VAHANEN CENTRUM BALTICUM

SPEEDING UP THE ECOLOGICAL RECOVERY OF THE BALTIC SEA

Assessment of the contribution of internal nutrient storages to the eutrophied state of the Baltic Sea and technical, socio-economic, political, legal and institutional aspects of potential measures to mitigate the internal nutrient leakage from bottom sediments

Client: Ministry of the Environment

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Photograph: Janne Gröning

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Foreword

In this study commissioned by the Ministry of the Environment of Finland, an international consultant team has assessed:

- the role of internal nutrient sinks and sources that are connected to internal nutrient leakages that contribute to causing and maintaining eutrophication in the Baltic Sea
- potential sea-based measures to address the release of nutrients from internal storages to supplement land-based measures in order to speed up the recovery of the Baltic Sea and achieving of good environmental status (GES) according to the MSFD and the HELCOM Baltic Sea Action Plan (BSAP) targets.

The assessment focuses on measures aiming at enhancing the phosphorus binding capacity of the sediment, which includes oxygenation of anoxic bottoms and chemical binding, as well as extraction of nutrients from the sea by dredging.

The study is divided in the following parts:

- Chapter 1: Introduction to the assessment
- Chapter 2: A professional and scientific assessment of the status and dynamics of internal nutrient sources and sinks related to internal nutrient storages
- Chapters 3 and 4: Ecological, technical and socio-economic aspects of sea-based measures that address releases of nutrients from internal sources
- Chapter 5: A study of the policy, legal and institutional framework for implementation of the measures, carried out by a consultant group lead by Centrum Balticum/BALEX
- Chapter 6: A roadmap, an overview of the analysis results, conclusions and recommendations.

The project team led by Vahanen Environment Oy (Chapters 1-4 and 6) consisted of experts and scientists from Finland, Sweden, Lithuania and Estonia. The key experts are: Esa Salminen (team leader), Juhani Anhava, Daiva Semėnienė, Karl-Johan Lehtinen, Anders Stigebrandt, Risto Valo, Milja Vepsäläinen, Minna Pyhälä, Jurgita Vaitiekūnienė, Andres Piirsalu, Mathias Bergman, Pieta Jarva and Teija Kirkkala.

The tasks in the Chapter 5 were carried out by the Centrum Balticum/Baltic Area Legal Studies BALEX team consisting of Henrik Ringbom, Brita Bohman and Saara Ilvessalo.

The Ministry of the Environment appointed a Steering Group for the project that provided guidance and comments to the reports. The group had representatives from the Ministry, Centre for Economic Development, Transport and the Environment, University of Helsinki, Finnish Meteorological Institute and Finnish Environment Institute. Maria Laamanen, Laura Saijonmaa and Sanni Turunen from the Ministry of the Environment of Finland acted as contact points and representatives of the client to the project.

This report has been produced independently by the consultants and the conclusions and recommendations expressed in the report do not necessarily represent the views of the client.

Tiivistelmä

Itämeri on jo vuosikymmenien ajan kärsinyt liiallisen ravinnekuormituksen aiheuttamasta rehevöitymisestä. Valuma-alueen kaupungeista sekä teollisuudesta peräisin olevan fosforikuormituksen huomattava väheneminen 1980-luvulta alkaen on parantanut vesien tilaa suurten kaupunkien edustoilla, viimeksi Suomenlahden itäosassa. Varsinaisen Itämeren tila on silti edelleen huonontunut. Kokonaiskuormitus Itämereen sen koko valuma-alueelta oli vuosijaksolla 1997−2003 yhteensä 36 900 t/a fosforia ja 910 00 t/a typpeä (HELCOM 2013). Kokonaiskuormitus Suomesta Itämereen oli vuosijaksolla 2011−2016 3840 t/a fosforia ja 90 300 t/a typpeä (Räike and Knuuttila 2018).

Rehevöityminen on aiheuttanut Itämerellä monenlaisia ongelmia, kuten leväkukintoja ja rantojen limoittumista. Se on myös osasyy pohjien happikatoon avoimen Itämeren ja rannikkovesien syvänteissä. Rehevöityminen lisää plankton- ja rihmalevien sekä vesikasvien biomassaa. Kuoltuaan levät vajoavat pohjaan missä ne hajotessaan kuluttavat happea ja lisäävät pohjan ja pohjanläheisen veden ravinnemäärää. Hapettomissa olosuhteissa pohjan sedimentteihin sitoutunut fosfori vapautuu veteen kiihdyttäen rehevöitymistä entisestään (ks. kuva 1). Olosuhteista riippuen ongelmat näkyvät Itämeren eri osissa eri tavoin. Varsinaisen Itämeren tila vaikuttaa Suomenlahden veden laatuun ja vähemmän Pohjanlahden tilaan. Sisäsaaristossa veden tila riippuu enemmän paikallisista olosuhteista ja kuormituksesta.

Kuva 1. Itämeren rehevöitymisen noidankehä (P = fosfori, N = typpi).

Tavoitteena on saavuttaa Itämeren meriympäristön hyvä tila vuoden 2020 loppuun mennessä EU:n meristrategiadirektiivin tavoitteiden mukaisesti. Suomi on sitoutunut HELCOMin toimenpideohjelman ravinnekuormituksen vähentämisen tavoitteisiin. Valtioneuvosto hyväksyi Suomen kansallisen merenhoitosuunnitelman vuonna 2015. Merenhoitosuunnitelma sisältää toimenpiteet kuormituksen vähentämiseksi.

Itämeren hyvän tilan saavuttaminen nopeassa aikataulussa rehevöitymisen osalta edellyttänee nykyisen ravinnekuormituksen merkittävän vähentämisen lisäksi myös meren sisäiseen ravinnevarastoon puuttumista. Malmaeus and Karlsson (2012) arvioi että Itämeren pääaltaan sedimentissä yli 65 metrin syvyydessä on 55 000 – 156 000 tonnia fosforia, joka voisi vapautua veteen näiltä alueilta. Vaikka HELCOMin toimenpideohjelman tavoitteet kuormituksen vähentämiseksi Itämeren alueella saavutetaan, mallinnustentulosten perusteella (HELCOM 2017) toipuminen vie senkin jälkeen vuosikymmeniä. Ilmastonmuutos hidastaa Itämeren toipumista rehevöitymisestä.

Ympäristöministeriön toimeksiannosta Vahanen Environment Oy:n kokoama kansainvälinen konsortio on kerännyt tietoa Itämeren sisäisten ravinnevarastojen nykytilasta ja dynamiikasta sekä kartoittanut yhdessä Centrum Balticum/BALEXin asiantuntijoiden kanssa erilaisia merialueilla suoritettavia toimenpiteitä, joilla sisäisiä ravinnevarastoja ja ravinteiden vapautumista olisi ehkä mahdollista hallita. Selvityksen painopiste on fosforissa.

Tässä hankkeessa keskitytään merialueilla toteutettaviin kunnostusmenetelmiin, joilla pyritään vähentämään sedimenttiin sitoutuneiden ravinteiden vapautumista ja poistamaan/vähentämään ravinteita merestä. Ulkoisen kuormituksen vähentämiseen tähtäävien toimenpiteiden jatkaminen ja tehostaminen on edelleen keskeisessä asemassa rehevöitymisen vähentämisessä.

Tarkasteltavia toimenpiteitä ovat erityisesti merenpohjan hapettaminen, sedimentin kemiallinen käsittely sekä pohjasedimentin poisto. Selvityksessä punnitaan eri kunnostusmenetelmien haittoja ja hyötyjä sekä arvioidaan mahdollisia riskejä. Toimenpiteitä arvioidaan teknisestä, ekologisesta ja sosio-ekonomisesta sekä oikeudellisesta, poliittisesta ja institutionaalisesta näkökulmasta.

Rannikkovesillä hapetuksesta ja alumiinikäsittelystä on melko hyvin tietoa lyhyellä aikavälillä toteutuksen jälkeen. Muista menetelmistä, kuten pohjasedimentin poistosta ja sedimentin kemiallisesta käsittelystä luonnonmateriaaleilla ja teollisuuden sivumateriaaleilla tarvitaan lisää tutkimustietoa. Rannikkovesillä riskit ovat hallittavissa ja pilotointeja voidaan jatkaa pitkän aikavälin vaikutusten arvioimiseksi ja menetelmien kehittämiseksi edelleen. Toimenpiteissä onnistutaan parhaiten silloin, kun kohteen olosuhteet, kuten pohja- ja virtausolot sekä ravinteiden kemiallinen pidätyskapasiteetti ovat suosiolliset ja kunnostustoimenpiteiden suunnittelussa otetaan huomioon erot murtovesien ja makean veden kunnostustekniikoiden välillä.

Kunnostustoimien kustannuksista on vähän tietoa ja eri arviot vaihtelevat suuresti muutamista euroista satoihin euroihin poistettua fosforikiloa kohti. Sovelletun menetelmän lisäksi paikalliset olosuhteet vaikuttavat merkittävästi kustannuksiin.

Oikeudellisesta näkökulmasta käsiteltävät toimenpiteet edustavat tuntematonta aluetta. Näille toimenpiteille ei ole olemassa erityisiä oikeudellisia puitteita, mutta useat erilaiset kansainväliset, EU-tason ja kansalliset säädökset asettavat yleisiä velvoitteita meriympäristön suojelusta ja säilyttämisestä sekä tiettyjä erityisiä vaatimuksia joillekin toimenpiteille. Käsiteltävien toimenpiteiden laillisuutta voidaan arvioida tarkemmin jakamalla ne luokkiin riippuen niiden herättämistä kysymyksistä ja niihin sovellettavista säännöistä. Myös maantieteellinen eriyttäminen on tehtävä toimenpiteen sijainnin perusteella. Eri merivyöhykkeillä sovelletaan erilaisia sääntöjä, mikä vaikuttaa niin kansainvälisen oikeuden sovellettavuuteen kuin kansalliseen lainsäädäntöön. Kumpikaan näistä kahdesta luokittelusta ei kuitenkaan näytä olevan ratkaiseva toimenpiteisiin liittyvien juridisten oikeuksien ja velvollisuuksien kannalta. Mitään toimenpiteiden ryhmiä ei voida sulkea pois tai hyväksyä ilman tarkempaa arviointia niiden vaikutuksesta. Merioikeuteen perustuva maantieteellinen luokittelu ei myöskään ole ratkaisevan tärkeä, koska valtioilla on huomattavaa lainkäyttövaltaa tämän tyyppiseen toimintaan kaikilla niiden merialueilla.

Sen sijaan oikeudellisesta tarkastelusta ilmenee, että kaikilla merialueilla toimenpiteiden laillisuus riippuu loppujen lopuksi niiden aiheuttamista riskeistä – lyhyellä ja pitkällä aikavälillä – verrattuna pitkän aikavälin hyötyihin. Ongelmana on, että kaikki nämä kysymykset ovat epävarmoja. Toimenpiteiden, erityisesti suuren mittakaavan sovelluksissa, vaikutukset eivät ole tiedossa. Kansainvälinen oikeus sisältää periaatteita siitä, miten käsitellä tieteellistä epävarmuutta, joka korostaa varovaisuuden tarvetta, mutta vaatii myös tapauskohtaista arviointia. Tämä korostaa tarvetta paitsi suuremmalle määrälle tietoa, myös asianmukaiselle menettelylle ehdotettujen toimenpiteiden arvioimiseksi.

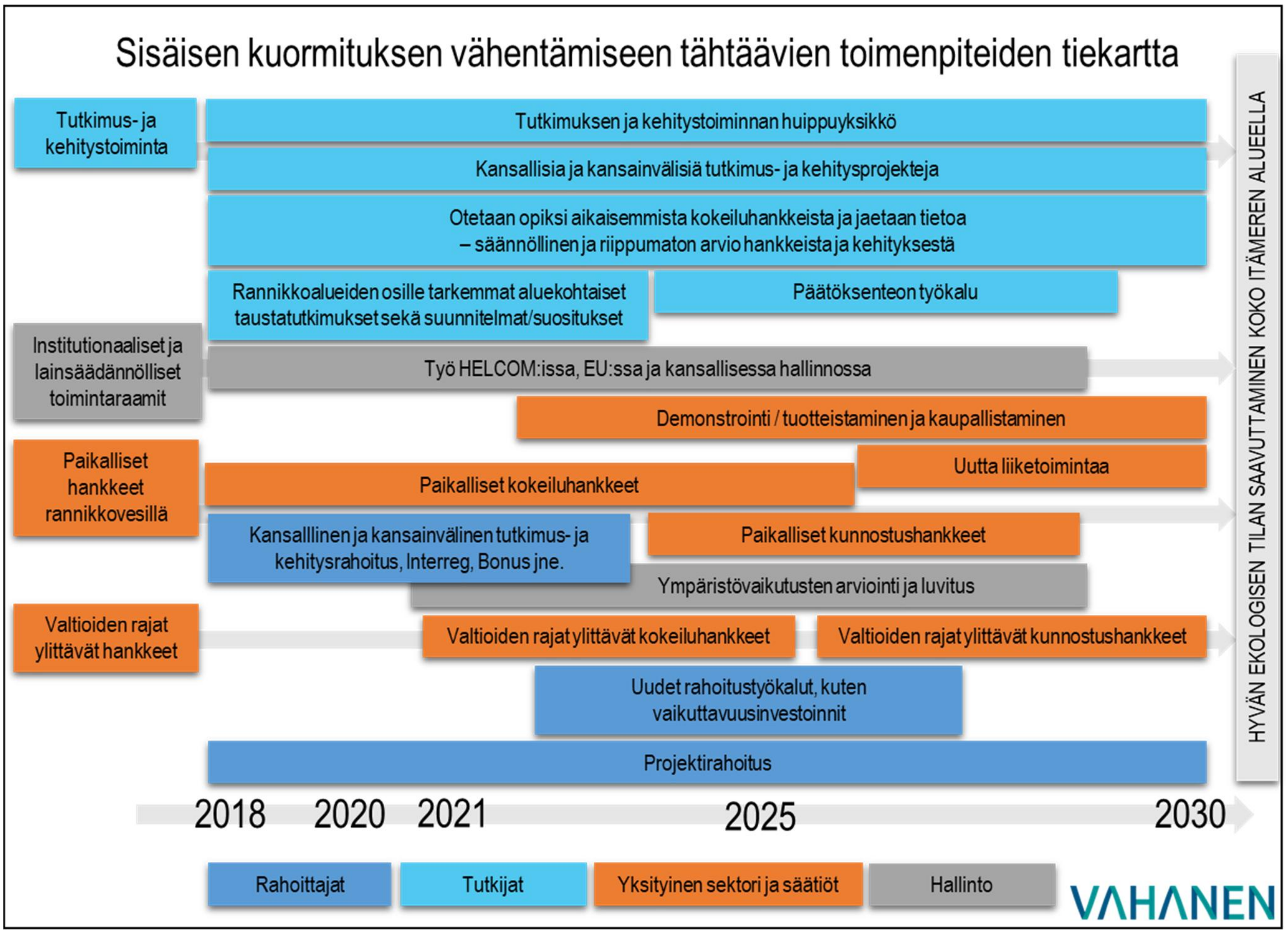
Kaikki tässä käsitellyt toimenpiteet, merialueesta tai niiden tarkoituksesta riippumatta, edellyttävät jonkinlaista lupaa molemmissa tässä selvityksessä tarkastellussa maassa, Suomessa ja Ruotsissa. Kansallinen lupamenettely on ratkaisevassa asemassa kansainvälisten ja kansallisten sääntöjen käytännön täytäntöönpanossa ja on siis vaihe, jossa velvoitteet ja hyödyt lopulta punnitaan toisiaan vastaan. Viimeaikaiset käänteet poliittisissa linjauksissa osoittavat suurempaa kiinnostusta käsitellä asiaa Itämeren alueen tasolla. Merenmuokkauksen sääntelyyn liittyvä globaali kehitys voisi tarjota mallin tällaisille alueellisille aloitteille.

Toimenpiteiden aiheuttamien vahinkojen taloudellinen vastuu kuuluu ensisijaisesti operaattorille eli henkilölle, jolla on lupa harjoittaa toimintaa. Valtiot eivät todennäköisesti ole taloudellisesti vastuussa roolistaan operaatioissa, mutta loppujen lopuksi niiden mahdollinen vastuu riippuu niiden roolista ja lupaehtojen mukaisista velvollisuuksista yksittäistapauksissa. Valtion kansainvälisen oikeuden mukainen vastuu ei todennäköisesti aktualisoidu käytännössä, mikä ei kuitenkaan sulje pois sitä, että valtiot voisivat mahdollisesti joutua kansainvälisoikeudelliseen vastuuseen erityisesti niitä koskevien lupa- ja valvontamenettelyvelvoitteiden johdosta.

Tutkimusta erilaisista merellä suoritettavista toimenpiteistä, niiden pitkän aikavälin tehosta ja kustannuksista tarvitaan lisää, jotta kunnostuksen vaikutukset tunnettaisiin nykyistä paremmin. Myös uusista menetelmistä tarvitaan tutkimustietoa, joka saatetaan nopeasti julkiseksi. Selvityksessä ehdotetaan, että noin kahden vuoden välein kootaan uusin saatavilla oleva tutkimustieto ja kokemukset toteutetuista toimista. Uusien paikallisten hankkeiden käynnistämiseksi ei ole esteitä niillä kunnostusmenetelmillä, joista tietoa on jo verrattain paljon olemassa, kuten ilmastus ja alumiinikäsittely. Rannikkovesien eri tyyppiset altaat ja suojaiset lahdet soveltuvat parhaiten koealueiksi. Selvityksessä ehdotetaan, että eri rannikkovesialueille tehdään aluekohtaiset selvitykset sisäisistä ravinnevarastoista sekä suunnitelmat ja suositukset niiden vähentämiseksi. Näiden pohjalta voitaisiin käynnistää paikallisia hankkeita. Toimiviksi ja kustannustehokkaiksi osoittautuvat menetelmät tulee saada rutiininomaiseen käyttöön pitkällä aikavälillä. Selvityksessä ehdotetaan lisäksi, että ministeriöt neuvottelevat Business Finlandin kanssa Itämeren sisäisten ravinnevarastojen vähentämiseen liittyvän innovaatiorahoitusohjelman käynnistämisestä teknologioiden kehittämiseksi sekä vastaavista toimista EU-rahoitus- ja tutkimusrahoitusohjelmien kanssa. Toistaiseksi tietopohja ei ole riittävä valtioiden rajat ylittävien laajojen hankkeiden toteuttamiseen.

Paikallisilla hankkeilla ei ole merkitystä koko Itämeren kannalta, mutta niiden paikalliset positiiviset vaikutukset voivat olla merkittäviä.

Haitalliset ympäristövaikutukset tulee hankkeissa selvittää ja minimoida – tämä tapahtuu luontevasti soveltuvien lupien hakemisen yhteydessä. Yhteisistä pelisäännöistä voidaan sopia HELCOMin piirissä, kuten on sovittu HELCOMin ministerideklaraatiossa 2018, jossa tunnustetaan alueellisen ohjauksen tarve asiassa ja kannustetaan alueelliseen riskinarviointikehykseen, jos toimenpiteillä on valtioiden rajat ylittäviä vaikutuksia. Toimenpiteistä on tärkeää tiedottaa ajoissa selkeästi ja avoimesti sekä paikallisella että kansainvälisellä tasolla, ja ottaa paikalliset asukkaat alusta lähtien mukaan prosessiin. Esitetyt toimenpiteet on koottu kuvan 2 tiekarttaan.



Kuva 2. Sedimentistä vapautuvien ravinteiden vähentämiseen tähtäävien toimenpiteiden tiekartta.

Executive summary

For decades, the Baltic Sea has been experiencing severe eutrophication caused by excessive external nutrient inputs. The significant decrease in phosphorus discharges from cities and industrial plants in the catchment area since the 1980s has improved water quality in the vicinity of cities, most recently in the Gulf of Finland. Nevertheless, the state of the Baltic Proper continues to deteriorate. The Baltic Sea annually receives a total of 36,900 tonnes phosphorus and 910,000 tonnes nitrogen from the catchment area (inputs in 1997-2003, HELCOM 2013). The annual inputs from Finland to the Baltic Sea are a total of 3,840 tonnes phosphorus and 90,300 tonnes nitrogen (2011-2016, Räike and Knuuttila 2018).

Eutrophication has caused a variety of problems, including blooms of blue-green algae (cyanobacteria) and the accumulation of slime along the shoreline. It is also part of the reason for oxygen debt in deep parts of the open sea and coast waters. Eutrophication increases the biomass of planktonic and filamentous algae and macrophytes. When the algae die, they sink to the bottom, where their decomposition consumes oxygen and increases the concentration of nutrients in the near-bottom water. In anoxic conditions, phosphorus that has been stored in the bottom sediments is released into the water, further accelerating eutrophication (Figure 3). Depending on local conditions, the problems manifest in different ways in different areas of the Baltic Sea. The water quality of the Baltic Proper affects the water quality of the Gulf of Finland and to a lesser extent that of the Gulf of Bothnia. In inner archipelagos, the water quality is more dependent on local conditions and nutrient inputs.

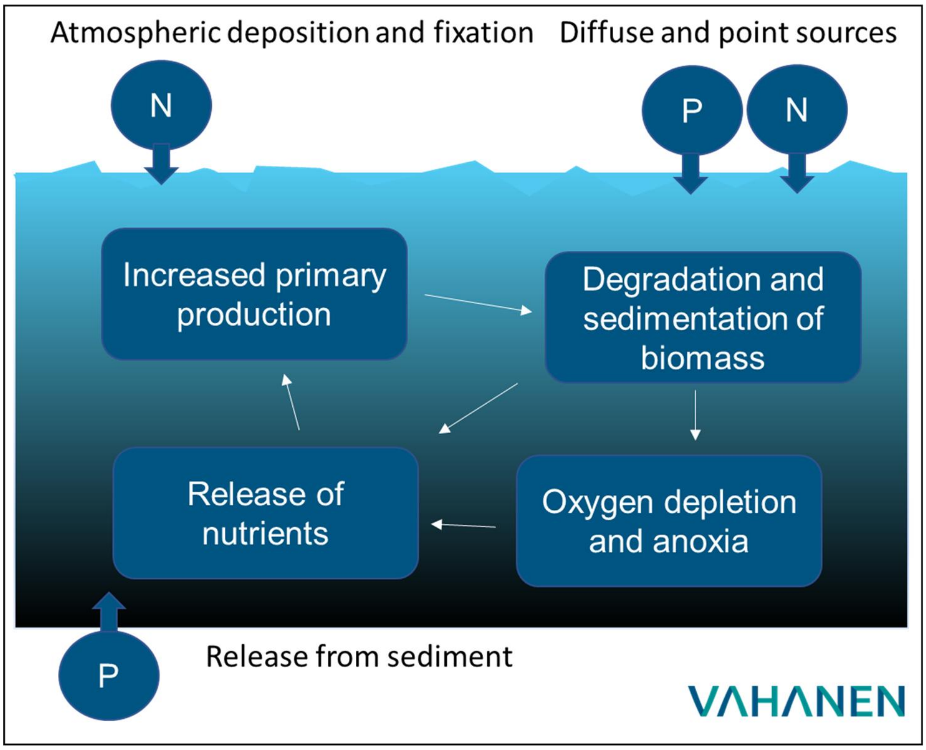


Figure 3. The vicious cycle of eutrophication *(P = phosphorus, N = nitrogen)*.

The objective is to reach a good status of the Baltic Sea by the end of 2020 in accordance with the targets of the EU Marine Strategy Framework Directive. Finland has committed to the nutrient reduction targets of the HELCOM Baltic Sea Action Plan. The Finnish government approved a national marine strategy in 2015. The strategy includes measures to reduce nutrient inputs.

In order to rapidly reach a good status of the Baltic Sea as concerns eutrophication, it is likely that there is a need to address also internal nutrient reserves, in addition to the current measures aimed at significantly reducing external nutrient inputs to the sea. Malmaeus and Karlsson (2012) estimated that the total amount of mobile P in the entire Baltic Proper sediments below 65 m water depth is between 55,000 tonnes and 156,000 tonnes representing the maximum amount of P that could possibly be released to the water column from these areas.

Even if the HELCOM Baltic Sea Action Plan nutrient reduction targets are achieved, model simulations (HELCOM 2017) indicate that it will take decades for the marine environment to recovery. Climate change slows down the recovery process of the Baltic Sea.

In this study commissioned by the Ministry of the Environment of Finland, an international consultant team lead by Vahanen Environment Oy has assessed the current status of the Baltic Sea's internal nutrient storages and dynamics and together with the expert team of Centrum Balticum/BALEX reviewed potential sea-based measures that could be used to possibly mitigate and manage the internal nutrient reserves. The main focus of the assessment is on phosphorus.

This study focuses on sea-based measures that aim to reduce the release of nutrients that are bound to bottom sediments and removal/reduction of nutrients from the sea. Land-based measures for reducing nutrient inputs continue to remain a priority for reducing eutrophication, and need to be continued and further enhanced.

The reviewed sea-based measures include mainly oxygenation of anoxic bottoms, chemical precipitation, and removal of sediment. The drawbacks, positive effects, and potential risks of the different measures were evaluated. The measures were assessed from technical, ecological, socio-economic, legal, political and institutional points of view.

For coastal waters, there is rather good understanding and experience of oxygenation and aluminum treatment and the short-term effects of these measures. More research is needed on other methods, such as sediment removal and especially more novel methods like clay bombing and marl treatment. In coastal waters, risks are manageable and local pilots can be continued to gather knowledge on long-term effects and to further develop methods. Sea-based measures are most likely to be successful when the bottom and current conditions as well as chemical nutrient retention capacity are favourable, and when the differences between brackish and lake conditions are taken into account in the planning of mitigation measures.

Limited information is available on the costs of the different measures and cost estimates vary greatly, from a few euros to hundreds of euros per removed kg of phosphorus. In addition to the applied measure, the cost is also largely affected by local conditions.

In legal terms, sea-based measures represent uncharted territory. There is no specific legal framework for such measures, but a number of different international, EU and national decrees set general obligations to protect and preserve the marine environment, along with certain more specific rules for some of the measures. The legality of sea-based measures can be assessed in more detail by dividing the measures into substantive categories depending on the types of issues they raise and the applicable rules. A geographical differentiation also needs to be made on the basis of the location of the measure. Different rules apply in the different maritime zones, which affects the applicability of international law as well as national legislation. Yet, in the end neither of the two categorizations appears to be of decisive importance for the legal rights and obligations involved in sea-based measures. None of the categories of measures can be ruled out or accepted without a closer assessment of their impact. The geographical categorization under the law of the sea is not of crucial relevance either, since there is considerable jurisdiction for states for this type of activities in all of their maritime zones.

Instead, what transpires from the legal review is that the legality of any kind of sea-based measure, in any sea area, in the end depends on the risks they present – in the short and longer term – balanced against their longer-term benefits. The problem is that there is considerable uncertainty on all these issues. The effects of such measures, in particular in large scale applications, are not known. International law includes principles on how to deal with scientific uncertainty that highlight the need for caution, but also call for a case-by-case assessment. This highlights the need for, not only more knowledge, but also a proper procedure for evaluating the proposed measures.

All sea-based measures discussed here, irrespective of the sea area or their purpose, need some form of permit in both states analysed in this study, Finland and Sweden. The national permit procedure will be decisive for implementing the international and national rules in practice and will hence be the place where the risks and benefits eventually will be weighed against each other. Recent policy developments suggest a larger interest for dealing with the matter at Baltic Sea regional level. The global developments relating to regulation of marine geo-engineering could provide a model for such regional initiatives.

The financial liability for any damage caused by such measures will typically fall on the operator, i.e. the person who has the permit or authorization to undertake the activity. States are less likely to be financially accountable for their role in the operation, but in the end, their exposure depends on their role and responsibilities under the permit regulations in the individual case. State responsibility under international law is unlikely to arise in practice, but it is not excluded that the international conditions for responsibility could be met, in particular regarding states' obligations to ensure the procedural framework for approving and monitoring the measures.

More research is needed on sea-based measures, their long-term efficiency and costs in order to have a better understanding of their impacts. Research is needed also on potential other new measures and it should be publicly disseminated quickly. This study proposes that information on new research and experiences gained on implemented measures is compiled and reviewed every second year. There are no obstacles for implementing new local projects using measures for which there is already substantial information, such as oxygenation and aluminium treatment. The best pilot areas are different types of basins and enclosed bays in coastal areas. This study suggests that local assessments of internal nutrient reserves, as well as plans and proposals for reducing them, should be made for different coastal areas. These would serve as a basis for starting local projects. Viable and cost-efficient measures should be taken into routine, long-term use. The study additionally proposes that, ministries should negotiate with Business Finland and corresponding EU financing and research programs about setting up an innovations funding programme to support the development of technologies that address the reduction of internal nutrient loading in the Baltic Sea. There is currently not enough information for implementing larger scale transnational projects.

Local projects have limited impact on the Baltic Sea as a whole, but they can have significant positive effects locally.

Projects should evaluate and minimize potential negative environment impacts – this happens naturally in the process of applying for relevant permits. Common rules could be agreed on in the HELCOM framework, as has been accepted in the HELCOM Ministerial Declaration of 6 March 2018, which acknowledges the need for regional guidance in this matter and encourages a regional risk assessment framework for measures with transboundary impacts. Transparent and open communication locally and internationally is important, and local resident should be involved in the process from the beginning. The proposed actions are summarized in the roadmap presented in Figure 4.

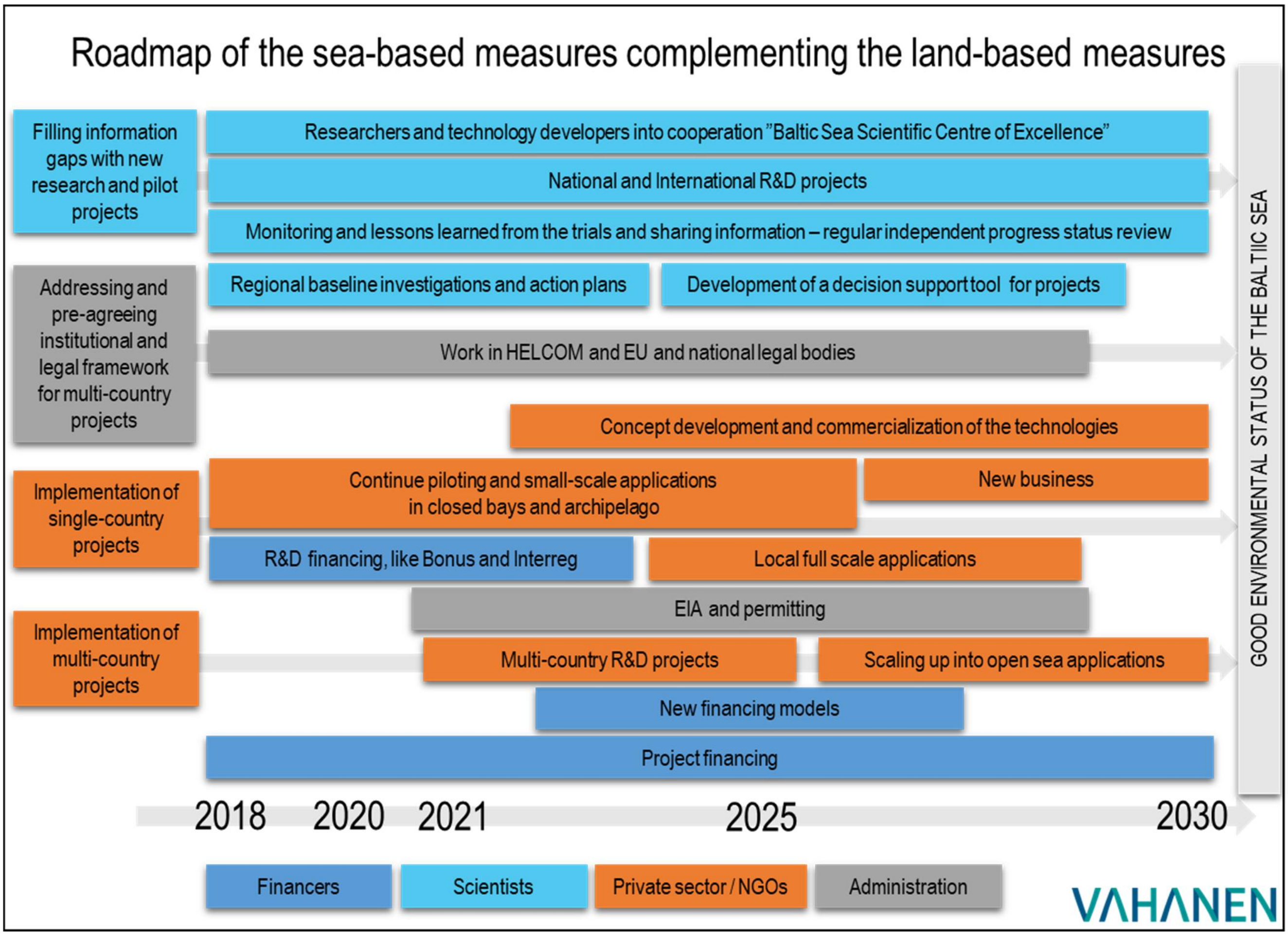


Figure 4. Roadmap of the sea-based measures.

List of abbreviations and acronyms

Aarhus Convention	The 1998 UNECE Convention on Access to Information, Public Participation in Decision-making and Access to Justice in Environmental Matters
Birds Directive	Directive 2009/147/EC on the conservation of wild birds
BSAP	HELCOM Baltic Sea Action Plan
CBD	The 1992 UN Convention on Biological Diversity
CJEU	Court of Justice of the European Union
CS	Continental shelf
ECJ	European Court of Justice
EEZ	Exclusive Economic Zone
EIA	Environmental Impact Assessment
EIA Directive	Directive 2011/92/EU on the assessment of the effects of certain public and private projects on the environment
EIS	Environmental Impact Statement
ELD, Environmental Liability Directive	Directive 2004/35/CE on environmental liability with regard to the prevention and remedying of environmental damage
Environmental Code	Swedish Environmental Code (1998:808)
EPA	Finnish Environmental Protection Act (527/2014)
EQS	Environmental Quality Standards
Espoo Convention	The 1991 UNECE Convention on Environmental Impact Assessment in a Transboundary Context
EU	European Union
EUSBSR	European Union Strategy for the Baltic Sea Region
GES	Good Environmental Status
GOF	the Gulf of Finland
GSLR	Global mean sea level rise
H_2S	Hydrogen sulphide
Habitats Directive	Directive 92/43/EEC on the conservation of natural habitats and of wild fauna and flora
HBCDD	Hexabromocyclododecane
Helsinki Convention	The 1992 Convention on the Protection of the Marine Environment of the Baltic Sea Area
ICJ	International Court of Justice
ILC	International Law Commission
ITLOS	International Tribunal for the Law of the Sea
London Convention, LC	The 1972 Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter
London Protocol, LP	The 1996 Protocol to the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter
LUBA	Finnish Land Use and Building Act (132/1999)
MCCP	Medium chain chlorinated paraffins

MSFD	Directive 2008/56/EC on establishing a framework for community action in the field of marine environmental policy (Marine Strategy Framework Directive)
MSPD	Directive 2014/89/EU on establishing a framework for maritime spatial planning (Maritime Spatial Planning Directive)
N	Nitrogen
NCA	Finnish Nature Conservation Act (1096/1996)
NGO	Non-governmental organisation
nm	Nautical mile
P	Phosphorus
PAH	Polyaromatic hydrocarbons
PBDE	Polybrominated diphenyl ethers
PBT	Persistent, Bioaccumulative and Toxic
PCB	Polychlorinated biphenyls
PCDD/F	Dioxins and furans
PFOA	Perfluorooctanoic acids
PFOS	Perfluorooctane sulfonate
Rio Declaration	UNCED Declaration of 1992 on Environment and Development
SCCPs	Short chain chlorinated paraffins
SDC	Seabed Disputes Chamber
SEA Directive	Directive 2001/42/EC on the assessment of the effects of certain plans and programmes on the environment
SwAM (HaV)	Swedish Agency for Marine and Water Management (Havs- och vattenmyndigheten)
TFEU	Treaty on the Functioning of the European Union
UN	United Nations
UNCED	United Nations Conference on Environment and Development
UNCLOS	The 1982 United Nations Convention on the Law of the Sea
UNECE	United Nations Economic Commission for Europe
WA	Finnish Water Act (587/2011)
Waste Framework Directive	Directive 2008/98/EC on waste
Weser Case	ECJ Case C-461/13 Bund für Umwelt und Naturschutz v Germany
WFD	Directive 2000/60/EC on establishing a framework for Community action in the field of water policy (Water Framework Directive)
WMA, Water Resource Management Act	Finnish Act on the Organisation of River Basin Management and the Marine Strategy (1299/2004)
WTP	Willingness to pay
WWTP	Wastewater treatment plant

1 Introduction

1.1 Background of the assessment

The EU Marine Strategy Framework Directive (MSFD) has the objective that good environmental status (GES) will be achieved in the EU's marine waters by 2020. The HELCOM Baltic Sea Action Plan has set out targets for nutrient input reductions and good status in terms of eutrophication. The MSFD requires member states to develop marine strategies and programmes of measures to achieve that objective. The government of Finland approved the programme of measures for the Finnish Marine Strategy 2016–2021 on 3 December 2015. According to the programme, in order to achieve a good environmental status and reduce eutrophication to an acceptable level in Finland's coastal and open sea waters, nutrient inputs must be cut by at least 440 tonnes of phosphorous and 6,600 tonnes of nitrogen a year in relation to the annual average level in 2006–2011. Implementation of the river basin management plans under the Water Framework Directive (WFD) play a key role in cutting nutrient inputs from land-based sources in the drainage area.

There has been a lot of discussion in recent years, especially in Sweden and Finland, about possibilities and associated risks of measures to speed-up the recovery of the Baltic Sea by using various sea-based measures. There have been several recent investigations and test results on such measures. According to the Finnish policy, reflected in the river basin management plans and programme of measures, cutting inputs from land to the sea is a priority and implementation of the agreed measures must continue. However, solely by implementing land-based measures, recovery of the Baltic Sea to a good status may take a century or more.

Sea-based measures are defined here as measures and methods that can be applied to reduce the release of nutrients from internal sources, mainly the sediment, to the water and that enable managing the nutrient storages in the Baltic Sea or extracting nutrients from the sea, as opposed to measures that limit the introduction of new nutrients into the sea from land, air and sea surface sources such as ships.

Until now, the predominant view has mainly been against medium to large-scale sea-based measures, which have potential cross-border environmental impacts or potentially long-term adverse effects on the environment, with a call for more research. During a recent HELCOM-EUSBSR Workshop on internal nutrient reserves held in Gothenburg in November 2017, there was common opinion that clearly approved of pilot projects with local environmental impacts. In Finland and Sweden the possibilities for new pilot projects and methods are being studied.

In March 2018 the HELCOM Ministerial meeting adopted the HELCOM Brussels Ministerial Declaration which also recognized that large amounts of nutrients have accumulated in the Baltic Sea resulting in an enhanced internal flux of nutrients. The ministers acknowledged the need to elaborate in line with the Helsinki Convention commonly agreed regional principles as guidance for internal nutrient reserves management and encouraged the development and application of a risk assessment framework in HELCOM to meet the necessary environmental requirements for measures planned for the open sea and any other measures having potentially significant transboundary effects. (HELCOM 2018)

1.2 Objectives

The overall objectives of this assessment are to increase the knowledge of:

- the role of internal nutrient sinks and sources that are connected to internal nutrient leakages that contribute to causing and maintaining eutrophication in the Baltic Sea
- potential sea-based measures to address the release of nutrients from internal storages to supplement the land-based measures for speeding up the recovery of the Baltic Sea and achieving good environmental status (GES) according to the MSFD and the HELCOM Baltic Sea Action Plan (BSAP) targets.

In accordance with the project terms of reference, the immediate objectives of this study are to:

- collect and analyse currently available knowledge of the internal nutrient dynamics and the sustainability of potential sea-based measures that address internal sources and their associated risks,
- identify knowledge gaps,
- assess the legal, political and institutional framework that governs sea-based measures in the Baltic Sea region, with a particular emphasis on Finnish and Swedish law
- propose a roadmap to increase knowledge on internal nutrient dynamics and implementation of sea-based measures, and
- prepare a concise Final Report and communicate the results to the participants of a concluding Workshop, as instructed by the Client and the Steering Group.

The study supports the implementation of Finnish Marine Strategy's programme of measures. It includes background information, relevant milestones of historic development, presentation of main technologies and sea restoration methods, analyses of their pros and cons, as well as an overview of their impacts and risks. Also the political, legal and institutional aspects are assessed. Finally, main recommendations, conclusions and a roadmap are presented. Although the geographical scope of the assignment is the whole Baltic Sea, the study focuses on the effects of the internal release of nutrients on Finland's marine waters up to the outer limit of Exclusive Economic Zone (EEZ). The entire Baltic Sea, including Bornholm Basin and Eastern Gotland Basin, are considered as they have an impact on Finland's marine waters.

2 Ecological review and assessment

SUMMARY

The Baltic Sea has suffered from eutrophication for decades. It is caused by excessive external nutrient inputs. The significant decrease in phosphorus discharges from cities and industrial plants since the 1980s has improved water quality in the vicinity of cities, most recently in the Gulf of Finland. Nevertheless, the state of the Baltic Proper continues to deteriorate.

The Baltic Sea received phosphorus 36,900 tons/year and nitrogen 910,000 tons/year from the catchment in total in the years 1997-2003 (HELCOM 2011). Inputs from Finland to the Baltic Sea was phosphorus 3,840 tons/year and nitrogen 90,300 tons/year in the years 2011-2016 (Räike and Knuuttila 2018).

Eutrophication has caused a variety of problems, including increased biomass of phytoplankton blooms of e.g. blue-green algae (cyanobacteria) and the accumulation of slime along the shoreline. It is also part of the reason for oxygen debt in deep parts of the open sea and coast waters. Eutrophication increases the biomass of planktonic and filamentous algae and macrophytes. Dead phytoplankton sink to the bottom, where their decomposition consumes oxygen and increases the concentration of nutrients in the near-bottom water. In anoxic conditions, phosphorus that has been stored in the bottom sediments is released into the water, further accelerating eutrophication. Depending on local conditions, the problems manifest in different ways in different areas of the Baltic Sea. The water quality of the Baltic Proper affects the water quality of the Gulf of Finland. The Gulf of Bothnia has less exchange of water with the Baltic Proper and the concentrations of phosphorus are generally lower. The conditions in open sea areas above the halocline are rather homogeneous in the whole Baltic Proper. In inshore areas with limited water exchange with the open sea, the conditions are often more dependent on local conditions and loading.

During the last century, both the extent of hypoxic sea bottom areas, as well as the duration of hypoxic periods, has increased in the Baltic Sea. At the same time the sediment pool of P has increased dramatically. Bottom sediments transform from phosphorus sinks to phosphorus sources when the state of the sediment-water interface changes from oxic to anoxic, although also various other local conditions in the sediments and at the sediment-water interface affect this balance. High levels of phosphorus are maintained in the water by the combined impact of residual external loading and phosphorus release from sediments in anoxic conditions.

A large proportion of N in the Baltic Sea is of anthropogenic origin from agriculture, forestry and dispersed settlements. Cycling of N is microbially mediated. Nitrogen from the water column is converted into nitrogen gas by a microbiological process, denitrification, and escapes from the sea into the atmosphere. Transformations of nitrogen are dependent on several factors and the dominant reactions vary.

It is evident that the recovery of the Baltic Sea will take a substantial time. Model simulations (HELCOM 2017) indicate no or only little improvement in water quality of the Baltic Sea compared to its present state as a result of the decrease in nutrient

loads in recent decades. Due to complex and non-linear processes, including counteracting impacts from climate change, it is challenging to predict the path of its recovery. According to the model simulations, significant improvements will be seen only decades after the land-based nutrient reduction targets defined in the HELCOM Nutrient Reduction Scheme have been fulfilled.

The main sink for hazardous substances in the aquatic environment is in sediments, although they also accumulate in water and biota. Some compounds are present in higher concentrations close to their discharge points, whereas some are more evenly distributed in the sediment across the Baltic Sea. The sea-based restoration solutions presented in this study may release harmful substances from sediments, which has to be taken into account in risk analysis (see Chapter 3).

2.1 Physical characteristics of the Baltic Sea

The geographical division of the Baltic Sea is based on the form of coastline, thresholds (sills) and other geomorphological formations (Myrberg et al. 2006). The sills are defined according to a minimum depth between two sub-basins, or in other words the depth up to which horizontal exchange between sub-basins is possible. The main sub-basins and sills are illustrated in Figure 5.

Figure 5. Main sub-basins of the Baltic Sea, the most important sills between the main sub-basins and the Landsort and Gotland deep. The lines represent the main sills and minimum water depth is given (HELCOM 2013a, Myrberg et al. 2006)

2.1.1 Geomorphology

The Arkona Basin is the first sub-basin to the east of the Danish Straits, followed by the Bornholm Basin, which is to the east of the island of Bornholm. The typical depth of Bornholm Basin is 60–80 m (maximum 105 m). To the north and east of these sub-basins are the Gotland Basin (eastern and western) and Northern Baltic Proper. These sub-basins, together with the Gdansk Basin constitute the Baltic Proper. East of the Baltic Proper, there are two major bays: the Gulf of Finland (GOF) and the Gulf of Riga. To the north is the Gulf of Bothnia, which can be further divided into the Bothnian Sea, the Quark and the Bothnian Bay. The Archipelago Sea and the Åland Sea can also be considered as part of the Gulf of Bothnia.

The deepest area of Gotland Basin, Landsort Deep (459 m), is located in the northern part of Western Gotland Basin. It is surrounded by a depth of 150 m. Gotland Deep (250 m) is located in Eastern Gotland Basin between the island of Gotland and the Latvian coast. The bottom zone below 200 m has been anoxic since the end of the 1950s. The major Baltic inflows, major salt pulses from the North Sea, replace significant volumes of anoxic water with high phosphorus concentration (e.g. Furman et al. 2013).

The topography of the Baltic Sea can be divided into three zones: coastal zone, transitional zone and open sea. The coastal zone extends from the mainland to the outer islands where the transitional zone begins and extends to a depth of 50 meters. The open sea area is extends out from beyond the transitional area.

The currents are driven by winds, differences of atmospheric pressure, density variation of water masses and geomorphology. The currents of the Baltic Sea vary according to the weather and stable currents do not exist as they do in the oceans. Dominating southwesterly winds, together with rotation of the globe, induce the counterclockwise circulation of surface waters during a long time span (Leppäranta and Myrberg 2009).

The depth of Gulf of Finland (GOF) is typically 20-40 m off the Finnish coast and 40-80 m off the Estonian coast, with the deepest areas being 80–100 m. There is no sill between the Northern Baltic Proper and the GOF and these areas have a continuous exchange of water at all layers depending on the winds, flows from the main rivers and the currents induced by horizontal density gradients. Due to the Coriolis force, the dominating long-term current direction is clockwise, i.e. in GOF to the east off the Estonian coast and to the west off the Finnish coast. Hence, the fresh waters entering the Baltic Sea via River Neva and the River Kymijoki, flow to the west along the Finnish coast.

The mean depth of Bothnian Sea is 60 m and the deepest (293 m) area is located near the Swedish coast. The mean depth of Bothnian Bay is 43 m with the deepest area being 147 m. The Quark (mean depth less than 10 m) and the Archipelago Sea (mean depth 23 m) are shallower, but the depth of Åland Sea varies from 70-80 m in the south to 200-300 m in the north. The sill between the Gulf of Bothnia and the Baltic Proper prevents efficient water exchange and usually only surface water from the Baltic Proper flows into the Gulf of Bothnia.

2.1.2 Water exchange and stagnation

The narrow and shallow Danish Straits prevent efficient water exchange between the North Sea and the Baltic Sea.

The currents near the deep bottoms are slower than on the surface. Occasionally, the Baltic Sea receives large pulses of salty water from the North Sea via Danish Straits. Such a salt pulse may throw 200-300 km^3 cold, oxygen-rich and salty surface water from the North Sea during few weeks. During large inflow events, the inflowing water from the Kattegat is much denser (saltier) than the water residing in the Baltic Proper and it flows therefore along the bottom as a dense bottom current pushing and lifting the residing deep water which is rich in nutrients and sulphur. The bottom current entrains overlying less saline water whereby the volume flow increases, and the salinity decreases as the new deep water progresses into the southern Baltic Proper. When this process is completed one unit of new deep water from Kattegat has been mixed with about two units of water from the Baltic Proper (e.g. Stigebrandt 2001).

The major Baltic inflows occur occasionally, varying from intervals of a few years to decades. The occurrence of the major Baltic inflow during autumn or winter is forced mainly by sea level differences and caused by constant strong westerly winds, preceded by easterly winds. The inflowing waters are usually rich in oxygen and carry significant amounts of salt and nutrients (Rak 2016). The salt pulses have occurred rather infrequently during recent decades. The latest strong event occurred in December 2014 (Gräwe et al. 2015, Mohrholz et al. 2015). Several theories have been proposed to explain the decrease of the frequency of the major Baltic inflows, which are e.g. coupled to changing riverine flow or meteorological patterns (e.g. Leppäranta and Myrberg 2009). Figure 6 illustrates the occurrence of minor and major Baltic inflows.

These major inflows are often followed by a period of stagnation, when only minor or no inflows occur, during which saline stratification decreases and oxygen deficiency develops in the bottom waters. Minor inflows occur several times a year, but major inflows may have long periods of absence. There were, for example, long stagnation periods during 1983-1993 and 2003–2014 (Figure 7), but before them, a maximum of three years stagnation periods were observed. The effects of inflows on the ecosystem depend on the amount and salinity of water.

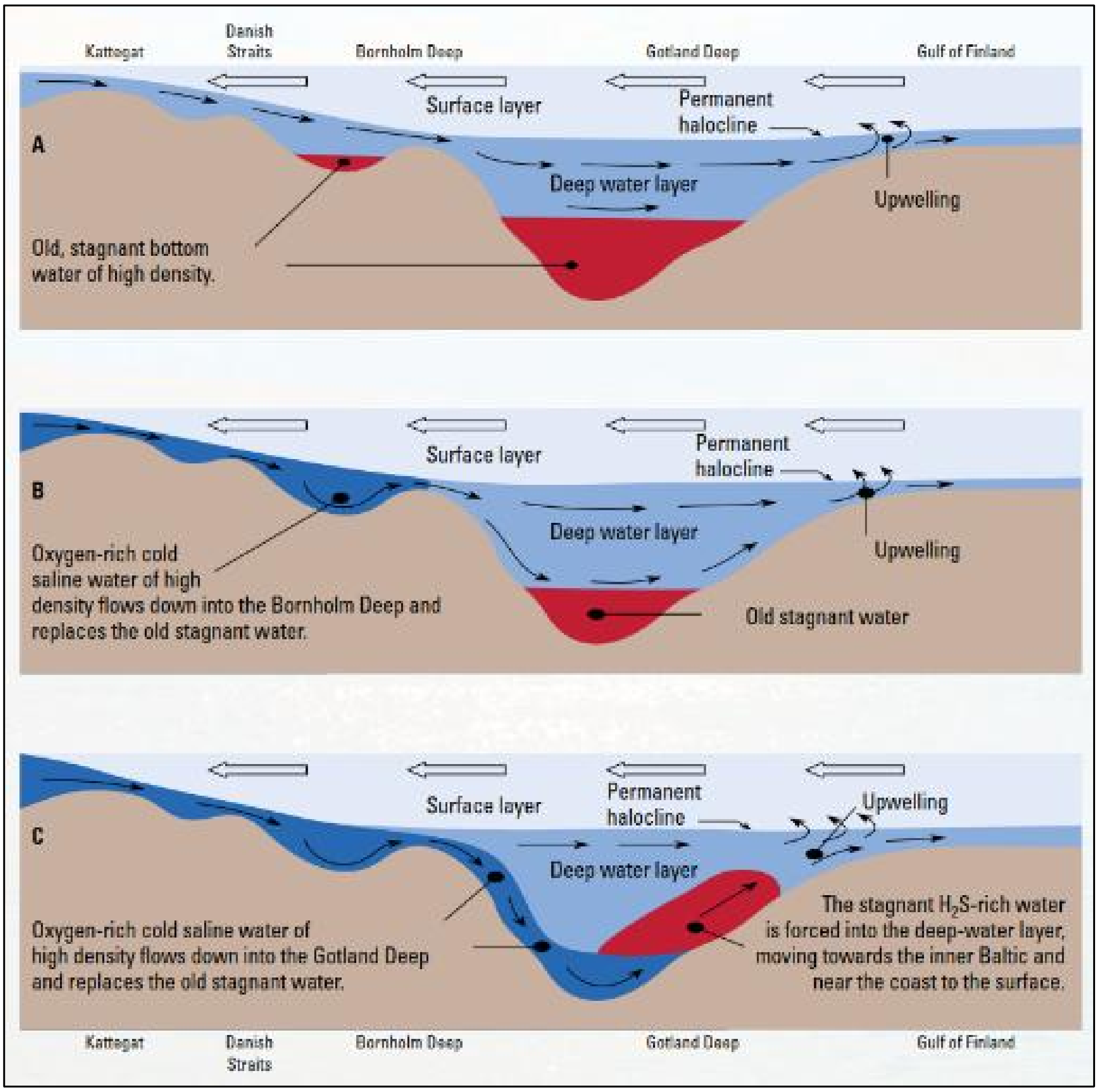


Figure 6. Schematic figure of the movements of Baltic Inflow of oxygen-rich water with high salinity from the North Sea (Furman et al. 2013).

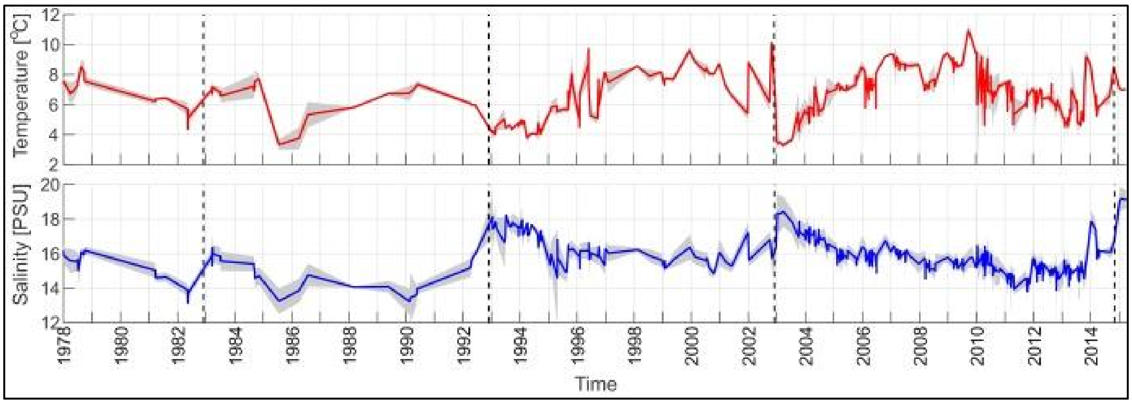


Figure 7. Temporal variability of the mean temperature and salinity in the Bornholm Basin averaged in the layer below 70 m during 1978–2015. The mean (line) and standard deviation (shaded area) of the temperature and salinity are based on individual cruises. (Rak 2016).

Baltic inflows temporarily improve the quality of the deep waters in the central Baltic Proper, and are therefore of great importance also for the water quality in the GOF. The minor inflows push only a small amount of saline water that cannot ventilate the deeps of the Baltic Proper. Somewhat larger inflows have the power to replace anoxic water from the Bornholm Deep, but have no effect on Gotland Deep. The major Baltic inflows replace the saline, low-oxygen, nutrient-rich water in the deeps, displacing these waters towards shallower coastal areas, where they are brought to the surface layer. This can be seen in the low oxygen content and high nutrient concentrations that impact the GOF and cause anoxia (Furman et al. 2013). The Gulf of Bothnia is significantly less influenced due to the two sills on both sides of Åland (Raateoja and Setälä 2016). The GOF, on the other hand, does not have such a “protective sill” and thus the deep water of the Gotland Basins can have a marked influence on the GOF hydrography. Although the narrow straits and high sills in the Åland Sea effectively prevent salt pulses from entering the Gulf of Bothnia, major pulses are strong enough to have effects on the water quality also in the Bothnian Sea. Since the P concentration in the Bothnian Sea is lower than in the GOF, the pulses result in a relatively higher increase in the P concentration in the Bothnian Sea than in the GOF (Andersen et al. 2011, Korpinen et al. 2018).

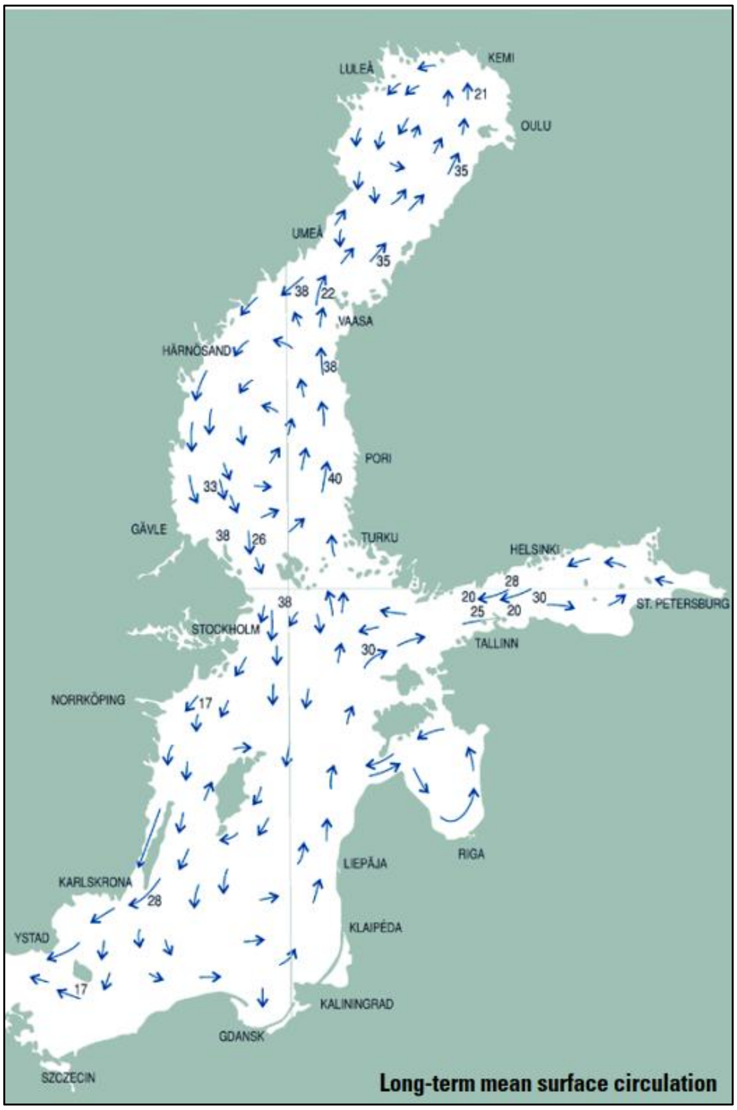


Figure 8. Long-term mean surface water circulation (Furman et al. 2013, originally presented by Leppäranta and Myrberg 2009)

2.1.3 Stratification

Role of thermocline

During spring and summer, a thermocline forms when surface water warms up and is separated from the cold water below. The thermocline is a layer of water in a thermally stratified body of water that displays a rapid decline in temperature and which separates an upper warmer layer (the epilimnion) and a lower colder layer (the hypolimnion). In summer, the thermocline occurs at 10-20 meters depth. It prevents the mixing of surface and near bottom waters, which often leads to the anoxia of deep areas. The thermocline breaks down during autumn when the surface water layer cools down and convective mixing breaks down the thermocline, allowing strong autumn storms to mix the water column all the way down to the bottom (or to the permanent halocline, where this exists). Nutrient-rich water is then distributed evenly throughout the whole water column.

Throughout the Finnish coastline, there are many relatively isolated small water bodies; bays and lagoons. The water exchange between these bays and open sea areas is sometimes restricted and their nutrient status is largely affected by surrounding land use and maritime activities, such as aquaculture (Viitasalo et al. 2005, Furman et al. 2013, Almroth-Rosell et al. 2016,). Stratification of these bays is often temperature based. Coastal ecosystems are much more unstable than pelagic or deep benthic ecosystems (Furman et al. 2013).

Hordoir and Meier (2012) used 3D modelling and sensitivity analysis to compare periods at the end of the 20th and 21st centuries and found in the northern Baltic Sea a strong increase in stratification at the bottom of the mixed surface layer. The increased vertical stratification is explained by a major change in re-stratification during spring, which is caused by the increase of the mean temperature. In future climate, changing spring and summer stratification at the bottom of the mixed layer will increase towards the north. Since in the present climate, winter water temperatures in the Baltic Sea are often below the temperature of maximum density, thermal convection occurs when water warms in spring. Re-stratification during the beginning of spring is then triggered by the spreading of freshwater. This process is believed to be important for the onset of the spring bloom. In the future, temperatures are expected to be higher than the temperature of maximum density and thermally induced stratification will start without prior thermal convection. Thus, freshwater controlled re-stratification during spring will no longer be an important process. It is suggested that these stratification changes may have an important impact on vertical nutrient fluxes and the intensity of the spring bloom in the future climate of the Baltic Sea.

Role of halocline

The surface water salinity in the Kattegat is around 20 ‰ and decreases gradually towards eastern Gulf of Finland and northern Gulf of Bothnia, where the surface salinity is about 0–3 ‰. Rivers bring fresh water into the Baltic Sea, whilst saline water flows in through the shallow Danish Straits.

The Baltic Sea is stratified (i.e. its salinity increases from the surface to the bottom) as a result of the inflowing salt water which is denser than the brackish water, with the most saline water occurring in the deepest parts of the Gotland and Bornholm Basins (Figure 9, Myrberg et al. 2006, Furman et al. 2013). The halocline is a layer that displays a clear increase in salinity and density in a stratified body of water. The layer above the halocline mixes in autumn and spring, but does not reach the water layer below halocline. Only inflows from the North Sea can renew the oxygen content of the deeper water layers. In the Finnish sea area, there is a strong halocline in the Northern Baltic Proper and in the western part of the GOF. The water column of the shallow Archipelago Sea mixes almost completely in autumn and winter.

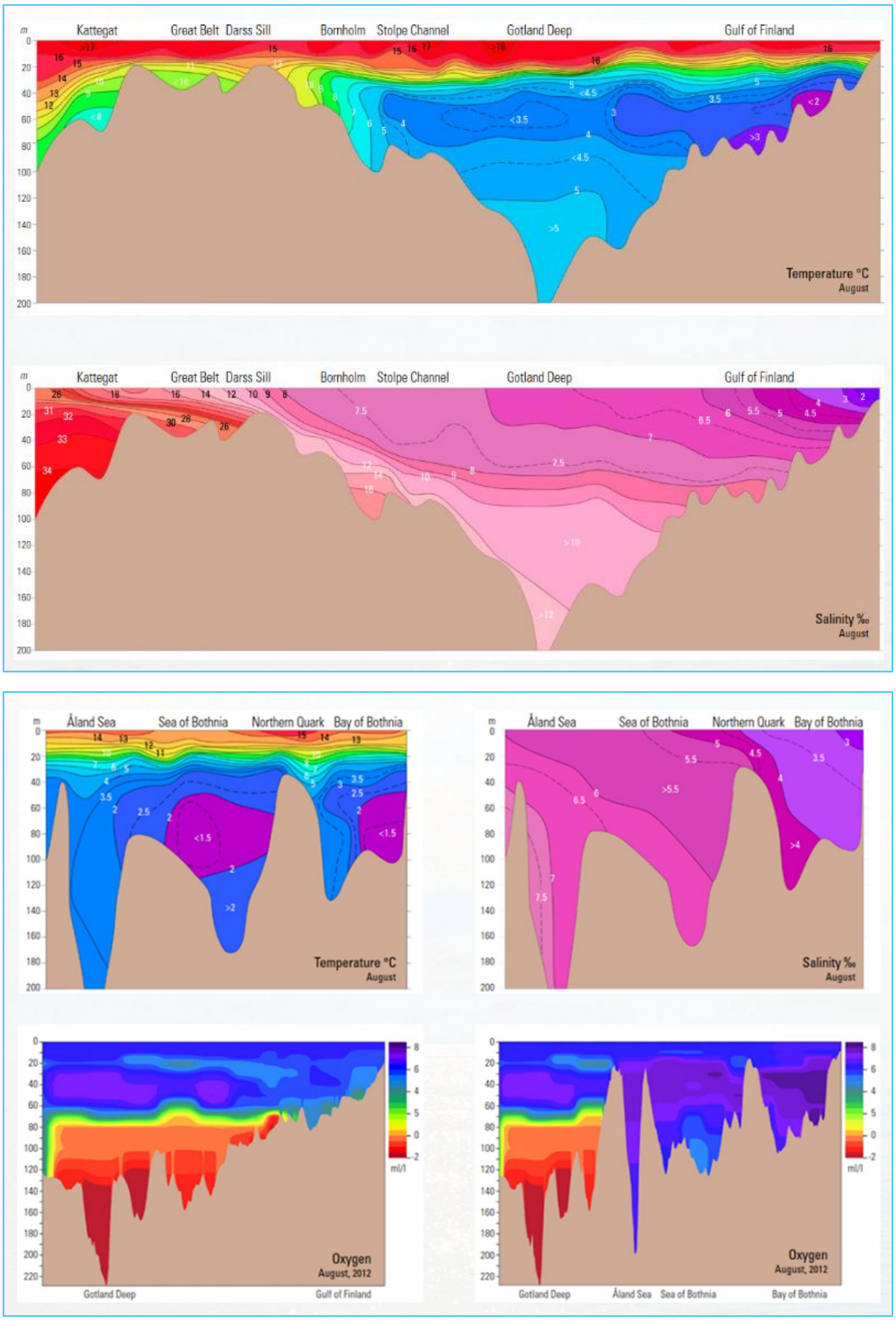


Figure 9. The Baltic Sea hydrography: horizontal profile of temperature, salinity and oxygen (Furman et al. 2013)

The strong vertical stratification in the halocline hampers vertical mixing and the transfer of oxygen from the surface layer to the deep water by diffusion. Therefore, almost all oxygen that is supplied to the deep basins of the Baltic Proper comes with inflows of new oxygen-rich water with high salinity from the Kattegat. Since organic matter sinks to the deep areas, decomposing and consuming oxygen from the near bottom water, anoxic areas develop and gradually widen until there is an inflow of oxygen-rich water to the Baltic Sea. Anoxic areas have significantly increased due to increased primary production and organic matter. Eutrophication also increases oxygen deficiency in basins between islands and shallows in coastal areas. The biotic community of the bed bottom changes because only few species tolerate oxygen deficiency. The trenches of the Northern Baltic Proper are continuously anoxic and in the GOF oxygen depletion occurs regularly. The oxygen situation is mainly good above the halocline and in other Finnish sea areas.

Lehtoranta et al. (2017) observed that the long-term salinity variation of the bottom water in the northern Baltic Proper controls the salinity levels in the GOF and that the deep water concentrations of oxygen and nutrients are significantly correlated between the basins. Over short timescales, winter winds in particular can control the in- and outflows of water, the vertical stratification and mixing, which to a large extent explain the inter-annual variation in the DIN and TP pools in the GOF. The inter-annual variation in the amounts and spatial distribution of nutrients sets variable preconditions for the spring and potential blue-green algae blooms (Figure 10).

The deep areas below the halocline in the Gotland Basins often run out of oxygen, and hydrogen sulphide is formed at the bottom of the deepest parts. In the Gulf of Bothnia, the oxygen concentration remains relatively high throughout the water column. This is mainly due to (1) the absence of a (or a weak) halocline, (2) the fact that the entire water column is well mixed throughout the year in the areas where water depth is less than 100 metres and (3) the shallow straits south of Åland (60–70 m) and the shallow Archipelago Sea, which prevent the inflow of the deep-lying, low-oxygen water from the Baltic Proper to into the Gulf of Bothnia.

