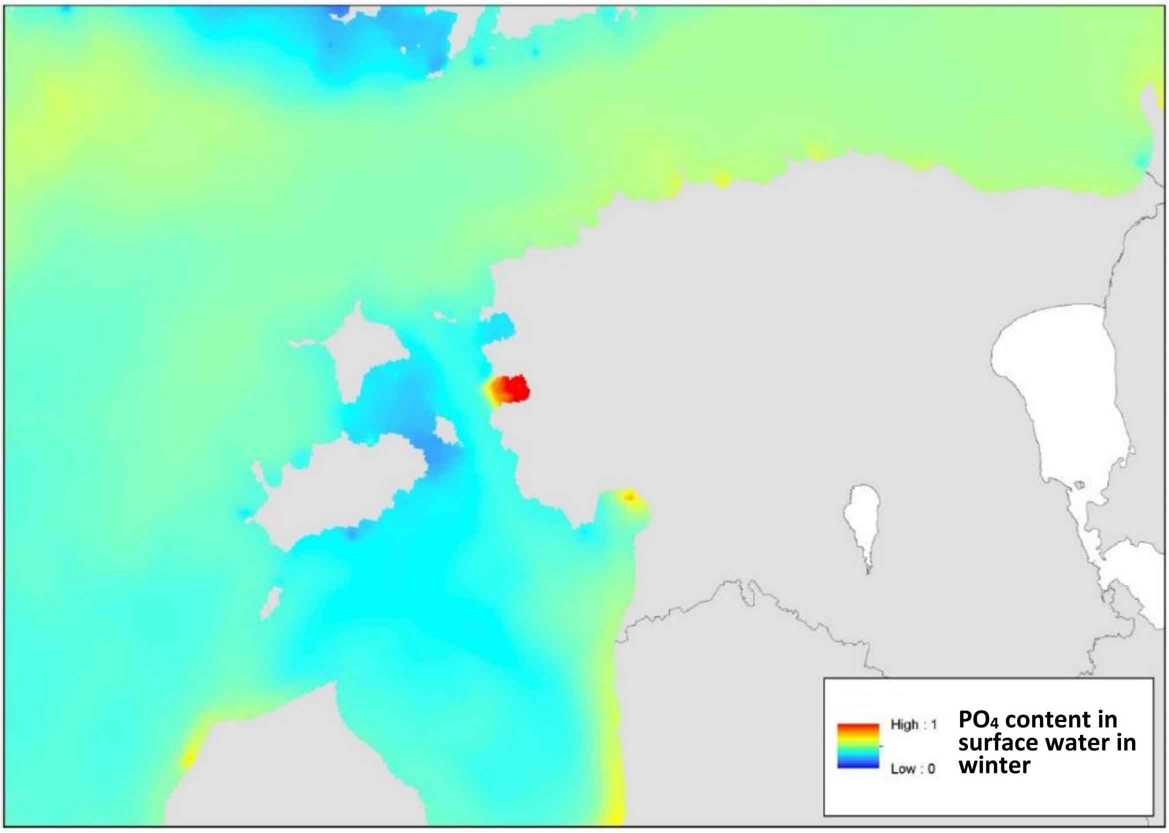


Figure 1.15. Average PO_4 content in surface water in Estonian marine waters in winter (mmol m^{-3}). The basic PO_4 data are from the Copernicus portal (BALTIC_ANALYSIS_FORECAST_BIO_003_007).

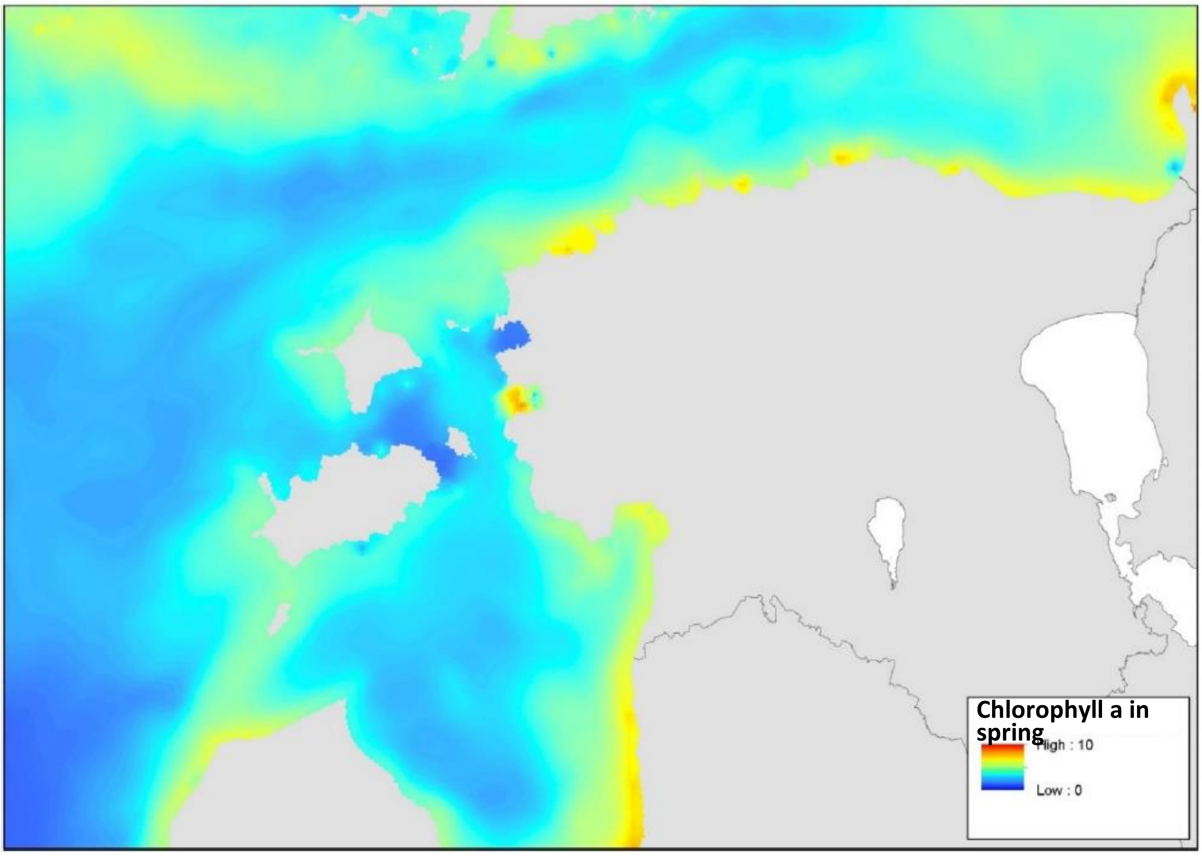


Figure 1.16. Average chlorophyll a content in surface water in Estonian marine waters in spring (mg m^{-3}). The basic chlorophyll data are from the Copernicus portal (BALTIC_ANALYSIS_FORECAST_BIO_003_007).

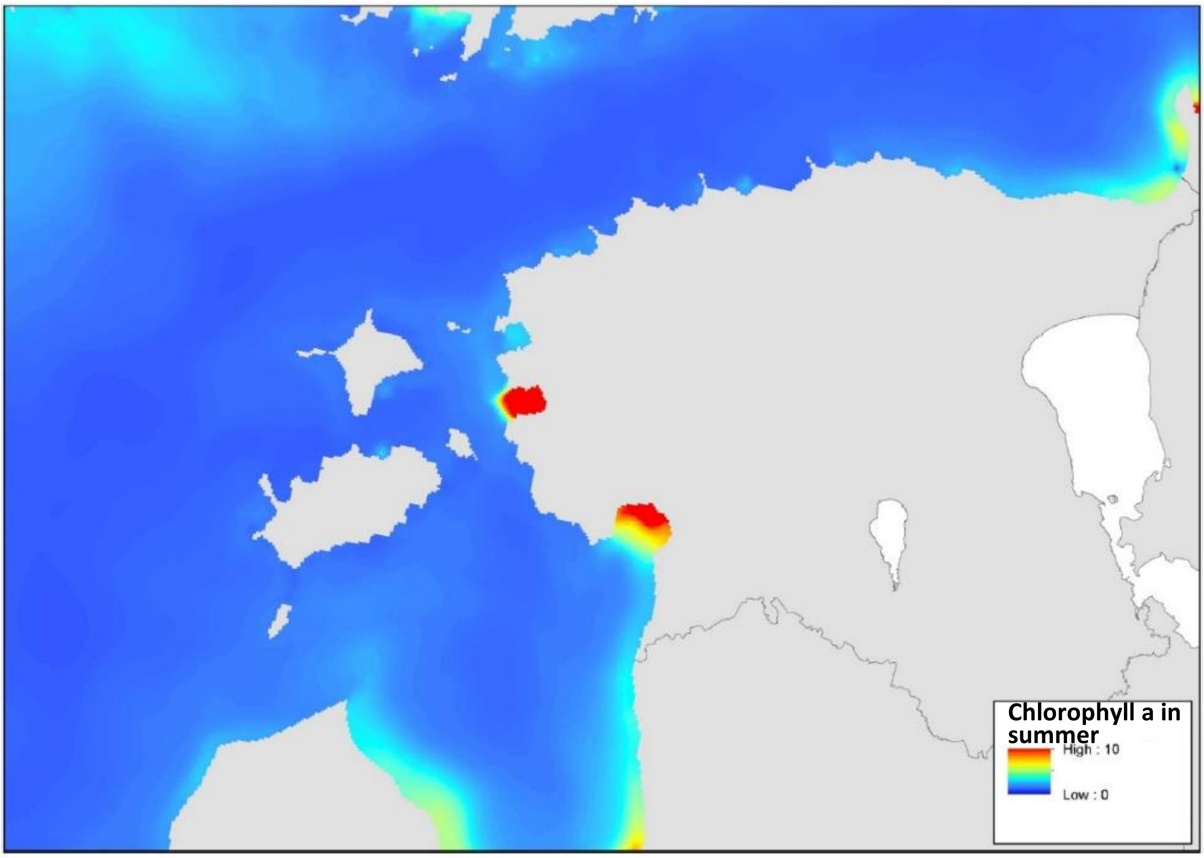


Figure 1.17. Average chlorophyll a content in surface water in Estonian marine waters in summer (mg m^{-3}). The basic chlorophyll data are from the Copernicus portal (BALTIC_ANALYSIS_FORECAST_BIO_003_007).

Seawater quality implies a set of values of indicators and status assessments used to assess the status of seawater. According to the latest assessment of the status of the Estonian marine waters (Ministry of the Environment, 2019), the majority of Estonian marine areas have not yet reached the level of good environmental status (GES). The level of good environmental status has only been achieved for the criteria of 'Benthic habitats' and 'Change in hydrographic conditions'. Estonian national marine environment monitoring data show that both the concentrations of inorganic nitrogen and phosphorus compounds in winter and the average concentrations of total nitrogen and total phosphorus in summer are well above the desired levels.

Water transparency is an important indicator of the quality of the marine environment. The availability of light determines the possibility of primary photosynthesis in the marine environment which, in the context of aquaculture, is particularly relevant in the planning of algae farming. In general, water transparency is higher on the high seas (in the Estonian marine waters for example in the East Gotland Basin and the northern part of the Baltic Sea) and lower in the Gulf of Riga and the Gulf of Finland.

Summary of assessment:

STATUS		**PRESSURE**	
Biodiversity	Poor	Poor	Alien species
○ Birds	Poor	Poor	Fisheries
○ Fish	Poor	Poor	Eutrophication
○ Mammals	Poor	Good	Change in hydrographic conditions
Water column habitats	Poor	Poor	Pollutants
Marine ecosystem and food networks	Poor	Poor	Marine litter
Benthic habitats	Good	N/A	Underwater noise pollution

Figure 1.18. Summary of the assessment of the status of Estonian marine waters by components of the marine ecosystem (Ministry of the Environment, 2019).

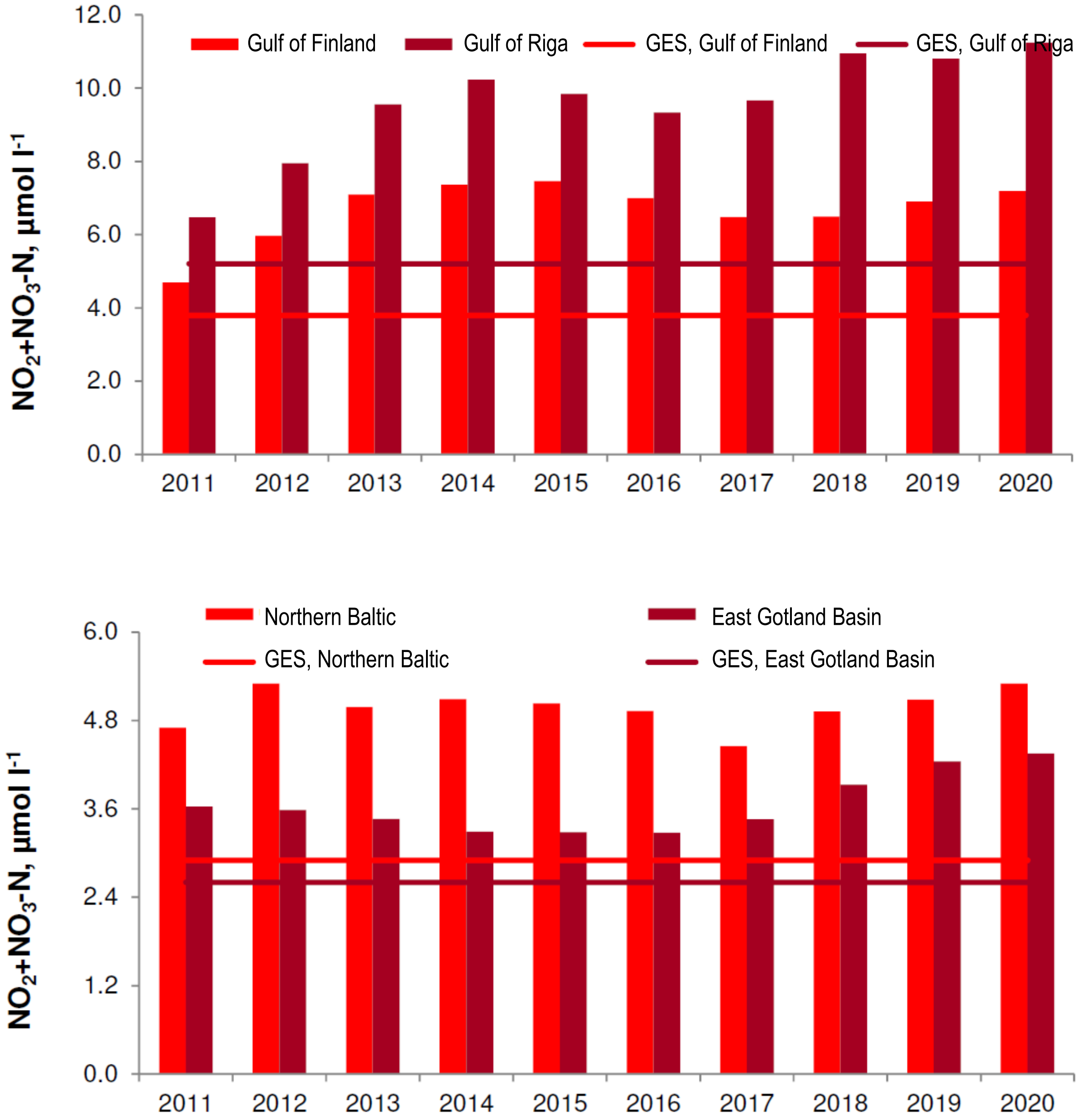


Figure 1.19. Threshold values for wintertime (December-February) inorganic nitrogen content (NO_2+NO_3-N; µmol l^{-1}) corresponding to good environmental status (GES) and indicator values in sub-basins in the period 2011-2020 (University of Tartu, Tallinn University of Technology, 2020).

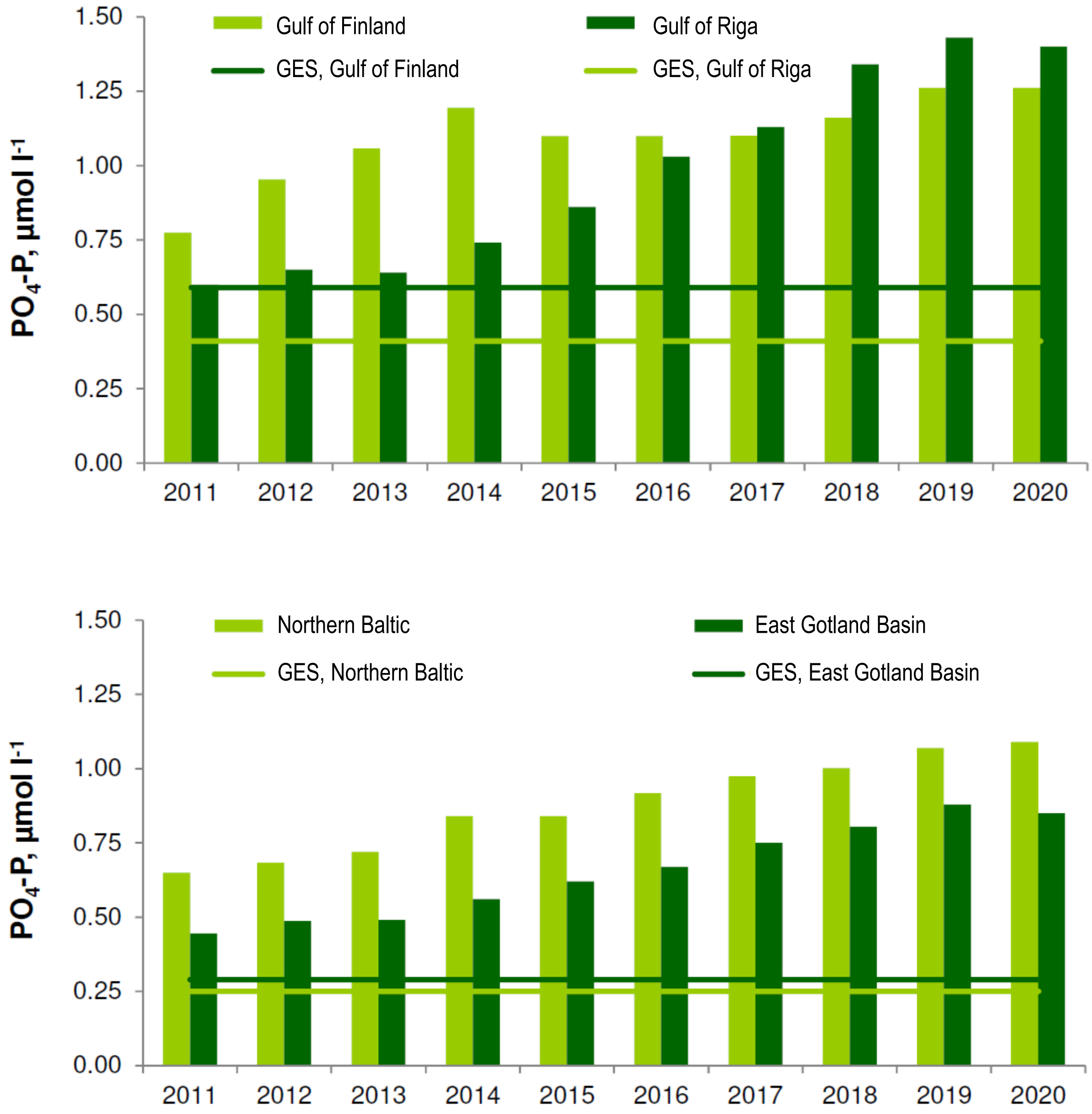


Figure 1.20. Threshold values for wintertime (December-February) phosphate contents (PO_4-P; µmol l^{-1}) corresponding to good environmental status (GES) and indicator values in sub-basins in the period 2011-2020, calculated as an average of the last five years (University of Tartu, Tallinn University of Technology, 2020).

