Common methodological approach on addressing the mussel farms in maritime spatial plans (MSP)

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About

Baltic Blue Growth is a three-year project financed by the European Regional Development Fund. The objective of the project is to remove nutrients from the Baltic Sea by farming and harvesting blue mussels. The farmed mussels will be used for the production of mussel meal, to be used in the feed industry. 18 partners from 7 countries are participating, with representatives from regional and national authorities, research institutions and private companies. The project is coordinated by Region Östergötland (Sweden) and has a total budget of 4,7 M€.

Partners

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- *East regional Aquaculture Centre VCO (SE)*
- *Kalmar municipality (SE)*
- *Kurzeme Planning Region (LV)*
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1. Introduction

Establishing and running a mussel farm in the Baltic have to be addressed in the maritime spatial planning (MSP) process based on a methodology supported by scientific knowledge, legislation and knowledge of business potentials for mussel farming. As Baltic Blue Growth (BBG) project was dedicated to blue mussel farming, the main focus of the methodology is on mussel farms. However, the proposed approach could also apply to other types of mariculture.

Mariculture development in the Baltic Sea is feeble in comparison to for example the North Sea. In case of mussels this is mostly due to the Baltic's low salinity, which causes their low growth rate and their smaller sizes. So far (status of February 2019) there are three types of maricultures that have been established in the Baltic:

1. mussel farms (in Denmark, Germany, Sweden, Finland (Åland), Estonia and Latvia),
2. algae cultivation (Estonia, Latvia, Denmark and Sweden) and
3. fish maricultures (in Denmark, Finland and Sweden).

While fish farming is carried out on a commercial basis in the Baltic (Denmark and Finland), the majority of mussel farms and algae cultivation sites are or were established as pilot research in projects such as AQUABEST, SUBMARINER, SEAFARM and Baltic Blue Growth. Only a few of them are based on commercial basis (in Denmark and Sweden).

Findings from BBG indicate that mussels may grow quite intensively in the western and proper Baltic: Kiel farm (Figure 1) had a yield of 3,30 kg/m rope after 1 year of growth [harvest of 5 tons on 0.21 hectares water surface] and at Sankt Anna BBG focus farm after 2 years of growth the yield was 3,40 kg/m rope [harvest of 78.7 tons on 4 hectares water surface] (Minnhagen S. et al, 2019[1]).

Mussels may be used as food for humans, feed for animals, source of biogas, a component in pharmaceutics or ingredient for cosmetics (e.g. collagen)[2]. In addition to the commercial uses, blue mussels – as other bivalves - are also a provider of several ecosystem services, out of which the most important regulating services are nutrient removal (Olivier et al, 2018[3]). Thus, mussels contribute to a reduced nutrient load in the Baltic Sea. Other ecosystem services provided by mussel farms (Gundersen et al. 2016[4]) are: supporting services (increasing biodiversity by providing substrate for algae and refuge for small animals, creation of unique habitats, changing the system from a turbid, plankton-dominated habitat to a highly diverse and productive benthic system, filtering considerable quantities of particulate matter), provisioning services (food and feed production), regulating services (Increase the ecological

[1] Minnhagen S. et al 'Results from Baltic Blue Growth project's mussel farms and a way forward for mussel farming in the Baltic Sea', https://www.submariner-network.eu/projects/balticbluegrowth/deliverables

[2] Schultz-Zehden, A. & Matczak, M. (eds.) 2012: SUBMARINER Compendium. An Assessment of innovative and Sustainable Uses of Baltic Marine Resources.

[3] 'A global review of the ecosystem services provided by bivalve aquaculture' Olivier et al., https://doi.org/10.1111/raq.12301-Reviews_in_Aquaculture

[4] Gundersen, V., Clarke, N., Dramstad, W., Fjellstad, F. (2016): Effects of bioenergy extraction on visual preferences in boreal forests: a review of surveys from Finland, Sweden and Norway. In: Scandinavian Journal of Forest Research 31 (3), pp. 323-334.

resilience, binding CO2 when building their shells, improving water clarity, decreasing the concentration of chlorophyll), cultural service (increasing the culinary offer, use as bait for fishing, indirectly supporting tourism industry through creation of attractive wildlife such as marine mammals and birds or increasing possibility for swimming / beaching).

Based on the experience of the Baltic Blue Growth (BBG) project's focus farms and via intensive communication with mussel farmers and the MSP practitioners, issues important from the MSP perspective for further development of mariculture in the Baltic Sea region are addressed in this proposal: optimal environmental conditions for mussels' growth, role and utilization of national and regional aquaculture development plans, legal regulations and formal procedures, role and power of associations representing the sector, potential conflicts with other marine use and ways to minimize / mitigate them.

Assuming that the ecosystem payment scheme to the Baltic blue mussel farms - as proposed by the Baltic Blue Growth project - will be established and operational, mussel farming should be considered as an important business activity, that have to be addressed in the maritime spatial planning process. In some cases, mussel farming will come into conflicts with other sea uses. Thus, it is important to have a clear, and as far as possible uniformed planning methodology among countries in the maritime spatial planning process.

2. Mariculture definition and types

A common definition of "Mariculture" or "marine aquaculture" is *"the farming of marine aquatic organisms, including finfish, shellfish (mollusks and crustaceans), and aquatic plants for food and other products such as pharmaceuticals, food additives, jewelry (e.g. cultured pearls), nutraceuticals, and cosmetics. Farming implies some form of intervention in the rearing process to enhance production, such as regular stocking, feeding, and protection from predators. Farming also implies individual or corporate ownership of cultivated stock. Mariculture is carried out both in the natural marine environment, or in land- or sea-based enclosures, such as cages, ponds, or raceways"* (FAO 1988[5]).

One can thus distinguish several types of maricultures depending on the marine organism being farmed.

Fish farming:

Fish farming involves raising fish commercially, usually for food and feed. Fish farming systems are diverse and can either be extensive or intensive in nature, closed or open systems. Extensive fish farming refers to fish farming conducted in parts or whole water bodies, e.g. lagoons. The fish production relies mainly on the natural productivity of the water which is only slightly or moderately enhanced. The control over the production factors is kept low. Costs of this type of framing is relatively low but also little efficient. In intensive fish farming, the fish are kept at too high a stocking density to obtain significant amounts of feed from their environment. Instead the fish are dependent on the feed provided and water must be replenished at a high rate to maintain oxygen levels and remove waste, either by selecting location by a high exchange of water (open net cage systems), or by pumping water as in closed systems (RAS). The levels of feed inputs and management of the water affect the stocking density of the fish that can be supported.