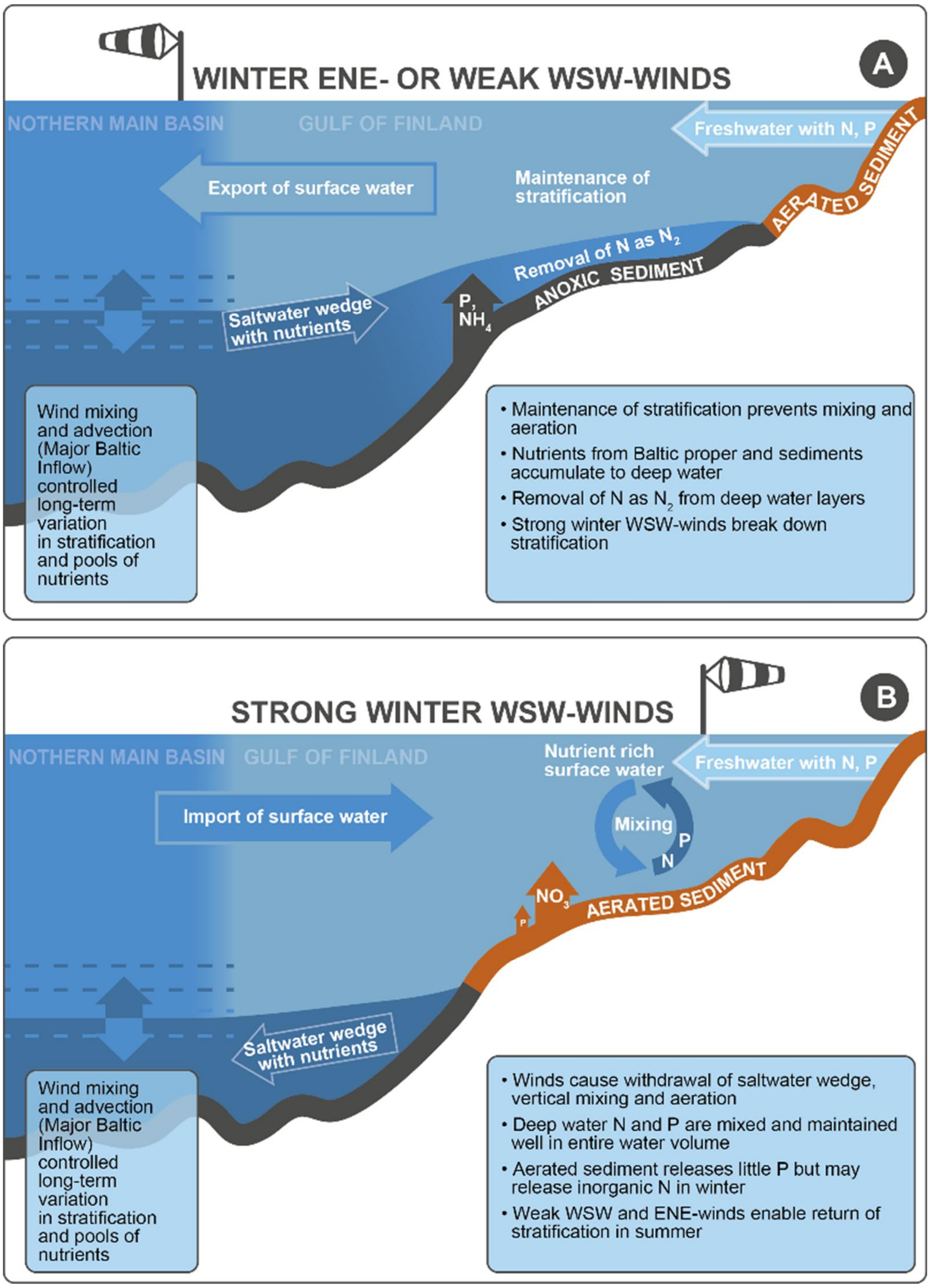


Figure 10. Atmospheric forcing controls inter-annual nutrient dynamics in the open Gulf of Finland (Lehtoranta 2017)

Upwelling

Upwelling, a penetration of denser, cooler, nutrient-rich waters to the sea surface, is a typical phenomenon in the Baltic Sea. Because the Baltic Sea is a semi- enclosed basin, winds from favorable directions - blowing predominately parallel to the coast - cause upwelling which leads to vertical displacement of the water body and mixing. During the thermally stratified period, upwelling can lead to a strong sea-surface temperature drop of more than 10 °C, which drastically changes the thermal balance and stability conditions at the sea surface. When the surface layer is depleted of nutrients, upwelling can play a key role in replenishing the euphotic zone with the nutrients needed for biological productivity (Lehmann and Myrberg 2007). Episodic upwelling is often the most noticeable medium-sized hydrographic phenomena in the GOF (Myrberg and Andrejev 2003, Lehmann et al. 2012). They not only dramatically affect the water column stratification, but also redistribute nutrients and other substances both horizontally and vertically. In the GOF, upwelling events are predominantly of coastal type and based on wind-driven motions in the surface layer. The winds along the GOF cause upwelling in either of the coasts and downwelling on the opposite coast, depending on the wind direction.

2.2 Eutrophication

2.2.1 Background to eutrophication

The vicious cycle of eutrophication

When there are large quantities of nutrients in water, the abundance and species composition of algae and aquatic plants are significantly altered and the water body is said to be suffering from eutrophication.

Excess nitrogen and phosphorus inputs from the land and from atmospheric deposition feed of phytoplankton, such as dinoflagellates, diatoms and cyanobacteria, i.e. blue-green algae.

Dead phytoplankton biomass falls to the sea bottom, increasing sedimentation of organic material, consuming oxygen in the bottom waters during decomposition and eventually leading to anoxia (a condition in which no oxygen is present). Under anoxic conditions, phosphorus is released from the sediment into the water column (i.e., the internal nutrient cycle), which further enhances the blooms of blue-green algae.

Unlike other planktonic algae, blue-green algae are able to fix atmospheric nitrogen (N_2). Therefore the blooms of blue-green algae are not dependent on the anthropogenic input of nitrogen from the land and deposition from the atmosphere. Furthermore, nitrogen fixation by the blue-green algae increases the availability of nitrogen in the water and their decomposition releases nitrogen into the water column. The nitrogen can subsequently be utilised by other planktonic algae. (Furman et al. 2013).

In addition to inputs of nutrients from external sources and the release from sediments, eutrophication is also affected by the warming of the average sea surface temperatures. The warming has led to changes in the annual cycle of algae blooms, changes in biologically available phosphorus and changes in algae species (Conley et al. 2002, Vahtera et al. 2007 and Lehtoranta et al. 2008). Oxygen saturation of water decreases with increasing water temperature and this might lead to less available oxygen in a warmer Baltic Sea (Carstensen et al. 2014).

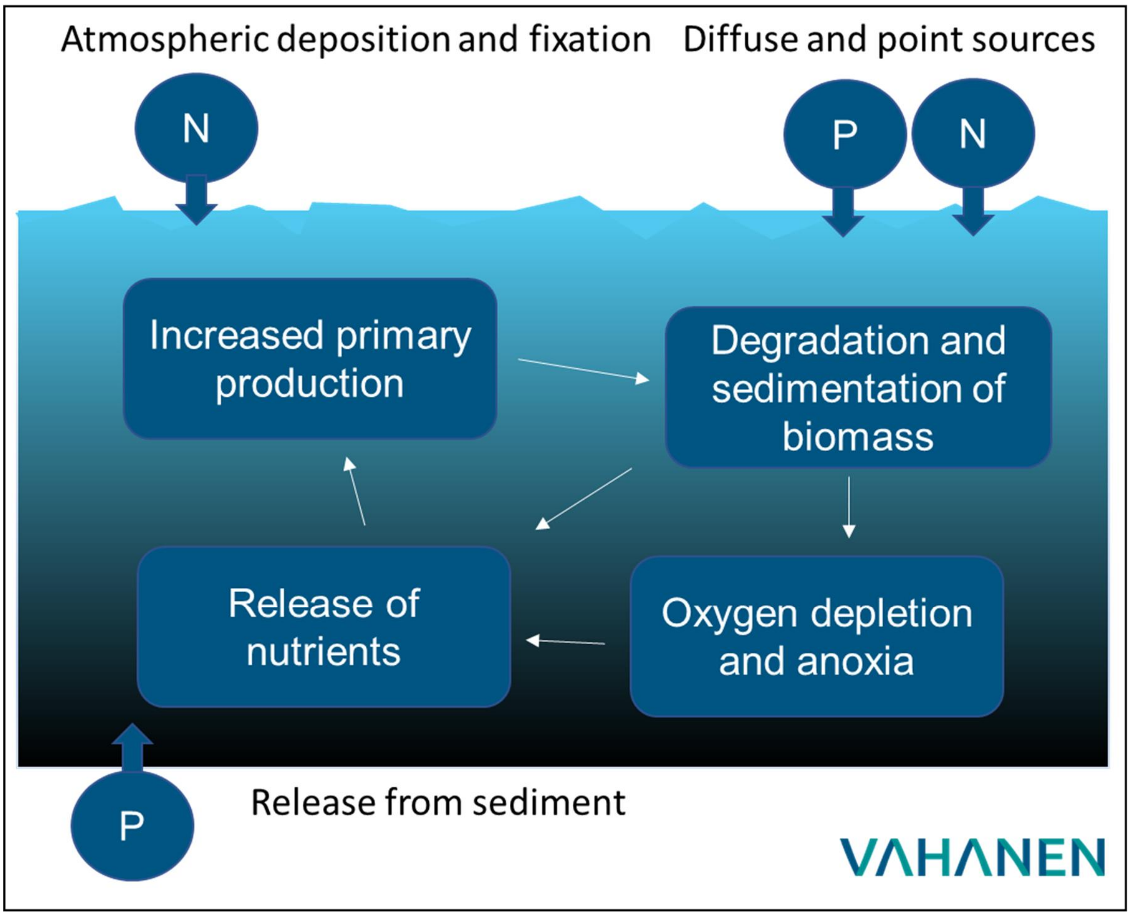


Figure 11. The vicious cycle of eutrophication

Key reactions of phosphorus

In general, P retention in the sediments is controlled by reactions with Fe and Al oxides. Retention onto Fe oxides is strongly dependent on oxygen status. When the sediment-water interface turns from oxic to anoxic, Fe(III) in the oxides will be reduced to soluble Fe(II), which is unable to retain P. This transforms the bottom sediments from P sinks to P sources (e.g. Conley et al. 2002). On the contrary, reactions between Al oxides and P are not affected by oxygen status. Furthermore, decrease in O_2 concentration shifts the microbial metabolism towards sulphate reduction producing hydrogen sulphide (H_2S). It reduces insoluble Fe(III) in the oxides to soluble Fe(II) and, consequently, releases PO_4^{3-} and produces FeS. This eliminates a large proportion of iron from the circulation process and reduces the ability of the sediment to trap phosphorus (Ekholm and Lehtoranta 2012). The formation of Ca–P compounds is also a major carrier for phosphates.

The release of P from the sediment is also affected by other factors both in the sediments and at the sediment-water interface. Various microbial processes and reactions between carbon, nitrogen, manganese, iron and sulphur couple the P cycling to redox reactions in sediments and concretions. Iron-manganese deposits form a poorly studied reserve of phosphorus in the Baltic Sea (Lehtoranta 2017). The pH of sediment determines the desorption of phosphate from Al and Fe oxide surfaces. The surface charge of oxides becomes more negative upon elevated pH, which favors desorption of phosphate sorbed on the oxide surfaces. The P desorption increases with elevated pH, which renders the oxide surface more negatively charged. Consequently, the repulsion between the oxide surface and negatively charged P-anion increases. Only the uppermost few centimeters of the sediment remain aerobic even in good oxygen conditions (Ekholm and Lehtoranta 2012).

Hypoxia is often defined as O_2 concentration below 2 mg/l (Conley et al. 2009). In open sea areas, hypoxia is strongly related to stagnation, i.e. prevention of water column mixing and excess O_2 consumption in relation to O_2 production/transport (Conley et al. 2009). In shallow coastal waters, nutrient inputs from land contribute to the O_2 depletion in bottom waters and a limited exchange of water prevents the intrusion of O_2-rich water from the open sea area to replenish the O_2 supply (Almroth-Rosell et al. 2016, Virtanen et al. 2018).

In healthy sediments, after depletion of O_2, the major pathway of organic matter degradation is connected to reduction of Fe^{3+} to Fe^{2+}. This anaerobic process solubilizes Fe(II) ions from oxides and concomitantly P is sorbed onto their surfaces. When the released ferrous iron (Fe^{2+}) ions meet oxic conditions they will be oxidized and transported as Fe^{3+} (hydr)oxides back to the sediment where phosphate anions will be sorbed onto their surface. This means that in oxic conditions, where the sediment is slightly anoxic, the ability of iron to bind phosphates remains. In addition, in oxic conditions P is more efficiently removed in the formation of organic matter than in anoxic conditions (Conley et al. 2009, Ekholm and Lehtoranta 2012). It is noteworthy, however, that Al-oxides being not redox-sensitive, do not lose their sorption ability in anoxic conditions.

Increased hypoxia typically decreases the formation and burial of organic P and promotes the release of PO_4-ions from dissolving of Fe-oxides (Conley et al. 2009). The response of the Fe-bound P pool to anoxia happens rather fast, whereas the mineralization of organic phosphorus is a slow process in anoxic conditions. The P concentrations in the stable deep-water layers may drastically increase during anoxic conditions (Raateoja and Setälä 2016). Fonselius (1967) showed that large amounts of P were released from the deep sediments in the Baltic Proper when they became anoxic.

When O_2 concentration decreases, the microbial metabolism shifts towards sulphate reduction producing hydrogen sulphide (H_2S). It reacts with insoluble Fe(III)-oxides producing FeS. This reaction pattern releases P sorbed onto Fe(III)-oxides. It eliminates a large proportion of iron from the circulation process and reduces the ability of the sediment to trap phosphorus (Ekholm and Lehtoranta 2012).

The release of P from the sediment is also affected by local conditions in the sediments and at the sediment-water interface. Various microbial processes and reactions between carbon, nitrogen, manganese, iron and sulphur couple the cycling of phosphorus to redox reactions in sediments and concretions (Lehtoranta et al. 2015). Iron-manganese deposits form a poorly studied reserve of phosphorus in the Baltic Sea (Lehtoranta 2017).

Key reactions of nitrogen

Nitrogen is recycled in water ecosystems in microbe mediated processes (Arrigo 2005). The nitrogen cycling in the Baltic Sea is controlled by sediment organic content, temperature and oxygen availability. Cyanobacteria blooms may also fix atmospheric nitrogen (Figure 12).

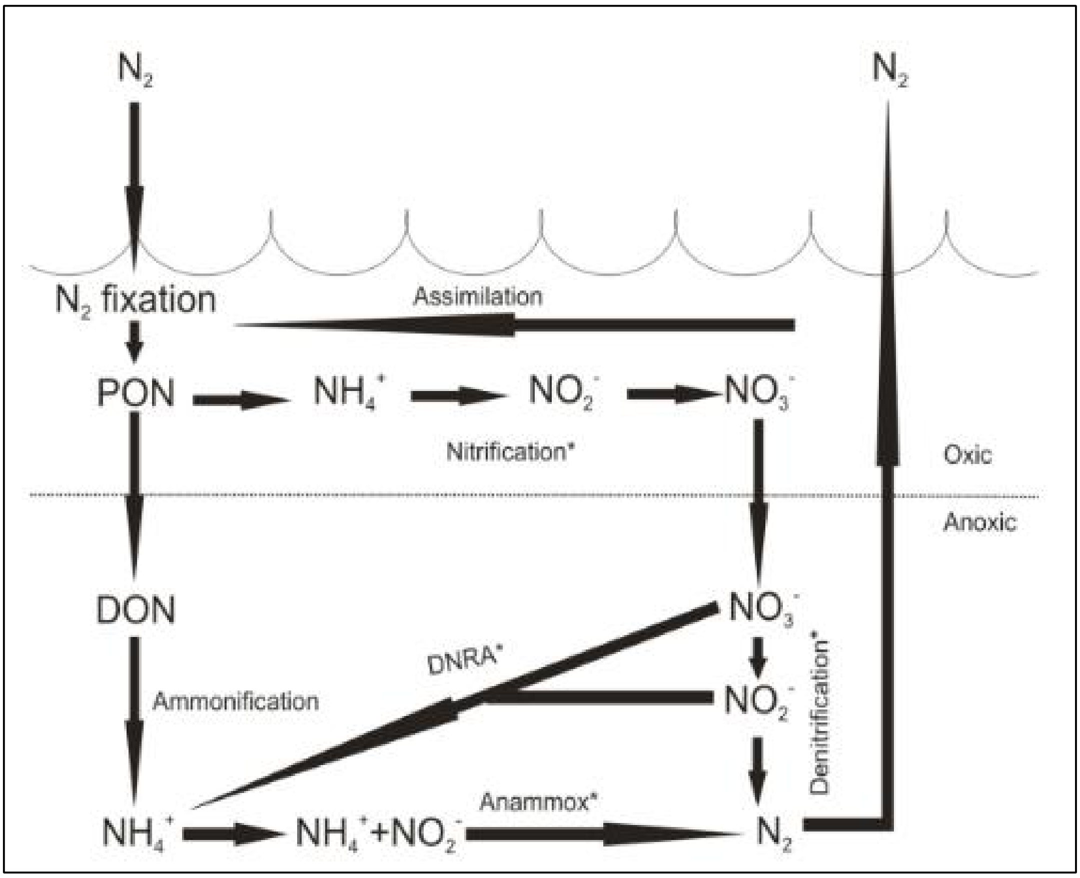


Figure 12. Nitrogen cycling in aquatic environments. PON=particulate organic nitrogen, DON=dissolved organic nitrogen, DNRA=dissimilatory nitrate reduction to ammonium, Anammox=anaerobic ammonium oxidation (Jäntti 2012, modified from Arrigo 2005)

Atmospheric nitrogen is captured by blue green algae through N_2 fixation, which produces organic N compounds for utilization by other organisms. Additional P inputs favour the occurrence of cyanobacteria blooms. They, in turn, lead to the binding of atmospheric N_2 into the sea, which further promotes the primary production and sedimentation of organic matter (Furman et al. 2013).

The key processes removing N from aquatic environments are denitrification and anammox, supplemented by dissimilatory nitrate reduction to ammonium. The latter process does not remove N but stores it in hypoxic waters. According to the prevailing understanding, the rate of denitrification decreases with decreasing O_2 concentration. In the Baltic Proper, GOF and Gulf of Riga the negative correlation between dissolved inorganic N and the volume of anoxic water indicates active denitrification. Recently it has also been shown in the open sea, that with hypoxia the N losses are attributable to significant denitrification and anammox. It seems that the process prevailing below the redoxcline (defined by nutrient and O_2 concentrations) is an upward flux of ammonium whereas the downward flux of nitrate dominates above the redoxcline. N_2 is formed via denitrification and anammox as these fluxes meet. (A large part of the N remineralized below the redoxcline is lost in N_2 formation at the redoxcline. Therefore, mineralization of dissolved organic N in the oxic water above the redoxcline is a prerequisite for production of inorganic N available needed in primary production (Conley et al. 2009).

Transformations of N depend on several factors and the dominant reactions vary. Losses through denitrification and anammox are the major sinks for N, but the relevance of fluctuating hypoxia to the key processes of nitrification remains open (Conley et al. 2009). The sediment under a non-stratified water column can remove N_2 gas from the system and retain phosphorus in sediments. In contrast, a strong vertical density stratification prevents the supply of oxygen to the hypolimnion, leading to depletion of oxygen and nitrate as sediment leaks ammonium and P to the near-bottom water (Lehtoranta et al. 2017). Major sinks for N are losses in denitrification and anammox processes but the relevance of fluctuating hypoxia to the key processes of nitrification remains open (Conley et al. 2009).

In the Curonian Lagoon, off the coast of Kaliningrad - and in similar confined and shallow lagoons (usually without a halocline) - N_2 fixation by cyanobacteria is found to be particularly intensive in summer when the water temperature is higher than in the rest of the year (Zilius et al. 2015). According to the same source, the cyanobacteria blooms prevent the penetration of light to more than a few centimeters depth. Together with the sinking and decaying cyanobacteria this often causes anoxic conditions. In the autumn, the flows of River Pregola to the Curonian Lagoon are higher than in summer and tend to flush water from the lagoon to the Baltic Proper. This water has significantly higher N content than the Baltic Sea waters outside the Curonian Lagoon. It can be taken to represent a special type of internal N loading to the Baltic Sea. In the coastal waters of Finland and Sweden there are also shallow bays with very small catchment areas and runoff to the bay (e.g. Sandöfjärden in Inkoo, Finland). In the bays of estuaries of medium-size or big rivers, where the residence time of water is significantly shorter, the preconditions for cyanobacteria growth and algal blooms are not as favourable to N_2 fixation from the atmosphere.

2.2.2 Eutrophication of the Baltic Sea

Inputs of nutrients into the Baltic Sea

Eutrophication of the Baltic Sea has largely been caused by nutrient inputs from anthropogenic activities, although it also has natural drivers. Concentrations of the main triggers of eutrophication (N and P) increased in many areas of the Baltic Sea up until the late 1980s, and can be attributed to increased inputs of nutrients from land through anthropogenic activities since the 1950s. Relatively, the increase in P input has been relatively greater than the input of N, which has resulted in a decrease in the molar ratio of N/P to the lowest level of 37 in 1980. During the preindustrial period, the molar ratio of N/P was about 68 (Gustafsson et al. 2012). Since the 1980s, nutrient inputs have gradually decreased by more than 50 % for phosphorus (P) and almost 25 % for nitrogen (N), yielding an increase in the N/P molar ratio (50 in 2006) (e.g. Gustafsson et al. 2012, Stigebrandt et al. 2014). The most extensive nutrient input reductions have been achieved in point sources such as municipal water treatment plants, but significant progress has also taken place in reducing inputs from diffuse sources (Furman et al. 2013, HELCOM 2017).

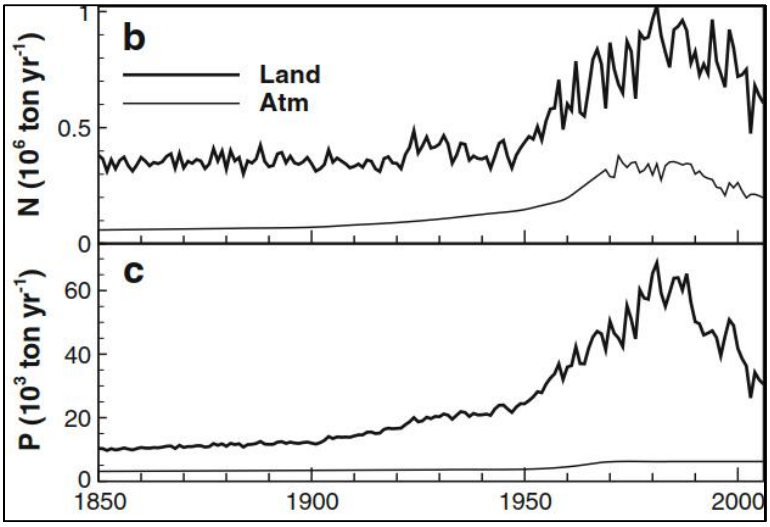


Figure 13. Temporal development of waterborne and airborne inputs of total nitrogen (above) and total phosphorus (below) to the Baltic Sea (Gustafsson et al. 2012)

The updated integrated eutrophication status assessment for 2011–2015 shows that the Baltic Sea is still affected by eutrophication (Figure 14). Out of the 247 assessment units included in the HELCOM assessment covering both coastal and open water bodies, only 17 achieved good status. Only a few coastal areas are unaffected by eutrophication. (HELCOM 2017)

The Baltic Sea annually receives a total of 36,900 tonnes phosphorus and 910,000 tonnes nitrogen from the catchment area (HELCOM 2013, see Figure 15). Almost half of the nutrients originating from land-based sources (18,300 tonnes phosphorus and 423,900 tonnes nitrogen) enter into the Baltic Proper. The GOF receives some 7,500 tonnes P and 116,300 tonnes N, the Bothnian Sea 2,800 and 79,400 tonnes and the Bothnian Bay 2,700 and 79,400 tonnes, respectively. The largest proportion (45 %) of land-based phosphorus input comes via rivers and originates from diffuse sources such as agriculture, forestry and dispersed settlements as well as storm water runoff from built-up areas. Point sources (municipal and industrial wastewaters and fish farming) cover 20 % of P load. Diffuse sources cover 45 % and point sources 12 % of the land-based nitrogen load. The remaining proportion originates from transboundary load, unspecified river load and natural background sources. Although the proportion of point sources is relatively low, it can be spatially and temporally higher. Since the nutrient input from point sources is the easiest to reduce, a marked reduction in nutrient input from i.e. municipal wastewater plants has been achieved during the last decades (Furman et al. 2013, HELCOM 2017).

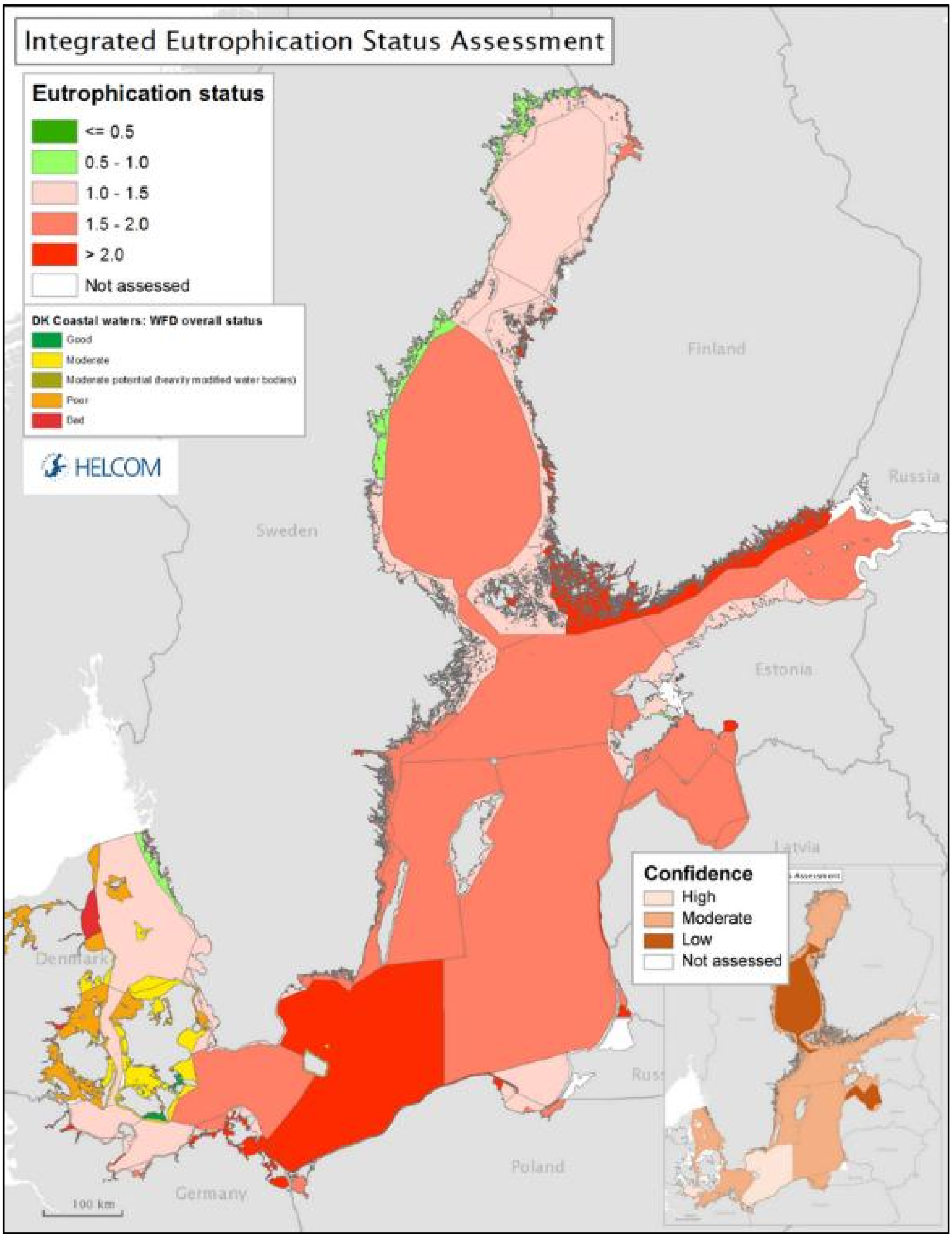


Figure 14. Integrated status assessment of eutrophication of the Baltic Sea (HELCOM 2017a)

Baltic Sea Sub-basin	Maximum Allowable Inputs		Reference inputs 1997-2003		Needed reductions	
	TN tons	TP tons	TN tons	TP Tons	TN tons	TP tons
Kattegat	74,000	1,687	78,761	1,687	4,761	0
Danish Straits	65,998	1,601	65,998	1,601	0	0
Baltic Proper	325,000	7,360	423,921	18,320	98,921	10,960
Bothnian Sea	79,372	2,773	79,372	2,773	0	0
Bothnian Bay	57,622	2,675	57,622	2,675	0	0
Gulf of Riga	88,417	2,020	88,417	2,328	0	308
Gulf of Finland	101,800	3,600	116,252	7,509	14,452	3,909
Baltic Sea	**792,209**	**21,716**	**910,344**	**36,894**	**118,134**	**15,178**

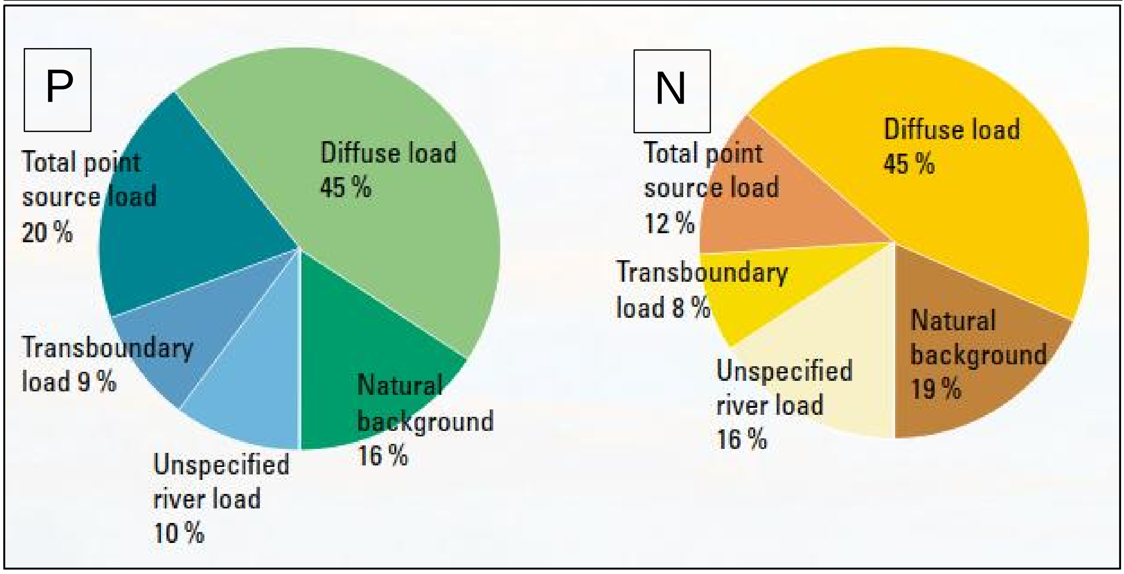


Figure 15. Sources of total waterborne P and total waterborne N (Table above in HELCOM 2013, Graph below in Furman et al. 2013)

In addition to waterborne input, atmospheric deposition of nitrogen is significant. About 25 % of the N that ends up in the Baltic Sea (and 1–5 % of the P) originates from emissions to the air from anthropogenic activities such as transport, combustion and animal farming.

Internal phosphorus leakage from anoxic bottoms in the Baltic Proper is an important source of P The magnitude of the flux varies in a complex way. Internal phosphorus leakage and estimates of its magnitude are discussed below.

Increasing hypoxia and anoxia and the pool of phosphorus in sediment and bottom water

Hypoxia first occurred in the Baltic Sea after its transition from a fresh waterbody to a brackish waterbody, ca. 8,000 cal. yr BP, and has been present intermittently throughout the Holocene (Zillen et al. 2008). During the last century, both the extent of hypoxic seafloor areas, as well as the duration of hypoxic periods, has increased in the Baltic Sea (Figure 16 and Figure 17; e.g. Fonselius and Valderama 2003, Savchuk et al. 2008, Conley et al. 2011, Carstensen et al. 2014, Hansson and Andersson 2017 and Puttonen 2017). The area of anoxic bottoms approximately doubled from the period 1960–1997 to the period 1998–2016 (Hansson and Andersson 2017) and the volume of anoxic water increased six times (Stigebrandt 2018).

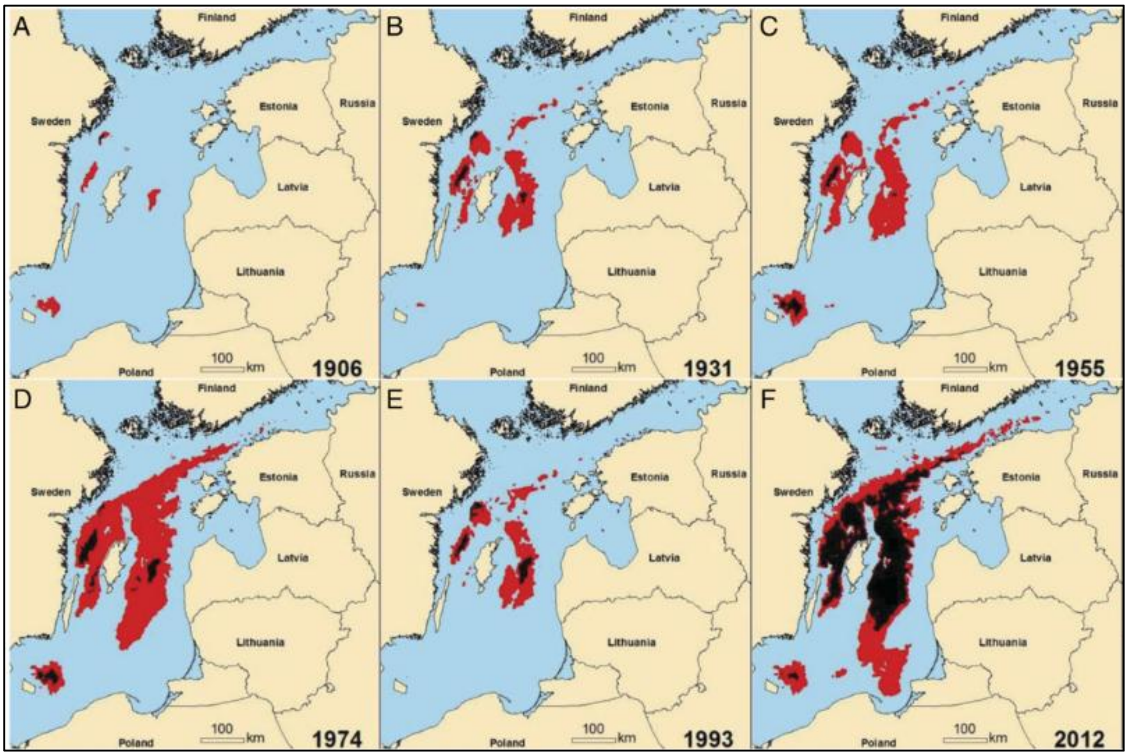


Figure 16. Spatial distribution of bottom hypoxia and anoxia over time. Estimated bottom oxygen concentrations of < 2 mg/l are shown in red, and concentrations of < 0 mg/l are shown in black for 1906 (A), 1931 (B), 1955 (C), 1974 (D), 1993 (E), and 2012 (F). The spatial distributions represent means across all months (January to December). (Carstensen et al. 2014)

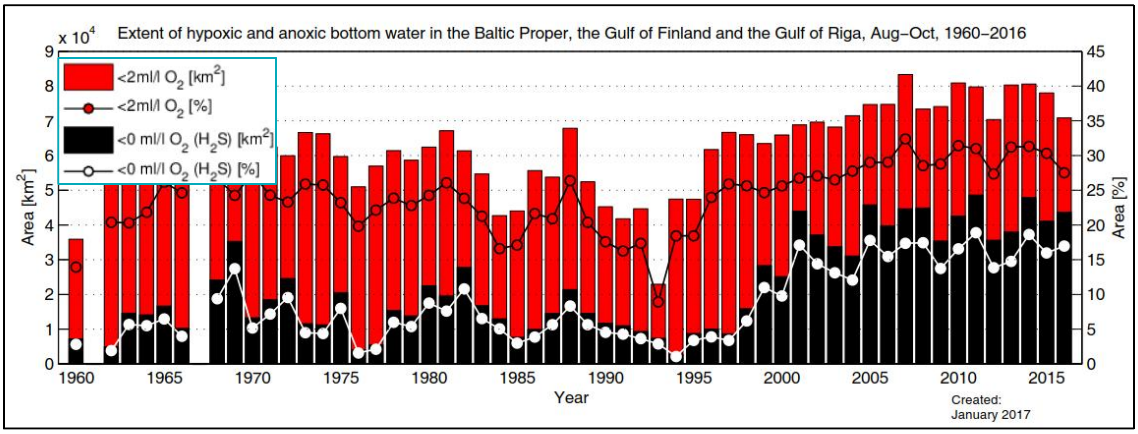


Figure 17. Extent of hypoxic and anoxic bottom water in the Baltic Proper, the Gulf of Finland and the Gulf of Riga, Aug−Oct, 1960−2016 (Hansson and Andersson 2017).

The oxygen concentration of the inflowing water from the North Sea changes during the inflow, depending on the oxygen concentration of the entrained water. If the oxygen concentration of the residing deep water is low, or even anoxic with an oxygen debt, then the inflowing water may lose oxygen due to oxidation of hydrogen sulfide and ammonia and it may have diminished or even depleted oxygen concentrations when it finally settles in the deep central basins. This phenomenon was touched upon already by Fonselius (1970) who noted that new deep water from the Kattegat during the 1960s showed a lower potential to oxygenate the deep basins than earlier because the residing old deep water mixed into the inflowing new deep water in the 1960s had lower oxygen concentrations than before the inflow started. This effect was clearly demonstrated after the very large inflow of new deep water in December 2014 and January 2015 (Mohrholz et al. 2015) when the maximum oxygen concentration in the Eastern Gotland Basin was only about 2 mL/L (e.g. Stigebrandt et al. 2018) and the new deep water was depleted in oxygen before reaching the Gulf of Finland and the Western Gotland Basin.

The highest concentrations of dissolved inorganic P in water were measured during the mid-1980s and the figures have decreased since then in the Kattegat and in the Baltic Proper but not in the GOF or in the Gulf of Bothnia (Figure 18) (HELCOM 2017). High levels of phosphorus are maintained in the water by the combined impact of residual external loading and phosphorus release from sediments in anoxic conditions. The vicious cycle of release of P from sediments is ongoing throughout the depths of the Baltic Sea, with the exception of the Gulf of Bothnia.

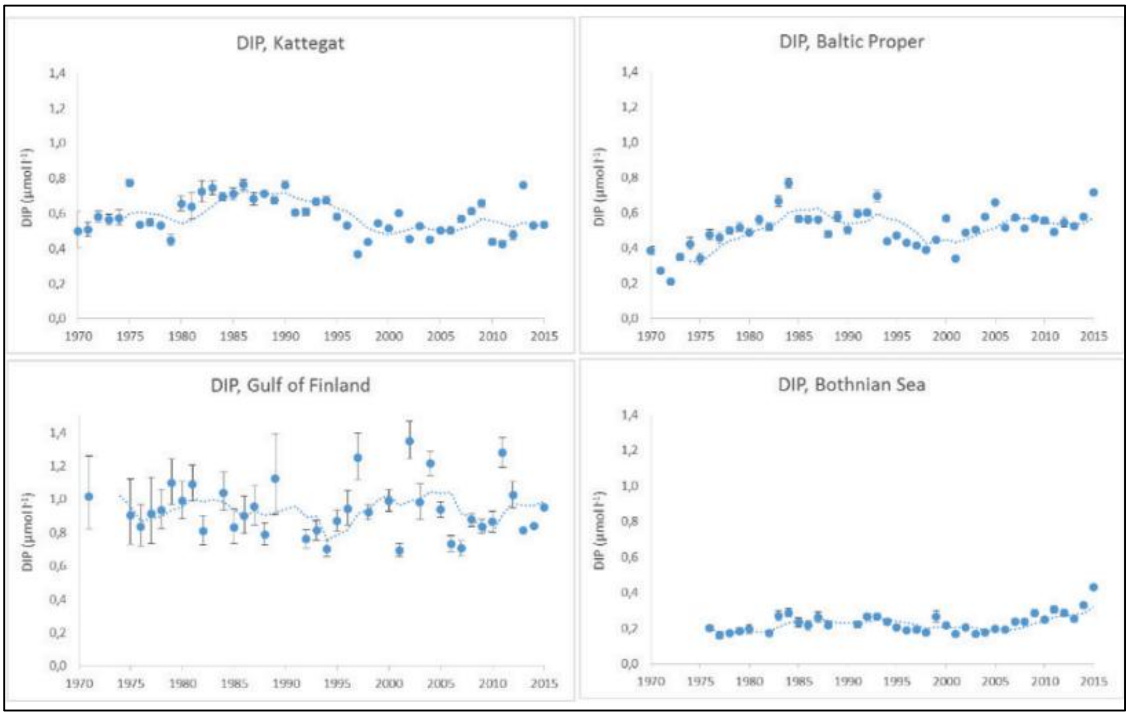


Figure 18. Example of long-term trends in nutrient levels in the Baltic Sea: Temporal development of dissolved inorganic phosphorus concentrations in winter in the Kattegat, the Baltic Proper, the Bothnian Sea and the Gulf of Finland. Dashed lines show the five-year moving averages and error bars are the standard errors. (HELCOM 2017)

Stigebrandt (2018) has suggested that the Baltic Sea recovered somewhat from earlier periods of eutrophication by extended periods of a very low halocline, such as during the period 1985-1992 when the top of the halocline was at 100 m depth instead of the usual 60 m depth. During this kind of period, the well oxygenated surface water layer is in direct contact with the deep bottom sediments which effectively stops the internal phosphorus release from deep anoxic bottoms. This case was modelled and the results show that the phosphorus concentrations in the surface water layer will decrease rapidly and the Baltic Sea would be restored in about 10 years with winter phosphorus concentrations in the surface water in balance with the land-based supply. The probability for the occurrence of sufficiently long periods with a low halocline is small, but it is not zero. Many changes that are often mentioned as expected results of anthropogenic induced recovery, are changes that also should occur during recovery forced by a natural event. The key question is thus whether a man-made recovery has greater or smaller risks than a natural recovery. A case of natural recovery was described by Stigebrandt (2018).

If there is an imbalance of nutrients in the surface water as compared to the needs of primary production, the surface layer will run out of, for instance nitrogen, during the spring bloom if nitrogen is in shortage. This is a regularly occurring situation in the Baltic Proper where usually a lot of phosphorus remains in the surface layer at the end of the spring bloom. The phosphorus surplus can be used by cyanobacteria that can use either nitrogen gas that is dissolved in the water or fix atmospheric nitrogen. Cyanobacteria thus act as nitrogen fertilizers for the Baltic Proper. If the amount of phosphorus remaining in the water column after the spring bloom is large, extensive blooming of cyanobacteria may occur. Extensive blooming of cyanobacteria is considered a serious nuisance that strongly reduces the water quality for recreational use of both coastal and offshore areas. The problem of large blooms of cyanobacteria has grown since the 1990s. In recent years, attention has been paid to the fact that many cyanobacteria produce β-methylamino-L-alanine, BMAA, a poison that may accumulate in the food web and is believed to cause nervous system diseases in the human body (such as ALS, Parkinson and Alzheimer diseases) (Cox et al., 2005).

Gustafsson et al. (2012) used the BALTSEM model to simulate the state of the Baltic Sea from 1850 to 2006. Nutrient inputs increased with a noteworthy acceleration from the 1950s until maximum values around 1980, followed by a decrease continuing up to 2006. The model shows a delayed response to the massive increase in inputs, with most eutrophic conditions occurring only at the end of the simulation. This is accompanied by an intensification of the pelagic cycling which is driven by a shift from spring to summer primary production. The simulation indicates that no improvement in water quality of the Baltic Sea compared to its present state can be expected from the decrease in nutrient loads in the next few decades. Sediment pools of nitrogen and phosphorus increased throughout the simulation, reaching a new equilibrium around the year 2000. The sediment nitrogen pool is about 10 times the annual load, except for the period around 1980 when it was somewhat smaller, about 6.5 times the load. Thus, the pool of nitrogen seems to adjust to the loads rather rapidly. The phosphorus pool, on the other hand, stored about 40 times the annual loads in 1900 to 27 times by 1950 and slightly less than 20 times by 1980. Due to the recent decrease in loads and the continued increase in the sediment pool, the sediment phosphorus pool was approximately 35 times the load by 2000.

Malmaeus and Karlsson (2012) estimated that the total amount of mobile P in the entire Baltic Proper sediments below 65 m water depth is between 55,000 tonnes and 156,000 tonnes representing the maximum amount of P that could possibly be released to the water column from these areas. The potential of internal P leakage is therefore clearly higher than the input of P from the catchment (see Figure 15). Puttonen (2017) investigated internal leakage of P in the coastal and archipelago areas in Sweden and Finland. The pool of potentially mobile P (defined as ‘Loosely bound P’, ‘Fe-P’ and ‘Unreactive P’ in Puttonen, 2017) in a two-centimetre thick sediment surface layer has been estimated to amount to 31,000-37,000 tonnes (Puttonen 2017), which corresponds to the external inputs of P (Figure 15).

Stigebrandt et al (2014) studied the internal P sources and sinks in the Baltic Proper using hydrographic data from 1960 to present and P fluxes estimated in situ from anoxic bottoms in the open Baltic Proper and from hydrographic data in the deep part of Bornholm Basin. The temporal and spatial mean specific internal P leakage from anoxic bottoms was estimated to be 2.3 g P/m^2/year, which is supported by data on P release from sediments in the Bornholm Basin (3–8.6 g P/m^2/year during anoxic conditions and 0.8–1.5 g P/m^2/year during oxic conditions). These figures also contain estimated P contributions from decomposition of fresh organic matter, about 0.7 g P/m^2/year), and in situ observations of benthic fluxes from anoxic bottoms in the central Baltic Sea (4 ± 2 g/m^2/year) reported by Viktorsson et al. (2013). According to the estimates (Stigebrandt et al 2014), the internal P source from anoxic bottoms in the Baltic Proper was less than the external sources up until about 1995. In 2005, however, the internal source was almost three times larger than the actual external nutrient inputs. From 1980 to 2005, the sum of external and internal sources was estimated to increase by 20,750 tonnes P/year, explaining why the amount of phosphorus in the Baltic Sea increased steadily by about 5,000 tonnes/ year during that period. This in turn was explained to mean that the export production of particulate organic phosphorus from the surface sediment layers has increased as a consequence of the areal extension of anoxia. The modeling results suggests that, due to anoxia, the internal leakage of P from the deep water in the Bornholm Basin to the Baltic Proper is 7,500 tonnes P/year.

Puttonen (2017) applied P fractionation results in estimating the magnitude of internal P release in the Archipelago Sea. The estimated average annual release, according to the three scenarios was 0.31-0.64 g P/m^2 from accumulation areas, depending on environmental conditions.

An increased availability of nutrients in the water column also leads to higher concentrations of plankton in the surface layer and reduced water transparency (measured as Secchi depth). This reduces the vertical penetration of light and shrinks the zone where bottom attached algae can grow. Sandén and Håkansson (1996) estimated that Secchi depth decreased by about 0.05 m per year from the period 1919-1939 to the period 1969-1991 and they estimated that this could be caused by an annual increase of primary production by about 1 %.

Hypoxia in the Swedish and Finnish archipelagos is influenced by phytoplankton growth that is stimulated by nutrient inputs from urban and agricultural sources, but also by restricted water circulation. By contrast, hypoxia is rare in the northern Baltic Sea estuaries located in the Gulf of Bothnia coastal zone where nutrient inputs from external sources are lower. Alteration of nutrient biogeochemical cycles can further increase the negative impacts of eutrophication through stimulation of phytoplankton growth when nutrient recycling processes are enhanced (Conley 2011).

Recovery of the Baltic Sea from eutrophication

The Baltic Sea has been under strong anthropogenic pressure for a long time and it is evident that recovery will take a substantial time. Due to complex and non-linear processes, it is challenging to predict the path of recovery. The needed nutrient reductions to achieve the goal of a Baltic Sea unaffected by eutrophication are defined in the HELCOM Nutrient Reduction Scheme, which consists of two main components (HELCOM 2017):

- Maximum Allowable Inputs (MAI) of nutrients, indicating the maximal level of inputs of water- and airborne nitrogen and phosphorus to Baltic Sea sub-basins that can be allowed to fulfill the targets for a non-eutrophied sea.
- Country Allocated Reduction Targets (CART), indicating how much the HELCOM countries need to reduce nutrient inputs compared to a reference period (1997-2003).

MAI is calculated using the coupled physical-biogeochemical model BALTSEM. The model simulates circulation and development of stratification driven by meteorology, river flow and boundary conditions to the North Sea, as well as simulating cycles of inorganic and organic nutrients and dominating plankton groups. The model explicitly takes into account sediment biogeochemistry so that the complete nutrient cycles of phosphorus, nitrogen and silica, including their internal loading, are covered. According to the model simulations, significant improvements will be seen a few decades after fulfillment of the nutrient input reductions targets. For example, concentrations of dissolved inorganic nitrogen in winter begin to diminish after 20-30 years and achieve the target level after 100 years. Concentrations of dissolved inorganic phosphorus begin to diminish immediately and achieve the respective target level in 100 years (Figure 19).

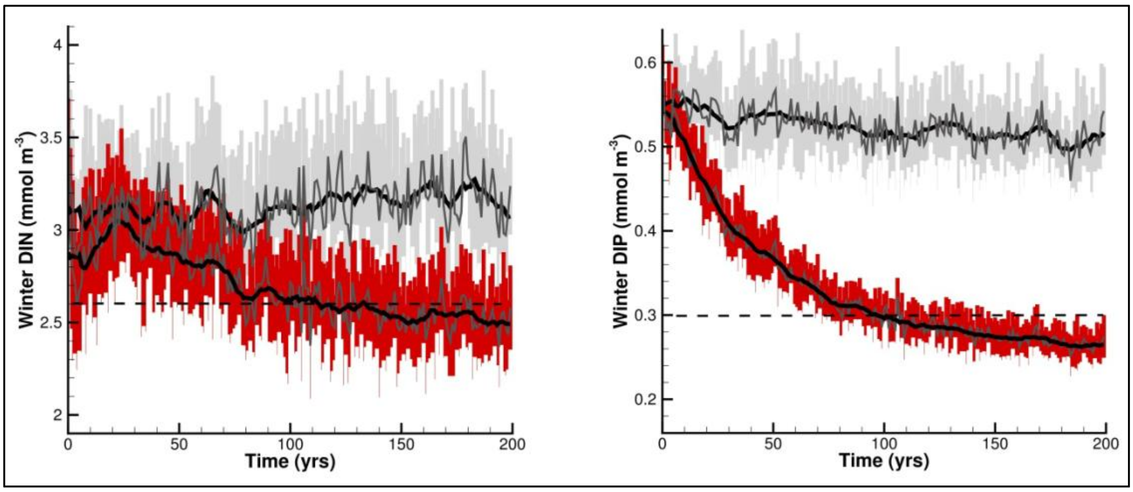


Figure *19*).

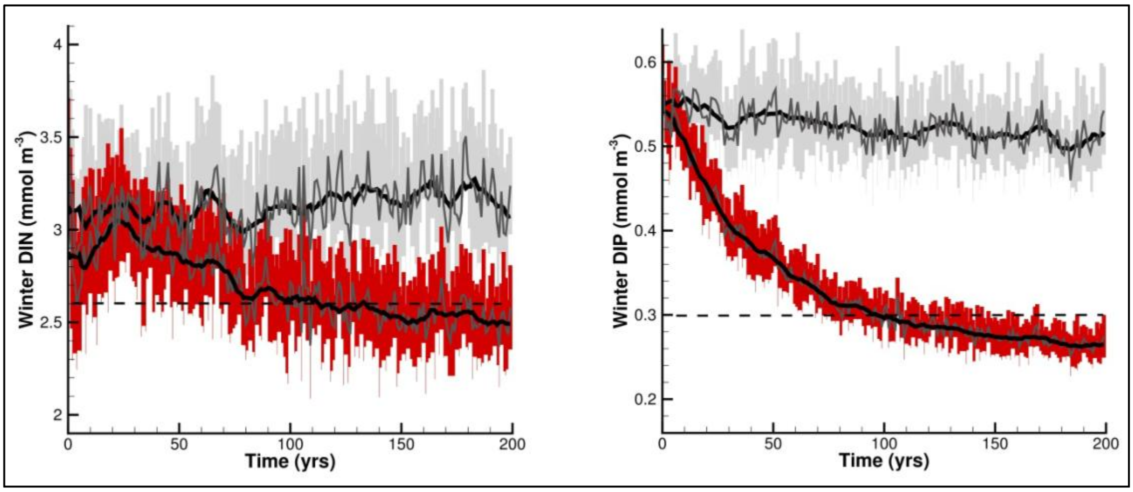


Figure 19. Time development of inorganic winter nutrient concentrations in the Baltic proper surface waters. The grey bars with associated curves represent the case with inputs as in the reference period (1997-2003) during the whole scenario, and the red represents inputs reduced to MAI by year 0. The thick lines are 11-years running average, thin lines average of 10 realizations using different weather forcing and the grey and red bars indicate the range of natural variability. The dotted line is the target (HELCOM 2017)

Physical models describing the Baltic Sea (currents, temperatures, salinity etc.) have been developed and used since at least 20 years. Large-scale water quality modelling has been carried out by several research teams using somewhat different models (e.g. Pitkänen et al. 2007, Bendtsen and Hansen 2013, Gustafsson 2000, Neumann et al. 2002, Neumann and Schernewski 2008, Eilola et al. 2009, Meier and Kauker 2003).

The potential impacts of climate change have also been estimated with models and it is anticipated that the negative impacts of eutrophication are likely to be amplified due to warmer temperatures in summer (Meier et al. 2011), in particular in late July and August (Bendtsen and Hansen 2013). Climate change will increase nutrient inputs and temperatures, which result in an intensification of biogeochemical processes and internal nutrient cycling, causing increases in both primary production of organic matter and oxygen consumption for its mineralization (BACC 2015). Meier et al. (2011) conducted a model ensemble study for Baltic Sea of hypoxia in future climate. They concluded that in the future climate, the HELCOM nutrient reduction targets are very likely not sufficient and it is unclear whether the environmental situation will improve at all compared to present conditions. However, without drastic nutrient input abatements, hypoxic and anoxic areas will continue to increase.

As climate change advances, it is predicted that riverine inflows especially in the northern parts of the Baltic Sea catchment will increase, which in turn increases nutrient inputs from land (HELCOM 2013, Meier et al. 2014, Viitasalo et al. 2015, Raateoja and Setälä 2016). This will also decrease the salinity of the Baltic Sea due to increased runoff. It is likely that the impacts will vary between the different sub-basins.

Meier et al. (2016) studied a coupled physical-biogeochemical model to estimate the impact of past and accelerated future global mean sea level rise (GSLR) on water exchange and oxygen conditions in a semi-enclosed, shallow sea. The model simulations suggest that GSLR will cause increases in the frequency and magnitude of saltwater inflows, salinity and phosphate concentrations in the Baltic Sea (as a direct or indirect consequence of increased cross sections in the Danish straits), and will contribute to increased hypoxia and anoxia. Thus it amplifies the future impacts of increased external nutrient inputs due to increased runoff, reduced oxygen flux from the atmosphere to the ocean and intensified internal nutrient cycling due to increased water temperatures in future climate. It should be considered that as the halocline deepens, the potentially oxygenated bottom area increases. Also, in the GOF reduced stratification results in an increase of bottom oxygen concentrations (Meier et al. 2011).

Simulating three different scenarios for future nutrient inputs into the Baltic Sea (current concentrations, BSAP target concentrations and Business-As-Usual increased concentrations), Meier et al. (2011) concluded that with reduced nutrient inputs according to HELCOM nutrient reduction scheme, the hypoxic and anoxic areas in the Baltic Sea will decrease slightly compared to 2007. Gustafsson et al. (2012) reconstructed the eutrophication development of the Baltic Sea during 1850–2016 and concluded that the current reductions in the external nutrient inputs to the sea have only brought the external inputs of phosphorus into equilibrium with the P content of the sea. This means that all efforts taken to reduce nutrient inputs up to now have basically resulted in maintaining the status quo and that additional action is needed in order to improve water quality. Additional activities for reducing nutrient inputs are needed in order to improve water quality, and the recovery will be slow.

2.3 Hazardous substances

2.3.1 Background

Hazardous substances enter the Baltic Sea from different sources, such as rivers, wastewater treatment plants, industrial plants, landfills, as well as atmospheric deposition from all types of emissions to the air from combustion processes and from land-based diffuse sources. There have been improvements in wastewater and air emissions treatments and many harmful chemicals have been banned. Still, many of them are highly persistent and remain in the sediments and biota of the Baltic Sea. Some compounds are present in higher concentrations close to their discharge points, whereas some are more evenly distributed in the sediment across the Baltic Sea. Hazardous substances can have various negative effects on marine biota, and to avian and terrestrial consumers along the food web, including humans (Raateoja and Setälä 2016).

The EU Directive on Environmental Quality (Directive 2008/105/EC) has defined priority hazardous substances based on their adverse effects, persistence and bioaccumulation and toxicity (PBT substances). The list identifies 33 substances or groups of substances shown to be of major concern for European waters. Within this list, 11 substances were identified as priority hazardous substances and therefore subject to cessation or phasing out of discharges, emissions and losses within an appropriate timetable not exceeding 20 years. A further 14 substances were chosen for a later review. The 11 priority hazardous substances include, for example, dioxins, organic tin compounds, polybrominated and perfluorinated compounds, mercury, cadmium, pesticides and polyaromatic hydrocarbons (PAH). The main sink for these compounds in the aquatic environment is in sediments, however they are also found in biota. For example, the maximum allowable concentrations of dioxins and dioxin-like polychlorinated biphenyls (PCB) for human consumption set by EU (EU 2011) are still exceeded in some fish species (Hallikainen et al. 2011). In sediments, some PBT compounds can be partially degraded or transformed by microbes into even more toxic metabolites. The metabolism of the PBT substances as well as the toxicity of the metabolites typically differ in anoxic and oxic environments.

According to a recent HELCOM report (HELCOM 2017) that provides an overview of hazardous substances in the Baltic Sea area in water, sediment and biota the current contamination status is elevated in all parts of the Baltic Sea, mainly driven by polybrominated flame retardants (Polybrominated diphenyl ethers, PBDE) and mercury (see Figure 20).

A recent report on the status of Finland's marine environment (Korpinen et al. 2018) presents an overview of hazardous substances in the Finland's marine waters with the conclusion that the overall contamination status has not changed markedly since the previous holistic assessment (HELCOM 2010).

This chapter gives an overview of the presence of hazardous substances in Baltic Sea sediments, with a focus on Finland's marine waters. The sea based restoration solutions presented may release harmful substances from sediments, which has to be taken into account in risk analysis.

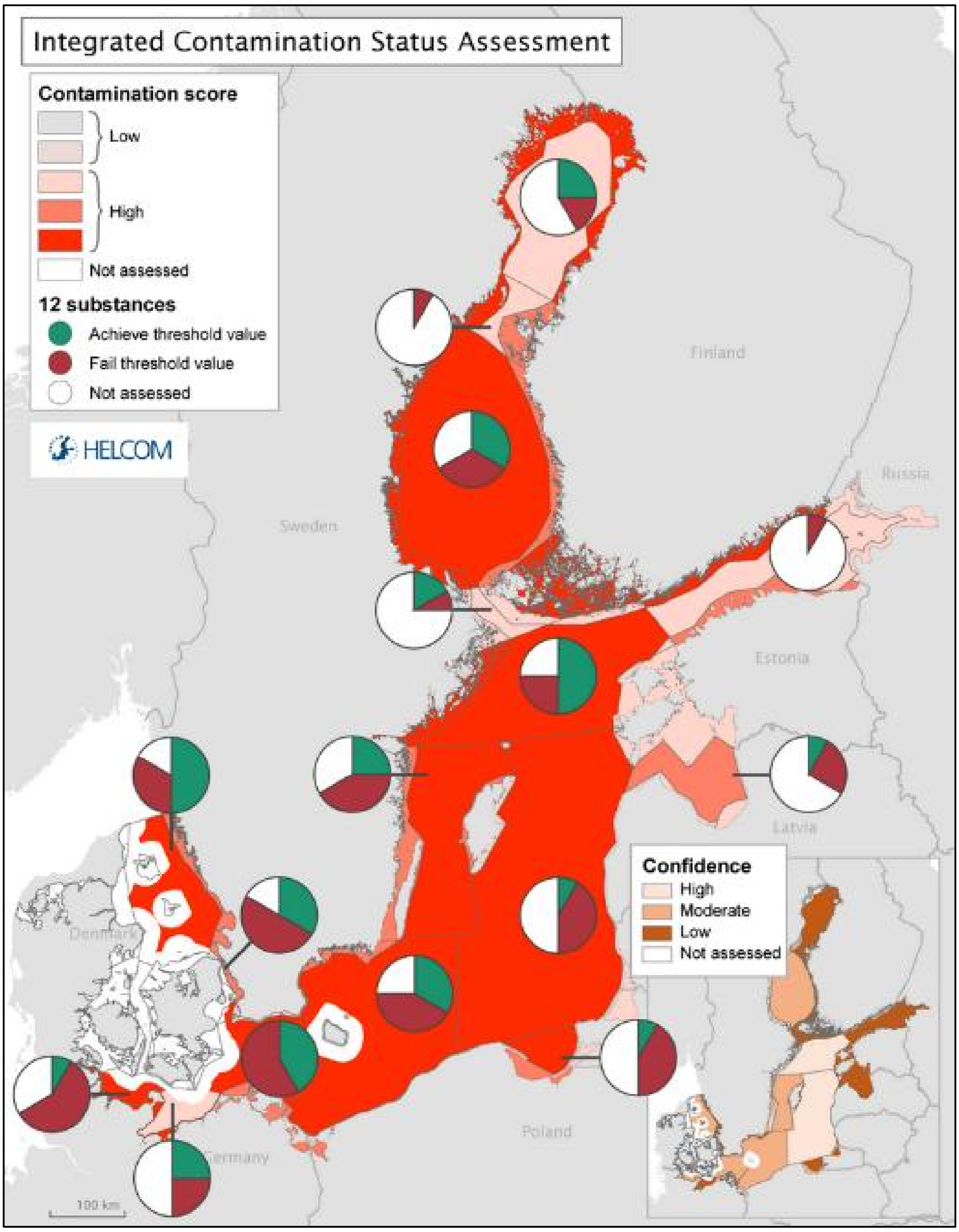


Figure 20. The integrated contamination status of the Baltic Sea assessed using the CHASE tool. The assessment shows that hazardous substances give cause for concern in all sub-areas. The integration is based on seven core indicators covering concentrations of twelve hazardous substances, using both the full data and 'initial status assessment' data. The pie charts show how many out of the twelve substance groups achieved or failed the threshold value in each assessment unit. Assessment units with lower confidence (as indicated in the map in the lower right corner) typically also have slightly better contamination status, indicating that these results may be worsened if more data were available (HELCOM 2017).

2.3.2 Metallic elements

Cadmium and mercury are metals that are included in the list of 11 priority hazardous substances and present a potential threat to the environment of the Baltic Sea. In addition to these metals, zinc, copper and lead are of concern, although to a lesser extent (Leivuori 1998, HELCOM 2010b, Vallius 2016).

Cadmium

Cadmium is one of the main contaminants in the sediments in the Baltic Sea. High cadmium concentrations have been observed in Bothnian Bay, eastern Gulf of Finland, Northern Baltic Proper, Western and Eastern Gotland Basins and the Pomeranian Bay (Figure 21). The surface sediment concentrations in large areas of the Baltic Sea clearly exceed the threshold values for good environmental status (HELCOM 2010b). In deeper sediments, accumulated in the 1960s and 1970s, the peak concentrations in central and eastern Gulf of Finland are 3–5 mg/kg dw, and in some harbour sediments (St. Petersburg) even higher than 30 mg/kg. Background concentration is at the level of 0.5 mg/kg dw (Ympäristöministeriö, 2015). Point sources of industrial wastewaters are important sources of cadmium. (Raateoja and Setälä, 2016)

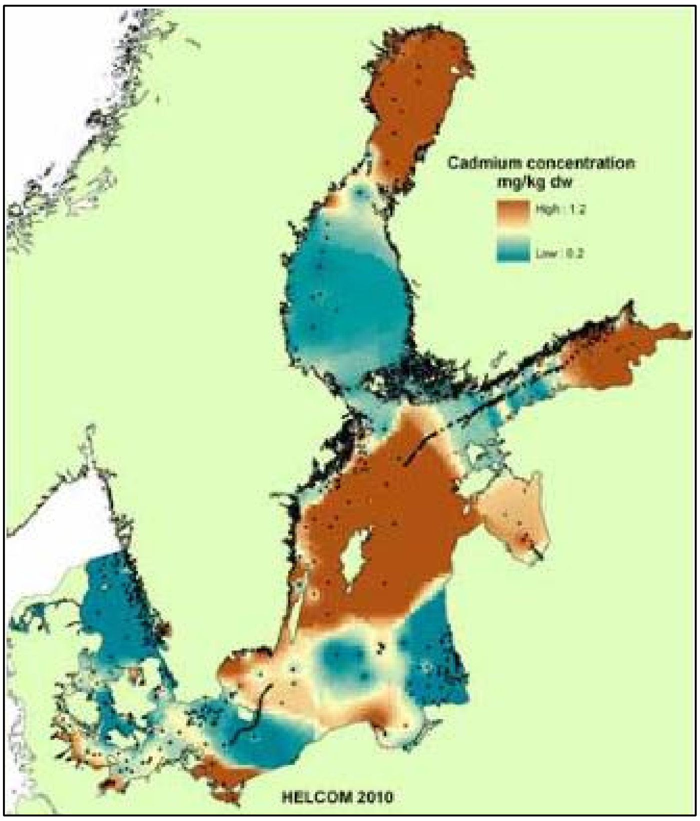


Figure 21. Levels of cadmium in surface sediments. The scale of the colour gradient is set to vary from 0.20 to 1.20 mg/kg dw, although higher values are also found in the contaminated areas shown on the map. The data (indicated with circles) are based on almost 2,000 spatially distinct measurements from 2001–2008 (HELCOM 2010b)

Mercury

High mercury concentrations have been observed in several estuaries and in particularly in the western Bothnian Bay, eastern Gulf of Finland, off southeastern Sweden and in the Sound (see Figure 22). The surface sediment concentrations in large areas of the Baltic Sea clearly exceed the threshold values for good environmental status (HELCOM 2010b). In older sediments from the 1950s and 1960s, peak concentrations of 0.5 mg/kg dw were detected in the eastern Gulf of Finland, especially in the estuary of the River Kymijoki and in the Russian territorial watershed. The overall concentrations of mercury in surface sediments have decreased in all parts of the Gulf of Finland in the last decades (Raateoja and Setälä, 2016).