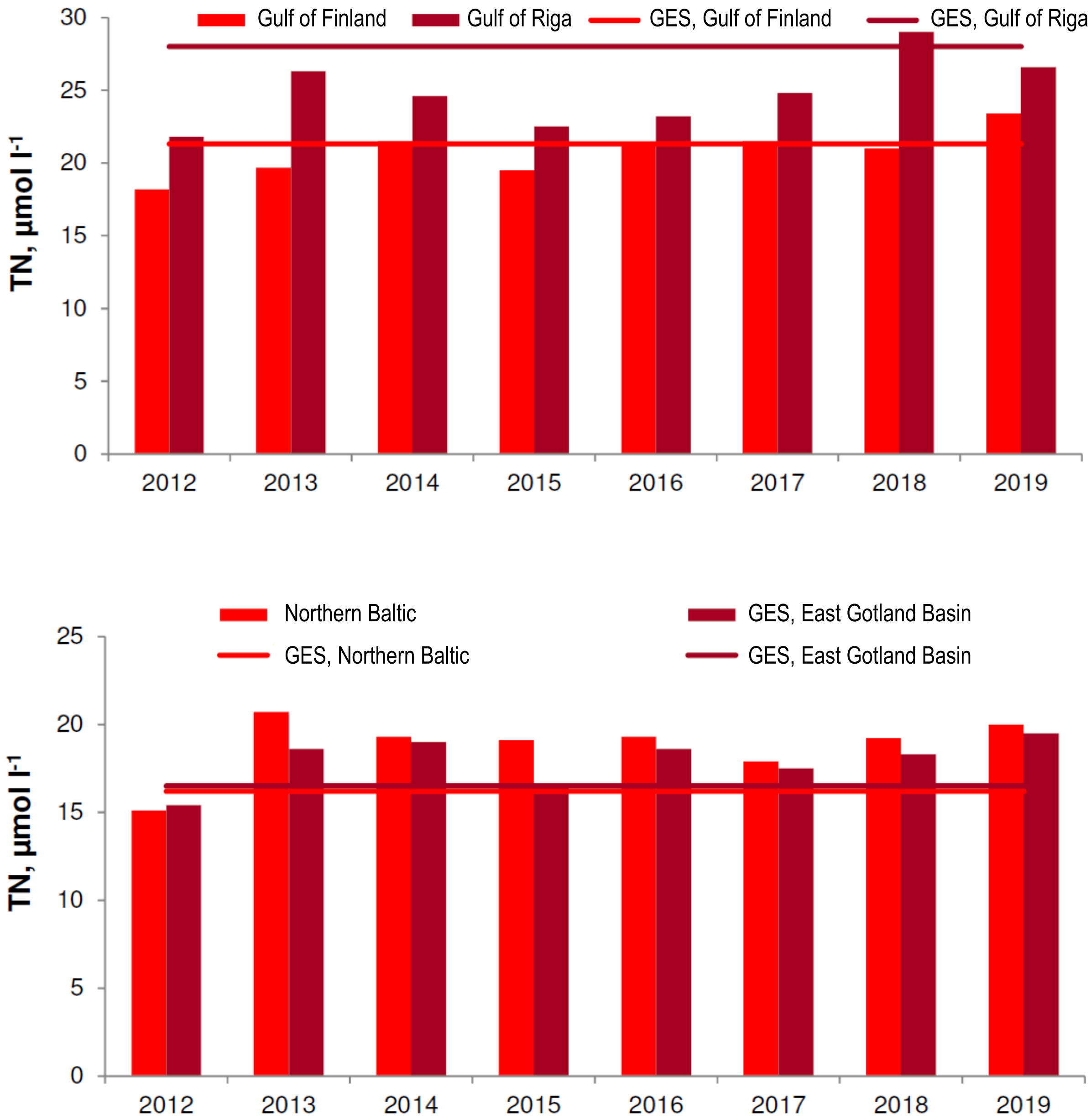
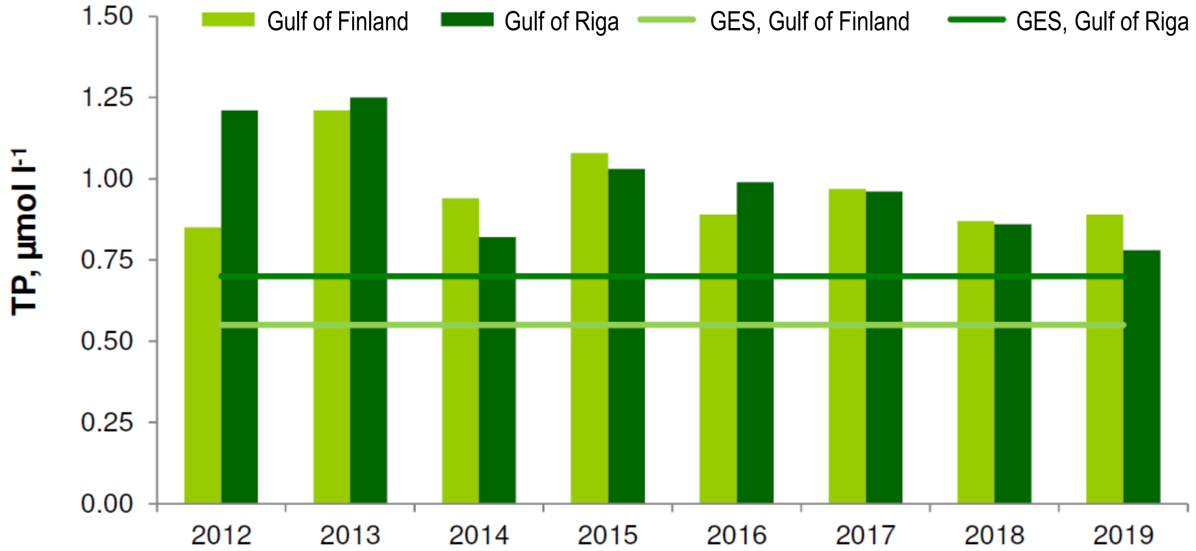


Figure 1.21. Threshold values for the annual average total nitrogen content (TN; µmol l^{-1}) corresponding to good environmental status (GES) and indicator values in sub-basins in the period 2012-2019 (University of Tartu, Tallinn University of Technology, 2020).



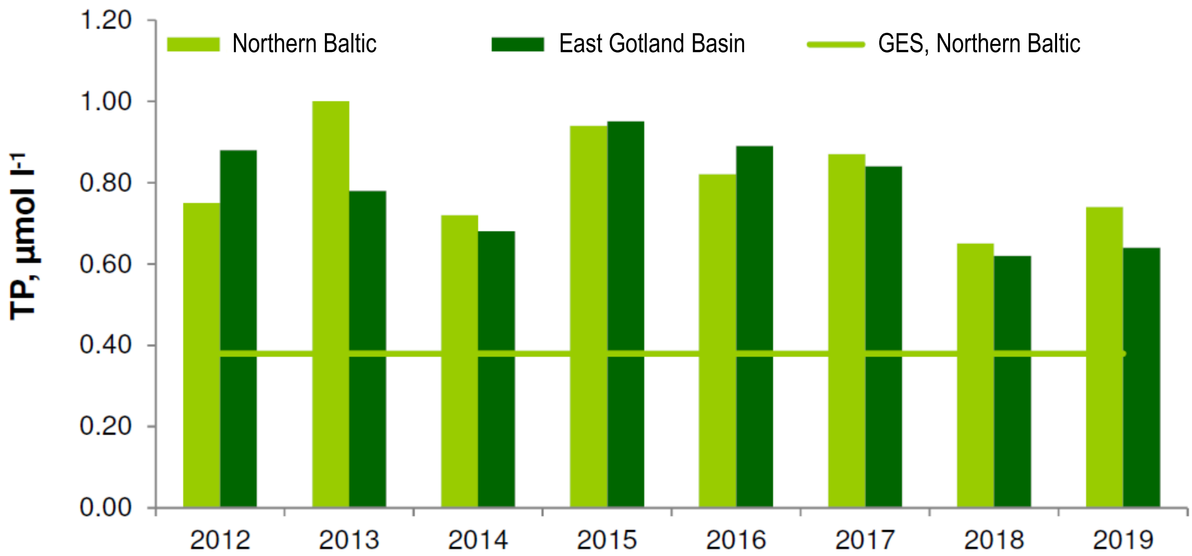


Figure 1.22. Threshold values for the annual average total phosphorus content (TP; µmol l^{-1}) corresponding to good environmental status (GES) and indicator values in sub-basins in the period 2012-2019 (University of Tartu, Tallinn University of Technology, 2020).

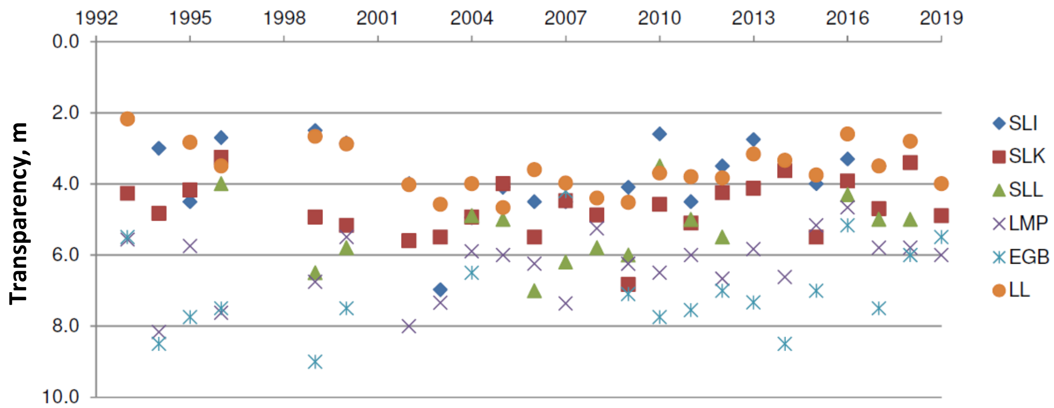


Figure 1.23. Variability of average seawater transparency (m) in different regions of marine waters in late May and early June 1993-2019. SLI – eastern part of the Gulf of Finland, SLK – central part of the Gulf of Finland, SLL – western part of the Gulf of Finland, LMP – northern part of the Baltic Sea, EGB – East Gotland Basin, LL – Gulf of Riga (University of Tartu, Tallinn University of Technology, 2020).

The **distribution of benthic habitats** must be taken into account in aquaculture planning, as marine habitats are among key instruments for practical nature protection in the marine environment. On the basis of particular habitats, restrictions are imposed on many human activities, especially complex ones and those that are difficult to relate to particular indicators.

There is a lot of uncertainty in habitat mapping, mainly due to the mapping methods used. Today, technological means do not enable accurate data to be collected from large areas, and thus "snapshot" mappings must be interpreted as spatial interpolation of point observations.

Mapping of benthic habitats was started in Estonia in 2005, and approximately one third (38%) of all Estonian marine waters had been studied by 2019. As regards the extent of the area covered by mapping, it should be borne in mind that the coverage estimate has been obtained by summing up the areas of study plots in all mapping areas, regardless of the specific mapping methods or the density of the network of sampling points.

All previous mapping work has been project-based and the results are mainly based on the study of large areas using a very sparse network of sampling points. The greater the distances between the sampling points, the lower the reliability of the resulting maps. Detailed knowledge of the seabed comes from points visited at sea. Seabed substrate and distribution of biota in the area between the sampling points are assessed using indirect mathematical methods, such as interpolation or directed modelling. Larger unmapped areas within the territorial sea are located in the eastern part of the Gulf of Finland and in the western and north-western parts of the territorial sea. Benthic habitats in the exclusive economic zone are much less mapped than habitats in the territorial sea.

In the European Union, habitat types important for nature conservation purposes are listed in Annex I to the Habitats Directive (Directive 92/43/EEC on the conservation of natural habitats and of wild fauna and flora), which sets out habitat types on land, in the sea and in freshwater. Annex I to the Habitats Directive includes a total of eight marine habitat types, of which six are present in the Estonian marine waters (codes according to Annex I to the Habitats Directive are given in brackets):

- sandbanks which are slightly covered by sea water all the time (1110),
- estuaries (1130),
- mudflats and sandflats not covered by seawater at low tide (1140),
- coastal lagoons (1150),
- large shallow inlets and bays (1160),
- reefs (1170).

Of the above, only seawater-covered sandbanks and reefs can be regarded as fully benthic habitat types, as their designation has nothing to do with the shape of the coastline or the land. Offshore conditions in the high seas preclude the occurrence of estuaries, mudflats and sandflats, coastal lagoons and large shallow inlets and bays, as all these habitat types are directly linked to the coastline. In the context of the Estonian Maritime Spatial Plan, therefore, attention was paid to the habitats on reefs (1170) and seawater-covered sandbanks (1110), which are more common in the Estonian marine waters (Ministry of Finance, Hendrikson&KO, 2020a).

In 2018, the distribution of reefs and seawater-covered sandbanks as habitat types in the Estonian marine waters was modelled on the basis of available materials. During this exercise, the level of detail of previous studies was also mapped. The density of sampling points determines the reliability of the models: the higher the density of points for taking samples from the seabed, the higher the reliability of model predictions in the region (University of Tartu, 2018a). According to the Marine Strategy Framework Directive (MSFD), large-scale habitats need to be taken into account when assessing the state of the environment. EU Commission Decision 2017/848, which specifies the broad benthic habitat types under the MSFD, has only recently been published and therefore MSFD benthic habitats have not yet been mapped in Estonia. However, in 2018, modelling of the distribution of the main types of MSFD benthic habitats was carried out, based on the same source data as in the previous modelling of habitats under the Habitats Directive. The sub-project 'Innovative approaches to monitoring and assessing marine environment and natural values in Estonian marine waters' is being carried out within the scope of the project 'mereRITA' (https://sisu.ut.ee/mererita/avaleht), in the course of which a number of innovative approaches are being developed to enable mapping and assessment of marine ecosystems and development of the blue economy. More information on ongoing projects is provided in Chapter 8.

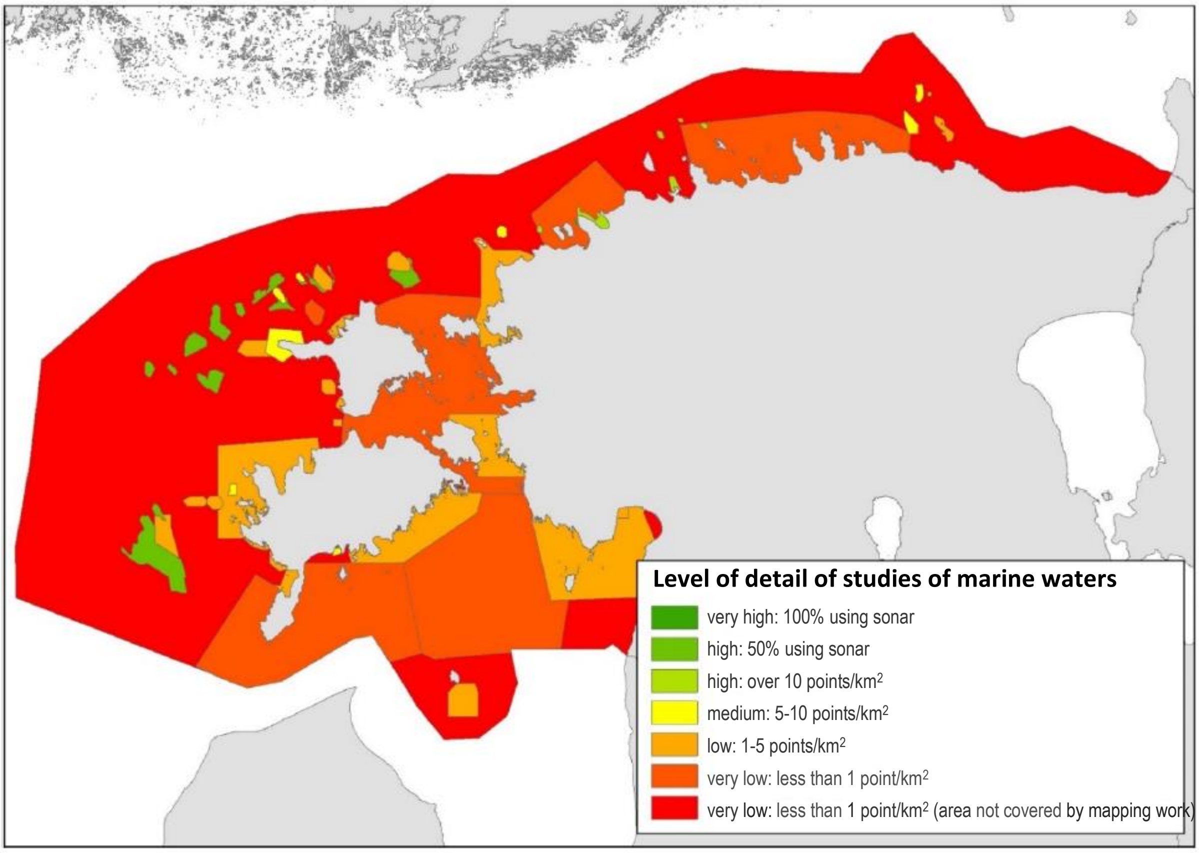


Figure 1.24. Assessment of reliability of benthic habitat mapping work based on input data type and spatial density (University of Tartu, 2018a).