A concept of the Integrated Multi-Trophic Aquaculture (IMTA)[6] has been introduced in fish farming in Denmark. IMTA constitutes an advancement of traditional farming systems in its incorporation of species from different trophic positions or nutritional levels into the same system, so that each organism profits from the other. In Denmark IMTA is the combination of fish culture with invertebrate culture. Invertebrates filter and absorb the nutrients from the fish operations. Then, not only can the cultured fish be sold, but also the mussels. This method reduces the environmental impact of aquaculture and simultaneously increases profitability. Adding variations of IMTA to existing near-shore open net cage systems can significantly reduce their environmental impact through the direct uptake of particulate nutrients by filter feeders (e.g. mussels), and through harvesting, remove the nutrients from the location.

[5] FAO (1988). Definition of aquaculture, Seventh Session of the IPFC Working Party of Expects on Aquaculture, IPFC/WPA/WPZ, p.1-3, RAPA/FAO, Bangkok.

[6] Schultz-Zehden, A. & Matczak, M. op.cit.

Furthermore, using the harvested mussel and macroalgae biomass for fish feed is an indirect reduction of the environmental pressure on wild stocks exploited for fish feed.

Shellfish farming:

Shellfish farming is based primarily on specimens born in the wild and on nutriments provided by the environment, without any type of input since those animals feed on plankton filtered through their gills. Different techniques can be used, including bottom farming which is often practiced in shallow coastal or estuarine areas, inter-tidal shellfish farming where areas between high and low tide are used, and floating systems such as rafts and longlines, which can be used in open sea or estuarine environments. The main species farmed in Europe are oyster and mussel.

Marine plants culture:

Cultivation of macro- but also microalgae and seagrass. Products of marine plants cultivations are for human use, i.e. cosmetics and consumption. In the industrial sector, many uses have been identified, such as the development of agar products.

3. Optimum environmental conditions for mussel growth

The following physical, chemical and biological factors affect mussel growth and condition most: salinity, water temperature, concentration of dissolved oxygen, exposure to waves and currents, primary production and amount of microplankton, other food particles, predators and concentrations of toxins in sea water. Additionally, following aspects are important when it comes to mussel farm siting: seabed type, exposure to waves and current speed and ice coverage.

Mussels are eurythermal and for a short period can survive freezing and temperatures as high as 27°C (Hiebenthal et al. 2012[7]). The optimal water temperature for mussel growth is about 20°C – it shouldn't exceed this value in the warmest months of the year but the time when the water temperature is below but near 20 °C should be as long as possible.

In terms of salinity, the geographical range of mussels includes areas with salinity of 3 PSU and areas where salinity may exceed 40 PSU (Gossling 2004[8]). The maximum mussel growth is observed at 26-28 PSU (Riisgard et al. 2013[9]). Salinity at 3 PSU is considered as a margin of mussels salinity tolerance. When finding an optimal site for mussel farm this rule should be applied – higher water salinity causes higher growth rates and maximum body size of mussels.

Oxygen concentration in water determines the rate of respiration. Mussels generally have a fairly high tolerance to low dissolved oxygen concentrations and can also adapt by reducing their metabolic activity rate, to the extent of using anaerobic respiration to provide energy needs. However, prolonged periods of very low oxygen mixed with high water temperature, can stress bivalves, causing them to gape and possibly to die. Normal respiration rates occur when oxygen concentration in water is higher than 5 $ml \cdot dm^{-3}$ (Laing and Spencer 2006[10]).

Mussels are susceptible to strong waving and sea currents, especially at the recruitment stage. They can dislodge young mussels from substratum and cause their high mortality, lowering their biomass in area of high water dynamics (The Baltic Ecomussel Project… 2003[11]). Highest biomass of mussels is therefore observed in wave protected shallows or at open areas at depths where surface water dynamics impact is small. The highest mussel biomass should then considered to occur in semi enclosed bays, archipelago areas and at depths below 10 m at offshore areas with regular harsh conditions.

Mussels are filter feeding organisms. Their primary food source is phytoplankton (microscopic algae) and to a lesser extent detritus. Therefore optimal growth of mussels depends on the amount of primary production which is measured by chlorophyll a concentration. Mussels stop filtering when concentration of chlorophyll a is below 1 $\mu g \cdot dm^{-3}$ and the optimal filtration rate occurs at 6 $\mu g \cdot dm^{-3}$

[7] Hiebenthal C., Philipp E.E.R., Eisenhauer A., Wahl M. 2012. Interactive effects of temperature and salinity on shell formation and general condition in Baltic Sea Mytilus edulis and Arctica islandica. Aquat. Biol. 14: 289-298

[8] Gosling E. 2004. Bivalve molluscs. Biology, ecology and culture. Blackwell Publishing Ltd., Oxford. p. 443.

[9] Riisgård H. U., Lüskow F., Pleissner D., Lundgreen K., López M. Á. P. 2013. Effect of salinity on filtration rates of mussels Mytilus edulis with special emphasis on dwarfed mussels from the low-saline Central Baltic Sea. Helgoland Marine Research: 591–598.

[10] Laing I. and Spencer B. E. 2006. Bivalve cultivation: criteria for selecting a site. Cefas Science Series Technical Report no. 136. p. 34.

[11] The Baltic Ecomussel Project. Final Report. 2013. Project financed by EU program "INTERREG IV A Programme 2007-2013. p. 403.

(Riisgård et al. 2012[12]). Minimum optimal chlorophyll a concentration at site should not be below 3 $\mu g \cdot dm^{-3}$.

Filter-feeding organisms like mussels accumulate hazardous substances (e.g. PCBs, heavy metals, DDT/DDE, TBT, PAHs and their metabolites) occurring in the water or bounded with organic matter (e.g. Przytarska et al. 2010[13], Olenycz et al. 2015[14]). High levels of hazardous substances can negatively affect development and growth of mussels. Areas heavy polluted with hazardous substances should not be taken into consideration when selecting the location of mussel farms which aim is to provide food or fodder for animals. This should also be the case for areas with regular toxic algae blooms. Some species of planktonic algae produce toxins which can affect negatively development and growth of mussels and accumulate in their tissue (Uronen 2007[15]). Opposite, if the purpose for mussel farm is to improve the ecological state of the environment then polluted areas should be considered as best location. However, it should be stressed that the use of mussels biomass farmed in such locations is limited to the uses not related to human or animal consumptions or other agricultural purposes, for example, to biogas production.