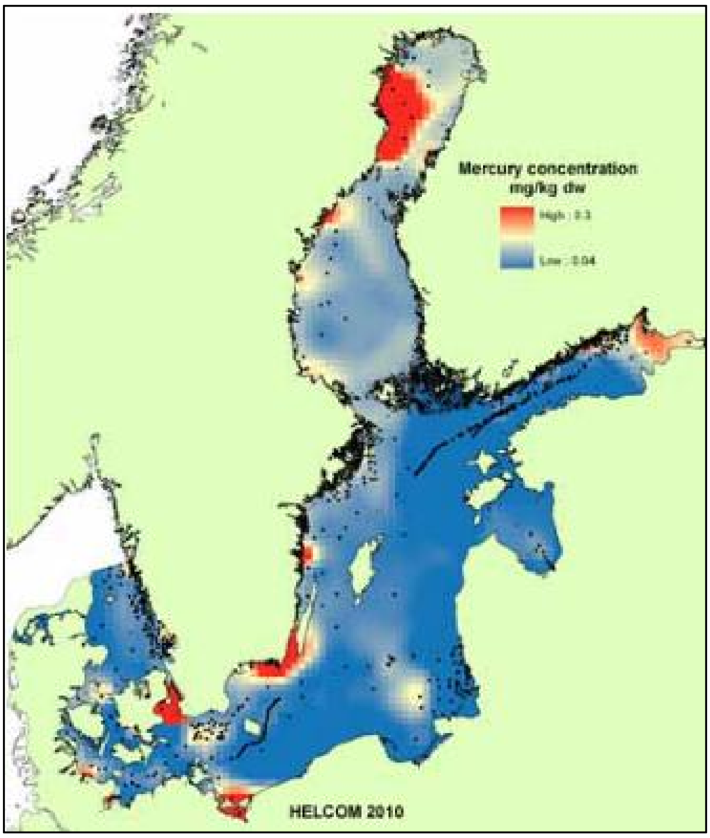


Figure 22. Concentrations of mercury in surface sediments. The scale of the colour gradient is set to vary from 0.04 to 0.3 mg/kg dw, although higher values also are found in the contaminated areas shown on the map. The data (indicated with circles) are based on almost 2,000 spatially distinct measurements from 2001–2008 (HELCOM 2010b)

2.3.3 Organic compounds

Most of the PBT substances are organic compounds that contain chlorine, bromide fluoride or metal atoms, or a long aliphatic carbon chain. The use of many organic PBT substances is banned or restricted in the EU. However, because of persistency they have accumulated in marine sediments where degradation is slow. The main sources of the organic PBT substances to the Baltic Sea are atmospheric long-distance transport of incineration emissions, effluents of domestic and industrial wastewater treatment plants via rivers, leaching from landfills and certain point sources such as harbours and industry. Traffic and agriculture are local sources. Maritime traffic, sea currents and dredging can mobilize and relocate contaminants in sediments.

Dioxins and furans (PCDD/F)

Dioxins and furans (PCDD/F) have never been produced intentionally but are side products of industry or products of incineration. The main source of dioxins to the Baltic Sea is long-range atmospheric transport and deposition within the whole Baltic Sea catchment area, resulting eventually in an accumulation of dioxins in sediments. A major point source of dioxins to the eastern Gulf of Finland is the River Kymijoki with its historical industrial activities along the river. Elevated concentrations are accumulated in both the river and estuary sediments. In reference locations of the Gulf of Finland, concentrations of dioxins in surface sediment were 430-2,900 ng/kg, but in the surface sediment of the River Kymijoki estuary and the sea area around Kotka, concentrations of 4,300-53,000 ng/kg have been found. Dioxin levels have decreased to some extent since industrial discharges ceased, but dioxins are highly stable in sediment environments. Sediments in St. Petersburg harbour areas and upstream River Neva, range between 2-20 ng/kg dw I-TEQ (n=5). In two sediment samples in the city area, concentrations of 230 and 250 ng/kg dw I-TEQ were detected (HELCOM BALTHAZAR / SCRES RAS 2012). Typical background concentrations in Finnish sediments are 5-10 ng/kg I-TEQ.

Polybrominated diphenyl ethers (PBDE)

Three congeners of BDEs - pentaBDE, octaBDE and decaBDE - belong to PBT compounds and have been used as flame retardants mainly in plastic products, cables and building materials as well as in firefighting foams. Since 2004, pentaBDE and octaBDEs have been banned and only the less toxic decaBDE is still used. The main sources of BDEs to the Baltic Sea are atmospheric deposition, leaching from landfills and wastewater treatment plants (mainly remains in sewage sludge). BDEs occur widely in the Baltic Sea environment, of which decaBDE is the most commonly occurring compound in sediments. Concentrations of 0.5-7 µg/kg dw of decaBDE have been found in the Baltic Sea, including the Gulf of Finland and coastal sediments (HELCOM 2010b).

Hexabromocyclododecane (HBCDD)

Hexabromocyclododecane (HBCDD) is an aliphatic brominated flame retardant used for example in expandable polystyrene, insulations, electrical equipment and textiles. HBCDD is emitted to the atmosphere in the production of HBCDD and during incineration of waste, and discharged to the aquatic environment via municipal and industrial wastewater plants treating wastewater from the textile industry and laundry. HBCDD may also leach from landfills containing HBCDD waste (e.g. construction and demolition waste). Concentrations of HBCDDs in 14 coastal sediment samples in Sweden were found to be below the detection limit of 1.7 µg/kg dw (Sternbeck et. al 2003). Although not detected in sediments, they have been reported in wastewater treatment plant sludge and untreated landfill leachate in Sweden.

Perfluorinated substances (PFOS, PFOA)

Perfluorooctane sulfonate (PFOS) and perfluorooctanoic acids (PFOA) are fully fluorinated surfactants that are used in impregnation of textiles and leather, paper and cardboard, cleaning products, firefighting foams and the electroplating industry. PFOS and PFOA can enter the environment at all stages of the product life cycle, although most likely via industrial and domestic wastewater treatment plants, landfills and waste incineration plants. It has been estimated that 70 % of PFOS in inflow to wastewater treatment plants is released in recipient water (HELCOM 2010b). Measured concentrations of PFOS in Baltic Sea coastal sediments (Germany) have been 0.3-0.7 µg/kg dw and in open sea sediments 0.03-0.13 µg/kg dw. Concentrations of PFOA were 0.1-0.7 and 0.06-0.2 µg/kg dw, respectively (HELCOM 2010b).

Organic tin compounds

Organic tin compounds include four butyltin compounds containing one to four butyl units and one tin atom (MBT, DBT, TBT, TeBT) of which tributyltin (TBT) is the most hazardous, together with triphemyltin (TPhT). Organic tin compounds have been used since the 1960s mainly in antifouling paints of ships and vessels. Use of TBT compounds in antifouling agents was globally banned in 2010 by the International Maritime Organization (IMO). Organic tin compounds are concentrated in sediments of ports, shipyards, marinas and seaways. Highest concentrations of 1,700-47,000 µg/kg dw of TBT have been found in Baltic Sea harbour sediments. In coastal and open sea sediments, the maximum concentrations of TBTs analysed have been 70-950 µg/kg dw (HELCOM 2010b). Only low concentrations of TPhTs (a few µg/kg dw) have been reported in harbour sediments.

Organic tin compounds tend to attach to particles in the aquatic environment and sink to the sediment. They can be mobilized from contaminated sediments by propeller mixing and sea currents followed by resedimentation. Microbes are known to degrade TBT to dibutyltin and even inorganic tin. Decrease of organic tin compound concentrations in sediments have been observed since the use of TBTs was banned, but in older sediments, high concentrations remain. Background concentrations of TBTs in unaffected sediments are 5-30 µg/kg dw (Finnish Ministry of the Environment 2015).

Nonylphenols and octylphenols

Nonylphenols and octylphenols represent a large group of isomeric compounds. They have versatile industrial and domestic uses in chemical synthesis, as stabilizers, paints, washing agents, plastic hardeners etc. Octylphenols are mainly used in rubber mixtures in tyre manufacturing. In aquatic environments, nonylphenols and nonylphenol ethoxylates accumulate in the sediments. Concentrations of octylphenols in sediments vary considerably, with reviewed investigations indicating concentrations ranging from below detection levels to highest concentrations of 100 µg/kg dw (HELCOM 2010b). Concentrations of nonylphenols in sediment are typically higher at 50-500 µg/kg dw. Typical sources of discharges to the aquatic environment are degradation of NPE-based products, wastewater treatment plants, metal, textile and photographic industries, landfills and waste sorting sites.

Short chain chlorinated paraffins (SCCPs, C_{10-13}) and medium chain chlorinated paraffins (MCCPs, C_{14-17})

Short chain chlorinated paraffins (SCCPs, C_{10-13}) and medium chain chlorinated paraffins (MCCPs, C_{14-17}) have various uses in industry and are found for example in rubber and PVC plastics, paints and metal cutting fluids. SCCPs are included in the list of priority hazardous compounds. SCCPs and MCCPs are released from products by emissions to air, and, to a lesser extent, by leaching from polymeric products. In wastewater treatment plants, the compounds are expected to accumulate in sludge and if the sludge is spread on agricultural fields, then the compounds can be released to the environment by leaching. Data are, however, very scarce. When released to the environment, SCCPs and MCCPs are distributed mainly onto soils from where they enter rivers via runoff and eventually end up in Baltic Sea sediments.

Based on the analysis of sediments in different parts of the Baltic Sea, the concentrations of SCCPs were typically 20-130 µg/kg dw and concentrations of MCCPs 40-300 µg/kg dw. In Swedish Gulf of Bothnian sediments, neither of the compound groups were detected (detection limit was 8 µg/kg dw). No information on SCCPs and MCCPs are available from several Baltic Sea states. The concentrations of SCCPS and MCCPs in published sediment investigations have been low compared to ecotoxicology-based no-effect concentrations (HELCOM 2010b).

Endosulfan

Endosulfan is listed as a priority hazardous substance. Its main use has been as an insecticide in agriculture. Endosulfan is banned or has not been used in Sweden, Germany, Denmark and Finland. Concentrations of endosulfan in Baltic Sea sediments in German and Lithuanian coastal waters were low - below the detection limits of 0.02 and 0.3 µg/kg dw. Also in Swedish sediments (Gotland Basin and Northern Baltic Proper) concentrations of endosulfan were below the detection limit of 0.5-1 µg/kg dw. In sediments, endosulfan is transformed by microbes to endosulfan sulphate, which has been detected in leachate at concentrations of 0.0002-0.0016 µg/l in Sweden.

Pharmaceuticals

Pharmaceuticals are released to the environment via untreated wastewater and effluents from wastewater treatment plants, as well as direct discharges from use within animal husbandry and aquaculture (UNESCO and HELCOM 2017). Concentrations of pharmaceuticals at hundreds of nanograms per liter have been found in wastewaters. Rivers flowing to the Baltic Sea have concentrations of pharmaceuticals as high as µg/liter (in Mannio et al. 2016). During the period 2002 to 2013, pharmaceuticals were detected in about 14 % of the water, sediment and biota samples in the Baltic Sea. The most frequently detected substances belong to the therapeutic groups of anti-inflammatory and analgesics, cardiovascular and central nervous system agents (UNESCO and HELCOM 2017).

Radioactive compounds

The main source of radioactivity in the Baltic Sea is the Chernobyl accident of 1986, and minor sources include atmospheric fall out from nuclear tests and routine operational discharges from nuclear facilities. After the Chernobyl accident, in the most contaminated areas (the Bothnian Sea and the Gulf of Finland) concentrations of ^{137}Cs in seawater exceeded 500 Bq m^{-3}, while in the western parts of the Baltic Sea they were close to 100 Bq m^{-3}. Since then the radioactivity in seawater has decreased but is still slightly above the pre-Chernobyl levels. In 2015, in the Bothnian Bay and Bothnian Sea the mean concentrations of 137Cs in seawater were 23.0 Bq m^{-3} and 27.0 Bq m^{-3} respectively. Lower mean concentrations, but still above the target level, were observed for the Gulf of Finland (18.3 Bq m^{-3}). In general, also the concentrations of 137Cs in biota (herring and flatfish) are still above the pre-Chernobyl levels (HELCOM 2017a).

In addition, there are some local hot spots of radioactive contamination such as outside Paldiski, near Tallinn, Estonia, where under the Soviet rule, a nuclear submarine training centre was built. Once the occupation forces pulled out, radioactive waste was left behind. Clean-up actions have taken place after Estonia became an independent state and a member of the EU. Nuclear power plants have minor radioactivity emissions, for example in 2014 emissions of tritium from Loviisa and Olkiluoto were 12.6 TBq and 1.46 TBq, respectively (Korpinen et al. 2018).

2.3.4 Chemical munitions in the sediment

Explosives and chemical weapons/waste have been disposed of by dumping in deep basins of the Baltic Sea. They are a potential risk when the metal caskets of the ammunition corrode and the chemicals are released into the water column and sediments. There are three main dumping areas for chemical weapons: the southeast of Gotland, close to Bornholm and in Kattegat (Bełdowski et al. 2016). Dumping sites of conventional explosive weapons are mostly unknown, but in old times a lot of aged conventional ammunitions were dumped into rivers and lakes. The sea bottom also includes large quantities of non-exploded mines from the First and Second World War.

Mustard gas containing ammunitions have been dumped in depths of around 100 m in anoxic bottoms of the Baltic Sea. This compound is degraded in aerobic conditions. A report by the Swedish BOX Win project indicates that degradation of mustard gas could be initiated when mixed with oxidized water (Hellström and Ödalen, 2013). Chemical munitions are typically insoluble and slowly degrading and stay in sediments for a long time (Knobloch et al. 2013).

3 Technical review of potential sea-based measures

SUMMARY

The objective of the technical review was to evaluate and discuss potential and tested sea-based measures that address the release of nutrients, mainly phosphorus, from internal sources for speeding up the recovery of the Baltic Sea, their applicability, positive effects and associated risks. In this study, we have focused on physical and chemical measures, which have been categorized in measures aiming at binding or extracting nutrients.

Oxygenation of anoxic bottoms aims to improve near-bottom oxygen conditions, remove a part of the nutrients from the water column and decrease benthic phosphorus release. Oxygenation using power from the electricity grid in restricted areas (such as lagoons and bays) has been successful in some experiments, whereas in some experiments results have been poor for different reasons (e.g. due to an insufficient pumping capacity). The technique is mature enough for continuing local projects in coastal areas and inner archipelago areas to gain local positive effects, better understanding of the short and long-term effects on ecology and to further improve the technology. Even though the ecological effects are not thoroughly known, risks in local projects can to a great extent be controlled. The technical requirements, hydrogeography and geochemistry of each area need to be carefully analysed in each project to avoid risks and failure of oxygenation. More research is needed on the durability of the effects of oxygenation, which appears to be highly dependent on local conditions, e.g. hydrography of the area. Monitoring needs to be continued for long enough after the treatment.

Chemical precipitation treatment aims to bind phosphorus to the sediment and decrease benthic phosphorus release. The method does not directly improve oxygen conditions in the bottom water, however, the reduced growth of algae and lower phosphorus levels in the water can lead to less oxygen consumption in the bottom water and recolonization of benthic fauna and fish in the water. The method is potentially suitable for local coastal areas and inner archipelago areas. *Aluminium treatment* has been successfully implemented in a marine bay in Sweden in 2012-2013. Monitoring after the treatment continues and according to the results, the ecological status of Björnöfjärden is improving. The technique is mature enough for continuing field experiments to gain more information on the reactions taking place in the sediment during and after the treatment. The results of case studies implemented so far suggest that the risks of local treatments can be controlled. More research is needed on the durability of the effects of aluminium treatment. Monitoring should be continued long enough after the treatment. Aluminium treatment is not considered a feasible treatment method at a large scale in open sea areas because of the large amount of chemical required.

Clay bombing utilizes clay dredged from waterways and *marl treatment* uses by-products of limestone production in chemical precipitation. Both are potentially attractive emerging methods, but need more research.

Methods for sediment dredging are technically well established. A specific method that removes only a thin layer of biologically active top sediment and nutrients from the sea bottom has been developed. Its effect on oxygen conditions in bottom waters and on benthic nutrient release and its feasibility in the marine environment needs further research as well as the applicability of the dredged and further processed sediment in agriculture as fertilizer and soil conditioner as proposed in the project.

The overall conclusion is that local projects should be continued to gain local positive effects, to gather more knowledge and to further develop the technologies. Applicability, positive effects and associated risks vary very much case by case and need to be carefully studied on a project-specific basis.

Local measures only have local impacts on the targeted area and in the immediate vicinity of the area.

3.1 Categorization of sea-based measures and objectives

The objective of the technical review is to evaluate and discuss potential and tested sea-based measures that address the release of nutrients, mainly phosphorus, from internal sources for speeding up the recovery of the Baltic Sea, their applicability and also associated risks. The review is based on currently available scientific and technical data and knowledge on techniques and experiments and complementary interviews.

Sea-based measures are here defined as measures and methods that can be applied to reduce the release of nutrients from internal sources, mainly the sediment, to water. These measures aim at managing the nutrient storages in the Baltic Sea, as opposed to measures that limit the introduction of new nutrients into the sea from land, air and sea surface sources such as ships.

In general, the measures fall into three categories (Table 1):

- Measures aiming at enhancing the phosphorus (P) binding capacity of the sediment,
- Extraction of nutrients from the sea, and
- Biomanipulation of the food web.

The measures can be further divided into physical, chemical and biological measures. Other categorizations are possible. This study focuses on physical and chemical measures because they potentially have significant impact on reducing eutrophication, in particular in Finland’s marine waters up to the outer limit of the EEZ. Since the Baltic Proper is recognized to have significant impact on eutrophication in the Gulf of Finland, it is also included in our assessment.

Table 1. Categorization and some examples of sea-based measures. The measures that we have focused in this report are underlined.

BINDING **of P to sediment**	**EXTRACTION** **of nutrients from the sea**	**BIOMANIPULATION** **of the food web**
<u>Oxygenation of anoxic bottoms</u> Chemical precipitation - <u>Aluminium compound treatment and precipitation</u> - Ferric compound treatment and precipitation - <u>Clay bombing</u> - <u>Marl treatment</u>	<u>Dredging</u> Mussel farming Algae harvesting Catching fish with low or no economic value (Commercial fishery is one significant way of nutrient removal.)	Removal of fish in order to manage food web interactions Fish production using local fish species as feed i.e. putting farmed species as top predators of local fish

The project has assessed the measures with the following criteria:

- significant potential in reducing eutrophication and nutrient recirculation either on a large-scale in the open sea or on a smaller-scale in archipelagos, lagoons or bays.
- technical and socio-economic viability, taking into consideration the technical limitations, costs and advantages
- probable low ecological and technical risks and potential benefits, based on current knowledge

Different measures have different risks and these are discussed in relation to the different presented measures. The risk probability of the different measures is estimated and ecological and financial costs evaluated and compared to the estimated benefits. The potential ecological risks as well as benefits are assessed against the criteria of the good environmental status (GES) as defined in the EU MSFD and Commission GES decision (EU 2017).

3.2 Oxygenation of anoxic bottoms

3.2.1 Description and applicability of the technology

Oxygenation of anoxic bottoms is a widely used restoration method in lakes (also referred to as destratification). The method has been applied in lakes of various sizes, also in Finland (lake area ranging between 0.07-150 km^2) (Lappalainen 1994, Lappalainen & Lakso 2005). Oxygenation pilots of small basins like the fjord-like brackish water Pojoviken Bay, Finland, has been undertaken already in the 1990s.

There are generally two types of systems applied to oxygenate anoxic bottoms: bubble plume aerators bringing air or oxygen to the bottom water and mechanical mixers bringing aerated surface water to the bottom water layer. Both systems generate turbulence, which weakens stratification and allows the influence of the prevailing wind (wind-forcing) to more readily mix the reservoir. Currently used techniques mostly utilize the latter method, where oxygen containing surface water is pumped through the pycnocline. This method benefits from density differences between the surface and deep water layers, because the lighter surface water efficiently mixes with deep water at the same time as it flows upwards (see Figure 23).

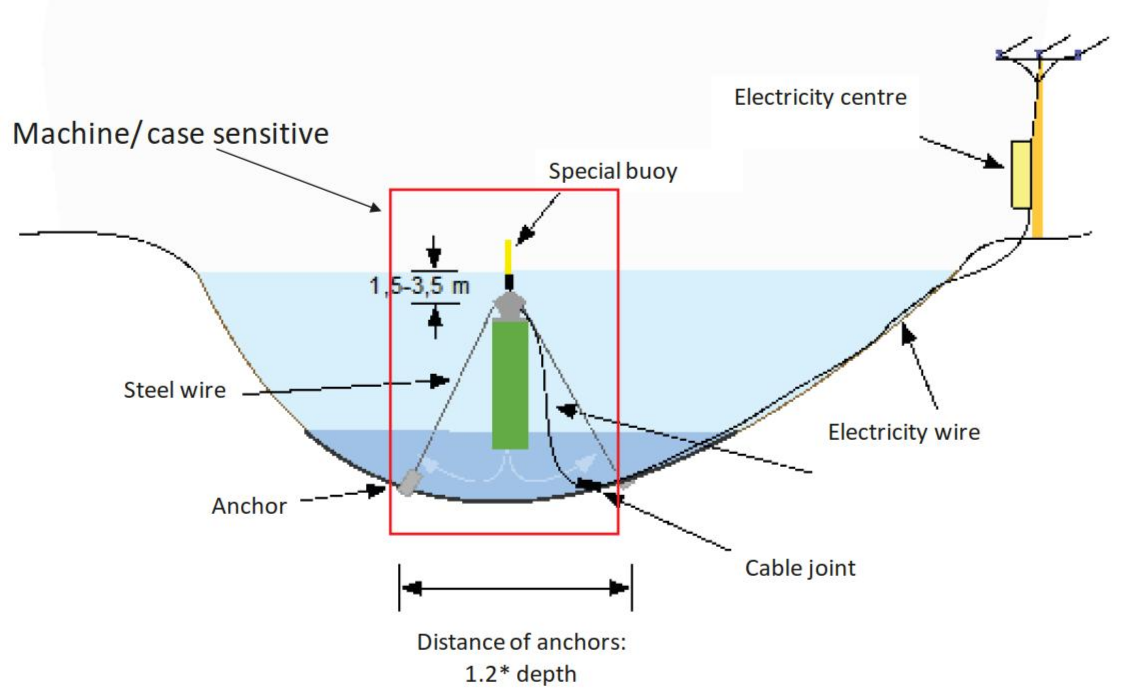


Figure 23. Schematic presentation of the general technical arrangement of the oxygenation method (Saarijärvi et al. 2012)

In recent years, a few pilot projects studying oxygenation of the Baltic Sea bottom have been carried out. The projects PROPPEN and BOX were carried out within a programme launched by the Swedish EPA in 2009. Both of these projects were implemented in partly isolated fjords; the PROPPEN project in Sandöfjärden, Sweden and Lännerstasundet, Finland (Rantajärvi et al. 2012, Saarijärvi et al 2012) and the BOX project in Byfjord, Sweden (Stigebrandt et al. 2015a). In the follow-up BOX-WIN project, the effects of large-scale oxygenation of the deep basins in the Baltic Sea were assessed as a desktop study and the results have been discussed in different publications (e.g. Stigebrandt and Kalén 2013, Stigebrandt et al. 2014, Stigebrandt et al. 2015a, Stigebrandt 2018). The WEBAP project studied oxygenation in Kanholmsfjärden, Sweden, in 2010-2013 (Baresel et al. 2013). The OXY project studied oxygenation in Hamina, Finland, in 2010-2013 (Pöyry 2017).

Outside the Baltic Sea area, in Rock Creek, USA, oxygenation has been carried out since 1988. Recent investigations have been carried out to further upgrade the system (Harris et al. 2015).

Oxygenation has been piloted also in Savannah Harbor, Georgia, USA, in 2007. The purpose of the project was to demonstrate that oxygenation technology could be successfully adapted and used in tidal Savannah Harbor for mitigation of impacts of reduced dissolved oxygen associated with proposed harbor deepening. The harbor deepening project is ongoing and will be completed in 2022. A dissolved oxygen injection system is in use and aims to supply oxygen to the harbor in hotter months. It is worth noting that pumping or injection of oxygen from air to water requires more than 10-times more energy than utilizing oxygen which is already dissolved in water (and pumping O2-rich water from upper layers to anoxic near-bottom layers of water). Hence, this method is suitable for large-scale oxygen aeration or pure oxygen injection mainly in regions and times of the day/year, where and when the price of electrical power is relatively inexpensive.

Energy supply is an important aspect to take into account when considering oxygenation. There are already electrical cables drawn to open sea areas close to Bornholm due to offshore wind power parks. Therefore, establishing connections to these grids could potentially be realistic. When scaling up to the Baltic Proper level, extensive cabling (even 200 km) might be required if taken from the mainland. In the BOX-WIN project the use of floating windmills in open sea areas has been investigated, which is quite similar to the windmill ‘Hywind’ that is built and sold by Statoil (Stigebrandt and Gustafsson 2007). Further technology improvements require field tests. Cooperation with shipbuilders and other stakeholders would be beneficial.

Local conditions determine the applicability of the technology in the marine environment. The results of the PROPPEN project (Lehtoranta et al. 2012) suggest that the factors favouring positive results of oxygenation pumping are:

- Sufficient relative pumping efficiency compared to deep water volume
- Favourable basin topography
- Sill topography and stratification which allows inflow of oxygen-rich water into the deep basin under pumping

Furthermore, critical to successful binding of phosphorus is that there is enough Fe(III) and Al(III) to bind phosphorus. Projects in lakes have shown that in some situations, geochemistry favours addition of oxygen as sufficient. In other situations, geochemistry requires addition of Fe(III) or Al(III) with the oxygen if the project is to be successful (David Austin CH2M; personal communication).

3.2.2 Risks and positive effects on ecology

The benefits of the oxygenation technologies have been proven in lake environments, however, the results and techniques cannot be directly applied in the marine environment. The consequences of restoration of previously hypoxic or anoxic sea bottoms are not very well known. A number of risks and uncertainties associated with oxygenation pumping have been proposed. Generally, the risks or consequences are considered to increase when the scale of the treatment increases.

The projects PROPPEN and BOX have assessed the potential risks and benefits of oxygenation in detail, and these are briefly presented here.

In the BOX project, oxygenation pumping carried out in Byfjord showed successful water exchange in deep waters. The oxygen containing water binds phosphorus to the sediment and simultaneously oxygenates the bottom water. The top of the sediment was oxidized about one year after the start of oxygenation and colonization of benthic animals was observed (see Stigebrandt et al. 2015). Rosenberg et al. (2016) observed that the top of the sediments in the Eastern Gotland Basin in 2015 were oxidized about three months after the arrival of the new deep water. A crucial factor for the success was that the required pump capacity was first computed using a model of the effects of pumping and water exchange on the oxygenation (Stigebrandt and Liljebladh 2011). Pumping of cold winter water lowers the risk of warming of deep waters, which can stimulate decomposition and further oxygen consumption.

Ecological succession of deep bottom areas was studied by Stigebrandt et al. (2017). The authors found that benthic colonization following a huge intrusion of salty oxygenated water from the Danish Straits was not initiated as expected. The presumed reason behind the delayed colonization of the sediment was thought to be the layer of old hypoxic water above the new oxygen containing water on the sediment surface. As a consequence, recolonization of benthic fish food organisms would, at least initially, be dependent on organisms contained in the freshly intruded marine water. Due to the above described mechanisms as well as other species specific behavior of different fish species, the period for recolonization of fish into previously anoxic or hypoxic areas could be considerably longer than expected (Stigebrandt et al. 2015). During a restoration project performed in the Byfjor (Stigebrandt and Kalén 2013) recolonization of the sediment was observed about one year after the start of the reoxygenation of the bottom water.

Modelling results of the BOX WIN project suggest that pumping 1,000 m^3/s would keep the Bornholm Basin well oxygenated, which would improve the hydrographic conditions for cod spawning and allow colonization of the presently dead deep bottoms. If internal phosphorus loading was permanently shut off and biological production decreased so much that anoxia does not develop when the oxygenation is turned off, there would be an important long-term effect as proposed by Stigebrandt and Liljebladh (2011). The modelling results suggest that in 10-15 years the Baltic Proper could be restored to a state that is determined only by the external nutrient inputs, if the internal source is eliminated by keeping deep bottoms oxygenated (Stigebrandt 2018).

The present extent of hypoxic and anoxic areas of about 100,000 km^2, with an estimated total volume of about 3,000 km^3 (Stigebrandt et al. 2017), is likely hampering migration, feeding and reproduction of a large number of fish species occurring in the Baltic Sea. This will also have consequences on fish catches. Apart from high fishery pressure on several fish species, the constricted present ecological niche may also form a considerable reason for dwindling populations of fishes. This is particularly acute and described for the Baltic cod, *Gadus morhua*. Other species that may benefit from improved deep water oxygen conditions are the Baltic herring, *Clupea harengus*, Sprat, *Sprattus sprattus*, Baltic salmon, *Salmo salar*, and Sea trout, *Salmo trutta*. Fishes belonging to the flatfish category also undertake extensive migrations to feed or spawn over large parts of the main Baltic Sea basin in order to reach the Gulf of Bothnian and Gulf of Finland. Turbot, Psetta maxima, flounder, *Platichtys flesus*, and plaice, *Pleuronectes platessa* are the main species that may be favoured by improved oxygen conditions of the central Baltic Sea.

Bartolino et al. (2017) analysed the density-dependent and density-independent mechanisms of the distribution of cod in the Baltic Sea. Oxygen and salinity were used as density-independent factors. The results indicated that oxygen levels as well as salinity had a clear influence on the distribution of cod. Stigebrandt et al. (2015) calculated that oxygenation of the Bornholm area would increase the cod reproduction volume from the present almost zero to about 50 km^3, amounting to increased catches of about 12,000 tonnes annually. This would be a significant contribution to the present total annual catch of about 44,000 tonnes. It is worth remembering that during the peak years in the 1990s, the total annual catch of Baltic cod was about 400,000 tonnes; i.e. ten times the current level of cod catches. Upwelling deep water to the coastal areas of the GOF would, with time, stabilize favourable conditions for benthic communities and contribute to improvement of coastal fisheries as well.

One concern, however, is that disturbance or failure in cod reproduction may occur as a result of oxygenation. Floating cod spawn requires salt concentration of >10 ‰ and oxygen concentration of ca. 2 mg/l and any changes in these concentrations will have positive or negative impacts on reproductive success. Floating spawn must not fall to the sediment and the floating depth must be oxic; if water salinity/density decreases so that the spawn sinks to anoxic depth, it dies rapidly (Ollikainen et al. 2012, Conley et al. 2009).

More information is needed from future field experiments on consequences of restoration of previously hypoxic or anoxic sea bottoms.

It is likely that oxygenation of a semi-closed bay or lagoon will have an effect as long as oxygenation continues, with the effects ceasing after the pumping is shut off. How soon this happens, depends largely on local conditions. The natural bottom structure along the coast of Finland is such that anoxic/hypoxic conditions may always develop. In the Baltic Proper, macroscale events may dominate the oxygen conditions. The North Sea inflows push anoxic water from the Baltic Proper (BP) to the GOF, which increases oxygen depletion and strengthens the stratification and halocline in the GOF. This is probably the most dominating factor controlling anoxia in GOF, especially in western GOF, and at least in the open sea area. Continuous smaller deep water flow from BP to western GOF is also probable, because there is no sill separating the GOF from the BP. An anoxic water inflow from BP to eastern GOF may also counteract any oxygenation efforts.

Aeration of anoxic sediment can facilitate aerobic microbial degradation of some hazardous substances and lower or increase their toxicity. In anoxic sediments, some hazardous substances such as mercury can be methylated to more toxic forms and bioconcentrating metabolites, which might call for oxygenation of anoxic bottoms. On the other hand, some measures may spread hazardous substances to non-contaminated areas or release them to the food web. In the BOX project in the Byfjord, it was found that oxygenation of the bottoms did not increase fluxes of poisonous organic compounds and metals from the bottom sediments (Stigebrandt et al. 2015).

The Table 2 summarizes the risks and potential positive effects of oxygenation of anoxic bottoms with surface water in relation to the descriptors of Annex I of the MSFD as based on the literature review and expert opinion by the consultant team.

In the Multi-Criteria Analysis (MCA) workshop (see Chapter 4.6), ten Finnish experts provided their opinions on the possible impacts of potential sea-based measures on ecosystem services/benefits. MCA applies cost-benefit thinking to cases where there is a need to present impacts that are a mixture of qualitative, quantitative and monetary data, and where there are varying degrees of certainty. According to the opinion of the survey participants, oxygenation holds highest priority position when combining cost-benefit and risk ranging results.

Table 2. Summary of risks and potential positive effects of oxygenation of anoxic bottoms with surface water in relation to the descriptors of Annex I of the MSFD.

Descriptors of the Annex I of the MSFD to determine the GES	Impact of measure	
	Risks	**Potential positive effects**
(1) **Biological diversity** is maintained. The quality and occurrence of habitats and the distribution and abundance of species are in line with prevailing physiographic, geographic and climatic conditions.	No identified risks to biological diversity	Oxygenation of anoxic/hypoxic bottoms is expected to improve the quality and occurrence of habitats
(2) **Non-indigenous species** introduced by human activities are at levels that do not adversely alter the ecosystems.	Unlikely to introduce non-indigenous species at levels that would adversely alter the ecosystems Risk of non-indigenous species introduced by human activities	Not relevant
(3) **Populations of** all **commercially exploited fish and shellfish** are within safe biological limits, exhibiting a population age and size distribution that is indicative of a healthy stock.	Risk of disturbance or failure in cod reproduction (This applies to areas where cod reproduce and is not relevant in the Finnish EEZ)	Recolonization of the sediments would permit fish populations to recolonize previously uninhabitable areas. Hydrographical conditions for cod spawning would improve.
(4) All elements of the **marine food webs**, to the extent that they are known, occur at normal abundance and diversity and levels capable of ensuring the long-term abundance of the species and the retention of their full reproductive capacity.	No identified risks to marine food webs	Oxygenation of anoxic/hypoxic bottoms would revitalize benthos and strengthen marine food webs
(5) Human-induced **eutrophication** is minimised, especially adverse effects thereof, such as losses in biodiversity, ecosystem degradation, harmful algae blooms and oxygen deficiency in bottom waters.	No identified risks to increase eutrophication	Positive changes in nutrient concentrations Nutrients bound to sediment
(6) **Sea-floor integrity** is at a level that ensures that the structure and functions of the ecosystems are safeguarded and benthic ecosystems, in particular, are not adversely affected.	No identified risk of endangering sea-floor integrity	Reintroduced

Descriptors of the Annex I of the MSFD to determine the GES	Impact of measure	
	Risks	**Potential positive effects**
(7) **Permanent alteration of hydrographical conditions** does not adversely affect marine ecosystems.	Risk of changing water circulation by changing salinity Risk of warming of deep waters Oxygenation may break stratification too early	It is possible that the hydrographical conditions for cod spawning would improve
(8) **Concentrations of contaminants** are at levels not giving rise to pollution effects.	Risk of release of pollutants from sediments	Aerobic degradation of pollutants Decrease of H_2S Decreased leakage of toxic substances when bottoms are oxidized
(9) **Contaminants in fish and other seafood for human consumption** do not exceed levels established by Community legislation or other relevant standards.	Risk of release of pollutants from sediments into the food chain	Aerobic degradation of pollutants
(10) Properties and quantities of **marine litter** do not cause harm to the coastal and marine environment.	Not applicable	Not applicable
(11) Introduction of **energy, including underwater noise**, is at levels that do not adversely affect the marine environment.	Underwater noise could adversely affect the marine environment Introduction of energy	

3.2.3 Case examples

The following case examples show that oxygenation can remove a part of the nutrients from the water column and decrease benthic nutrient release as long as the oxygenation continues. Oxygenation has been successful in some experiments, whereas in others results have been poor for different reasons (e.g. due to insufficient pumping capacity). The durability of the effects of oxygenation on bottom water oxygen concentrations and internal phosphorus leakage has not been investigated in the long-term and based on the studied cases, appears to be highly dependent on local conditions, e.g. hydrography of the area.

EXAMPLE 1. PROPPEN PROJECT - CONTROLLING BENTHIC RELEASE OF PHOSPHORUS IN DIFFERENT BALTIC SEA SCALES

In the PROPPEN project, oxygen pumping was piloted in the basin of Sandöfjärden in the outer Archipelago of Finland and in the sub-basin of Lännerstasundet in the inner archipelago of Sweden (Figure 24). These areas vary highly regarding hydrodynamic and geomorphologic conditions.

Figure 24. Study locations (Rantajärvi et al. 2012, Saarijärvi et al 2012)

The needed pumping capacity and daily oxygen consumption rates were calculated based on earlier experiments. The pumps were driven by power from the grid and the field experiments took place during three years in 2009-2011. The pumps were not used at winter. The project in Lännerstasundet was more successful than in Sandöfjärden, where the oxygenation capacity was apparently too weak.

In Lännerstasundet, the concentration of phosphate remained at a lowered level as long as near bottom water stayed oxic and as long as the project continued (Figure 25). One of the clear positive effects of pumping was a decrease in the density stratification, which induced long-term conditions favoring inflows from the adjacent basin. The inflows were capable of oxidizing the bottom water, and depending on the volume of the water, they may even exceed the oxygenation capacity produced with the pumps.

No monitoring results were available from the area after the project was completed in 2012.

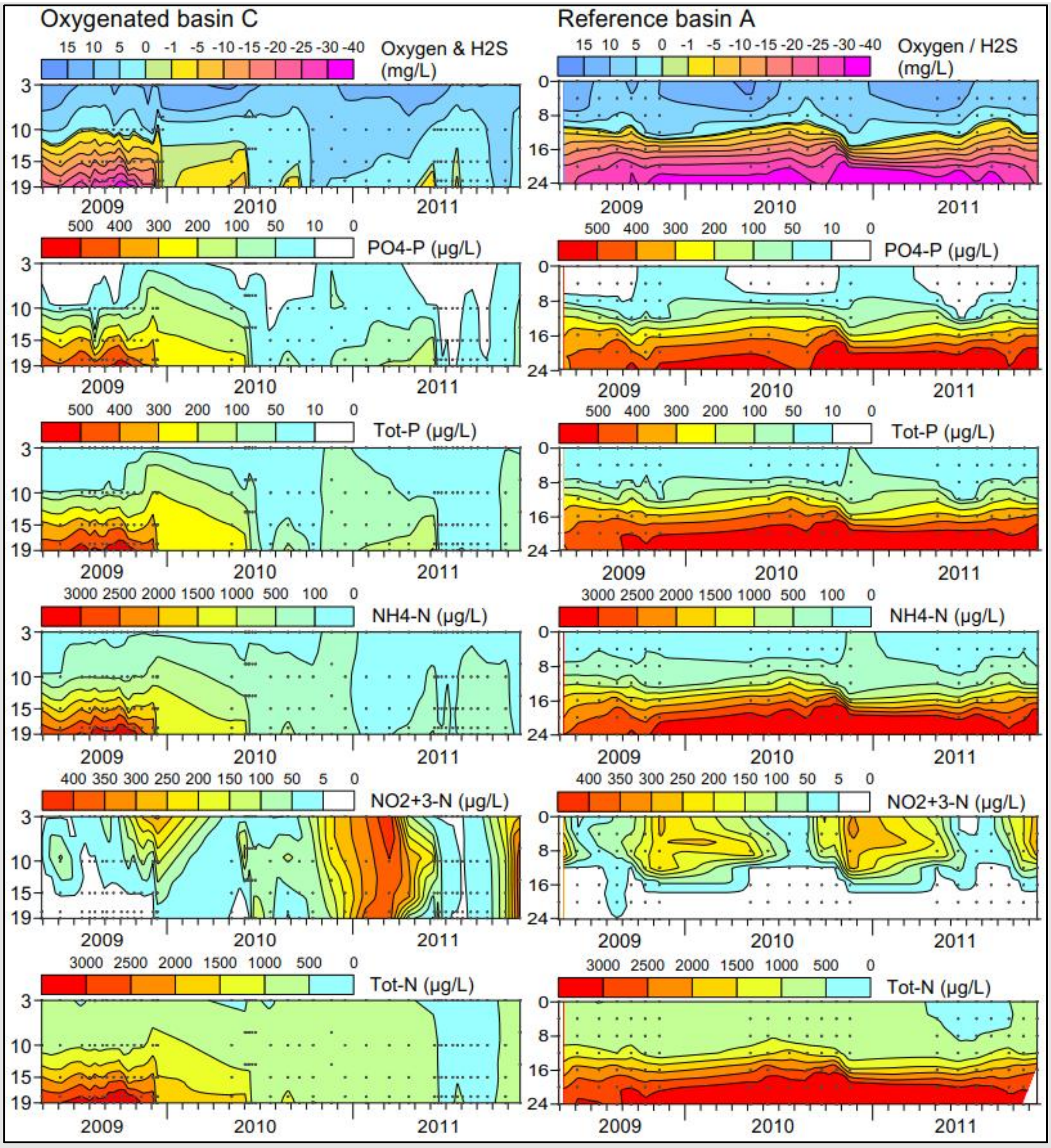


Figure 25. Variation in concentration of oxygen and H2S, phosphate, total phosphorus, ammonium, nitrite-nitrate sum and total nitrogen in the pumped area (oxygenated basin C, left panels) and regularly monitored area (reference basin A, right panels) in Lännerstasundet (Lehtoranta et al. 2012)

The project was led by the Finnish Environment Institute (SYKE) during 2009-2012 and was financed by the Swedish Environmental Protection Agency, FORMAS, Vinnova and Baltic Sea 2020.

References: Lehtoranta et al. 2012, Rantajärvi et al. 2012, Saarijärvi et al. 2012

EXAMPLE 2. BOX PROJECT - OXYGENATION PILOT AT THE BALTIC SEA

The Baltic Deepwater Oxygenation (BOX) project piloted technology to oxygenate deep bottoms by pumping down oxygen saturated water in Byfjord, Western Sweden (Figure 26). The project took place in 2009-2012.

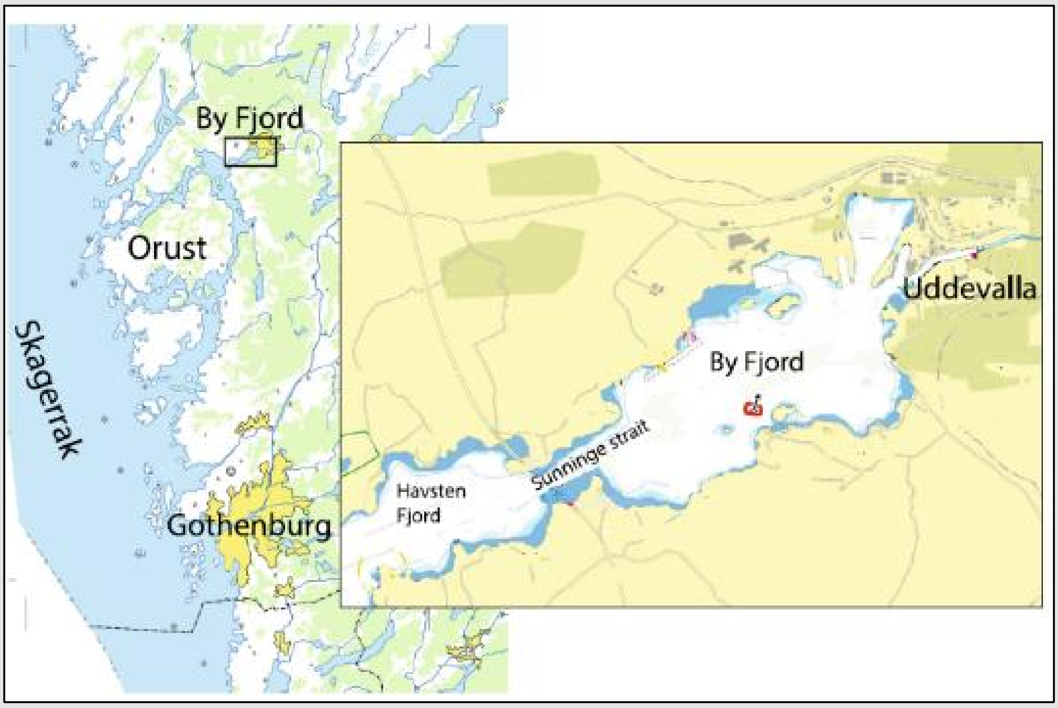


Figure 26. Study locations of BOX projects (Stigebrandt et al 2014)

Before the experiment, the pump capacity needed to keep the basin water oxygenated was estimated using a model that simulates the circulation with pumping, water exchange with the neighbouring Havsten Fjord and oxygen consumption (Stigebrandt and Liljebladh 2011). The experiments lasted 2.5 years. The pumps were driven by power from the grid. The pumping of 2 m^3/s caused an approximately 30 times increase in vertical circulation in the deep water of the fjord and the rate of water exchange in the deep water by inflows from the Havsten Fjord increased by a factor of 10 (Stigebrandt et al 2015).

In the BOX project, oxygenation pumping showed successful water exchange in the deep water. The amount of P in the deep water decreased significantly, due to both increased flushing and decreased leakage from the (oxygenated) sediments (Figure 27).

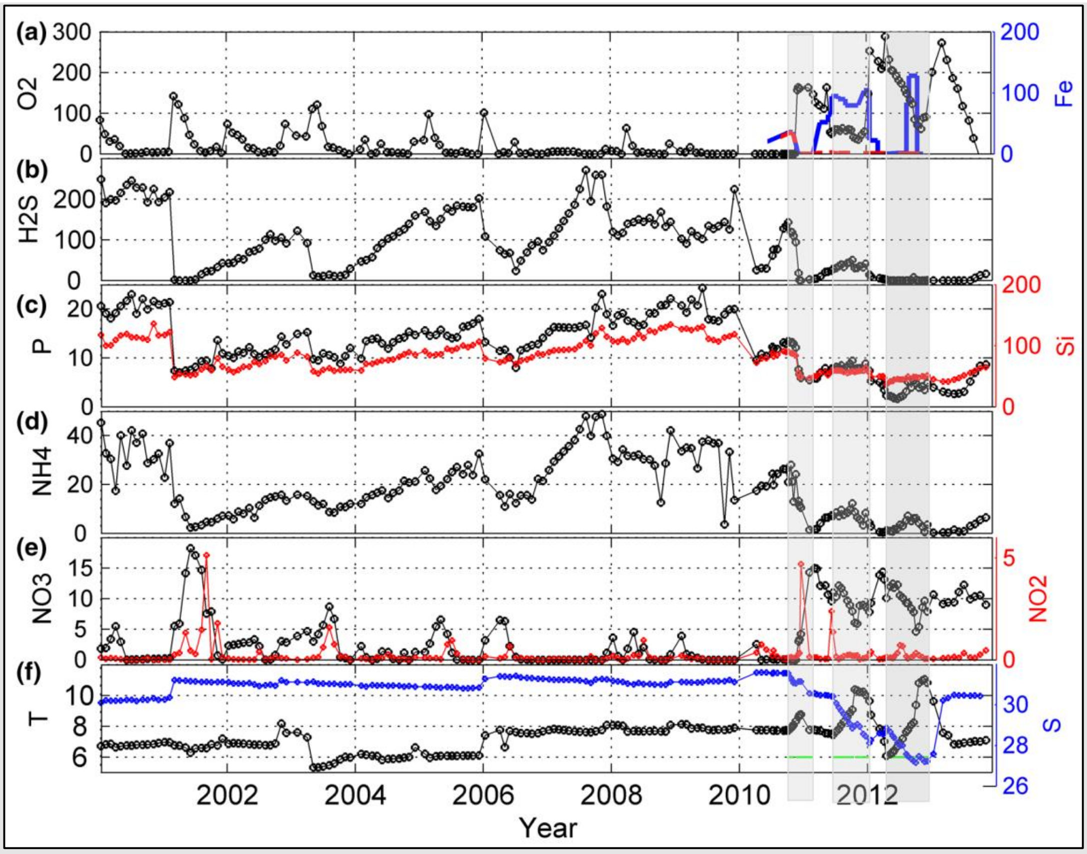


Figure 27. Panels a–e show total amounts (in tonnes) in the volume below 17.5 m from 2000 to 2014 of a) Oxygen, b) Hydrogen Sulfide, c) Phosphate and Silicate (red), d) Ammonium, and e) Nitrite (red) and Nitrate. Panel f) shows the volume mean Temperature, and the volume mean Salinity (blue). a) Shows the concentration of Fe^{2+} (in µg/l), at 32 (blue) and 41-m depth (red dashed), respectively. The gray shaded areas show the periods when pumping was on (Stigebrandt et al 2014)

The BOX project also investigated oxygenation of the top of the sediment by taking sediment profile images. The results suggest that the top of the sediment was oxidized about one year after the start of oxygenation and colonization of benthic animals was recorded as described in Stigebrandt et al. (2015). The flux of toxic substances from the sediment also decreased when the water was oxygenated.

The project was led by Gothenburg University, Sweden, and was financed by the Swedish Agency for Marine and Water Management, FORMAS and Vinnova. The technical and scientific publications of the project can be found at: http://www.balticsearestoration.org.

References: Stigebrandt et al. 2014, Stigebrandt et al. 2015, Stigebrandt and Liljebladh 2011

EXAMPLE 3. BOX-WIN AND FOLLOW-UP PROJECTS – DESKTOP STUDY AIMING AT LARGE-SCALE RESTORATION OF THE BALTIC SEA

The BOX-WIN project was a follow-up desktop study to the BOX project that investigated the feasibility of using large moored floating wind mills equipped with pumps in the open Baltic Sea. According to the plans, the wind mills could be connected to the grid and deliver excess power to the grid in windy conditions. By buying power from the grid in periods with weak winds the pumps could work perpetually. Large-scale oxygenation of the Bornholm Basin was modelled. The modelling suggested that pumping 1,000 m^3/s would keep the Bornholm Basin well oxygenated, which would improve the hydrographic conditions for cod spawning, and allow colonization of the presently dead deep bottoms (Stigebrandt and Kalén 2013, Stigebrandt et al. 2015).

According to the phosphorus model of the Baltic Proper (Stigebrandt et al. 2014), 2.3 tonnes P/km^2/year are leaching from anoxic bottoms in the Baltic Proper. In a follow-up study (Stigebrandt 2018), it was modelled that the Baltic Sea strives towards equilibrium with the total phosphorus supply which equals the external land-based supply plus the internal supply, plus the external oceanic supply from Kattegat. It was concluded that the Baltic Proper could be restored in 10-15 years to a state that is determined by the external nutrient sources (which at the present are at the same levels as in the 1950s) if the internal source is eliminated by keeping deep bottoms oxygenated. The restoration would lead to a strong reduction of phosphorus (by about 70 %) in the surface layer (i.e. above the halocline) of the whole Baltic Proper and thereby also to a substantial reduction in the supply of organic matter to the deep water where oxygen consumption will be reduced accordingly. The phosphorus concentration in the surface waters of the coastal zone would be only about 30 % of present day concentrations, which would have large impacts on water quality both at open coasts and in archipelagoes and other coastal areas.

The natural oxygenation process provided by the major Baltic inflow in December 2014 was used to study the effects of oxygenation. Taking sediment profiles in a section east of Gotland in July 2015, about 3 months after the arrival of the oxygenated water, it was found that the top of the sediment had been oxidized but not colonized (Rosenberg et al. 2016). A follow-up expedition in April 2016 showed that the sediment was still not colonized and it was concluded that oxygenated deep bottoms beneath a thick hypoxic layer lack potential of benthic colonization (Stigebrandt et al. 2018).

The BOX-WIN project was implemented in 2013 and financed by the Swedish Agency for Marine and Water Management, Nordic Investment Bank (NIB) and Nordic Environment Finance Corporation (NEFCO). The expeditions to the Gotland Basin in 2015 and 2016 were financed by University of Gothenburg and FORMAS. The technical and scientific publications of the project can be found at: http://www.balticsearestoration.org.

References: Stigebrandt and Kalén 2013, Stigebrandt et al. 2015, Stigebrandt 2018, Stigebrandt et al. 2018

EXAMPLE 4. THE ROCK CREEK, USA

Chesapeake Bay is the largest estuary in North America. Rock Creek is a sub-tributary of the Patapsco River in the northern portion of Chesapeake Bay (Figure 28) The Rock Creek aeration system has been in place since 1988 (refurbished in 1998) and the current equipment is reaching the end of its useful life. Over the last 25 years the system has been largely successful in preventing fish and crab kills while at the same time significantly mitigating odors and other adverse aesthetic conditions associated with low dissolved oxygen concentrations and hydrogen sulfide present in the creek.

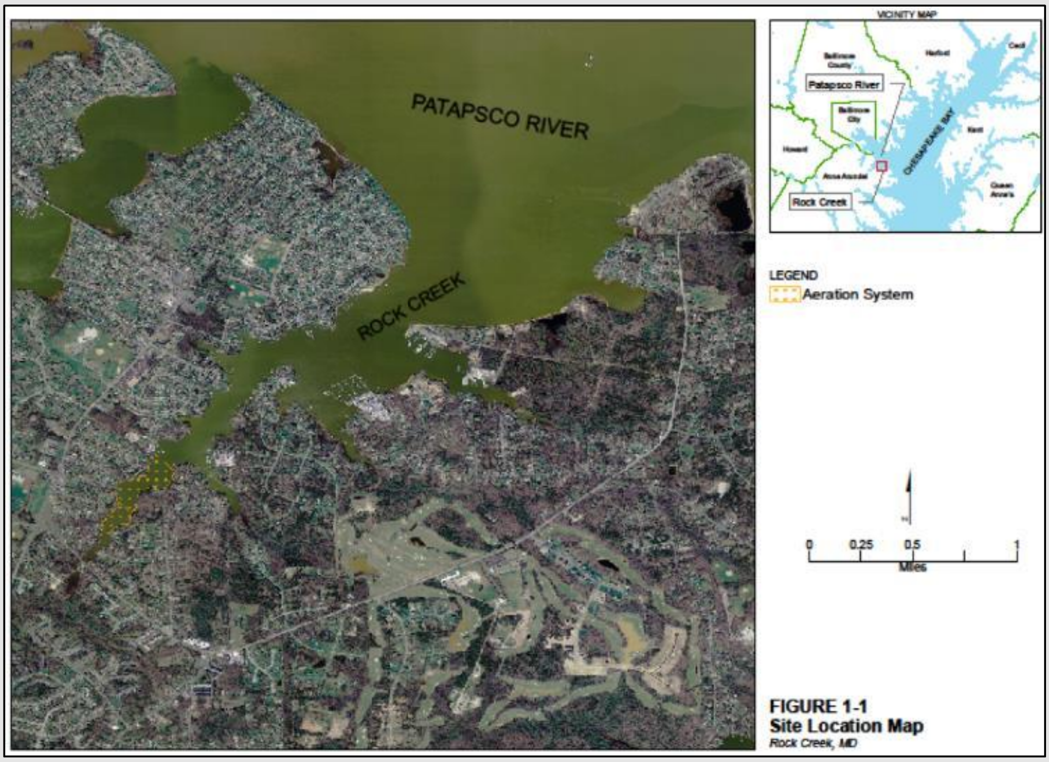


Figure 28. Study location (CH2MHILL 2013)

Baseline measurements demonstrated that the aeration system successfully mixed the water column, preventing dissolved oxygen levels from dropping below 3 mg/l and the concentrations during the baseline period were generally above 5 mg/l even in the bottom waters. When the aeration system was turned off for the experimental period, restratification occurred quickly and decrease in dissolved oxygen was apparent. With the aeration system shut down, the condition worsened and within 2 days the bottom water dissolved oxygen concentrations dropped to less than 2 mg/l. By the end of the experimental period (9 days) the dissolved oxygen was less than 2 mg/l throughout the water column.

Based on the results of the study, it is apparent that some form of supplemental aeration is necessary in Rock Creek to prevent at least periodic anoxic conditions and the associated odors, fish kills, and other adverse effects.

Continuous aeration may not be necessary because the system is able to recover quickly once the system is restarted. Therefore, a dynamic system that operates only during the periods of high stratification and low bottom dissolved oxygen concentrations could potentially alleviate the adverse conditions in an efficient manner. As conditions throughout the Rock Creek and Patapsco system improve with regard to the nutrient concentrations and the resulting improved dissolved oxygen concentrations, the period of Rock Creek aeration could be reduced and further increase efficiency. The existing mechanical aeration equipment and diffusers are in severe need of replacement and dynamic system controls could be incorporated in the system when the equipment is replaced.

References: CH2MHILL 2013, Harris et al. 2015, Lora Harris, University of Maryland Center for Environmental Science, personal communication, David Clidence, ECO2, personal communication

EXAMPLE 5. SAVANNAH HARBOR, SAVANNAH, GEORGIA

The MACTEC Engineering and Consulting Inc. (MACTEC), through the Georgia Port Authority, conducted the Savannah Harbor ReOxygenation Demonstration Project in the summer (August to mid-September) of 2007 using ECO2's proprietary Speece Cone technology. The purpose of the Savannah Harbor ReOx Project was to demonstrate at full-scale that Speece Cone supplemental oxygenation technology could be successfully adapted and used in tidal Savannah Harbor for mitigation of impacts of reduced dissolved oxygen associated with proposed harbor deepening.

The demonstration system consisted of two barge-mounted 12-foot diameter Speece Cones with a combined nominal design capacity of 30 000 pounds (14 tonnes) per day of supplemental dissolved oxygen.

Overall, the project demonstrated in full-scale and under field conditions that Speece Cone oxygenation technology can be adapted to the tidal conditions of Savannah Harbor for mitigation of impacts of reduced dissolved oxygen associated with proposed harbor deepening.

The harbor deepening project is ongoing and will be complete in 2022. A dissolved oxygen injection system is in use and aims to supply oxygen to the harbor in hotter months.

Figure 29. Speece cones delivered as part of the Savannah Harbor Expansion Project environmental mitigation (US Army Corps of Engineers 2017)

References: ECO Oxygen Technologies LLC 2017

EXAMPLE 6. WEBAB

The results of the Wave Energized Baltic Aeration Pump (WEBAP) project (Baresel et al. 2013) can be summarized as follows. The Wave Energized Baltic Aeration Pump, was developed to mitigate the problem of oxygen depletion in coastal zones. The method has been developed since 2007 by Aalborg University in Denmark and was tested in collaboration with the Swedish Water and Air research institute IVL in Hanöbukten (open sea area north of Bornholm) and Kanholmsfjärden (in the middle of Stockholm archipelago), Sweden, in September – October 2010 and April 2011. Two pilot plants, one wave powered and one electric oxygen pump, were in operation for over a year.

According to Baresel et al. (2013), "The equipment units proved feasible, functional and effective at delivering fresh water down to hypoxic layers. However, the functionality depended on weather conditions (high seas reduced efficiency), which need to be continuously monitored to guarantee efficient operation. Over a period of more than 12 months, the pumping devices worked efficiently in technical terms and, with low energy consumption, moved oxygen-rich surface water down to oxygen-poor deeper sea levels. The analyzed phosphorus concentration in deep waters (100 m from the sea surface) decreased from 250 µg P/l to 70 µg P/l, but started to increase again when the pumping was stopped. In surface waters (5 m from the sea surface), the phosphorus concentration remained at 20 µg P/l.

The pumping activity was accompanied by active collection of marine and biological data around the test areas. Subsequent monitoring and evaluation of the marine environment, water, biota and bottom sediments indicated that the enhanced water streams did not disturb the salinity stratification, which is important for all marine life. The pumping activity was sensitive enough not disturb the bottom sediments, which might be, in the worst case, a huge phosphorus source that could enhance algae blooms and eutrophication. The monitoring and evaluation did not reveal any adverse impacts on bottom-dwelling flora and fauna or increased toxic contents.

Combatting oxygen depletion utilising the WEBAP method could be an effective and efficient alternative (or complement) to other methods, like diesel/electricity-powered water injection or chemical treatment, and a complement to the efforts to reduce the run-off of fertiliser and wastewater effluents. The method can be scaled up at relatively low costs, with an evaluation predicting that a 10-fold increase in terms of water volumes, compared with the WEBAP pilot, could have a real impact on hypoxia and thus improve the conditions on the sea bottom in coastal zones.

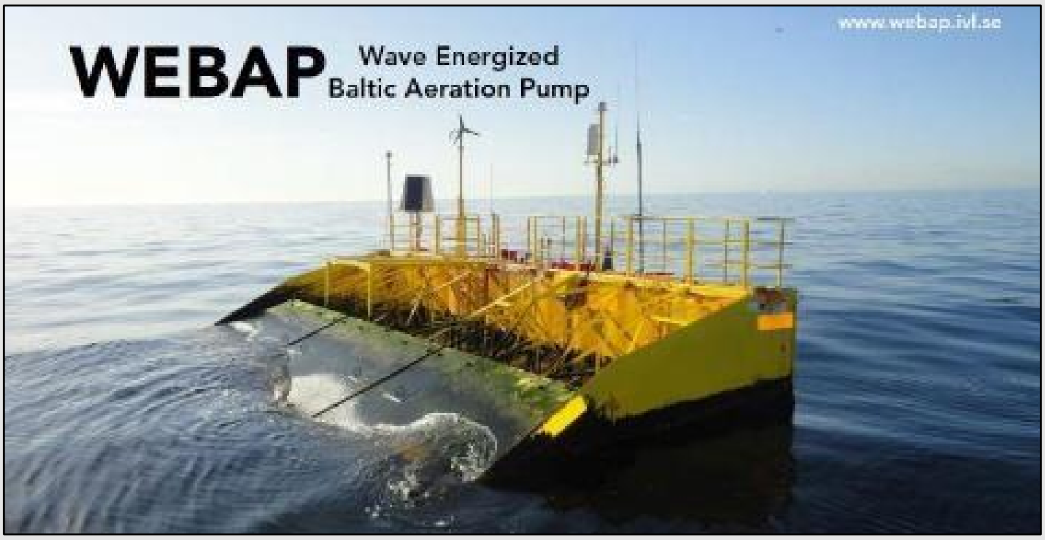


Figure 30. "Wave Energized Baltic Aeration Pump (WEBAP)"

References: IVL Swedish Environmental Research Institute 2017, Baresel et al. 2013

3.3 Precipitating phosphorus in the sediment

3.3.1 Description of the technology

Internal phosphorus leakage can be eliminated by binding it to the sediment through chemical precipitation using natural or chemically processed substances.

In water and wastewater treatment, aluminium and ferrous chemicals are the most often used substances. Aluminium treatment, traditionally carried out by using aluminium chloride, has been used to fix phosphorus in lakes for more than 40 years in Sweden, as well as in Finland, other parts of Europe and the United States. The application of polymerized aluminium chloride in full-scale was carried out in the Baltic Sea in Björnöfjärden in the Stockholm archipelago, Sweden, and has been followed by comprehensive monitoring during 2011-2016 (Rydin et al. 2017). In lake environments, aluminium chemical is typically spread from a boat into the water phase or directly to the sediment surface. In Björnöfjärden, the treatment was carried out by a patented method where the aluminium solution is mixed into the bottom water and the bottom sediments with a kind of harrow that is pulled behind a barge. The internal release of phosphorus in the bay decreased by more than 90 %.

In order to restrict phosphorus leakage from the sediment chemically, also other materials have been tested and applied. For example, the use of Phoslock (a lanthanum-modified bentonite clay product), modified local soil materials as well as marl in combination with by-products, have been studied. Gypsum treatment of the seabed has been tested in lake environments.

An emerging, and possibly very cost-effective, method called “clay bombing” has been proposed by Mikko Kiirikki (Luode Consulting Oy, personal communication) and Petri Ekholm (Finnish Environmental Institute, personal communication). Dredging of waterways produces clay that could be placed into anoxic deep bottoms with high phosphorus content. “Bombing” the sediment with clay produces sorption surface to directly diminish phosphorus release. The clay minerals also trap and inactivate enzymes related to phosphorus cycling, thus slowing down the release of phosphorus.

3.3.2 Risks and positive effects on ecology

In aluminium treatment, added Al efficiently binds P that would otherwise leak into the water. This reaction is not dependent on oxygen conditions. Al is added in a form of salt (e.g. polyaluminium chloride) to water or sediment. In contact with water, aluminium hydroxide is formed yielding binding sites for P. The binding effect could potentially be long-term if the bound P is buried under new sediment layers (Figure 31).

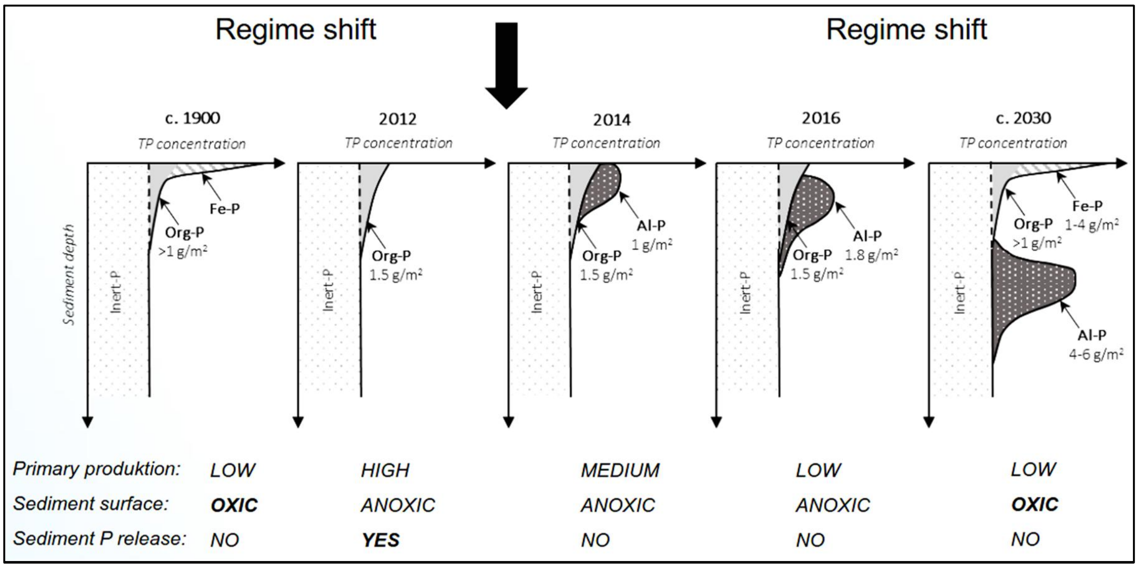


Figure 31. Illustration on presence of phosphorus in sediment before and after the carrying out of aluminium treatment (Rydin and Kumblad 2017)

Aluminium treatment has been used to fix phosphorus in lakes for more than 40 years. No negative side-effects have been observed to date, as long as very acidic conditions do not prevail in the water.

In Björnöfjärden, the treatment resulted in lower concentrations of water column phosphorus, reduced phytoplankton growth and improved water transparency. After 40 months, 1.3 tonnes of dissolved phosphorus has been trapped by aluminium in the 0.7 km^2 treated anoxic sediment area, turning the treated bay into a sink for phosphorus in the Baltic Sea ecosystem. Although there were quick improvements in water chemistry variables, and subsequent positive responses in biota, oxygen conditions in the bottom water after the treatment remained poor. However, the reduced growth of algae, clearer water and lower phosphorus levels in the water are expected to lead to less oxygen consumption in the bottom water and recolonization of benthic fauna and fish in the water.