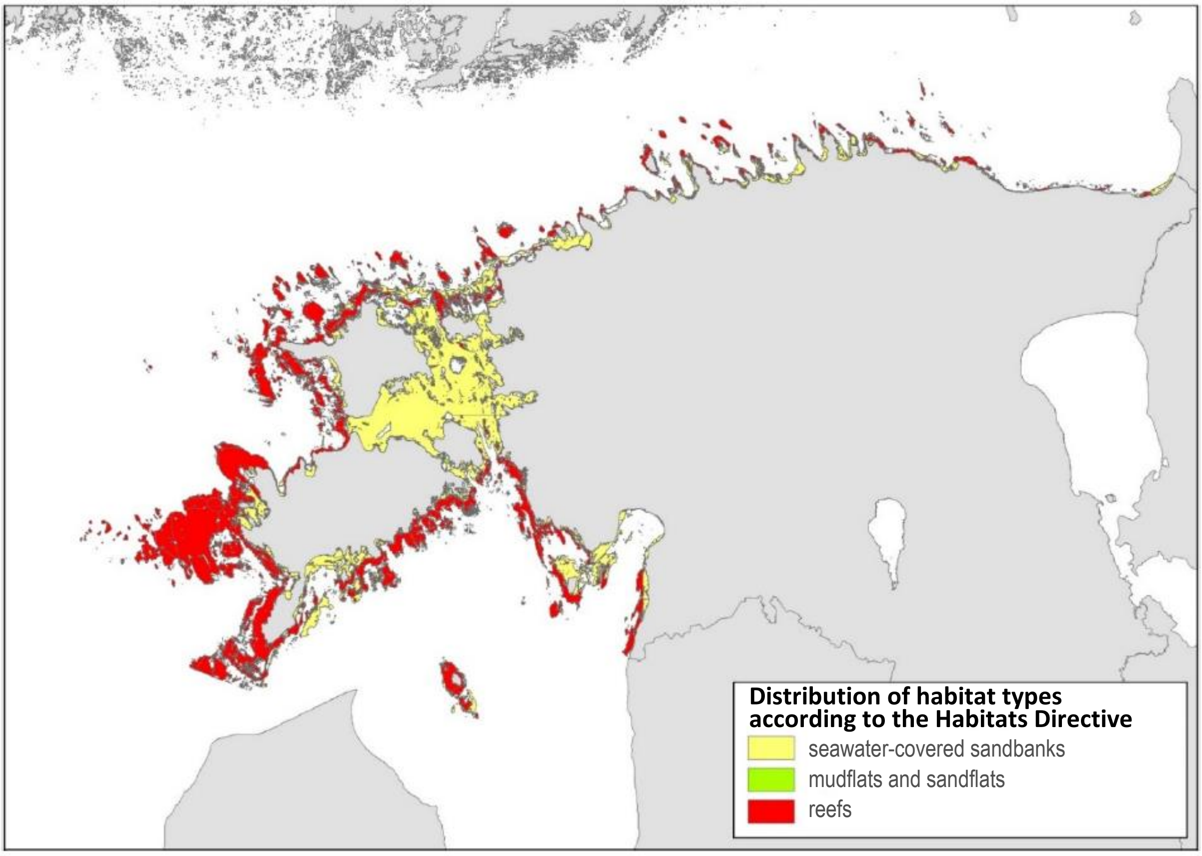


Figure 1.25. Distribution of habitat types according to the Habitats Directive (University of Tartu, 2018a).

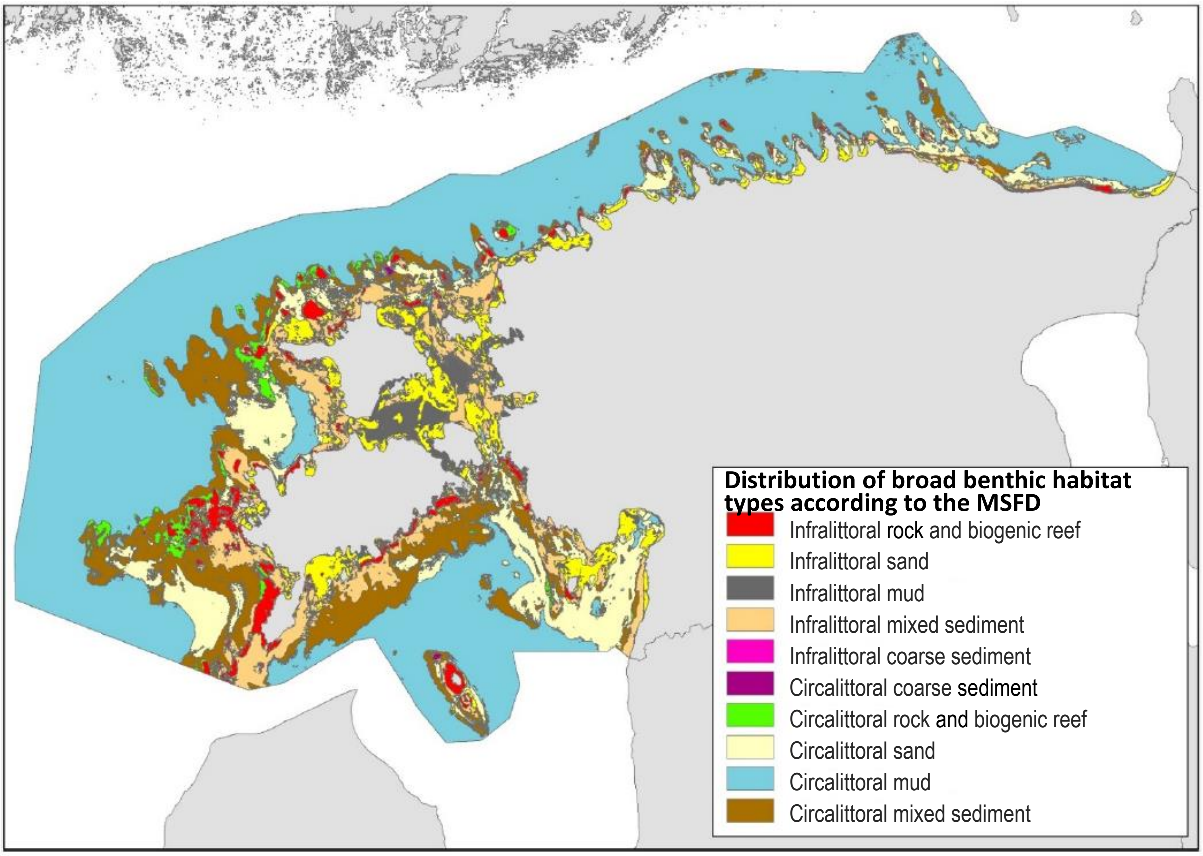


Figure 1.26. Distribution of broad benthic habitat types according to the Marine Strategy Framework Directive (University of Tartu, 2018a).

2. Fish farming and fishing

The lion's share of Estonian **fish farming** production comes from freshwater farms. One company is currently farming fish in net cages at sea. To set up and operate a freshwater farm, appropriate water resources must be available. In the case of surface water-based farms, it is important to find a suitable location where water from a body of surface water can be used by pumping or by impounding a river. Choosing the location requires thorough preliminary work. For example, impounding or changing the natural bed or hydrological regime of a water body designated as a spawning ground and habitat of salmonids or of a part of such water body is prohibited. In surface water-based farms, the water temperature is affected by the external environment, and the active growing period of fish only lasts for a certain period of the year. There are fewer limitations on the choice of location for fish farms based on the RAS (recirculation-based aquaculture system). The availability of a suitable amount of groundwater resources is the most important precondition. In the case of the RAS, it is possible to keep the water temperature suitable for the growth of fish stable throughout the year; unfortunately, the costs of setting up and running such a farm are high and therefore the cost price of fish is higher than in farms using surface water.

Currently, the only net cage farm in Estonia is located near Veere in the Tagalaht Bay. Net cage farms were operated to a small extent in Estonia in the 2000s in Veere (Tagalaht Bay) and Salmistu (Kolga Bay). The farms ceased operations in the second half of the 2000s – for various reasons. Many farms were started with the support of the European Fisheries Fund, but the operators were not able to get the farms up and running in accordance with the conditions set out in the project (due to design errors, incorrect financial plan, etc.). In the case of the farm run in the Tagalaht Bay, the fish grew well, but it was not expedient to continue the work of the farm due to the lack of qualified labour. In the case of the Salmistu farm, 7 tonnes of rainbow trout died at the end of 2008 for an unknown reason, and the farm ceased operations. The farm associated the death of fish with the blasting exercises of the Defence Forces, but the Tallinn Administrative Court decided not to review the claim of OÜ Poseidon, the company running the farm, for nearly four million Estonian kroons in compensation from the Defence Forces for the perished rainbow trout.

Rainbow trout is the most suitable species for farming in Estonian conditions. When setting up a farm, it is important to verify that the sea area is of a sufficient depth and that suitable currents ensure a sufficient amount of fresh water. Fish can be farmed during the ice-free period, as winter ice combined with volatile weather conditions can destroy cage structures. In Estonia, there are no sea areas with suitable water depths sheltered from winds (in contrast to, for example, the Finnish Åland region), and this fact should be taken into account when choosing the location of net cages.

The farms that are currently operating are set out in Table 2.1 and their locations are shown in Figure 2.1.

Rainbow trout is the most common farmed species in Estonia (927 tonnes in 2019). In most cases, fish of 1-2.5 kg intended for human consumption are farmed. Rainbow trout in portion size (250-400 g) is also produced to some extent, but the demand of Estonian consumers for this product is low. Some farms are also engaged in pre-farming of fish for other farms as an additional activity when necessary.

For the purpose of restoring natural fish stocks, roe of salmonids is produced only in Põlula Fish Farm of the State Forest Management Centre. There is no production of the roe of salmonids for the farming of food fish in Estonia. Roe is imported from other countries, incl. Denmark, Scotland, Poland and Lithuania. In the past, roe of salmonids has also been imported from Finland.

Pursuing aquaculture with a production growth of over 1 tonne per year requires a water permit. The quantity of water allowed to be used and the quantity of effluent to be discharged into the water body are assessed during the water permit issuance process. A superficies licence must be applied for from the Consumer Protection and Technical Regulatory Authority to build a construction works not permanently connected to the shore in a public water body (net cage farm). A public water body belongs to the state and the superficies licence gives the right to erect construction works not permanently connected to the shore in it for a specified period of time.

According to the official publication *Ametlikud Teadaanded*, no proceedings concerning new water permits for terrestrial or marine fish farms have been commenced. Proceedings concerning superficies licences have been commenced for sea fish farms on the basis of 6 applications. According to the applications, farms are intended to be set up in regions PV1, PV2, PV3, PV4 in the Lahepere Bay, Tagalaht Bay, north of Vormsi Island and in Kesknõmme (Saaremaa Island) on the basis of the Hiiumaa Maritime Spatial Plan.

Table 2.1. Fish farms operating on the basis of an activity license issued (approved) by the Veterinary and Food Board, and fish farms that have ceased activities (Source: Veterinary and Food Board, Environmental Board).

No.	Company name	Location	Type of farm; water use; main species farmed	Incubation of roe (operating farms)	In operation/ closed	Water permit No.	Permitted quantity of feed as per water permit
1	Põlula Fish Farm of the State Forest Management Centre	Lavi village, Vinni Rural Municipality, Lääne-Viru County	Restoring natural fish stocks (salmon, sea trout, grayling, whitefish)	Yes	in operation	L.VV/32 8042	12 t
2	OÜ Simuna Ivax	Äntu village, Väike-Maarja Rural Municipality, Lääne-Viru County	Concrete pools; surface water; rainbow trout, Arctic char	Yes	in operation	L.VV/32 5241	190 t
3	OÜ Simuna Ivax	Nõmme village, Väike-Maarja Rural Municipality, Lääne-Viru County	Concrete pools; surface water; rainbow trout		in operation	L.VV/32 5241	150 t
4	OÜ Simuna Ivax	Käru village, Väike-Maarja Rural Municipality, Lääne-Viru County	Soil ponds; surface water; rainbow trout		in operation	L.VV/32 5241	190 t
5	OÜ Simuna Ivax	Mõdriku village, Vinni Rural Municipality, Lääne-Viru County	Concrete pools; surface water; rainbow trout		in operation	L.VV/32 5241	100 t

6	OÜ Aviiso	Vohnja fish farm, Vaiatu village, Kadrina Rural Municipality, Lääne-Viru County	Concrete pools; surface water; rainbow trout		in operation	L.VV/325713	195 t
7	Aravuse Kalakasvandus OÜ	Aravuse village, Vinni Rural Municipality, Lääne-Viru County	Concrete pools; surface water; rainbow trout		Closed	–	–
8	Härjanurme Fish Farm	Jõune village, Jõgeva Rural Municipality, Jõgeva County	Concrete pools, soil ponds; rainbow trout, common carp, sturgeon, pikeperch	Yes	in operation	pending renewal	265 t (applied for)
9	Leokitalu OÜ	Hänike village, Võru Rural Municipality, Võru County	Soil ponds; surface water; rainbow trout, Arctic char, Siberian sturgeon		in operation	L.VV/329571	37 t
10	Riina Kalda's fish holding CARPIO (sole proprietor)	Haaslava village, Kastre Rural Municipality, Tartu County	Surface water; soil ponds; common carp, pike, tench, pikeperch and asp	Yes	in operation	L.VV/331541	70 t (incl. 60 t of wheat)
11	OÜ Arowana	Kaavi village, Saaremaa Rural Municipality, Saare County	RAS; groundwater; rainbow trout		Closed		
12	AguaMyk OÜ	Kanissaare village, Saaremaa Rural Municipality, Saare County	RAS; groundwater; rainbow trout	Yes	in operation	L.VV/329390	200 t
13	OÜ Pähkla Vähi- ja Kalakasvatus	Pähkla village, Saaremaa Rural Municipality, Saare County	Concrete pools; surface water; rainbow trout		in operation	L.VV/329915	120 t
14	SK TRADE OÜ	Pirgu village, Rapla Rural Municipality, Rapla County	Soil ponds; surface water; rainbow trout		in operation	L.VV/329480	4 t
15	Karilatsi Kalamajand OÜ	Karilatsi village, Kanepi Rural Municipality, Põlva County	Soil ponds; concrete pools; surface water; rainbow trout	Yes	in operation	L.VV/331394	60 t
16	OÜ Ösel Harvest	Nurmetiigi, Pihtla village, Saaremaa Rural Municipality, Saare County	RAS; groundwater; rainbow trout	Yes	in operation	L.VV/326019	150 t
17	Neli Elementi OÜ	Roosna-Alliku Village, Paide town, Järva County	Concrete pools; surface water; rainbow trout	Yes	in operation	L.VV/332901	70 t

18	For Angula OÜ	Lüüste village, Põhja-Pärnumaa Rural Municipality, Pärnu County	RAS; groundwater; eel		in operation	L.VV/330295	94 t
19	Paadi Talu OÜ	Hänike village, Võru Rural Municipality, Võru County	RAS; groundwater; African catfish	Yes	in operation	–	–
20	Lapavira OÜ	Rutikvere village, Järva Rural Municipality, Järva County	RAS, concrete pools; groundwater, surface water; rainbow trout, Siberian sturgeon, Russian sturgeon	Yes	in operation	L.VV/328585	190 t
21	BM Trade OÜ	Mäeltküla village, Viljandi Rural Municipality, Viljandi County	RAS; groundwater; eel		in operation	L.VV/327809	90 t
22	Krei-Jõe OÜ	Karilatsi village, Kanepi Rural Municipality, Põlva County	Soil ponds; surface water; rainbow trout	Yes	in operation	L.VV/325380	20 t
23	Aquaculture training and testing base of Järva County Vocational Training Centre	Särevere, Türi Rural Municipality, Järva County	RAS; groundwater; vocational education and practical training; sturgeons, rainbow trout	Yes	in operation	L.VV/328190	
24	Joala Fish OÜ	Auvere village, Narva-Jõesuu City, Ida-Viru County	Surface water; net cage farm in the cooling water channel of a power plant; sturgeons, rainbow trout		Closed	–	–
25	Ahja Kalakasvatus OÜ	Ibaste village, Põlva Rural Municipality, Põlva County	Soil ponds; surface water; rainbow trout, Siberian sturgeon		in operation	L.VV/330545	150 t
26	Ilmatsalu Kala OÜ	Ilmatsalu, Tartu City, Tartu County	Soil ponds; pond farm; common carp		Closed	L.VV/330941	Not Permitted
27	Triton PR AS	Koruste village, Elva Rural Municipality, Tartu County	RAS; groundwater; eel		Closed		
28	OÜ Piscor	Jõeküla, Türi Rural Municipality, Järva County	RAS; groundwater; rainbow trout		Closed		
29	AS Pärnu Laht	Pärnu City	RAS; groundwater; perch		Closed	–	–

30	Varbla Kalakasvatuse OÜ	Paatsalu village, Lääneranna Rural Municipality, Pärnu County	RAS; groundwater; sturgeons		Closed	–	–
31	Redstorm OÜ	Veeremäe village, Saaremaa Rural Municipality, Saare County	Sea; net cage farm; rainbow trout		in operation	L.VV/32 9075	100 t
32	Torgu Kala OÜ	Kaavi village, Saaremaa Rural Municipality, Saare County	RAS; concrete pools; groundwater; rainbow trout		Closed		

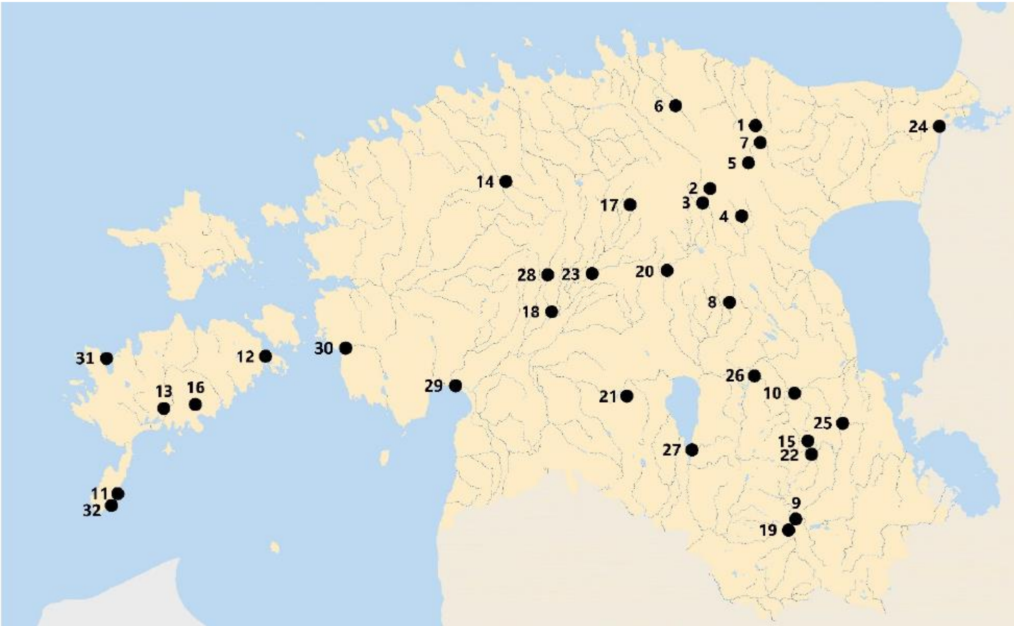


Figure 2.1. Fish farms operating and closed in Estonia (2010-2020)

1 Põlula Fish Farm of the State Forest Management Centre
2 Simuna Ivax OÜ Äntu Fish Farm
3 Simuna Ivax OÜ Nõmmeveski Fish Farm
4 Simuna Ivax OÜ Käruveski Fish Farm
5 Simuna Ivax OÜ Mõdriku Fish Farm
6 Aviiso OÜ
7 Aravuse Kalakasvandus OÜ
8 Härjanurme Fish Farm
9 Leokitalu OÜ
10 Riina Kalda's fish holding CARPIO
11 Arowana OÜ
12 AquaMyk OÜ
13 Pähkla Vähi- ja Kalakasvatus OÜ
17 Neli Elementi OÜ
18 For Angula OÜ
19 Paadi Talu OÜ
20 Lapavira OÜ
21 BM Trade OÜ
22 Krei-Jõe OÜ
23 Aquaculture training and testing base of Järva County Vocational Training Centre
24 Joala Fish OÜ
25 Ahja Kalakasvatus OÜ
26 Ilmatsalu Kala OÜ
27 Triton PR OÜ
28 Piscor OÜ
29 Pärnu Laht OÜ

14 SK Trade OÜ	30 Varbla Kalakasvatuse OÜ
15 Karilatsi Kalamajand OÜ	31 Redstorm OÜ
16 Ösel Harvest OÜ	32 Torgu Kala OÜ

Viral and bacterial diseases detected in sea trout, rainbow trout and salmon in Estonia are presented in Table 2.2. There is no recognised veterinarian in the field of fish in Estonia who could advise fish farmers on the treatment of fish. Information needed to treat fish is obtained from other fish farmers or from veterinarians in other countries (e.g. Denmark).