During winter large area of the Baltic Sea (mostly northern and eastern parts) is covered with ice. Ice thickness ranges from few millimeters to 60-70 cm in the Gulf of Finland and the Gulf of Bothnia (HELCOM 2012[16]). In some areas ice coverage is absent but drifting ice can occur, especially in the spring when the ice is melting - drifting ice may harm the mussel farm. Ice cover doesn't affects directly mussels but it prolonged presence can negatively affect the operation of the farm.

To sum up, the optimum conditions for the mussels to growth are characterized by the following parameters: water temperature – near 20°C, water salinity: the optimal salinity is 26 PSU, oxygen concentration over 5 $ml \cdot dm^{-3}$, chlorophyll-a concentration from 3 $\mu g \cdot dm^{-3}$ and higher. In practice, this means that there are not too many optimal areas in the Baltic for the growth of mussels. This is confirmed by the results of the production numerical model (Kotta et al. in prep.[17]) carried out in the BBG project. The Baltic scale production model [Figure 1] presents the modeled total wet mass (i.e. shell and soft tissue) of mussels harvested per meter rope two years after farm inception. 14.7 kg mussels wet weight per meter rope over two years was the maximum growth modelled. However, experiments preformed during the Baltic Blue Growth project indicate that high production per

[12] Riisgård H. U. and Lundgreen K. 2012. Field data and growth model for mussels Mytilus edulis in Danish waters. Marine Biology Research 8: 683-700.

[13] Przytarska J. E., Sokołowski A., Wołowicz M., Hummel H., Jansen J. 2010. Comparison of trace metal bioavailabilities in European coastal waters using mussels from Mytilus edulis complex as biomonitors. Environ Monit Assess (2010) 166: 461-476.

[14] Olenycz M., Sokołowski A., Niewińska A., Wołowicz M., Namieśnik J., Hummel H., Janesn J. 2015. Comparison of PCBs and PAHs levels in European coastal waters using mussels from the Mytilus edulis complex as biomonitors. Oceanologia 57 (2): 196-211.

[15] Uronen P. 2007. Harmful algae in the planktonic food web of the Baltic Sea. Monograph of the Boreal Environment Research 28. p. 47.

[16] HELCOM 2012. The Baltic Sea ice season (2005-2012). http://www.helcom.fi/baltic-sea-trends/environment-fact-sheets/hydrography/ice-season.

[17] J Kotta, MN Futter, A Kasik, K Liversage, M Rätsep, FR Barboza, L Bergström, P Bergström, I Bobsien, E Diaz, K Herkül, P Jonsson, S Korpinen, P Kraufvelin, P Krost, O Lindahl, M Lindegart, M Moltke Lyngsgaard, M Mühl, A Nyström Sandman, H Orav-Kotta, M Orlova, H Skov, J Rissanen, A Šiaulys, A Vidakovic, E Virtanen. Cleaning up seas using blue growth initiatives: mussel farming in the Baltic Sea region. In prep.

meter rope is observed in locations that are not optimal for the growth of a saltwater species when farm technologies are optimized for production of small mussels. The harvest data from Sankt Anna focus farm indicate that farm system used there may be more effective for small mussels.

The Baltic scale production model is presented on the Operational Decision Support System platform (check Mussel growth (model) bookmark on http://www.sea.ee/bbg-odss/Map/MapMain). The ODSS platform offers a tool called ”Plan Your FARM” were one can easily get detailed information on the environmental conditions and maritime activities in an area selected by the tool user. This tool offers interesting possibilities of its use in the planning process, because it allows quick identification of marine areas predestined for the location of mussel farms at the scale of the whole Baltic. The Baltic scale production model is driven by gridded estimates of physical conditions and water chemistry. These scientifically validated gridded input data provide a regional picture and may not be sufficiently representative of small-scale local conditions (for example, the gridded data may not capture the effects on water quality of local features such as the barrier impacts of peninsulas on the production potential of coastal waters, e.g. Puck Bay, Vistula or Curonian Lagoons). Therefore, further to identification of the site by use of this ODSS tool, the suitability of candidate farm locations should be corroborated by site visits and collections of water samples for salinity and chlorophyll analysis to compare actual site conditions to the input data used for production modelling.

For siting mussel farm environmental criteria described above are of the key importance. Salinity, temperature concentration of chlorophyll-a and oxygen have an impact on mussel growth, hazardous substances and toxic algae limit the use of mussels biomass as human food and animal feeder, the water dynamic (waves and currents) and ice coverage affect the operation of and on the farm. One should also take into account that the location of the farm has also an important economic dimension: depending on the distance from the shore, running costs of the farm varies (expenses raises with the distance from the harbour).