Aluminium hydroxide has very low solubility at circum-neutral pH, but dissolves at alkaline and acid pH, and might then be acutely toxic to aquatic organisms including fish. Aluminum is relatively insoluble at pH 6 to 8 (e.g. formation of amorphous gibbsite-like $Al(OH)_3$, see Figure 32), but the solubility of Al increases under more acidic and more alkaline conditions, in the presence of complexing ligands, and at lower temperatures. Aqueous Al is comprised of inorganic Al hydroxy species (Al^{3+}, $AlOH^{2+}$, $Al(OH)^{2+}$, $Al(OH)_3°$, and $Al(OH)_4^{-*}$), the proportion of which vary with pH. Aqueous Al also forms inorganic complexes with F^- and SO_4^{2-}, the formation of which also varies with pH, the concentration of the inorganic ligands, ionic strength, and water temperature. Aluminum forms both weak and strong complexes with organic material such as humic and fulvic acids that tend to keep Al in solution but make it less toxic to organisms. Finally, there is an exchangeable fraction of Al in soils and sediments, as well as complexed with organic material.

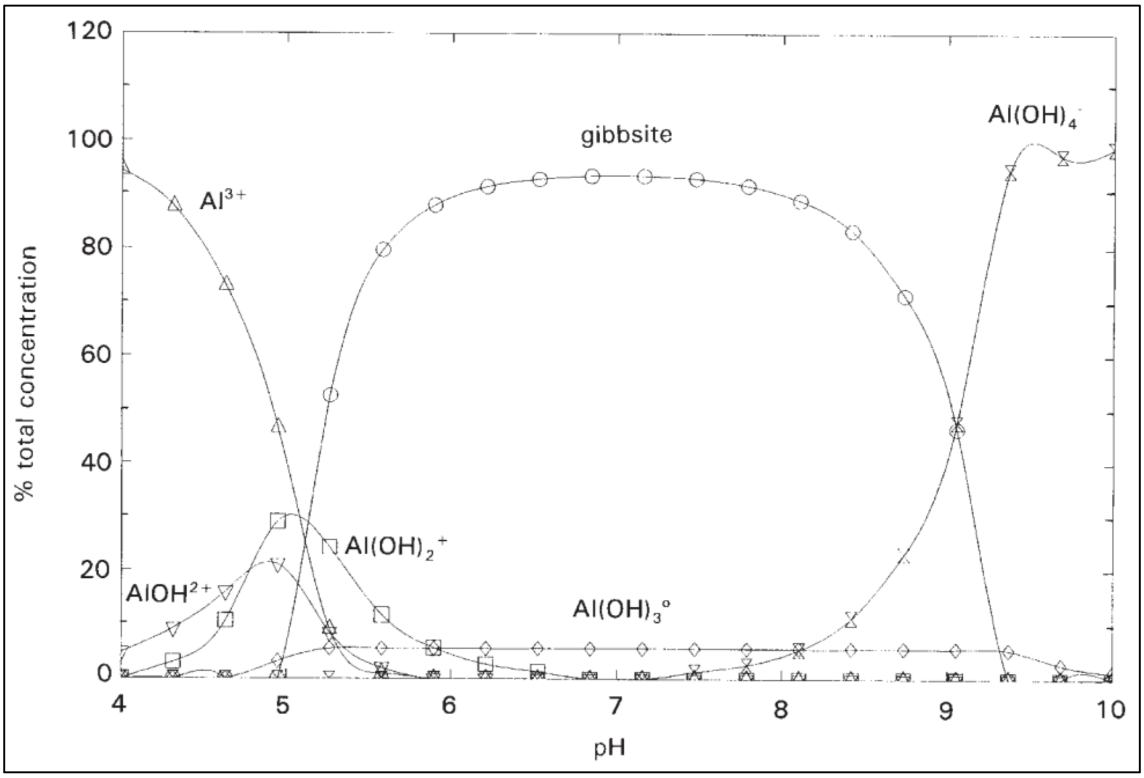


Figure 32. Aluminum speciation from a model simulation (Schecher and McAvory, 1992) using five aquatic species of Al plus gibbsite, and varying water pH from pH 4 to 10. The simulation was run using 4 µM total Al (=100%), and 15°C. The simulation used 1 mM concentrations for Ca, Cl, Na, and NO_3, with the system open to the atmosphere. (Gensemer et al. 1999)

In the experiments in Björnöfjärden, the mean pH remained at 7.0 in the bottom water. The Baltic Sea has a good buffering capacity compared to many lakes and therefore risks in the Baltic Sea are lower than in lakes with low buffering capacity, like most lakes in the Scandinavia are.

Aluminium concentrations somewhat increased in fish after the treatment in Björnöfjärden, but returned to background concentrations within a few years (Figure 33).

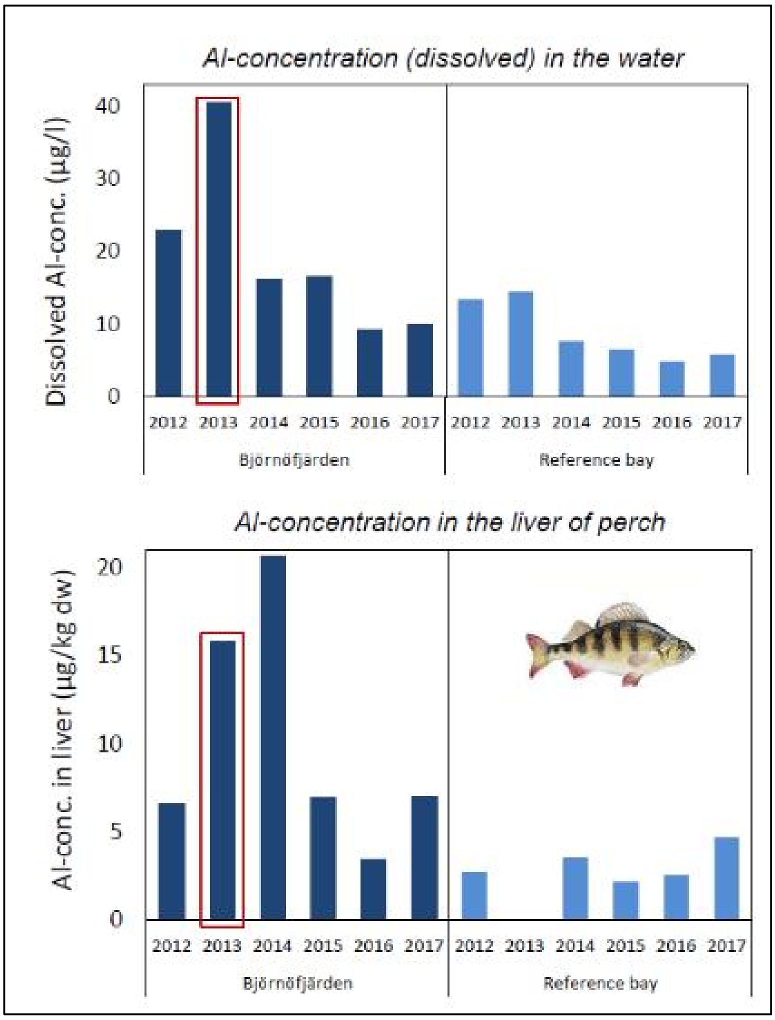


Figure 33. Aluminium concentration (dissolved) in the water and in the liver of perch. The red line around the year 2013 bar refers to the year of application of Al. (Rydin et al. 2017)

The risks and positive effects on ecology are very different with different materials and depend on the way the treatment is carried out. Similarly to oxygenation, the natural bottom structure along the coast of Finland is such that anoxic/hypoxic conditions may always develop. In the Baltic Proper, macroscale events may dominate the oxygen conditions. Therefore the treatment may not have a permanent impact.

The risks associated with the treatment method depend on hazardous substances and impurities in the treatment chemical. Even natural minerals can contain hazardous substances as impurities. The leachability of hazardous substances depends on e.g. pH and redox.

The positive effects on ecology depend on the efficiency of the treatment to bind phosphorus. Some chemicals bind phosphorus more permanently than others. The efficiency of the method may also be affected by local conditions such as redox.

The method of treatment (and how the chemical treatment is applied) determines the dispersal of particles.

The risks and positive effects on ecology are very different for different substances, depending on their chemical and physical properties as well as local conditions. The risks and benefits of aluminium treatment are summarized in the Table 3. The use of other substances is not discussed further since no case examples in the marine environment were readily available.

In the Multi-Criteria Analysis (MCA) workshop (see Chapter 4.6), according to the opinion of the survey participants, aluminium treatment was rated as the lowest priority measure because of high costs, unknown effects and high risks of failure.

Table 3. Summary of risks and potential positive effects of aluminium treatment in relation to the descriptors of Annex I of the MSFD)

Descriptors of the Annex I of the MSFD to determine the GES	**Impact of measure**	
	Risks	**Potential positive effects**
(1) **Biological diversity** is maintained. The quality and occurrence of habitats and the distribution and abundance of species are in line with prevailing physiographic, geographic and climatic conditions.	No anticipated risks if the necessary pH conditions are fulfilled. Aluminium hydroxide has very low solubility at circum-neutral pH, but dissolves at alkaline and acid pH, and might then be acutely toxic to aquatic organisms including fish	Precipitation of phosphorus in the seabed could improve the quality and occurrence of habitats
(2) **Non-indigenous species** introduced by human activities are at levels that do not adversely alter the ecosystems.	Not applicable	Not applicable
(3) **Populations of** all **commercially exploited fish and shellfish** are within safe biological limits, exhibiting a population age and size distribution that is indicative of a healthy stock.	No anticipated risk if the necessary pH conditions are fulfilled. Aluminium hydroxide has very low solubility at circum-neutral pH, but dissolves at alkaline and acid pH, and might then be acutely toxic to aquatic organisms including fish	Precipitation of phosphorus in the seabed could potentially permit fish populations to recolonize previously uninhabitable areas
(4) All elements of the **marine food webs**, to the extent that they are known, occur at normal abundance and diversity and levels capable of ensuring the long-term abundance of the species and the retention of their full reproductive capacity.	No anticipated risk if the necessary pH conditions are fulfilled. Aluminium hydroxide has very low solubility at circum-neutral pH, but dissolves at alkaline and acid pH, and might then be acutely toxic to aquatic organisms including fish	Precipitation of phosphorus in the seabed could potentially revitalize benthos and strengthen marine food webs

Descriptors of the Annex I of the MSFD to determine the GES	Impact of measure	
	Risks	**Potential positive effects**
(5) Human-induced **eutrophication** is minimised, especially adverse effects thereof, such as losses in biodiversity, ecosystem degradation, harmful algae blooms and oxygen deficiency in bottom waters.	Efficiency of the method may be poor because the impact area may be only local	Potentially positive changes in nutrient concentrations and oxygen conditions in bottom waters Phosphorus precipitated and bound to the seabed
(6) **Sea-floor integrity** is at a level that ensures that the structure and functions of the ecosystems are safeguarded and benthic ecosystems, in particular, are not adversely affected.	Risk of worsening the sea-floor integrity is low, because it is already compromised in the anoxic zones where the measures would be implemented	No impact
(7) **Permanent alteration of hydrographical conditions** does not adversely affect marine ecosystems.	No identified risk	No impact
(8) **Concentrations of contaminants** are at levels not giving rise to pollution effects.	No anticipated impact if the necessary pH conditions are fulfilled. Aluminium hydroxide has very low solubility at circum-neutral pH, but dissolves at alkaline and acid pH, and might then be acutely toxic to aquatic organisms including fish	No impact
(9) **Contaminants in fish and other seafood for human consumption** do not exceed levels established by Community legislation or other relevant standards.	No anticipated impact if the necessary pH conditions are fulfilled. Aluminium hydroxide has very low solubility at circum-neutral pH, but dissolves at alkaline and acid pH, and might then be acutely toxic to aquatic organisms including fish	No impact
(10) Properties and quantities of **marine litter** do not cause harm to the coastal and marine environment.	Not relevant	Not relevant
(11) Introduction of **energy, including underwater noise**, is at levels that do not adversely affect the marine environment.	No impact	No impact

3.3.3 Case examples

Aluminium treatment was successfully implemented in a marine bay, binding phosphorus into the sea bottom in 2012-2013. Monitoring after the treatment continues and according to the results, the ecological status of Björnöfjärden is improving. Clay bombing utilizes clay dredged from waterways and marl treatment uses by-products of limestone production in chemical precipitation. Both are potentially attractive emerging methods, but need more research.

EXAMPLE 7. FULL-SCALE ALUMINIUM TREATMENT IN BJÖRNÖFJÄRDEN, SWEDEN

Full-scale aluminum treatment and follow-up monitoring was carried out in Björnöfjärden in 2011-2016 (area 1.5 km^2, maximum/mean depth 25/6 m). The conditions of the bay after the chemical treatment were compared to a reference bay (Fjallsviksviken) (area 0.7 km^2, maximum/mean depth 15/4 m) which has many common characteristics. Dissolved polyaluminium chloride was used as the treatment chemical. The treatment was carried out by using a patented method where the aluminium solution is mixed into the bottom water and the bottom sediments with a kind of harrow that is pulled behind a barge. The solution was applied in three rounds so that it spreads evenly over the bottom surface. The aluminium treatment was carried out in two stages. Primarily bottom areas with a depth of 6-12 m, from the north (Säbyviken) to south (Björnöfjärden), were treated during the summer of 2012. During the summer of 2013, the deeper bottoms and Torpe-Infjärden were treated.

The total dose during eight summer weeks in 2012 and 2013 was 50 g Al/m^2 on 0.73 km^2, adding up to 36 tonnes of aluminium. Treatment was repeated three times with the same Al dose, to ensure homogeneous application. The 36 tonnes of added Al to the sediment was forecasted to permanently bind 4 tonnes of dissolved phosphorus that otherwise would have been recycled to the water column within a decade. Although the expected ratio of Al to P binding is up to a factor 5 less effective than chemical precipitation in sewage treatment plants, the mechanism is the same. Typically, the Al dose is determined by a laboratory test using sediment from the treatment site to yield enough aluminium bound phosphate.

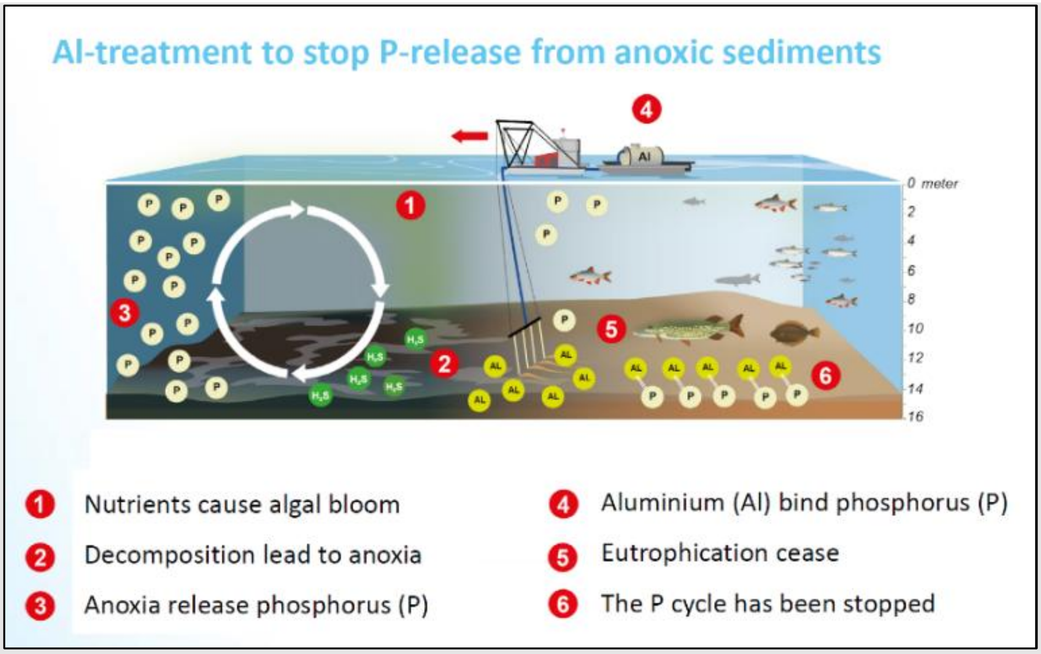


Figure 34. Schematic figure of remediation using aluminium treatment in Björnöfjärden (Rydin et al. 2017)

As a result of the aluminum treatment, the supply of phosphorus in the bay was reduced by more than 90 %. The phosphorus concentration in the bay has also been much lower than in the reference bay Fjällviksviken (See Figure 35). The P concentration and visibility in the water now correspond with the levels that were observed in the middle of the last century.

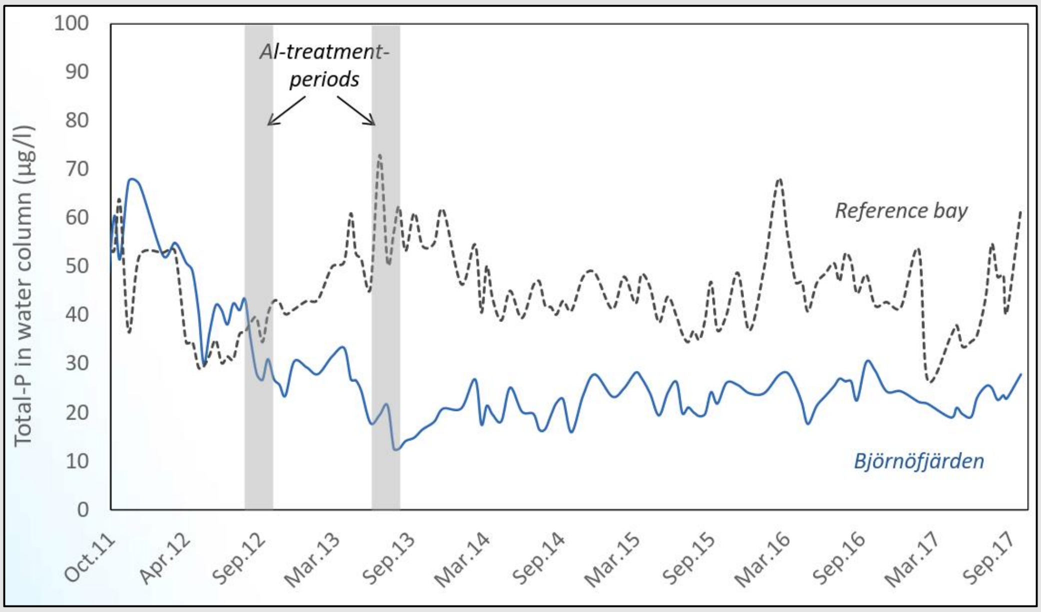


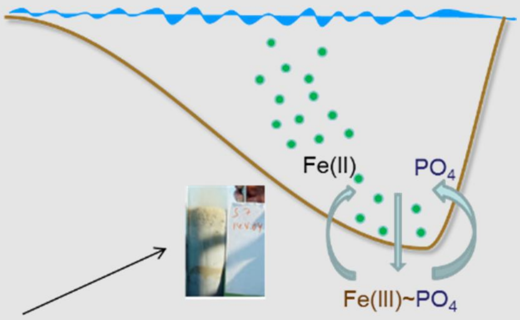
Figure 35. Total phosphorus concentrations in the water column (µg/l) (Rydin et al. 2017)

As a consequence of the reduced supply of phosphorus resulting from the phosphorus treatment, the bay system is expected to have reduced growth of algae, clearer water and lower phosphorus levels in the water. This is expected to lead to less oxygen consumption in the bottom water and recolonization of benthic fauna and fish in the water. Monitoring after the treatment continues and according to the chemical and biological monitoring results, the ecological status of Björnöfjärden is improving (e.g. change in benthic vegetation and fish composition).

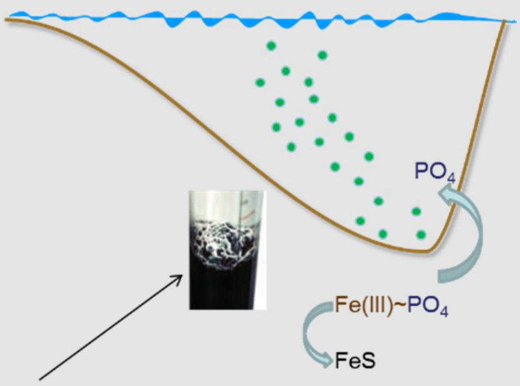
References: Rydin et al. 2017, Kumblad & Rydin 2017

EXAMPLE 8. CLAY BOMBING

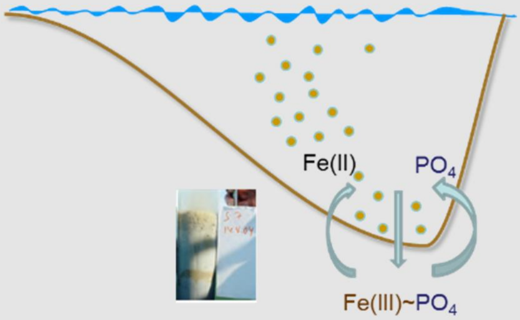
Dredging of waterways produces clay that could be placed into anoxic deep bottoms with high phosphorus content. “Bombing” the sediment with clay produces sorption surface to directly diminish phosphorus release. The clay minerals also trap and inactivate enzymes related to phosphorus cycling, thus slowing down the release of phosphorus. The proposed mechanism is as follows:



1. In good oxic conditions, organic matter is largely broken down by iron reduction. Solid Fe (III) oxides are reduced to a dissolved Fe (II) and oxides bound P is released. When Fe (II) faces oxic water mass it oxidizes back to Fe (III), sediments to the bottom and binds the released P -> low internal load.



2. In poor anoxic conditions, the organic matter is partially broken down by sulphate reduction. Fe forms a solid Fe-sulphide with hydrogen sulphide, which is no longer circulating and releases P to reach algae -> strong internal load.



3. The situation can be improved by adding clay to sediment as:

- the Fe (III) oxides contained in clay promote iron reduction, reduce sulphate reduction and increase the P-binding capacity

- the clay can immobilize the organic matter

-> reduced internal load.

In addition, the clay can accelerate the deposition of the algae in the water phase, i.e. reduce the algae suspension formation.

References: Petri Ekholm, Finnish Environmental Institute, personal communication, Mikko Kiirikki, Luode Consulting, personal communication, Avnimelech Y et al 1982, Ekholm and Lehtoranta 2012, Hedges and Keil 1995, Lehtoranta et al 2008.

EXAMPLE 9. MARL TREATMENT

Marl refers to an earthy mixture of fine-grained minerals. The term has been applied to a great variety of sediments and rocks with a considerable range of composition.

In the project "Permanent binding of phosphorus in the Baltic Sea bottom", Sven Blomqvist, Stockholm University, investigated whether calcium-based residues from industry can effectively bind phosphorus in the Baltic Sea bottom sediment. Marl was obtained from Nordkalk AB in Storugns, Lärbro, and the material originated from mines in Storugns. The smaller fraction of processed limestone (<25 mm), is a byproduct and stored in landfill.

Laboratory results show that in optimal conditions phosphate (PO_4^{3-}) is effectively adsorbed by marl. Adsorption was influenced by the salinity of the water, but above all by particle size, i.e. the specific surface. The measured maximum adsorption capacity amounted to 0.50 mol P/m^2 particle area, for particles <75µm. The method has not yet been tested in pilot or full-scale. Addition of a few percent Cement Kiln Dust (CKD) increased the ability to absorb phosphate up to four times. CKD is a by-product of cement manufacture and consists mainly of calcined lime. Phosphate adsorbed on the material even at low temperatures (5 °C) and under acidic conditions. The exact absorption mechanism is not yet known.

According to the experimental data, the amount of marl needed to bind mobile-P in oxygen-poor Baltic Sea sediment was estimated at ~ 1.5 dm^3 fine particle size per m^2 bottom surface.

The project was funded by BalticSea2020 in 2011-2014 and will be tested in Central Baltic Interreg-project Seabased which will be launched in Spring 2018 and coordinated by John Nurminen Foundation (Marjukka Porvari, personal communication).

Figure 36. Limestone byproduct pile of Nordkalk AB in Storugns, Lärbro (Blomqvist and Björkman 2014)

References: Blomqvist and Björkman 2014, Marjukka Porvari, John Nurminen Foundation, personal communication

3.4 Removing phosphorus and nitrogen from the seabed by dredging and related technologies

3.4.1 Description of the technology

General

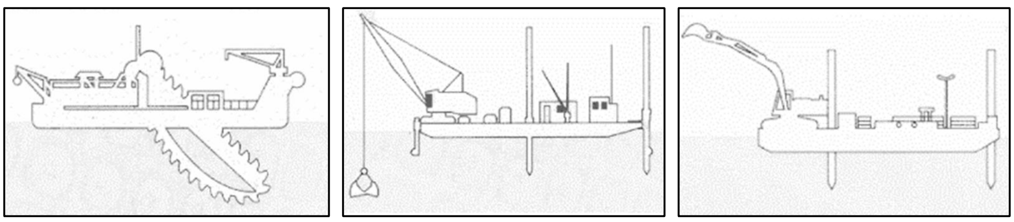
Internal phosphorus releases can be reduced by removing sediments from water bodies by dredging. In lake restoration, sediment removal is sometimes carried out, but it is considered an expensive option and often as a last resort for restoration (Sarvilinna & Sammalkorpi 2010, Newcombe et al. 2010).

Dredging is typically carried out during construction of harbours or other infrastructure in aquatic environments like bridges, offshore wind farms, underwater pipelines, etc. In many countries sand and gravel extraction from the seabed has been carried out for decades, using this loose rock to make concrete, as backfill on building sites and in harbours, and also as beach nourishment to protect coastlines. Dredging has also been carried out for completed artificial island projects (e.g. Palm Islands of Dubai) and newly reclaimed land projects are under development (e.g. expansion of Hong Kong airport). More recently there have also been some sea mining projects and new ones are being planned (e.g. submersible phosphate rock mining is planned in New Zealand).

Traditional bulk dredging methods

Traditional dredging methods can be divided into mechanical and hydraulic methods. Their combination is also possible. Selection of dredging equipment and method used depends on e.g. the physical characteristics and quantities of the material to be dredged, depth, method and way of disposal of dredged material and contamination of the sediment.

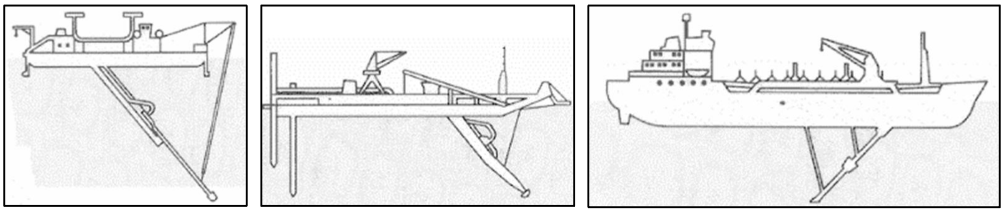
Mechanical dredgers include e.g. bucket ladder dredgers, grab dredgers and dipper and backhoe dredgers. Mechanical dredgers of different sizes are usually used in harbour construction and maintenance as well as restoration of shallow bays and straits, where the main objectives are to increase the depth of the area and/or remove macrophytes.



Bucket ladder dredge   Grab dredge   Dipper and backhoe dredge

Figure 37. Typical mechanical dredge types (Vlasblom 2003)

Hydraulic dredgers include e.g. plain suction dredger, cutter suction dredger and trailing suction hopper dredger. Generally, the method requires that the dredged material is free running or that the cut or breach height is sufficient. The discharge of the material sucked is done either by pipeline or by barges. Most suction dredgers are equipped with jet water pumps to assist either the beaching process or to improve the mixture forming process near the suction mouth. The cutter suction dredger is equipped with a cutter head which excavates the soil before it is sucked up by the flow of the dredge pump(s). Plain suction dredging and cutter dredging are stationary, whereas trailing suction hopper dredging moves while suction mouths are dragged over the seabed during dredging.



Plain suction dredge Cutter dredge Trailing suction hopper dredge

Figure 38. Typical hydraulic dredge types. (Vlasblom 2003)

The extracted material is transported away and dumped in permitted dumping areas in the sea (if it does not contain hazardous substances) or treated and disposed of on land.

Selective applications to extract phosphorus from seabed

The technical concept by the Swedish company TechMarket AB targets extraction of nutrients from the seabed. The technology differs from traditional dredging methods. In the patented method, only a thin layer of a few centimeters of recent sediments is retrieved from the seabed and transported up to the surface along with the process water. The dewatering of sediments then takes place and the aim is to anaerobically treat the sediment and then use it as soil conditioner in agriculture. The assumption is that by recovering the recently settled organic material, in addition to that nutrients are removed, the oxygen consumption in the bottom water decreases. The improved oxygen condition decreases the release of phosphorus from the sediment. This technology has already been tested in a few lakes in Sweden, for example Barnarpasjön, and there has been one experiment in the Baltic Sea, in 2014, where sediment was retrieved from deep waters at a depth of 120 m. (For further details, see the Chapter 3.4.3)

Outside Europe, there have been sea mining projects and new ones are being planned.The phosphorus concentration in sediments in the Baltic Sea is much lower compared to that in these mining projects, which makes mining of phosphorus in the Baltic Sea economically less attractive when taking into account current phosphate rock price levels.

Nutrients can be released also from shallow oxic areas due to mechanical mixing of loose surface sediment caused by winds and waves or due to high pH during high primary production periods. Dredging of shallow areas could constrain especially the nutrient release caused by mechanical mixing.

Extraction of nutrients from the seabed by dredging will be tested in the Central Baltic Interreg-project Seabased being launched in spring 2018 and coordinated by John Nurminen Foundation (Marjukka Porvari, personal communication).

3.4.2 Risks and positive effects

Dredging can have severe adverse impacts, including:

- Formation of sediment plumes and potential release and dispersal of nutrients and hazardous substances
- Visual disturbance (turbidity) may affect fish, seabirds and marine mammals. In shallow areas, the effect is relatively more significant than in deep areas because shallow waters tend to be most important areas for reproduction of fish and water birds
- Noise and vibration disturbance may cause potential behavioural responses
- Risks of possible encounter with dumped munitions and ordinance
- Impacts on benthic marine organisms and seabed morphology (confined to footprint of extraction).
- Dredging of shallow areas may destroy the spawning and feeding areas of fish and other aquatic fauna. For example, bottom fauna will be destroyed in dredged area.

Hazardous substances in sediment may hinder also the feasibility of further utilization of the dredged material.

The scale of impacts varies considerably depending on the method and intensity of dredging, sediment type and local hydrodynamics. Physical and biological impacts may persist well after the dredging has been completed. Recovery times are likely to vary greatly and be species specific. The experiences and results from dredging of harbour areas and open sea areas show that the turbidity effect is usually rather brief (a few weeks). The biota also usually recover during the next 1-3 years in Finnish coastal waters. Also studies from other European coastal waters show that recovery of the biota takes about 0.5–3 years (e.g. Dernie et al. 2003, Newell et al. 1998). There are also various mitigation measures that can be applied to minimize the impacts of dredging, for example:

- The use of curtains to contain dredge plumes
- Locating dredging activities away from known migratory pathways and reproductive or feeding grounds
- Defining the hours and dates when dredging is allowed, e.g. preventing dredging during the spawning time of fish and nesting time of birds
- Excluding nature protection areas and avoiding dredging near them
- Limiting the number of vessels or operations in given areas
- Engineering to reduce the noise of the dredging and lift operations
- Limiting unnecessary use of platform and vessel flood lights at night and ensuring that those that are required are directed approximately vertically onto work surfaces to avoid or mitigate collisions by seabird
- Leaving patches within a dredging site un-dredged to increase the rate of recolonization and recovery of benthic fauna
- Excluding areas from dredging if they support unique populations of marine life

- Depositing dredged sediment onshore or to the special areas pointed for sediment heaping in the vicinity of the dredged area.

According to information obtained from TechMarket AB (Teknikmarknad 2014, Personal communication Bengt Simonsson from Teknikmarknad), potential risks of the method have been assessed and taken into consideration in the technical and methodological design by:

- minimizing stirring and dispersion of pollutants that otherwise could pose an environmental risk due to the proposed activity
- The deep hollows in the design have low energy and do not allow for natural particle movement or diffusion to other locations. The system itself does not add high levels of kinetic energy outside system pipes, and
- The top layer of sediment is relatively clean from pollutants. Low levels of pollutants were detected in the performed analysis.

The sediment removal can be carried out both under anaerobic and aerobic conditions. Sediment removal does not improve oxygen conditions, which are of fundamental importance for the water quality of the coastal as well as the deep waters of the GOF.

In the Multi-Criteria Analysis (MCA) workshop (see Chapter 4.6), according to the opinion of the survey participants, aluminium treatment was rated as the lowest priority measure. It was assessed as having low cost, but also low benefits and having high risks of failure.

Table 4. Summary of risks and potential positive effects of selective sediment dredging (deep zone suction or skimming technologies) in relation to descriptors of Annex I of the MSFD

Descriptors of the Annex I of the MSFD to determine the GES	**Impact of measure**	
	Risks	**Potential positive effects**
(1) **Biological diversity** is maintained. The quality and occurrence of habitats and the distribution and abundance of species are in line with prevailing physiographic, geographic and climatic conditions.	Potentially damages benthic marine organisms and seabed morphology. In anoxic zones the risk of worsening the biological diversity is lower, because it is already compromised.	Removal of nutrients could improve the quality and occurrence of habitats. If P concentration is high enough, the submersible phosphate mining can be somewhat profitable or at least bring some revenues to the project
(2) **Non-indigenous species** introduced by human activities are at levels that do not adversely alter the ecosystems.	The risk of introduction of non-indigenous species is very low as marine transport in conjunction with the project takes place locally.	No impact

Descriptors of the Annex I of the MSFD to determine the GES	Impact of measure	
	Risks	**Potential positive effects**
(3) **Populations of** all **commercially exploited fish and shellfish** are within safe biological limits, exhibiting a population age and size distribution that is indicative of a healthy stock.	No adverse impact. Fish spawning areas are usually located in relatively shallow areas (e.g. 0-15 m) and these areas do not typically overlap with deep zone suction or skimming.	Removal of nutrients could potentially permit fish populations to recolonize previously uninhabitable areas
(4) All elements of the **marine food webs**, to the extent that they are known, occur at normal abundance and diversity and levels capable of ensuring the long-term abundance of the species and the retention of their full reproductive capacity.	Potential adverse impact of sediment plume during dredging work to plankton, fish and birds	Removal of organic matter could potentially revitalize benthos and strengthen marine food webs
(5) Human-induced **eutrophication** is minimised, especially adverse effects thereof, such as losses in biodiversity, ecosystem degradation, harmful algae blooms and oxygen deficiency in bottom waters.	Efficiency of the method can be poor because the impact area may be local	Potentially positive changes in nutrient concentrations Nutrients removed from the sea
(6) **Sea-floor integrity** is at a level that ensures that the structure and functions of the ecosystems are safeguarded and benthic ecosystems, in particular, are not adversely affected.	Potentially damages benthic ecosystem. In the anoxic zones the risk of worsening the sea-floor integrity is lower, because it is already compromised.	No significant impact Positive improvements in nutrient ratios and oxygen conditions could improve the sea-floor integrity
(7) **Permanent alteration of hydrographical conditions** does not adversely affect marine ecosystems.	No impact because actions are targeted in top layer of seabed only.	No impact
(8) **Concentrations of contaminants** are at levels not giving rise to pollution effects.	Risk of release of pollutants from sediment during dredging. However, the methods are designed to have very local impact.	No impact / Potential removal of pollutants from benthos (sediment containing hazardous substances is disposed on land)

Descriptors of the Annex I of the MSFD to determine the GES	Impact of measure	
	Risks	Potential positive effects
(9) **Contaminants in fish and other seafood for human consumption** do not exceed levels established by Community legislation or other relevant standards.	Risk of release of pollutants from sediment if new sediments are removed, old potentially more contaminated sediments are exposed to sediment water interactions and benthic animals and fish.	No impact / Potential removal of pollutants from benthos.
(10) Properties and quantities of **marine litter** do not cause harm to the coastal and marine environment.	Not relevant	Not relevant
(11) Introduction of **energy, including underwater noise**, is at levels that do not adversely affect the marine environment.	Underwater noise level will be slightly increased during operations but it would hardly cause adverse impacts on the marine environment	No impact

3.4.3 Case examples

A specific method that removes only a thin layer of biologically active top sediment and nutrients from the sea bottom has been developed. Its effects on oxygen conditions in bottom waters and on benthic nutrient release and its feasibility in the marine environment needs more research.

EXAMPLE 10. EXTRACTING THE TOP SEDIMENT LAYER FROM THE SEABED WHICH CONTRIBUTES TO EUTROPHICATION BY INTERNAL NUTRIENT LEAKAGE

TechMarket AB has investigated and piloted, in 2014, a technology that targets removal of the top sediment layer from the seabed that contributes to eutrophication by internal nutrient loading. TechMarket's technology has been applied in lakes in Sweden, for example Barnarpasjön. There has also been one experiment at sea, in Öxelösund, Sweden, where sediment was retrieved from deep waters at a depth of 120 m. In the patented method, only a thin layer of a few centimeters of recently deposited sediments is retrieved from the seabed and transported up to the surface along with process water.

Removal of sediment removes nutrients from the seabed. Furthermore, by recovering the recently settled organic material, the oxygen consumption in the bottom water was observed to decrease. The improved oxygen condition was shown to decrease the release of phosphorus from the sediment. The monitoring results of the test were not readily available.

Dewatering of removed sediments takes place, assuming that the concentration of hazardous substances is not elevated, with the aim to further process the dredged sediment so that it can be used as soil conditioner in agriculture.

Results from the experiment showed low concentrations of hazardous substances in the extracted top sediment layer. Furthermore, as the further processed sediment material was compared to a commercial feritiser in growing plants, the results were positive. Analysis results or detailed information on the growing tests was not readily available.

A total volume of 4,170 m^3 sediments was dredged and 1 tonne of phosphorus was recovered.

Figure 39. Picture of TechMarket AB's technology

The project was financed by the Baltic Sea Action Plan Fund.

References: Teknikmarknad 2014, Personal communication Bengt Simonsson from Teknikmarknad

3.5 Other methods

In this study we have focused on physical and chemical measures. Biological measures are briefly discussed in this chapter. Biological measures that could be effective at a local scale include, for example, cultivation and harvesting of mussels and water plants, harvesting algae, removal of fish with low or no economic value, removal of fish in order to manage food web interactions, microbial biomanipulation, etc.

Mussel farming filters water, whereby P and N accumulate in the shells and tissues of mussels. The tissues can be used in biogas production and as complementary feedstock or in as fertilizer in agriculture. The project Baltic Blue Growth aims to improve the Baltic Sea's water quality and at the same time create new business models for animal feed production. Six mussel farms in different parts of the Baltic Sea have participated in the project. Different cultivation methods and technologies have been tested earlier on a small scale. Baltic Blue Growth will build on these results, and set up several large-scale cultivations. They will be located in the archipelago of Östergötland, Kalmar Strait, Kiel Bight, Southern Jutland, Gulf of Riga and next to Vormsi island in Estonia. The project will also develop a process and test facilities to produce mussel meal (SUBMARINER Network 2018).

One major effect of eutrophication is that seaweed and algae accumulate in large volumes on beaches. The seaweed and algae partly decompose, which constitutes a major obstacle for usage of the beaches for bathing and other recreational activities. The costs of removing the seaweed and algae in order to make the beaches available for tourism and recreation are substantial, however, the benefits from tourism greatly exceed the costs of removing the algae. The PhosCad project has investigated and examined the most cost-efficient solutions for removing algae from beaches, recycling of phosphorous, reducing the level of cadmium and utilizing the residue for production of biogas and as fertilizer or incineration. Drying, incineration and ash disposal, with partial drying and incineration for district heating and electricity, is considered to be the most viable way to handle the material. The studies showed that the method is not economically feasible. However, the project suggested that benefits (including municipal tax revenues from beach related tourism and environmental positive effects) substantially outweigh the costs. Trelleborg municipality has initiated projects to use algae biomass for biogas production. A facility for biogas production from beach cast algae has been built next to the communal wastewater treatment plant in Smygehamn (Kommunförbundet Skåne 2017).

According to estimates, fishing recycles approximately 600 tonnes of phosphorus annually from waterbodies to solid ground in Finland. Even though reducing the inputs of nutrients from land-based sources is the primary means to combat eutrophication, targeted fishing of cyprinid fish can reduce the nutrient volumes of a marine ecosystem significantly, thus complementing the terrestrial measures that aim at reducing nutrient inputs. According to scientific research on Finnish lakes, targeted cyprinid fishing might also have a positive impact on fish stocks and the food web by restoring fish communities closer to their natural balance, since eutrophication has favoured the growth of cyprinid populations. However, these results are not directly applicable to the marine environment. With targeted fishing of cyprinid fish, the Pilot Fish project aims to recycle a significant amount of nutrients from the marine ecosystem to solid ground, thus complementing land-based measures that seek to reduce nutrient inputs to the sea. Pilot Fish also seeks to increase the utilization of cyprinid fish as food consumed by humans. The catch of cyprinid fish will be utilized in its entirety: the majority will be processed further for use, with unused fish parts used for livestock or fish feed and in energy production (Nutritrade 2017, Marjukka Porvari, John Nurminen Foundation, personal communication).

Other new types of measures are also being investigated. The Finnish company Eko Harden Technology markets the EKOGRID process, which is based on electrochemical and electrokinetic processes supported by electrodes installed into the seabed. The process uses low operation voltage and low current density, where molecular oxygen and oxygen radicals are produced that enhance aerobic in-situ biodegradation as well as oxygen radical based chemical degradation of organic compounds. In sediments, electrochemical reaction could potentially stabilize phosphorus by oxygenation and compact loose sediment by removing water. Pilot scale tests on sediment compaction and hydrocarbon reduction is ongoing in Helsinki.

4 Socio-economy and financing of sea-based measures

SUMMARY

This chapter analyses costs, cost-effectiveness and benefits of the above described sea-based measures. The performed Multi-Criteria analysis included also biological measures.

Available information on the costs of removal of one kg of P and N in EUR was compared in the studies/projects where such data were provided or where it was possible to calculate. The costs vary greatly between the different measures, but also between different studies/projects using the same measures. The results suggest the lowest cost for oxygenation pumping (2-32 EUR/kg P) and highest costs for aluminium treatment (58-318 EUR/kg P). Cost information is mainly available on P removal and no cost information was available on many of the studied measures. It should be noted that comparisons and analyses of costs of different measures are to be made cautiously, as there are many factors influencing costs of removal of one unit of a nutrient from the sea. These factors include e.g. area, depth, location and time of the implementation of a measure, possible income from products, as well as some indicators used for cost calculation, such as discount or interest rate.

Total net benefits of achieving the BSAP goals were evaluated as approximately 1,000-2,000 million EUR/year (BalticSTERN 2013).

Comprehensive analysis of costs and benefits associated with implementation of various oxygenation alternatives was carried out in the PROPPEN project (Ollikainen et al. 2012). The general conclusion from the project is that oxygenation is desirable in the coastal areas to speed up the recovery of the sea, but it is not desirable in open sea areas, similar to the Gulf of Finland because of large uncertainties in long-term direct and indirect effects.

Results from the monetary valuation study carried out in Finland and Sweden showed that in case the oxygenation of the bottom sediments gives desirable results, the average household willingness to pay would be 45 and 48 EUR/year respectively.

Enhanced wastewater treatment and the ban of phosphorus in detergents were found to be the most cost-effective measures for reduction of land-based phosphorus inputs. However, increasing P abatement in wastewater treatment plants would result in 80% of the BSAP phosphorus reduction target and cannot ensure achievement of the overall BSAP goals alone (Hautakangas et al. 2014). For phosphorus, the abatement costs in agriculture would be comparatively high. Thus, implementation of the sea-based measures could potentially be supplementary to policies and measures aimed at reducing phosphorus inputs to the marine environment.

The pilot studies and projects on sea-based measures analyzed in this report were funded either by EU programmes, such as Interreg, LIFE+, or by special funds/foundations created to support improvement of the Baltic Sea environmental conditions. Governmental institutions such as the Finnish Ministry of Environment or Swedish Environmental Protection Agency also provide funding for the pilot projects.

In addition to these, one of the more frequent financiers of the pilot projects on sea-based measures is the Baltic Sea Action Plan (BSAP) Fund[1].

Several financing schemes for implementation of the sea-based measures were proposed and described by the studies/projects reviewed. The project "Nutrient Retrieval from Seabeds" (Phase 2 Dredging tests) suggests that the retrieval of organic substances from seabeds has the potential to form a solid base for sustainable financing schemes. The project also described three potential financing schemes of proposed systems and operation: Swedish municipal sewage fee (for the sewage community); compensation throughout the years (for the industry sector); switching from buying imported phosphorus to a national recycled form of phosphorus (for the agricultural sector). The project also studied possible circular economy schemes and suggested a Flexible Emission Fee System.

For this project, the Ministry of the Environment of Finland and the Consultant agreed to test the applicability of Multi-Criteria Analysis (MCA) for prioritising the potential sea-based measures in terms of their efficiency for the sea areas of Finland and the whole Baltic Sea. During the MCA workshop, 10 Finnish experts provided their opinions on the importance of, and current threat level to, the Baltic Sea's ecosystem services, as well as impacts of potential sea-based measures on the ecosystem services/benefits.

The MCA results support the cost-effectiveness of the sea-based measures analysis outcome to some extent. Oxygenation, as the best known and tested measure in the Baltic Sea, holds highest priority position. Chemical treatment with aluminium, because of a combination of high costs, unknown effects and thus quite highly assessed risks of failure, is in the last position in the list. Dredging, even though assessed as having low cost, because of assumed low benefits and having high risks of failure, is also in the lowest position in the priority list. It is important to stress that the first priority measures were assessed as providing the highest positive impacts to the marine ecosystem services.

4.1 Introduction

The objectives of this sub-task included review of costs and cost-effectiveness, potential funding sources and cost recovery mechanisms of various sea-based measures, as well as comparison of cost effectiveness of sea- and land-based measures targeted at the reduction and control of nutrient pollution. To achieve the objectives, the project team has reviewed scientific and technical reports, articles and other documents from projects implemented by the countries around the Baltic Sea.

Moreover, in the course of the project the Ministry and the Consultant agreed to test the applicability of Multi-Criteria Analysis for prioritising the potential sea-based measures in terms of their efficiency.

[1] https://www.nib.int/news_publications/575/nib_and_nefco_to_manage_new_fund_for_a_cleaner_baltic_sea

4.2 Costs and benefits of land-based measures

4.2.1 Costs and cost-effectiveness of land-based measures

During the last 20 years, many studies on costs of reducing land-based nutrient loads have been carried out. Different studies indicate that the costs for achievement of the BSAP goals vary widely depending on the implementation scenario. For example, in 2008, Gren (2008) investigated and compared cost and benefits for three different policies: 1) marine basin targets according to the BSAP (HELCOM 2007), 2) catchment-wise targets according to the BSAP and 3) cost-effective reduction of total nitrogen and phosphorus inputs to coastal waters where the total nutrient input reductions are equal to the total reductions suggested by the BSAP. Here, the total cost for the first scenario amounted to 5.0 billion EUR per year, for the second to 2.6 billion EUR per year and for the third 1.7 billion EUR per year.

The BalticSTERN study (BalticSTERN report 2013), which analysed the implementation of nine measures, concluded that the total annual costs of reaching the targets for nutrient reductions with an allocation according to the BSAP would amount to around 2,800 million EUR. A quite similar estimate of 3,000 million EUR per year is given by COWI (COWI 2007), which considered implementation of 16 measures. If to consider cost-effective allocation of measures, i.e. if the measures which give the biggest effects with lowest cost were prioritised[2], the costs can be reduced to 2,300 million EUR per year. The costs for achievement of the BSAP goals under a cost-effective scheme for allocation of measures are presented in Table 5.

Table 5. Reduction (tonnes/year) and cost (million EUR/year) for different measures in a cost-effective solution (BalticSTERN report 2013)

	Cost		Nitrogen reduction		Phosphorus reduction	
	Million EUR/year	Percent	Tonnes/year	Percent	Tonnes/year	Percent
Fertilization	672.4	29	41,420	38.0	1,112	9.7
Cattle	242.5	10				
Pig	176.7	8				
Poultry	41.4	2				
Catch crops	60.3	3	2,708	2.5	36	0.3
P-ponds	45.3	2	0	0	900	7.9
Wetlands	387.7	17	28,818	26.5	364	3.2
Detergents	45.2	2	0	0	1,279	11.2
WWTP	664.6	28	35,904	33	7,718	67.7
Total	2,336.1	100	108,850	100	11,409	100

Cost-effectiveness of the measures above (Table 5), are presented in Table 6.

[2] Assessment covers only nine measures, which are considered the most cost-effective

Table 6. Cost-effectiveness of different land-based measures (based on BalticSTERN report 2013)

	Cost-effectiveness of nitrogen reduction, EUR/kgN	Cost-effectiveness of phosphorus reduction, EUR/kgP
Fertilization Cattle Pig Poultry	27	1,019
Catch crops	22	1,675
P-ponds		50
Wetlands	14	1,065
Detergents		35
WWTP	19	86

The most cost-effective measures to reduce nitrogen inputs from land are wetlands, catch crops and wastewater treatment plants. Reduction of livestock (e.g. cattle, pigs and poultry) and large reduction in use of fertilization prove to be the most expensive measures.

As described in BalticStern report 2013, the most cost-effective measures to reduce the phosphorus load are phosphorus ponds (P-ponds), ban of phosphorus in detergents, wastewater treatment plants and relatively small reductions of application of fertilization.

As opposed to in the case of nitrogen abatement, wetlands and catch crops turn out to be very costly for reducing phosphorus. The cost of reducing the application of fertilization is very low for any initial reduction, while it increases with high levels of reduction. Looking at each measure’s contribution to the load reduction is not as straightforward with regard to fertilizer reduction, since such reduction can be obtained by either livestock (cattle, pig and poultry) reduction, which reduces the application of manure, or reduction of inorganic fertilizers. Since these are interlinked, reduction numbers are only obtained and showed for “total fertilization”, which is a combination of both reduced inorganic and organic fertilization.

Measures targeted at reduction of atmospheric NOx emissions (e.g. from energy production, vehicles and ships) can be an alternative to the above-mentioned measures, however, assessments demonstrate that the impacts on the Baltic Sea from such actions would be rather insignificant, resulting in poor cost-effectiveness (NEFCO 2007).

Cost-effectiveness of various measures is reflected in Figure 40, where the unit abatement cost (UAC) and the estimated potential for reduction of nutrients of the various scenarios are shown towards the calculated BSAP target for maximum nutrient inputs to the Baltic Proper. It can be seen from the figure that wastewater treatment, although being a cost-effective option to a certain degree, most probably will not have sufficient potential to facilitate full achievement of the BSAP goals[3]. The implementation of agricultural measures should be enhanced and continued.

[3] It has to be noted that the analysis and calculation of the UAC for wastewater did not include the possibility of adding chemical flocculation as a step in the future for increasing the removal of P in the wastewater from 80 % to 90 %, which is a low-cost alternative for reduction of P from wastewater as compared with tertiary treatment which was the basis for the calculation.

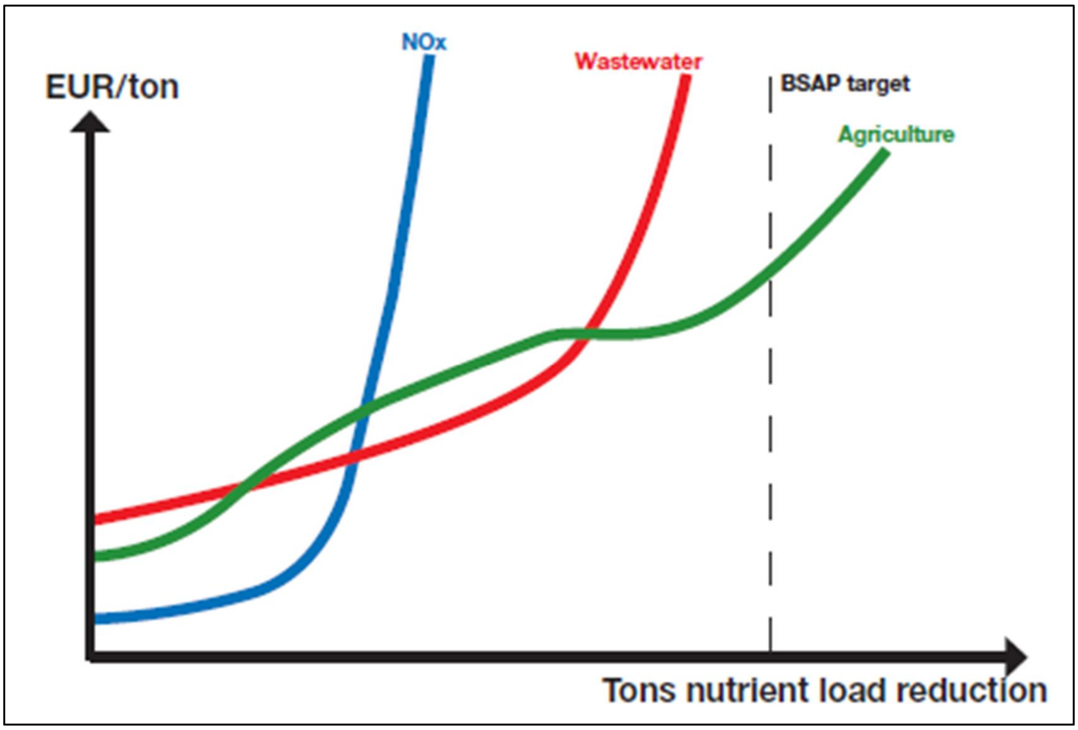


Figure 40. Cost effectiveness curves. (NEFCO, 2007)

Importance of agricultural measures in restoration of the Baltic Sea

Diffuse losses from agriculture are the most important land-based nutrient sources to the Baltic Sea today and, according to the HELCOM pollution load compilation results (HELCOM 2011), contribute approximately 45 % of overall waterborne nitrogen and phosphorus inputs to the sea. However, implementation of measures targeted at the reduction of agricultural pollution still lacks sufficient ambition and commitment to significantly cut nutrient inputs to the sea. One of the reasons for this is that it is often difficult to raise public and political support for implementation of agricultural measures.

Although 9.9 billion EUR[4] was allocated for agri-environmental payments under Rural Development Programmes to all eight Baltic Sea coastal EU Member States[5] during the period 2007-2013, the latest report from the European Court of Auditors (European Court of Auditors 2016) concludes that EU co-financed rural development measures in the 2007-2013 period have had little effect on reducing nutrient pollution. The report highlights the problem of insufficient targeting of measures in the areas identified as needing them. Moreover, some agri environmental scheme requirements were not demanding enough, being sometimes only slightly stricter than the baseline requirements. No Member State has used the option under EU regulations of making some agri-environmental measures compulsory for farms located in the most problematic areas.

[4] The amount that was specifically dedicated to address water protection is not known.

[5] Poland (4.4 billion euro), Finland (1.5 billion euro), Sweden (1.3 billion euro), Germany (1.1 billion euro), Lithuania (0.6 billion euro), Latvia (0.4 billion euro), Denmark (0.3 billion euro) and Estonia (0.3 billion euro).

Similar findings are presented in a recent report of the EU Commission (European Commission 2017). The Commission declared that more targeted investments are needed and stressed the need to enhance coherence in implementing the EU water and agriculture policy so that the objectives of both are achieved.

As phosphorus abatement costs in agriculture are comparatively high, implementation of the sea-based measures could potentially be supplementary policies to control and reduce phosphorus loads.

4.2.2 Monetised benefits of a less eutrophied Baltic Sea

According to the research conducted in the BalticSTERN network (BalticSTERN report 2013), the citizens of the Baltic Sea countries are willing to pay approximately 3,800 million EUR annually to achieve a less eutrophied Sea by 2050. People of Sweden agree to pay on average 110 EUR per person per year, while in Latvia, Lithuania, Poland and Russia people are willing to pay only less than 10 EUR (Figure 41).

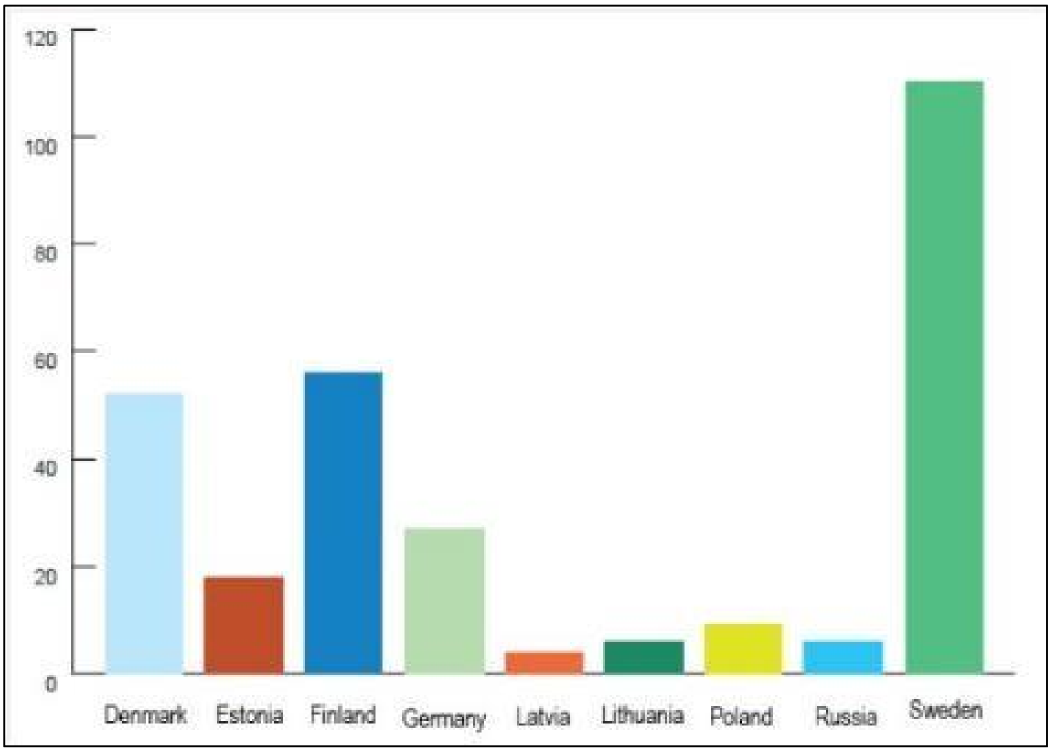


Figure 41. Average Willingness-To-Pay per person in different Baltic Sea countries expressed in EUR/year (BalticSTERN report, 2013)

The BalticSTERN report (2013), carried out a comparison of the estimated cost of reaching the BSAP and the benefits of reduced eutrophication. The assessed results indicate total welfare gains of about 1,500 million EUR annually under a cost-effective allocation and about 1,000 million EUR annually under the BSAP country-wise nutrient reduction quotas. However, although the total gain amounts to 1,000-1,500 million EUR, for some countries costs would exceed the benefits they obtain (Table 7).

Table 7. Distribution of benefits and costs (million EUR/year) between countries under a cost-effective solution. (BalticSTERN report 2013)

Country	Benefits (Million EUR/year)	Costs (Million EUR/year)	Net (Million EUR/year)	Benefit/Cost ratio
Denmark	205	630	-425	0.3
Estonia	17	78	-61	0.2
Finland	201	105	178	8.7
Germany	1,870	480	1,406	3.9
Latvia	7	85	-78	0.1
Lithuania	16	101	-85	0.2
Poland	211	544	-333	0.4
Russia	473	105	368	4.5
Sweden	838	290	548	2.9
Total	**3,838**	**2,336**	**1,740**	**1.7**

It should be stressed that the benefits presented in this section should not necessarily be restricted to only land-based measures as the figures reflect the value of a less eutrophied Baltic Sea in general.

4.3 Costs and cost effectiveness of potential sea-based measures

The below review reflects information on presently available potential sea-based measures. The following sea-based measures were analysed for their costs and cost-effectiveness, as well as benefits (see the next section) they can potentially provide if implemented:

- Small-scale oxygenation of anoxic bottoms
- Large-scale oxygenation of anoxic bottoms
- Aluminium treatment
- Dredging

4.3.1 Oxygenation of anoxic bottoms

The experiment in the PROPPEN project (Rantajärvi et al. 2012, Ollikainen et al 2012) included artificial bottom water ventilation by oxygenation pumping in two selected pilot sites:

- a coastal basin of Sandöfjärden in the outer archipelago of the western Gulf of Finland and
- a relatively small sub-basin of Lännerstasundet in the inner archipelago of Stockholm.

As noted in the report of the project, in Lännerstasundet, oxygenation clearly improved near-bottom oxygen conditions and removed a part of the nutrients from the water column and decreased benthic nutrient release whereas in Sandöfjärden, the field experiment could not prevent the formation of anoxia in late July/early August.

To calculate nutrient abatement costs, basic data from the actual experiments in Lännerstasundet and Sandofjärden (pumping capacity, reduction in phosphorus and nitrogen release, costs of pumping) was used by the project implementers. As oxygenation in Sandofjärden failed to produce a reduction in nutrients, probably due to undersized pumping capacity, an additional hypothetical case for Sandofjärden, called "Sandofjärden idealized", was examined. The idealized case for Sandofjärden provided a hypothetical assessment of how much the reduction in phosphorus and nitrogen release would have been had the pumping capacity been adequate.

As reported in the PROPPEN project, in Lännerstasundet, the unit cost of reduction of nitrogen equivalents is slightly below 5 EUR/kg, which is roughly the marginal cost of abating 70 % of nitrogen in wastewater treatment plants (10,000 PE). The cost of phosphorus equivalents is relatively high and exceeds the costs of phosphorus abatement (13-17 EUR/kg) in wastewater treatment plants. Thus, both estimates are higher than abatement costs in most wastewater treatment plants in the Gulf of Finland sub-basin. However, for the sub-basins receiving non-point source pollution from distant areas, reducing external nutrient inputs would be quite expensive.

The BOX and BOX-WIN (Baltic deepwater Oxygenation experiment) projects (BOX-WIN Technical Report no. 8, 2013) aimed to make an initial investigation of the feasibility of decreasing the phosphorus content in the water column and thereby the eutrophication of the Baltic Proper by oxygenation of the anoxic deep water. The projects concluded that the oxygenation of the Bornholm deep would be extremely cost effective and rebind about 5,000 tonnes P to the bottom sediment.

As part of the BOX project, a pilot experiment was done in the ByFjord that was oxygenated by pumping 2 m^3/s of oxygen saturated surface water into the deep water. The BOX project also made theoretical investigations of oxygenation in the Bornholm Basin. The costs for oxygenation were calculated both for using wind power and other energy sources. Cost assessment was built on the basis of the Demonstrator which was composed of a self-supporting, floating wind turbine unit with a generator producing electric power for deep water oxygenation by pumping and for delivery to the grid.

Cost estimates for the Demonstrator in SEK (calculated by the BOX-WIN project) and in EUR in the second quarter of 2013 (and without VAT) are provided in Table 8, Table 9, Table 10 and Table 11.

Table 8. Capital costs – excluding cable for the Demonstrator (BOX-WIN Technical Report no. 8, 2013)

Cost Item	Cost Estimate (MSEK)	Cost Estimate (MEUR*)
Engineering	26	3.00
Client Preliminaries (contractor management costs)	15	1.73
Construction of substructure	60	6.93
Construction of pumping units	9	1.04
Construction of wind turbine unit	39	4.51
Marine Operations	33	3.81
Sum	**182**	**21.03**
Contingency: + 25 %	45	5.20
Total capital costs- excluding cable	***227***	***26.23***

*-annual exchange rate of 2013 between SEK and EUR was used (1EUR=8.6552 SEK)

Table 9. Capital costs of cable (only), including installation and infrastructure (BOX-WIN Technical Report no. 8, 2013)

Cost Item	Cost Estimate (MSEK)	Cost Estimate (MEUR)
Offshore infrastructure	36	4.16
Onshore infrastructure	26	3.00
Marine operations	40	4.62
Transport and logistics	3	0.35
Project management	10	1.16
Insurance	2	0.23
Sum	**117**	**13.52**
Contingency: + 25 %	29	3.35
Total capital costs of cable (only)	***146***	***16.87***

*-annual exchange rate of 2013 between SEK and EUR was used (1EUR=8.6552 SEK)

Table 10. Total capital costs – including cable for the Demonstrator (BOX-WIN Technical Report no. 8, 2013)

Cost Item	Cost Estimate (MSEK)	Cost Estimate (MEUR)
Capital costs – excluding cable	227	26.23
Cable	146	16.87
Total capital costs	***373***	***43.10***

*-annual exchange rate of 2013 between SEK and EUR was used (1EUR=8.6552 SEK)

Table 11. Total operational costs per year for the Demonstrator (BOX-WIN Technical Report no. 8, 2013)

Cost Item	Cost Estimate (MSEK)	Cost Estimate (MEUR)
Operation of Wind Turbine Unit	2	0.23
Operation of Pump Units	1	0.12
Research and Monitoring	7	0.81
Total operational costs	***10***	***1.16***

*-annual exchange rate of 2013 between SEK and EUR was used (1EUR=8.6552 SEK)

The design lifetime for the Demonstrator is 20 years and an interest rate of 4 % was applied by the BOX-WIN project.

It was estimated that oxygenation of the Bornholm Basin would require pumping of about 1,000 m^3/s of winter water from about 30 m depth to 90 m depth in the deep water. A pumping system for the Bornholm Basin is assumed to require 10 units based on the Demonstrator design. The average cost for construction and installation of one unit was supposed to be smaller than the cost estimated for the single Demonstrator.

The annual cost to oxygenate the Bornholm Basin was estimated at 150-300 MSEK (~17-35 MEUR), depending on the chosen energy source and method of pumping (depreciation time 20 years). Annual costs to suppress the supply of P from the internal source would then amount to 20,000- 40,000 SEK (2,310-4,620 EUR) per tonne of P.

A complete oxygenation system for the Baltic Proper requires pumping of 10,000 m^3/s. If the floating pumps are arranged in clusters, powered by wind turbines of different size or by diesel, the total annual cost for six alternative configurations was calculated by the BOX-WIN project as varying between 695 and 1,244 MSEK (80-144 MEUR).

The main objective of the WEBAP project (WEBAP project report 2014) was to demonstrate a cost-effective wave-powered device, entitled the "Wave Energized Baltic Aeration Pump (WEBAP) that mitigates the problem of oxygen depletion (hypoxia) in coastal zones and open seas. The project also developed and demonstrated a cost-effective electrically-powered aeration pump for use in marine environments without enough wave energy accessible.

During the project, two demonstration units were installed: WEBAP I, which was a wave powered oxygen pump and WEBAP II, which was an electrical oxygen pump. The evaluation of the environmental and economic performance of the proposed techniques was done by simplified LCA (Life Cycle Assessment) and LCC (Life Cycle Cost) modelling.

Four techniques to remove phosphorus were investigated in six scenarios. Three scenarios involved oxygen pumping into the sea, with the secondary effect of phosphorus turnover and removal, either by the WEBAP I wave-energized aeration pump, or by an electric pump (WEBAP II, diesel aggregate offshore, or electricity near shore). Three scenarios consisted of precipitation, either in wastewater treatment plants or by spreading of treatment chemical on the seabed. Removal of 1 kg of phosphorus was chosen as the basis for comparison (functional unit).