The Veterinary and Food Board is responsible for the organisation and implementation of measures for the prevention and control of animal diseases in Estonia. Fish diseases are diagnosed by the Veterinary and Food Laboratory.

Table 2.2. Viral and bacterial diseases detected in sea trout, rainbow trout and salmon (Source: Veterinary and Food Board, Veterinary and Food Laboratory, Ene Saadre, Priit Päkk).

Viral diseases	Abbreviation	Sea	Internal waters
Viral haemorrhagic septicaemia	VHS	X	X
Infectious haematopoietic necrosis of fish	IHN		X
Infectious pancreatic necrosis	IPN	X	X
Bacterial diseases			
Furunculosis (*Aeromonas salmonicida*)	ASS	X	X
Yersiniosis (enteric redmouth disease) (*Yersinia ruckeri)*	ERM	X	X
Vibriosis (*Vibrio anguillarum*)		X	X
Coldwater disease (Flavobacterium psychrophilum)			X
Columnariosis (Flavobacterium columnare)			X
Aeromonas hydrophilia		X	X
Pseudomonas anguilliseptica			X
Rainbow trout gastroenteritis (*Candidatus arthromitus*)	RTGE		X

Due to the small size of the market in Estonia, there is no production of roe for commercial fish farming. Only Põlula Fish Farming Centre collects the roe of salmonids for the purpose of restoring fish stocks. For this reason, all the roe or juveniles (salmonids) needed for fish farming must be imported from fish farms of other countries. When buying roe, the desired breed, the number of chromosome sets specific to the species, the price, information about diseases and other characteristics are considered. In the future, imports will be affected by the establishment of 'disease-free zones' the date of entry into force and the exact rules of which are currently unknown.

Trade in aquaculture animals is regulated by the Trade in, Import and Export of Animals and Animal Products Act, Regulation No. 46 of the Minister of Agriculture of 13.08.2008 'Veterinary requirements for the movement of aquaculture animals and trade in animal products derived from them' and Regulation No. 85 of the Minister of Agriculture of 13.08.2008 'Rules for the control of aquatic animal diseases' (Veterinary and Food Board, 2019).

Any batch of aquaculture animals being transported must be accompanied by an animal health certificate. Such movement between Member States may not take place without prior notification to the competent authorities of the Member States concerned. All animals and reproductive material move with a TRACES (Trade Control and Expert System) document. An application for the certificate has to be submitted to the centre supervising the company concerned at least 48 hours before the animals are exported or transported to another Member State.

The disease category of an aquaculture zone or region (or farm) for non-exotic aquatic animal diseases is determined by the Veterinary and Food Board. In Estonia, the goal is to establish an aquaculture zone with a disease-free status in the future, as a result of which aquaculture animals may be introduced into farms only from an aquaculture zone or farm having the same status.

Fishing takes place in all of the marine waters of Estonia with the exception of the regions where fishing restrictions established by law apply. Coastal and recreational fishing is more intensive in coastal regions and in shallower sea. Commercial fish stocks are intended to be exploited to a limit that will ensure catches of at least the same magnitude in the following years. Commercial trawling (herring and sprat) takes place in marine waters with depths exceeding 20 m. In shallower waters, trawling is generally prohibited, as this activity causes damage to the seabed and thus to biodiversity.

Catch data for commercial fishing are based on official statistics collected by the Veterinary and Food Board. The Veterinary and Food Board receives catch data from fishermen, who are obliged to register each catch and submit the data at least once a month. Table 2.3 sets out the catches of Estonian fisheries and the total values of catches in the years 2007-2018, calculated on the basis of first-sale prices in 2018. Trawling catches contain herring and sprat, and the average catch of the trawling sector amounted to 56 thousand tonnes in the observed period. In coastal fishery, mostly different types of traps and gill nets are used, and catches consist of many different species of fish. However, herring accounts for the largest share also in coastal fishery. The average catch of coastal fishery in the period 2007-2018 was nearly 11 thousand tonnes. The catches of key fish species and their estimated values are given in Table 2.4. Catch data for 2019 by different fish species and regions of Estonian marine waters can be found in the reports at https://www.envir.ee/sites/default/files/2020.02.01 aruanne 2019 raim kilu.pdf and https://www.envir.ee/sites/default/files/2020.02.01 rannikumeri 2019.pdf, which also include forecasts of catches in the years to come. Predicting the catches of a more distant future is limited by the lifespan of fish and the fact that the abundance of each new generation of fish is only known after the fish of that generation have survived their first winter and their abundance has been scientifically estimated. Given that the management of Estonian fish stocks is based on the principle of sustainability, no major changes in fish catches are foreseen. Fluctuations of catches caused by natural conditions, quotas, market demand and other factors are likely to be of the same magnitude as in the previous period. The current situation of fisheries and development objectives are described in more detail in the draft 'Agriculture and Fisheries Development Plan up to 2030' which can be found at https://www.agri.ee/sites/default/files/content/arengukavad/poka-2030/poka-2030-eelnou-2020-02-21.pdf.

Table 2.3. Estonian fish catches in thousands of tonnes and catch values in millions of euros in the period 2007-2018 (distant-water fishery catches taken in oceans are given for the period 2008-2018) (Source: Ministry of Rural Affairs, Veterinary and Food Board, official publication *Ametlikud Teadaanded*)

Year	2007		2008		2009		2010		2011		2012		2013		2014		2015		2016		2017		2018		2007(2008)-2018	2007-2018
Catch/Value	Catch	Value	Catch	Value	Catch	Value	Catch	Value	Catch	Value	Catch	Value	Catch	Value	Catch	Value	Catch	Value	Catch	Value	Catch	Value	Catch	Value	Average catch	Average value
Trawling	71.7	13.0	70.9	12.5	69.5	12.5	68.3	12.3	53.0	10.1	43.5	8.1	44.9	7.9	44.4	8.0	47.3	8.4	48.9	8.5	53.6	9.2	56.5	9.7	56.0	10.0
Coastal fishery	8.6	4.5	12.6	4.9	14.0	5.4	11.2	4.8	10.4	4.5	8.7	3.9	9.6	5.6	10.3	6.5	12.0	6.4	11.5	6.1	10.8	5.6	10.5	5.2	10.9	5.3
Total Baltic Sea	80.2	17.5	83.6	17.8	83.6	17.9	79.6	17.1	63.4	14.6	52.2	12.0	54.6	13.6	54.6	14.5	59.3	14.8	60.4	14.6	64.5	14.8	67.0	14.9	66.9	15.3
Inland water bodies	2.6	5.3	2.7	5.3	2.8	5.5	2.8	5.5	2.6	5.2	3.0	6.0	2.9	5.7	2.8	5.3	2.6	4.7	3.0	6.0	3.0	5.9	3.2	5.5	2.8	5.5
Total in Estonia	82.8	22.8	86.3	23.0	86.4	23.3	82.3	22.7	66.0	19.8	55.2	18.0	57.4	19.2	57.5	19.8	61.9	19.4	63.5	20.6	67.4	20.7	70.1	20.5	69.7	20.8
Catches from oceans			14.6		10.9		12.7		14.6		12.0		12.0		10.9		11.1		12.0		15.1		17.2		13.0	
TOTAL			**100.9**		**97.3**		**95.0**		**80.6**		**67.2**		**69.4**		**68.3**		**73.0**		**75.5**		**82.6**		**87.3**		**82.7**	

Table 2.4. Catches of key fish species in thousands of tonnes from the Baltic Sea and inland waters, and estimated values of the catches in thousands of euros in the period 2007-2018 based on the average first-sale prices in 2018 (Source: Ministry of Rural Affairs, Veterinary and Food Board, official publication *Ametlikud Teadaanded*)

Species/ Water body	2018	2007		2008		2009		2010		2011		2012		2013		2014		2015		2016		2017		2018		2007-2018	
Baltic Sea	Price	Catch	Value	Catch	Value	Catch	Value	Catch	Value	Catch	Value	Catch	Value	Catch	Value	Catch	Value	Catch	Value	Catch	Value	Catch	Value	Catch	Value	Average catch	Average value
Perch	2.3	0.8	1786.6	0.7	1617.6	0.8	1868.7	0.9	2022.4	0.8	1831.3	0.5	1264.8	1.2	2798.8	1.6	3603.4	1.5	3502.5	1.4	3158.8	1.3	2965.5	1.1	2613.3	1.1	2419.5
Pikeperch	3.4	0.1	339.2	0.1	219.0	0.1	228.3	0.1	250.9	0.1	378.0	0.1	502.2	0.1	417.8	0.2	592.6	0.1	283.9	0.1	364.9	0.1	191.8	0.1	225.5	0.1	332.8
Pike	1.8	0.0	24.4	0.0	28.1	0.0	23.8	0.0	40.6	0.0	57.1	0.0	63.0	0.1	117.3	0.1	116.5	0.1	92.2	0.0	74.0	0.0	71.8	0.1	121.1	0.0	69.2
Herring	0.2	26.1	4438.4	31.8	5412.6	33.2	5638.0	28.9	4906.5	25.3	4305.3	22.0	3748.1	21.9	3729.9	23.1	3932.1	32.3	5494.0	33.8	5740.8	35.2	5976.3	34.8	5909.7	29.0	4936.0
Sprat	0.2	51.0	8671.2	48.6	8258.9	47.3	8040.7	47.9	8136.5	35.0	5946.0	27.7	4708.5	29.8	5066.9	28.5	4844.7	24.0	4072.1	23.7	4026.8	26.5	4512.8	29.6	5036.3	35.0	5943.5
TOTAL		**78**	**15,260**	**81**	**15,536**	**81**	**15,800**	**78**	**15,357**	**61**	**12,518**	**50**	**10,287**	**53**	**12,131**	**53**	**13,089**	**58**	**13,445**	**59**	**13,365**	**63**	**13,718**	**66**	**13,906**	**65**	**13,701**
Inland water bodies																											
Perch	2.3	0.4	840.3	0.8	1740.7	0.8	1878.5	1.2	2800.1	0.8	1783.1	1.1	2476.6	0.9	2117.0	0.8	1832.2	0.8	1922.9	1.0	2357.6	0.7	1568.8	0.6	1306.9	0.8	1885.4
Pikeperch	3.4	0.9	3177.0	0.7	2277.0	0.7	2468.8	0.5	1826.7	0.7	2421.6	0.7	2330.6	0.7	2298.2	0.7	2247.6	0.5	1578.4	0.8	2602.1	0.9	3140.7	0.7	2515.5	0.7	2407.0
Pike	1.8	0.2	313.4	0.1	159.7	0.1	181.0	0.1	150.7	0.1	239.0	0.2	361.4	0.2	385.7	0.2	334.6	0.1	255.5	0.1	254.5	0.1	239.3	0.1	217.4	0.1	257.7
TOTAL		**1**	**4331**	**2**	**4177**	**2**	**4528**	**2**	**4777**	**2**	**4444**	**2**	**5169**	**2**	**4801**	**2**	**4414**	**1**	**3757**	**2**	**5214**	**2**	**4949**	**1**	**4040**	**2**	**4550**

The suitability of Estonian **ports** where it will be possible to combine the landing (processing) of herring and sprat with the landing of rainbow trout in the future must be assessed separately for each port and according to needs. Table 2.5 sets out the Estonian ports where fish catches were landed from trawlers in 2018. In these ports, the conditions and infrastructure are in place to accommodate larger vessels carrying fish and to land larger quantities of fish, which means that they can also be considered suitable for landing fish from fish farms. For the remaining numerous ports, it would be necessary to analyse, for each port, the usability of the port for larger vessels, the existence of the infrastructure needed to land larger quantities of fish, the availability of suitable land connections and the level of investment required in case of problems.

Table 2.5. Landings in Estonian ports of fish caught from the Baltic Sea by trawlers in 2018

County	Place of landing	Landings, t	Proportion (%) of total landings of trawlers	Maximum draught of vessel
Lääne	Dirhami	13,624	27.45	3.7
Saare	Veere	7259	14.63	3.5
Harju	Miiduranna	5001	10.08	12.3
Harju	Meeruse	4172	8.41	6.3
Harju	Paldiski South Harbour	3272	6.59	14
Hiiu	Lehtma	3006	6.06	4.2
Saare	Saaremaa	2617	5.27	9.5
Pärnu	Virtsu	2416	4.87	6.5
Saare	Mõntu	1885	3.80	4
Lääne-Viru	Kunda	1874	3.78	8.6
Saare	Roomassaare	1746	3.52	4.6
Harju	Loksa	1060	2.14	4.5
Lääne	Westmeri	954	1.92	3
Harju	Bekkeri	519	1.05	8.1
Lääne	Rohuküla	146	0.29	4.7
Pärnu	Virtsu fish port	39	0.08	0.8
Harju	Leppneeme fish port	36	0.07	1.4
Harju	Tapurla	0.3	0.00	3.5

The minimum depths of the fairways leading to the main fishing ports and the maximum permissible draughts of vessels are provided on the map at:

https://www.google.com/maps/d/u/0/viewer?hl=et&ll=58.74544504089607%2C24.814989600000104&z=7&mid=1xw73jHS3VTCN5dVofxrnu4ep8SYkOrBU .

Technical data of all fishing ports can be found in the port register at https://www.sadamaregister.ee/SadamaRegister.

Information on companies engaged in **fish processing** is available from the register of the Veterinary and Food Board at https://jvis.agri.ee/jvis/avalik.html#/toitKaitlemisettevotedparing.

3. Mussel cultivation

Mussels are mostly cultivated in the water column, using various types of floating substrates which are suspended in the water column and fixed to the seabed with the help of weights. These are often smooth ropes (e.g. Nylon-6 ropes with a diameter of 0.5-1 cm), looped ropes (e.g. Donaghys ROM 1407 – Aqualoop Crop HM Rope) or ribbon-shaped ropes. The use of trawl nets is also common. This method of cultivation, using floating substrates, is considered to be the most efficient because predators do not have access to the mussels and, due to warmer and more nutritious water, mussels grow faster than in near-bottom water. As there are essentially only two key mussel species in Estonian marine waters that attach themselves to substrates, floating substrates need to be placed in a place suitable for the growth of these aquaculture species. When the substrate and the growth depth are right, the desired species adheres to the suspended substrate.

The results of the BBG (Baltic Blue Growth) project (https://www.submariner-network.eu/balticbluegrowth) showed that mussel cultivation in Estonia can be efficient, economically viable and contribute to the removal or large amounts of nutrients from the sea. Thorough environmental monitoring of all six mussel farms in the Baltic Sea did not identify any significant negative environmental impacts during three years. However, negative environmental impacts cannot be ruled out for very large mussel farms (with an area of over 1 km^2), but the establishment of so large farms is not yet realistic in Estonia, given the technologies available; neither is it reasonable from the point of view of nature conservation. In addition to the above, the content of toxins in mussels in the Estonian marine waters is very low, which is why this resource can be used for human consumption and/or as animal feed. Despite these positive circumstances, there are currently no sizeable mussel farms in Estonia.

In the course of the project 'Preparation of regional plans for aquaculture to control potential environmental pressure' (University of Tartu, 2019b), the production potential of our more promising aquaculture mussel species in Estonian marine waters was modelled. Blue mussel *Mytilus edulis/trossulus* is our most important potential aquaculture species. The growth cycle of blue mussels in mussel farms in our coastal sea is from one and a half to two years, and therefore the growth potential of mussels is traditionally expressed for that period. The modelling of mussel growth rate is based on measurements made in mussel farms in the Baltic Sea and thus the estimates obtained are close to the real farming potential.

The spatial variability of mussel growth rate is most affected by seawater salinity, current velocity, water temperature, and abundance of phytoplankton. The growth rate of mussels is higher in saltier and warmer waters, which are characterised by rapid water movement and moderate levels of phytoplankton (Figure 3.1). The best places for cultivating mussels in the Estonian coastal sea are located in the Baltic main basin west of the islands of Hiiumaa and Saaremaa (Figure 3.2).

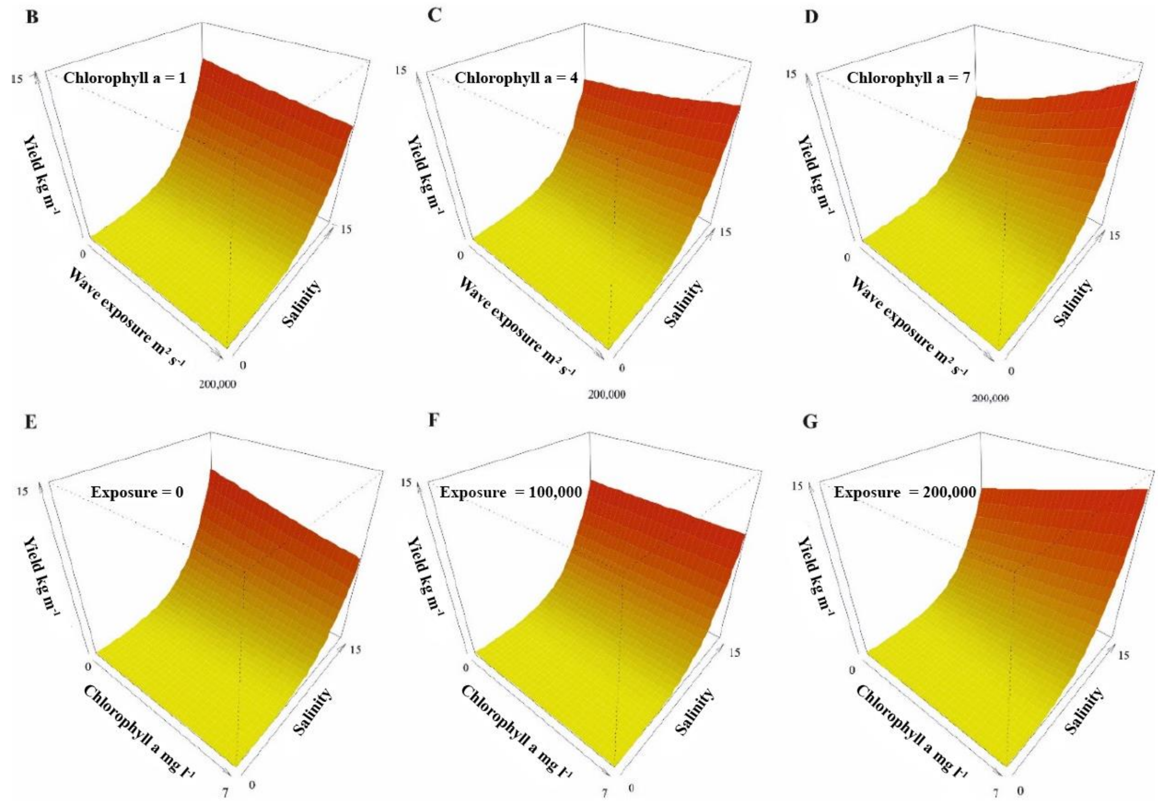


Figure 3.1. Functional relationships between different environmental conditions and the yield of blue mussels (kg m^{-1} in two years) (University of Tartu, 2019b).