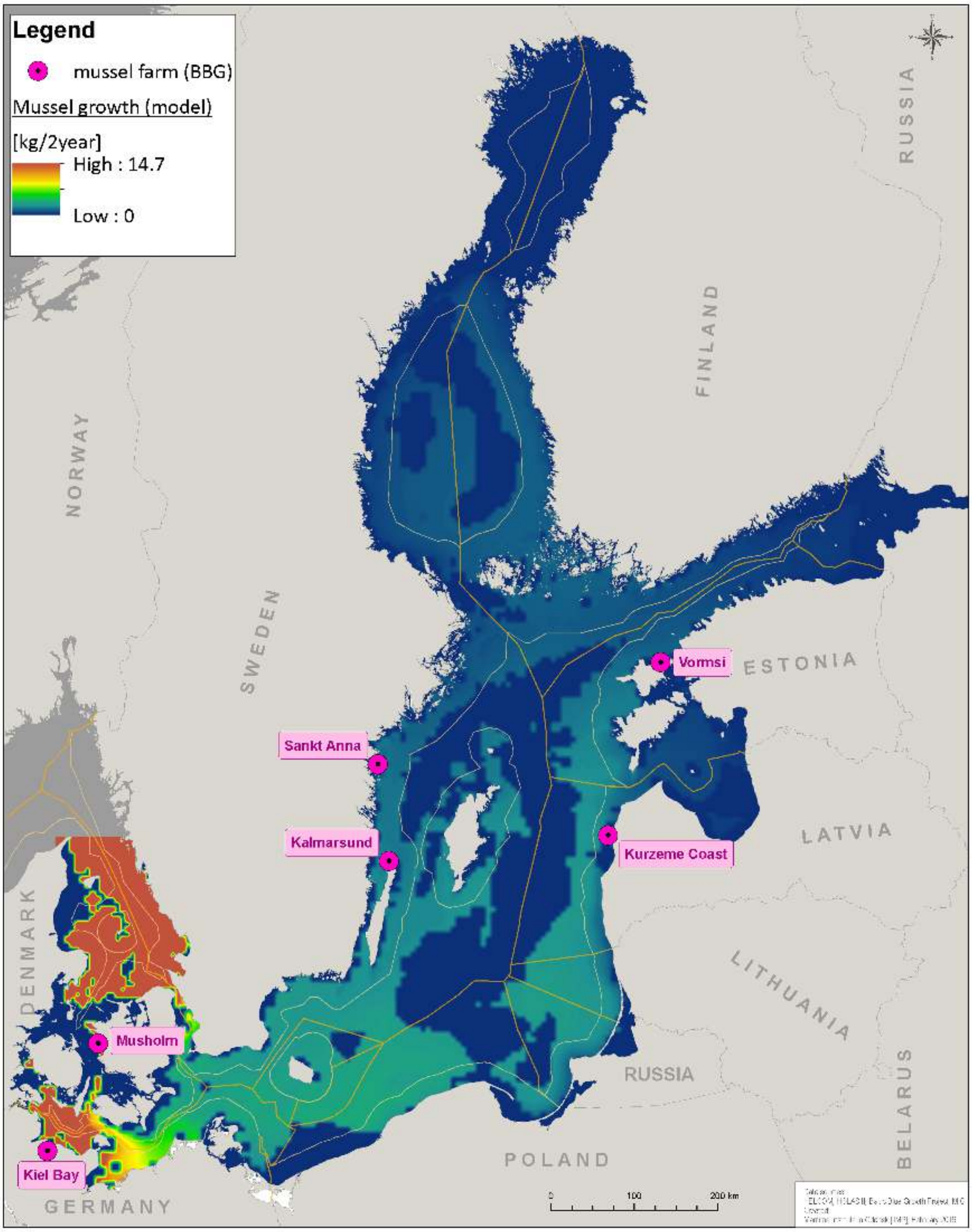

Figure 1. The blue mussel production in the Baltic Sea (results of numerical modelling)

4. Interaction and combination of maricultures with other maritime uses

The Baltic Blue Growth project products as well as external data collected during its realization, allowed to identify which current and planned usage of the sea interacts with mussel farming in terms of space occupation. The most important **interactions** are:

- mussel farming – transport,
- mussel farming – fishery,
- mussel farming – tourism and recreational activities as kayaking, surfing etc. ,
- mussel farming – environmental protection,
- mussel farming – offshore wind farms.

For transport and fishery interactions with mussel farms are negative. That is because of the conflict over the use of the sea space - the establishment of mussel farm results in permanent or temporary reservation of space, both on the surface and on the seabed, meaning the complete exclusion of other activities on the site. In case of tourism/recreation and offshore wind farms one may consider combinations of these activities with mariculture, as described later in the text.

The interaction between mussel farming and protection of the environment can be twofold:

- positive: filtration of mussels leads to cleaning of sea water from suspended organic matter and general improvement of the state of sea water quality in the area of the farm;
- negative: mussels faecal pellets falling on the seabed undergo the process of mineralization, which depletes oxygen in the bottom water and pore water in sediments, and that leads to degradation of living organisms assemblages inhabiting the sea bottom in the area of the farm.

It should be noted that the impact range for these interactions is local. And in case of interactions with environment protection, their strength is significantly dependent on the dynamics of water.

Combination of maricultures with other maritime uses may be considered as an option for fostering the sector's development. Due to growing pressure on the sea space and having in mind the on-going technology development in planning the sea space, the multi–use concept may become an important trend that shall be considered in the planning process. A brief overview of the existing and potential multi-uses in the Baltic Sea region is presented in this chapter.

The concept of multiple use or co-existence of maritime uses has been investigated in several research projects across the EU. In general it consists in the joint use of a given sea space by two or more operators, for example an offshore wind farm and fishing. The most recent project, Multi-Use in European Seas (MUSES) investigated potential of multi-use combinations with aquaculture in the Baltic Sea. MUSES has defined the multi-use (MU) as *the joint use of resources in close geographic proximity. This can involve either a single user or multiple users performing multiple uses. It is an* *umbrella term that covers a multitude of use combinations and represents a radical change from the concept of exclusive resource rights to the inclusive sharing of resources by one or more users*[18].

A range of benefits was recognized in the combination of maritime activities with aquaculture[19]:

1. social: increasing publics' and local communities (incl. municipalities) interest and acceptance for benefits of aquaculture, increased local incomes from tourism, increased interest in local farmed seafood;
2. environmental: reducing eutrophication with some type of mariculture and related to this increased knowledge on ecosystem service provided by mariculture, education of human footprint on the ocean (space efficiency), recognition of environmental values linked to the off shore wind;
3. economic: job opportunities, reduction of cost from shared infrastructure, operations and maintenance, potentially increased revenue.

In the MUSES project four potential combination of mariculture activity with other maritime uses have been identified [20]:

- mariculture and offshore wind energy production (in Denmark, Estonia, Germany, Latvia, Sweden),
- mariculture and tourism (in Sweden),
- mariculture and wave energy production (in Denmark),
- mariculture and environmental protection (in Estonia and Latvia).

However, only three of these were actually tested in real environment: with offshore wind energy and with wave energy in Denmark, and with environmental protection in Latvia. Others were identified by stakeholders as having a potential on the basis that one of the maritime use from the combination is already in place in a given country.

According to the study on the potential combination of the mariculture with the offshore wind farms[21] done by the National Institute of Aquatic Resources (DTU-Aqua), present design of the offshore wind farm operation and maintenance, likewise rough wind and wave conditions provide challenges for mussel cultivation. Results of this study show feasibility for farming of a blue mussel in the Kattegat - Anholt wind farm area; limitations for having an aquaculture site in the Nysted/Rødsand wind farm due to the low salinity; while compensation cultivation of seaweed and mussels would be possible in the marine area north of Lolland, in the southeastern part of Denmark.

One of the initial trials of combining mariculture with offshore wind production was conducted in the Rødsand 2 offshore wind park (SUBMARINER project)[22]. The study has shown that there are a number of practical challenges to be addressed in order to facilitate the cultivation of marine biomass in offshore wind parks space: technological constrains (existing wind mills are not design to

[18] Zaucha J. et al. (2016) Analytical Framework (AF) – Analysing Multi-Use (MU) in the European Sea Basins, MUSES project Edinburgh

[19] Lukic I., Schultz-Zehden A. and Onwona Ansong J. et al. (2018). Multi-Use Action Plan, MUSES project. Edinburgh.