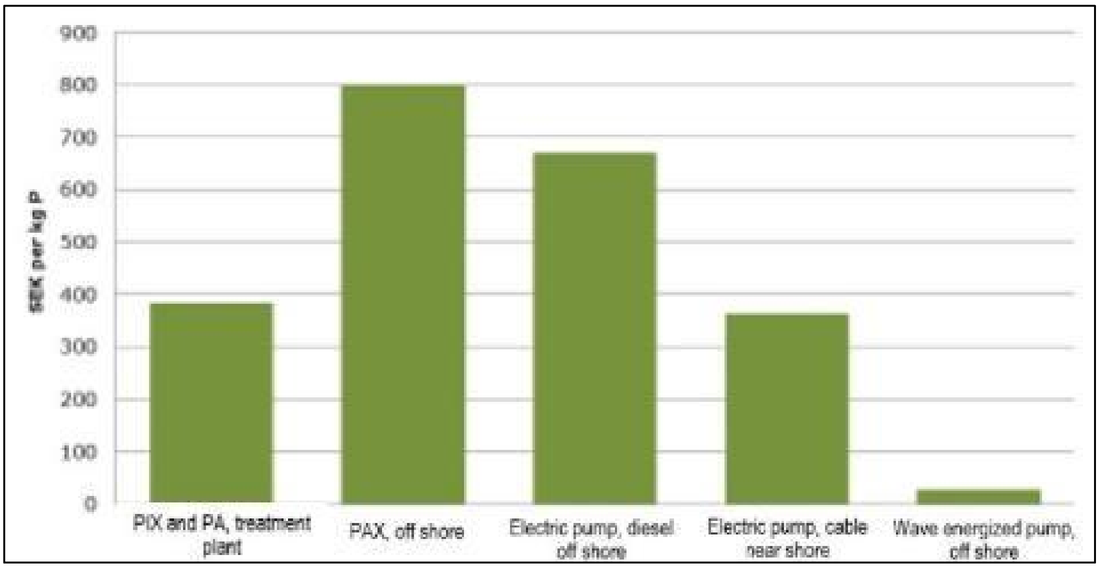


Figure 42. Life cycle cost of techniques per 1 kg P removed (PIX refers to FeCl3, PAX AlCl3 and PA peracetic acid which are all wastewater coagulants) (WEBAP project report 2014)

The results for the costs demonstrated that the wave-energized pump (WEBAP I) had very low life cycle cost compared to other techniques, which means efficient P removal for the money invested and a realistic option for management of the internal nutrient reserves of the Baltic Sea.

The calculation of costs for full-scale wave-powered oxygen pumping was based on the pilot plant WEBAP I with a width of 14 m. It was estimated that the production of such a pump would amount to a cost of around 1-1.2 MSEK (~0.12-0.14 MEUR). Production of multiple devices would reduce unit costs significantly (Table 12).

Table 12. Simplified calculation of unit production costs as well as assumed life of 10 years and discount rate of 4 % (WEBAP project report, 2014)

Produced unit	Investment SEK	Capital cost SEK/year	Investment EUR	Capital cost EUR/year
1	1,200,000	147,000	140,000	17,000
10	700,000	86,000	81,000	10,000
100	407,000	50,000	47,000	5,800
1,000	237,000	29,150	27,400	3,370
Mean for 1,000	309,000	38,000	35,700	4,400

*-annual exchange rate of 2013 between SEK and EUR was used (1EUR=8.6552 SEK)

As noted in the report, for areas with limited waves, an electric oxygenation pump consisting of one or more modules is the only alternative. When using standard components, for example floating pontoons etc., a full-scale plant would, based on estimations from companies that have been involved in and constructed the prototype, cost about 700-800 thousand SEK (81-92 thousand EUR). However, in contrast to wave-powered oxygenation pumps, larger operational costs for electricity or biofuel as well as service of pumps are required. On the other hand, a more stable and controllable pumping can be achieved.

CoreOceanPump is another approach for a wave-powered oxygenation pump. The pump is a development of the company Inovacor AB and can be seen as a further development of WEBAP concept, which combines the advantages of WEBAP I and II. The development of this type oxygen pump was initiated by the WEBAP activities and a side-development of an on-going compact wave energy project (WEBAP project report 2014; www.corpowerocean.com). Up-scaling calculations and cost calculations from the wave power project indicate that investment costs, including installation of a standard unit (for 3-5 m^3/sec and 0.05 bar pressure, and 100 meters depth), should be less than 500 thousand SEK (58 thousand EUR), although design of the pipe is the most uncertain cost item (WEBAP project report 2014).

4.3.2 Chemical precipitation

The BalticSea2020 project Aluminium treatment project in Björnöfjärden (Rydin & Kumblad 2014) was performed in anoxic sediments (with an area of ca 80 ha). A special technique developed by Vattenresurs AB (Sweden) was used, where the AlCl3-solution PAX XL 100 was injected directly into the sediment.

The estimated cost for the Al-PAX-solution used as treatment chemical was approximately 20,000 SEK/tonne (~2,310 EUR/tonne). Assuming a 5:1 binding efficiency (Rydin 2014), one tonne of Al would bind 200 kg P, resulting in a chemical cost of 200 SEK/kg P (~23 EUR/kg P). Including application costs, estimated to 30,000 SEK/tonne Al (~3,500 EUR/tonne Al) (or 300 SEK/kg P) (or 35 EUR/kg P), the total phosphorus abatement cost would be 500 SEK/kg P (~58 EUR/kg P). Expressed per unit surface, the high dose applied corresponds to 1 MSEK/km^2 (0.12 MEUR/km^2). Including the application costs, the total is 2.5 MSEK/km2 (0.3 MEUR/km^2). The project implementers expected that treating larger areas would lower the applications costs, and that many areas require lower doses, and thus lower chemical cost, ending up with overall expected treatment costs of around 1-1.5

MSEK/km^2 (0.12-0.17 MEUR/km^2) However, development costs for boats with capacity for treating areas at greater depths, etc. were not accounted for.

In another BalticSea2020 project on Permanent phosphorus binding in Baltic Sea bottom sediments (Blomqvist 2014), pilot studies were launched in June 2012 with a series of laboratory experiments, focusing on the adsorption of phosphate on marl particles. This was considered a promising and cost-effective treatment that permanently inactivates available P in Baltic sediments. The marl used is a by-product of lime quarrying on the island of Gotland, a favourable location with respect to logistics, harbour facilities, periodical surplus of cheap wind power electricity, and a valuable lime-industry tradition.

As a first order estimate, experts calculated that the cost to prepare the amount of fine-particle marl (lutite) needed to adsorb one kilogram of P was less than 3 EUR. This is magnitudes lower than other suggested alternatives; for instance, removal of P by sand filters, which is 200-450 EUR or building wastewater treatment systems for single households which cost ~4,000 EUR per kilogram of P (Blomqvist 2014).

4.3.3 Dredging

The project Nutrient Retrieval from Seabeds (Teknikmarknad, 2014), carried out by TechMarket from Sweden in 2014 and funded by the NIB, tested and verified or confirmed a few challenges.

Zero dispersion vacuum extraction is proposed to remove the top, eutrophication-causing, sediment layer from the sea floor in this project. The approach considers removal of this top layer and using it as an input for biogas and fertilizer production. To test this approach, a deep water project was implemented in the waters east of Oxelösund in Sweden.

The following calculation shows unit abatements costs per tonne, with an annualized investment cost (at 5 %, with a 20-year capital recovery time) (Simonsson 2014):

- Sediment retrieval 68,000 EUR per tonne of P
- Biogas/fertilizer production plant 52,000 EUR per tonne of P
- Income from biogas and fertilizer 88,000 EUR per tonne of P
- Net Unit Abatement Cost 32,000 EUR per tonne of P

As shown above, the TechMarket experts expect that the method should finance itself up to 75 %. Two main revenue streams should come from biogas and nutrients making this method unique in comparison with other methods designed to decrease internal leakage of phosphorus. TechMarket experts have proposed that the remaining 25 % could be funded by means of emission fees.

4.3.4 Summary costs for nutrient removal by sea-based measures

Table 13 provides a summary of the costs for removal of one kg of P and N in EUR for the studies/projects where such data were provided or where it was possible to calculate it. In cases where the above described studies/projects provided costs only in SEK, a conversion to EUR at the annual exchange rate of a specific year of a study was applied.

It should be noted that comparisons and analyses of costs of different measures are to be made cautiously, as there are many factors influencing costs of removal of one unit of a nutrient from the sea. Among these are: area, depth, location and time of the implementation of a measure, possible income from products, as well as some indicators used for cost calculation, such as discount or interest rate. The below figures provide only a scale of potential costs for different sea-based measures.

Table 13. Summary of costs for nutrient removal from the internal sources of the Baltic Sea

Cost for nutrient removal, EUR/kg		**Project/ reference, year**	**Note**
P	**N**		
Oxygenation of anoxic bottoms			
30-32	4.2 – 4.4	PROPPEN project report, 2012 Ollikainen et al. 2012	- Tests in two coastal basins - Electric pumps used - 4 % interest rate
2-4		BOX-WIN project, 2014 Stigebrandt 2014	- Experiment in Byfjord (BOX project) - Modelling for the entire Bornholm Basin - Use of electric pumps is considered - Depreciation time of 20 years - 5 % interest rate

3.5
40
75
		WEBAP project report, 2014
		Baresel et al. 2013
			- Demonstrations in Hanöbukten and Kanholmsfjärden
			- Life cycle costs for:
			  - wave energized pump
			  - electric pump cable near shore
			  - electric pump cable offshore

Chemical precipitation			
58-318		BalticSea2020 project, 2013 Rydin & Kumblad 2014	Anoxic bottom treatment with aluminium - Experiment in Björnöfjärden (ca. 80 ha) - The cost includes costs for chemicals and application - The cost per kg of P retained can vary greatly depending on the scale of operation
3		Permanent inactivation of phosphorus in Baltic sediments, 2012 Blomqvist 2014	Phosphorus adsorption on fine-particulate marl - Laboratory experiments - The cost covers only expenses for the preparation of marl to retain one kilogram of phosphorus - Field tests are needed
Dredging			
32		Nutrient retrieval from seabed, 2015 Simonsson 2014	Density sorting dredging - Total cost for sediment retrieval and biogas/ fertilizer production - 120 EUR/ kg P; - Income from biogas and fertilizer – 88 EUR/ kg P - 5 % interest rate, 20 years capital recovery time

4.4 Monetised benefits of potential sea-based measures

4.4.1 Overview of benefits

Along with the analysis of costs, a preliminarily review of the potential benefits of the sea-based measures has been carried out. Both direct and indirect marine benefits' valuations have been preliminarily examined, including a few of those existing for the sea-based measures. For example, monetary valuation studies for the oxygenation of the bottom sediments in Finland and Sweden conducted by the PROPPEN project (in cooperation with BONUS funded project, PreHab, have shown that in case the project gives successful results, the average household willingness to pay would be 45 and 48 EUR/year respectively (Ollikainen et al. 2012).

Total net benefits of achieving the BSAP goals are estimated at approximately 1,000-2,000 million EUR/year (BalticSTERN report 2013; Ahtiainen 2016). Positive effects of potential sea-based measures, highlighted in the projects/studies analysed, are presented in Chapter 3 of this report. In general, sea-based measures are considered to speed-up recovery of the Baltic Sea in 30-50 years, improve conditions for cod reproduction, facilitate colonization of deep bottoms, decrease greenhouse effects and stimulate circular economy investment by bringing nutrient rich biomass back upstream and similar.

Effects are monetized, i.e. monetary benefits are assessed only for oxygenation. Results of these studies are presented below.

4.4.2 Benefits of oxygenation

The benefits of oxygenation were extensively analysed only during the PROPPEN project (Ollikainen et al. 2012). Two alternative approaches to social desirability of oxygenation were identified:

- The first approach regards oxygenation ***as an additional means of reducing eutrophication*** giving oxygenation a similar status as actions to reduce nutrient inputs from external sources. From this angle, the social benefits of oxygenation are the same as those that society assigns to nutrient reductions from external sources. Under this approach, pumping is desirable only if it produces higher net benefits than reductions in external inputs.
- The second and more commonly stated approach is to regard oxygenation ***as a complementary instrument to reductions of external loads***, a means for speeding up the recovery of the Baltic Sea (Stigebrandt and Gustafsson 2007, Conley et al. 2009). Under this angle, the research question of the study was: assuming that countries implement BSAP does oxygenation by pumping produce positive net benefits, or not? Under this approach, oxygenation is desirable provided that it produces positive net benefits.

First approach - Oxygenation *as an additional means of reducing eutrophication*

Oxygenation as an additional means of reducing eutrophication was analysed on local and regional scale in the anoxic coastal areas of the Gulf of Finland:

Local scale

The analysis was based on data from the actual experiments in Lännerstasundet and Sandofjärden. For Sandofjärden, where the experiment failed to reach its objectives due to insufficient pumping capacity, an idealized scenario was also analysed, which provided a hypothetical assessment of how much the reduction in phosphorus and nitrogen release would have been had the pumping capacity been adequate.

Estimated benefits are provided in Table 14. The two first columns report the annual reduction of phosphorus and nitrogen in each case, and the third column adds them up as nitrogen-equivalents using Redfield ratio. Annual economic benefits are obtained by multiplying nitrogen-equivalents by the willingness to pay (WTP) estimate (9.92 EUR/kg N-equivalent as an estimate of the citizens' WTP for reduced eutrophication in Sweden and Finland was used). The difference between the annual benefits and costs defines the annual net benefits, and total net benefit is their net present value over the 20-year period.

Table 14. Net benefits from pumping in experimental sites (interest rate 4 %) (Ollikainen et al. 2012)

	PO_4 kg	DIN kg	N-eq. kg	Benefits B/year	Costs C/year	Net benefits NB/year	Total NB 20 years
Lännerstasundet							
Min	130	310	1,246	12,357	6,039	6,318	**93,998**
Mean	145	321	1,365	13,533	6,039	7,493	**111,482**
Max	160	331	1,483	14,708	6,039	8,669	**128,967**
Sandöfjärden actual							
Min	0	-1,000	-1,000	-9,918	20,256	-30,174	**-410,081**
Mean	0	-1,500	-1,500	-14,876	20,256	-35,132	**-477,462**
Max	0	-2,000	-2,000	-19,835	20,256	-40,091	**-544,856**
Sandöfjärden idealized							
Min	1,798	3,499	16,445	163,092	83,932	79,159	**1,075,798**
Mean	2,100	4,890	20,010	198,452	83,932	114,519	**1,556,357**
Max	2,402	6,281	23,575	233,812	83,932	149,880	**2,036,915**

Results for Lännerstasundet and Sandöfjärden idealized show that ***oxygenation produces positive net benefits***. However, the message from Sandöfjärden is important: oxygenation may fail due to uncertainties associated with the design of the pumping area and capacity. Moreover, actual experiment in Sandöfjärden did not reduce phosphorus release; instead, the amount of nitrogen was increased in sea water. Thus, as noted in the PROPPEN project report, at a large scale, this kind of failure can be costly (the present value of net benefits indicates losses of a half a million EUR over the 20 years period), and for a smaller scale it can be harmful due to potential increase of nitrogen loads.

Regional scale

To analyse potential benefits of oxygenation on the regional scale, the PROPPEN project experts generalized results from the experimental sites to anoxic sites of the Gulf of Finland (an area estimated approximately as 185 km^2) using three scenarios: Scenario 1:

Optimistic, Scenario 2: Idealized and Scenario 3: Pessimistic. Additionally, combinations of the above-mentioned scenarios (so called success-failure combinations) were analysed. Three combinations were analysed:

- Combination 1: 0.25 of Optimistic Scenario, 0.25 of Idealized Scenario, 0.5 of Pessimistic Scenario;
- Combination 2: 0.1 of Optimistic Scenario, 0.5 of Idealized Scenario, 0.4 of Pessimistic Scenario;
- Combination 3: 0.05 of Optimistic Scenario, 0.4 of Idealized Scenario, 0.55 of Pessimistic Scenario.

For all scenarios (pure and combined), reduction of nutrients in N-equivalents was calculated by the PROPPEN experts. Total net benefits (20 years, 4 % interest rate) were also estimated for all scenarios (Ollikainen et al. 2012, Ollikainen et al 2012).

To compare oxygenation with pollution reduction alternatives from external sources, the phosphorus and nitrogen abatement potential in selected Finnish coastal wastewater treatment plants (WWTPs) was calculated as well as costs and benefits of load reductions in the selected Finnish WWTPs and in the WWTPs in Saint Petersburg.

Table 15 provides a comprehensive comparison and ranking of all studied alternatives. Alternatives are ranked with respect to two terms: annual net benefits and rolled over net benefits for 60 years.

Table 15. Ranking the alternatives of reducing nutrients in coastal waters of the Gulf of Finland (Ollikainen et al. 2012)

	Net benefits Annual	**Ranking**	**Net benefits Roll over 60 years**	**Ranking**
	MEUR	**#**	**MEUR**	**#**
Scenario 1	5.6	2	133.1	2
Scenario 2	4.5	3	106.9	3
Scenario 3	-1.5	8	-34.8	8
Combination 1	3.3	4	78.2	5
Combination 2	2.2	6	52.9	6
Combination 3	1.3	7	30.4	7
WWTPs-Finland	3.3	5	106.8	4
WWTPs-St. Petersburg	7.0	1	229.2	1

The PROPPEN project experts concluded ***that reducing nutrient inputs from external sources was the preferred option and oxygenation as an additional means of reducing eutrophication was not desirable under the current cost structure.*** However, they also suggested that pumping of oxygen-rich water might become an important measure in cost-effective policy once the marginal abatement costs in external sources increase and exceed the unit (and marginal) costs of oxygenation pumping.

In the PROPPEN study, the assumption was made that the littoral countries are truly willing to reduce nutrient inputs from external sources by the amounts allocated to them in the Baltic Sea Action Plan, but a very long-time horizon is needed before these reductions translate into the targeted reductions in eutrophication. Thus, experts examined whether the benefits from a faster recovery exceed the costs of oxygenation.

Second approach - Oxygenation as a means of *speeding up the recovery* of the Baltic Sea

This approach was also applied for both coastal and deep open sea areas.

Anoxic coastal areas

Estimated net benefits of different oxygenation scenarios at the regional scale of the Gulf of Finland are presented in Table 16.

Table 16. Net benefits of different pumping scenarios (4 % real interest rate) (Ollikainen et al. 2012)

	Phosphorus Equivalents, tonnes	Present value of net benefits 20 years		
		WTP Min, MEUR	MTP Mean, MEUR	WTP Max, MEUR
Scenario 1				
min	128	22.3	36.1	50.0
mean	140	30.2	45.4	60.5
max	143	38.1	54.5	71.0
Scenario 2				
min	89	13.2	22.9	32.5
mean	108	25.7	37.4	49.1
max	128	38.2	52.0	65.8
Scenario 3				
min	-11	-17.7	-18.9	-20.1
mean	-8	-16	-16.9	-17.7
max	-5	-14.2	-14.8	-15.4
Combination 1				
min	74	7.8	15.7	23.7
mean	87	16.4	25.8	35.3
max	100	25.1	35.9	46.8
Combination 2				
min	53	1.8	7.5	13.2
mean	65	9.5	16.5	23.5
max	77	17.2	25.5	33.8
Combination 3				
min	36	-3.3	0.5	4.4
mean	46	3	8	12.9
max	56	9.4	15.4	21.4

The conclusion from the assessment is that oxygenation in the anoxic coastal areas of the Gulf of Finland provides positive net benefits and is desirable, provided it truly speeds up the recovery of the coastal areas of the Gulf of Finland.

Anoxic Deep Open Sea areas

Table 17 condenses the net benefits of oxygenation for a faster recovery for the range of WTP estimates. The first column gives the simulated phosphorus retention under high and low impacts of oxygenation.

Table 17. Present value of net benefits from pumping the anoxic Gulf of Finland Deep (Ollikainen et al. 2012)

	P reduction, tonnes	Net benefits Min WTP, MEUR	Net benefits Mean WTP, MEUR	Net benefits Max WTP, MEUR
Case 1. High				
min	60	-142.3	-137.5	-132.7
mean	210	-70.3	-53.5	-36.7
max	360	1.7	30.6	59.4
Case 2. Low				
min	60	-142	-137	-133
mean	155	-75	-59	-43
max	250	-51	-31	-11

The conclusion from the study is that oxygenation in the open sea areas of the Gulf of Finland is not desirable under current pumping technology.

The general conclusion is that oxygenation is desirable in the coastal areas to speed recovery, but it is not desirable in the open sea areas, similar to the Gulf of Finland.

Public perception of risks of oxygenation

During the PROPPEN project, the survey of risk perception covered oxygenation pumping at different scales (i.e. small scale, medium scale, and large scale pumping). Results of the survey demonstrate that:

- As the scale of oxygenation increases from small to large-scale, people are more concerned about the potential ecological risks and are less willing to accept the risks and uncertainties of oxygenation for the prospects of a faster recovery of the Baltic Sea through oxygenation. Still, around one third of the population in the three surveyed countries (Finland, Sweden, and Lithuania) find the state of the Baltic Sea so severe that they would be willing to accept even high risks induced by oxygenation pumping for a faster recovery of the sea.
- There is a preference for requiring that benefits of oxygenation outweigh costs and risks. Around 30 % of people agree that oxygenation should be undertaken only if risks can be shown to be minimal; 6-9 % of people require that oxygenation should only be undertaken in coastal areas to minimize risks, while in Sweden 13-16 % of respondents indicated that large-scale pumping should not be undertaken under any circumstance.

4.5 Review of potential financing sources and cost recovery mechanisms

4.5.1 Overview of financial aspects of implemented projects/studies

The pilot studies and projects on sea-based measures analysed in this report were funded either by EU programmes, such as Interreg, LIFE+, or by special funds/foundations created to support improvement of the Baltic Sea environmental conditions. Table 18 provides an overview of the funding sources of the projects / studies which investigated sea-based measures, as well as whether those studies analysed potential future funding sources and whether cost-benefit analyses had been carried out. Below the table, financing aspects of the projects implemented and those which dealt with the financing issues, are described in more detail.

Table 18. Overview of financial aspects of projects/studies on sea-based measures

No.	Project/study	Funded by:	Is there any information on potential future funding for sea-based measures?	Is Cost Benefit Analysis carried out?
Oxygenation of anoxic bottoms				
1.	PROPPEN project report, 2012	Swedish Environment Protection Agency (1.1 MEUR in 2009-2011), Formas and VINNOVA. The total Swedish contribution is about 1.3 MEUR. The own contribution of the participating research institutes, universities and companies is about 0.8 MEUR.	No	Yes
2.	BOX and BOX-WIN, 2015	NIB, BSAP FUND Swedish Environmental Protection Agency	No	No
3.	WEBAP project report, 2014	EU funding instrument for the environment LIFE+	No	No
Chemical precipitation				
4.	Aluminium treatment project in Björnöfjärden (2012-2013)	Foundation BalticSea2020	No	No
5.	Permanent phosphorus binding in Baltic Sea bottom sediments project (use of marl, 2012-2013)	Foundation BalticSea2020	No	No
Dredging				
6.	Project Nutrient Retrieval from Seabeds project final report, 2014 / Dredging	BSAP Fund	The method is expected to finance itself up to 75 %. The two main revenue streams come from biogas and nutrients making this method unique in comparison with other methods designed to decrease internal leakage of phosphorus. Experts proposed that the remaining 25 % could be funded by means of emission fees.	Financial cost benefit analysis

4.5.2 Financiers of projects implemented

In addition to state institutions such as the Swedish Environmental Protection Agency or the Finnish Ministry of the Environment, one of the more frequent financiers of the pilot projects on sea-based measures listed above is the Baltic Sea Action Plan **(BSAP) Fund**[6]. It is managed by the Nordic Investment Bank (NIB) and the Nordic Environment Finance Corporation (NEFCO), contributors are Swedish and Finnish governments. To speed up the implementation of the Baltic Sea Action Plan, the BSAP Fund was set up in 2009. NIB and NEFCO, both having a long-term engagement in the Baltic Sea region and strong environmental mandates, are joint managers of the fund.

The **Nordic Investment Bank** (NIB) is the common international financial institution of the eight Nordic and Baltic countries. NIB provides long-term financing to the energy, environmental, transport, logistics and communications, and innovation sectors for projects that strengthen competitiveness and enhance the environment.

NEFCO is an international financial institution owned by the five Nordic countries. NEFCO finances investments and projects in Russia, Ukraine, Estonia, Latvia, Lithuania and Belarus, in order to generate positive environmental effects of interest to the Nordic region.

The **BalticSea2020** was founded by Mr Björn Carlson through a donation of 500 million SEK in 2006. The assets are supposed to fund projects that are action-oriented, innovative and contribute to a healthier Baltic Sea. The foundation also works to spread knowledge and information about the Baltic Sea to decision makers, authorities, schools and individuals. Since its inception, the foundation has influenced the EU's fishery- and agricultural legislation, initiated 85 projects for a healthier sea and helped to conduct and publish more than 20 scientific articles. Since the start in 2006, the foundation has allocated approximately 510 million SEK to projects in fishing eutrophication and information sectors.

The **Interreg Baltic Sea Region Programme** supports integrated territorial development and cooperation for a more innovative, better accessible and sustainable Baltic Sea region. A few projects on sea-based measures have been implemented using funds from the Interreg 2007-2013 Programme. Currently the 2014-2020 Programme is under implementation. The Programme is funded by the European Union and approved by the European Commission.

The **Interreg Central Baltic Programme** 2014-2020 is a cross-border cooperation programme. Its scope is to finance high quality projects in Finland (including Åland), Estonia, Latvia and Sweden that aim at solving common challenges together and across borders. The Programme supports projects in four priorities: Competitive economy, Sustainable use of common resources, Well-connected region and Skilled and socially inclusive region. It is important to note that SEABASED (Seabased Measures in Baltic Sea Nutrient Management) project started on 1 March 2018 and aims at reducing nutrients from the Baltic Sea and at improving water quality, especially in coastal areas, by piloting and developing sea-based activities. The project will pilot a few measures, such as 1) recycling nutrients from bottom sediments or nutrient-rich bottom waters for further use on land, 2) recycling nutrients on land in the form of fish such as stickleback, 3) applying various nutrient binding materials to sediments.

[6]https://www.nib.int/news_publications/575/nib_and_nefco_to_manage_new_fund_for_a_cleaner_baltic_sea

It is useful to mention here environmental Baltic Sea valuation studies, which are not directly related to the sea-based measures, but where people's attitudes and willingness to finance protection of the sea were assessed. The latter allows carrying out cost-benefit analysis of the sea-based measures. Funding of the valuation studies was received from:

- **The Finnish Government** – project PROBAPS (2008-2015)
- **Swedish Environmental Protection Agency** – projects BalticSurvey (2010), FishStern (2011)
- **The Swedish Research Council for Environment, Agricultural Sciences and Spatial Planning** – project Managing Baltic nutrients in relation to cyanobacterial blooms: what should we aim for? (2009-2012)
- **The Danish Strategic Research Council** - project IMAGE (Integrated Management of Agriculture, Fishery, Environment and Economy) (2010-2014)".

4.5.3 Potential future funding

Potential future funding issues were mentioned in three projects/studies analysed. Reports of other projects did not include descriptions of any future funding opportunities.

The Final report of the BSAP Fund project "Nutrient Retrieval from Seabeds" (Phase 2 Dredging tests), concluded on the technically feasible measures listed under section 4.2.2 of this report. The project also described three potential financing schemes of proposed systems and operation. The project has shown that the retrieval of organic substances from seabeds has the capacity to form a solid base for sustainable financing schemes. By retrieving matter, at least two Swedish precedents yield that compensation of emissions is possible within the legal framework of existing Swedish Environmental Code:

Financing scheme A – The sewage community. The ***Swedish municipal sewage fee*** – notably not a tax – does not require additional legislation to be used for covering the remaining leakage of nutrients. Most Swedish municipal sewage plants reach a 97-98% phosphorus precipitation. The remaining 2-3%, roughly 2-4 metric tonnes for a Swedish city like Linköping, finally end up in the Baltic Sea. Thus, the sewage community would finance a yearly retrieval of 2-4 tonnes of phosphorus.

Financing scheme B – The industrial sector. The project had performed indepth interviews with industrial sectors that emit substances that contribute to increased organic matter in the Baltic Sea. The Swedish industrial sector has suggested ***compensation throughout the years***, especially the forest industry. A leakage of 60 tonnes of nitrogen to water would finance a yearly retrieval of 60 tonnes.

Financing scheme C – The agricultural sector. The project performed indepth interviews with the agricultural sector, including farmers, federations, authorities, agencies and universities. The interviews showed a positive attitude by farmers to acquiring such kind of phosphorus. By ***switching from buying imported phosphorus to a national recycled form of phosphorus***, a total of 10,000 metric tonnes of phosphorus yearly would be prevented from entering the system.

The project had also studied possible circular economy schemes. The project suggested a ***Flexible Emission Fee System*** that would stimulate the market to develop more cost-effective upstream solutions and that would eventually compete with sediment retrieval. In the meantime, the sediment retrieval would unload the internal leakage of the Baltic and lakes.

Project Baltic EcoMussel, among other things, assessed and considered the environmental and socio-economic realities of three regions in the Baltic Sea to establish mussel farm activities: the east coast of Sweden, the open coast in Latvia, and at the entrance of the Gulf of Finland in Finland. Additionally, as a third goal, the necessary investments and costs were identified for a reference production of 80-100 tonnes of mussels every second year within a water area of 1 hectare. These investments could be ***subsidized by municipalities, regional development programmes and EU development programmes or by the private sector.***

The BalticSea2020 funded project “Mussel Farming as an Environmental Measures in the Baltic” concluded that mussel farms are one of many ways of helping our seas, but they face considerable challenges in the Baltic. It is well-established that mussels have the potential to remove nitrogen and phosphorus from seawater, but mussel farming is financially risky and not a cost-effective environmental measure for the Baltic Sea based on current technology and know-how. The Baltic blue mussel is generally too small to be used as traditional seafood. Consequently, Baltic mussel farming must focus on the harvest of mussel biomass to be used for other purposes such as feedstuff or biogas production/fertilizer.

The commercial value of the products from mussel farming in the Baltic Sea generally would not cover the full production cost. Thus, the main idea reflected in the project report, is that a ***mussel farming enterprise should be paid for the environmental service it provides in returning nutrients from sea back to land***. This Nutrient Emissions Trading instrument, which talks about recycling of nutrients using mussel farming as a part of a nutrient discharge trading system (Lindahl et al., 2005) requires that political decisions are taken, probably at the level of the European Community, on the EU agro-environmental aid programme (as the major part of the nutrient supply to coastal waters of the Baltic has its origin in agricultural operations). In turn, this could enable a competitive price for mussels to be used for feed production for poultry and fish production. This could be a simple, cost-effective and straightforward way of improving coastal water quality.

Other funding sources

There are some other funding organizations which could directly or indirectly support sea-based measures, in particular research and development costs. For example, under the Baltic Funding tool (http://funding.balticsea-region.eu/) there are listed various funding instruments, such as:

1. Common Initiatives in Fisheries, Denmark
2. EUDP - Energy Technology Development and Demonstration
3. Nordic Marine Innovation Programme
4. Baltic Conservation Foundation (the foundation funds environmental protection and nature conservation projects that aim to improve the ecological situation of the Baltic Sea region)

5. BONUS (Baltic sea research and development programmes)
6. Support for fishing foundation, Sweden
7. Protection Fund for the Archipelago Sea, Finland (the objective of the Protection Fund is to contribute to stopping the eutrophication of the Archipelago and to improve the general condition of the waters)
8. German-Polish Sustainability Research
9. Water and sewage in agglomerations, Poland
10. SITRA – The Finnish Innovation Fund etc.
11. LOVA – a Swedish system of governmental grants to local water management initiatives.

Moreover, environmental Baltic Sea valuation studies (BalticSun and similar) contain some proposals on potential funding. For example, most of the respondents in the BalticSurvey see it as necessary that their own country's wastewater treatment plants, industries, maritime transports, ports, farmers and professional fishermen take actions to improve the Baltic Sea environment. A majority of respondents in all countries also consider increased charges on pollution emissions to be an acceptable way of funding actions to improve the environment. There is thus widespread support in the region that the polluters should bear the costs for their pollution. Increases in taxes or water bills are not popular, although people are in general less negative towards making payments that are paid by everyone and are earmarked for funding actions.

Understandably, further discussions and negotiations are needed to clarify realistic possibilities to fund sea-based marine protection measures.

4.6 Multi-Criteria Analysis for prioritisation of potential sea-based measures

For this project, the Ministry of the Environment of Finland and the Consultant agreed to test the applicability of Multi-Criteria Analysis (MCA) for prioritising the potential sea-based measures in terms of their efficiency for the sea areas of Finland and the whole Baltic Sea. During the MCA workshop 10 Finnish experts provided their opinions on the importance of, and current threat level to the Baltic Sea's ecosystem services, as well as impacts of potential sea-based measures on the ecosystem services/benefits.

MCA applies cost-benefit thinking to cases where there is a need to present impacts that are a mixture of qualitative, quantitative and monetary data, and where there are varying degrees of certainty. This is typical in the Marine Strategy Framework Directive (MSFD) context. Thus, due to limited knowledge on both the range of costs and benefits that each measure would entail it was decided to apply the MCA.

In the framework of the assessment at hand, four consecutive broad steps have been taken:

1. Assessment of cost ranges of proposed sea-based measures
2. Determination of benefit ranges of proposed measures

3. Synthesis of costs and benefits
4. Inclusion of risk analysis and final prioritisation of measures.

MCA analysis covered nine sea-based measures (including so-called biological measures):

1. Small-scale oxygenation of anoxic bottoms
2. Large-scale oxygenation of anoxic bottoms
3. Aluminium treatment
4. Marl treatment
5. Clay bombing
6. Dredging
7. Mussel farming
8. Algae harvesting
9. Removal of low economic value fish.

Large-scale oxygenation of anoxic bottoms has been considered for the open sea areas, while the remaining measures are mostly relevant for small-scale projects at coastal areas.

Review of Costs

The costs of the proposed measures have been categorised in three groups (Table 19). As explained in Section 4.2 of this report, costs of some measures vary significantly, thus, classification of costs into the categories is to a large extent based on expert judgement.

Table 19. Categories of costs of sea-based measures

No	Measure	Cost for removal of 1 kg P, EUR	Cost category
1.	Small-scale oxygenation of anoxic bottoms	2 - 40	**L**
2.	Large-scale oxygenation of anoxic bottoms	2 - 75	**M**
3.	Aluminium treatment	58 - 318	**H**
4.	Marl treatment	n/a	**M**
5.	Clay bombing	n/a	**L**
6.	Dredging	32	**L**
7.	Mussel farming	67 - 350 440 1,700 – 6,300	**H**
8.	Algae harvesting	60	**M**
9.	Removal of low economic value fish	n/a	**M**

Review of Benefits

Three main categories of Ecosystem Services (ES) have been taken into account in the benefits' analysis:

- ***Provisioning services*** relate to the tangible products, such as fish or pharmaceuticals, provided by marine ecosystems.
- ***Regulating services*** refer to the marine environment's natural processes such as waste assimilation and carbon sequestration that contribute to social wellbeing.
- ***Cultural services*** are associated with both use and non-use values and relate to the non-material benefits obtained from ecosystems, for example, through tourism and educational use of the marine environment.

In order to assess the full range of benefits that arise from the natural functioning of marine ecosystems, the project's economic and social analysis team applied a typology of marine and coastal ecosystem services, based on the latest version (No 5.1) of The Common International Classification of Ecosystem Services (CICES V5.1). The developed typology consists of 17 benefits, which were assessed by the MCA workshop participants.

The typology was adapted to a simple survey format. For the ecosystems which are potentially under pressure, participants had to mark the level of pressure as either 'high', 'medium' or 'low'. In other words, the participants' expert opinion was consulted to gather a sample on the urgency of policy action.

The next step of the related benefits' analysis required calculation of high, medium and low-pressure score for each marine ecosystem provided benefit. To rate all marine ecosystem services with respect to their relevance and importance and, later on, evaluate the relative benefit that each proposed measure could bring, weighting of score was done.

The survey results reflect perceptions of participants regarding the most critical marine ecosystem services. Results from this task demonstrate that participants' ranking of ecosystem services is quite similar for both the sea areas of Finland and the whole Baltic Sea. Participants find that most of regulation and maintenance services are of high concern. Additionally, provisioning service "wild animals for nutrition, materials and energy" and cultural service "other biotic characteristics that have a non-use value" were also rated by participants as of high concern.

For the final benefits analysis participants of the workshop were asked to fill survey sheets where they had to indicate potential effects (positive and/or negative) of the proposed nine sea-based measures on the listed marine ecosystem services.

The final benefit score was found out by summarizing weighted positive and negative scores. This resulted in the overall benefit ranges for each measure used in the MCA. Total benefit category was estimated accounting for the difference between the highest and the lowest score value and establishing equal score intervals for three benefit classes: high (H), medium (M) and low (L) (Table 20).

Results of the benefit analysis demonstrate that the highest benefits for the sea areas of Finland should be brought by implementation of large and small scale oxygenation projects, as well as mussel harvesting and removal of low economic value fish while the whole Baltic Sea should mostly benefit from small-scale oxygenation, mussel farming, algae harvesting and removal of low economic value fish. For both the sea areas of Finland and the whole Baltic Sea, aluminium treatment, marl treatment, clay bombing and dredging were classified as measures with the lowest benefits. This is mainly a result of the participants' limited knowledge about potentials and effects of these measures and a perception that implementation of these measures might be associated with relatively big negative effects.

Table 20. Overall benefit ranges for the sea areas of Finland and the whole Baltic Sea

No.	Measure title	Sea areas of Finland		Whole Baltic Sea	
		Final benefit	Total benefit category	Final benefit	Total benefit category
1.	Small-scale oxygenation of anoxic bottoms	275	H	723	H
2.	Large-scale oxygenation of anoxic bottoms	185	H	-1	M
3.	Aluminium treatment	51	L	-659	L
4.	Marl treatment	-20	L	-780	L
5.	Clay bombing	37	L	-388	M
6.	Dredging	15	L	-1,324	L
7.	Mussel farming	274	H	877	H
8.	Algae harvesting	151	M	559	H
9.	Removal of low economic value fish	183	H	784	H

The perceived benefits that each measure might provide to the ecosystem services reflect to some extent the positive effects described in Chapter 3 of this report, as the measures in the highest category in the above table are described as having also more positive effects in Chapter 3 (except for biological measures, which were assessed only in the MCA). However, direct comparison is not possible since Chapter 3 describes the effects according to MSFD Descriptor and the MCA assesses ecosystem services according to The Common International Classification of Ecosystem Services (CICES V5.1).

MCA Results for Cost and Benefit Comparison

To prioritise the proposed measures according to the costs and benefits, seven priority groups were used for both the sea areas of Finland and the whole Baltic Sea.

The MCA results and prioritisation of measures for the sea areas of Finland and the whole Baltic Sea are provided in Table 21.

Table 21. MCA results and prioritisation of proposed measures for the sea areas of Finland and the whole Baltic Sea

No	Measure title	Cost category	Sea areas of Finland		Whole Baltic Sea	
			Total benefit category	Priority	Total benefit category	Priority
1.	Small-scale oxygenation of anoxic bottoms	L	H	1	H	1
2.	Large-scale oxygenation of anoxic bottoms	M	H	2	M	3
3.	Aluminium treatment	H	L	7	L	7
4.	Marl treatment	M	L	6	L	6
5.	Clay bombing	L	L	5	M	2
6.	Dredging	L	L	5	L	5
7.	Mussel farming	H	H	3	H	3
8.	Algae harvesting	M	M	3	H	2
9.	Removal of low economic value fish	M	H	2	H	2

As the results above show, small-scale oxygenation of anoxic bottoms is the first priority measure for both the sea areas of Finland and the whole Baltic Sea, while aluminium treatment and marl treatment are rated as the least priority measures in both cases. All the measures, in both sea areas of Finland and the whole Baltic Sea, are of a similar priority level, except for clay bombing, which according to the experts participating in the MCA workshop, was perceived as more beneficial to the ecosystem services in the whole Baltic Sea than in the sea areas of Finland.

MCA Results with Risk Assessment

MCA, after assessing costs and benefits, was supplemented with the risk analysis.

Workshop participants were submitted questionnaires and asked one additional question: “What is the risk of not achieving desired (sustainable and long-term) effect of a measure stipulated by technological and nature conditions?” Participants had to indicate the level of risk of failure to implement a measure as high, medium or low.

To classify the risks associated with the failure to implement the proposed sea measures into categories, participant scores were weighted: scores for high risks were assigned weight 5, scores for medium risk – weight 3 and scores for low risk – weight 1. Final categorisation of risks is presented in Table 22.

Table 22. Final risk score and categorisation

No	Measure title	Total score			Risk category	
		sea areas of Finland	whole Baltic Sea		sea areas of Finland	whole Baltic Sea
1.	Small-scale oxygenation of anoxic bottoms	30	28		M	L
2.	Large-scale oxygenation of anoxic bottoms	34	36		M	M
3.	Aluminium treatment	38	41		H	H
4.	Marl treatment	27	31		L	L
5.	Clay bombing	25	27		L	L
6.	Dredging	40	41		H	H
7.	Mussel farming	33	35		M	M
8.	Algae harvesting	28	28		L	L
9.	Removal of low economic value fish	33	33		M	M

Final prioritisation step was carried out by combining cost-benefit and risk ranging results.

The result of prioritisation of measures including risk assessment is shown in Table 23. It suggests that oxygenation of anoxic bottoms along with biological measures such as mussel farming, algae harvesting, and removal of low economic value fish are, according to the opinion of survey participants, the top priority measures for the restoration of the Baltic Sea, including sea areas of Finland. Because of high costs, unknown effects and high risks of failure aluminium treatment and dredging are rated as the least priority measures. Insufficient knowledge about marl treatment and clay bombing resulted in low prioritisation of these measures. Although clay bombing was rated as one of the first priority measures for the whole Baltic Sea, big uncertainty is associated with this estimate, as only few participants assessed the effects of clay bombing on the Baltic Sea.

Table 23. Final prioritisation of measures

No	Measure title	Priority	
		sea areas of Finland	whole Baltic Sea
1.	Small-scale oxygenation of anoxic bottoms	2	1
2.	Large-scale oxygenation of anoxic bottoms	2	3
3.	Aluminium treatment	7	7
4.	Marl treatment	5	5
5.	Clay bombing	5	1
6.	Dredging	7	7
7.	Mussel farming	3	3
8.	Algae harvesting	2	1
9.	Removal of low economic value fish	2	2

The MCA results confirm outcome of the cost-effectiveness of the sea-based measures' analysis, presented in Section 4.2. It is also important to stress that the first priority measures were assessed by the MCA participants as providing the highest positive impacts on the marine ecosystem services. The latter assessment plays an important role in this MCA.

It is understood that the MCA above produced only indicative results, because the risks, benefits and costs are still poorly known. During the process of selection / prioritisation of sea-based measures other aspects should ideally also be taken into consideration:

- public consultation; this helps to check social acceptability and crystallize measures;
- measures need to be concretised (number and locations) and costed (not only ranged);
- concrete funding possibilities, which responsible actors will possess, also play a very important role.

5 Policy, legal and institutional framework and procedures regarding sea-based measures

SUMMARY

This chapter reviews policy, legal and institutional framework and procedures regarding sea-based measures and provides an overview of the general legal framework and its applicability from an international and national perspective (primarily Finland, but also Sweden), as well as a review of the main policy interest in sea-based measures by different institutions.

Sea-based measures are relatively new and there are no laws relating specifically to such measures. Instead, this chapter reviews what laws and principles apply to different types of measures in different sea areas. The relevant rules and principles are mainly those that govern different forms of marine activities and activities with (potential) effects on the marine environment. A broad range of such rules and principles apply, at several different levels of regulation. The main material rules originate from international and EU legislation, while the implementation takes place at national level.

A main conclusion following from the review is that the legality of sea-based measures is closely related to their short-term and long-term effects. The environmental risks will for example decide on whether the matter is to be considered as 'pollution of the marine environment', dumping or marine geoengineering. In other words, if the measures succeed in improving the environment without posing short-term risks, law presents few obstacles for their introduction. Conversely, if the benefits are limited and environmental risks important, a whole range of legal obstacles present themselves at all legal levels.

There is considerable uncertainty about the effects of the different kinds of measures, which complicates this legal assessment that eventually will be made by national authorities when evaluating the permit request for the measure. Environmental law includes mechanisms for dealing with scientific uncertainty, notably through the so-called 'precautionary principle'. This principle has not been operationalised at regional level in a Baltic Sea context, which means that there is little guidance for national authorities on this matter. However, recent developments in the global regulation of geo-engineering could provide inspiration for how the matter could be approached at regional level in the Baltic Sea region if, as it seems, there is an interest to discuss regional guidelines within HELCOM.

In view of the strong link to international and EU rules and principles, the differences between the material rules that apply in different states in the Baltic Sea region is not expected to be very significant. This is certainly the case between the two states studied in this report, Finland and Sweden whose approach is very similar.

National differences may nevertheless exist in implementation, depending on the procedures and policy approach taken by national authorities (of the state in which the activity takes place) when issuing the permits. National permit procedures will be of critical relevance for how the applicable rules and principles will be

implemented and how various interests will be weighed against each other in practice. The conditions attached to such permits will also be decisive for determining the more precise legal obligations of the operator, but also the role and responsibility of the authorities. EU legislation, as implemented by the Court of Justice, turns out to involve rather strict requirements on how states are to consider applications for permits.

5.1 Introduction

5.1.1 Scope and delimitations

The key task of this chapter is to review the legal framework that applies to sea-based measures in the absence of any rules specifically designed for that purpose. This includes categorizing the sea-based measures, making potential analogies and assessing to what extent the existing legal framework is applicable to the sea-based measures at all. In addition, the study includes a review of the policy and institutional framework relating to sea-based measures. The policy review is based partly on a review of official documentation and partly on interviews with certain key actors in the field. Interviewees have been selected among key players who have been considered to offer perspectives on the key issues involved, the institutional framework and the future development of a legal and institutional framework for such measures.

The legal and institutional review (this chapter) is linked to the scope of measures addressed in chapters 1–4. This means, *inter alia*, that the main focus lies on sea-based measures of a technical character, i.e. methods mainly aiming for eliminating (or reducing) phosphorus leakage, rather than measures that are based on enhancing biological processes. This also means that the methods reviewed apply specifically to phosphorus leakage and do not include measures to remove or reduce nitrogen. Measures intended to remove or reduce nitrogen, which are more complex processes and raise different technical issues, are not covered, although many of the policy and legal aspects reviewed here will be of equal relevance to such measures.

There are three main categories of technical methods in focus in the study: *1) dredging, 2) chemical treatment to bind phosphorus at the seabed, and 3) oxygenation of the seabed by pumping oxygen-rich water close to the seabed in order for the phosphorus not to dissolve and to change the environment of anoxic parts of the seabed.* These methods have different features and thus in part invoke different legal questions and requirements, as discussed in section 5.4 below.

5.1.2 Outline and general structure of the policy, legal and institutional review and assessment

In the absence of specific rules, sea-based measures must be compared to similar activities that are specifically regulated or to rules and principles of general applicability. This means, on the one hand, that a very broad range of legal rules will potentially be invoked. On the other hand, it means that the rules will not normally provide precise answers to questions of direct implementation. The focus of the review is on rules of international law and EU law. These rules represent the substantive underpinning of the national rules in Finland and Sweden, and apply beyond that to most Baltic Sea states (the most obvious exception being the Russian Federation that is not an EU member state).

An overall review of the legal framework is provided in section 5.2, providing a broad overview of the relevant rules at international, EU and national level.

Section 5.3 deals with the policy aspects of sea-based measures. It addresses, firstly, general policy questions related to the acceptability of sea-based measures in the Baltic Sea region. Secondly, the chapter also raises an essentially legal question, which is closely connected to the political readiness of states to implement such measures, that is, how such measures are to be recorded as part of the current national obligations to reduce eutrophic pollution in the Baltic Sea. Thirdly, communication of sea-based measures is analysed.

Section 5.4 is the principal analytic part of the study. Here, sea-based measures are categorized in the existing legal framework. This provides an overview of what rules apply to what category of measures. In the absence of laws relating specifically to these types of measures, it is necessary to establish whether the existing legal framework still covers such activities at all, whether analogies can be made to regulation of comparable activities, or whether they remain to be governed only by more generic (environmental) legal principles. Some selected rules and cases of specific relevance to any category of sea-based measures are highlighted separately in view of the need for a more detailed review of their implications (section 5.4.4). It was already noted that the legal framework is not providing clear answers to the permissibility on different types of measures. This, however, has more to do with uncertainties of the effects of seabed measures than with ambiguities in the law as such. The section therefore includes a review of how the various interests involved could or should be balanced when applying the relevant law, but also addresses the critical question as to how law deals with scientific uncertainty (section 5.4.5).

Relevant national laws, mostly in relation to procedures, are discussed in section 5.5, separately for Finland and Sweden. Here, the main focus is on establishing the procedural requirements for an operator of sea-based measures and any additional balancing of interests to be undertaken in this context.

Section 5.6 finally includes a brief review of laws related to liability of various parties under international, EU and national laws.

5.2 General legal framework

5.2.1 Introduction

The Baltic Sea region is arguably the world's most regulated international marine area, with up to five layers of regulation (general international law, regional conventions, EU-law, national laws, local and municipal rules) acting in parallel. All these layers, as pictured below in Figure 43, have their own role to play also with respect to sea-based measures and all of them need to be considered.

Figure 43. *Layers of regulation*

The two highest layers in the figure consist of public international law. States that have accepted obligations under a treaty (ratified or acceded to a convention) are bound by them under international law. Conflicting national law is not an argument not to comply. Formally there is no hierarchy between different rules of international law, but in the present field, one instrument, the UN Convention on the Law of the Sea (UNCLOS), thanks to its character, content and broad participation, is a particularly authoritative instrument frequently referred to as the 'Constitution for the Oceans'. Other relevant treaties include conventions that are adopted specifically for dealing with specific environmental concerns (e.g. biodiversity protection) or procedures (e.g. environmental impact assessment) or regional marine environmental protection treaties, notably the Helsinki Convention on the Protection of the Marine Environment of the Baltic Sea Area (hereinafter the Helsinki Convention). In addition to treaties, the other main source of international law is customary law, which is unwritten law, evidenced by widespread and consistent practice by states, driven by so-called *opinio juris*, i.e. a belief by states that they have a legal duty to act in that way. Customary law is binding to all states, but its relevance decreases as more and more rules are written down in conventions. The role of customary law in the present field is mainly relevant with respect to the status of certain environmental principles.

EU law is a specific category of law, different from its national and international counterparts. EU-law ranks hierarchically higher than national law. The EU can also be a party to international conventions, either alone or, more commonly in our case, alongside its member states. Where the EU is a party to an international convention the convention becomes part of the EU legal order, to the extent the EU has competence over the agreement. Apart from the EU's 'Constitution', consisting of the Treaty on European Union and the Treaty on the Functioning of the European Union (TFEU), EU legislation comes in two main formats. Regulations are generally and directly applicable in all member states, without further action by the member states, while directives are binding with respect to their results, but leave the choice of methods to achieve those results to member states and hence requires implementation measures at national level.[7]

The international and regional rules influence to a large extent the content of the national rules, and international obligations need to be transposed into national laws in both countries covered by this study, namely Finland and Sweden. However, national legislation also covers a very broad spectrum of matters that have not been addressed at international or EU-level and is hence by far the broadest regulatory layer. It is often at this level that the rules are effectively implemented or put into practice, e.g. through planning processes, permit procedures, enforcement measures etc.

Sub-regional actors are for present purposes mostly relevant when it comes to planning and permits. In many cases, it is sub-national regional bodies, or even municipalities, that will be responsible for the approval of plans and certain permits, but they are not, in the present case, an independent source of substantive rules.

The remainder of this introductory section is structured in terms of the layers, beginning with international law, through EU law, and the most relevant Finnish and Swedish laws, along with certain generally applicable principles of environmental law.

5.2.2 International law

5.2.2.1 The UN Convention on the Law of the Sea

5.2.2.1.1 General

The 1982 UN Convention on the Law of the Sea (UNCLOS) is the key international instrument dealing with all usages of the seas. It is a universally applicable comprehensive framework convention seeking to regulate all activities in marine areas. All states in the Baltic Sea region, and the EU, are parties to the convention, which is widely regarded to be a 'Constitution for the Oceans' and representative of customary law even for the states that have not formally ratified it. It applies to any marine area, including those beyond the jurisdiction of any state, and also includes rules for delimiting sea areas.

In the case of the Baltic Sea, the maritime delimitation is nearly complete, i.e. the maritime borders are largely settled between the neighbouring countries. Apart from a few delimitation points that are yet to be settled,[8] the entire Baltic Sea is divided between the coastal states and every part of it is subject to the jurisdiction of one of the coastal states. The 'high seas' areas of the Baltic Sea have thus disappeared in the process and there

[7] TFEU, art. 288.

[8] See e.g. E. Franckx, 'Gaps in Baltic Sea Maritime Boundaries', in H. Ringbom (ed.), *Regulatory Gaps in Baltic Sea Governance - Selected Isues*, Springer, 2018, pp. 7-20.

are no more ‘no man’s lands’ in the Baltic Sea or its seabed. This state of affairs strengthens the picture - and jurisdictional reality - that questions related to the regulation and usage of the Baltic Sea and its resources are now for the Baltic Sea littoral states themselves to regulate and resolve. The maritime boundaries in the Baltic Sea are shown below in the map.

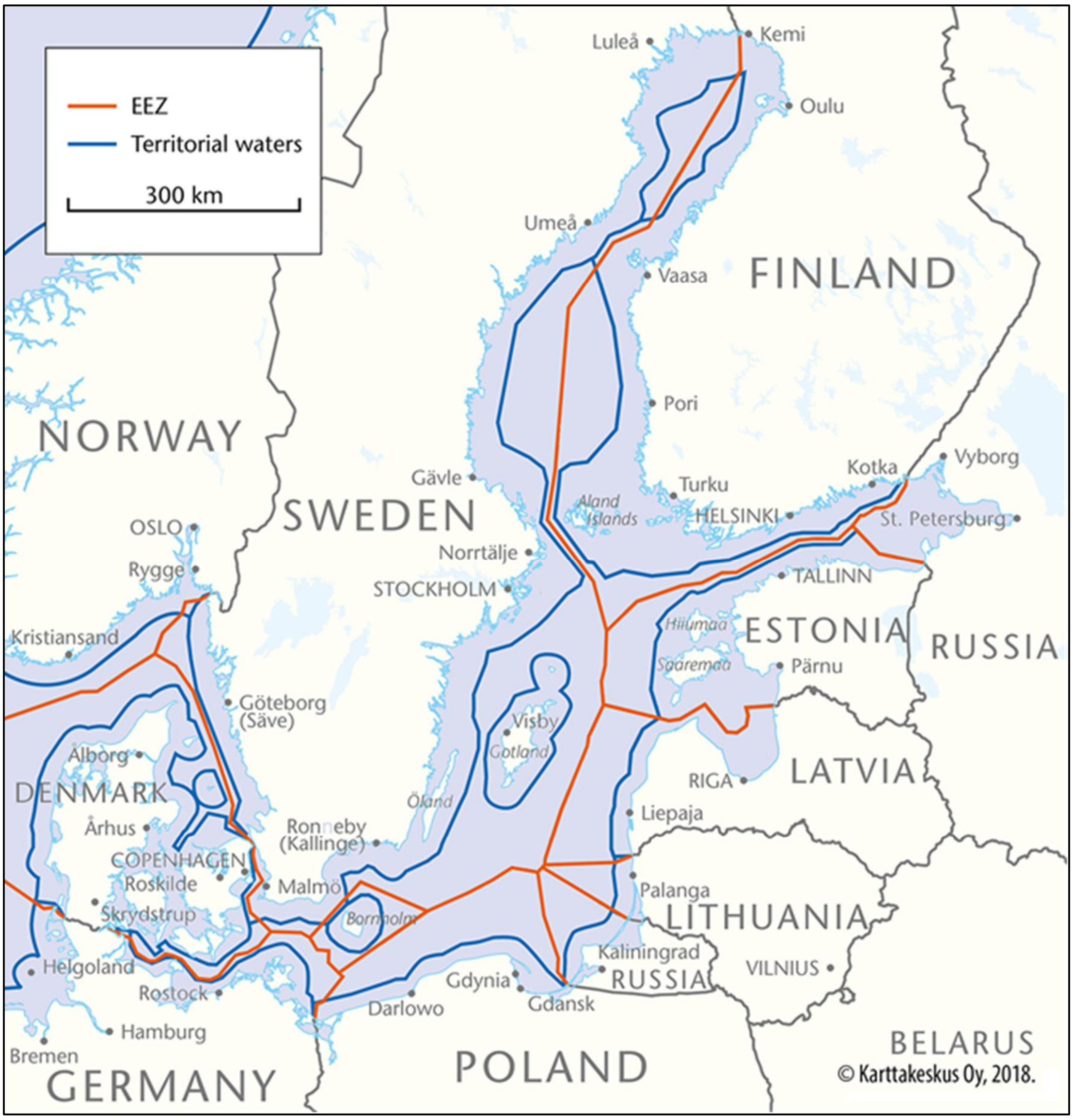


Figure 44. Maritime zones in the Baltic Sea. The SAR zones refer to search and rescue responsibilities only and are not relevant in the present context.

UNCLOS comprehensively regulates jurisdiction at sea, i.e. what states can and cannot do in different sea areas, separately for the seabed and the water column. The jurisdictional principles of UNCLOS are based on the premise that flag states' jurisdiction is the same irrespective of the location of the activity in question, whereas coastal states' jurisdiction depends on the maritime zone concerned. The rules differ depending on what activity is concerned, but the principle for the seabed as well as the water column is that coastal states' jurisdiction over foreign ships and operators is larger in maritime areas near the coast and more limited on the Exclusive Economic Zone (EEZ).

Furthest away from the coastline is the EEZ, which can reach a maximum of 200 nautical miles (nm) from the coastal baseline. The EEZ represents a mix between the high seas freedom and regular coastal state jurisdiction. On the one hand, the coastal state has sovereign rights to perform activities with the purpose of exploring, exploiting, conserving and managing the living as well as the non-living natural resources, and for the purpose of other activities for the economic exploitation and exploration of the zone.[9] On the other hand, all states enjoy high sea freedoms with respect to navigation, laying of submarine cables and other lawful uses of the seas, subject to the relevant provisions of UNCLOS. Coastal states have similar rights over their continental shelves (the underlying seabed). The coastal state accordingly has the right to regulate the drilling of oil or gas in its seabed and to regulate fisheries in their EEZ/continental shelf.

In the EEZ, coastal states also have jurisdiction over the protection and preservation of the marine environment, marine scientific research, and the establishment and use of artificial islands, installations and structures.[10] These rights are only moderated by specific limitations laid down in UNCLOS or by the general obligation to have due regard for the interests of other states and to observe the general principles *inter alia* relating to the protection of the marine environment.

Specific provisions apply to the laying of cables and pipelines. All states are entitled to lay submarine cables and pipelines on the continental shelf of other states, and coastal states may not impede the laying or maintenance of such cables or pipelines "subject to its right to take reasonable measures for the exploration of the continental shelf, the exploitation of its natural resources and the prevention, reduction and control of pollution from pipelines".

Apart from this limitation, which is further detailed in UNCLOS Article 79, the general picture is that coastal states have significant influence over sea-based measures their EEZ. The rules on “installations or structures" could be particularly relevant in this context, providing, as they do, the exclusive right for the coastal state to construct and to authorize and regulate the construction, operation and use of such installations and structures in the EEZ and the continental shelf.[11] There is no definition of such installations and structures.

For activities that are not specifically mentioned in UNCLOS Part V on the EEZ, i.e. do not fall within the categories of marine scientific research, resource utilization, environmental protection etc., the freedoms of the high seas apply. Coastal state authority over such activities is much more limited and mainly subject to the duty of all states to have due regard to the interests of other states.

[9] UNCLOS, Art 56(1)a.
[10] UNCLOS, Art. 56(1)b.
[11] UNCLOS, Art. 60; and regarding jurisdiction for installations on the continental shelf, see Art 80.

Closer to the coast, at a distance of maximum 12 nm from the baseline, the territorial sea forms a part of the coastal state's territory and is hence, as a starting point, subject to the complete sovereignty of the coastal state.[12] However, a main exception to this is the right of foreign ships to exercise the right of innocent passage in other states' territorial seas. The activities associated with this right are linked to navigation and the right would normally not extend to ships involved in sea-based measures. Research or survey activities in foreign states' territorial sea are specifically prohibited under UNCLOS Article 19(2)(j). In other words, coastal states have far-reaching rights to regulate any potentially environmentally harmful or hazardous activities in the vicinity of their coasts, and also have the right to take measures to reduce pollution, such as prohibiting dumping. The sovereignty over the territorial sea also covers the underlying seabed.

The waters inside the baseline, e.g. inside the outer limits of the archipelagos of Finland and Sweden, are called internal waters. In these areas, the law of the seas does not place any limitations of relevance to sea-based measures. It is accordingly for the coastal state to decide on the usage of these waters in all respects.

The Convention also contains special provisions regarding enclosed or semi-enclosed seas, providing that the bordering states should cooperate, where appropriate through a regional organization, to implement their rights and duties regarding the protection and preservation of the marine environment.[13] The Helsinki Convention is obviously of relevance when assessing cooperative arrangements and new measures in the Baltic Sea and HELCOM accordingly plays a potentially significant role also in relation to fulfilling the purposes of UNCLOS in this regard.

UNCLOS does not, in other words, offer precise answers to the rights and obligations relating to sea-based measures. It does not foresee this type of activities and even the nature of states' rights or jurisdiction over its internal nutrient load is not entirely clear, as the matter depends, *inter alia*, on the status of the internal load as a (non-living) 'natural resource' and whether the activity in question is considered to represent 'marine scientific research', 'protection of the marine environment' or 'dumping'. Different types of sea-based measures raise different questions in this regard.

5.2.2.1.2 Obligations to protect and preserve the marine environment

Outside the zonal framework, UNCLOS Part XII also includes certain requirements on states to protect and preserve the marine environment, which apply irrespectively of whether or not the activity in question is specifically regulated by UNCLOS and irrespectively of the zone involved and of the capacity in which the state acts.[14] All states have an obligation to protect the marine environment (Article 192), and they must ensure that activities being carried out under their jurisdiction or control do not cause damage by pollution to other states and their environment or do not spread pollution beyond their borders (Article 194(2)). Furthermore, states shall, individually or jointly, take "all measures

[12] UNCLOS, Arts 2–4. Exceptions: UNCLOS, Arts 17–19.
[13] UNCLOS, Part IX, Art 123. See also Art 197.
[14] UNCLOS, Part XII, Arts 192-195.

consistent with this Convention that are necessary to prevent, reduce and control pollution of the marine environment from any source".[15]

'Pollution of the marine environment' is broadly defined to include "the introduction by man of substance or energy into the marine environment", but the definition also includes a requirement with respect to the (likely) environmental effect of such activity.[16]

Other articles specifically highlight the need for protecting sensitive areas, such as the need to take measures 'necessary to protect and preserve rare or fragile ecosystems as well as the habitat of depleted, threatened or endangered species and other forms of marine life'[17], and more general duties of cooperation at global and regional levels to prevent, minimize and control environmental harm.[18] Moreover, when taking such measures to prevent, reduce or control pollution, states must "act so as not to transfer directly or indirectly damage or hazards from one area to another or transform one type of pollution into another".[19]

UNCLOS was negotiated in the late 1970s and early 1980s in the very early days of international environmental law; it therefore does not include many of the principles, tools and approaches that have since been developed and included in later environmental treaties. While UNCLOS includes the fundamental obligation of states not to cause harm to the environment of other states and to prevent pollution from spreading beyond their own jurisdiction,[20] it does not, for example, include references to the precautionary principle, the polluter pays principle (see further in section 5.2.3 below), or references to the use of modern management mechanisms such as the ecosystem approach, or tools such as maritime spatial planning.

However, the subsequent development of such environmental principles cannot be ignored when UNCLOS is applied today.[21] Many key principles have since been developed, not only in terms of substantive content, but also in terms of legal status.[22] The 'precautionary principle', in which the lack of scientific certainty shall not be used as a reason to postpone cost-effective measures to prevent environmental degradation, is a case in point. This principle was introduced as Principle 15 in the Rio Declaration in 1992,

[15] UNCLOS, Article 194(1). Paragraph 3 of the same article goes on to provide that the measures taken shall include measures to "minimize to the fullest possible extent" the release of toxic, harmful and noxious substances, pollution from vessels, and from installations and devices operating in the marine environment.

[16] Under UNCLOS article 1(4) the full definition of 'pollution of the marine environment' reads "the introduction by man, directly or indirectly, of substances or energy into the marine environment, including estuaries, which results or is likely to result in such deleterious effects as harm to living resources and marine life, hazards to human health, hindrance to marine activities, including fishing and other legitimate uses of the sea, impairment of quality for use of sea water and reduction of amenities". The definition is focused on the environmental perspective alone and is not dependent on e.g. the intention behind the act that caused it. See also Birnie, Boyle, Redgwell, International Law and the Environment, pp. 188–189.

[17] UNCLOS, Article 194(5). See also the much less committing articles 123 on enclosed and semi-enclosed seas, and article 197 on regional co-operation.

[18] UNCLOS, Articles 197 *et seq*.

[19] UNCLOS Article 195.

[20] UNCLOS, Article 194(2) reads: "States shall take all measures necessary to ensure that activities under their jurisdiction or control are so conducted as not to cause damage by pollution to other States and their environment, and that pollution arising from incidents or activities under their jurisdiction or control does not spread beyond the areas where they exercise sovereign rights in accordance with this Convention."

[21] This is recognized by UNCLOS itself, e.g., when providing that the freedom of the high seas "is exercised under the conditions laid down by this convention and by other rules of international law" (article 87(1)).

[22] The interpretation of a treaty should, according to article 31(3)(c) of the Vienna Convention on the Law of Treaties, take into account not only the context but "any relevant rules of international law applicable in the relations between the parties".

and has since been reiterated in many international conventions, including the Convention on Biological Diversity (the CBD), the Kyoto Protocol adopted under the UN Framework Convention on Climate Change, the 1995 Fish Stocks Agreement[23] and the 1996 London Dumping Protocol. The principle has also been regarded as representing customary law by international courts.[24]

The environmental obligations and principles of UNCLOS have also been interpreted and developed by international case law. Several international courts and tribunals acting under the UNCLOS umbrella have recently dealt with the status of states' environmental obligations under UNCLOS and concluded, *inter alia*, that states' duty to protect the marine environment encompasses the conservation of the living resources of the sea,[25] and extends beyond controlling pollution to measures focused primarily on conservation and the preservation of ecosystems[26] and "to the prevention of harms that would affect depleted, threatened, or endangered species indirectly through the destruction of their habitat".[27] Case law, in other words, suggests a development towards a more holistic and integrated understanding of states' environmental obligations than the sectoral regime of UNCLOS might otherwise suggest. The duties in UNCLOS Part XII are to be read as a duty to protect the marine environment as a whole, hence also departing from the needs of the ecosystem.

Of particular relevance for the present context is finally also the obligation laid down in Article 204(2) for states to "keep under surveillance the effects of any activities which they permit or in which they engage in order to determine whether these activities are likely to pollute the marine environment."

5.2.2.2 The London Convention and the London Protocol

The 1972 London Convention and its 1996 Protocol restrict dumping at sea of wastes and other matter that can create hazards to, *inter alia*, marine life. The aim is to protect the marine environment from pollution by dumping and the main rule is that dumping is generally prohibited. With the adoption of the 1996 London Protocol, an even stricter protection against environmental hazards from dumping at sea was accomplished.[28]

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[23] The full name is the 1995 United Nations Agreement for the Implementation of the Provisions of the United Nations Convention on the Law of the Sea of 10 December 1982 relating to the Conservation and Management of Straddling Fish Stocks and Highly Migratory Fish Stocks

[24] See for example the 2010 decision of the ICJ in the *Pulp Mills on the River Uruguay* Case (Argentina v. Uruguay) [2010] ICJ Rep 14, para 164 and *Responsibilities and Obligations of States Sponsoring Persons and Entities with Respect to Activities in the Area (Advisory Opinion)* [2011] ITLOS Rep 10, para. 135. Yet, even with widespread agreement of the status of the principle as such and its fundamental importance in the environmental decision-making process, there is still plenty of scope for disagreement on the implications of the principle in individual cases. Issues such as whether the identification of a serious risk imposes an obligation to refrain from the activity in question altogether, and questions relating to determining a serious risk and the burden of proof are likely to come up in any concrete dispute.