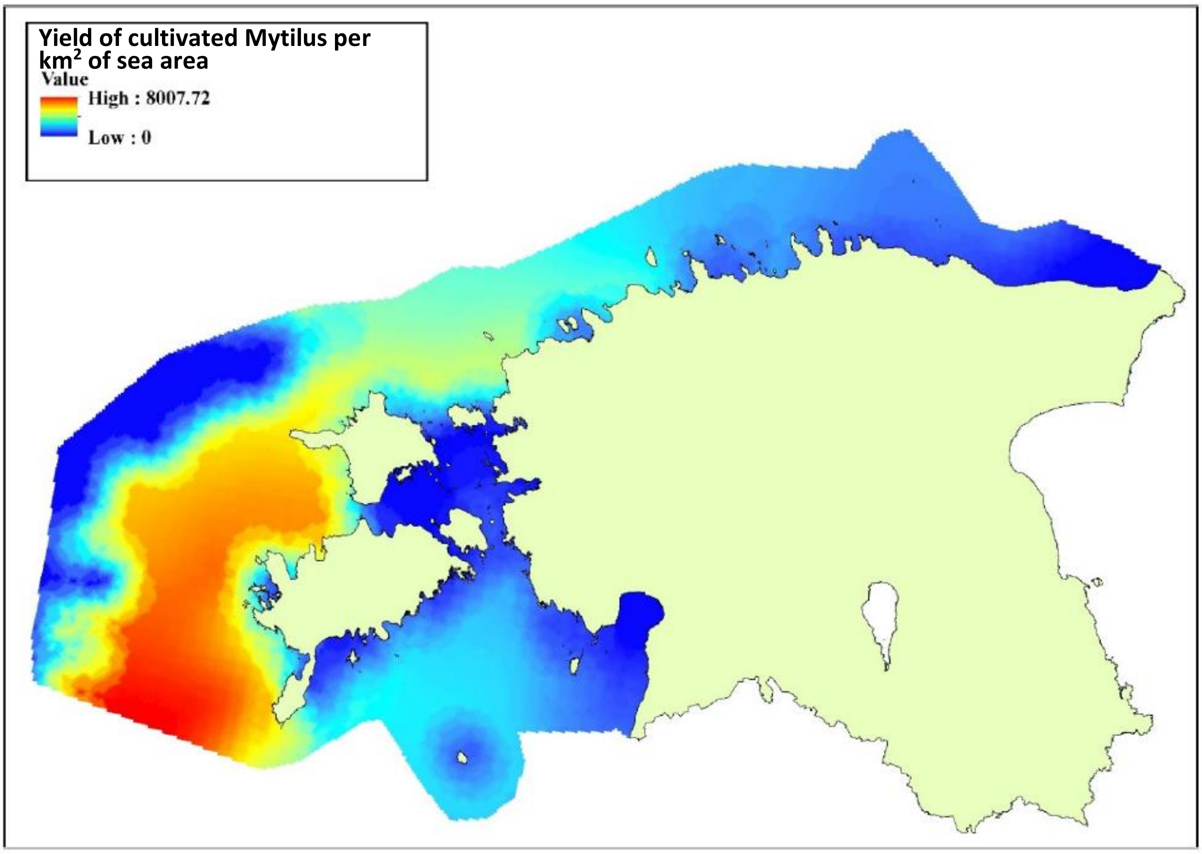


Figure 3.2. Mussel yield in potential mussel farms, calculated for two-year growth period (tonnes of wet weight per km^2 of sea area) (University of Tartu, 2019b).

In addition to blue mussel, cultivation of zebra mussel (*Dreissena polymorpha*) has previously been piloted for water purification purposes in the Szczecin Lagoon (Poland) and in Pärnu Bay. The results so far are promising, but in contrast to blue mussel, there are still no suitable large-scale farm solutions available for zebra mussel cultivation, which is why the modelled values of zebra mussel growth potential are theoretical (similar to the algae growth rate calculations described in the following sections). Thus, it is economically reasonable to cultivate zebra mussels if the state guarantees the commissioning of the removal of nutrients from seawater with the help of mussel farms.

Modelling showed that zebra mussels grow fast at moderate and high concentrations of phytoplankton. When the concentration of phytoplankton is low, the food limits the growth of mussels; on the other hand, when the concentration of phytoplankton is too high, the filtering "apparatus" of mussels becomes clogged and their feeding is disturbed. The higher the water temperature, the faster the growth of zebra mussels. In addition, the growth rate of mussels is significantly affected by salinity: zebra mussels grow faster at lower salinity (Figure 3.3). Potential mussel farming areas are located in low-salinity bays, which are characterised by relatively good water exchange, e.g. Pärnu Bay and Narva Bay (Figure 3.4). As the natural range of the mussel is located south of the Baltic Sea, in the Black Sea region, the growth rate of mussels is higher in warmer marine waters. Therefore, the projected efficiency of mussel farms is the highest in the Gulf of Riga region.

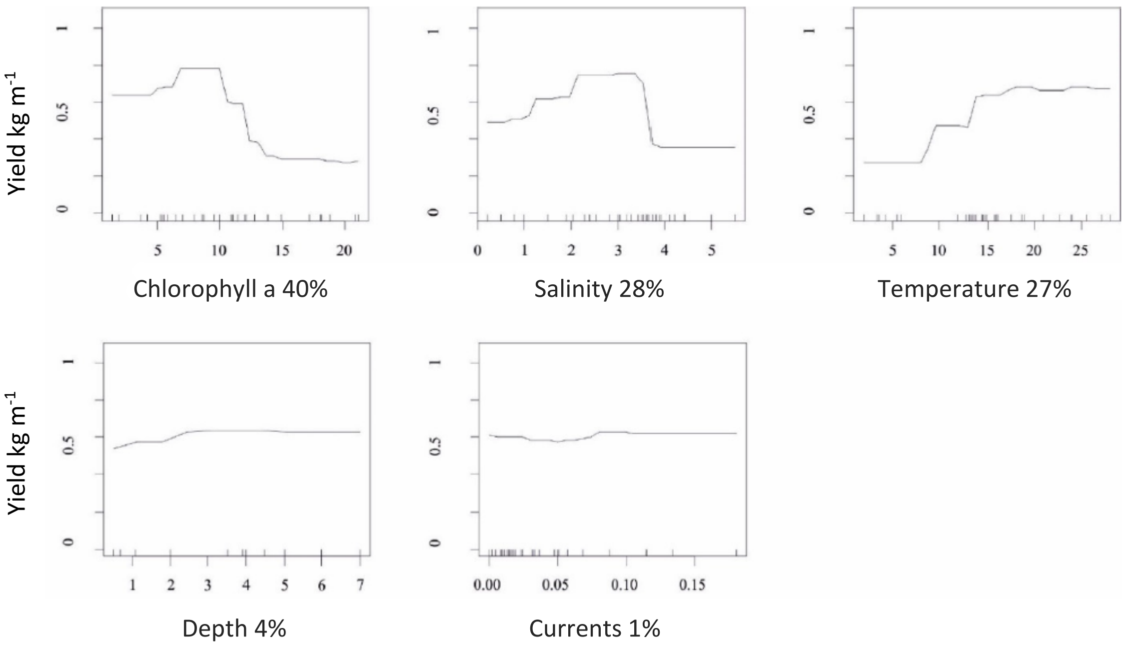


Figure 3.3. Functional relationships between different environmental conditions and the yield of zebra mussels (kg m^{-1} in two years). Below each figure, the relative importance of the environmental parameter in describing the mussel yield is indicated (University of Tartu, 2019b).

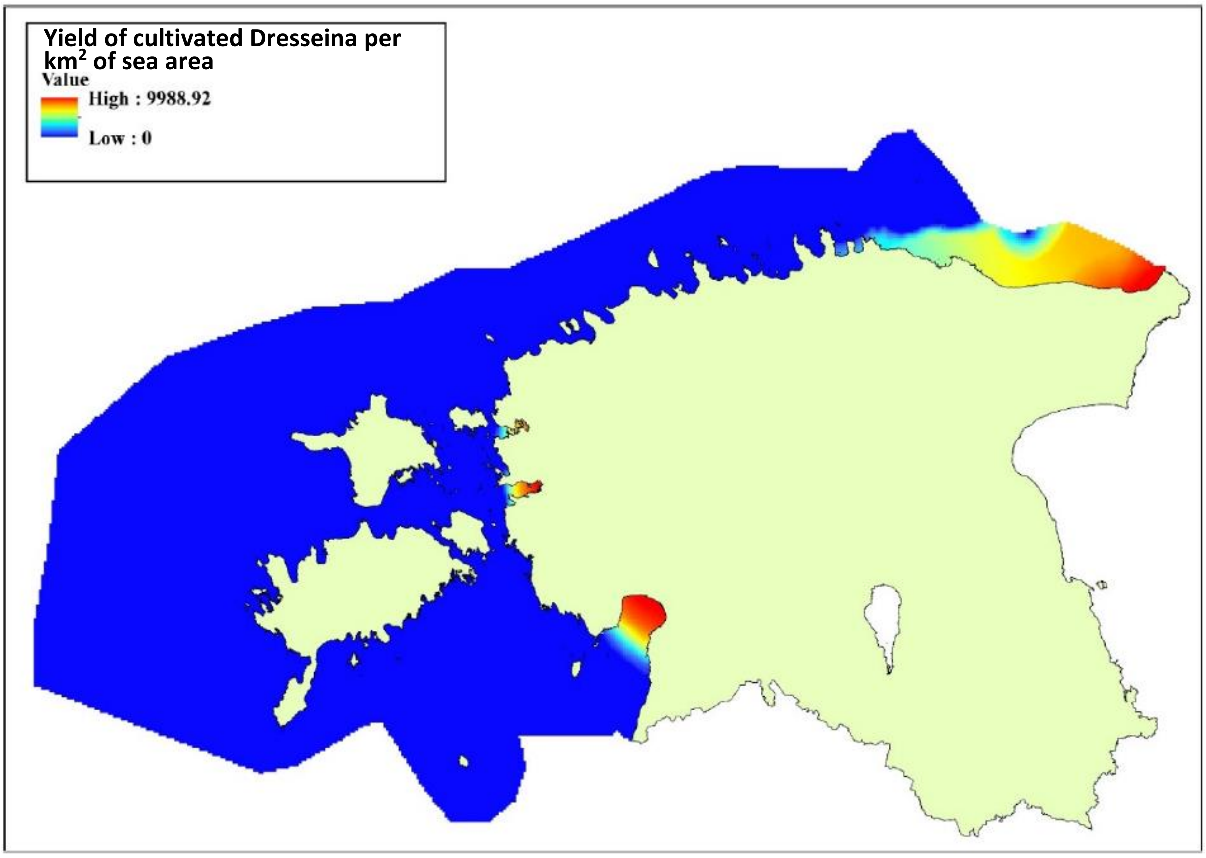


Figure 3.4. Zebra mussel yield in potential mussel farms, calculated for two-year growth period (tonnes of wet weight per km^2 of sea area) (University of Tartu, 2019b).

4. Macroalgae cultivation

Algae species larger than 2 cm are considered macroalgae (seaweeds). There are more than 550 species of macroalgae in the Baltic Sea. The spread of macroalgae in the Baltic Sea is primarily related to salinity, the presence of a suitable substrate, exposure and water transparency. Each species needs a set of certain ecological factors for its life. Due to the low salinity of water, the species diversity of seabed vegetation in the Estonian coastal sea is generally quite low. Up to 80 species of macroalgae and higher vegetation can be found in our waters. Around 20 species of these are the most common. Some environmental factors (substrate, wave effects, nutrient concentration, and availability of light) can be controlled and modified with the help of certain aquaculture technologies, but for some environmental parameters (such as seawater salinity) this is practically impossible. Consequently, as far as aquaculture is concerned, it makes sense to cultivate the species that are already widespread in the Baltic Sea.

In general, macroalgae that grow very fast, use the most nutrients and are able to compete for resources with other species are best suited for aquaculture. In the course of the project 'Preparation of regional plans for aquaculture to control potential environmental pressure' (University of Tartu, 2019b), a list of economically promising macroalgae species which are suitable for mitigating environmental risks and have an economic potential for cultivation in the Estonian coastal sea was compiled. Promising macroalgae species for aquaculture include *Fucus vesiculosus*, *Furcellaria lumbricalis*, *Cladophora glomerata* and *Ulva intestinalis*. For these species, the relationships between the environmental variables and the production of macroalgae were modelled and the potential growth rates of the species in the Estonian marine waters were projected. In the parts of the Baltic Sea that are less salty, incl. Estonian waters, economic activities in the field of algae cultivation have not yet started, and individual experimental farms do not amount to a phase of development of the sector. It would be necessary to set up pilot algae and mussel farms in the Estonian marine waters in order to assess the farms' economic viability and effectiveness in removing nutrients from the marine environment (incl. assessing the volume of removed nutrients and the spatial extent of the impact). In addition, it is necessary to assess the potential negative environmental impact of such farms. Preference should be given to smaller algae and mussel farms of a few hectares scattered throughout the sea. The productivity of smaller farms per unit area is higher, smaller farms can remove significantly more nutrients from the marine environment with the same amount of investment than individual large farms, and the potential negative environmental impact of small farms is significantly lower (University of Tartu, 2019b).

In the following, we describe the species of macroalgae that are more suitable for aquaculture in our marine waters. ***Furcellaria*** spreads naturally throughout the North Atlantic region and is also a very common macroalgae species in Estonian waters. It exists in two forms – the most common form is the attached *Furcellaria*, which finds its habitat at a depth of 5-10 m on a hard substrate in moderately or completely exposed coastal waters. The other form is unattached *Furcellaria*, which can only spread in hydrologically suitable seabed conditions (usually within an archipelago, on a soft seabed). This form of *Furcellaria* is found primarily in the Väinameri Sea region, where it is also harvested commercially in Kassari Bay. The natural spread of *Furcellaria* has been described quite thoroughly and its distribution can be modelled. *Furcellaria* is a fairly resilient species and it also generally tolerates lower salinity (up to 3-4 g/kg).

The life cycle of *Furcellaria* is complex and consists of several stages (Figures 4.1 and 4.2). In the Southern Baltic, which is characterised by higher salinity, both sexual and asexual reproduction of *Furcellaria* have been identified. So far, only two types of asexual reproduction have been described in the Northern Baltic – tetraspore propagation and thallus fragmentation. Fragments of the plant's thallus have the ability to reattach themselves to the substrate. However, these reproductive processes are not completely clear at the moment. Several studies have been conducted in Estonia, where attempts were made to propagate *Furcellaria* both from fragments and with the help of tetraspores. So far, however, these efforts have not borne fruit and it has not been possible to artificially introduce *Furcellaria* into the substrate.

Furcellaria is so far the only **commercially exploited macroalgae species** in Estonia. It is used to produce gelling polysaccharides. It is collected after it has been washed up on the shore, and trawled from the sea in the Väinameri Sea region. The use of the resource began in the late 1960s already. According to statistics, a total of 653.9 tonnes (wet weight) of *Furcellaria* has been collected from the Väinameri Sea in two years (2014-2015) (University of Tartu, 2019a).

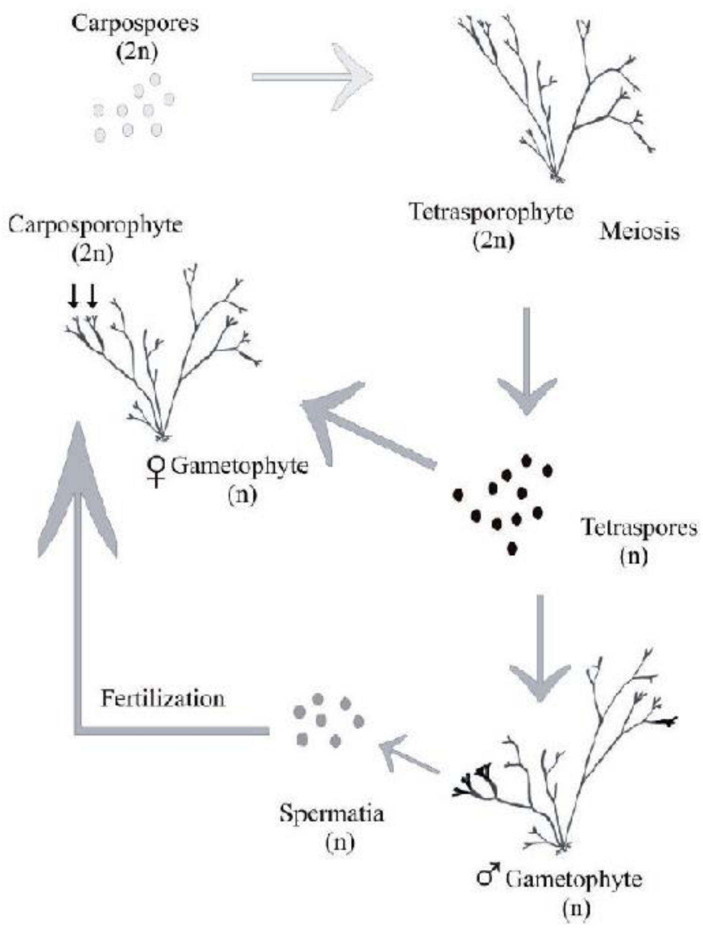


Figure 4.1. Life cycle of *Furcellaria*. In the case of sexual reproduction, the life cycle of *Furcellaria* consists of three phases: tetrasporophyte, gametophyte and carposporophyte (Kostamo, 2008).