[20] Przedrzymirska J., Zaucha J. et al. (2018). Multi-use concept in European Sea Basins, MUSES project. Edinburgh

[21] Stenberg C., et al. 2010. Offshore wind farms and their potential for shellfish aquaculture and restocking. ICES CM. https://www.researchgate.net/publication/265275142_Offshore_wind_farms_and_their_potential_for_shellfish_aquaculture_and_restocking

[22] Pia Bro Christensen, Marvin Poulsen & Jørgen Enggaard Boelsmand (2013). Combined uses – Marine biomass from offshore wind parks

carry out additional installations), unknown potential interference with the natural ecosystem (e.g. noise, shadowing effects) and unknown potential negative cumulative (from both uses) impacts, lack of tradition for cooperation between the different sectors, lack of legal and planning incentives to promote co-localization, complicate insurance issues and difficulties in obtaining the necessary environmental permits.

The "Study on mapping of areas most suitable for expanding aquaculture, developing relevant infrastructure and applicability of innovative technologies"[23] provides an overview on current status of aquaculture in Estonia. Out of 10 suitable areas for marine aquaculture, three overlaps with planned offshore wind farms: (1) A *Mytilus* farm combined with a wind farm 30 km south from Saaremaa island; (2) Wind farm planned in Pärnu Bay suits for Mytilus farming and under certain conditions also fish farming; (3) Wind farm planned north from Hiiumaa island may be combined mostly with the fish farming and future potential for having mussel farms.

The offer of the Musselbaren Ljungskile in Sweden is a show case of combination of mariculture and tourism. The restaurant organises boat trips to show tourists the mussel farms and offer them partake in the harvesting of the mussels.[24]

Testing offshore wave energy generation and mussel aquaculture has been conducted at the Danish Wave Energy Test Centre testing site in the northern part of Denmark. It was a small-scale experiment of using wave energy for the purpose of supplying the aquaculture production with needed electrical energy[25].

An experimental implementation of MU combination of aquaculture and environmental protection exists in Latvia, within the Baltic Blue Growth project, where the mussel farm has been established in the western coast of Latvia (near Pavilosta) in spring 2017. The results of the test, monitored by the Latvian Institute of Aquatic Ecology (LHEI), will assess the impact of environmental conditions on mussels farming and vice versa. The mussel farm is also integrated in Latvian Program of Measures for Marine directive.

[23] Jaanuska, H. (2015), op. cit.
[24] http://www.musselbaren.se/en/#34
[25] MUSES Baltic Sea Basin Report – not published, can be obtained upon request from the Maritime Institute in Gdańsk (Joanna Przedrzymirska, Jacek Zaucha)

5. Stage of mussel farms development in the Baltic Sea region countries

Currently (spring 2019) commercial mussel farms exist in Denmark, Sweden and Germany; experimental research farms are on-going in Estonia, Latvia and Sweden (as part of the BBG project) and in Denmark (as part of the MuMiPro project[26]); there were few finalised scientific trials of mussel cultivation in Finland and Poland. One shall also mention that freshwater zebra mussels (*Dreissena polymorpha*) were experimentally cultivated in Curonian (Lithuania[27]) and Szczecin (Germany[28]) Lagoon.

For details concerning legislation aspects of maricultures in the countries around the Baltic Sea please also see BBG report 'Legislation Issues Status Report'[29].

The current approach to mariculture in the maritime spatial planning process reflects the sector development and/or strength in the given country.

Denmark

Farming blue mussels on long lines or Smart Farm units takes place mainly in the Limfjord in the northern part of Jutland; it is an activity that started in 2006, and total volumes reached 2 221 tonnes in 2016[30]. According to the Danish Association for aquaculture (Dansk Akvakultur) there are 12 mussel mariculture facilities in Danish marine waters. According to the Danish Bureau of Statistics, in 2017 production of farmed mussels totalled 2.814 tonnes. 62 permits for mussel farms are registered at the Danish Directorate of Fisheries totalling 9.55 km2 in 2018, only 5 of the permits is outside the Limfjord. A few of the Danish mussel farms represent the "Danish model" of fish farms that compensate nutrient outlet from their fish farm by growing and harvesting mussels (IMTA).
Dansk Akvakultur - the umbrella organisation for aquaculture – represents interests of Danish mussel farmers, it also provides support to members: advice on legislation issues, framework conditions, data sharing, R&D etc. Dansk Akvakultur also represents the mussel farmers in the on-going MSP process in Denmark.
Responsibilities for mariculture related policy holds jointly the Danish Fishery Agency in the Ministry of Foreign Affairs (farming of mussels), and the Ministry of Environment and Food (farming of fish and macroalgae).

[26] http://www.mumipro.dk/
[27] Anastasija Zaiko, Romualda Budvytytė, Neringa Usanova, Giedrius Mikalauskas "Mussel farming in the Curonian Lagoon - challenges and perspectives"
[28] Schernewski, G., N. Stybel, and T. Neumann. 2012. Zebra mussel farming in the Szczecin (Oder) Lagoon: water-quality objectives and cost-effectiveness. Ecology and Society 17(2): 4. http://dx.doi.org/10.5751/ES-04644-170204
[29] https://www.submariner-network.eu/projects/balticbluegrowth/deliverables
[30] https://www.eurofish.dk/denmark

In countries with well-established mariculture sector like Denmark (developed mariculture policy, standards for siting mariculture, clear governance structure and clear administrative procedures), the sector is involved in the planning process from the very beginning and its interest is advocated by a strong association. Data required for the planning purposes is obtained from DTU Aqua - the National Institute of Aquatic Resources that is an institute at the Technical University of Denmark. As for March 2019, the Danish maritime spatial plan is in a developing phase, still according to the Danish Maritime Authority (national institution responsible for MSP) mariculture will be included in the plan, and areas for mariculture will be reserved for exclusive use.

Sweden

The commercial mussel farms in Sweden are located on the west coast of Bohuslän. Most of the mussel farms belong to the Scanfjord company, which accounts for 95 percent of the Swedish bivalve production. A new company is established, Orust Havsbruk, producing mussels on net. In this region there is also a factory which produces mussel flour for animal feed[31].

Sweden has developed three marine spatial plans for its territorial waters and exclusive economic zone. The Swedish Agency for Marine and Water Management has developed the marine spatial plans together with other agencies and the county administrative boards while consulting coastal municipalities, NGOs and the public. Most of the Swedish mussel farms are located within the baseline. Hence, they are not covered by the national maritime spatial plans but are subject to municipal plans for the coastal areas.