[25] Southern Bluefin Tuna (ITLOS provisional measures, www.itlos.org/fileadmin/itlos/documents/cases/case_no_3_4/Order.27.08.99.E.pdf), para. 70; Request for an advisory opinion by Sub-regional fisheries Commission (ITLOS Advisory opinion, www.itlos.org/fileadmin/itlos/documents/cases/case_no.21/advisory_opinion/C21_AdvOp_02.04.pdf, para. 120

[26] Chago Islands Marine Protected Area Arbitration (UNCLOS Annex VII Arbitral tribunal, www.pcacases.com/pcadocs/MU-UK%2020150318%20Award.pdf), para. 538.

[27] The Matter of the South China Sea Arbitration (UNCLOS Annex VII Arbitral Tribunal, www.pcacases.com/pcadocs/MU-UK%2020150318%20Award.pdf, para. 945

[28] Birnie, P., Boyle, A. and Redgwell, C., International Law and the Environment, 3rd Ed., Oxford University Press, 2009, p. 466.

According to the Convention, Parties are "*…to take all practicable steps to prevent the pollution of the sea by the dumping of waste and other matter that is liable to create hazards to human health, to harm living resources and marine life, to damage amenities or to interfere with other legitimate uses of the sea*."[29] Dumping is also regulated in UNCLOS, but it is not strictly prohibited. UNCLOS only requires that states shall regulate and control pollution by dumping at sea.[30]

Both the London Convention and the London Protocol apply to all waters, except to the internal waters of states, hence including both the EEZ and the territorial sea of the states parties. This means that there is little or no room for states to allow any form of dumping in these areas, if not identified as an exception. In addition, the Protocol extends certain parts of its permit procedures to internal waters. The requirements of both instruments also apply to vessels and aircraft under the flag of the contracting parties, irrespective of their location, and to vessels loading in their territory/territorial sea.[31]

In the Baltic Sea region, Latvia and Lithuania are the only states that have not ratified either the London Convention or the London Protocol. The Russian Federation and Poland have currently not ratified the Protocol but are Parties to the Convention. Denmark, Estonia, Finland, Germany and Sweden are all parties to both instruments. If sea-based measures are to be taken in cooperation, the different levels of acceptance and ratification of the London Convention and Protocol could affect the possibilities to find a mutual understanding. Moreover, the London Protocol has adopted an amendment on geo-engineering; it is ratified only by Finland and the United Kingdom, which could affect the assessment of the permissibility of sea-based measures.[32]

The London Convention, like UNCLOS, defines dumping as "deliberate disposal at sea of wastes or other matter from vessels, aircraft, platforms or other man-made structures at sea."[33] However, the Convention also includes some exceptions to this definition. Discharge or waste occurring in the normal operation of ships or other forms of structures at sea are, for example, not included. Nor is deliberate "placement of matter for a purpose other than the mere disposal thereof" seen as dumping according to the Convention, as long as it does not contravene with the aim of the Convention.[34]

In brief, the general objective of the London Convention is that certain forms of dumping that are listed shall be prohibited and that those that are not prohibited require a permit.[35] The London Protocol goes further. All dumping shall be prohibited, with exception from certain wastes that are listed in its Annex I.[36] However, even the disposal of wastes that is not prohibited, i.e. those listed in Annex I, require a permit and even then the states are required to consider environmentally preferred alternatives.[37]

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[29] London Convention, Art I.
[30] UNCLOS, arts 210 and 216
[31] London Convention, Arts 6 and 7; London Protocol, Arts 7 and 10.
[32] London Protocol Art III(1); Resolution LC-LP.1(2008) on the Regulation of Ocean Fertilization, adopted on the Thirtieth Meeting of the Contracting Parties to the London Convention and the Third Meeting of the Contracting Parties to the London Protocol; see also Sands, P. and Peel, J., *Principles of International Environmental Law*, 3rd Ed., Cambridge University Press, 2012, p. 396.
[33] London Convention, Art III(1)a(i).
[34] London Convention, Art III(1)b
[35] London Convention, Art IV.
[36] London Protocol, Art 4(1)1.
[37] London Protocol, Art 4(1)2

The Protocol also introduces a specific obligation for the states parties to apply a precautionary approach to environmental protection from dumping, which is not mentioned in the Convention.[38]

5.2.2.3 The Espoo Convention

The Espoo Convention is applicable in the context of sea-based measures since such measures, regardless where they are applied in the Baltic Sea, might entail transboundary environmental impacts. The main obligation in the Espoo Convention is for states to “prevent, reduce and control significant adverse transboundary environmental impact from proposed activities.”[39]

Among the key requirements is to adopt an environmental impact assessment (EIA) and to consult with neighbouring states according to the Espoo Convention. Since potential environmental threats are not limited to the state that decides on a certain activity, the Espoo Convention requires that states take early action to avert danger by notifying and consulting with neighbouring states on major projects that are under consideration, which could have such impact on the environment beyond the national borders.[40] To this end, the Espoo Convention specifically lists certain activities that are always considered “likely to cause a significant adverse transboundary impact”.[41] This list includes, *inter alia*, “waste-disposal installations for the incineration, chemical treatment or landfill of toxic and dangerous wastes”,[42] but not dredging or other specifically marine activities.

The EIA rules may also be activated in relation to activities other than those listed, if they are likely to cause a significant adverse transboundary impact.[43] This option could be applicable in relation to sea-based measures, to the extent any such (likely) impact could extend beyond national borders.

Russia is the only Baltic Sea coastal state that is not a party to the Espoo Convention, but consultation and EIA is required by all other coastal states, also on the basis of the EU Directive on EIAs (discussed in section 5.2.4.3 below), and must at least be taken into consideration when studying the consequences and effects of the measures planned. There is also a parallel requirement in the Helsinki Convention that states that the parties should communicate their EIA when it is likely that an activity would cause significant adverse effects to the environment.[44] This obligation is only applicable to states that are subject to such requirements under other laws, such as the Espoo Convention, and is thus not creating any direct obligation for Russia. However, establishing an EIA and notifying the states concerned has been considered to represent a general principle of international environmental law under certain circumstances, hence placing limitations even for non-parties such as Russia.[45]

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[38] London Protocol, Art 3.
[39] Espoo Convention, Art 2(1).
[40] Espoo Convention, Art 2.
[41] Espoo Convention, Art. 2(2) and Appendix I.
[42] Espoo Convention, Appendix I (10).
[43] Espoo Convention, Art, 2(5).
[44] The Helsinki Convention, Art. 7.
[45] The ICJ Judgment in the Case Concerning Pulp Mills on the River Uruguay (Argentina v. Uruguay), Judgment of 20 April, recognizes EIAs as a duty under international law.

Based on such criteria, sea-based measures must be assessed in relation to where and at what scale they are undertaken. Measures in a closed bay or close to the coast seem less likely to have transboundary effects, despite the sensitivity of the sea. Conversely, if large-scale sea-based measures were to be undertaken in open waters, perhaps in one of the deep-sea basins of the Baltic Sea, measures are very likely to meet the criteria for triggering the requirements under the Espoo Convention.

5.2.2.4 The Convention on Biological Diversity

The objectives of the CBD are the conservation of biological diversity, the sustainable use of its components and the fair and equitable sharing of the benefits arising out of the utilization of genetic resources.[46] The convention is to be implemented in accordance with the particular conditions of each party and its specific environmental conditions. The parties, which includes all Baltic Sea states and the EU, are then to develop national strategies, plans or programmes for conservation of biological diversity and integrate the conservation and sustainable use of biological diversity into relevant sectoral plans, programmes and policies.[47] The provisions of the CBD apply within the area of its national jurisdiction or beyond the limits of national jurisdiction, in the case of processes and activities, regardless of where their effects occur, carried out under its jurisdiction or control.[48] Hence, sea-based measures undertaken by coastal states in the Baltic Sea will be subject to the rules of the CBD. However, Article 2(2) of the CBD provides that nothing in the convention shall affect rights or obligations under the law of the sea.

5.2.2.5 The Aarhus Convention

In the general legal framework for sea-based measures, also the Convention on Access to Information, Public Participation in Decision-making and Access to Justice in Environmental Matters (the Aarhus Convention) must be taken into account. The Aarhus Convention does not regulate or control offshore activities but sets out minimum requirements on states to provide rights for ‘the public’ to have access to information on projects and other environmental matters of their concern, and for ‘the public concerned’ to have the right to participate in environmental decision-making and have access to justice. ‘The public’ and ‘the public concerned’ specifically include non-governmental organizations (NGOs).[49] The objective of these rights is the protection of the right of every person of present and future generations to live in an environment adequate to his or her health and well-being.[50] The Aarhus Convention is ratified by all Baltic Sea coastal states, except Russia, and by the EU.

In a practical perspective, public participation and access to justice mean that the public will be provided with the possibility to take part in and, to some extent, influence decision-making in environmental matters, including, for example, national decisions on permits. Access to justice includes the right to appeal against court judgments in environmental

[46] The CBD, Art. 1.
[47] The CBD, Art 6.
[48] The CBD, Art 4 (b).
[49] The Aarhus Convention, Arts 2(4) and 2(5).
[50] The Aarhus Convention, Art 1.

matters. This may be of particular relevance in relation to sea-based measures, as it enables participation even in cases where persons, organizations or other representatives of 'the public' would normally not have such access due to the general requirement of having a direct and private interest at stake.

5.2.3 Environmental law principles

In addition to the substantive and procedural requirements in different fields, international environmental law includes a number of general principles. These principles have successively grown to become internationally acknowledged and are often integrated into international agreements, including those that are applicable in this context of sea-based measures.

Although the precise meaning of some of these principles may be debated, they generally reflect what should be regarded as minimum standards and general directions regarding how and to what extent environmental risks and effects should be addressed in the individual cases. Environmental law principles such as the precautionary principle, the polluter pays principle, the principles on the use of 'Best Available Technique', and 'Best Environmental Practices' represent regulatory responses to the need for proactivity and precaution in relation to the environment.[51] In contrast to rules, principles give direction without calling for a specific outcome, i.e. what an operator should or should not do. The environmental law principles are flexible in this regard and their application will always be related to the individual situation.

Many of the principles are written down in the more recent environmental treaties. The precautionary principle, for example, is written down, in somewhat different ways, in the Fish Stock Agreement, the CBD, the Helsinki Convention and the London Dumping Protocol. Many of them are also listed in Article 177 of TFEU.

5.2.4 Regional rules

5.2.4.1 The Helsinki Convention

The Helsinki Convention, being a convention specific to the environmental protection of the Baltic Sea, is of course highly relevant in the present context. It is the only instrument that directly regulates the marine environment of the Baltic Sea. The Helsinki Convention includes a wide range of activities within its scope. Its administrative organization, HELCOM, has been established as an important platform for monitoring, scientific cooperation, and data-collection, providing important prerequisites for developing more effective approaches in protecting the Baltic Sea environment. The HELCOM framework is then indirectly referred to in the many UNCLOS provisions that refer to further regional environmental collaboration and rule-development through the 'competent international organizations'. Similarly, the Helsinki Convention in itself also represents 'applicable

[51] Sands, P. and Peel, J., *Principles of International Environmental Law,* 3rd Ed, Cambridge University Press, 2012, pp. 187ff. Many of these principles are also listed in TFEU Article 191 as guiding principles for the EU's environmental policy.

international rules and standards', as far as such references refer to regional marine environmental law-making and enforcement.[52]

Through EU's formal participation in the Helsinki Convention, the latter also forms, at least in part, an integral part of EU law. This means that EU member states and the EU institutions can rely on EU's law enforcement apparatus and procedures, which are significantly more powerful than those of general international law that would otherwise apply for implementing the obligations of the Helsinki Convention. Case law at the Court of Justice of the European Union (CJEU or 'the Court') has also confirmed that EU's participation in an international convention has the effect that that the rules of the Convention (which fall under EU's competence) have precedence over EU directives and regulations.[53] A consequence of this is that if a clear and precise rule of the Helsinki Convention, or its Annexes, conflicts with an EU law, the Helsinki Convention shall prevail. This, however, does not extend to recommendations or other non-binding instruments adopted by HELCOM.

The main obligation of the Helsinki Convention is that "the Contracting Parties shall individually or jointly take all appropriate legislative, administrative or other relevant measures to prevent and eliminate pollution in order to promote the ecological restoration of the Baltic Sea Area and the preservation of its ecological balance."[54] The Helsinki Convention also requires that the environmental law principles listed in Article 3 are applied for any kind of measures taken.[55] Article 5 contains a requirement to eliminate and prevent pollution of harmful substances from all sources. According to the definition in Article 2(7) and the criteria found in Annex I of the Convention, harmful substances include any substance liable to cause pollution. This shall apply to anthropogenically produced substances liable to cause eutrophication, such as nitrogen and phosphorus compounds. These substances are also found in a priority group of harmful substances in Annex I, i.e. a list of substances that should be given priority by the parties in their implementation of preventive measures.

Beside the requirements found in the Convention provisions and its annexes, the substantive requirements are usually found in Recommendations, which is the main regulatory tool of HELCOM. The Convention has also been further developed in its structure and aim with the adoption of the Baltic Sea Action Plan (BSAP) in 2007, which puts further emphasis on key issues, such as eutrophication, and acknowledges the importance of an ecosystem approach. In terms of the ecosystem approach, the BSAP is also operationalizing the HELCOM Vision.[56]

All the Baltic Sea coastal states are parties to the Convention, which applies to the Baltic Sea area, including the internal waters of the coastal states.[57] From a substantive point of view, the Helsinki Convention including its annexes, recommendations and Action Plan

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[52] UNCLOS, Art 197 and Section 6 on Enforcement.
[53] See e.g. Case C-344/04 IATA and ELFAA, para. 35.
[54] The Helsinki Convention, Art 3(1).
[55] Helsinki Convention, Art 3 (2–6).
[56] "The aim is to reach HELCOM's vision for good environmental status in the Baltic Sea", BSAP Eutrophication segment, p. 7; The BSAP Preamble, p. 4. See also: "HELCOM Ecological Objectives for an Ecosystem Approach", document for HELCOM Stakeholder Conference on the Baltic Sea Action Plan, Helsinki, Finland, 7 March 2006, p. 1f., where HELCOM declares the connections between EU legislation, the CBD, the HELCOM Vision, its Ecological Objectives and the BSAP and furthermore states that the BSAP is the tool of implementation of an ecosystem approach.
[57] Helsinki Convention, Art 1.

contain little specific regulation concerning such activities that represent sea-based measures. Most requirements and approaches taken to combat eutrophication to date have focused on land-based sources and measures to reduce pollution from land. The general approach in the BSAP Policy and the related recommendations adopted in recent years have exclusively been focusing on how to encourage states to more effective and ambitious implementation of 'land-based measures'.[58] How this responds to the suggested sea-based measures, both in terms of legal obligations and general policy demands, will therefore be necessary to further assess. In section 5.3.4 below, it will be reviewed to what extent, if at all, the rules and principles that apply to other measures aimed at mitigating eutrophication can be applied by analogy to sea-based measures and, if so, in what circumstances.

5.2.4.2 EU laws for water and marine environment

5.2.4.2.1 General

There are several different kinds of EU laws that are relevant for a general approach to combat eutrophication. A first set of EU laws regulate activities related to land-based measures and sectors, and thus falls beyond the scope here. Another category of EU laws, which will be addressed here, consists of instruments that have a more general and process-oriented focus, based on the ecosystem approach, focusing specifically on water and the marine environment. The main rules of this kind are the Directive 2008/56/EC on establishing a framework for community action in the field of marine environmental policy (Marine Strategy Framework Directive, MSFD), the Directive 2000/60/EC on establishing a framework for Community action in the field of water policy (Water Framework Directive, WFD), and the Directive 2014/89/EU on establishing a framework for maritime spatial planning (Maritime Spatial Planning Directive, MSPD), which will be further presented in sections 5.2.4.2.2 and 5.2.4.2.3 below.

Moreover, certain EU environmental rules of more horizontal applicability will be of relevance for sea-based measures. The EIA Directive and the Waste Framework Directive will be discussed in sections 5.2.4.3 and 5.2.4.5, whereas the directives aimed at protecting biodiversity and nature, i.e. the Habitats and Birds Directives, are addressed in section 5.2.4.4. The Directive 2004/35/CE on environmental liability with regard to the prevention and remedying of environmental damage (Environmental Liability Directive, ELD) on obligations related to restoration of damage is dealt with separately in section 5.6.3.

The EU rules that specifically relate to the marine environment normally clarify their geographical scope. Hence, it is clear that the MSPD and the MSFD primarily apply to marine waters, defined as waters, the seabed and subsoil on the seaward side of the baseline extending to the outmost reach of the area where a member state has and/or exercises jurisdictional rights in accordance with the UNCLOS (i.e. up to 200 nm from the baseline).[59] The WFD applies to inland surface waters, transitional waters, coastal waters

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[58] See for example the HELCOM Copenhagen Ministerial Declaration, "*Taking Further Action to Implement the Baltic Sea Action Plan - Reaching Good Environmental Status for a healthy Baltic Sea"*, Copenhagen Denmark, 3 October 2013, including the acts adopted, HELCOM Palette of optional agro-environmental measures and Recommendations.
[59] MSFD, Art 3(1)a and b.

and groundwater.[60] Coastal waters, which according to the WFD is the surface waters on the landward side of a line 1 nm on the seaward side from the baseline.[61] The geographical scope of the MSFD and the WFD hence overlap, but the MSFD then only applies to coastal waters in so far as particular aspects of the environmental status of the marine environment are not already addressed through the WFD.[62]

5.2.4.2.2 MSFD and WFD

The MSFD and the WFD are complementary in scope and will be presented together here. The MSFD is the main legal act at EU level for the sea-based measures planned. The aim of the MSFD is for the states to adopt a marine strategy with a 'Programme of Measures' with the goal to achieve *good environmental status*.[63] The goal of good environmental status seen in relation to eutrophication means that "*human-induced eutrophication is minimised, especially adverse effects thereof, such as losses in biodiversity, ecosystem degradation, harmful algae blooms and oxygen deficiency in bottom waters*."[64]

The provisions in the MSFD include a requirement to restore marine ecosystems where they have been adversely affected.[65] The latter could include taking *inter alia* sea-based measures. The WFD, similar to the MSFD, adopts a general goal-oriented approach with the aim to achieve good status through adopting 'River Basin Management Plans' with 'Programmes of Measures'.[66] In order to operationalize the goal of good status in the WFD, however, member states are also to define the ecological objectives for each type of water. In order to achieve those ecological objectives, states are also obliged to take further supplementary measures in order to provide for improvement of the waters covered by the directive.

Both directives include a rule aimed at preventing environmental deterioration.[67] The CJEU has interpreted this rule strictly in its case law on the WFD, by ruling that any activity – in that case the activity concerned was dredging – that will lead to deterioration, even on a temporary basis, is prohibited by the non-deterioration rule. [68] This interpretation of the WFD significantly restricts the space given for taking sea-based measures in the internal and coastal waters (up to 1 nm from the baseline) to abate eutrophication. While it is not certain that a similar interpretation would apply to the MSFD, the ruling must be given consideration when making the choice of method or technology of sea-based measures, given the scientific uncertainties that are involved. Both the WFD and the MSFD also emphasize international law and the contribution to the enforcement of international agreements applicable to the subject matter. The international rules and principles discussed above will accordingly also have impact on how EU law is applied and understood here.

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[60] WFD, Arts 1 and 2.
[61] WFD, Art 2(7).
[62] MSFD, Art 3(1)b.
[63] MSFD, Arts 5(2)b and 13.
[64] MSFD, Arts 13(1), 9(1) and Annex I.
[65] MSFD, Art 1(2)b.
[66] WFD, Arts 1 and 11.
[67] MSFD, Art 1(2)a and WFD art 4.
[68] Case C-461/13 Bund v Germany (the Weser Case). See section 5.4.4.4.2 below.

5.2.4.2.3 MSPD

The MSPD creates a platform for the EU member states to make better planning for the use of maritime areas and the marine waters, taking into account the land-sea interface and interaction.[69] Maritime spatial planning aims at planning the uses of the sea, alongside other substantial or procedural limitations that may apply, such as nature conservation sites etc.

Under the MSPD, the member states shall set up maritime spatial plans that identify the spatial and temporal distribution of relevant existing and future activities and uses in their marine waters.[70] The plans will provide guidance to the usage of the different marine areas. Even if the plans are non-binding they will matter in relation to sea-based measure since the activities included in the plans should be given priority if other uses would be conflicting with the designated activities. However, the MSPD only applies to the marine waters of member states. It does therefore not apply to coastal waters or parts thereof falling under a member state’s town and country planning, provided that this is communicated in its maritime spatial plans.[71] Hence, for sea-based measures being pursued in the coastal areas or in the internal waters, which seems to be the case for the majority of prospective measures foreseen today, the national planning regulation will be more important.[72] The actual balancing and decisions in relation to planning will be made in the plans themselves, i.e. by national authorities.

5.2.4.3 The EIA Directive

The EIA Directive is not specifically connected to marine activities or the protection of the marine environment. It mainly requires that member states shall adopt measures to ensure that any project that is “likely to have significant effects on the environment”[73] is reviewed and made subject to a requirement for development consent.[74] This procedure should also include an EIA.[75] A project is defined as “the execution of construction works or of other installations or schemes” or “other interventions in the natural surroundings and landscape including those involving the extraction of mineral resources.”[76] Thus, it could apply to sea-based measures, even though the extent to which impacts must be assessed varies individually in relation to the specific activities. The Directive requires that member states adopt all measures necessary to ensure that, before development consent is given, projects likely to have significant effects on the environment by virtue, *inter alia*, of their nature, size or location are made subject to a requirement for development consent and an assessment with regard to their effects on the environment.[77]

[69] MSPD, Art 4.
[70] MSPD, Art. 8(1).
[71] MSPD, Art 2(1). Marine and coastal waters are defined by reference to the definitions in the MSFD and WFD.
[72] For the Swedish situation, see also Havs- och vattenmyndighetens (SwAM) rapport 2015:2, ”Havsplanering – nuläge 2014: Statlig planering i territorialhav och ekonomisk zon”, Diarienummer 137-2014, published February 2015, pp. 44ff. [in Swedish].
[73] EIA Directive, Art 1(1).
[74] EIA Directive, Art 2(1).
[75] EIA Directive, Art 2(2).
[76] EIA Directive, Art 1(2)a.
[77] EIA Directive, Art 2(1).

The Directive specifically lists types of projects that fall within the requirements.[78] It does not apply to projects that are adopted by a specific act of national legislation because, according to the objectives of the Directive, it is then seen as being achieved through the legislative process.[79]

The EIA Directive is also connected to the Espoo Convention and imposes a similar communication obligation on member states. If a member state is aware that a project is likely to have significant effects on the environment in another member state, it must inform the state concerned and provide, *inter alia*, a description of the project so that the state concerned can enter into consultations about the project.[80]

The Directive also outlines a number of criteria for which projects that must be subject to the different procedures are defined, as well as more specific requirements on the reports, assessments and processes. Article 4 states that for certain kinds of projects, listed in the Directive's Annex I, following the procedures and assessment requirements laid out in Articles 5-10 are obligatory.[81] None of these projects seems to match sea-based measures however. The more precise obligation that this involves for sea-based measures will be examined further in section 5.4.4.2.

5.2.4.4 The Habitats Directive and the Birds Directive

The Habitats and Birds directives primarily aim at protecting important habitats and species.[82] The purpose of these directives is to ensure biodiversity through the conservation of natural habitats, including of species protected in either the Habitats Directive or in the Birds Directive, so called Natura 2000 sights.[83] This aim is regulated both through a specific protection of different species as well as through requirements on the protection of habitats.[84]

The protection of these species and habitats is operationalized through preventing activities that could have significant adverse effects on protected species and habitats in these areas. The Natura 2000 habitats create a European ecological network of special areas of conservation.[85] The Habitats Directive thus requires that, in such areas, member states take appropriate steps to avoid the deterioration of natural habitats and the habitats of species as well as disturbance of the species for which the areas have been designated, in so far as such disturbance could be significant in relation to the objectives of the Directive.[86]

In such areas, a plan or project can only be permitted after it is ascertained that it will not adversely affect the integrity of the site concerned. This is required regardless of whether

[78] EIA Directive, Art. 4 and Annexes I and II.
[79] EIA Directive, Art 1 and 2; see also Langlet, D. and Mahmoudi, S., *EU Environmental Law and Policy*, Oxford University Press, Oxford, 2016, p. 159.
[80] EIA Directive, Art 7.
[81] EIA Directive, Art 4(1).
[82] Birds Directive, Arts 1 and 2; Habitats Directive, Art 2.
[83] Habitats Directive, Arts 2 and 3.
[84] Birds Directive, Arts 1-4; Habitats Directive, Arts 2-4
[85] Habitats Directive, Art 3(1).
[86] Habitats Directive, Art 6(2).

the project is planned to take place in the area or outside.[87] A similar provision exists in the CBD. The Habitats Directive is applicable in all the EU territory, i.e. in the territory of the member states and the EEZ and particularly in relation to those habitats and special protected areas designated by a member state.[88] If a member state, in other words, has designated an area for habitat protection, it will significantly restrict the use of the area and its surrounding, including the extent to which sea-based measures can be undertaken.[89]

The specific protection of species is relevant in this context to the extent that sea-based measures could pose a threat to a specific marine species, and this would limit the possibilities to take measures in relation to the directives. The protection of habitats at sea could similarly have an effect on the location of sea-based measures, since projects in or nearby a protected area are only permitted if it is certain that they will not adversely affect the area or its species.

On the other hand, another perspective is that sea-based measures could be encouraged if they are likely to enhance the marine environment in the protected area or create better conditions for a protected species in the longer run.

5.2.4.5 The Waste Framework Directive

The Waste Framework Directive lays down measures to protect the environment and human health by preventing or reducing the adverse impacts of the generation and management of waste and by reducing overall impacts of resource use and improving the efficiency of such use.[90] It sets the basic concepts and definitions related to waste management, such as definitions of waste, recycling and recovery. The aim and main requirement in the directive is that waste shall be managed without endangering human health and harming the environment, and it is based on, *inter alia*, the polluter pays principle.[91] It also clarifies the criteria for when waste ceases to be waste and on how to distinguish between waste and by-products.[92] While this directive is not directly applicable to marine activities and will mainly have impact through its implementation in the member states, it is still important to understand its basic principles and its potential significance for the operation of sea-based measures since it will, for example, set the frame for how to handle dredged materials and play an important role in the definition and potential recycling of such phosphorus-rich materials. An interesting and important thing to note here is the specific restriction of its application, stating that sediments being relocated inside surface water for different purposes, are only excluded for the scope of the directive as long as they are proven non-hazardous.[93]

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[87] Habitats Directive, Art 6(3).
[88] Habitats Directive, Art 2.
[89] Swedish Environmental Protection Agency (Naturvårdsverket), Report, ”Muddring och hantering av muddermassor: Vägledning om tillämpning av 11 och 15 kap Miljöbalken”, Miljörättsavdelningen 2010- 02-18, pp. 34ff. [in Swedish].
[90] Waste Directive, Art 1.
[91] Waste Directive, Arts 13 and 14.
[92] Waste Directive, Arts 5 and 6.
[93] Waste Directive, Art 2(3).

5.2.5 National law

5.2.5.1 General

Since the suggested measures will be subject to national implementation, it is relevant to assess what national laws apply. The main focus is on Finnish law, but applicable Swedish legislation will also be reviewed. Both Finnish and Swedish national regulatory systems have two types of rules that are relevant with respect to sea-based measures. The first set of rules are broad and generally applicable, as they apply to most activities that could potentially cause environmental harm. This category includes the environmental law principles, requirements to make an EIA, MSP and the procedures for applying for an environmental permit. In addition, for some of the sea-based measures discussed, there are the more specific rules and requirements that (potentially) apply to those activities only. In this section, the applicable national legal framework will be presented briefly to provide an overview. The more specific laws and their application to the suggested measures is assessed in more detail in section 4.

5.2.5.2 Finland

5.2.5.2.1 Environmental Protection Act

The main Finnish law applicable to environmental issues is the Environmental Protection Act[94] (527/2014), the objectives of which include preventing pollution of the environment and the danger of it, preventing and reducing emissions, removing damage caused by pollution and preventing environmental damage. Other objectives of the Act are to reduce the amount and harmfulness of waste and prevent the harmful effects of waste, to improve and integrate assessment of the impact of activities that pollute the environment and to improve citizens' opportunities to influence decisions concerning the environment.

The Environmental Protection Act targets emissions and aims at preventing the contamination of the environment caused by the emissions. It is applied to industrial and other activities that cause or may cause environmental degradation, to activities that generate waste and to waste management. The Act includes both material and procedural requirements e.g. on permit requirements, special prohibitions pertaining to the sea and a number of general rules giving effect to environmental law principles, such as:

- the prevention or reduction of harmful impacts (principle of preventing and minimizing harmful impact);
- the exercise of proper care and caution to prevent pollution (principle of caution and care);
- the use of best available technique (BAT principle);
- the use of best practices to prevent pollution (principle of environmentally best use); and

[94] It must be noted that the English translations of the Finnish regulation are unofficial and Finnish law is binding only in Finnish or Swedish.

- the duty to prevent or minimize harmful impacts of parties engaged in activities that pose a risk of pollution (polluter pays principle).[95]

The Act applies in Finnish territorial waters and EEZ. For activities beyond these areas, including in other states' waters, the Act on the Protection of the Marine Environment (1415/1994) applies.

The key instrument through which the Environment Protection Act operates is the integrated permit system, which covers essentially all sectors. The Act also defines duties for operators, including their knowledge requirement, which means that operators must have sufficient knowledge of their activities' environmental impacts and risks, as well as of ways to reduce harmful effects and to prevent pollution.[96]

Chapter 2 of the Act contains general obligations, principles and prohibitions, the most relevant in the present context being the special prohibition pertaining to the sea in section 18. Under this provision, no action may be taken in Finnish waters (i.e. internal waters, territorial sea and the EEZ) that may cause marine pollution outside those waters.

The general supervisory authorities referred to in the Act are the Centre for Economic Development, Transport and the Environment (State supervisory authority) and the municipal environmental protection authorities.[97] However, the regional reform that is currently under preparation in Finland will imply changes in the competent authorities. According to the proposition, the new region (county) organisations will take over some of the tasks of the Centres for Economic Development, Transport and the Environment, Employment and Economic Development Offices, regional councils and municipalities. The Centres for Economic Development, Transport and the Environment and regional councils will cease to exist as from 1 January 2020. All statutory duties handled by the regional councils will be transferred to the counties, as will some of the duties of the Centres for Economic Development, Transport and the Environment. The current six Regional State Administrative Agencies will be formed into a single authority with nationwide responsibilities. The new regional state authority will operate in regional units or offices. Environmental supervision and nature conservation, handled by the Centres for Economic Development, Transport and the Environment, will be merged into the regional state authority.[98]

Chapter 18 of the Environmental Protection Act concerns control and administrative compulsion. The state control authority and the municipal environmental protection authority must, for example, regularly monitor the activities that require an environmental permit or registration. Section 175 concerns the rectification of a violation or negligence. A supervisory authority may prohibit a party that violates the Act or a decree or regulation based on it from continuing or repeating a procedure contrary to a provision or regulation, or order the party to fulfil its duty in some other way. Respectively, the authority can order the party to restore the environment to what it was before or to eliminate the harm to the environment caused by the violation; or to order an operator to conduct an investigation on a scale sufficient to establish the environmental impact of operations if there is justified cause to suspect that they are causing pollution contrary to the Act

[95] Borgström, Suvi & Koivurova, Timo 2016: Environmental Law in Finland, p. 45.
[96] Borgström, Suvi & Koivurova, Timo 2016: Environmental Law in Finland, p. 45.
[97] Section 23 of the Environmental Protection Act.
[98] See more: www.alueuudistus.fi/en.

Section 225 of the Act concerns sanctions and Section 224 refers to Chapter 48 of the Penal Code (39/1889) containing penal provisions on environmental desecration. Penalties for environmental offences range from fines to imprisonment for up to six years. The sanction for an environmental offence regulated in the Environmental Protection Act is fines, while the more severe environmental penal provisions have been transferred to the Penal Code.

According to Section 225 of the Act, one who deliberately or through negligence e.g. neglects his or her duty laid down in a permit condition of an environmental permit or breaches the special prohibition pertaining to the sea laid down in Section 18, shall be fined for violation of the Environmental Protection Act, unless a more severe punishment is provided for elsewhere in the law.

Chapter 48 of the Penal Code contains regulations on environmental offences. A person who intentionally or through gross negligence, *inter alia*, introduces, emits or disposes into the environment an object, a substance, radiation or something similar in violation of the law, a provision based on law, a general or a specific order, or without a permit required by law or in violation of permit conditions, so that the act is conducive to causing contamination of the environment, other corresponding environmental despoliation or littering or a health hazard, shall be sentenced for impairment of the environment.[99] The chapter also includes provisions on aggravated impairment of the environment, environmental infraction and negligent impairment of the environment.

Chapter 9 of the Penal Code concerns corporate criminal liability, which according to Section 9 of Chapter 48 can also be applied on environmental offences. A corporation or other legal entity can be sentenced to a corporate fine if a person who is part of the entity's statutory organ or other management or who exercises actual decision-making authority therein has been an accomplice in an offence. A corporate fine can also be sentenced if such a person has allowed the commission of the offence or if the care and diligence necessary for the prevention of the offence have not been observed in the operations of the corporation.[100]

The environmental permit procedure[101]

Chapter 4 of the Environmental Protection Act contains provisions on the need of an environmental permit. A permit is required for activities that cause a risk of pollution, which is broadly defined. The activities subject to a permit are prescribed in more detail in appendices 1 and 2. In addition, an environmental permit is also required e.g. for activities that may cause pollution of a water body and the project in question is not subject to a permit under the Water Act, or for activities that may place an unreasonable burden on the

[99] Section 1 of Chapter 48 of the Penal Code.
[100] Section 2(1) of Chapter 9 of the Penal Code.
[101] During the making of this study, a draft law by the Ministry of the Environment on the simplification of the permit procedures is on a circulation of a proposal for comment. The revision would concern environmental permits, permits under the Water Act, exemption decisions under the Nature Conservation Act, environmental impact assessments and building permits. The aim is to coordinate and merge different procedures, such as consultations, in line with the 'one-stop shop' principle to make the permit procedure easier for the customer. Also the EIA and permit procedures would be coordinated. The legal basis for the decisions would remain unchanged. The aim is for the government's proposal to be submitted to Parliament in spring 2018. This amendment would change the procedures and authorities described in this study. See more: www.ym.fi/fi-FI/content/40604/25516.

surroundings, as referred to in the Adjoining Properties Act (26/1920).[102] Section 27(2)(1) on the requirement of a permit for activities that may cause pollution of a water body is especially significant in the context of sea-based measures. A permit is also required for any substantial alteration of an activity.[103]

There are some exceptions to the requirement of obtaining a permit. In Section 31, derogations from the permit requirement are granted for certain experimental activities that then only require a notification. However, an environment permit is required also for these activities if there is a risk for consequences mentioned in Subsection 2 of Section 27, e.g. pollution of a water body.

The competent authority for granting the permit is either the Regional State Administrative Agency or a Municipal Environment Authority, depending on the scale of the activity and the significance of environmental effects.[104] If a permit is required e.g. under Section 27(2)(1), the Regional State Administrative Agency shall decide on the application. If the activity is also subject to a permit under Chapter 3 of the Water Act, permit applications must be handled through joint processing in accordance with Section 47. The competence of the authorities is regulated more precisely in Sections 1 and 2 of the Government Decree on Environmental Protection (713/2014).

The provisions on permit application and permit procedure are laid down in Chapter 5 of the Act. Section 39 includes the specific requirements for the content of a permit application, for instance the EIA in accordance with the Act on Environmental Impact Assessment Procedure (252/2017). If an environmental impact assessment is needed according to the Act on Environmental Impact Assessment Procedure, the application shall also include the necessary Environmental Impact Assessment Statement. In addition, the assessment referred to in Section 65 of the Nature Conservation Act (1096/1996) shall also be enclosed in the application, as necessary.

Chapter 6 contains sections on permit consideration and permit regulations. Sections dealing with conditions for monitoring and supervision, obtaining a financial guarantee, and the provisions for reviewing the permit can be found in Chapter 6 of the Act. Chapter 13 concerns compensations and Chapter 15 the state of the environment.

5.2.5.2.2 The Water Act

The purpose of the Water Act (587/2011) is to promote, organise and coordinate the use of water resources and the aquatic environment, so as to render it socially, economically and ecologically sustainable, to prevent and reduce the adverse effects of water and the use of the aquatic environment, and to improve the state of water resources and the aquatic environment. The Water Act applies in Finnish waters (internal waters and territorial sea) and in the EEZ.[105]

The Water Act applies to water resource management issues, as further defined in section 3(1) of Chapter 1 of the Act. A water resource management project refers to a water or

[102] Section 27 of the Act.
[103] Section 29 of the Act.
[104] Section 34 of the Act.
[105] Section 4 of Chapter 1 of the Act.

land operation or use of an installation, which may affect surface water or groundwater, water environment, water resources engineering, or the use of waters. According to Section 2 of Chapter 1, the provisions of the Environmental Protection Act apply to any water resources management issues that poses a threat of pollution of water bodies and that are not subject to a permit in accordance with the Water Act.

The chapters of importance for this study are mainly chapters 2 and 3. Chapter 2 of the Water Act contains provisions on e.g. placing a cable in other's area in a river or a stream (Section 5a), general obligations for the use of water resources and water areas (Section 7) and the right to use an area or a structure belonging to another party (Section 13). Chapter 3 covers the permit system.

Chapter 13 contains regulation on compensation, Chapter 14 on supervision and administrative enforcement, Chapter 15 on appeal and implementation of a decision and Chapter 16 on penal provisions. Penal provisions for impairment of the environment in violation of the Water Act are laid down in Chapter 48, sections 1–4, of the Penal Code. Penal provisions on committing criminal mischief, aggravated criminal mischief, negligent endangerment or gross negligent endangerment by causing a flood are laid down in Chapter 34, sections 1, 3, 7 and 8, of the Penal Code. Minor offences for breaching the Water Act are laid down in Chapter 16 of the Water Act and are punishable by fine.

Closer regulation on water resource management projects and the permit contents are laid down in the Government Decree on Water Resource Issues (2011/1560).

Permit under the Water Act

While an environmental permit according to the Environmental Protection Act is an instrument for emission and pollution control, structural changes caused by water management projects are regulated through the water permit scheme according to the Water Act. In many cases, an activity requires both a water permit and an environmental permit, and in those cases, permit applications must be handled through joint processing in accordance with Section 47, as referred to in the previous section (5.2.5.2.1).

Chapter 3 of the Water Act covers projects subject to a permit and applies to all water resource management projects, unless otherwise is provided. The Chapter contains provisions on e.g. the general permit requirements, the projects that are always subject to a permit, general conditions for granting a permit, and permit regulations. The competent authority for granting the permit is the Regional State Administrative Agency, while the Centre for Economic Development, Transport and the Environment and the Municipal Environment Authority serve as the supervisory authorities. Chapter 11 provides more specific provisions on the application procedure and e.g. the content of the permit application.

5.2.5.2.3 Act on the Protection of the Marine Environment

The Act on the Protection of the Marine Environment (1415/1994) applies to Finnish vessels or individuals operating outside of the Finnish territorial sea and EEZ. Section 1 of the Act contains a prohibition pertaining to the sea similar to the one in Section 18 of the Environmental Protection Act. Under that provision, no Finnish vessel, offshore unit or aircraft may, outside the Finnish EEZ, engage in activities that may cause pollution of the sea. In addition, a Finnish citizen or a legal person shall not engage in activities that may cause pollution of the sea. Such activities, which cause pollution of the sea, are considered to be activities from which directly or indirectly end up in the sea substance or energy, which may endanger human health, damage to living resources or marine life, prevent fishing or other legitimate uses of the sea, degrade the marine potential, reduce cosiness or otherwise cause comparable disadvantage. In addition to the first Section, the Act also applies in other marine protection outside the Finnish EEZ.

Section 7 of the Act on the Protection of the Marine Environment contains a ban on dumping ("*mereen laskemista koskeva kielto*"). No waste or other material shall be dumped in the sea outside the Finnish EEZ by a Finnish vessel, an offshore unit or an aircraft or a ship or aircraft loaded with waste in Finland. The dumping of waste originating from Finland is also otherwise prohibited. However, these prohibitions do not apply to dumping of the dredged material referred to in Section 9 of the Act or the geological storage of carbon dioxide as referred to in Section 4 of the Act on Capturing and Storage of Carbon (416/2012). The Act also contains a definition of the use of the best available technique.[106]

According to the regulation on dumping of dredged materials outside of the Finnish EEZ in Section 9, a permit is required from the Finnish Environmental Institute unless a due permit has been given by the other state's authority. According to Section 10, constructions outside the Finnish EEZ in the high seas require a permit from the Finnish Environment Institute. If the construction extends to the EEZ or the territorial seas, the permit is given by the Regional State Administrative Agency of Southern Finland. Section 11 concerns the permit for exploration and exploitation of the seabed and its interior outside the Finnish continental shelf. Again, a permit by the Finnish Environment Institute is needed for such activities unless a due permit has been given by the other state's authority.

5.2.5.2.4 Act on the Organisation of River Basin Management and the Marine Strategy

The Act on the Organisation of River Basin Management and the Marine Strategy (1299/2004, below: "*the Water Resource Management Act*") implements the Marine Strategy Framework Directive and the Water Framework Directive. The Act lays down provisions on the organisation of river basin management and development and implementation of the marine strategy, the related analysis work, cooperation and participation within the river basin districts and marine strategy implementation area, and international cooperation.

The general objective of the Act is to protect, improve and restore waters and the Baltic Sea in such a way that the status of surface waters, groundwater or the Baltic Sea does not deteriorate and remains at least 'good'. River basin management and work on the marine strategy are carried out and implemented in a coordinated manner and with coherent objectives.

The purpose of the Water Resource Management Act is that water management, besides the water quality, also takes into account the sufficiency and sustainable use of waters,

[106] Section 6 of the Act.

water services and economic analyses, flood risk management, recreational use of waters, waterborne diseases, and protection of aquatic ecosystems and terrestrial ecosystems and wetlands directly connected to aquatic ecosystems. Chapter 2 of the Act includes provisions on the status of waters.

In the organisation of the development and planning of the marine strategy, an ecosystem-based approach to the management of human activities causing pressures on and impacting the marine environment is applied in such a way that achieving good environmental status of the marine environment or the capacity of marine ecosystems to respond to human-induced changes is not compromised, while enabling the sustainable use of marine goods and services.[107]

Chapter 3 of the Act regulates the river basin management plans and programmes of measures. The river basin management plans are drawn up for river basin districts, each consisting of one or more river basins.[108] The river basin management plans affect the inner waters and reach out to up to 1nm from the baseline as regulated in the WFD. This covers a significant part of the Finnish sea areas, including all archipelagoes. Chapter 4 of the Act includes regulations on the environmental objectives in the river basin management plans and the possibilities of derogating from the objectives on the grounds of a significant new project. When the Water Resource Management Act and its environmental objectives were passed, it was interpreted to be less binding than what is now seen in the light of both EU and national case law.[109]

Chapter 4a regulates the organisation of the development and implementation of the marine strategy. To organise the development and implementation of the marine strategy, the Ministry of the Environment draws up, in cooperation with the Ministry of Agriculture and Forestry and Ministry of Transport and Communications, a marine strategy document for the Finnish marine waters. The marine strategy document shall present measures for protecting and preserving the marine environment, for preventing the deterioration of its status and for safeguarding and restoring marine ecosystems in a way that good environmental status of the marine environment can be maintained or achieved by 2020.[110]

The marine strategy shall be taken into account when drawing up and reviewing a river basin management plan. A programme of measures of the marine strategy document shall be drawn up by the Centre for Economic Development, Transport and the Environment. Additionally, monitoring programmes shall be established and implemented for the ongoing assessment of the status of the marine environment. Further provisions on the organisation of the development and implementation of the marine strategy are laid down in Government Decree on the Organisation of the Development and Implementation of the Marine Strategy (980/2011).

The regional reform of Finland will also affect the river basin management and the marine strategy. According to the Government proposal HE 15/2017, the regional management of river basin management and the marine strategy would be transferred to the new

[107] Water Resource Management Act, section 1.
[108] Sections 3 and 11 of the Water Resource Management Act.
[109] See the Weser Case and Belinskij, Antti & Paloniitty, Tiina 2015: Poikkeaminen vesienhoidon ympäristötavoitteista uuden hankkeen takia.
[110] Water Resource Management Act, Section 26b.

counties. The contents of the law will remain the same but the responsible organisations will change.[111]

5.2.5.2.5 Nature Conservation Act

The backbone of Finnish nature conservation law is the Nature Conservation Act (1096/1996), which is the key instrument implementing the EU's Habitats and Birds Directives. The protected areas set requirements and constraints to the use of sea-based measures if they have potential effect on the areas. The Act includes provisions on the establishment and management of protected areas, protection of habitats and species, prevention of the spread of invasive alien species and restriction on the trade of endangered species.[112]

Nature reserves constitute of national parks, strict nature reserves and other nature reserves. Chapter 2 includes provisions on the planning of nature conservation and Chapter 3 on the nature conservation areas. Sections 13–14 in Chapter 3 of the Nature Conservation Act lay down provisions on the protection orders that are observed on nature reserves, and any exceptions to them.

Most of the protected areas in Finland are included in the Natura 2000 network of protected areas. The rules for the management of the Natura 2000 network are laid down in Article 6 of the Habitats Directive. Provisions are included in Chapter 10 of the Nature Conservation Act. Moreover, Chapter 8 contains provisions on injunctions, coercive measures and penalties. The penalty for causing damage to the environment, or for any other nature conservation offence, is laid down in Chapter 48, sections 1–5, of the Penal Code. Minor offences are punishable by fine under the Nature Conservation Act.

Finally, Section 5a of the Nature Conservation Act contains provisions on damage to protected species and natural habitats and Section 57a on prevention and remediation of damage to protected species and natural habitats.

5.2.5.2.6 Land Use and Building Act

The Land Use and Building Act (132/1999) contains the most important regulations controlling land use, spatial planning and construction in Finland. The Act is also applied in the Finnish waters, where the plans by municipalities and regions affect the use of waters as well as potential sea-based measures.

The MSPD is implemented in Finland mostly through Chapter 8a (Sections 67a – 67d) of this Act. Maritime spatial planning can promote the achievement of a good environmental status of the Baltic Sea and is accordingly included as one of the measures in the programme of measures of the national marine strategy.[113]

According to Section 67b of the Act, maritime spatial plans shall be drawn up for the Finnish waters and the EEZ. The preparation and approval of the maritime spatial plans is

[111] See more HE 15/2017, "*Yksityiskohtaiset perustelut*", "*2 luku Maakunnan tehtävät*".
[112] Borgström, Suvi & Koivurova, Timo 2016: Environmental Law in Finland.
[113] Kaituri et.al.: Merialuesuunnittelun lähtökohtia. Ympäristöministeriön raportteja 15/2017, p. 15.

governed by those Regional Councils whose areas contain territorial waters. The Regional Councils must prepare the maritime spatial plans in co-operation and the plans must be reconciled.

More detailed provisions on the presentation of the maritime spatial plan and the number, planning areas and deadlines of maritime spatial plans are given by the Government Decree on Maritime spatial Planning (816/2016). Under it, three maritime spatial plans shall be drawn so that the borders follow the borders between the regions of Helsinki-Uusimaa and Southwest Finland, and Satakunta and Ostrobothnia.

In Finland, the maritime spatial planning process is only at its beginning, so its contents are not yet known, but territorial plans and territorial reservations by municipalities and regions have already been made in some sea areas. In the Government proposal for regional reform, the responsibility for maritime spatial planning is foreseen to be transferred to the new counties.[114] The timing follows the Directive meaning that plans be draw up and accepted before the end of March 2021. The accuracy of the plans shall be reviewed at least every ten years.

5.2.5.2.7 Act on the Finnish Exclusive Economic Zone

Finland established its EEZ in 2004 by enacting the Act on the Finnish EEZ (1058/2004), which defines the EEZ and the rights and jurisdiction of the state in this zone. The Act also prescribes that the specified environment and wildlife protection legislation and Finnish Penal Code shall apply in the EEZ, defines offences relating to fishing, hunting, mining and the environment in general and provides with respect to enforcement and legal proceedings. The Act on the Finnish EEZ repealed the Continental Shelf Act of 1965, and the continental shelf is nowadays equivalent to the EEZ.[115]

The Act contains provisions on the rights of the Finnish state in the EEZ to explore and exploit the zone and to conserve and manage the natural resources. The state also has jurisdiction over establishing installations and other structures and to protection of the marine environment and marine scientific research. It is also established that, *inter alia*, the following laws apply in the EEZ: the Act on Environmental Impact Assessment Procedure, the Environmental Protection Act, the Water Act, the Water Resource Management Act and the maritime spatial planning regulations in the Land Use and Building Act. Furthermore, the Waste Act shall be applied as provided for separately. The Water Act shall be applied to e.g. the extraction of soil materials in the EEZ.

The Government may, on application, give its consent to the exploitation of natural resources of the seabed and its subsoil located in the EEZ and to exploration aimed at such exploitation or to carrying on of other activities aimed at the economic exploitation of the zone. Additionally, the Government may, on application, give its consent to the construction and use of installations and other structures used in activities referred to above and such other installations and structures that may interfere with the exercise, in the EEZ, of rights that according to international law belong to Finland.[116]

[114] HE 15/2017, Section 6 of the law proposal.
[115] See more: Koivurova, Timo; Ringbom, Henrik; Kleemola-Juntunen, Pirjo 2017: Merioikeus ja Itämeri, p. 50.
[116] Section 7 of the Act.

5.2.5.2.8 Legislation on territorial waters

The Act on the Delimitation of the Territorial Waters of Finland (463/1956) defines the Finnish territorial waters. The territorial waters consist of internal waters and external waters or the territorial sea. The state owns the territorial waters and the seabed in the territorial waters outside of municipality borders.[117] Inside the municipality borders, the water areas can be owned by municipalities or by private parties.

5.2.5.2.9 Waste Act

The purpose of the Waste Act (646/2011) is to prevent the hazard and harm to human health and the environment posed by waste and waste management, to reduce the amount and harmfulness of waste, to promote the sustainable use of natural resources, to ensure functioning waste management, and to prevent littering. Further provisions on preventing pollution of the environment by waste are laid down in the Environmental Protection Act. The Act sets the frame in Finland for how to handle dredged materials and potentially recycle such phosphorus rich materials. The Finnish waste legislation is largely based on EU legislation, i.e. the Waste Framework Directive (section 5.2.4.5 above).

5.2.5.2.10 Conclusion

The picture below summarizes the maritime zones as defined by UNCLOS. In addition, the additional 1 nm limit introduced by the WFD is added, along with the relevant plans and strategies under the Finnish legislation. The same setting applies in Sweden, but it should be noted that neither country can make full use of the extent of their 200nm EEZ/continental shelf, due to the proximity of a neighbouring opposite state.

[117] Act on the Right to General Waters (Laki oikeudesta yleisiin vesialueisiin) 1966/204, Section 1.

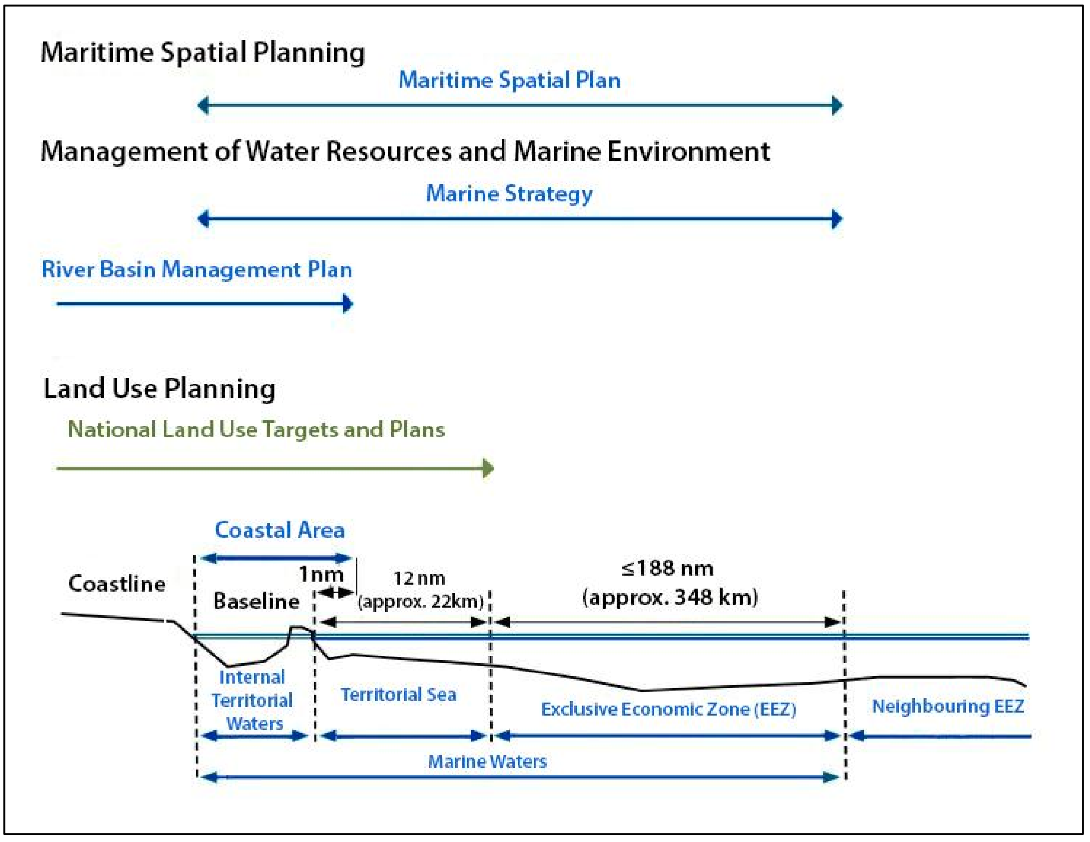

Figure 45. The geographical distribution of different plans in the maritime zones. Source: Kaituri et.al. 2017: Merialuesuunnittelun lähtökohtia. Ympäristöministeriön raportteja 15/2017, p. 17.

5.2.5.3 Sweden

5.2.5.3.1 Introduction

Swedish environmental law builds mainly on the Swedish Environmental Code (1998:808) ("Miljöbalken"). The general purpose of the Swedish Environmental Code is to promote sustainable development.[118] The Environmental Code applies to all activities which could cause negative impacts on human health or the environment and thus to all persons and operators who undertake activities or measures which may have an impact on the fulfilment of the objectives of the Environmental Code. Hence, the Environmental Code also applies to the kind of activities reviewed in this study since all of them they may entail risks for the marine environment.

The Swedish Environmental Code is designed to provide a basic framework for environmental legislation. Its provisions do not generally include detailed requirements.

[118] Env. Code (1998:808), Chapter 1, Section 1.

Instead, in a more adaptive approach, detailed provisions on issues that are ocean-related and concerning the Baltic Sea are laid down in ordinances issued by the Government or in regulations issued by government agencies, such as the Swedish Environmental Protection Agency or the Swedish Agency for Marine and Water Management (SwAM). Much of Sweden's transposition of EU law is done through governmental ordinances and regulations by government agencies. Furthermore, the government agencies issue general guidelines providing assistance concerning the interpretation of the Environmental Code and underlying legislation.[119]

All acts that involve environmental legislation are not, however, included in the Environmental Code. Much of the more specific legislation for certain sectors and activities that do not have environmental protection as their principal purpose are still regulated in separate legal acts, and come into play in parallel to the Environmental Code.[120]

5.2.5.3.2 Relevant parts of the Environmental Code

The most important part of the Swedish Environmental Code is Chapter 2, which includes the 'General Rules of Consideration'. These general rules constitute fundamental principles for the application of the Environmental Code, and they apply to all activities that have an impact on the environment, regardless of the extent or scale of the activity. Consequently, these principles must, for example, be applied when setting conditions for permits or in matters regarding environmental supervision.[121]

Among the principles included in the general rules of consideration is the burden of proof principle[122], which states that it is the party who pursues an activity that must prove that the obligations arising out of the Code are complied with. This Chapter also includes the precautionary principle[123] – with emphasis on taking preventive measures but also including the precautionary aspect – and the principle of Best Available Technique[124], the polluter pays principle[125] and a principle that requires that the party who pursues an activity with potentially adverse effects on the environment must have, or collect, all relevant knowledge[126] about the activity and its potential consequences. The rule on relevant knowledge is linked to the preventive and the precautionary principle, as well as to the principle on the burden of proof, since knowledge is a precondition for making sure that all relevant measures needed to prevent harm to the environment is taken. The Chapter on general rules of consideration, however, also includes a proportionality principle, stating that the general rules of consideration apply as long as they are not unreasonable, measured in terms of environmental effects and economic reasonability.[127]

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[119] For a more thorough introduction and review of the Swedish environmental law, see also Swedish Environmental Protection Agency (Naturvårdsverket), Report 6790 – October 2017, "Swedish Environmental Law - An introduction to the Swedish legal system for environmental protection".
[120] Env. Code, Chapter 1, Section 3.
[121] Env. Code, Chapter 2, Section 1.
[122] Env. Code, Chapter 2, Section 1.
[123] Env. Code, Chapter 2, Section 3.
[124] Env. Code, Chapter 2, Section 3.
[125] Env. Code, Chapter 2, Section 8.
[126] Env. Code, Chapter 2, Section 2.
[127] Env. Code, Chapter 2, Section 7.

In addition to the general rules of consideration, the Environmental Code includes a number of Chapters that more specifically address certain activities or procedures. Chapter 5 regulates Environmental Quality Standards (EQS) which the Government may issue for certain geographical areas or the country as a whole, concerning the quality of land, water, air or the environment in general, if it is necessary for the protection of human health or the environment etc.[128] With certain limited exceptions, permits, approvals and exemptions cannot be granted for activities which are likely to lead to non-compliance with some forms of the EQSs.[129] The permit authority may revise a permit for an activity with respect to the permissible volume of production or the scope of the activity, alter or cancel conditions or other provisions, or issue new provisions where the activity is to a significant extent responsible for an infringement of an EQS.[130] The regulation on EQS in Chapter 5 to a large extent incorporates the WFD into the Swedish law.[131] The more detailed regulation of the water management system of the WFD is found in lower level legislation, fundamentally in Ordinance 2004:660 on Management of Water Quality and Environment (the Water Management Ordinance, "*Förordning om förvaltning av kvaliteten på vattenmiljön*"),[132] and then further regulated in the quality norms, etc., on water district level.

The MSFD is also implemented with support in Chapter 5 of the Environmental Code, although most of its provisions are found in Ordinance 2010:1341 on Marine Environment, ("*Havsmiljöförordning*"), delegating further legislative powers to SwAM. SwAM, in turn, delegates some responsibilities to other Swedish agencies, but the powers given to SwAM primarily means that SwAM is in charge of the international collaborations that the MSFD demands.[133]

Chapter 6 is the Swedish implementation of the EIA Directive, and the Directive on the assessment of the effects of certain plans and programmes on the environment (2001/42/EC), (the SEA Directive), as well as the Espoo Convention, requiring operators and agencies to present Environmental Impact Assessments (EIA) and Environmental Impact Statements (EIS) for a plan or a project with potential adverse effects for the environment. Chapter 6 in the Environmental Code, however, also provides additional requirements for procedures that exceed the requirements under international and EU law. To some extent, the Chapter also reflects parts of the Aarhus Convention in that it requires that the process of making an EIS and an EIA includes not only the relevant authorities but also the members of the public that are concerned, and that information about plans

[128] Env Code, Chapter 5, Section 1; Swedish Environmental Protection Agency (Naturvårdsverket), Report 6790, p. 18.

[129] In April 2018 the Swedish Government proposed changes in the Swedish legislation that would enter into force in January 2019, to make it more coherent with the Weser Judgment, Regeringens proposition 2017/18:243 Vattenmiljö och vattenkraft (Prepatory of changes to parts of the Swedish legislation for the aquatic environment and hydropower).

[130] Env. Code, Chapter 2, Section 7; Chapter 5; Chapter 24. See also Swedish Environmental Protection Agency (Naturvårdsverket), Report 6790, p. 19

[131] Env. Code, Chapter 5, Sections 10–12.

[132] Ordinance (2004:660) on the Management of Water Quality and Environment, as amended (2018:77). See also Annika K. Nilsson, "Regulating Zero Eutrophication: Swedish Law on Controlling Emissions of Nutrients to the Baltic Sea", part of *Country Studies*, published digitally on the official web page of Stockholm University and BEAM, pp. 47f.

[133] The Ordinance (2010:1341) on Marine Environment, Sections 1 and 8; SwAM web page: https://www.havochvatten.se/hav/samordning--fakta/miljomal--direktiv/havsmiljodirektivet/organisation-och-ansvarsomraden-for-havsmiljodirektivet.html [2018-01-21 in Swedish]. See also Annika K. Nilsson, "Regulating Zero Eutrophication: Swedish Law on Controlling Emissions of Nutrients to the Baltic Sea", part of *Country Studies*, published digitally on the official web page of Stockholm University and BEAM, pp. 47f.

and projects are officially announced. The EIS must describe the impact of the activity or plan on people, flora and fauna, land, water, air, the climate, the landscape and the cultural environment, on the management of land, water and the physical environment in general and on the management of materials, raw materials and energy.[134]

Chapters 7 and 8 regulate different forms of nature protection, including Natura 2000. Chapter 7 clearly states that the Natura 2000 regulation is applicable also in the EEZ.[135] More general provisions for management of land and water areas are found in Chapters 3 and 4. These Chapters include balancing principles for the use of land and waters areas, including other forms of protection for areas other than the nature conservation regulations that are in focus of Chapter 7. Chapter 4 includes different land and waters areas that are specifically targeted to be protected by different forms of exploitation, not least areas along the coastline. Chapter 4 integrates and implements the rules on maritime spatial planning laws from the MSPD, with requirements for the Water Authorities to create plans for the coastal areas.[136]

Chapters 9 to 15 contain provisions concerning certain specific activities, of which some are particularly relevant here. Chapter 9 concerns environmentally hazardous activities and to some extent frames the requirements on permits for such activities, Chapter 11 specifically regulates water operations in a parallel system to that of environmentally hazardous activities. Chapter 15 is the part of the Environmental Code that concerns waste management, which to some extent is relevant in this context. General procedural provisions, regulating in part the permitting process, are found in Chapters 16 to 25. Chapter 26 concerns control and monitoring, and Chapter 29 to 30 concerns sanctions and penal provisions. Last in the Environmental Code, the Chapters 31 to 32 includes provisions on compensation and environmental damages.

Another important provision in the Environmental Code is Chapter 17, where it is established that the Government may consider the permissibility of certain matters before the permit procedure in the Land and Environment Court.

5.2.5.3.3 The Swedish permit system

The primary frame for regulation of environmentally hazardous activities is found in Chapter 9 of the Environmental Code, which requires a permit for certain listed activities. Furthermore, there is a permit regime for water operations in Chapter 11. The more specific requirements for activities that need a permit under Chapters 9 and 11 are laid down in ordinances issued under the Environmental Code – particularly the Ordinance (2013:251) on Environmental Assessment ("*Miljöprövningsförordningen*"). The activities listed there and their related operations may not commence without a permit from a competent authority, e.g. the Land and Environment Court or the County administrative boards. The permit sets out the scope of the activity concerned and must include the conditions under which the activity may be carried out. The permit authority may also reject a permit application if it deems that the activity is not permissible under the Code. In return, the permit essentially protects the operator from any claims or actions due to disturbances

[134] Swedish Environmental Protection Agency (Naturvårdsverket), Report 6790, p. 19.
[135] Env. Code, Chapter 7, Section 32.
[136] Env. Code, Chapter 4, Section 10.

caused by the activity, provided that the activity is carried out in compliance with the conditions of the permit.[137]

The general rules of consideration in Chapter 2 of the Code are of fundamental importance for the Swedish permit system. They provide the basis for determining whether and, if so, under what conditions a permit can be issued. It is often the case that specific types of conditions are required, e.g. conditions setting out emission limits or on emissions monitoring. The conditions set out in the permit vary depending on the activity in question.[138]

In addition, as explained above, there are also certain activities that the Government can declare as permissive before entering into the procedure of environmental assessment and the setting of conditions. This feature in the Swedish legal system, which is regulated in Chapter 17 of the Code, is called the Government's consideration of permissibility for certain matters, and it is limited to certain major infrastructure projects and nuclear activities, but could possibly also be applicable to the kind for projects in focus of this study.

5.2.5.3.4 Swedish environmental penal law

With the introduction of the Environmental Code, essentially all environmental penal provisions were transferred to Chapter 29 of the Code. The penal provisions in the Environmental Code are subsidiary to offences in the Penal Code. Penalties for environmental offences range from fines to imprisonment for up to six years.[139]

The penalty provisions are broad and cover a wide range of environmental harm for which different levels of punishments can be enforced, from fines up to 6 years imprisonment. An environmental offence either wilfully or through negligence is punished. One example, appropriate in this context, is if someone wilfully or through negligence causes the emission to land, water or air of a substance which results in or could result in pollution detrimental to human health, flora or fauna or any other significant detrimental to the environment, the punishment would be in the normal degree be imprisonment up till two years.[140]

5.2.5.3.5 Continental Shelf Act

There is also some regulation applicable to be found in the Act on the Continental Shelf (1966:314) (the Swedish Continental Shelf Act), ("*Lag om kontinentalsockeln*"), which applies to certain activities taking place at the Swedish continental shelf. According to the Swedish Continental Shelf Act, the Continental Shelf is the seabed and its subsoil within Swedish public waters and within such an area of the sea outside the territorial limits as far as the Swedish EEZ extends.[141]

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[137] See also: Swedish Environmental Protection Agency (Naturvårdsverket), Report 6790, p. 24.
[138] Swedish Environmental Protection Agency (Naturvårdsverket), Report 6790, p. 24.
[139] Swedish Environmental Protection Agency (Naturvårdsverket), Report 6790, p. 34.
[140] Swedish Env. Code, Chapter 29, Section 1.
[141] The Continental Shelf Law, Section 1.

Under this law, the right to explore the continental shelf and to extract its natural resources shall vest in the Swedish State.[142] The Government, or such authority as it may designate, shall have the right to grant a concession to another party to explore the continental shelf by means of geophysical measurements, drilling or other methods, and to extract its natural resources.[143]

5.2.5.3.6 Act on the EEZ

In addition to the Environmental Code, the Act on Sweden's Exclusive Economic Zone (1992:1140) (the Act on the Swedish EEZ), ("*Lag om Sveriges ekonomiska zon*") is central to the approval of sea-based measures. The Act on the Swedish EEZ is complementary to the Act on the Continental Shelf. The EEZ Act delimits the EEZ of Sweden and deals with the prerequisites or basic framework for protection of the marine environment, the utilisation of marine resources, scientific research, supervision, applicable law, and prescribes penalties – in relation to activities and operations in the EEZ.