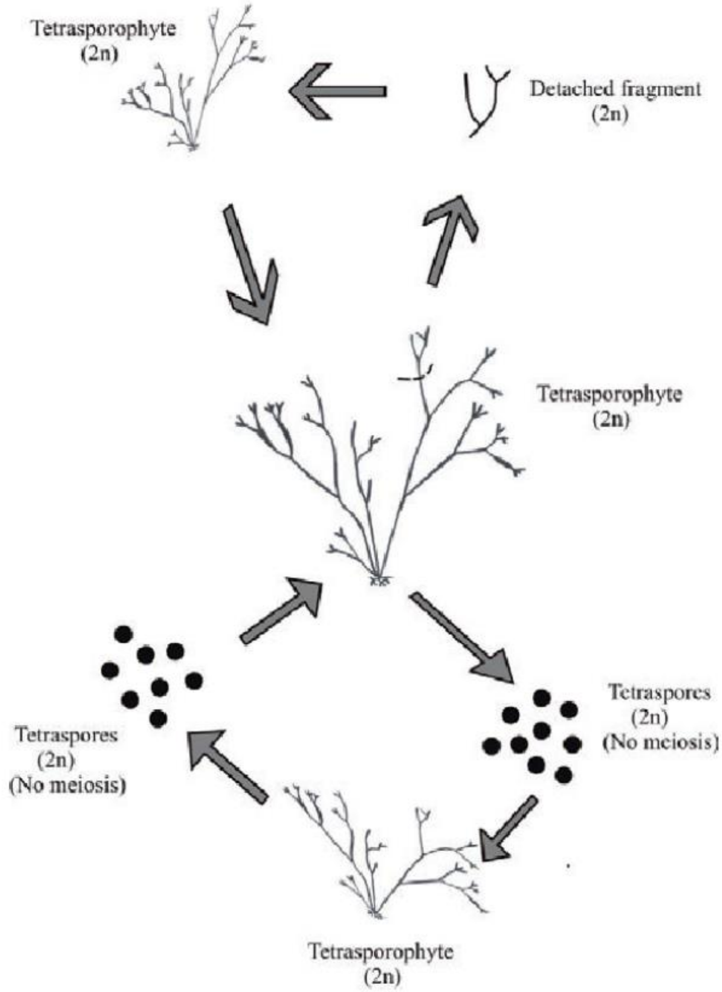


Figure 4.2. Asexual reproduction of *Furcellaria* can take place either through thallus fragmentation or tetraspore propagation (Kostamo, 2008).

Bladderwrack is one of the most common species in the Baltic Sea. It inhabits all the regions of the Baltic Sea where the salinity is higher than 3-4 g/kg and there is a suitable attachment substrate in the photic zone. Bladderwrack spreads in shallower sea areas than *Furcellaria*. Different forms of bladderwrack are known to occur in the Baltic Sea in areas that differ either in terms of hydrodynamic conditions or water properties.

The reproductive cycle of the bladderwrack is well known, but it is also quite complex. The reproduction of bladderwrack is mostly sexual (Figure 4.3). Cases of artificial reproduction of bladderwrack have been rare (Forslund & Kautsky, 2013). The ability of vegetative reproduction of attached forms of bladderwrack has been described in few cases and mostly under experimental conditions (Schagerström, 2013). However, bladderwrack has been described to have a very good regenerative ability (for example, after ice damage).

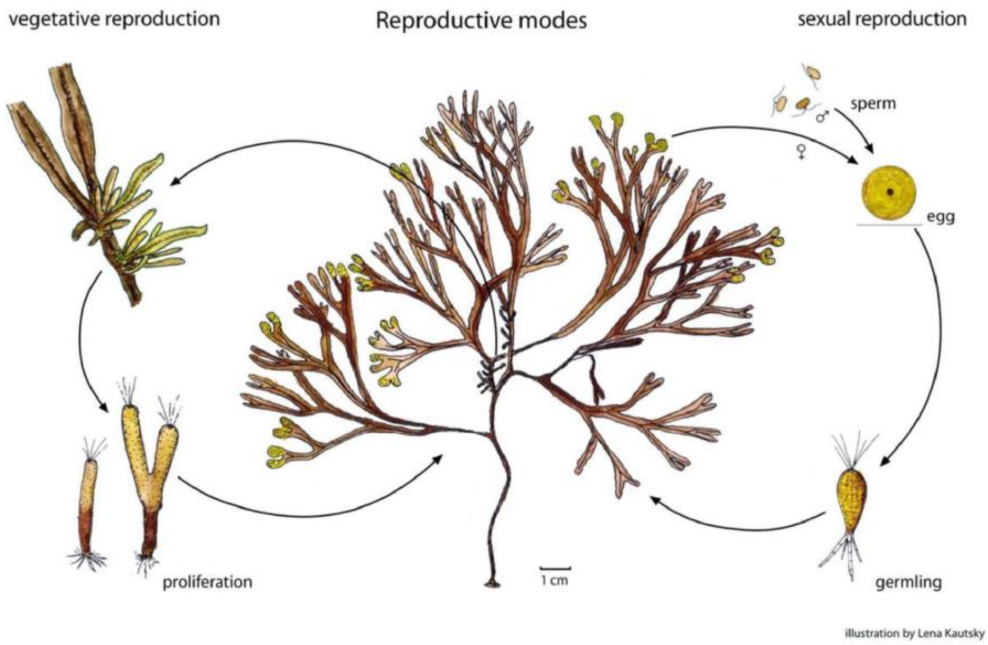


Figure 4.3. Asexual and sexual reproduction of bladderwrack (Schagerström, 2013).

The green alga ***Ulva intestinalis*** is one of the most promising aquaculture species, as its growth is very fast. The species inhabits a large part of the Baltic Sea and is also found in freshwater. The species has a simple reproductive cycle (Figure 4.4). Freshwater *Ulva* farms are run in Germany, the Netherlands and Asian countries. Due to its delicate structure, this species of algae can be cultivated primarily in tanks, less so in open water. Technological solutions for cultivating *Ulva* in tanks are available, but they are still in the phase of being tested in Estonia at the moment. When cultivating *Ulva*, the plant does not have to attach to a substrate but can float in the water column. This feature makes it much easier to cultivate the species.

Under the auspices of the Marine Institute of the University of Tartu, the project 'Purification of the effluent of seawater-based fish farms through the cultivation of macroalgae' is being carried out (the project is scheduled to end in March 2021). While the main focus of this project is not the cultivation of *Ulva*, this species of algae is used as one of the test species to study the removal of nutrients from fish farming effluent. The experiments carried out in the course of the project have yielded good results and *Ulva* is probably going to be the species that can be effectively used to treat the effluent of fish farms. More information on this project can be found in Chapter 8 of this report.

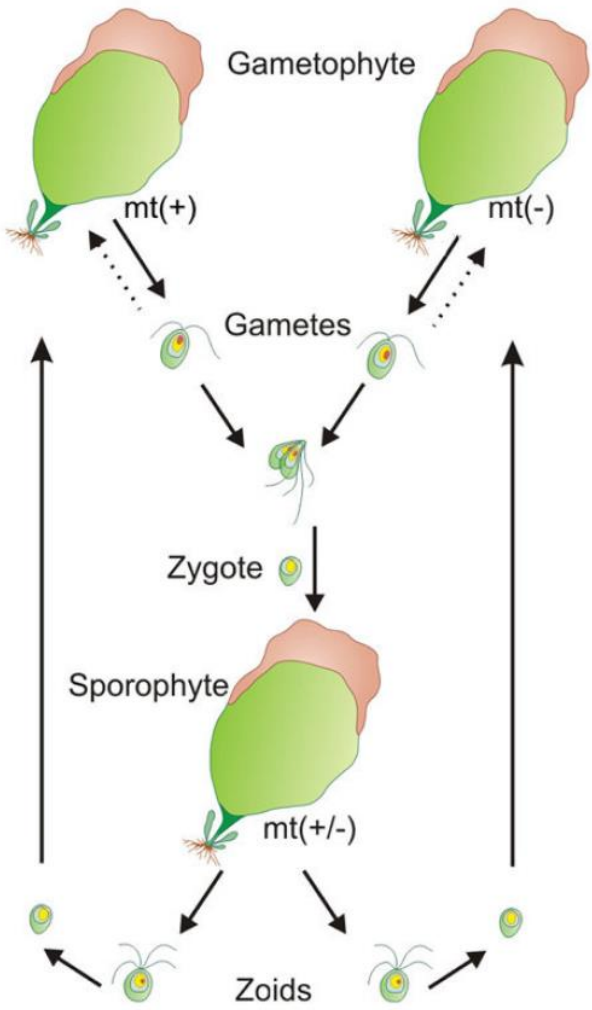


Figure 4.4. Life cycle of *Ulva intestinalis* (Wichard, 2015).

The green alga ***Cladophora glomerata*** spreads in brackish water and freshwater, grows rapidly and may therefore be suitable for use in aquaculture. The reproduction cycle of *Cladophora glomerata* is largely similar to that of *Ulva*. In the wild, *Cladophora glomerata* is active throughout the summer. The species does not grow while being freely suspended in the water column and needs an attachment substrate for growth.

Figures 4.5-4.7 show the best areas for potential cultivation of promising algae and mussel species in the Estonian marine waters (University of Tartu, 2019b). Due to the species' different preferences for living environment, different marine areas are suitable for the cultivation of different species. As most of the studied aquaculture species are of marine origin, their growth rates are also the highest in the salty water of the Baltic main basin. It is important to emphasise that these maps represent estimates of the modelled growth rates of algae and mussels, which means that the application of different technologies on real farms may give results that significantly differ from the modelling results.

Figure 4.5. The best areas for cultivation of aquaculture species that remove nutrients from the marine environment (algae and mussels) in the Gulf of Riga and the Väinameri Sea (University of Tartu, 2019b).

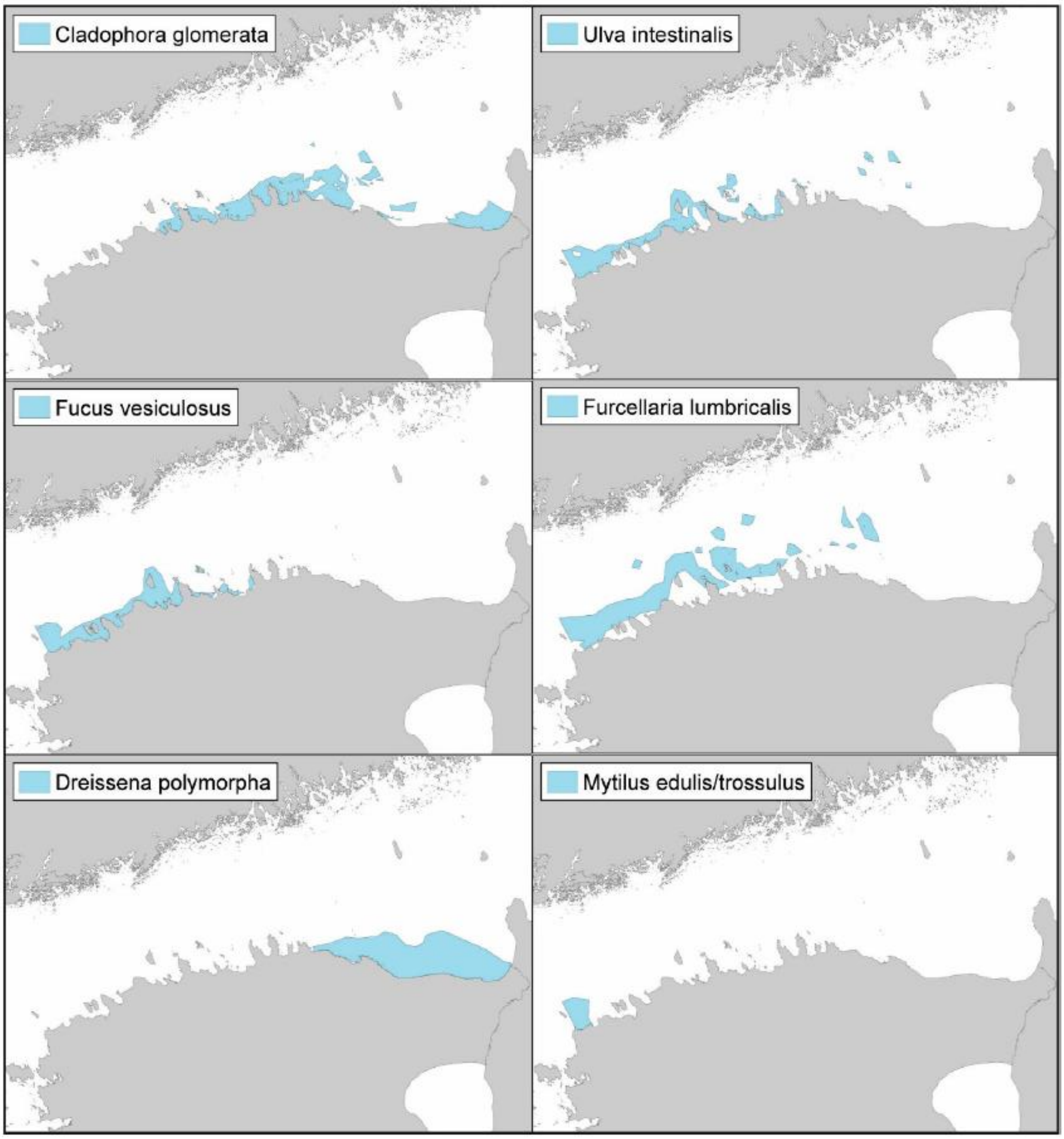


Figure 4.6. The best areas for cultivation of aquaculture species that remove nutrients from the marine environment (algae and mussels) in the Gulf of Finland (University of Tartu, 2019b).

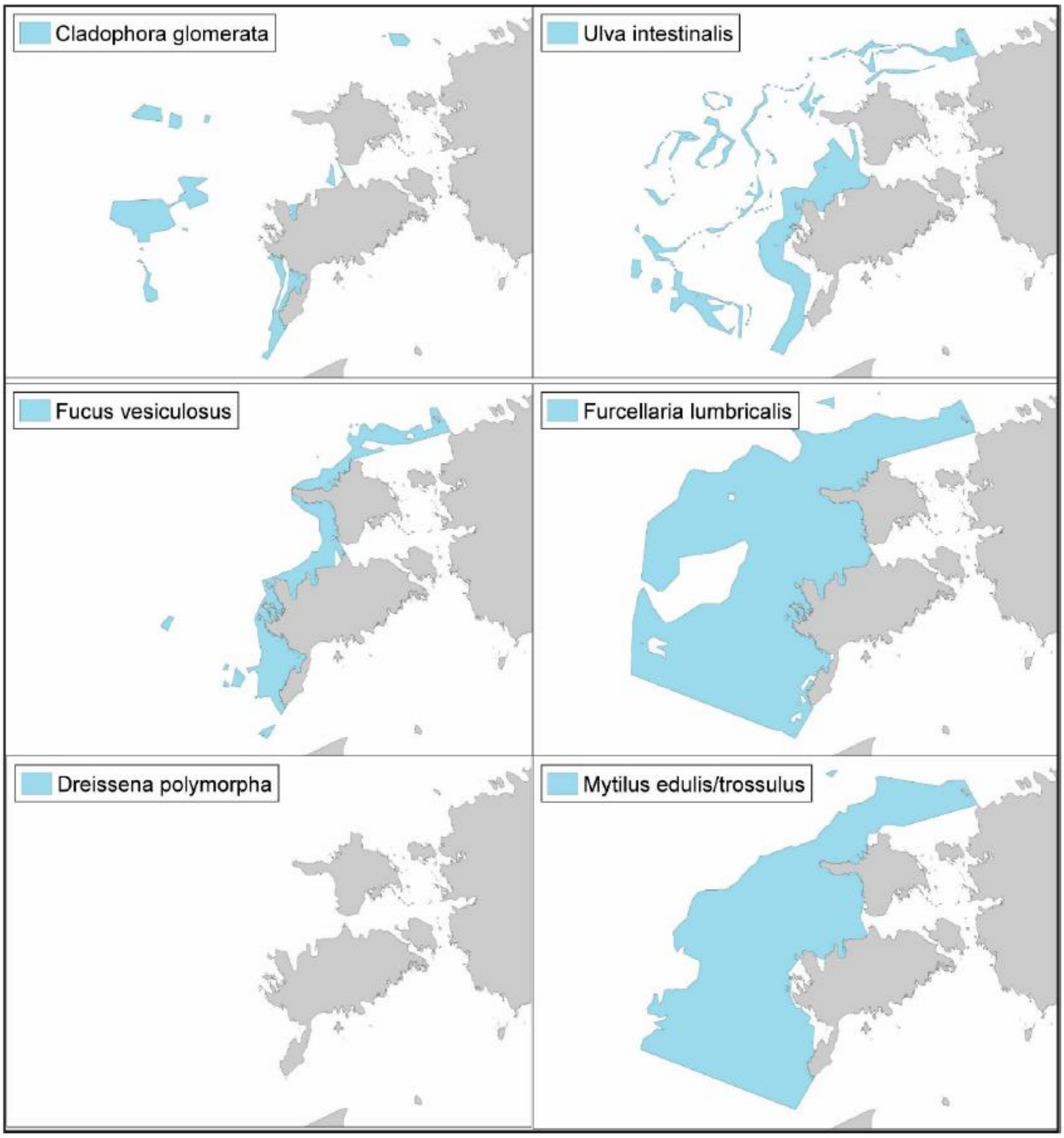


Figure 4.7. The best areas for cultivation of aquaculture species that remove nutrients from the marine environment (algae and mussels) in the Baltic main basin (University of Tartu, 2019b).

At present, *Furcellaria lumbricalis* is the only commercially used species of macroalgae in Estonia. It is either collected on the shore or trawled from the seabed. The only user of the algae mass in Estonia is Est-Agar AS. The quantities of algae collected and processed are in the order of 1000 tonnes of wet weight per year. The annual production of furcellaran has averaged between 50 and 60 tonnes in recent years (Fisheries Information Centre & SakiConsult OÜ, 2018). The collection and processing of other species in very small quantities has also been tried (for example, the collection of bladderwrap for use in cosmetics as well as for food).

Based on the experience of neighbouring countries, large vessels are generally not used for maintaining algae and mussel farms and for collecting the harvest. For example, rafts with a draught not exceeding 1.5 m are used in Swedish mussel farms. Mussels are collected at sea into bags with a capacity of around 2 m^3, and a small winch/crane is enough to unload the bags in the port. Thus, algae and mussel farms do not require any specific technical solutions in the port, and most of the small ports are suitable for servicing algae and mussel farms.

5. Legislation

General principles

Abbreviations

WA	Water Act
BC	Building Code
PA	Planning Act
EIAMSA	Environmental Impact Assessment and Environmental Management System Act
GECA	General Part of the Environmental Code Act
IADCA	Infectious Animal Disease Control Act
GEACA	General Part of the Economic Activities Code Act
CPTRA	Consumer Protection and Technical Regulatory Authority
ARIB	Agricultural Registers and Information Board
VFB	Veterinary and Food Board
AFDP 2030	Agriculture and Fisheries Development Plan up to 2030
EIA	Environmental impact assessment

When starting aquaculture, the Water Act is the central piece of legislation. The new Water Act entered into force in 2019. The previous Water Act was from 1994. An important change is that it is no longer necessary to apply for a water permit for activities that are not hazardous to the aquatic environment. Activities with a lower impact must be registered with the Environmental Board, but this is a simpler procedure than applying for a water permit. The definition of a water body has also been clarified – lagoons of wastewater treatment plants and ponds and pools for aquaculture are no longer regarded as water bodies.