The Swedish mariculture is relatively small-scale and has a great potential to grow. The Swedish Board of Agriculture, which is responsible for mariculture related policies, has therefore developed an action plan for developing aquaculture (2012-2020). Even though the plan considers maricultures, no detailed plan or recommendations for siting mariculture in Swedish coastal and marine areas has yet been developed.

Germany

The only existing 'Baltic' commercial mariculture is located in Kiel Fjord[32]. The Kieler Meeresfarm – one of the BBG project focus farms - combines mussel farm with algae cultivation and produces food and products for cosmetics. Mussel farming is much more important in the German Wadden Sea along the Schleswig-Holstein North Sea coast with an annual harvest of about 15.000 metric tons.
Mariculture sector in Germany is represented by associations for aquaculture in general; each state has its own federal fisheries association representing the interests of stakeholders. In Kiel

[31] http://musselfeed.com/
[32] https://www.kieler-meeresfarm.de/unternehmen/

it is the Bundesverband Aquakultur e.V. (www.bundesverband-aquakultur.de).
Administrative control of aquaculture is the responsibility of and under authority of the various German States, which are the legislative bodies for aquaculture. As a result, each State has specific laws and regulations for fisheries and aquaculture which may differ across the different States[33].
Strategy for the Development of Aquaculture in Mecklenburg-Western Pomerania from June 2016 considers mariculture and IMTA. However, it states that the further development of the IMTA approach and therefore the investigation into suitable fish rearing technologies in net enclosures should only be carried out when the described approach of mussel aquaculture is economically successful or at least feasible without additional costs[34].
Mariculture in Germany has not been considered in the national maritime spatial plan for EEZ. However, the State Development Plan (LEP) for Schleswig-Holstein which also covers also marine areas anticipate supports the aquaculture sector. The plan came into effect in 2010 and is currently in the process of updating. In the draft of this update the mariculture as a whole gets more significance compared to the LEP 2010, however, it is concerned in a more general style, without any details to special sites or farms and therefore also not for the Kiel Bay.
The State Development Programme Mecklenburg-Vorpommern 2016 ("Landesraumentwicklungsprogramm Mecklenburg-Vorpommern 2016 (LEP M-V 2016)") came into force in 2016. The validity period of the state development programme is approximately 10 years. An evaluation of the programme is foreseen in 2021. The Programme allows the construction of mariculture facilities. The corresponding stipulation 8.4(5) reads as follows: "The construction, testing and operation of aquaculture [i.e. mariculture] facilities, also in combination with other fixed installations, should be compatible with the area."

Finland

Fish farming is the only type of commercial mariculture in Finland. An asset for the development of this sector is an existence of the strong mariculture associations at the national level - Finnish Fish Farmers Association, which provide advice, training, and in general protection of the sector's interests.
The Ministry of Agriculture and Forestry is responsible for mariculture sector development, practical management is delegated to Regional Economic, Transport and Environmental Centres (the economy division). Environmental management of aquaculture is the responsibility of the Ministry of the Environment that also has delegated practical environmental management and monitoring to Regional Economic, Transport and Environmental Centres (the environmental division).
MSP process in Finland is at its early stage (so far there were no consultations of the plan with sectors), however - given the existence of a strong fish farming sector - it is anticipated that

[33] http://www.fao.org/fishery/countrysector/naso_germany/en. For details on please also see BBG 5.2 report.
[34] Strategy for the Development of Aquaculture in Mecklenburg-Western Pomerania, http://www.aquaculture-mv.com/Information/

the maritime spatial plan will take into account this sector. There is a national aquaculture management plan from 2014, in which mussel farming is not foreseen.

Estonia

Currently in Estonia only one experimental mussel farm is established as the BBG project focus farm. Additionally, one algae farm located in the coastal inner waters is operating (seaweed is used for production of food ingredients). In 2016 a research about best suitable places for aquaculture (environmental conditions) was carried out (available only in Estonian[35]).
Estonian Association of Fish and Crayfish Farming (http://www.kalakasvatajad.ee/?pid=2) is dedicated to mariculture in Estonia, there is also producers' organisation Estonian Fish Breeders Association Ecofarm Partnership (http://ecofarm.ee/en/).
The Ministry of Rural Affairs is responsible for mariculture related policy.
Estonia is an example of a country which, despite of not existing mariculture sector at the moment, is taking the sectorial plans development seriously in its planning process. Maritime spatial planning – according to the 'Initial outline for the Estonian maritime spatial plan and the memorandum of intention to conduct impact assessment'[36] - requires the creation of spatial prerequisites for the sustainable development and competitiveness of fisheries and aquaculture as an economic sector, by establishing the appropriate marine areas for different and innovative aquaculture (including mussel and algae). Public consultations of the 1st draft of the plan are foreseen in May 2019. However, by now the Ministry of Finance has organised meetings with different stakeholder groups. According to the information provided by the Estonian interviewee, there will be no areas designated for aquaculture but MSP will set guidelines determining conditions for aquaculture. These conditions are still being negotiated with stakeholders. The problem is eutrophication, so aquaculture should not add any nutrients to the sea. Therefore combining fish farming with mussel/algae farming is favoured.

Latvia

At the moment only one experimental mussel farm is established as the BBG project focus farm that is managed by the Latvian Institute of Aquatic Ecology (LIAE).
The Ministry of Agriculture is responsible for mariculture related policy.
The MSP process in Latvia is currently in the finalising stage and the plan does not include marine aquaculture. Nonetheless, stakeholders representing BBG focus mussel farm have been engaged in the MSP development process, through the workshops and seminars, with an impression that their inputs were considered in the development of the plan.

[35] Jaanuska, H., 2015. Vesiviljeluse laiendamiseks sobivaimate alade kaardistamise, vajalike infrastruktuuride arendamise ja innovatsiooniliste tehnoloogiate elluviidavas

[36] https://mereala.hendrikson.ee/l%C3%A4hteseisukohad-en.html

Lithuania

There is no mariculture in Lithuania, nor were any experimental pilot research. A land-based experimental Recirculated Aquaculture System (RAS) for shrimp culture is under development in the frames of the InnoAquaTech project[37].

There is an association 'Alternative aquaculture aiming at development and promotion of recirculating and cage aquaculture of fish in Lithuania. But in fact, it is only RAS competence there.

The Ministry of Agriculture is responsible for mariculture related policy.