The Act on the Swedish EEZ does not cover fisheries, and the right to explore the floor of the continental shelf in the zone and to exploit the natural resources of the continental shelf is primarily regulated in the Swedish Continental Shelf Act. The Act on the Swedish EEZ does, however, include environmental requirements on certain other activities, stating that with reference to natural resources in the economic zone, a license from the Government or from such authority as the Government determines shall be required for 1) investigation, extraction and other utilization of natural resources; 2) the establishment and utilization of artificial islands; and 3) the establishment and utilization of installations and other equipment for commercial purposes.[144]

The activities that require a license shall apply to the general rules of consideration in Chapter 2 of the Environmental Code. Furthermore, all those that navigate in the EEZ or have any other operations in this zone also shall take such considerations on precautionary measures into account to avoid damage to the marine environment.[145] The EEZ Act further refers to other rules in the Environmental Code and thus implies that they are applicable also in the EEZ and in parallel to the general requirements stated there.[146] Among the more interesting rules of the Environmental Code that the EEZ law refers to are the rules concerning protected areas according to the Natura 2000 regulation and the Birds and Habitats Directives as implemented by Sweden.[147] In addition, reference is made to the Waste management rules in Chapter 15 of the Environmental Code, which include the rules on dumping.[148]

The regulation of licensed activities in the EEZ Act can also, by decision from the Government or from such authority as the Government determines, be subject to special ordinances on safety zones – which is in line with the requirements found in UNCLOS

[142] The Continental Shelf Law, Section 2.
[143] The Continental Shelf Law, Section 3.
[144] The Act on the Swedish EEZ, Section 5.
[145] The Act on the Swedish EEZ, Section 2.
[146] The Act on the Swedish EEZ, Section 3.
[147] Env. Code, Chapter 7, Sections 27–30 and 32.
[148] Env. Code, Chapter 15, Sections 27–29.

regarding installations and structures.[149] Finally, the EEZ law also provides that it, along with the regulations and conditions that are issued based on the Act, shall not include any restrictions of the rights, existing under international law, to free navigation in the economic zone, to overflight of the zone and to the placement of cables and pipelines in the zone, nor of any other rights that follow from the generally recognized principles of international law.[150]

5.3 Sea-based measures in a policy context

5.3.1 Introduction

Before assessing the legal framework for sea-based measures in more detail, it is useful to study their place in a broader policy framework. The prospect of a more active utilization of sea-based measures depends strongly on the policy stance taken by certain key players in the field, notably governmental authorities in Finland and Sweden and at international level. Within the scope of this study, a number of questions have been presented to national authorities and other interested parties. The questions relate to the authorization and funding of sea-based measures and to assuming responsibility for them. The outcome of the small survey is referred to in section 5.3.2 below, apart from the questions linked to liability, which are addressed in section 5.6.5. More detailed summaries of all replies to the questionnaire are included in Annex 1.

Section 5.3.3 includes a review of how sea-based measures have featured in the press until now and addresses other aspects of communicating the matter to the general public.

The final section 5.3.4 addresses an essentially legal question which is presumed to be relevant for the policy context, that is, whether and to what extent sea-based measures can be accounted for as part of states' current obligations to take protective and reduction measures. Can sea-based measures, in other words, count as reduction/restoration measures for the purpose of meeting the commitments states have undertaken under the Helsinki Convention, MSFD and the BSAP and their national programmes?

5.3.2 Policy on sea-based measures in the Baltic Sea region

The states around the Baltic Sea indicate a significant divergence in their attitudes towards sea-based measures. When it comes to the general state-level acceptance and interest in taking sea-based measures as a method to reduce eutrophication, the impression is that there is considerable reluctance among several HELCOM states. Only Sweden and Finland are openly positive towards taking such measures, as a supplement to land-based measures, and about exploring how this openness could be translated into practice.[151] Other countries are less convinced, noting, *inter alia*, that land-based measures are not yet exhausted as a mechanism to reduce nutrient inputs to the Baltic Sea. Even the

[149] The Act on the Swedish EEZ, Section 7.
[150] The Act on the Swedish EEZ, Section 10.
[151] HELCOM HOD 50-2016, "OUTCOME of the 50th Meeting of the Heads of Delegation", Agenda Item 4, (4.64); HELCOM Pressure 6-2017, "A joint HELCOM-EUSBSR workshop on internal nutrient reserves", (7-10-Rev.1), Agenda Item 7; HELCOM HOD 52-2017, "HELCOM-EUSBSR workshop on internal nutrient reserves", (3–4), Agenda Item 3.

majority of the organisations that see the potential merits of sea-based measures have emphasized that reducing the external nutrient load should still be the principal way to reduce eutrophication.

HELCOM's policy on eutrophication has been focused on land-based measures.[152] The position has been that reducing pollution at the source is the only way to reach the aim of a Baltic Sea unaffected by eutrophication and good environmental status in the long term.[153] More recently, HELCOM has indicated more openness towards sea-based measures. In a Ministerial Declaration adopted on 6 March 2018, the need for regional guidance in this matter is acknowledged and a regional risk assessment framework is encouraged, at least for measured planned for open waters.[154]

The EU has had no official policy regarding eutrophication measures, but through its Strategy for the Baltic Sea Region (EUSBSR) in its Policy Action Area 'Nutri', reference has been made to such measures.[155] At the initiative of Sweden and Finland, HELCOM together with EUSBSR organised a common workshop to initiate the discussion.[156]

A general impression from the small – and not entirely representative – survey is that the overall policy resistance towards sea-based relates both to concerns about what risks such measures may have for the ecosystem and to concerns about what such measures would implicate for the overall regulatory or policy approach for the choice of measures to combat eutrophication.

Among the main benefits of sea-based measures, most answers refer to the potential of reducing large amounts of nutrient release, addressing the internal sources, both in the entire Baltic Sea and locally. The potential for using the sediment, seen as a by-product of sea-based measures, as suitable material for fertilization and as improvement for agricultural fields, was mentioned as another positive effect. Sea-based measures were also held to represent a locally cost-effective way to combat eutrophication and the negative consequences of it. It was considered that the risks can be managed by careful planning and testing and that the costs (i.e. monetary, life quality, life in the sea, biodiversity etc.) of non-action are and will be very high.

Yet, even the promoters of a quick implementation of sea-based measures acknowledge that not all issues related to the risks and benefits of sea-based measures are known. The only research institute contacted emphasizes the need to focus on land-based measures and expresses a concern that sea-based measure might interfere with the work done in the field of reductions from land-based sources, noting that not all land-based measures

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[152] See e.g. the HELCOM action areas: http://www.helcom.fi/action-areas.

[153] See e.g. HELCOM Copenhagen Ministerial Declaration, 'Taking Further Action to Implement the Baltic Sea Action Plan - Reaching Good Environmental Status for a healthy Baltic Sea', Copenhagen Denmark, 3 October 2013.

[154] HELCOM Ministerial Declaration 6 March 2018, para. 26. The full paragraph is quoted in section 5.4.5.5.2 below.

[155] The EUSBSR was approved by the European Council in 2009 following a communication from the European Commission. The EUSBSR is implemented in concrete joint projects and processes in its different Policy Action Areas, and especially through so-called Flagship projects. So far, sea-based measures have not reached the status of a Flagship project, and thus only represent an 'Action Area' within the strategy. See Actions 1 and 6: http://groupspaces.com/eusbsr-nutrient-inputs/pages/actions.

[156] HELCOM and the EUSBSR (the Nutri Policy Action Area) arranged a common workshop on this topic along the frame of this current project, which has been initiated by Finland and Sweden. See http://groupspaces.com/eusbsr-nutrient-inputs/pages/actions; https://portal.helcom.fi/meetings/HELCOM-EUSBSR%20WS%201-2017-498/default.aspx; and Policy area Nutri Actions at the EUSBSR Action Plan, number 6.

are exhausted yet. The institute, moreover, contends that the potential of sea-based measures is strongly over-estimated.

A similar perspective has been presented earlier by the Baltic environmental NGOs in a joint statement, represented by Coalition Clean Baltic network and the WWF Baltic Ecoregion Programme, submitted to HELCOM in October 2016.[157] The WWF has since somewhat changed their position towards a more neutral standpoint, expressing an understanding for the urge in Sweden and Finland to take further measures against eutrophication. However, the organization calls for further research and mapping of risks and ecosystem perspective, as well as policy and legal framework etc.[158]

There are significant knowledge gaps and lack of information concerning the ecological aspects of sea-based measures.[159] This concern was shared by all parties approached in the policy review. The main view on the circumstances under which sea-based measures could be put into practice was through smaller-scale pilot projects in enclosed bays and coastal areas, especially for research purposes. Many respondents considered that this is a prerequisite for potential larger-scale applications. On the other hand, the question as to whether results from small-scaled pilot projects can directly be applied in larger-scale projects was also raised.

It is commonly agreed that obtaining knowledge about the nature and dynamics of internal nutrient reserves, as well as on the effects of sea-based measures, is a challenge, as is the design of efficient funding mechanisms for the purpose. Different areas may need different solutions. It was also noted that the discussion is polarized and the knowledge is scattered and not in a format that allows useful comparisons. A main challenge is thus to find social and scientific consensus between the interest groups.

Another challenge indicated is to find suitable places on land where the sediment could be stored, in cases when the sediment is removed from the sea. It was also mentioned that external loading could prevent the long-term effects of sea-based measures and that techniques are not yet ready for large-scale implementation. Wider international cooperation and discussion between the Baltic Sea states was called for.

When it comes to the need for updating existing legislation, the opinions among the respondents are divided. Some indicate that the available permit legislation, environmental regulation and principles provide a sufficient basis for dealing with the matter, and that the current policy is working. Others call for special regulation on sea-based measures at national, international and HELCOM level, perhaps even through the establishment of a new division of HELCOM with more regulatory and legal authority. The possibilities of taking sea-based measures into account in maritime spatial planning and creating a coordinated map/plan of possible areas for such measures were widely recognized. Also common procedures, processes and guidance were called for. The permit practices should be coherent and the potential problems must be thought through. The funding of sea-

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[157] HELCOM Pressure 5-2016, “Joint position of environmental NGOs on internal loading in the Baltic Sea”, (8-6), Agenda Item 8.

[158] See WWF Report 2018, “Baltic Sea Action Plan Scorecard 2018”, WWF Baltic Ecoregion Programme, p. 9, published in March 2018 at:
http://www.wwf.se/source.php/1733846/WWF%20Baltic%20Sea%20Action%20Pland%20Scorecard%202018_LR.pdf.

[159] HELCOM-EUSBSR Workshop, 28-29 November 2017 in Gothenburg; Baltic Sea Center, Stockholm 2015, the minutes from the seminar “*Sea-based Measures – to reduce consequences of Eutrophication*”, held at Stockholm University 12 February 2015, and planned jointly with Stockholm University, SWAM and the Swedish Ministry of Environment and Energy.

based measures was seen as one of the key questions that needs to be agreed upon between the respondents.

If sea-based measures were to be undertaken large-scale, the involvement of national authorities, regional authorities (HELCOM) and scientific institutions was considered to be very important. The potential role of EU was noted in this respect, while private foundations could act as donors and operators in pilot projects. The involvement of private businesses divided the opinions. Some of the respondents thought it was impossible to make sea-based measures profitable, others saw a big role for private or state business in the field, both in relation to technological development, operation and funding.

5.3.3 Communication

5.3.3.1 Retrospective media review

A retrospective media review was executed to map the ethos around the Baltic Sea internal nutrient storage and leakage problem and its mitigation measures. The results of the review have been used to pinpoint possible challenges and opportunities for future communication on the subject.

The media analysis covers stories published during the years 2011–2017 in selected Finnish and Swedish fora. According to the analysis, Baltic Sea eutrophication gets media space but the nature and origin of the internal nutrient storage and leakage are rarely mentioned.

Media entries were searched using the media monitoring tool Meltwater. Archives from Helsingin Sanomat, Turun Sanomat, Maaseudun Tulevaisuus, Yle, Svenska Dagbladet and Göteborgs-Posten were examined.

The search provided 1,428 results during 2011–2017; 1,166 in Finnish newspapers and 262 in Swedish newspapers.[160] Entries included 12 editorials, 12 opinion pieces, 4 blog posts and 1 column. Out of these 1,428 results, 132 included references to internal nutrient storage and leakage (117 in Finnish newspapers and 15 in Swedish newspapers). These 132 entries were further divided into those that acknowledged internal nutrient storage and leakage directly, for example mentioning nutrients being released from the bottom sediments, and into those that referred to internal nutrient storage and leakage more indirectly, for example mentioning “old nutrient loads still causing eutrophication”. Seventy four entries mentioned internal nutrient storage and leakage directly (67 in Finland and 7 in Sweden), and 58 indirectly (50 in Finland and 8 in Sweden). It seems that while the Baltic Sea and its problems (such as eutrophication, hypoxia and massive cyanobacterial blooms) are on the news regularly, internal nutrient storages and leakage, and their role in the aforementioned issues, is mostly left unrecognized.

[160] There are some uncertainties in the results, as the links for the articles did not always work, i.e. the entries in question could no longer be accessed. Some Baltic Sea and internal loading related entries may have been missing from the Meltwater database altogether. Especially in small local newspapers, not all written pieces may have been published online. The search words used could have also left out some relevant entries both in Meltwater and the news archives. This means that there may have been more entries referring to internal loading than the results suggest. However, this probably would not have affected the general conclusions.

Of the 132 entries that acknowledge internal nutrient storage and leakage, many stress the importance of further minimizing external loading, while also recognizing internal nutrient leakage.

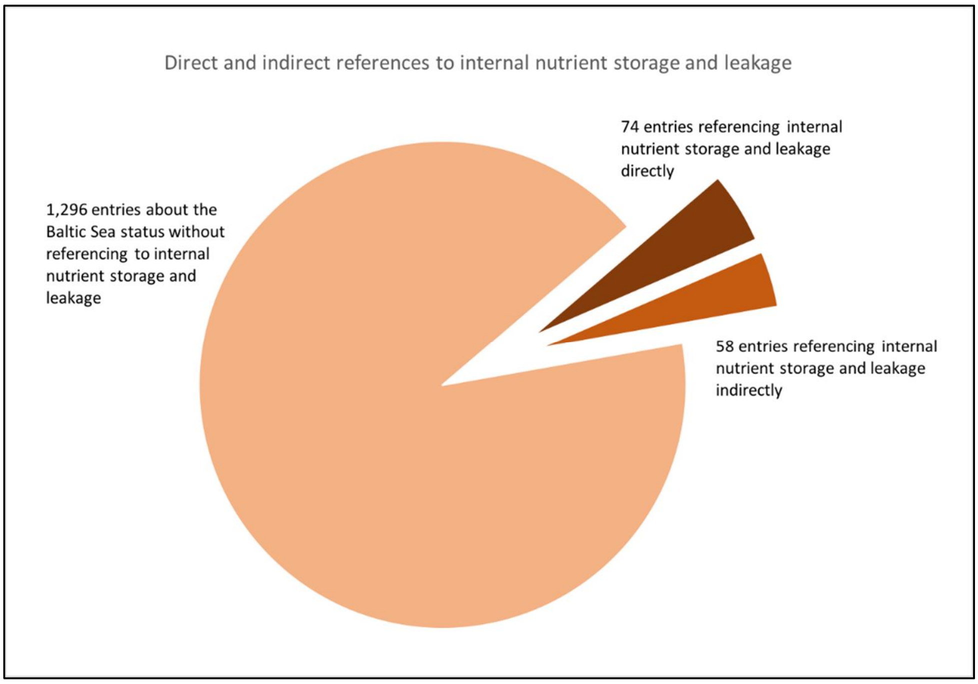

Figure 46. Entries about the Baltic Sea status without referencing to internal nutrient storage and leakage, and the amount of entries referencing internal nutrient storage and leakage either directly or indirectly. The total amount of entries is 1,428.

One of the key findings of the review is that these two sources for excess nutrients in the Baltic Sea, i.e. land-based emissions and internal nutrient storages and leakage, are often treated as separate and even conflicting, in the sense that there is an assumption that when one of these sources is acknowledged, the other is being ignored. This perception is clearly something to be taken into consideration in future communication on the subject.

Both internal nutrient storage and leakage, as well as land-based nutrient emissions, were often discussed in connection with the contribution of inputs from agriculture and from urban waste water treatment plants. Forty one entries mentioned farming and 53 mentioned sewage as the main sources of excess nutrients in the Baltic Sea. Additionally, 13 entries (of which 10 were opinion pieces or editorials) emphasized that farming is not to blame and one opinion piece asserted that sewage is not to blame for the excess nutrients in the sea. For future communication, it is good to bear in mind that when talking about internal nutrient storage and leakages or sea-based mitigation measures, one can easily be pulled to the previous debates on the relevance of particular nutrient emission sources.

Examining indirect references to internal nutrient storage and leakage also provided interesting observations. These entries did not specifically name internal nutrient storage or leakage but addressed the issue indirectly. Many entries mentioned “old nutrient loads” causing eutrophication in the Baltic Sea but did not clarify why or how old nutrients are still active in the sea. Similarly, “upwelling of nutrients from deep water to the surface” is written about frequently, but the reason for high nutrient concentrations in deep waters (i.e. phosphorus leaking from sediment) is usually left unclear. Also, hypoxia and anoxia in sea bottoms is mentioned quite often. In many entries, these conditions were linked to eutrophication, however, the link between the two phenomena was not explained.

It appears that many journalists do not adequately understand the mechanisms of internal nutrient storage and leakage, which leads to vague news coverage and sometimes even to factual errors. This can lead the reader to also perceive the issue as something that is too difficult and complex to address as a society.

These observations suggest that, when communicating on the subject, basic information on the internal nutrient processes should always be readily available, in an easily usable format. This would support also journalists who may already be familiar with the issue, but would be more likely to cover the subject if provided with good information materials.

Most people get their information on Baltic Sea related issues from the media, which is why it is important that the media presents the problems and solutions based on best available information and facts. The retrospective media review suggests that this is not always the case when issues related to internal nutrient storage and leakage are presented in the media.

Journalists are important gatekeepers for bringing the issue of internal nutrient storages and leakages to public discussion. The support of the general public for testing any sea-based measures should not be underestimated. Public demand for action can hasten the implementation of measures, whereas disapproval and doubt can hinder it.

Politicians tend to also choose actions based on public opinion; at least they avoid going against it. It is likely that the public will support the use of sea-based measures if they are aware of the conditions on the sea bottom, i.e. internal nutrient storage and leakage and their consequences. Also the public should get sufficient credible information on the conditions in the sea and the planned actions. A starting point for achieving these could be to provide training for a selected group of journalists on the subject of internal nutrient storages and leakages and their dynamics in the Baltic Sea. A policy brief paper on the subject would also be one of the first obvious tasks. The dynamics of internal nutrient storage and leakage could be further visualized by creating for example an animation on the subject. The animation could be circulated to journalists, educators, and other interested parties. Having more accurate background information about the Baltic Sea would benefit reporters also for stories that are not directly related to internal nutrient storage and leakage. The project could also benefit from a charismatic and well-informed spokesperson.

The review pointed out that currently internal and external sources of nutrients to the Baltic Sea are often written about in a manner that might suggest that the two phenomena are completely separate and unrelated to each other, or even opposites. In reality, internal and external nutrient loads are part of the same continuum. This should be one of the main messages to be followed through in future communications. It should be clearly denoted that external nutrient inputs should be diminished even though the magnitude of the problem is such that it is essential to also find additional ways of dealing with old nutrient storages. This type of discourse has already become more commonplace in the field of climate change where mitigating new carbon dioxide emissions is no longer seen as sufficient in itself, and increasing attention is being given towards simultaneously tackling excess carbon dioxide already present in the atmosphere.

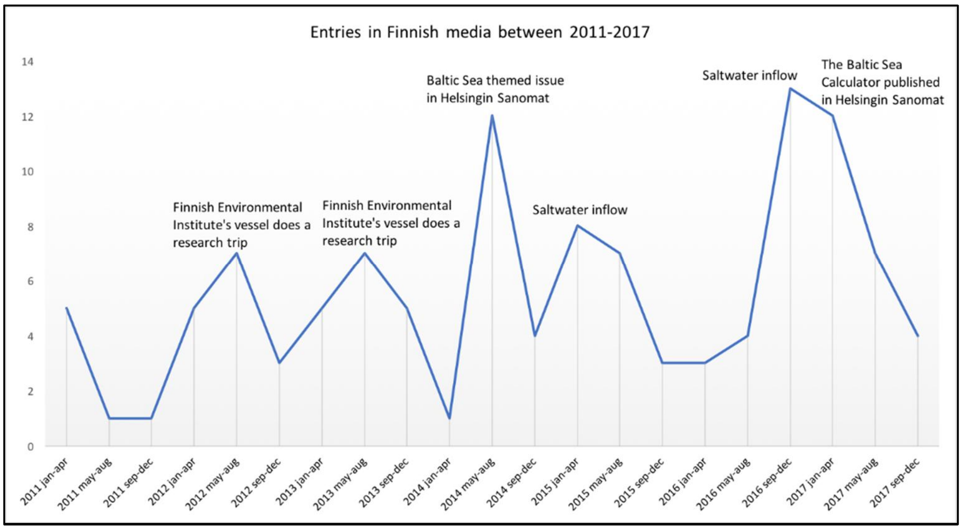

Figure 47. The amount of entries referencing internal nutrient storages and leakage in Finnish media during 2011-2017.

As an example of related themes and temporal variation in the amount of media coverage, one can look at the media hits from the summers of 2012 and 2013, when the number of entries peaked in the study. This was when the Finnish Environmental Institute's research vessel Muikku did its annual monitoring cruise on the Baltic Sea, assessing among other things the condition of the sea floor. Muikku's findings were reported in the media on these two consecutive summers. Many of these entries presented information about the hypoxic or anoxic conditions on the sea floor, and their effects on internal nutrient leakage.

This is a good reminder of the fact that although internal nutrient storage and leakage is a continuous problem and does not rank high on journalistic news criteria, events that interest media can be planned and used to increase communication on the subject.

On 6 August 2014 Helsingin Sanomat published multiple articles covering the current status of the Baltic Sea, which explains the peak in the amount of entries during the summer of 2014.

In the beginning of 2015, and again in the winter of 2016, the Baltic Sea received saltwater inflows through the Danish straits. These inflows and their effects were written about in numerous entries. Such naturally occurring phenomena can also be used to draw the media's (and the public's) attention to the subject of internal nutrient storage and leakage.

In the beginning of February 2017, Helsingin Sanomat published the Baltic Sea Calculator. It gave readers a chance to calculate their nutrient footprint, i.e. examine how their personal habits affect the eutrophication of the sea. This sparked controversy, which led to various articles published both in Helsingin Sanomat and other publications. Some commentators pointed out that the calculator did not take internal nutrient storages or leakage into account. This suggests that some readers may have wanted better inclusion of internal nutrient storages, although it might also be that they wished for justify also other emission sources.

The Baltic Sea themed issue in Helsingin Sanomat as well as the Baltic Sea Calculator and its aftermath illustrate how planned co-operation with media can act as an initiator in raising certain topics to the public discussion. Perhaps it would be possible to introduce internal nutrient storages and leakage to the public in this manner.

The topic could be tied in with the dead zones on the sea floor, as they are a captivating image and a symbol for the sea's poor condition. Dead zones could thus provide a good angle for reporting on internal nutrient storage and leakage, as long as the connection between the two phenomena is adequately explained and justified.

It is also vital to identify potential pitfalls in communicating about sea-based measures. Communication should emphasize that possible risks related to sea-based measures need to be taken into account. Communicating about sea-based measures should not be simplified too much, i.e. they should not be presented as an easy and fast solution. On the other hand, it is also important to avoid causing unnecessary alarm.

5.3.3.2 Forming messages to identified key target groups

Key communication target groups were first identified in internal workshops. The analysis of the retrospective media review was used to identify ideas that could be used for forming the messages to these key target groups in the future.

Table 24. Forming messages to identified key target groups.

Target group	What to take into account when forming the message:
Citizens	· The role of internal nutrient storage and leakage in the Baltic Sea's current condition explains the need for sea-based measures: land-based inputs of nutrients need to be minimized, but to gain good ecological status for the Baltic Sea internal nutrient storage should also be addressed. · A positive, hopeful message; the Baltic Sea can be saved · Emphasizing proper risk assessment and caution used in implementing sea-based measures. · First, small-scale, local actions are needed to improve knowledge and to develop technologies and measures that can make a difference at a larger scale in the future
Municipalities	· Improving the condition of the local environment (e.g. minimizing cyanobacterial blooms, aesthetic benefits) · Good for tourism · Creates jobs · Benefits local fishermen

Target group	What to take into account when forming the message:
Media	· The role of internal nutrient storages and leakage in the Baltic Sea's current condition, explains the need for sea-based measures: land-based inputs of nutrients need to be minimized but to gain good ecological status for the Baltic Sea internal nutrient storage should also be addressed. · internal and external nutrient loads are part of the same continuum · A positive, hopeful message; the Baltic Sea can be saved · Emphasizing proper risk assessment and caution used in implementing sea-based measures. · First, small-scale local actions are needed to improve knowledge and to develop technologies and measures that can make a difference at a larger scale in the future · Provide good, informative, ready-to-use materials · Create/ identify an event that meets the "happening now" news criteria · Link carefully to other narratives regarding nutrient inputs to the Baltic Sea
Politicians	· New technologies and knowledge about improving the condition of the sea floor could be sold worldwide · Technologies designed for aquatic environments could also be applied on land, thus creating new marketing opportunities · Finland as a forerunner · Finland's international commitment to improve the condition of the Baltic Sea; old methods are not sufficient for achieving this goal
HELCOM	· HELCOM has a unique possibility to act as a moderator for joint decision-making since sea-based measures are in many cases done in international waters and may have transboundary impacts · Commitment to improving the Baltic Sea's condition; old methods are not sufficient for achieving this goal
Financers	· New technologies and knowledge about improving the condition of the seafloor could be sold worldwide · Technologies designed for aquatic environments could also be applied on land, thus creating new marketing opportunities

5.3.4 Sea-based measures in the Baltic Sea legal framework

A matter of key relevance for the willingness of the Baltic Sea states to accept sea-based measures is presumably also the question as to whether and to what extent sea-based measures can be accounted for as part of the current national obligations to protect the Baltic Sea environment from eutrophic pollution.

A first binding reference is the general obligation found in the Helsinki Convention, stating that the Parties shall take *"…all appropriate legislative, administrative or other relevant* *measures to prevent and eliminate pollution…*"[161] In assessing the appropriateness and relevance of sea-based measures, they need to be placed in their context. In other words, what other mechanisms exist to achieve the same results and how do they compare in terms of effectiveness, cost and environmental risk. If equally effective measures exist, but at lower environmental risk or lower cost, it will be more difficult to argue for the appropriateness of sea-based measures. This consideration highlights the importance of having information about existing effects and alternative methods available. Another question is whether sea-based measures can be regarded as appropriate or relevant as long as the level of scientific knowledge does not match the general level of knowledge requirement for a legal review and permit procedure or, as a basis for this, an EIA. It has also been argued that in assessing the appropriateness of the measure, it should be borne in mind that fulfilling the obligations of good environmental status, and other requirements of the MSFD and BSAP, calls for a continued implementation of land-based measures to reduce eutrophication.[162]

The aim to integrate sea-based measures in the environmental governance of the Baltic Sea relates to the implementation of the HELCOM BSAP and the EU MSFD. As a consequence of the aim to implement the MSFD with such measures, the proposed actions are also included as a part of Finland's Programme of Measures with a strategy to achieve good environmental status.[163]

There is a close connection between the MSFD and the Helsinki Convention, through the BSAP, which has an important role here. The MSFD aims at creating a comprehensive framework for the protection of the marine environment within the different regional seas in the EU. In order to accomplish that, and to be adjusted to the specific regional environmental setting, it includes a requirement that it shall be implemented through regional international institutional structures of the different marine regions.[164] Hence, in the Baltic Sea, the MSFD is to be implemented through the regulatory structures established by HELCOM. Against this backdrop the BSAP was adopted with the aim of creating an instrument reflecting the MSFD, but with adjustments to the Baltic Sea setting.[165] The BSAP also aims at achieving good environmental status and has a similar goal-oriented structure as the MSFD. The goals set up within the BSAP are, however, more specific to the Baltic Sea environment and the conditions found there. The BSAP is also the instrument through which HELCOM has acknowledged and operationalized an ecosystem approach, with influence from the EU and the MSFD. Just like the MSFD, also the BSAP is based on an adaptive structure and its implementation is assessed in an adaptive review process, where the national plans will be reviewed and evaluated by

[161] Helsinki Convention, Art 3(1).
[162] HELCOM 2017, Memo of the HELCOM-EUSBSR Workshop on internal nutrient reserves, held 28-29 November 2017 Gothenburg, Sweden. See also: Viktorsson, L., "Perspectives on sea based measures" in "*Sea-based Measures – to reduce consequences of Eutrophication*", held at Stockholm University 12 February 2015, and planned jointly with Stockholm University, SWAM and the Swedish Ministry of Environment and Energy, minutes from the seminar, pp. 15f. and; HELCOM Copenhagen Ministerial Declaration, "*Taking Further Action to Implement the Baltic Sea Action Plan - Reaching Good Environmental Status for a healthy Baltic Sea"*, Copenhagen Denmark, 3 October 2013.
[163] Åtgärdsprogram för Finlands havsförvaltningsplan 2016–2021, MILJÖMINISTERIETS RAPPORTER 5sv, 2016, Miljöministeriet, Naturmiljöavdelnigen, Helsingfors 2016, Chapter 5, pp. 135ff (Eutroph 6), [in the edition provided in Swedish].
[164] MSFD, Art 6.
[165] This is apparent in the statements made in the Joint HELCOM-OSPAR Ministerial Meeting, held in Bremen 2003, HELCOM, "Declaration of the Joint Ministerial Meeting (JMM) of the Helsinki and OSPAR Commissions", JMM 2003/3(final version)-E, agenda item 6; The aim to coordinate the work of the BSAP with the EU MSFD is also made clear in the preamble of the BSAP.

HELCOM.[166] It is through the work of HELCOM and the parallel implementation or evaluation/review of the BSAP, that the implementation of the MSFD is provided with common indicators and assessments. HELCOM has established itself as a coordinating platform for the integrated work of HELCOM and the EU in these issues.

Given this close connection, it is generally accepted that the implementation plans linked to the BSAP are substantially equal to the MSFD Programmes of measures. The implementation of these instruments can thus be done through the same measures, including also the measures identified in the WFD River Basin Managements Plans. The BSAP also makes an important contribution here in defining what 'good environmental status' in relation to eutrophication means in more concrete terms. Through the principal reduction targets adopted in the BSAP, it becomes quite clear to what extent the Baltic Sea coastal states need to reduce their pollution to the Baltic Sea. This, in turn, provides some kind of measurement on whether the measures included in the programmes of measures are sufficient. In the HELCOM assessments of the BSAP implementation, suggested measures have also been discussed quite specifically in relation to the main problem sources, including agriculture, and how these problems could be approached by the parties, hence providing indirectly guidance also to the implementation of the MSFD.

According to the MSFD, good environmental status means "the environmental status of marine waters where these provide ecologically diverse and dynamic oceans and seas which are clean, healthy and productive within their intrinsic conditions, and the use of the marine environment is at a level that is sustainable, thus safeguarding the potential for uses and activities by current and future generations".[167] Good environmental status under the BSAP is defined and framed by the HELCOM Ecological Objectives specifically in relation to eutrophication and moreover in relation to the reduction targets defined within the BSAP.[168]

Both the Helsinki Convention and the BSAP refer to land-based measures, but include no reference to sea-based measures. This does not mean that sea-based measures are necessarily unlawful, but it does mean that there are no specific requirements concerning such measures. In addition, it means that undertaking sea-based measures does not do away with the obligation of the parties to take measures to reduce pollution from land. Rather, the main issue is whether sea-based measures have the potential to contribute and fulfil the general aim of the Helsinki Convention. In relation to fulfilling that general aim, as noted above, a relevant factor is also whether land-based measures entail aspects that would be lost by undertaking sea-based measures, and whether they, despite their aim to abate eutrophication, could have an adverse effect on the overall ecological status of the Baltic Sea.[169]

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[166] HELCOM BSAP, Eutrophication segment, p. 9.
[167] MSFD Art 3(5).
[168] BSAP Preamble and Eutrophication Segment.
[169] See also Bohman, B., *Transboundary Law for Social-Ecological Resilience? A study on eutrophication in the Baltic Sea area,* (dissertation), Stockholm University, US-AB Stockholm, 2017, noting that the adoption of the BSAP and the MSFD have had a positive effect on the collaboration in HELCOM, especially with regard to measures to reduce diffuse land-based sources from, for example, agriculture. There is accordingly a risk that turning focus and resources on cooperating and mobilizing towards sea-based measures could disturb this positive trend in taking measures at land, which would then be at variance with more general obligations under the Helsinki Convention and endanger the long-term achievement and maintenance of good environmental status.

The general assumption behind introducing sea-based measures is that they could significantly reduce the internal phosphorus reserves that contribute to eutrophication.[170] This supports the idea that a successful implementation of sea-based measures would speed up the process to achieve good environmental status according to its general definition in the MSFD. On the other hand, it has also been held that it is only by reducing the pollution at source that states can contribute to achieving good environmental status in the long term.[171] In reflection of that, it is not obvious that sea-based measures can be accounted for within the applicable legal instruments, the aim of which is primarily to reduce input of nutrients.

It should also be borne in mind that the sea-based measures mainly target phosphorus, while it is acknowledged in the relevant legal instruments – not least in the BSAP with its specific focus on eutrophication – that nitrogen is as important to reduce as phosphorus. This suggests that in order to achieve the required good environmental status, nitrogen must be targeted as well. Depending on the differences of the methods in ecological effects, it may also be that an appropriate balance between the two main categories of nutrients is called for by the requirements to having an ecosystem approach to governance.

The MSFD states that the purpose of marine strategies and the connected Programmes of Measures is to "protect and preserve the marine environment, prevent its deterioration or, where practicable, restore marine ecosystems"[172] and furthermore to "prevent and reduce inputs in the marine environment, with a view to phasing out pollution".[173] It does not specifically regulate what measures the member states shall include in the Programme of Measures or how they shall work to achieve good environmental status, but an ecosystem approach to human activities is to be applied.[174] An ecosystem approach is also emphasized in the BSAP as an extension of the Helsinki Convention and an operationalization of the HELCOM vision.[175] Exactly what an ecosystem approach implies in terms of legal measures and regulation is not completely clarified.[176] Generally, however, it is agreed that regulation of activities and measures taken shall be assessed with the ecosystem and its diversity in focus. Whether sea-based measures fulfil that requirement is open to argument in view of the absence of certainty about their short-term and longer-term effects. This contrasts with land-based measures which involve less known risks,

[170] The scientific evidence on actual effects and benefits are debated, see for example: Minutes from the seminar "*Sea-based Measures – to reduce consequences of Eutrophication*", held at Stockholm University 12 February 2015, and planned jointly with Stockholm University, SWAM and the Swedish Ministry of Environment and Energy, and HELCOM 2017, Memo of the HELCOM-EUSBSR Workshop on internal nutrient reserves, held 28-29 November 2017 Gothenburg, Sweden.
[171] Minutes from the seminar "*Sea-based Measures – to reduce consequences of Eutrophication*", held at Stockholm University 12 February 2015, and planned jointly with Stockholm University, SWAM and the Swedish Ministry of Environment and Energy, Viktorsson, L., "Perspectives on sea-based measures", pp. 15f.; see also HELCOM Copenhagen Ministerial Declaration, 2013.
[172] MSFD Art 1(2)a.
[173] MSFD Art 1(2)b.
[174] MSFD Art 2.
[175] HELCOM declares the connections between EU legislation, the CBD, the HELCOM Vision, its Ecological Objectives and the BSAP and furthermore states that the BSAP is the tool of implementation of an ecosystem approach in: HELCOM, "HELCOM Ecological Objectives for an Ecosystem Approach", document for HELCOM Stakeholder Conference on the Baltic Sea Action Plan, Helsinki, Finland, 7 March 2006, p 1f. See also the preamble of BSAP.
[176] See e.g. Long, R., "Legal Aspects of Ecosystem-Based Marine Management in Europe", in Chircop, A., McConnell, M. L. and Coffen-Smou, S., (eds.), *Ocean Yearbook*, Vol. 26, Hijhoff, The Hague, 2012; Nilsson, A. K. and Bohman, B., "Legal prerequisites for ecosystem-based management in the Baltic Sea area: The example of eutrophication" *Ambio*, Vol. 44, Suppl. 3, 2015, pp. 370–380.

have broader scope of benefits (by improving the quality of inland waters and lakes), are less likely to interfere with states' duties relating to the protection of species and habitats in EU law and the CBD, and are set out as specific requirements in the existing legal framework.

On this basis, it is not clear where sea-based measures would fit, in order to meet the targets aimed at with the MSFD and the BSAP. It does not appear as if the regional legal instruments impose any direct obstacles to sea-based measures, depending on their effect, but nor do they provide support for that implementation strategy. For reasons discussed above, sea-based measures could hardly be the *only* strategy for implementing the requirements relating to eutrophication, and targeting land-based measures is easier to fit into the present regime. Returning to the terminology of the Helsinki Convention, it seems safe to conclude that land-based measures are more 'appropriate' as a measure in the light of the existing legal framework. It is not ruled out that sea-based measures could be appropriate, too, if they turn out to improve the environmental status, but full equivalence between the two cannot be achieved even through additional adjustments of the existing targets and plans. Sea-based measures thus remain complementary to land-based measures in relation to the objectives of the Helsinki Convention.

5.4 Sea-based measures – Categorisation and applicable legal framework

5.4.1 Introduction

This section starts with a legal categorization of the main types of sea-based measures. There exists a variety of different techniques to reduce the leakage of phosphorus from the seabed, even among the 'technical' measures in focus of the present study. Some of the techniques raise similar legal issues while others are so different that their legal implications need to be assessed in different ways. What is common for all of them, however, is that none of the measures is specifically regulated at any of the legal levels. In view of this, it is useful to establish certain main categories of measures depending on the type of measure as well as the type of legal challenges they raise. Three such categories have been identified here and will be further discussed, along with their main legal characteristics, in section 5.4.2. The categories are: dredging (5.4.2.1), chemical treatment (5.4.2.2) and oxygenation (5.4.2.3).

Section 5.4.3 makes a geographical distinction between the applicable laws, briefly enumerating the differences is legal requirements depending on the location of the site of the measures in terms of maritime zones. Some important rules that cover any type of sea-based measures are scrutinized in section 5.4.4, while section 5.4.5 analyses the weighing of the different interests involved and the experiences with dealing with scientific uncertainty.

Section 5.4.6 makes some conclusions in a simplified tabular format, while procedural processes to technically decide these matters on the basis of national law are discussed separately in section 5.5.

5.4.2 Legal categorization and definition of sea-based measures

5.4.2.1 General

In view of the variety of different types of sea-based measures, and the absence of a dedicated regulatory framework for them, it is useful to categorize the measures on the basis of the nature of the legal questions they raise. For present purposes, three such categories appear to be sufficient, based on the different technologies and methods used to address the matter.

In the following sections, the legal categorization of the methods is analysed in some more detail. It should be kept in mind that different measures could be regulated differently at different regulatory levels, and that some activities might be regulated at some levels but not at others. A general assumption for all categories is that while the aim of taking sea-based measures is to combat eutrophication and make the environmental status better, there are also risks entailed with these measure that trigger different environmental laws, principles and protection obligations.

5.4.2.2 Dredging of phosphorus-rich sediment

The first category of methods is dredging of phosphorus-rich sediment with the intention to eliminate phosphorus stored in the sediment. This method seeks to remove sediments from the seabed. Dredging is an activity that is generally unregulated in international legal instruments and regimes. UNCLOS is the only international instrument that has some express reference to dredging, requiring states to take necessary measures to ensure the protection of the marine environment in the Area from harmful effects of, *inter alia*, dredging.[177] This rule is not directly applicable in the Baltic Sea since it applies to the deep seabed or Area, and the Baltic Sea is covered by national continental shelves. A corresponding general obligation applies, however, through the more general environmental obligations of states in UNCLOS Part XII. Apart from that, dredging clearly falls among the sovereign rights that states have over their continental shelves under Article 77(1).

The Helsinki Convention does not specifically mention dredging either. It regulates exploration or exploitation of the seabed and other offshore activities with the aim to prevent pollution of the marine environment form such activities, but this primarily concerns the production or extraction of gas and oil.[178]

While dredging as such is not regulated internationally, the treatment of the dredged material is subject to a number of rules at regional (and national) level. The disposal of dredged materials is covered by the rules of the Helsinki Convention, which provides an exemption from the general dumping prohibition for dredged materials, but even in the case of dumping of such materials strict requirements on permits and other precautions are set out in Annex V.[179]

[177] UNCLOS, Art 145. See also Art 17(2)(f) of Annex III
[178] The Helsinki Convention, Art 12.
[179] The Helsinki Convention, Art 11. In 2015 HELCOM adopted revised Guidelines for Management of Dredged Material at Sea.

Yet, as the purpose of dredging normally is to remove the sediment without returning the dredged materials into the sea, this regulation does not find application. It may be worth mentioning, however, that the effects of dredging and dumping of such materials in some aspects are comparable, e.g. as regards turbidity. On this basis, it has been suggested that if dumping of dredged materials is restricted, the dredging activity itself should also be undertaken with corresponding caution and restrictions.[180]

Beyond the risk that dredging might imply from the direct activities for any flora or fauna found in the seabed, dredging may also entail adverse effects for the marine ecosystem because of the temporary increases in turbidity of sediment and the risk of release of contaminants to the water column.[181] Because of this, dredging potentially invokes a number of more general environmental laws and principles and could very well fall within the definition of 'pollution of the marine environment' in UNCLOS and other instruments.

EU law does not provide any specific regulation on dredging either, although it is indirectly within the scope of the water/marine framework directives which regulate the environmental quality status of waters, irrespective of the activity involved. In addition, if the dredged materials are considered to be waste – perhaps also including toxic substances or other forms of contaminants that are stored in the sediment – with the only purpose to be disposed of or stored, the regime for waste comes into play. This includes a variety of requirements relating to the disposal, permits, and procedures etc. which are mainly regulated by EU law and, through that, in national implementing legislation.[182]

If the activity is taken near the coast, the WFD is applicable. This means that the environmental objectives of the WFD have to be taken into account, and at a national level this could also include environmental quality standards (EQS). Moreover, the WFD's principle of non-deterioration would then also be relevant.[183] The extension of the non-deterioration principle was the key question in the so-called Weser Case at the CJEU, which will also significantly restrict the extent to which such activities can be pursued. The Court ruled that any activity – such as dredging – leading to deterioration is prohibited, even if the deterioration is only temporary.[184]

A question that arises in the context of sea-based measures is whether and how the intentions behind the activity affect the application of this rule, and whether the environmental impact shall be considered in relation to the potential long-term environmental benefits of the activity or only through the short-term environmental impact. This issue is discussed further in sections 5.4.4.2.2 and 5.4.5 below.

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[180] Swedish Environmental Protection Agency (Naturvårdsverket), Report, "Muddring och hantering av muddermassor: Vägledning om tillämpning av 11 och 15 kap Miljöbalken", Miljörättsavdelningen 2010- 02-18, pp. 34ff. [in Swedish].

[181] Swedish Environmental Protection Agency (Naturvårdsverket), Rapport 5999, October 2009, "Miljöeffekter vid muddring och dumpning: En litteratursammanställning" [in Swedish].

[182] Regulated in Directive 2008/98/EC on waste (Waste Framework Directive).

[183] WFD, Art 4.

[184] Case C-461/13 Bund v Germany (the Weser Case). Cf. Common Implementation Strategy for the Water Framework Directive and the Floods Directive, Guidance Doc no 36, "Exemptions to the Environmental Objectives according to Article 4(7): New modifications to the physical characteristics of surface water bodies, alterations to the level of groundwater, or new sustainable human development activities", *Document endorsed by EU Water Directors at their meeting in Tallinn on 4-5 December 2017* pp. 21-22, where the time span is defined in different terms.

5.4.2.3 Chemical treatment

The use of chemicals to fixate the phosphorus in the sediment is the second category identified. The underlying idea here is to treat the seabed with certain chemicals, such as aluminium, which bind the phosphorus to the sediment so that it cannot leak into the water. Other materials that could be used for the purpose include marl, mineral clay or iron, as further described in section 3.3.1 of this study. The environmental effects of these substances differ and different chemicals will entail to different risks for the ecosystem. The legal assessment depends on the environmental effects and may hence well be different depending on the substance used. However, the techniques for treatment and their legal attributes are similar, which means that they may be categorized together.

In this case, too, the starting point is an essentially permissive framework in which states have exclusive jurisdiction over the exploitation of their national waters and EEZ/continental shelf and to authorize and control marine scientific research in these areas. However, the general obligation to have due regard to the interest of other states apply along with the general obligations to protect the marine environment and prevent pollution.

As opposed to dredging, chemical treatment involves the introduction of substances into the sea, which not only potentially falls within the definition of marine pollution of UNCLOS, but also raises the question whether it could be considered to represent dumping at sea.

In the London Convention, and in the London Protocol, dumping means *inter alia*: “any deliberate disposal at sea of wastes or other matter from vessels, aircraft, platforms or other man-made structures at sea”.[185] The same definition is found in UNCLOS and in the Helsinki Convention.[186] The term 'disposal' is not legally defined, but given that ocean fertilization has been considered to come under the scope of the London Convention and Protocol,[187] it is by no means excluded that chemical treatment of the seabed would be covered too. While chemicals deliberately used for the purpose of fixating phosphorus to the sediment would probably not represent 'waste' under this definition, they may still be considered dumping to the extent it falls under the notion of ‘other matter’.

Another key question in this regard relates to the purpose of the placing of the matter in the sea. Both the London Convention and the Protocol provide that “placement of matter for a purpose other than the mere disposal thereof” is excluded from the scope dumping, “provided that such placement is not contrary to the aims of [the] Convention [Protocol].”[188] A similar exception is found also in the Helsinki Convention.[189] Since the purpose of chemical treatment is not "mere disposal" of the chemicals in question, this exemption may accordingly be used for excluding the activity from the dumping regime altogether, provided that it is not contrary to the aims of the conventions or protocol.

What, then, are the aims of the conventions? The general objective of the London Convention is for states to control pollution and thus, as part of this, to prevent dumping of wastes or other matter into the sea if it is “liable to create hazards to human health, to harm living resources and marine life, to damage amenities or to interfere with other

185 London Convention, Art III(1)a; London Protocol, Art 1(4)1(1).).
186 UNCLOS, Art 1(5)(a)(i); Helsinki Convention, Art 2(4)a(i).).
187 Resolution LC-LP (2008), para. 1.
188 London Convention, Art III (1)(b)(ii); London Protocol, Art 1(4)2(2).).
189 Helsinki Convention, Art 2(4)b(ii)

legitimate uses of the sea."[190] The Helsinki Convention does not include a similar general article to declare its objective, but it follows from the text that the objectives of that convention are somewhat broader in that they also include protection of intrinsic natural values including to "conserve natural habitats and biological diversity and to protect ecological processes".[191] The applicability of the dumping obligations to chemical treatment accordingly depends on the effects, including the environmental effects, of such measures. The greater a risk for the marine environment they constitute, the more likely it is that they will be considered to be contrary to the aims of the conventions and hence included in the scope of dumping, independently of whether or not the purpose is to dispose of the chemicals. Depending on what substances that are used and the scientific basis for their use, it cannot be excluded that release of chemicals into the marine environment entails some level of risk and thus be seen as both dumping and pollution of the marine environment (see section 5.4.5.3).

Even if an activity falls within the definition of dumping, it does not necessarily follow that it is forbidden. The London Convention only prohibits dumping of wastes or other matters that are listed in its Annex I. Wastes or other matters listed in Annex II requires a special permit, while wastes and other matters that are not included in the list only require a general permit. Depending on the substance chosen for chemical treatment, the Convention thus limits most dumping to become a question of a permit procedure. A special permit means permission granted specifically on application.[192] Both permit procedures require advance application, but the permit procedure is more stringent for Annex II substances that require "special care". Neither aluminium nor clay, which represent the main sediment-treating substances considered here, are listed in any of the Annexes and thus treatment of the seabed with those chemicals would be subject to more permissive general permit according to the London Convention. However, Annex II does make a reference to "materials which, though of a non-toxic nature, may become harmful due to the quantities in which they are dumped, or which are liable to seriously reduce amenities."

However, under the London Protocol, which applies in both Finland and Sweden, the regime is different. The London Protocol establishes a general prohibition of dumping, with the exception of wastes and other matters listed in its Annex I. Neither aluminium nor iron is listed in the Annex, but it does provide for the issue of permits in respect of "inert, inorganic, geological material" and "organic material of natural origin", which again highlights the difference that applies depending on what material is used. Even the matters listed are only allowed if a permit is granted and they shall be subject to permit procedures set out in Annex II. In addition, it is stated that any alternative to dumping that is more environmentally preferable shall be used as a first choice.[193] As a starting point, therefore, the Protocol rules out the introduction of aluminium into the sea, to the extent the matter falls within the definition of dumping, which in turn depends on whether they are contrary to the aims of the protocol.

[190] London Convention, Art I.
[191] Helsinki Convention Art. 15. See also Art. 3(1) "The Contracting Parties shall individually or jointly take all appropriate legislative, administrative or other relevant measures to prevent and eliminate pollution in order to promote the ecological restoration of the Baltic Sea Area and the preservation of its ecological balance."
[192] London Convention, Art. III(5).
[193] London Protocol, Art 4(1).

The London Protocol also includes “any storage of wastes or other matter in the seabed and the subsoil thereof” within the definition of dumping.[194] This takes the concept of dumping further, but an amendment adopted in 2006 permits so-called permanent carbon sequestration under the seabed under certain prerequisites.[195] Carbon sequestration is included among the matter approved for dumping with a permit, found in Annex I. The aim of this is to reduce atmospheric CO2 emissions from different industrial sources.[196] This represents a rare example of a case where one form of dumping has been approved for the purpose of protecting the environment in other ways.

However, other climate mitigation measures that classify as dumping have been rejected under the London Protocol. A particularly relevant example is ocean fertilization for mitigation of climate change. Such measures have not been accepted within the frame of the Protocol, with reference to the precautionary approach laid down in the Protocol.[197] However, a framework for assessing ocean fertilization for research purposes has been developed and adopted, which allows such measures to be carried out under certain conditions. The measures suggested to reduce the amount of phosphorus in the Baltic Sea include certain important similarities to such geo-engineering activities, which will be discussed in more detail in section 5.4.5.5.2.

In EU law, there are no rules specifically regulating dumping, though the EU is a party to UNCLOS, the London Convention, the London Protocol, and to the Helsinki Convention which include prohibitions of dumping. Like with the case of dredging, the risks involved with chemical treatment of the seabed raise matters linked to the WFD and in particular the Weser Case, evoking the non-deterioration principle. The prohibition that the Weser Case establishes against activities causing any deterioration of the WFD classification indicators suggests that risks of chemical treatment of the seabed might very well be an obstacle to such measures too, if performed in an area where the WFD is applicable.

5.4.2.4 Oxygenation

Oxygenation of the seabed by pumping more oxygenated water from the surface to further depths with the purpose of oxygenating the seabed is the third main category of sea-based measures that has been identified within the scope of the study. Oxygenation is a technique that does not immediately resemble any other activities at sea as regulated by international law.

In practice, oxygenation differs from the other categories in that it is a long-term activity and requires a semi-permanent installation. While skimming and chemical treatment are one-off interventions, oxygenation is an on-going process which is likely to continue for months or years and will hence have longer-term implications both for the environment and for other users of the sea.

[194] London Protocol, Art 1(4)(3).
[195] Amendment to include CO2 sequestration in sub-seabed geological formations in Annex 1 to the London Protocol Adopted on 2 November 2006, by Resolution LP.1(1), see circular LC - LP.1/Circ.5.
[196] Birnie, Boyle, Redgwell, International Law and the Environment, p 468.
[197] London Protocol Art 3(1); Resolution LC-LP.1(2008) on the Regulation of Ocean Fertilization, adopted on the Thirtieth Meeting of the Contracting Parties to the London Convention and the Third Meeting of the Contracting Parties to the London Protocol; see also Sands, P. and Peel, J., *Principles of International Environmental Law*, 3rd Ed., Cambridge University Press, 2012, p. 396.

Oxygenation also differs from the other methods in that it is not as easy to categorize in the existing legal framework. Pumping oxygen-rich water from one part of the sea to another does not fit within the definitions of dumping as discussed above. It does not involve any disposal of waste or other matter, and it is similarly doubtful that it involves "placement of matter for a purpose other than the mere disposal thereof", which could invoke the question of compatibility with the aims of the convention. It is accordingly difficult to apply the rules for dumping as such to oxygenation.

By contrast, oxygenation does represent a “deliberate intervention in the marine environment to manipulate natural processes” and could hence fall within the definition of 'marine geo-engineering' adopted under the London Protocol in 2012, but not yet in force. Whether this means that the London Protocol framework for assessments would be applicable is not certain, as it is not clear whether geo-engineering measures also need to qualify as "placement of matter" and considered to be against the purpose of the convention to fall within the scope of the regime. In the end, this issue will be decided by the contracting parties to the Protocol. The significance of the 'geo-engineering' rules of the London Protocol for sea-based measures more generally is discussed below in section 5.4.5.5.2.

The absence of an applicable international legal framework specifically dealing with oxygenation leaves the matter subject to the more general provisions of UNCLOS and other instruments on the protection and preservation of the marine environment, together with the environmental law principles which provide guidance on the balancing of interests involved.

Apart from those general environmental rules, which mainly address the environmental and other impacts of the circulation of water that the technology entails, the legal framework also includes rules on the installation as such. Oxygenation requires technical equipment that is placed in the ocean, presumably tied to the seabed in some way, and that needs to be supplied with energy. The construction and maintenance of such installations is regulated in UNCLOS.

The technical construction necessary for the operation of oxygenation measures appears to fall squarely within the scope of the term "installation or structure" as regulated by, but not defined in, UNCLOS. In the absence of a definition, the boundaries of the concept can be sought in relation to other activities and constructions that are specifically regulated, such as artificial islands, submarine cables and pipelines. Jurisdiction-wise, UNCLOS provides that in the EEZ and on the continental shelf, the coastal states have the exclusive right to authorize and regulate the construction, operation and use of, *inter alia*, installations and structures.[198] The only limitations or restrictions to the construction or operation of an installation are the general environmental principles, the requirements found in Part XII of UNCLOS and that such installation cannot interfere with the recognized sea lanes essential to international navigation. A safety zone of maximum 500 meters may, where necessary, be established around such installations to ensure the safety of navigation and of the installation itself. There is also an established duty to notify where such installation is and to remove it after its use.[199] In brief, this regime places certain obligations on the setting up and operation of such installations, but does not question the

[198] UNCLOS, Art 60; and regarding jurisdiction for installations on the continental shelf, see Art 80.
[199] UNCLOS, Art 60.

exclusive authority of the coastal state to establish and operate them in their EEZ and, a fortiori, their territorial sea.

The EU law that is applicable to oxygenation is, also in this category and to some extent, the general requirements on good environmental status found in the WFD and – for large-scale trials in the deep basins – the MSFD. Moreover, the Birds and the Habitats Directive may restrict the geographical areas where such installation could be allowed without a special permit.[200]

Also in this case, the conclusions of the Weser judgment regarding the no-deterioration principle would draw a rather strict line for what is permissible, if the WFD is applicable. The pumping process connected to the oxygenation seems, for example, to entail a risk of stirring effects. However, the WFD applies a range of quality indicators and it is possible that an oxygenation installation could have adverse effects on the environmental status also in other ways.

The MSFD, as was already noted, applies in all sea areas beyond the baseline, only overlapping the geographical scope of the WFD with 1 nm. The MSFD is not directly applicable to a specific activity or project. Instead, the MSFD functions as a steering mechanism for the overall approach taken by the member states in their planning and managing of land-use and water areas at a general level. The indicators and status classifications made in relation to the MSFD are also at a larger scale and are not specific to single effects on a limited area. It is not clear, therefore, that the logic of the Weser Case could be transposed to this setting (section 5.4.4.2.3). Rather, the wider question is whether the potential positive effects of sea-based measures could also have effects for the purpose and goal of good environmental status according to the MSFD.

5.4.3 Geographical differentiation

5.4.3.1 General

A second type of legal categorization relates to the geographical area in which the sea-based measures are undertaken. It follows from the above that the applicable substantive rules differ not only depending on what measures, but also on what location, are in question. This matter will briefly be studied here, starting from the innermost areas and moving seawards.

Generally speaking, the coastal state's authority over the activity in question increases with the proximity to its coast. Hence, a coastal state has broader possibilities to introduce its own rules in its internal waters than on the EEZ. Similarly, national and EU rules are more dominant in the innermost sea areas, while the relevance of international rules increases as the activity moves seawards. However, it should be noted that the national rules in this area are strongly influenced by international obligations, and the substantive differences between the various layers are not necessarily very big. Where national laws are used as an example, reference will be made to Finnish law.

[200] Habitats Directive, Art 6.

The review is purely juridical and does not address certain matters of fact, such as the cost-effectiveness or suitability of the technologies for operation in different sea areas.

5.4.3.2 Internal waters

Internal waters refer to the sea area that is landward of the baseline, which in the case of Finland and Sweden essentially means the coastal archipelagos. In this area, the coastal state enjoys full sovereignty and can regulate activities on and usage of the waters as it pleases, subject to its international obligations.

National and EU rules accordingly apply in full in this area, unless otherwise is specifically provided, while the applicability of the international obligations has to be addressed case by case based on the scope of the conventions concerned.

The general environmental obligations of UNCLOS, including the general obligation to protect the marine environment,[201] including fragile ecosystems,[202] also apply to the internal waters and hence represent a limitation to state's sovereignty to use its sovereign waters as it wishes. Some of these obligations, such as the 'no harm' obligation contained in Article 194(2), are only activated if there is a cross-border element of the pollution. Even if they apply to internal waters, they will generally be of lesser relevance to measures taken in the internal waters simply because those measures are less likely to generate effects in other states.

It has been observed above that some of the relevant international obligations in specific conventions do not extend to the internal waters of the states parties (like the London Convention), while others do so only in part (like the London Protocol) and others apply in these areas in full (Helsinki Convention). This difference in scope of application has the effect that even if dumping is not prohibited in the internal waters under the global rules, the less detailed, but similarly stringent, rules of the Helsinki Convention apply with full force. Moreover, Article 7(2) of the London Protocol provides that if the rules of the Protocol are not directly applied in the internal waters, states shall "adopt other effective permitting and regulatory measures" to cover dumping activities if conducted at sea. Dumping is, accordingly, not permitted in the internal waters of Finland or Sweden. Disposal that falls outside the definition of dumping would not be prohibited by international rules in the internal waters, nor would they be covered by the obligations of London Protocol Article 7(2). However, EU and national law still place a range of obligations to prevent activities that cause pollution in the internal waters, including directly from land.

5.4.3.3 Territorial sea

Since the entry into force of UNCLOS in 1994, Finland and Sweden have amended their national legislation to make full use of the right to apply a territorial sea of up to 12nm. In certain cases, the sea area may be narrower than that, due to insufficient space with respect to neighbouring states. This sea area forms part of the territory of the state and is hence as a starting point subject to its territorial sovereignty.

[201] UNCLOS Art. 192
[202] UNCLOS Art. 194(5).

In this area, too, all EU rules apply, unless otherwise is explicitly provided, in view of the reference of the applicability of the TFEU to the member states, which is generally understood as referring to all the areas that are within sovereignty or jurisdiction of the member states, including maritime areas.

A particular oddity introduced by EU law is the legal limit of 1 nm from the baseline which is introduced by the WFD. It does not have a counterpart under international law, but significantly alters the applicability of the rules in EU member states. Within the 1nm limit, the WFD applies, with some complementary requirements of the MSFD, while outside the limit, the rules of the MSFD apply. As was noted above, there are material differences between these rules and it is not clear whether the strict interpretation of the non-deterioration principle that was applied by the ECJ in the Weser judgment (which concerned the WFD) can be applied analogically to areas falling under the MSFD which uses a somewhat different logic and structure (section 5.4.4.2.3).

All international conventions discussed in this chapter apply in the territorial seas of their parties. The law of the sea includes certain exceptions from the sovereignty of the coastal states in this area, for example with respect to the right of innocent passage of foreign ships, but these limitations are not likely to be significant for sea-based measures implemented in the territorial sea. One such limitation could be, however, that oxygenation installations in the territorial sea could not be placed in locations that would have the effect of hampering this right of ships. Even so, however, the right of innocent passage may be temporarily withdrawn and ships may be required to follow particular sea lanes.[203]

5.4.3.4 Exclusive Economic Zone

The EEZ was created through UNCLOS as a *sui generis* maritime zone, jurisdiction-wise lying somewhere between the territorial sea and the high seas. As a starting point, the freedoms of the high seas apply in this zone unless otherwise is provided in UNCLOS. With respect to environmental protection, coastal states are granted jurisdiction in this zone as well as sovereign rights over their living and non-living resources.

The extent to which EU rules apply beyond the limits of the territorial sea has been subject to some uncertainty. At least with respect to certain instruments, the Court has confirmed that EU law applies to activities falling within the coastal member state's jurisdiction or sovereign right to the extent that the state has exercised its sovereign rights.[204] The extent to which EU law extends to the EEZ and the continental shelf may thus vary from one field to another, but for the key directives of relevance here, it seems clear that they apply. This is specifically confirmed in the scope of the MSFD and the MSPD. The waste directive is not clear on this point,[205] while the EIA Directive extends to projects affecting directly or indirectly "water" without further specification.

The applicability of national law to this area depends on the scope of the law. Many of the Finnish laws of direct relevance to sea-based measures include specific reference to the EEZ within their scope of application.[206] Apart from that, as was noted in section 5.2.5.2.7

[203] UNCLOS Arts 22 and 25(3).
[204] Case C-6/2004, *Habitats Directive*. Case C-111/05
[205] But see e.g. how it was applied in Case C-188/07, *Commune de Mesquer*
[206] E.g. the Environmental Protection Act (section 2(3))

above, the EEZ Act expands the application of specific national laws, including all key laws for the purpose of this study, to the EEZ. The Act also includes specific provisions on seabed activities and marine scientific research in the EEZ.

5.4.3.5 Activities beyond the national areas

The international environmental obligations of states extend to harm caused beyond their own territory, and in many respects even strengthen in such cases in view of the cross-border elements. Whether the EU and national laws apply in such areas depends on the scope of the rule in question.

In Finland, a separate law, the Act on the Protection of the Marine Environment, deals with rules that apply for Finnish ships and persons beyond the coastal zones of Finland. Broadly speaking, the Act prohibits activities that may cause pollution of the seas by Finnish ships, citizens and legal persons outside of the Finnish maritime zones. Moving beyond these zones will not therefore dramatically change the applicable legal requirements. The Act also provides for permits for e.g. dumping of dredged materials and the exploration and exploitation of the seabed, unless national authorities in the state where the activity takes place issue such a permit.

Given that the Baltic Sea is already fully covered by coastal maritime zones, any activity beyond Finnish jurisdiction in the Baltic Sea will inevitably mean that an additional set of rules apply to such operations. In view of the sovereign rights and jurisdiction of states under the law of the sea, the coastal state in which the operation takes place will have jurisdiction over such activities. It will also be the coastal state, with whatever national procedures and substantive rules it has, that issues the relevant permit for the operation.

5.4.4 Some relevant rules of general applicability

5.4.4.1 General

The general classification of the sea-based measures was based on the specific rules that apply to the individual categories. In addition to that, there are certain rules that apply generally, for any measure, which are of critical relevance for the rules governing sea-based measures and therefore deserve to be studied in some more detail.

First, the measures discussed here may be subject to some level of EIA (section 5.4.4.2). Second, the Helsinki Convention includes certain general obligations that apply across the board (5.4.4.3). Third, the requirements of the EU marine directives (WFD and MSFD) need to be assessed in more detail, not least following the judgment by the CJEU in the Weser Case in 2015, which may imply important restrictions for some or all of the sea-based measures discussed here (5.4.4.4).

5.4.4.2 Environmental Impact Assessments

As was noted in sections 5.2.2.3 and 5.2.4.3, the EIA procedure is an important instrument for the reviewing and mapping the knowledge of direct and indirect effects of the planned project or activity, and potential precautionary measures that are specific to any activity or measures that has potential hazardous effects on the environment. More specific procedural requirements are found both at EU level (the EIA Directive) and at international level (the Espoo Convention). Moreover, national implementing laws may include additional requirements of what should be included in an EIA, and what activities that should be reviewed on the basis of EIAs.

The Espoo Convention aims for states to take early action to avert danger by notifying and consulting with neighbouring states on major projects that are under consideration and that could have impact on the environment beyond the national borders.[207] To this end, the Espoo Convention specifically lists certain activities that should always fall under this obligation.[208] None of these are directly applicable to sea-based measures, but the Convention also contains a possibility for activating the EIA rules also in relation to other activities, which are considered likely to cause a significant adverse transboundary impact.[209] This could be applied to the suggested sea-based measures. The EIA Directive includes similar obligations, but with a more narrow range of targeted activities which does not seem to cover sea-based measures.

The requirement to make EIAs is only a procedural requirement that does not as such control or restrict measures taken. However, EIAs are relevant in this context since it is through this process that the different potential risks, benefits and other interest or issues are to be presented and assessed. This information, and any knowledge gaps it may highlight, may be of critical importance when applying the (separate) national permit procedures, discussed in section 5.5, to which the EIA shall be submitted.

5.4.4.3 Helsinki Convention

At intergovernmental level, the Helsinki Convention is the point of departure for any activity involving the environment of the Baltic Sea. The convention and the rules and recommendations adopted for its implementation confirm the necessity of significant nutrient pollution reductions in order to achieve the HELCOM Vision on a healthy Baltic Sea and a good environmental status, as required also by the MSFD in relation to eutrophication in the Baltic Sea.

However, the Helsinki Convention, the BSAP and the MSFD offer little guidance on how these pollution reductions are to be achieved and there are no express requirements in relation to the categories of measures discussed here. The Helsinki Convention regulates dumping, and also includes requirements on EIAs, but even if the Convention is generally seen as having a broad and cross-sectoral scope, it includes no express provisions on dredging, nor on structures that could match the technical installations needed for oxygen pumping. Instead, the main structure and tenet of the Convention is a general approach towards any kind of pollution and any measures taken in the region to reduce eutrophication. This also has the consequence that it relies on environmental law principles to govern activities or measures discussed here and even lays down the most relevant principles in this respect.

[207] Espoo Convention, Art 2.
[208] Espoo Convention, Art. 2(2) and Appendix I.
[209] Espoo Convention, Art, 2(5).

The Helsinki Convention requires its parties to "take all appropriate legislative, administrative or other relevant measures to prevent and eliminate pollution in order to promote the ecological restoration of the Baltic Sea Area and the preservation of its ecological balance."[210] It also applies the precautionary principle, by obliging the parties to "take preventive measures when there is reason to assume that substances or energy introduced, directly or indirectly, into the marine environment may create hazards to human health, harm living resources and marine ecosystems, damage amenities or interfere with other legitimate uses of the sea even when there is no conclusive evidence of a causal relationship between inputs and their alleged effects."[211] Both principles refer to the ecosystem, as does the obligation in Article 15 for the parties to "take all appropriate measures with respect to the Baltic Sea Area and its coastal ecosystems influenced by the Baltic Sea to conserve natural habitats and biological diversity and to protect ecological processes."[212] With the adoption of the BSAP, the HELCOM regime further acknowledged and operationalized the ecosystem approach. Even if generic and difficult to operationalize in the abstract, these principles may be of importance when balancing the interests involved in sea-based measures.