The Regulation 'Water protection requirements for aquaculture, limit values for pollutant content of effluent water from aquaculture, and requirements for discharge and monitoring of such water' was established in April 2020 under section 131 (2) of the Water Act. The new Water Act treats water discharged from aquaculture differently from wastewater, and therefore a separate authorisation provision was also established for the Regulation. The Regulation provides for a change in the determination of the quantities of pollutants generated and in the calculation of the pollution charge if the developer exceeds the quantities of pollutants permitted by the water permit. Previously, the pollutant content of water discharged from fish farms was determined on the basis of analyses performed on water samples. Based on the differences between the respective parameters of the samples of water flowing in and out of the farm, pollution charges were calculated according to the Environmental Charges Act. The explanatory memorandum to the new Regulation states that this is a major fundamental change: a feed-based calculation methodology will be used to determine the pollution from aquaculture farms. This approach allows a more accurate assessment of the amount of pollutants discharged from the farm into the environment and thus the environmental impact of the farm. This improves the control of point sources and reduces the impact of pollutants on the environment. The change in the methodology for determining the quantities of pollutants serving as the basis for calculation of pollution charges is expected to also have an economic impact on farm owners. The aim is to encourage farm owners to use efficient feeds that have a minimal environmental impact (load of pollutants from the farm). On the other hand, it is also beneficial for farm owners because with the same permissible load of pollutants they can produce more by enhancing the efficiency of management (Ministry of the Environment, 2020).

Aquaculture in the sea and in public water bodies

The chapter below provides an overview of which permits need to be obtained and which authorities need to be contacted if there is a desire to start aquaculture in a public water body, incl. fish farming using net cages in coastal waters. The list of public water bodies is provided in section 23 of the Water Act. This chapter also advises on the first steps to be taken in order to obtain the necessary permits, but the overview does not contain all the details.

Consumer Protection and Technical Regulatory Authority (CPTRA)

- Superficies licence (sections 217-229 of the Water Act)
  - An application for a superficies licence must be accompanied by a map of the location of the planned construction works and of the civil engineering works required for servicing the construction works, including submerged cable lines, and other documents relevant to encumbering a public water body with the construction works (section 218 (4) of the Water Act).
  - When deciding on the issuance of a superficies licence, the CPTRA takes into account the principles, guidelines and conditions provided in the Maritime Spatial Plan (see Chapter 4).
- Building notice: in order to build a construction works that has no permanent connection to the shore, the applicant has to submit a building notice (section 106 (2) of the Building Code).
- Building permit (sections 107-109 of the Building Code). According to section 108 (2) of the Building Code, an application for a building permit for a construction works that has no permanent connection to the shore has to be submitted together with an application for a superficies licence or with a superficies licence. If an application for the building permit is submitted together with an application for a superficies licence, proceedings concerning the issuance of the building permit are suspended until the superficies licence is issued.
- Use and occupancy notice and use and occupancy permit (sections 110-113 of the Building Code): required for using a construction works not permanently connected to the shore.

Environmental Board

- Registration of activities involving a risk to the aquatic environment (sections 196-202 of the Water Act) or water permit (sections 186-195 of the Water Act). In the case of several (spatially or technologically) related activities, it is possible to include all the relevant activities in one environmental permit (section 41 (4) of the GECA). It is also possible to apply for the registration of spatially or technologically related activities involving a risk to the aquatic environment together, i.e. in one document (section 197 (4) of the Water Act).

The **local authority** is the competent authority to permit the building of a construction works that has a permanent connection to the shore or that is functionally connected to the shore (section 106 (1) of the Building Code; sections 107 (2), 110 (1), 111 (1) of the Building Code).

- Building notice (section 106 of the Building Code)
- Building permit (sections 107-109 of the Building Code)
- Use and occupancy notice and use and occupancy permit (sections 110-113 of the Building Code)

Environmental impact assessment

- According to section 7 of the EIAMSA, a development consent is a building permit or a use and occupancy permit of a building; an integrated environmental permit or an environmental permit; or a superficies licence.
- In the case of activities specified in section 6 (2) of the EIAMSA and Government of the Republic Regulation No. 224 of 29.08.2005 on the 'Detailed list of activities for which a preliminary assessment of the need for environmental impact assessment must be provided', the authority issuing a development consent (e.g. the CPTRA in the case of a superficies licence) has to provide a preliminary assessment of environmental impacts and decide to initiate or not to initiate an environmental impact assessment pursuant to section 11.
- In the case of activities specified in section 6 (1) of the EIAMSA, the authority issuing a development consent will review the application for the development consent and decide to initiate or not to initiate an environmental impact assessment (section 11 (2) of the EIAMSA).
- The person carrying out the environmental impact assessment must hold a licence for environmental impact assessment (section 14 of the EIAMSA).

Aquaculture in freshwater

This chapter provides an overview of which permits need to be obtained and which authorities need to be contacted if there is a desire to start aquaculture in freshwater, incl. fish farming in a pond or pool. This chapter also advises on the first steps to be taken in order to obtain the necessary permits, but the overview does not contain all the details.

Environmental Board

- Registration of activities involving a risk to the aquatic environment (sections 196-202 of the Water Act) or water permit (sections 186-195 of the Water Act). In the case of several (spatially or technologically) related activities, it is possible to include all the relevant activities in one environmental permit (section 41 (4) of the GECA). It is also possible to apply for the registration of spatially or technologically related activities involving a risk to the aquatic environment together, i.e. in one document (section 197 (4) of the Water Act).

Local authority

- Building permit or building notice and, in certain cases, building design documentation (sections 35-46 of the Building Code; Annex 1 to the Building Code)
- Use and occupancy notice or use and occupancy permit (sections 47-57 of the Building Code; Annex 2 to the Building Code)

Environmental impact assessment

- According to section 7 of the EIAMSA, a development consent is a building permit or a use and occupancy permit of a building; an integrated environmental permit or an environmental permit; or a superficies licence.
- In the case of activities specified in section 6 (2) of the EIAMSA and Government of the Republic Regulation No. 224 of 29.08.2005 on the 'Detailed list of activities for which a preliminary assessment of the need for environmental impact assessment must be provided', the authority issuing a development consent (e.g. the CPTRA in the case of a superficies licence) has to provide a preliminary assessment of environmental impacts and decide to initiate or not to initiate an environmental impact assessment pursuant to section 11.
- In the case of activities specified in section 6 (1) of the EIAMSA, the authority issuing a development consent will review the application for the development consent and decide to initiate or not to initiate an environmental impact assessment (section 11 (2) of the EIAMSA).
- The person carrying out the environmental impact assessment must hold a licence for environmental impact assessment (section 14 of the EIAMSA).

Aquaculture: starting production

In order to keep aquaculture animals, the keeper has to enter the required data in the ARIB's register of farmed animals. Data on farming buildings and facilities and areas designated for keeping animals must also be entered in the register of farmed animals. If it is desired to commence economic activities in a field that is subject to an activity licence, an application for the activity license must be submitted in the register of farmed animals before commencing the economic activities. There are three ways to enter data in the register: ARIB's self-service environment, digitally completed and digitally signed application sent by e-mail, or paper application sent by regular post. More information can be found on the ARIB's website (ARIB, 2020).

Agricultural Registers and Information Board (ARIB)

- **Registration in the Register of Farmed Animals** (sections 10-11 of the IADCA; Statutes of the Register of Farmed Animals): https://www.pria.ee/registrid/alustavale-kliendile
- **Registration of the place of business in the Register of Farmed Animals**: https://www.pria.ee/registrid/tegevuskoha- registreerimine
- **Application for an activity licence in the Register of Farmed Animals**: https://www.pria.ee/registrid/loakohustus

Once the application for an activity license together with the required documents and data has been entered in the ARIB's Register of Farmed Animals, the VFB can start processing the application for the activity license.

Veterinary and Food Board (VFB)

- Activity license (sections 191-195 of the IADCA, sections 16-20 of the GEACA): https://vet.agri.ee/et/loom-soot/kalad-ja-vahid/tegevusloa- taotlemine-vesiviljelus
- **Notice of economic activities (feedingstuffs and feeding):** an animal keeper who markets animal

products derived from animals and/or produces feed for their animals and/or sells cereals, hay or silage must submit a notice of economic activities. In order to declare economic activities, a relevant form must be submitted directly to the VFB or online at https://portaal.agri.ee/epm-portal-ng/esileht.html. By way of derogation, an animal keeper need not be registered in the feed register if the amount of production derived from animals is small (up to 100 kg of fish per day) and it is marketed directly only to final consumers.

Aquaculture: shortcomings in legislation

The lion's share of Estonian fish farming production comes from freshwater farms. Only one company is currently farming fish in net cages at sea. Thus, there are elements in the legislation related to marine aquaculture that need to be reviewed.

- Mussel and algae cultivation can be combined with fish farming. In this integrated multitrophic aquaculture, mussels and algae use the nutrients generated by the metabolism of fish feed (European Commission, 2018). **There is currently no legislation specifically addressing multitrophic aquaculture.**
- Algae, mussel and fish farming are, according to law, almost equivalent to the construction of wind farms, although the specifics of these activities are very different. In this situation, it is difficult to plan and invest in aquaculture. **More targeted legislation** would be needed to develop the aquaculture sector and facilitate access to it.
- **Issues related to superficies licences and auctions**. Section 219 of the Water Act provides the conditions related to the commencement of the procedure concerning a superficies licence. If there are no circumstances precluding the commencement of the procedure for the issuance of a superficies licence, the CPTRA will publish a notice in the official publication *Ametlikud Teadaanded*, in at least one national daily newspaper and on its website before commencement of the procedure. Within 20 days as of the publication of the notice, other interested persons have the right to submit their own application for a superficies licence for encumbering the same public water body part with construction works. If several applications are submitted to the competent authority in respect of one and the same area of a public water body and there are no grounds for refusal to issue the superficies licence as provided for in section 223 of the Water Act, the procedure for the issuance of the superficies licence will be commenced on the basis of the application that best meets the social and economic needs of Estonian society as a whole, national strategic development plans and the spatial plans for the region. Section 220 (2) of the Water Act provides that if, in the case of several applications for a superficies licence, it is not possible to make a decision due to the lack of adequate considerations, the competent authority will organise a competition by written auction among the applicants in order to commence the procedure for the issuance of a superficies licence. Subsection (10) of the same section states that the procedure and conditions for organising such competitions will be established by a regulation of the minister responsible for the field. There is currently no such regulation and therefore no conditions have been laid down for conducting auctions. In addition, it is worth noting that obtaining the right of superficies as a result of such an auction does not automatically provide a basis for economic activities, and an environmental impact assessment must also be carried out.

6. Maritime spatial planning

On 25 May 2017, the Government of the Republic initiated national **maritime spatial planning** for the Estonian marine waters in their entirety, i.e. the internal sea, the territorial sea and the exclusive economic zone, and an **assessment of the impact of the spatial plan** (Ministry of Finance, 2020). The aim of maritime spatial planning is to agree on the principles of the use of Estonian marine waters in the long run in order to contribute to the achievement and preservation of good status of the marine environment and to promote the maritime economy. The plan specifies in which regions and under which conditions activities may be carried out in marine waters. In the future, the established maritime spatial plan will serve as a basis for making various decisions authorising the use of marine waters for both ministries and agencies, and will also be the basis for entrepreneurs, investors, local authorities and coastal communities in planning their activities. The establishment of the planning solutions for the Estonian maritime spatial plan is scheduled to take place in October 2020 (Ministry of Finance, Hendrikson&KO, 2020a). The following is an excerpt from the Explanatory Memorandum to the Maritime Spatial Plan regarding fish, mussel and algae farming.

The Maritime Spatial Plan (Ministry of Finance, Hendrikson 2020a) does not identify suitable areas for **fish farming**, as the technology for offshore fish farms is still being developed and therefore the designation of suitable areas may unreasonably restrict the development of the blue economy that takes into account environmental conditions. The establishment of fish farms in unsuitable areas must be avoided (Figure 6.1). The development of fish farming will be regulated by guidelines and conditions. The most important guideline is the balanced development of fish farming in all areas that are not designated as unsuitable in Figure 6.1. An example of a balanced development is the combination of nutrient-supplementing fish farming at sea with nutrient-removing algae and/or mussel cultivation at the same location or in a nearby area. However, it is also possible to cultivate different aquaculture species separately. In addition, wider cluster solutions employing sea-land connections (e.g. use of joint labour, infrastructure, vessels, etc.) are favoured. It is important to involve fishermen and other marine users in the maintenance of aquaculture facilities in order to alleviate the seasonality of employment related to marine use.

The most important conditions of fish farming are related to the sustainable and nature-friendly use of the marine environment. According to the conditions, fish farms must be established in deeper (>5 m) and more open regions of the sea in order to reduce the local impact of pollution and ensure that the effects of setting up a fish farm involve an acceptable load on the marine environment. In the development of mussel and algae farms, overlaps with water traffic areas must be avoided. The establishment of fish farms in special national defence areas, on fairways (incl. ship-to-ship areas), in nature conservation areas, dumping areas, anchorage areas, places of refuge and areas of cable corridors must also be avoided.

AREAS UNSUITABLE FOR THE ESTABLISHMENT
OF FISH FARMS

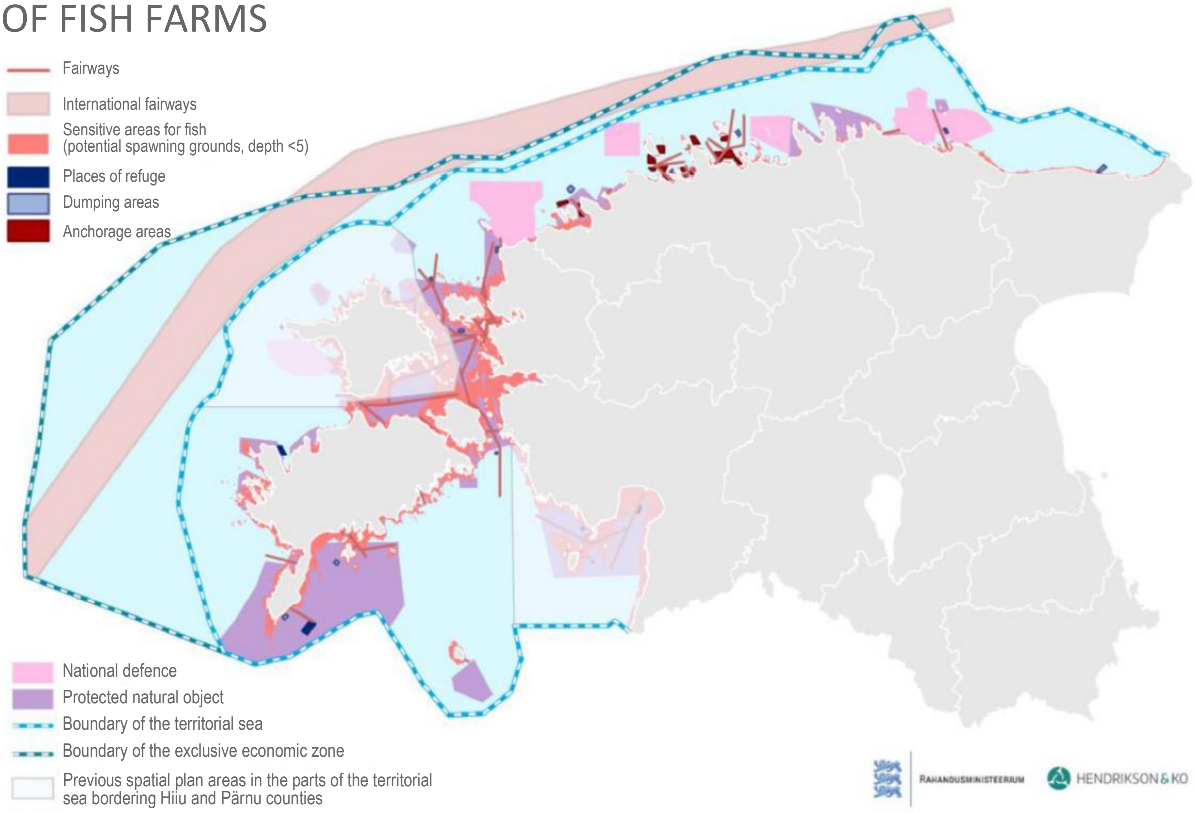


Figure 6.1. Areas unsuitable for fish farming as identified in the Estonian Maritime Spatial Plan.

The Estonian marine waters have a great potential for **cultivation of blue mussels**. Marine waters suitable for mussel cultivation are located mainly in the areas west of the islands of Saaremaa and Hiiumaa.

The Estonian Maritime Spatial Plan promotes the balanced development of mussel and algae cultivation in naturally suitable places. Preference is given to the development of mussel and/or algae cultivation in wind energy areas in order to achieve positive synergy. The foundations of wind turbines are a suitable environment for algae and mussel cultivation and offer good opportunities for fastening farm lines.

When planning mussel and algae cultivation in a nature conservation area, the possibility of interaction will be specified in conjunction with the Environmental Board.

The increasingly diverse use of marine waters necessitates the accommodation of various activities in these waters (Hendrikson, 2020a). The promotion of joint use reduces the spatial pressure on marine waters. Therefore, a general guideline of the Maritime Spatial Plan is to promote the joint use of maritime space wherever possible and to enhance positive synergies between different uses.

Across Europe as well as in the Estonian Maritime Spatial Plan, there is a trend towards promoting the following joint uses of marine waters, including fisheries and aquaculture (European Commission's MUSES project, Ocean Multi-Use Action Plan, see https://www.msp-platform.eu/practices/ocean-multi-use-action-plan):

- Tourism, fisheries and environmental protection. The so-called fishing tourism, with fishing traditions being introduced to tourists on fishing boat trips. This kind of tourism provides additional income opportunities for fishermen and helps to promote an ecofriendly attitude towards fish stocks.
- Tourism and aquaculture. Boat trips, snorkelling and diving near or in the immediate vicinity of aquaculture infrastructure. This provides an alternative source of income for aquaculture operators, raises awareness of local aquaculture products and increases the tolerance needed to develop aquaculture. This approach is currently being pursued on a small scale in the Baltic Sea, e.g. the St. Anna mussel farm on the Swedish coast.
- Wind energy and fisheries. Setting conditions for fishing in the vicinity of wind turbines; sharing of labour and vessels. This provides fishermen with an alternative source of income, e.g. in connection with monitoring.
- Wind energy and aquaculture. Use of wind turbines for fastening aquaculture infrastructure or for developing new infrastructure solutions. Use of the area of wind turbines for mussel farming. This allows cost savings and setting up farms in deeper waters. There are still few examples at the moment.

7. Characteristics of the West-Estonian region

One of the characteristics of Western Estonia is the existence of an extensive archipelago and strait system. This morphology of the coastline and marine waters means that there are a lot of areas sheltered from waves where it is possible to carry out different types of human activities without fear of the destructive effects of waves. At the same time, this region is very diverse in terms of hydrophysical, hydrochemical and hydrobiological parameters.

The marine waters in Western Estonia are affected by the processes of the three largest sub-basins of the Baltic Sea. The northern part of the sea is influenced by the conditions of the Gulf of Finland (strong salinity gradient, high exposure to waves and upwelling, and blue-green algal blooms in summer). The conditions of the Gulf of Riga prevail in the southern part of the sea (relatively high trophic level, low water transparency, low salinity). The westernmost region of the sea is under the influence of the Baltic main basin (the highest salinity values, lower nutrient contents, good water transparency). Between these three parts of the sea lies the Väinameri Sea, which is by its nature an extremely dynamic sea area, where the prevailing environmental conditions depend primarily on the weather and the direction of the wind. This area can be filled with water from both the Gulf of Riga and the mouth of the Gulf of Finland (depending on the direction of the wind). The western part of the Väinameri Sea (especially Kassari Bay) is under the strong influence of the Baltic main basin (Kotta et al., 2008ab, Snoeijs-Leijonmalm et al., 2017).