Promotion of mariculture in the maritime spatial plan of Lithuania has not included mapping of potential areas. There is no national policy supporting mariculture development as well as there is no experience in farming of marine aquatic organisms. On the other hand, data needed for mariculture development are either available or possible to gather (or to be modelled) by the Marine Research Institute of the Klaipeda University - a strong marine science centre. However, description of the sector within the plan is seen as a needed action for promotion of the aquaculture as one of the future uses to be supported by the country, in the moment when technology and knowledge advance the sector to be applicable in Lithuanian marine areas. During the MSP development process stakeholders from the mariculture sector has been occasionally (episodically) consulted. Planners had an opportunity to get the basic knowledge on the situation and demand from the aquaculture related community (including the researchers, developers and representatives of fishery association and Ministry of Agriculture – Fishery department).

Poland

There is no mariculture in Poland, only experimental research has been conducted by the University of Gdansk in the Puck Bay. There is no association dedicated to mariculture in Poland. There are several associations of on land aquaculture producers.

The Ministry of Maritime Economy and Inland Navigation is responsible for mariculture related policy. Operational Program "Fisheries and Sea" for 2014-2020 (a national instrument for implementing the European Maritime and Fisheries Fund) is aiming at upholding the leading position of inland aquaculture producers in Poland, thus more focus is put on inland aquaculture than on mariculture.

Polish MSP process is well advanced and several workshops with different sectors were carried out. Given the fact that aquaculture in Poland consists exclusively of the rearing and culture of freshwater fish, primarily carp and trout, it is not expected that mariculture sector will developed in the near future. However, the draft maritime plan considers fish, mussels, algae, other types of mariculture - they are determined as an "aquaculture function" and are regarded as allowed activity on the areas with basic functions: production of renewable energy and exploration of mineral resources.

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[37] https://www.submariner-network.eu/projects/innoaquatech/innoaquatech-pilots/zero-emission-ras-innovative-and-sustainable-energy-solutions-for-shrimp-production

6. Practical approach to mussel farms (mariculture) in the maritime spatial planning process

The maritime spatial planning process (MSP process) - as a cyclical approach involving political and technical elements with stakeholder's engagement resulting with active participation and acceptance – may play an important role in further development of the mussels farming in the Baltic Sea countries. The planning process may be inspired by research and technological development penetrating sector development potential but for the mussels farms development in the Baltic - as for any other maritime uses - the MSP process cannot substitute policies and other instruments enabling its growth. Equally important are: fishery (aquaculture) policy at EU in national level, existence of ecosystem payment scheme, local and regional blue growth agendas etc.

The proposed approach does not make difference between an existence and non-existence of the mariculture sector in a given country, nor between types of mariculture. An assumption is that the methodology should be meaningful and useful in the process of planning the sea space now and in the future. The inspiration for such an approach to the mariculture issue was the Estonian case, where there is no mariculture at present, but in the planning process, this sector gained an equivalent rank to other existing uses. Polish approach has also been taken into account: thanks to different projects carried out in Poland, the planners started to analyze the sector (as such the sector does not exist in Poland). This case shows that the MSP process has an "inspirational" and "awakening" value. Additionally, at the moment in many countries around the Baltic the mussel farming is considered as a 'risky' business, however the future may bring surprising developments and reserving now the area with the favorable (optimal) biological conditions may be beneficial in the future. Having this in mind the proposed approach enables the planners to consider the mariculture sector even in situations if there is no sectorial plan for this sector. Nevertheless, it is important to understand that MSP process as a decision making process may lower or remove the barriers for the mariculture development (by for instance allocating a space for future farms) but definitely, it is not the main and only driver for the sector's development.

Maritime spatial planning process is carried out in a series of basic steps[38]:
Step 1: Identifying need and establishing authority
Step 2: Obtaining financial support
Step 3: Organizing the process through pre-planning
Step 4: Organizing stakeholder participation
Step 5: Defining and analyzing existing conditions
Step 6: Defining and analyzing future conditions
Step 7: Preparing and approving the spatial management plan
Step 8: Implementing and enforcing the spatial management plan

[38] UNESCO's Step-by-step Approach for Marine Spatial Planning toward Ecosystem-based Management

Step 9: Monitoring and evaluating performance
Step 10: Adapting the spatial management process

Given the fact that steps 1-3 are of pure organisational/administrative nature, they do not concern maritime uses as such. The proposed approach focuses on steps 4-6 and 9 as the most crucial one in addressing the needs and expectations of the mariculture sector. Additionally, step 5 and 6 have been combined.

The approach is dedicated to maritime spatial planners regardless the level at which the planning is carried out (national planning, regional planning – in case of Germany, local planning – in case of Sweden). In each steps proposals for specific actions and tasks are given, as well as recommendations on how to optimise efficiency of the process, these are based on the good practices and experiences identified in the course of the survey.

Step 4 - Organizing stakeholder participation

Identify mariculture stakeholders:

- National and regional authorities responsible for mariculture policy,
- Administration responsible for the sector performance at all levels that are relevant in your country (national, regional, local). These can be institutions issuing a concession or permits for use of the sea space or for an activity at sea, institutions dedicated to environmental protection, inspection and security control bodies.
- Mariculture associations at different levels (national, regional, local).
- Individual farmers or potential investors.
- Regional and local communities.
- Scientific community.

Remember that mussel cultivation may be considered as a nutrient capture measure in your national/regional plans (as it is now being persuaded in currently being revised the HELCOM Baltc Sea action plan), so stakeholders from environmental protection entities shall also be considered and engaged.

In case the sector does not exist in a given country, one shall consider engaging stakeholders that potentially could create such sector; these could come from fishery and on land aquaculture sector. Important would be to engage representatives from science and research as they may possess information crucial for consideration of the new sector establishment.

Perform stakeholder analyses – learn their powers, characteristics, attitudes and behaviors. Criteria to assess the importance or relevance of stakeholders in MSP process proposed by UNESCO[39] can be helpful in this analysis. For identification and analysis a matrix is often used

[39] UNESCO's Step-by-step Approach.. op. cit.

(see below diagram). While this matrix is extremely useful in determining the frequency of communication with various stakeholders one should remember that in the process both power and interest of a given stakeholder may change so in order to prevent unexpected problems one shall monitor all stakeholders with the same level of effort.

Identify stakeholders representing uses conflicting with mariculture (potential: tourism, recreational users, nature protection, fishery, shipping, offshore energy generation, cables and pipes). These should also be analyzed and included in your stakeholder engagement strategy.

Stakeholder analysis is a time consuming process (that however always pays back if done honestly and professionally) so one shall allocate relevant resources to it.

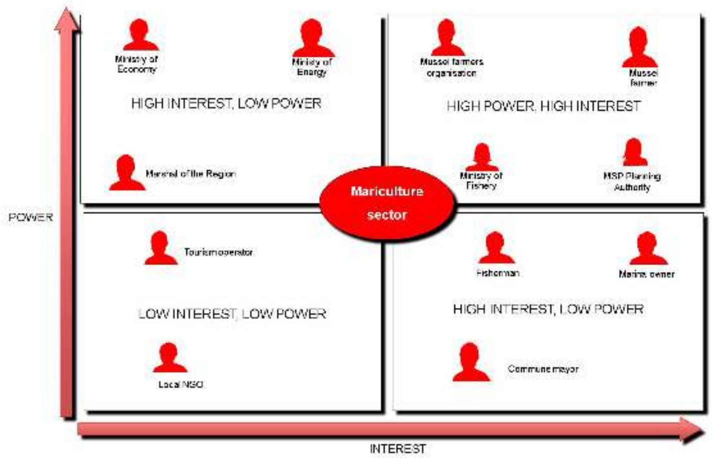

Figure 2. Stakeholder matrix (Source: own elaboration adapted from Business Analyst Learnings[40]).

Experience shows that this element of the process is very important, and yet it is too often treated superficially (stakeholders are identified, but their power is not analyzed) or even overlooked. It ends with the fact that there is no thought-out strategy of engaging the stakeholders. As a result, in the best case, the plan's provisions do not harm the sector despite the silence of its stakeholders. In the worst case 'not assessed' stakeholders prolong the planning process or worse, thanks to their power changes unfavorable for other sectors are brought about in the plan.

Hints and advices:

- Prepare your stakeholder engagement strategy. Consider which form of communication and engagement will be the most efficient for each stakeholder. Keep in mind that mussel farmers are busy people so perhaps it is better to use online communication techniques. They may be intimidated by a large group of participants of consultation meetings, so

[40] https://businessanalystlearnings.com/ba-techniques/2013/1/23/how-to-draw-a-stakeholder-matrix?rq=matrix

consider the possibility of dedicated meetings (even individual ones) and study visits.

- Prepare short and sector relevant information about MSP process - simple language, clear message.
- Get in touch with stakeholders and make sure that they are familiar with your consultation time table – personal contacts are strongly encouraged especially in case of stakeholders having high power (regardless their interest level).
- Avoid the situations creating mistrust: once you engage a given stakeholder make sure that his/her opinion and inputs to the plan will be considered and – what is even more important - make them aware of the decision making process (collection of inputs from stakeholders doesn't always mean that their expectations will be reflected in the plan – they should be made aware of this fact from the very beginning of their engagement.

Step 5 and 6 - Defining and analyzing existing and future conditions

Analyze strategic documents including long-term regional and national strategies, i.e. identify recognition of aquaculture at the level of national / regional priorities.

Identify and consider projects and analysis aiming at foresight for the mariculture: for instance analysis dedicated to investigation of the effect of climate change on the development of mariculture, impact of fisheries decline on mariculture development, etc.

Identify and analyze current and future need to consider mussel farms in maritime spatial plan in the light of current and projected market demand for farm products, environmental conditions.

Identify locations of existing mariculture and short-time development plans of their owners/operators. Collect data about these farm (size of the farm and its buffer zone – if exists, details about operation and maintenance, the farm performance, impacts on environment etc.). In majority of the countries around the Baltic, there are two or more sources of data required for the planning of mariculture, however there are good examples of having one source of all necessary data – either national research institution or strong association or strong department in the national governing body - for instance: DTU AQUA (Denmark) or Marine Research Institute (Lithuania).

Check if there are standards for siting mariculture in your country. In a long run, having such standards facilitates better planning and thus make way for investments and further development.

Identify sea areas having optimal conditions for mussels to grow. As presented in Chapter 2, the optimum conditions for the mussels to growth are characterized by the following parameters: water temperature – near 20°C, water salinity – the higher, the better, oxygen concentration over 5 ml·dm-3, chlorophyll a concentration over 3 µg·dm-3. One may find information on suitable sites in the studies available in the given country (e.g. Estonia), one may also make use of the tools like 'Plan Your FARM' at the ODSS developed in the BBG project. It allows quick identification of marine areas predestined for the location of mussels farms at the scale of the whole Baltic. However, it is recommended to adapt the tool to the scale of your maritime spatial plan (or even more detailed scale as the sites may be quite small in comparison to you plan scale).

Identify interactions (synergies and conflicts) between other uses and maricultures (existing and potential ones at the locations with optimal condistions for mussel farms) and current uses in areas: are these always mutually exclusive, are there solutions for coexistence and maybe synergy? Prepare conflict/synergies matrix. Consider possibility of multi-use combinations for both existing and future maricultures. Here take into account not only technologies avaiable at the moment but also an emerging once (e.g. floating offshore wind platforms that can be used as a multi-purpose platforms).

In case of conflicts with other uses one following options may be considered (please note that this is not a closed 'catalogue', one may come up with other ways of resolving the given conflict):

1. Exclusions - maricultures cannot be located at:
- key, important, frequented shipping routes;
- main fishing grounds;
- areas intensively used by water tourism and recreation;
- sand deposits for artificial nourishment of the coast (coastal protection);
- military polygons;
- cables and pipes;
- marine protected areas;
- other closed areas (e.g. safety zones around oil and gas installations).
2. Mussel farm area should be excluded from fishing and shipping and sailing.
3. It is possible to allow tourism, the details of entering the farm's area must be agreed with the farm investor/operator.

Experience with existing mariculture shows that marking aquaculture areas in the sea is a challenge for farm operators. Informing or marking of installations at sea is regulated by other than maritime plans regulations - each navigation obstacle is marked according to the regulations and placed on the navigation map. However, cases from Estonian, Latvian and Swedish focus farms shows that often other sea users are not aware of the installations (they seem not to be familiar with updated navigation maps).

Step 9: Monitoring and evaluating performance

In this step a monitoring system is designed to measure indicators of the performance of marine spatial management measures including arrangements for collecting Information on the performance to be used for evaluation. Therefore, one could consider whether it is worth creating a specific mariculture indicator (s). However, based on lessons learned from monitoring and evaluation in the Great Barrier Reef Marine Park[41], it is advisable to o start with a relatively modest program for a few key performance indicators and expand the program as guided by experience. It is also important to notice that in order to determine relative changes (e.g., to establish whether detected changes are due to management actions or other factors, or to determine whether the objectives of a managed area are being achieved in comparison with adjacent areas that are similarly managed) there might be a need to measure indicators both within a marine management area and outside the area.

[41] UNESCO's Step-by-step Approach.. op. cit.