The coastal sea of Western Estonia can be briefly characterised as follows:

- Very diverse coastline
- Shallow water in the east
- Varying hydrological conditions
- Low nutrient load from land (no significant agricultural or municipal pollution)

The following characteristics of the West Estonian marine waters are relevant to the development of aquaculture:

- The content of nutrients and suspended solids is higher in the coastal waters of the Gulf of Riga than in the Baltic main basin. Therefore, this region should be suitable primarily for mussel cultivation, but also for algae cultivation if an effective technology is available (especially for species such as *Ulva* sp.).
- Due to its shallow water and variable hydrology, the Väinameri Sea is probably less suitable for large-scale aquaculture.
- The waters to the west of the islands are particularly suitable for offshore fish farming, but they are also excellent for mussel and algae cultivation, especially due to the "marine" conditions. Higher salinity of seawater ensures better growth of most marine species. The low nutrient content of seawater eliminates undesirable environmental effects, and exposure to waves contributes to the rapid "dissolution effect" of the nutrient load from aquaculture.

- The sea area north of the Väinameri Sea also has rather good "marine" conditions and is suitable mainly for the development of fish farms, but also mussel and algae farms. Here, however, attention must be paid to the areas of upwelling. Namely, abrupt changes in temperature, salinity and oxygen concentration in the areas of upwelling may impose certain restrictions on aquaculture.

8. Completed and ongoing aquaculture studies

The following is an overview of completed and ongoing studies, the results of which are directly or indirectly useful in the development of the aquaculture sector.

Completed studies

Estonian University of Life Sciences. 2015. Mapping of the most suitable areas for expanding aquaculture, development of necessary infrastructures and feasibility of innovative technologies. https://www.agri.ee/sites/default/files/content/uuringud/2015/uuring-2015-vesiviljelus-potentsiaal.pdf

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https://www.agri.ee/sites/default/files/content/arengukavad/vesiviljelus-arengustrateegia-2014-2020.pdf

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Tallinn University. 2019. Adding value to the biomass of red alga *Furcellaria lumbricalis*: pigment separation and properties. https://www.kalateave.ee/images/pdf/Punavetika_Furcellaria_lumbricalis_biomassi_v%C3%A4%C3%A4ristamine-pigmentide_eraldamine_ja_omadused_Saluri_2019.pdf

University of Tartu. 2016. Baseline study for the Maritime Spatial Plan – areas suitable for aquaculture of invertebrates and algae. https://www.rahandusministeerium.ee/et/system/files_force/document_files/2016ram_aruanne_taiendatud.pdf

University of Tartu, Fisheries Information Centre, SakiConsult OÜ. 2017. Analysis of the implementation of the Estonian Aquaculture Development Strategy 2014-2020, and proposals for further development of the Action Plan. https://www.kalateave.ee/images/pdf/Uuringud/vesiviljeluse%20strateegia%202014-2020%20elluviimise%20analyys_2017_l6plik.pdf

University of Tartu, Fisheries Information Centre, SakiConsult OÜ. 2018. Current situation, perspectives and challenges of research, experiments and practical outputs of algae and mussel cultivation in Estonia. https://www.kalateave.ee/images/eesti_vetika-_ja_karbikasvatuse_uuring_2018_04.pdf

University of Tartu. 2019. Development of measures to compensate for nitrogen and phosphorus pressure of fish farms on the sea. https://www.kalateave.ee/et/teadus-ja-arendustegevus/uurimused/303-2019-uurimused-arhiiv/8695-kalakasvatuste-kaudu-merre-suunatud-lammastiku-ja-fosforikoormust-kompenseerivate-meetmete-valjatoeoetamine-tartu-ulikool-2019

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University of Tartu. 2019. Preparation of regional plans for aquaculture to control potential environmental pressure. https://www.envir.ee/sites/default/files/MKO/2019_11_01_lopparuanne_pikk_versioon_2.pdf

Ongoing studies

University of Tartu. Duration: 1.08.2017-31.12.2020. The ongoing aquaculture innovation support project 'Purification of the effluent of seawater-based fish farms through the cultivation of macroalgae' funded by the European Maritime and Fisheries Fund aims to develop and test the ways of removal of nutrients from used seawater from fish farms, using various combinations of mechanical treatment and biofiltration based on macroalgae of the Baltic Sea. In the course of the work, the species of macroalgae suitable for this activity are selected. Preliminary results indicate that incubation of macroalgae can reduce the concentrations of nitrogen and phosphorus compounds in the water passing through the incubation chamber by up to 30%. In the Estonian coastal sea, the most suitable species to be incubated is *Ulva intestinalis*; however, maintaining the algal culture for a long time requires very precise control of water flow, nutrient concentration and light conditions.

Estonian University of Life Sciences. Duration: 07.07.2017-31.08.2022. Development of artificial reproduction and farming technologies and identification of the best performing strains of catfish (*Silurus glanis*) as a prospective new aquaculture species.

Tallinn University of Technology. Duration: 1.03.2018-28.02.2021. RITA1/01-18. The aim of the **BioRITA** study 'Maximising added value and efficient use of raw materials in bioeconomy and its sectors in Estonia' is to identify opportunities for the development of the Estonian bioeconomy and its main value chains and the use of bioresources to increase competitiveness. The perspectives of increasing added value and ensuring better use of raw materials are considered, taking into account the principles of sustainable development. Based on the holistic approach to value chains, the current state of the Estonian bioeconomy is analysed across six value chains: food and feed; pulp, paper, wood products and wood construction; textiles and clothing; fuels and energy; biomaterials, chemicals, pharmaceuticals and plastics, and ecosystem services related to the bioeconomy. The suitability of the best possible innovative technologies for adding value to Estonian bioresources is studied. New business models will be developed for selected fields and their socio-economic impact will be analysed. The developed business models and scenarios can be used for forward-looking scientific and knowledge-based planning of activities and policies of companies and decision-makers.

University of Tartu. Duration: 01.01.2019-31.12.2021. The sub-project 'Innovative approaches to monitoring and assessing marine environment and natural values in Estonian marine waters' is being carried out within the scope of the project '**mereRITA**' (https://sisu.ut.ee/mererita/avaleht) the aim of which is to develop methods for monitoring, analysis and assessment of marine waters, which help to assess the condition of marine waters and the pressures affecting them in accordance with the requirements of the Marine Strategy and the European Union's Habitats Directive. In the course of the mereRITA project, more time- and cost-effective assessment methods are developed, which will be used to assess the environmental status of and pressures on benthic communities and spawning grounds of economically important fish species, as well as tolerance towards various maritime activities, pollution pressures and alien species. The main regions of implementation of the project are the marine waters west of Saaremaa up to the border of the exclusive economic zone, regions of the coastal sea of Saaremaa around Kübassaare, Sõrve and Pammana peninsulas (studies of fish spawning grounds), water area of the Port of Muuga where the environmental DNA is analysed (early detection of alien species). The mereRITA project lasts from 01.01.2019 to 31.12.2021. The project is funded by the European Regional Development Fund and it is carried out under action 1 'Supporting strategic research and development' of the programme

‘Strengthening Sectoral Research and Development’ (RITA) of the Estonian Research Council. Project reports can be found at https://sisu.ut.ee/mererita/tulemused.

University of Tartu. Duration: 01.01.2019-30.06.2021. The INTERREG project Grass or ‘Sustainable algae cultivation in the Baltic Sea’ develops the potential for cultivation and use of algae in the Baltic Sea, including (1) assessing the potential for cultivation and use of the natural resources of macroalgae in order to identify suitable areas and methods for cultivation and evaluate the positive environmental effects of such activities in terms of mitigation of the negative effects of eutrophication; (2) identifying legislative and other regulatory barriers and gaps related to algae cultivation and proposing solutions to address these barriers in order to create opportunities for economic activities related to sustainable cultivation and use of algae; (3) mapping the socio-economic opportunities in relation to the cultivation and use of algae and developing a set of information materials for the public sector to support decision-making in the field of algae cultivation.

9. Aquaculture: future trends and initiatives for the blue economy

In order to expand and popularise the aquaculture sector, opportunities have been sought to facilitate the start of aquaculture. One of the opportunities is to simplify the legislation, in particular the Water Act, so that the state can speed up the use of waters where aquaculture is to be developed. The state could grant the use of a part of a public water body for aquaculture and enter into a contract with the user to this end.

The Agriculture and Fisheries Development Plan up to 2030 (AFDP 2030) sets out the objectives and activities of the fisheries sector. The following is the part of AFDP 2030 that concerns the current situation of aquaculture and processing and marketing of biological resources (Ministry of Rural Affairs, 2020).

Estonia has good preconditions for the production of aquaculture products, and production volumes have increased in recent years, but the sector is not yet able to provide processing companies with a stable supply of high-quality raw material. There has recently been more joint action, especially through producer organisations, which enables market power to be increased and economies of scale to be achieved. The short supply chain for the marketing of locally sourced aquaculture products ensures the freshness of the production, but the total volume of production is rather small. In the EU, consumer demand for fish products is growing, but only 1% of all fish and shellfish production was sold abroad (Statistics Estonia, 2019).

Companies engaged in the production and processing of fish and aquaculture products have started to introduce new processing equipment employing more modern technological solutions, as well as environmentally friendly farming technologies, but the level of investment in innovation and product development has been relatively low so far. Micro and small enterprises operating in the Estonian fisheries sector have had a low self-financing capacity. Financial resources have also been difficult for the target group to access. In order to alleviate these market failures, opportunities have been created to raise a loan through the Rural Development Foundation (Ministry of Rural Affairs, 2020).

The establishment of offshore farms in Estonia is limited by unfavourable climatic conditions and the environmental condition of the Baltic Sea, as well as the time-consuming and complicated process of obtaining superficies licences. The Estonian aquaculture sector is small, there is no sufficient market for veterinarians and consultants specialising in the aquaculture sector, and there is a shortage of skilled labour, because the sector is characterised by demanding manual work and low wages (Ministry of Rural Affairs, 2020).

Aquaculture production sold, 1992-2019

Tonnes of live fish

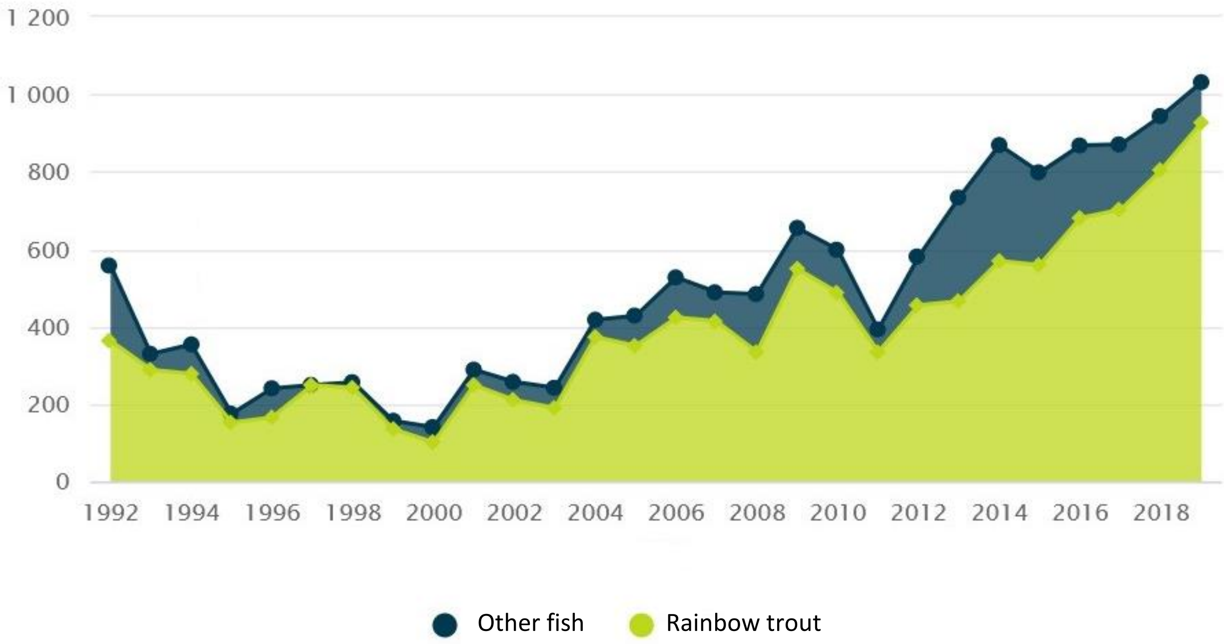

Figure 9.1. Dynamics of the volume of aquaculture production sold in Estonia in the period 1992-2018 (Statistics Estonia).

Some attempts have been made to cultivate new fish species and interest in the cultivation of algae and mussels has arisen in the aquaculture sector. The cultivation of red algae (*Furcellaria lumbricalis*) and blue mussels (*Mytilus edulis/trossulus*) has already been piloted in the Väinameri Sea, the Gulf of Riga and the Baltic main basin. In other countries around the Baltic Sea, mussel and algae cultivation has been seen as an opportunity to reduce eutrophication in the marine environment (Ministry of Rural Affairs, 2020).

Algae and mussel cultivation can also be used to compensate for the negative environmental impacts of fish farming (University of Tartu, 2019a). It is a fairly common practice in modern aquaculture to combine the cultivation of macroalgae with other branches of aquaculture. In the course of the aquaculture innovation project ‘Purification of the effluent of seawater-based fish farms through the cultivation of macroalgae’, a technology suitable for use in the Estonian waters is being developed that enables the treatment of effluent from fish farming with the help of macroalgae (mainly *Ulva*). However, if the fish farm is located in the coastal sea, it is reasonable to locate algae and/or mussel cultivation in the vicinity of the fish farm as a compensatory measure. With such co-use, it is possible to compensate for the flow of nutrients released from the fish farm into the sea and to keep the water in the vicinity of the fish farm transparent. For the activities described above, it is very important to carry out an ex-ante assessment of the exact location of the algae and mussel farms in order to achieve the expected reduction in the nutrient content of the water body. The choice of location requires an assessment of the hydrological regime and spatial coherence of the sea areas.

AFDP 2030 includes an intervention plan for meeting the objectives of the fisheries policy. The state can guide the development of fisheries and aquaculture through legislation, measures of the European Maritime and Fisheries Fund, the state budget and other recommended and voluntary activities, based, inter alia, on the objectives of the EU's Common Fisheries Policy. AFDP 2030 outlines the following state intervention mechanisms for aquaculture (Ministry of Rural Affairs, 2020a):

- ✓ To pay attention to **increasing productivity and added value and to opportunities arising from the development of products, ICT and digital solutions, involving more research potential**. The state must promote environmentally friendly production and processing by supporting the enhancement of capacity for product development and technological capacity with a view to more efficient use of local and hitherto unused living aquatic resources (incl. processing residues). It is necessary to move up on the value chain towards the production of higher value-added products. In order to add value to living aquatic resources, the state will support the development of innovative technological solutions (e.g. technologies enabling new developments, incl. biotechnology) in cooperation with companies and research and development institutions, incl. internationally.

- ✓ **To encourage joint action.** The role of the state is to support those joint investments and initiatives that lead to changes in the sector that enable economies of scale and competitive advantages to be achieved.
- ✓ **To develop a holistic and positive image to increase the attractiveness of the fisheries sector**, which would contribute to bringing young people into the sector, training specialists and consultants, and establishing companies.
- ✓ In developing sustainable marine aquaculture, the state must see to it that **the health of the marine environment does not deteriorate** and, based on the principles of maritime spatial planning and environmental aspects, **create opportunities for synergistic solutions** (e.g. multitrophic aquaculture, aquaculture in combination with wind farms) or closed-loop nutrient cycling. The cultivation of algae and mussels would, on the one hand, enable the removal of excess nutrients (N, P) from the sea and, on the other hand, add value to aquaculture products with high export potential (e.g. *Furcellaria lumbricalis* – protein pigments, nanocellulose). In order to ensure the sustainability of the sector, support should be given to mitigation measures and investments in technologies that are economically viable in the future and do not require additional operating grants.
- ✓ In order to meet the objectives of the fisheries measure, it is important to **create conditions for a more economically viable and competitive development of onshore aquaculture**. Most attention needs to be paid to improving productivity, increasing production, farming of new species, and research and development in order to be able to meet processing companies' demand for raw material and satisfy the domestic demand. In order to increase competitiveness, more attention needs to be paid to cultivation technologies and to ways of adding value to the production. In order to increase the high-quality production of the aquaculture sector, it is important for the state to follow the principle of ensuring the competitiveness of the actors in the field in the Baltic Sea region and the preservation of good environmental status as production intensifies. By supporting the introduction of economically viable, environmentally friendly and energy-saving technologies and encouraging more efficient use of resources (e.g. aquaponics), it is possible to contribute to the fulfilment of the obligations that Estonia has undertaken in maintaining good environmental status and reducing nutrient run-off.
- ✓ **High-quality and high value-added fish and aquaculture production, increased consumer awareness and sustainable management of fish stocks** create preconditions for increasing the consumption of fish and aquaculture products. The state has a responsibility to contribute to an efficient and transparent internal market for fishery and aquaculture products by contributing to the development of a short supply chain safe for the consumer (from producer to consumer), increasing consumer awareness (fish is good for your health) and promoting the consumption of fishery and aquaculture products in general. The implementation of the activities necessary for the intervention requires good cooperation between various ministries and between agencies in their respective areas of government.
- ✓ In order to satisfy the continuing demand for fishery and aquaculture products in the world while ensuring a high level of self-sufficiency of Estonia in terms of fishery products, it is important to **ensure high-quality production with high added value and high export potential**. State intervention must ensure a level playing field for fishery and aquaculture products marketed in the EU and encourage the finding of new markets in order to reduce potential risks in today's main target markets and seek new consumers for the products (e.g. in Asia and Africa).

The **European Maritime and Fisheries Fund (EMFF)** is a European funding instrument that supports fisheries policy, inland fishing, aquaculture and the maritime sector. The financial framework of the EU for the years 2021-2027 envisages a budget of 6.14 billion euros for the Fund (Council of the European Union, 2020).

For the period 2021-2027, the EMFF supports the implementation of the Common Fisheries Policy and the Maritime Policy through four priorities (Ministry of Rural Affairs, 2020b):

- Fostering sustainable fisheries and the conservation of marine biological resources;
- Contributing to food security in the Union through competitive and sustainable aquaculture and markets;
- Enabling the growth of a sustainable blue economy and fostering prosperous coastal communities;
- Strengthening international ocean governance and enabling safe, secure, clean and sustainably managed seas and oceans.

A national operational programme of the European Maritime and Fisheries Fund for the financial period 2021-2027 is currently being prepared, within which more specific interventions will be developed. The developments concerning the operational programme can be followed on the website of the Ministry of Rural Affairs at https://www.agri.ee/et/eesmargid-tegevused/euroopa-merendus-ia-kalandusfond-emkf-2021-2027/rakenduskava.

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