The Convention also reiterates the obligations provided in the Espoo Convention on establishing an EIA and notifying other states concerned[213] and includes regulation regarding the exploration and exploitation of the seabed and its subsoil.[214]

More importantly, for present purposes, the Helsinki Convention prohibits dumping, with a main exemption only for dredged material, but even in the case of dumping of such materials, strict requirements on permits and other precautions are set out in Annex V.[215] Dumping of dredged materials must be carried out under a prior special permit issued by the appropriate national authority, but then only within the area of internal waters and the territorial sea of the contracting party. If a party wants to dump such materials outside its internal waters and territorial sea it requires prior consultation in HELCOM.[216] For this purpose, HELCOM has recently adopted specific guidelines regarding dumping of dredged materials and the processes or requirements that states parties shall apply.[217]

The Helsinki Convention, in other words, provides a general ban on dumping and hence goes beyond the rules of the London Convention to which many of the Baltic coastal states are still parties. Moreover, since the Helsinki Convention, as opposed to the global dumping rules, has a geographical scope which includes internal waters, the Baltic Sea states do not have any freedom to apply other rules in these areas.[218]

Finally, the Helsinki Convention places obligations on states to take all appropriate measures to "conserve natural habitats and biological diversity and to protect ecological

[210] Helsinki Convention, Art 3(1).
[211] Helsinki Convention, Art 3(2).
[212] Helsinki Convention, Art 15.
[213] Helsinki Convention, Art. 7.
[214] Helsinki Convention, Arts. 11 and 12.
[215] The Helsinki Convention, Art 11.
[216] The Helsinki Convention, Annex V, Regulation 1, b).
[217] HELCOM Guidelines for Management of Dredged Material at Sea, Adopted by HELCOM 36-2015 on 4 March 2015.
[218] The Helsinki Convention, Art 1.

processes"[219] and includes a variety of cooperative obligations, which will be of relevance for assessing the manner in which sea-based measures will be undertaken.

5.4.4.4 The marine directives (WFD and MSFD)

5.4.4.4.1 General

Through the framework directives, EU law directly and indirectly addresses any kind of marine activities which may entail reduction of the water quality. The WFD involves the most direct limitations in this regard. It is directly relevant for dredging activities, but in view of its focus on any activity that could involve environmental degradation, it could also be applied to chemical treatment of the seabed or oxygen pumping.

The WFD applies to internal waters, including inland surface waters, transitional waters, coastal waters and groundwater, and has a geographical scope which stretches in total maximum 1 nm beyond the baseline on the seaward side, except in respect of chemical status for which it shall include territorial waters and may hence extend up to 12nm from the baseline.[220] In comparison, the MSFD is applicable to marine waters from the baseline on the seaward side extending to the outmost reach of the area where a member state has and/or exercises jurisdictional rights in accordance with UNCLOS.[221] To the extent the two directives overlap (for waters within the 1 nm limit from the baseline), the MSFD gives precedence to the WFD by only including "coastal waters as defined by Directive 2000/60/EC, their seabed and their subsoil, in so far as particular aspects of the environmental status of the marine environment are not already addressed through that Directive or other Community legislation."[222]

If the WFD is applicable, i.e. if the measure is taken in internal waters or less than 1nm from the baseline, the environmental objectives of the WFD become central to permitting the activities. The general aim of the WFD is to create a framework for the protection of water for a number of different purposes, including to prevent further deterioration and to enhance the status of aquatic ecosystems, with regard to their water needs, terrestrial ecosystems and wetlands directly depending on the aquatic ecosystems.[223] The framework set out for this protection is based on environmental objectives and the general aim to reach good ecological/chemical water status. In order to assess the ecological status, member states are to identify river basin districts and make river basin management plans. In order to be able to monitor environmental status in these river basins, the member states are first to make an initial assessment of the water status in each river basin, to classify the water status from which to track development towards better water quality. The protective framework also prohibits that the water quality deteriorates for any of the waters assessed and classified, based on the principle of no deterioration.[224]

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[219] Article 15.
[220] WFD, Arts 1 and 2.
[221] MSFD, Art 3(1)a.
[222] MSFD Art. 3(1)(b)
[223] WFD, Art 1.
[224] WFD, Art 4.

The classification of water status is based on a range of quality elements or indicators, adjusted to the specific types and characteristics of waters and the particular environmental objectives. Depending on these quality indicators, waters are classified as having high, good, moderate, poor and bad status. The sum of the level or existence of all quality elements – as specifically described in the Annexes to the Directive – decides the general quality level or the general status classification. A water body is classified in the class immediately below as soon as the ratio of one of the quality elements falls below the level for the current class, according to the principle “one out all out”, which is linked to the definition of “surface water status” in Article 2 of the WFD: the status is to be determined by the poorer of the ecological status and the chemical status of the body of surface water.[225] This classification and the environmental objectives are factors that become central when assessing whether the activities connected to sea-based measures could be permitted, since they could potentially harm the quality elements and the ecological status.

Since the WFD is a directive, these rules are to be implemented through national law.[226] It is therefore up to individual member state legislation to specify how different areas are assessed, classified and monitored. In Finland, implementation is ensured through the Water Resource Management Act. In Sweden, the implementation is primarily done through Chapter 5 of the Environmental Code and the Water Management Ordinance. Further harmonization of the national requirements may be achieved not only by means of amendments to the WFD,[227] but also through judgments and rulings by the CJEU. A particularly relevant ruling on the interpretation and application of the WFD rules is the Weser judgment from 2015. Since this case has wide consequences for activities affecting the water status in an area protected by the WFD, it deserves more detailed scrutiny here.

5.4.4.4.2 The Weser Case

The Weser Case[228] was initiated by a permit procedure for a project that included dredging activities in the river Weser in Germany. In a court procedure on potential permit for a planned project, questions regarding the legal extension of the WFD and its ecological objectives arose. The German Federal Administrative Court (“Bundesverwaltungsgericht”) asked the CJEU (the Court) for a preliminary ruling on the interpretation of the extension of the WFD ecological objectives and the non-deterioration principle.

The case in the Court focused particularly on the obligation of member states to achieve ‘good surface water status’ in Article 4(1)(a)(ii) of the WFD, which all bodies of water in the EU territories ought to have achieved by 2015.[229] The most central question was whether the member states are required to refuse authorisation for a project where it may cause a deterioration of, *inter alia*, the status of a water body or where it jeopardises the attainment

[225] WFD, Article 2(17); Case C-461/13 Bund v Germany (the Weser Case), Para 59.
[226] Under TFEU art 288, directives do not have direct applicability. However, case law by the CJEU has confirmed the "vertical" direct effect of directives, which permits citizens to invoke non-implementation of the directive against a member state (but not against private persons) in case national implementation does not meet the requirements of the directive once the deadline for implementation has expired.
[227] WFD has been amended 7 times since it was adopted in 2000.
[228] Case C-461/13 Bund v Germany (the Weser Case),
[229] Paloniitty, T., Analysis: The Weser Case: Case C-461/13 BUND V GERMANY, *Journal of Environmental Law*, 2016, 28, 151–158 doi: 10.1093/jel/eqv032.

of good surface water status in accordance with the general requirements laid down by the directive.[230]

The questions could be divided into two main themes. The first theme was concerning whether the quality standards set out by the WFD were only goals for management planning or whether they were binding for concrete authorizations of projects and permitting decisions. The second theme was concerning the way the standards have to be applied and focused more specifically on how the term “no deterioration” should be understood.[231]

The Court ruled that the objectives of the WFD are legally binding. The wording of Article 4(1)(a)(i), which provides that member states shall implement the necessary measures to prevent deterioration of the status of all bodies of surface water, involves an obligation on the member states, meaning that also authorisation of individual projects also falls within the scope of that obligation.[232] The member states are accordingly obliged to refuse authorisation of individual projects estimated to compromise the objectives. The Court also took a strong stance on the so-called non-deterioration principle, which thus is of significance also in relation to the proposed sea-based measures. The ruling by the Court in this part was that it binds the member states to such an extent that not any decline of the quality of the surface waters is allowed.

In summary, this means that the member states are required to refuse authorisation for an individual project where it may cause a deterioration of, *inter alia*, the status of a body of surface water or where it jeopardises the attainment of good surface water status, unless the procedures of Article 4(7) are applied.[233]

Another central aspect of this judgment is the more specific definition of deterioration and whether the wider intentions of a project would have any impact on the effects for the environmental status; that is, whether a more long-term goal of better environmental status would somehow be able to compensate for a potential short-term deterioration of the ecological status. The Court found that the wording of Article 4(1)(a)(i) of the WFD supports an interpretation according to which the concept of “deterioration of the status” of a body of surface water covers deterioration which does not result in any other classification of the water body, meaning that it would be sufficient that only one quality element would deteriorate in order for it to constitute a breach of the non-deterioration principle.[234]

The Court furthermore stated that an interpretation of “serious impairment”, as a contrast, constitutes a deterioration of the status of a body of water. This interpretation is based on the weighing up of, on the one hand, the adverse effects on waters and, on the other, water-related economic interests. Such interpretation of “serious impairment” does not respect the difference established by the directive between the obligation to prevent deterioration of the status of a body of water and the grounds of derogation laid down in Article 4(7) of the directive, since only the latter involve some weighing up of interests. Here, the Court in other words suggests that there is no room for valuing long-term versus

[230] Case C-461/13 Bund v Germany (the Weser Case), Para 29.
[231] van Rijswick, H.F.M.W. and Backes, C.W., ”Ground Breaking Landmark Case on Environmental Quality Standards?: The Consequences of the cjeu ‘Weser-judgment’ (C-461/13) for Water Policy and Law and Quality Standards in EU Environmental Law”, *Journal for European Environmental & Planning Law*, 12 (2015), p. 368
[232] Case C-461/13 Bund v Germany, Paras 31–32.
[233] Case C-461/13 Bund v Germany, Para 51.
[234] Case C-461/13 Bund v Germany, Para 55.

short-term consequences in relation to activities that deteriorate the ecological surface status, but such a balancing is to be made in the context of derogations under Article 4(7).[235] All this means that even a very slight – and potentially short-term – degradation of the water status is a breach of the rules laid down in the WFD.

In the case of sea-based measures, the relevant interests are, on the one hand, the attainment or maintenance of the Directive's water status objectives and the fulfilment of the non-deterioration principle and, on the other hand, the significance of an undertaking requiring derogation. According to the reasoning here, it seems that impairment of the quality of the water body could be justified where the interests favouring a project of exemption are sufficiently significant.[236] However, derogations can only be granted under certain specific circumstances.

Moreover, even for the derogations, found in Article 4(7), the WFD still requires that "all practicable steps are taken to mitigate the adverse impact on the status of the body of water", that "the reasons for those modifications or alterations are of overriding public interest and/or the benefits to the environment and to society of achieving the objectives ... are outweighed by the benefits of the new modifications or alterations to human health, to the maintenance of human safety or to sustainable development", and that "the beneficial objectives served by those modifications or alterations of the water body cannot for reasons of technical feasibility or disproportionate cost be achieved by other means, which are a significantly better environmental option."

5.4.4.4.3 The application of the Case to MSFD

Another important question related to the Weser Case is whether an analogy can be made to the application of the MSFD. The MSFD is in many ways complementary to the WFD and similar in aim and nature. It, too, includes a non-deterioration rule, which could suggest that the interpretations made in the Weser ruling could be applied analogously. However, many aspects of the assessment of indicators, environmental status, and the programs of measures in the MSFD are designed rather differently from the approach in the WFD. While the general principles of the Weser ruling could maybe be seen as parallel in relation to the aim and application of MSFD, the general conclusions are probably not directly transferable. One important difference is that the areas protected by the MSFD are much larger than in the WFD, hence also more difficult to monitor and control.[237] For such reasons it is generally not possible to connect one specific plan, project, or other source of pollution to a specific occurrence of deterioration under the MSFD. The more general purpose and approach of the MSFD is to steer the general legislation and application of laws in a direction towards pollution reduction. Hence, in contrast to the WFD, the MSFD

[235] Case C-461/13 Bund v Germany, Para 68. See also Paloniitty, T., 2016, p. 157; Common Implementation Strategy for the Water Framework Directive and the Floods Directive, Guidance Doc no 36, "Exemptions to the Environmental Objectives according to Article 4(7): New modifications to the physical characteristics of surface water bodies, alterations to the level of groundwater, or new sustainable human development activities", *Document endorsed by EU Water Directors at their meeting in Tallinn on 4-5 December 2017.*
[236] Paloniitty, T., 2016, p. 157.
[237] Under art. 4(2) of the MSFD, member states may further divide the marine regions into marine sub-regions. However even the marine sub-regions adopted hereunder are considerably larger than the water bodies referred to in the WFD.

does not seek to establish limits to specific projects but rather acts as a general adaptive instrument based on a more general approach.

To the extent parallels can be made, though, the Weser ruling makes it clear that adaptive and flexible legislation, based on ecosystem indicators, is not just a general instrument of guidance to be used as a planning tool. These instruments set out concrete requirements for the states to implement and follow at every level. Hence, it follows that also the requirements of the MSFD are to be acknowledged as binding and should be implemented strictly, otherwise the Court could interfere. It seems clear, for example, that any project, permit or other activity that would clearly contradict with the goal of the MSFD and the ecological indicators used for assessing the process towards the goal would represent a violation of the MSFD. Yet, as was concluded above, the assessment on what a strict implementation entails in practice will probably have to be handled differently for the MSFD than for the WFD, simply due to the different scope and degree of specificity of the two instruments.

5.4.5 Balancing the interests involved - some key issues

5.4.5.1 General

The review above has provided few concrete answers as to what type of sea-based measures are permitted or not. Instead, the legal survey highlights the need for balancing different interests against each other for arriving at the question of whether or not a particular activity involving sea-based measures is lawful.

Those questions of balancing recur with respect to all sea-based measures and in all sea areas. Since all measures discussed here are of the kind that require permit under national and EU legislation, the balancing will in practical terms take place when the permit request is being considered. This section addresses some of the key issues that need to be assessed in this process while the more specific (national) permit procedures are discussed in section 5.5.

First, it is assessed whether the sea-based measures might qualify as 'pollution of the marine environment' which, in that case, brings along a number of other UNCLOS obligations. Secondly, questions regarding the environmental risks with the measures are considered, followed by some thoughts on the balance between the short-term risks and long-term effects of the measures. Finally, it is reviewed how international environmental law deals with scientific uncertainty, in theory as well as through a practical example.

5.4.5.2 The duty to protect the marine environment

While states have extensive rights to use their waters and resources, those rights need to be exercised in light of the rights of other states. The principle that states shall not permit their territory or operations under their jurisdiction to harm the interests of other states is the most basic and long-standing principle of international environmental law. Even if the principle is often referred to as the 'no harm' principle, it does not mean a duty to prevent environmental harm, but only an obligation to exercise due diligence to that end. It is a duty to take preventive steps, not an unqualified obligation of prevention of all harm.

Potential harm must be taken into account if it is significant, but need not be serious or irreversible.[238] The duty of diligence varies but is more severe for riskier activities.[239]

In UNCLOS, the duty protect the marine environment takes this duty further. The obligation extends to all sea areas, including the states' own waters, and hence represents a limitation of the general right of states to exercise full sovereignty over their waters. The obligation applies independently of any harm to other states. It is a duty to protect the environment for its own sake, its own intrinsic value. Here, too, it is an obligation of conduct, i.e. to take preventive measures, but does not mean that harming the environment as such necessarily violates the obligation.

The Helsinki Convention on its part requires that states "shall individually or jointly take all appropriate legislative, administrative or other relevant measures to prevent and eliminate pollution in order to promote the ecological restoration of the Baltic Sea Area and the preservation of its ecological balance." This clarifies some aspects of the due diligence obligation of states and places specific emphasis on the ecological effects of their action or inaction.

In assessing the more precise meaning of the obligation to protect or the appropriateness and relevance of sea-based measures, a specific challenge is that the obligations may work both ways. These obligations could entail restrictions on the operation of such measures, in any sea area, but could also be interpreted as an obligation to actively take such measures in order to protect the marine environment from the threats of eutrophication. The balancing to be done here is between the risks and benefits, both short-term and long-term, of the proposed measures.

This assessment depends on a variety of factors. What are the benefits of the activity? What other mechanisms exist to achieve the same results and how do they compare in terms of effectiveness, price and environmental risk? If equally effective measures exist, but at lower environmental risk or lower price, it will be more difficult to argue for the appropriateness of sea-based measures.

In other words, even the most basic substantive obligations in this field are highly dependent on a wide set of information about the methods and their risks.

5.4.5.3 Are sea-based measures 'pollution'?

Another basic question, which eventually depends on the level of the environmental risk of the activity, is whether a particular activity is to be regarded as 'pollution of the marine environment' or 'dumping', both of which in that case trigger a series of consequential obligations.

All sea-based measures discussed in this study include certain environmental risks, albeit that the size of that risk depends from one technique to another. Treating the seabed with chemicals entails risks of pollution and deterioration in the chemical status, the significance of which depends on the substance used. Research indicates, for example, that the level of free aluminium in the ecosystem and in the fish stock rises after making such treatment,

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[238] ICJ, Pulp Mills, para. 101
[239] SDC ITLOS Case 17, para 117.

even if the levels also tend to normalize rather fast.[240] Other substances, like clay, may involve considerably smaller risks. For dredging, it has similarly been observed that the activity may cause e.g. turbidity of the sediment, but the longer-term effects are not well understood.[241] The environmental risks involved with oxygenations have also been highlighted[242] and in this case the risks are clearly longer-term in view of the continuous nature of the operation.

Even if there is no threshold for how large the risk for environmental harm, some guidance on how the matter should be approached follows directly from the definitions. First, none of the definitions include any transboundary element, which means that harm to the marine environment in any sea area will suffice for coming within the scope to trigger the definition. In relation to dumping, the critical criteria for any "placement of a matter other than the mere disposal thereof" is whether or not it is "contrary to the aims of the Convention (or Protocol)".[243] Second, the definition does not qualify the level of harm by additional requirements, such as 'significant' damage or threat of 'irreversible' damage etc. Merely harming the environment suffices and this harm may under Article 1(4) take different shapes, including "harm to living resources and marine life, ... hindrance to marine activities ... and other legitimate uses of the sea ... and reduction of amenities ". Moreover, under both definitions potential harm to the environment suffices, as it is enough that the activities concerned are “liable" or "likely” to bring about harmful effects. Similar wording is used in the definition of geo-engineering in the amendment of the London Protocol. In other words, a mere risk of harmful effects triggers the definitions and it is enough that the harm is likely to occur. Conversely, to remain maintain outside of the scope of these definitions, environmental harm should be considered to be unlikely, which appears to be challenging in the light of existing knowledge.

The extent to which the purpose behind the measure affects their legal characterization differs between the wordings of the different international instruments. While the definition of dumping appears to give a certain significance to the aim of the activity, the definition of pollution of the marine environment in UNCLOS and other instruments is neutral with respect to the intention behind the actions. If the definition is neutral, the placing of the substance in the sea for the purpose of longer-term environmental benefits would not affect its status as pollution.

On this basis, it seems prudent to assume that the sea-based measures discussed here fall under the definition of pollution to the marine environment. This does not in itself rule out that such activities are permitted, but brings along a range of obligations in UNCLOS and other instruments that specifically relate to pollution.[244] It may finally be noted that states are bound by a number of environmental obligations, including the no-harm principle and the general obligation to protect the marine environment and fragile ecosystems, even if the activity in question is not classified as pollution.

[240] See section 3.3.2.
[241] See section 3.4.2.
[242] See section 3.2.2.
[243] London Convention, Art III(1)b
[244] E.g. UNCLOS Arts 194(2) and (4), 195, 199, 204 and 205.

5.4.5.4 Long-term vs short-term environmental effects

The environmental risks involved with sea-based measures must also be balanced against their intended environmental benefits. The very purpose of undertaking sea-based measures is to improve the marine environment, and it would seem awkward if environmental rules and procedures were only used to complicate their adoption without having regard to environmental benefits of the measure itself.

It is estimated that sea-based measures have a potentially significant role in reducing eutrophication in the Baltic Sea, but it is also acknowledged that none of the measures is entirely without environmental risk.[245] The question of how this is to be valued is particularly pertinent with respect to the measures that only need a very short-term environmental interference to be put in place. This applies to two of the three categories identified above i.e. dredging and chemical treatment of the seabed.

It was already noted above that the purpose of the activity does not seem relevant for whether or not the activity should be characterized as pollution. At international law level, there is no known case law where the short term and long-term effects have been balanced against each other, nor was this the theme in the Weser Ruling by the CJEU. The latter case, however, suggests that the deterioration of the environment is to be assessed independently, without regard to the purpose or even duration of the activity, as long as the activity is not specifically part of a long-term plan and subject to a derogation.

In the regulatory field, two types of ocean-related measures aimed at mitigating climate change have been discussed in the past decades in the framework of the London Dumping regime.[246] The outcome of those discussions was different for the two types of measures. While measures focusing on the storage of carbon dioxide in the seabed were accepted, subject to certain rigorous procedures, marine geo-engineering measures such as ocean fertilization have been considered to be contrary to the aims of the convention, unless carried out for research purposes. In neither discussion did the environmental purpose of the measure (mitigating climate change) prove decisive. While the uncertainty of the environmental effectiveness was noted in both cases, not least in relation to the available means of measuring those effects, it was the effect and risk of the measure itself that guided the decision-makers to different solutions.[247]

The above suggests that there are no general principles in place to govern the balancing between short-term and long-term impact of the measures. This needs to be reviewed individually in view of the available knowledge of the (short-term and long-term) risks involved. On the assumption that the longer-term benefits are the same, it will obviously be easier to justify a measure with very limited proven risks of a very limited period of time, than a more uncertain technology that impacts the ecosystem for a long period.

A particular feature of seabased measures in this respect, which differs from traditional balancing between and environmental and other (usually commercial) interests, is that the long-term benefits of the measures and the short-term risks essentially relate to the same

[245] See sections 3.2.2, 3.3.2 and 3.4.2.
[246] See section 5.4.2.3.
[247] See Scott, Karen N., Geoengineering and the Marine Environment, in Rosemary Rayfuse (ed.) Research Handbook on International Marine Environmental Law, Edward Elgar Publishing, Cheltenham, 2015, at pp. 458-461, and Williamsson et al, Ocean fertilization for geoengineering: A review of effectiveness, environmental impacts and emerging governance, Process Safety and Environmental Protection 90(2012), pp. 475–488.

concern. The purpose underlying the measures is to improve the ecological state of the marine environment, but the principal risks associated with the measures relate to the very same interest, which emphasizes the role of science in the overall assessment.

A main problem for anyone seeking to strike a balance between the interests involved is that there is little knowledge available on both the short-term risks and long-term benefits for any of the sea-based measure discussed here. Since both the risks and benefits are uncertain, the legal framework – which to a large extent is determined by these elements – will necessarily also be uncertain. An important issue is therefore to analyse how law deals with such uncertainty.

5.4.5.5 How to deal with scientific uncertainties?

5.4.5.5.1 The precautionary principle

The precautionary principle is designed precisely to deal with scientific uncertainties in relation to activities that may be harmful to the environment. The precise content of the principle is not settled, however, ranging from a 'weak' version, which triggers the principle only in cases of serious or irreversible damage and even then does not oblige the state to do anything,[248] to a 'strong' version that heavily inclines towards preserving status quo and places the burden of proving that there will be no environmental harm on to the operator alone.[249] In view of this uncertainty, international courts, including the International Court of Justice (ICJ), have been resistant towards acknowledging the principle as part of customary law.[250]

For present purposes, it suffices to note that the principle is laid down in relatively similar terms in both the Helsinki Convention and the London Protocol.[251] The former definition reads:

> The Contracting Parties shall apply the precautionary principle, i.e., to take preventive measures when there is reason to assume that substances or energy introduced, directly or indirectly, into the marine environment may create hazards to human health, harm living resources and marine ecosystems, damage amenities or interfere with other legitimate uses of the sea even when there is no conclusive evidence of a causal relationship between inputs and their alleged effects.

The definition makes it clear that application of the principle is not facultative but that states shall apply preventive measures when a certain activity may harm the marine environment. The reference to absence of conclusive evidence presupposes that some evidence exists to suggest that the activity is harmful, but there is no certainty about the matter.

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[248] Rio Declaration Principle 15.
[249] World Charter for Nature, 1982, UNGA Res. 37/7, art. 11b.
[250] E.g. ICJ Judgment in the Case Concerning *Pulp Mills on the River Uruguay* (Argentina v. Uruguay) of 20 April, 2010 ICJ Rep 14. However, a Special Chamber of the International Tribunal for the Law of the Sea in 2011 declared that the inclusion of Rio Principle 15 into several international conventions "has initiated a trend towards making this approach part of customary international law." SDC Adv Opinion, Case 17, Para 135.
[251] Helsinki Convention Art 3(2), London Protocol, Art 3(1). The precautionary principle is also mentioned in TFEU, Art. 191(2).

The definition, which applies to all sea areas, thus appears to cover the potential harm and scientific uncertainty that surrounds all sea-based measures discussed here. It suggests that states in these circumstances shall "take preventive measures", which in itself is unclear, but presumably involves significant restraints in authorising the activity.

On the other hand, the environmental objectives of the action need to be acknowledged here, too. It may be argued that the state of the eutrophication in Baltic Sea requires more mitigating measures and that all options have to be examined. On this basis, it may be argued that the precautionary approach should not be used as an excuse for not further exploring new options. At the very least, the fact that there is a significant knowledge gap – which triggers the precautionary principle – should not be used as an excuse for not undertaking the kind of research that is necessary to gain that missing knowledge.[252]

The precautionary principle is operationalized by procedural tools, notably the obligations related to EIAs, which include an assessment of the overall risks and benefits prior to any activity that may cause significant damage. For measures involving transboundary impacts, the Espoo convention specifically calls for special caution and cooperation with neighbouring states that are potentially affected, while EU and national laws cover the other cases. These obligations seek to ensure that the state is well informed at the time of decision-making and that the uncertainty of the impact is reduced to a minimum.

In addition, various instruments call for a duty of states to monitor the environmental impact of activities under their jurisdiction.[253] Those obligations highlight the continuous nature of the state's obligations and, in particular, that the state's obligations do not end with the termination of the permit process.

5.4.5.5.2 The geo-engineering example

The precautionary principle has not been applied to concrete questions under the Helsinki Convention, but the London Dumping regime has recently addressed a case concerning geo-engineering measures in the oceans to mitigate climate change. While the outcome of the discussions resulted in an amendment to the London Protocol which is not yet in force, it deserves to be assessed in more detail. It represents an example of a way to balance the different risks and interests involved in novel measures to address environmental concerns and hence involve many parallels to sea-based measures.

The framework for dealing with geo-engineering measures under the London Protocol has been developed to deal specifically with ocean fertilization to abate climate change, but may be extended to other geo-engineering activities.[254] Even though sea-based measures

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[252] Galaz, V. 2012: Geo-engineering, governance, and social-ecological systems: critical issues and joint research needs. Ecology and Society 17(1): 24, http://dx.doi.org/10.5751/ES-04677-170124; K. Güssow et al. 2010: Ocean iron fertilization: Why further research is needed. Marine Policy 34, pp. 911–918.

[253] UNCLOS Art 204(2) provides that "States shall keep under surveillance the effects of any activities which they permit or in which they engage in order to determine whether these activities are likely to pollute the marine environment" while Article 6(3) of the Helsinki Convention provides that "Contracting Parties shall ensure that authorized emissions to water and air are monitored and controlled."

[254] The London Protocol defines marine geoengineering as the "deliberate intervention in the marine environment to manipulate natural processes, including to counteract anthropogenic climate change and/or its impacts, and that has the potential to result in deleterious effects, especially where those effects may be widespread, long-lasting or severe". LC 36/16, Annex 5, page 1, Guidance for Consideration of Marine Geoengineering Activities, Section 2, para. 2. Geoengineering includes a wide variety of

in many respects have the opposite purpose to that of ocean fertilization, as they seeks to reduce – rather than increase – nutrients in the sea, the principal issues are similar.

As a first step, the Parties to the London Convention Framework confirmed the applicability of ocean fertilization measures under the regime. By means of a common resolution, the governing bodies of the Convention and the Protocol established in 2008 that "the scope of the London Convention and Protocol includes ocean fertilization activities".[255] Ocean fertilization, in turn, was defined as "any activity undertaken by humans with the principal intention of stimulating primary productivity in the oceans."[256]

Most importantly, the resolution provided that “given the present state of knowledge, ocean fertilization activities other than legitimate scientific research should not be allowed”.[257] The Parties further agreed that in order to provide for legitimate scientific research, and hence to gain more knowledge about ocean fertilization, an assessment framework should be adopted in order to define projects for research purposes. That framework was to include, *inter alia*, tools for determining whether or not the proposed activity is contrary to the aims of the Convention and Protocol.[258]

In 2010, the Contracting Parties adopted a new resolution, the “Assessment Framework for Scientific Research Involving Ocean Fertilization”.[259] This Assessment Framework guides Parties on how to assess proposals they receive for ocean fertilization research and provides criteria for an initial assessment of such proposals, including detailed steps for completion of an environmental assessment, which encompasses risk management and monitoring.[260]

The London Protocol approach to geo-engineering was settled in 2013, when the parties adopted a resolution on the “Amendment to the London Protocol to regulate the placement of matter for ocean fertilization and other marine geo-engineering activities”.[261] The amendment adds a new Article 6bis to the Protocol which provides that “Contracting Parties shall not allow the placement of matter into the sea from vessels, aircraft, platforms or other man-made structures at sea for marine geoengineering activities listed in Annex 4, unless the listing provides that the activity or the sub-category of an activity may be authorized under a permit”.

'Marine geo-engineering' was defined in a new Article 1(5bis) as meaning "a deliberate intervention in the marine environment to manipulate natural processes, including to counteract anthropogenic climate change and/or its impacts, and that has the potential to

techniques, which involve either adding substances to the ocean or placing structures into the ocean, primarily for climate mitigation purposes but also for the purpose of enhancing fisheries. Proceedings of the 2015 Science Day Symposium on Marine Geoengineering, held on 23 April 2015 at IMO Headquarters, London, United Kingdom.

[255] Resolution LC-LP.1(2008) on the Regulation of Ocean Fertilization, Para 3.

[256] Resolution LC-LP.1(2008) on the Regulation of Ocean Fertilization, Para 3.

[257] Resolution LC-LP.1(2008) on the Regulation of Ocean Fertilization, Para 8. The text continues; " To this end, such other activities should be considered as contrary to the aims of the Convention and Protocol and not currently qualify for any exemption from the definition of dumping in Article III.1(b) of the Convention and Article 1.4.2 of the Protocol". Even if the resolution is non-binding as such, it can be seen as a subsequent agreement or practice between the parties under the Vienna Convention on the Law of Treaties, Art. 31(3) and, through that, have implications for the interpretation of the London Convention and Protocol.

[258] Resolution LC-LP.1(2008) on the Regulation of Ocean Fertilization, Para 5.

[259] Resolution LC-LP.2(2010).

[260] Proceedings of the 2015 Science Day Symposium on Marine Geoengineering, held on 23 April 2015 at IMO Headquarters, London, United Kingdom.

[261] LP.4(8), see circular LC-LP.1/Circ.61.

result in deleterious effects, especially where those effects may be widespread, long lasting and severe."

So far, Annex 4 of the London Protocol only lists ocean fertilization. The Annex provides that all ocean fertilization activities other than those referred to above shall not be permitted. An ocean fertilization activity may only be considered for a permit if it is assessed as constituting legitimate scientific research taking into account any specific placement assessment framework.

A new Annex 5 also adds the “Assessment Framework for matter that may be considered for placement under Annex 4”. The Assessment Framework lists a number of points to be described, following an initial assessment of whether the activity falls within the definition of dumping at all and hence can be considered within the framework. The points include: problem formulation; site selection and description; exposure assessment; effects assessment; risk characterization; and risk management. The Assessment Framework further provides that contracting parties should consider any advice on proposals for activities listed from independent international experts or an independent international advisory group of experts.[262]

If the project is accepted under Assessment Framework it is also to establish a thorough monitoring mechanism which takes into account both long-term and short-term impacts of the activity. This forms a safeguard for the general lack of knowledge that remains, despite the review process, and bridges the risks that cannot be accounted for due to the fact that these are methods still under research.

There are clear parallels between the measures that these provisions seek to address and all categories of sea-based measures discussed in this study. However, the London Convention and Protocol are only applicable to measures that fall within the definition of dumping.[263] It was noted above in section 5.4.2.3 that, currently, it is only the chemical treatment of the seabed that appears to meet this criterion, depending on the substances used and the relation to the purposes of the convention. Other activities are more difficult to cover under this regime, even if they were covered by the geo-engineering definition. Even if the 2013 amendments were in force, it appears difficult to apply the geo-engineering prohibition in Art 6bis as long as the activity is not specifically listed in Annex 4. In addition, it should be remembered that an integral part of the definition of geo-engineering measures is the potential to cause deleterious effects. On the other hand, states parties to the London Protocol have a large discretion when deciding on the inclusion of more geo-engineering measures into Annex 4 in the future.[264] In particular, states are not, it seems, limited to activities defined as dumping or disposal in this respect. It could well be, therefore, that all categories of sea-based measures discussed here could be covered by this regime in the future, should they be included in Annex 4, which is essentially a political decision. If so, the measures could only be adopted for research purposes and only under the assessment framework set out in Annex 5 or other specific requirements accepted for the measures in question.

[262] An arrangement of such experts in the consultation process has been adopted by the governing bodies in 2014 as annex 4 of document LC 36/16.
[263] This follows partly from the mandate of the London Convention, but also from para. 3 of the Resolution 1.
[264] Working Group 41 of GESAMP is currently providing an assessment of various geo-engineering measures for publication in 2018. See www.gesamp.org/work/groups/41.

While the 2013 amendment is not formally in force, even for Finland which is one of only two states that has ratified it,[265] it provides an interesting model of the operationalization of the precautionary principle for activities aimed at environmental protection that are coupled with uncertain risks. It may therefore also serve as a model for addressing sea-based measures more generally in a specific Baltic Sea context with a view to gaining more knowledge about the effects of such measures.[266] This is particularly relevant in view of the 2018 HELCOM Ministerial Declaration which appears to accept a certain responsibility for HELCOM to address these measures at regional level. Para. 26 of the Ministerial Declaration reads as follows:

"We encourage, as a second step, undertaking research on the potential of measures to manage internal nutrient reserves that have accumulated in the sediments due to anthropogenic activities in the last decades;

We emphasize that the risks to ecosystem and human health stemming from measures to manage internal nutrient reserves, as well as the long-term sustainability of their effects, need to be considered and thoroughly evaluated;

We also encourage in parallel developing and applying a risk assessment framework in HELCOM to meet the necessary environmental requirements for measures planned for the open sea and any other measures having potentially significant transboundary effects;

We also acknowledge the need to elaborate in line with the Helsinki Convention commonly agreed regional principles as guidance for internal nutrient reserves management."

5.4.6 Summary

The different categories of sea-based measures give rise to rather similar questions. It has been concluded above that most of them should probably be considered to fall within the definition of 'pollution of the marine environment', but none of the categories of measures can be ruled out, whether at national or international level. Dumping, or seabed treatment, is the only category of measures that is clearly subject to a specific category of rules. The main rule is that it is prohibited, except where the material used is permitted under Annex I. However, if dumping is done for purposes other than to discard the matter in question, there are exemptions available at all levels of law. Exemptions apply if there is sufficient environmental data and scientific evidence to support that such treatment is not “liable to create hazards to human health, to harm living resources and marine life" or against the objectives of the relevant conventions. Even with the reasonably clear legal framework for chemical measures, in other words, the matter eventually depends on the impact of the measure.

To deal with the scientific uncertainties that exist in a similar area, the London Protocol regime has set up a strict framework for geo-engineering measures, which is not yet in

[265] It should be noted that the acceptance of the amendment by Finland and other states is not void of legal significance even if it is not in force. Under Art 18(b) of the Vienna Convention on the Law of Treaties, a state that has expressed its consent to be bound by a treaty is "obliged to refrain from acts which would defeat (its) object and purpose", pending its entry into force "provided that such entry into force is not unduly delayed."

[266] See also Article 24(1) of the Helsinki Convention, providing: "In order to facilitate research and monitoring activities in the Baltic Sea Area the Contracting Parties undertake to harmonize their policies with respect to permission procedures for conducting such activities.

force. Once that regime becomes effective, the only option for implement geo-engineering measures lawfully would be to include them in the Protocol's Annex 4, which would permit measures for research purposes only. Whether chemical treatment of the seabed would fall under this regime in the first place would, again, depend on environmental effects, notably on whether the measure "has the potential to result in deleterious effects, especially where those effects may be widespread, long-lasting or severe."[267]

Dredging and oxygenation are subject to less specific rules. Both categories are, at least at an international level, regulated by general principles and over-arching legislation. Given its more long-term status, oxygenation raises certain law of the sea questions, e.g. with respect to the obligation to pay due regard to the interest of other users of the sea, including safety and navigation, and questions related to the installation itself. While oxygenation could fall within the definition of geo-engineering adopted under the London Protocol, it does not – in the absence of any addition of substance or "matter" into the sea – constitute dumping and would therefore not be covered by the London Protocol.

Common for all three categories of measures is that they have to be in line with a range of other more generic environmental requirements. Most such requirements are focused on environmental assessments, procedural rules and environmental objectives. Under EU law, the WFD with its goal of good ecological status introduces the most specific limitations. Since the Weser Judgment, the space for the operator to take measures that could have even a slight (and perhaps temporary) deteriorating effect on the water status appears to be ruled-out, unless a derogation is in place, which in turn requires its own assessments and procedures.

The Helsinki Convention places a range of relevant obligations on its states parties, but also includes significant discretion for states to make decisions in the individual case. Measures are to be “relevant and appropriate” for protecting the Baltic Sea. In assessing the appropriateness and relevance of sea-based measures, they need to be placed in context. In other words, they have to be compared to what other mechanisms are available to achieve the same results and how they compare in terms of effectiveness, price and environmental risk. If equally effective measures exist, but at lower environmental risk or lower price, it will be more difficult to argue for the appropriateness of the measure in question. This consideration also highlights the importance of having information about existing alternative methods available and, again, the necessity to assess whether the level of scientific knowledge is sufficient for concluding on the appropriateness of sea-based measures, both in terms of technology and in the overall ecological context.

The rules that are most relevant for assessing the lawfulness of sea-based measures, in all categories and at all sea areas, accordingly refer to the potential environmental risks linked to with the activities. The duties to protect and preserve the marine environment, as well as to the duty to take preventive measures and apply a precautionary principle, are all related to that risk and the scientific uncertainties connected to sea-based measures and will inevitably play a role in that assessment. In each individual case, the environmental assessments and the extent of any scientific evidence will be crucial for the permissibly of the activity. There is less legal material to draw upon for evaluating the significance of the potential environmental benefits of the measure in the overall balancing, but on this matter scientific evidence is even harder to obtain. Some scattered examples

[267] London Protocol Art 1(10).

referred to above suggest that the longer-term purpose of the measure may not be as relevant a consideration as the adverse environmental impact of the measure. At the same time, the environmental risks of not undertaking sea-based measures should be included in the equation. Here, too, however, scientific opinion diverges and the very need for such measures is doubted by several senior scientists in the region.

The main legal (and policy) limitation for sea-based measure discussed in this study is accordingly the lack of knowledge or certainty about their short-term and long-term effects. The principal way to get such knowledge is through further research and trials. When faced with a similar dilemma of environmental risk contra the need for more knowledge in the context of ocean fertilization, the London Dumping regime developed an assessment framework to allow further activities, but under strict control of both the purpose of the research and the activities undertaken. This could be a path forward also in the relation to the sea-based measures in the Baltic Sea, and it may even be argued that some of the legal principles discussed in this section actually call for the development of a corresponding framework to advance the matter, in terms of law and otherwise.

5.5 The role of national law

5.5.1 Briefly on substantive rules

In brief, Finnish substantive laws of relevance to sea-based measures, as described in section 5.2.5 above, essentially follow the relevant international and EU rules that they seek to implement. The WFD and MSFD are implemented through the Act on the Organisation of River Basin Management and the Marine Strategy (the Water Resource Management Act) and the related Decrees, the Habitats and Birds Directives (among others) through the Nature Conservation Act, the obligations beyond national waters are to be found in the Act on Prevention of Marine Pollution etc. Some of the relevant environmental law principles have also been introduced into national legislation, such as the general prohibition to take action within the national jurisdiction that causes marine pollution elsewhere (Section 18(1) of the EPA).

As regards dumping, Section 18(2) of the Environmental Protection Act prohibits dumping in Finnish water section, while Section 7(4) of the Act on the Protection of the Marine Environment extends the obligation to other Finnish ships or subjects of law in other sea areas. The dumping of waste originating from land is also prohibited. These prohibitions do not apply to dumping of the dredged material in a water area regulated in the Water Act, which requires a permit from the Finnish Environment Institute, in line with the requirement in the Helsinki Convention. The conditions for that permit are regulated in significant detail in Section 3 of Chapter 3 of the Water Act and, for other than Finnish jurisdictions, Section 9 of the Act on the Protection of the Marine Environment.

Differences that could have some relevance for sea-based measures do exist, however. For example, the concept of dumping appears somewhat different from the international definitions under Finnish law. On the one hand, the Finnish law in Section 18(2) of the Environmental Protection Act prohibits in general all discharging of waste or other matter into Finnish territorial waters and the EEZ to be dumped or otherwise placed ("upottamis- tai muussa hylkäämistarkoituksessa"), regardless of the consequence of the action. In the absence of a reference to the objectives of the dumping conventions, this is wider than the corresponding international rules. On the other hand, the Finnish rules are at the same time narrower than the international rules, as they specifically refer to abandonment and offer no option of discarding for other purposes. Since the purpose of chemical treatment of the seabed is not (at least not merely) to abandon the chemicals, but to fixate the phosphorus in the sediment, it can be argued that Section 18 of the Act should be interpreted in a sense where chemical treatment is not strictly forbidden under Finnish law.

Another example could be that while section 1(2) of the Act on the Protection of the Marine Environment matches the UNCLOS definition of pollution of the marine environment, the concepts defined in Section 5 of the Environmental Protection Act to trigger its pollution provisions are broader.[268]

In Sweden, similarly, the environmental laws – mainly found in the Environmental Code – reflect to a large extent international and especially EU environmental law. General rules and environmental law principles are regulated in Chapter 2 of the Environmental Code. The MSFD and the WFD are to some extent reflected or included in the Environmental Code, but more specifically implemented through the Water Management Ordinance and the Ordinance on Marine Environment. Also the EU rules on protection of biodiversity are implemented in the Code.

Rules that apply to dumping, dredging and installations in the water areas are also found in the more sectoral, or specific, chapters of the Code. While both dredging and the kind of installation required for oxygenation are primarily regulated by Chapter 11 on water operations (if not placed in the EEZ), dumping is instead regulated in Chapter 15 of the Environmental Code. Chapter 15 and the Ordinance (2011:927) on Waste ("Avfallsförordningen") is the main piece of Swedish environmental legislation on waste management, implementing the EU Waste Directive, and also including rules on dumping and on recycling. While the storing of wastes are also connected and regulated by the definitions of wastes and the processing (including recycling) of wastes in Chapter 15 and the Ordinance of Waste, it is also regulated as an environmentally hazardous activity which requires a permit in accordance with Chapter 9. While this will not be further evaluated here, it is worth mentioning that the rules on storing wastes are quite strict, especially if including toxic substances. It might therefore also be difficult to receive a permit for storing large amounts of toxic dredged materials.

However, an issue with greater significance in this context is the definition on wastes, so-called by-products, and moreover the definition of dumping, found in the waste legislation. Here, the national regulation reflects the same kind of difference from international law as in Finland. First of all, the regulation on dumping only includes the dumping of wastes, and thus evokes the question of whether aluminium or clay with the purpose of fixating

[268] Section 5 of the Environmental Protection Act provides a broad definition of pollution. The Section defines pollution as discharge of, leading or depositing a substance, energy, noise, vibration, radiation, light, heat or odour caused by human activity, from one or several sources, directly or indirectly in the air, water or soil. In terms of sea-based measures, chemical treatment includes emitting, leading or depositing a substance in the water, whereas in the oxygenation process, energy is lead to the water.
Environmental degradation is defined in the Act as a pollution described above that either alone or together with other emissions causes harm to health; causes harm to nature and its functions; prevents or materially hinders the use of natural resources; decreases the general amenity of the environment or degenerates special cultural values; reduces the environment's suitability for general recreation purposes; damages or harms property or its use; or constitutes a comparable violation of the public or private good.

phosphorus are included. Secondly, the definition of waste according to Chapter 15 is a substance with the purpose of being disposed of. While the concept of waste is wide, and should for the purposes of the Waste Framework Directive be interpreted without general restrictions, it is still not possible to ignore the purpose and intention underlying chemical treatment.269 This leads back to the assessment questions addressed in section 5.4.5, when it comes to pollution and application of the potential exemptions and as in the discussion of Finnish law in this section. If chemical treatment of the seabed is to be regarded as dumping according to Chapter 15 in the Environmental Code, the main rule is that it is banned.[270] However, as a contrast to the laws in Finland, Swedish law provides that the Government, or such authority as it may designate, can also grant an exemption if the dumping can be done without hazards to health or the environment.[271]

Oxygenation could, in addition to being subject to the procedures and requirements in Chapter 11, also be the regulated as a 'Hazardous activity' according to Chapter 9. Dredging and chemical treatment do not fit the definition of environmentally hazardous activities in Chapter 9, primarily because this definition does not apply to pollution sources that are not fixated to a specific land or water area. Only those pollution sources that have effects on the environment from a fixed point can be defined as hazardous activities. Storing dredged materials on the other hand, which would become an issue connected to dredging, is also a hazardous activity. Although, it might also in parallel be regulated by Chapter 15 (and the Waste Framework Directive).

In terms of practical application, however, any potential substantive variations between national and international rules should not be overstated. States have an international obligation to give effect to international rules and EU rules are hierarchically superior to national rules. It is therefore both required and expected that the international and EU rules will be taken into account and affect the interpretation at national level, too. It has also been noted that the main part of the international and EU rules apply even in the internal waters of the parties, and this conclusion therefore applies irrespective of the sea area concerned. The main exception to this is where national rules apply additional requirements that exceed the ones established internationally and hence impose national obligations on top of the international ones. In view of the review above, and the general stringency of the international and EU rules in this field, there appear to be relatively few such instances, however.

Rather, the main contribution of national laws in this area lies in the elaboration of a procedural framework for addressing the questions in individual cases. The main vehicle for implementing the standards discussed in this area are permits issued by the authorities for persons seeking to undertake sea-based measures. It will be these permits that in reality decide on whether or not a person is entitled to carry out the measures in the sea area concerned and under what conditions. As a starting point, it appears that all sea-based measures discussed in this study, irrespective of the sea area concerned, or even of the scale and purpose of the activity, will be subject to some permit requirements. In view of the crucial relevance of the permits for the future of seabed measures, the details of those permits will be discussed in more detail below, separately for Finland and Sweden.

[269] Michanek, G. & Zetterberg, C., *Den Svenska Miljörätten*, 4 uppl, Iustus 2017, pp. 368–369.
[270] Env. Code, Chapter 15, Section 27.
[271] Env. Code, Chapter 15, Section 29.

5.5.2 Procedural rules - Finland

5.5.2.1 Environmental permit

The starting point of the environmental permit system is that the activities creating a risk of environmental degradation listed in Annexes 1 (the so-called directive facilities) and 2 of the Environmental Protection Act require a permit. In addition, a permit is required for, *inter alia*, activities that may cause pollution of a water body, and that the project in question is not subject to a permit under the Water Act.[272] A permit is also required for any substantial alteration of such activity.[273] Since all sea-based measures entail a risk of pollution of a water body, as a starting point, they require an environmental permit under the Environmental Protection Act under Subsection 2 of Section 27, unless a permit under the Water Act is required.[274]

There are some exceptions to the permit requirement. In Section 31, derogations from the permit requirement are granted for certain short-term activities undertaken on an experimental basis with the purpose of testing a new technique, raw material, fuel, manufacturing or incineration method or treatment equipment, or institutional or commercial processing of waste to investigate the impact, usefulness or other corresponding feature of such activities. These kinds of activities only require a notification. However, an environment permit is required even for these activities if a consequence mentioned in Section 27(2), for example the above-mentioned risk of pollution of a water body, might be caused. Therefore, it does not seem likely that sea-based measures could be carried out with a mere notification of an experimental activity unless it can be made sure that there is no risk of water pollution.

In Finland, the national EIA system is to a large extent a copy of the requirements of the EIA Directive. The Act on Environmental Impact Assessment Procedure has in the Finnish system a rather formal or procedural function.[275] The outcome of the EIA has no direct influence on the decision-making of other authorities. The permit application may, however, be modified by the applicant if he sees that the EIA procedure gives reason for that.[276]

The above does not, however, mean that the EIA process is without relevance in Finland. In defined situations when an EIA is needed, the application to a permit authority must include the EIA assessment report. According to Section 3 of the EIA Act, the environmental impact assessment procedure is applied to projects and changes to projects that are likely to have significant environmental impacts. The projects to be assessed under the EIA and their modifications are listed in Annex 1 of the Act on Environmental Impact Assessment Procedure. According to Subsection 2 of Section 3, in addition to the projects listed in the annex, the EIA procedure shall in individual cases also apply in other projects or changes in projects if they are likely to cause significant

[272] Section 27(2) of the Act.
[273] Section 29 of the Act.
[274] See section 5.2.5.2.1 on joint processing of the permits and, on the other hand, section 5.5.2.6 on the requirement of either an environmental permint or a permit under the Water Act for sea-based measures.
[275] Hollo, E.J. 2008: Legal Aspects on the Construction of a Gas Pipeline in the EEZ of Finland, p. 3.
[276] Hollo, E.J. 2008: Legal Aspects on the Construction of a Gas Pipeline in the EEZ of Finland, p. 4.

environmental impacts comparable to the effects of the projects referred to in Subsection 1, taking into account the nature and scope of the project.

When deciding whether or not an EIA shall take place, the features and location of the project and the nature of its effects shall be taken into account. The environmental impacts referred to are listed in Section 2 of the Act and contain, *inter alia*, the direct or indirect effects of the project or activity, in Finland and outside its territory, on water, organisms and on the diversity of the nature. Hence, at least larger-scale sea-based measures are likely to need an EIA. In these situations, the decision-making authority shall not take the substantial permit decision before having at hand the EIA assessment report and the statement of the EIA authority.[277] More specific information needed in the EIA procedure can be found in the Government Decree on Environmental Impact Assessment Procedure (277/2017).

Since the need for an environmental permit for sea-based measures arises from Section 27(2) of the Act, the environmental permit applications for sea-based measures in Finnish territorial waters and the Finnish EEZ will be decided on by the Regional State Administrative Agency rather than a Municipal Environment Authority. Also the nature and possible significant effects of sea-based methods speak for the authority of the Regional State Administrative Agency.

According to Section 48 of the Environmental Protection Act, a permit shall be granted if the activity in question meets the requirements laid down in the Environmental Protection Act and the Waste Act. This implies that the considerations of the permit authority are essentially judicial: the permit cannot be denied on grounds other than those defined by law. On the other hand, the permit cannot be granted if these conditions are lacking.[278]

Section 49 defines the conditions under which a permit can be granted. It is required that the activity, individually or together with other activities, when taking the permit regulations and the location of the activity into account, does not result in, *inter alia*: adverse effects on human health, other significant environmental pollution or risk thereof, pollution of soil or groundwater or sea outside Finnish territorial waters, deterioration of special natural conditions, or pose a risk to water supply or any other potential use important to the public interest in the area of impact of the activity.

As the permit is most often either wholly or partially granted and not dismissed, the substantive content of the permit, i.e. the permit conditions or permit regulations, are crucial.[279] Section 52 contains provisions on permit regulations for the purpose of preventing pollution. Permits shall contain necessary provisions on:

- emissions, emission limit values, the prevention and limitation of emissions and the location of the site of emission;
- the prevention of pollution of the soil and ground water;
- wastes and reduction of their quantity and harmfulness;
- action to be taken in case of a disturbance or in other exceptional situations;

[277] Hollo, E.J. 2008: Legal Aspects on the Construction of a Gas Pipeline in the EEZ of Finland, p. 5.
[278] Borgström, Suvi & Koivurova, Timo 2016: Environmental Law in Finland, p. 50.
[279] Borgström, Suvi & Koivurova, Timo 2016: Environmental Law in Finland, p. 51.

- measures to be taken after cessation of operations, such as remediation of the area and prevention of emissions;
- other measures to prevent, reduce or assess pollution, the risk thereof and adverse effects caused by it.

When permit regulations are issued, the nature of the activity, the properties of the area where the impact of the activity appears, the impact of the activity on the environment as a whole, the significance of measures intended to prevent pollution of the environment as a whole and the technical and financial feasibility of this action shall be taken into account. In addition, energy efficiency and efficiency in the use of materials, and precautions for preventing accidents and limiting their consequences, must be taken into account as needed.

Permit regulations concerning emission limit values and the prevention and limitation of emissions must be based on the best available technology, the assessment aspects of which is regulated in Section 53. The permit regulations may not, however, require the operator to apply any specific technology. Section 5 of the Act defines best available technology as the most effective and developed, technically and economically feasible production and purification methods and design, construction, maintenance, use and disposal procedures to prevent or effectively reduce environmental pollution caused by the activity, which are suitable as the basis of environmental permit requirements. The technology is technically and economically feasible when it is universally available and can be applied in the area of activity concerned at a reasonable cost.

The permit regulations are of the essence in permits for sea-based measures. The key question is, whether the risk of pollution caused by the sea-based measures be handled through the permit regulations, and if so, how the regulations should be formulated. From the ecosystem approach, the important question is whether the maintenance of the resilience of the marine ecosystem be guaranteed through the permit regulations. Again, in order to know how the risks for the water environment and ecosystem can be managed and removed, sufficient information about the risks themselves must be obtained.

According to Section 6 of the Act, operators must have sufficient knowledge of their activities' environmental impacts and risks, and ways to reduce harmful effects and to prevent pollution (operators' knowledge requirement). This duty also concerns operators using sea-based measures. Sufficient research and understanding is needed, also of the ways to prevent potential harmful effects.

In the Environmental Permit Process, also the Water Resource Management Act must be taken into consideration. The Environmental Protection Act refers to the Water Resource Management Act in several sections. The latter and the programs and strategies drawn up in accordance to it shall be taken into consideration, *inter alia*, when considering the granting of a permit and the significance of a potential environmental degradation of the environment caused by the activity.[280]

The Marine Strategy based on the Water Resource Management Act shall also present measures for restoring the marine ecosystems. This talks for the sea-based measures, assuming that the risks for the marine environment and the ecosystem can be managed and eliminated. If an area is protected through the Nature Conservation Act or prioritized

[280] Sections 49 and 51 of the Environmental Protection Act.

in the Marine Strategy for a certain purpose, it must be taken into account when granting a permit for sea-based measures, but it does not mean that any other activity would be strictly forbidden.

Activities posing a risk of pollution must be located so that they will not cause pollution or pose a risk thereof and so that pollution can be prevented, whenever feasible.[281] Activities requiring a permit or registration must not be situated contrary to a town plan and they shall not hinder the use of an area reserved for another use in a master plan or a regional plan.[282]

Compensation

Compensation for environmental damage is partly connected to the environmental permit. The provisions on possible compensations are laid down in Chapter 13 of the Act. In addition to what is regulated in the Act on Compensation for Environmental Damage, the provisions of Chapter 13 also apply to compensation questions concerning the pollution of a water body. Accordingly, when a permit authority grants an environmental permit, it shall at the same time, with certain exceptions, order ex-officio that damage from water pollution caused by the activity shall be compensated. When deciding on a compensation, due consideration shall be given to the fixed-term nature of the permit and the possibility of reviewing the regulations of a permit granted until further notice.[283] Notwithstanding earlier decisions, compensation may be demanded for damage not foreseen when the permit was granted by an application made to the Regional State Administrative Agency.[284]

Section 57 of the Act also contains a specific provision for compensation of damage caused to fish resources and to the fishery. Accordingly, if discharging wastewater or some other substances may cause harm to fish resources, a fish management obligation or fishery fee shall be issued in the environmental permit in accordance with Section 14 of Chapter 4 of the Water Act. In practice, a fish management obligation takes the form of a fish ladder obligation or detailed fish planting obligations.[285]

Section 176 deals with remedying substantial pollution of a water body and damage to protected species and natural habitats. If, as a consequence of a violation or negligence, substantial pollution of a water body results, or damage occurs to protected species and natural habitats, referred to in Section 5a of the Nature Conservation Act, the supervisory authority shall order the operator to undertake remedial measures against the environmental damage, referred to in the Act on the Remediation of Certain Environmental Damages (383/2009).[286]

In addition, if substantial pollution of the water body or damage to protected species and natural habitats is due to an accident or any other unpredictable cause, the supervisory authority shall order the operator which caused the damage to undertake remedial measures, referred to in the Act on the Remediation of Certain Environmental Damages. When assessing the significance of pollution of the water body, referred to in Section 176,

[281] Section 11 of the Act.
[282] Section 12 of the Act.
[283] Section 125 of the Act.
[284] Section 130 of the Act.
[285] Borgström, Suvi & Koivurova, Timo 2016: Environmental Law in Finland, p. 53.
[286] Section 177 of the Environmental Protection Act.

consideration shall be taken of what has been stated about the facts concerning the state of the waters and the marine environment in the area of impact of the operation in the River Basin Management Plan or the Marine Strategy, drawn up in accordance with the Water Resource Management Act. More precise regulations on assessing the significance of pollution is given in the Government Decree on the Remediation of Certain Environmental Damages (713/2009).

5.5.2.2 Permit under the Water Act

According to Section 2 of Chapter 3, water resources management projects are subject to a permit by the permit authority if they may cause changes in the state, depth, water level or flow, shore, or aquatic environment of a water body or the quality or quantity of groundwater, and this change:

1. results in a risk of flooding or general shortage of water;
2. results in detrimental changes in the natural environment and the way it functions or deterioration in the ecological status of a water body or groundwater body;
3. significantly reduces the beauty of nature, causes deterioration in the amenities of the environment or in cultural values or the suitability of the water body for recreational use;
4. poses a risk to human health;
5. substantially reduces the yield of an important or other groundwater body suitable for use for water supply purposes, or otherwise impairs its usability or causes other damage or harm to the water abstraction or the use of water as drinking water;
6. causes damage or harm to fishing or fish stocks;
7. causes damage or harm to waterborne traffic or timber floating;
8. jeopardises the conditions for a brook channel to remain in a natural state; or
9. violates the public interest in another manner similar to the above.

Moreover, a permit by a permit authority is required for a water resources management project if the change in the state, depth, water level or flow, shore, or aquatic environment of a water body or the quality or quantity of groundwater results in loss of benefit for the water area of another party, fishing, water supply, land, real estate or other property. However, a permit is not needed if the loss of benefit is caused to private interest only and the interested party has given written consent to the project.[287]

Regardless of the consequences referred to in Section 2 of Chapter 3, a permit by a permit authority is always required, according to Section 3 of Chapter 3, for e.g. the following water resources management projects:

[287] The activities requiring a permit include, *inter alia*, the construction of jetties, bridges, cable crossings, pipelines, dams, hydropower plants, waterways, log-floating routes, drainage ditches, canals, weirs and sluices, and any other regulation or use of water reserves, including groundwater. Borgström, Suvi & Koivurova, Timo 2016: Environmental Law in Finland, p. 103.

- closure or narrowing of a main channel or public channel or timber floating channel and placement of a device or another obstruction that hinders the use of the channel;
- construction of a water, sewage, power or other cable under a general passageway;
- dredging of a water area when the quantity of dredged material exceeds 500 m³, unless it is a question of maintaining of a public channel;
- placing of dredged material into Finland's territorial waters for the purpose of dumping it when the quantity of dredged material in question is not insignificant; and
- removal of soil material from the bottom of a water area for a purpose other than ordinary household use.

A permit is also required for making changes to a facility or structure referred to in Subsection 1 of Section 3 for which a permit has already been granted or their use if the change violates public or private interests.

Sea-based measures could have some of the listed consequences, such as detrimental changes in the natural environment and the way it functions, deterioration in the ecological status of a water body or groundwater body, reduced suitability of the water body for recreational use, or harm to fish stocks or waterborne traffic, and thus a permit under the Water Act would be needed. Additionally, an oxygenation pump might need construction of a cable under a general passageway and dredging includes removal of soil material from the bottom of a water area and could also include dredging over 500 m³ and/or placing dredged material into the territorial waters or removal of. These would mean that a permit under the Water Act would be needed.

Oxygenation could also require placing a cable in rivers or streams other than under a general passageway. In this case, Section 5a of Chapter 2 is applicable, if the operator does not own the area. A cable can be placed on other's water area if Section 2 of Chapter 3 or the Environmental Protection Act is not applied and the placement does not cause more than a minor harm for the owner. A notification shall be made to state's supervision authority about such placement of a cable. A notification shall also be made about removal of soil material from the bottom of a water area, if the removal does not need a permit under Section 2 or 3 of Chapter 3.[288] Building a high tension cable (over 110 kilovolts) requires a project permit from the Energy Authority.[289]

According to Section 4 of Chapter 3, there are three important legal thresholds under which water permits are considered: 1) a permit for a water resources management project will be granted if the project does not significantly violate public or private interests, or even if such violation takes place; 2) the benefit gained from the project to public or private interests is considerable in comparison to the losses incurred for public or private interests. However, 3) a permit may not be granted if the water resources management project jeopardises public health or safety, causes considerable detrimental changes in the natural state of the environment or the aquatic environment and its functions, or causes considerable deterioration in the local living or economic conditions. Thus, a permit

[288] Section 15 of Chapter 2 of the Act.
[289] See more https://www.energiavirasto.fi/hankeluvat.

consideration depends normally on a weighing of interests. The third threshold means though that even if the benefits of the project outweigh the losses considerably, a permit cannot be granted.

In order for the permit to be granted, the applicant shall hold a right of use to the areas required for the project. If the applicant does not own the area or control it through a permanent right of use, a permit may be granted on condition that the applicant is granted the right of use to the area or that the applicant presents a reliable account of how the right of use to the area will be arranged. Further regulation concerning the ownership and property administration of the water is provided in Chapter 2.

When considering the conditions for granting a permit, a general assessment shall be made of the benefits and losses caused to public interest by a water resources management project. A monetary value may be used in the assessment if the amount of the benefit or loss can be defined in monetary terms. Matters included in a river basin management plan and the Marine Strategy under Water Resource Management Act with respect to factors related to the state and use of waters in the area impacted by the project shall be taken into account in the assessment.[290] Also town plans and to some extent regional plans and master plans shall be taken into account, and it shall be ensured that the permit does not complicate the preparation of a plan in any significant way.[291]

When assessing the private benefits and losses, the increase in the utility value of property resulting from the improved productivity or usability of a land or water area or other property and any immediate other benefits gained from implementing the project shall be taken into account as a private benefit gained from a water resources management project. The right of use or right to purchase granted to the applicant; the costs incurred from damage and right of use that the applicant has separately agreed on with the stakeholder in order to implement the project and the costs of acquisition of areas voluntarily handed over to the applicant for a similar purpose; and other losses incurred by a party not participating in the project and a passive partner in a ditch drainage operation shall be taken into account as private losses.

It is stated in the preparatory work that losses and benefits of a project shall primarily be assessed from a general point of view, but even monetary valuation of losses or benefits can be made if it is possible.[292] In the preparatory work, nature protection is mentioned as one possible public benefit. The aim of the assessment is that it can be adjusted according to different prevailing understandings of public benefit. In the assessment, social, health and environmental perspectives shall have the same importance. Also in relation to sea-based measures, the costs or non-economic losses shall be assessed against the corresponding benefits from case to case.

Like the permits under the Environmental Protection Act, permits for water construction projects are more than mere consent. Normally, they include quite a number of various provisions by which the harmful impacts on public and private interests are reduced, eliminated or compensated. According to Section 10 of Chapter 3, the permit decision shall issue the necessary regulations on avoiding any nuisance resulting from the project and

[290] Section 6 of the Act.
[291] Section 5 of the Act. See also KHO 2014:41, where it was found that a dredging project would have considerably complicated the drafting of a partial master plan and a permit under the Water Act could not be given.
[292] HE 277/2009, “yksityiskohtaiset perustelut”, 3 luku 6 §.

its implementation under the provisions laid down in Chapter 2, Sections 7 and 8; landscaping and other elimination of traces of work; and measures and devices necessary to preserving the state of the water body and groundwater body. If a project subject to a permit under the Water Act causes environmental pollution in a water area or poses a threat of this,[293] the provisions laid down in the Environmental Protection Act on issuing permit regulations shall also apply when issuing the permit regulations under the Water Act.

In the permit decision, the permit authority may under certain prerequisites, regulated in Section 16 of Chapter 3, for a justified reason authorise the applicant to take preparatory measures even before the decision becomes legally valid.

Compensation

The operator engaging in a water resource management project is responsible for the lawfulness of its project and the detrimental consequences caused by it. As a general rule, when granting a permit or right under the Water Act, the authority shall ex officio order compensation for losses of benefit resulting from the project.[294] The party responsible for the project is liable to compensate any loss of benefit resulting from an operation performed or to be performed under the Water Act or a permit based on it in the manner provided in Chapter 13, if the loss of benefit is caused by e.g. a water resources management project under a permit; the right to use or purchase property belonging to another party; a measure which is subject to a permit but for which a permit has not been applied for because it could not have been foreseen to lead to the consequences referred to in that section; and placing a cable in accordance with Section 5a.

The Tort Liability Act (412/1974) shall apply to compensation for loss of benefit caused by a measure in violation of the Water Act or provisions or regulations issued under it and to compensation for personal damage caused by a measure under the Act. If the damage in question is environmental damage, the Environmental Damage Act shall apply to compensation for such damage.

5.5.2.3 Implementation of the WFD

When the WFD was implemented in Finland through the Water Resource Management Act, the directive was considered as a planning instrument, which is reflected in the Finnish legislation. In the preparatory work, it was stated that the Water Resource Management Act does not cause direct obligations or economic impacts to the operators.[295] The Weser case has strengthened the role of environmental objectives, sparked a debate on whether there is a need to amend the Finnish legislation on this point.[296] Following Weser, the prohibition of degradation of the state of a water body appears to be a clear permit

[293] See Section 5 of the Environmental Protection Act.
[294] Section 7(1) of Chapter 13 of the Act.
[295] HE 120/2004 vp, p. 24.
[296] See e.g. Belinskij, Antti & Paloniitty, Tiina 2015: Poikkeaminen vesienhoidon ympäristötavoitteista uuden hankkeen takia.

prerequisite in the permit processes under the Water Act and the Environmental Protection Act.[297]

Chapter 4 of the Water Resource Management Act contains the environmental objectives in the river basin management plans. Section 23 contains provisions on derogating from the environmental objectives on the grounds of a significant new project and is substantially similar to the derogations in WFD 4(7). Derogating from the environmental objectives may be allowed if:

1. the project is very important with regard to public interest and promotes sustainable development, human health or public safety in a significant way;
2. all available measures have been taken to prevent harm; and
3. targeted benefits cannot be achieved by other technically and economically reasonable means that would be significantly better for the environment than modifying the body of water.

An account of the fulfilment of the conditions in Section 23 and an account of the modifications caused by the project in the body of water and its status must be presented in the river basin management plan. The derogation has not been applied so far in Finland, but the conditions for derogating from the environmental objectives will sooner or later be subject to legal assessment. Possible derogations can be looked at every six years when the river basin management plans are being updated by the Government. The conditions of derogation would be looked at in the same process.[298]

In addition to the permit process, the possible need of a derogation from the environmental objectives in accordance with the Water Resource Management Act has to be taken into account when planning sea-based measures. The fact that the river management plans are reviewed only every six years might drag out the projects.

5.5.2.4 Permits and consents under the Act on the Finnish EEZ and outside the EEZ

Under Section 2 of the Act on the Finnish EEZ, the state has the right of exploring and exploiting, conserving and managing the natural resources, whether living or non-living, in the EEZ, and the right to other activities for the economic exploitation and exploration of the zone. Finland also has jurisdiction as provided for in international law with regard to the establishment and use of artificial islands, installations and other structures and to the protection of the marine environment and marine scientific research, and other rights and duties provided for in international law. The Water Act is applied to the extraction of soil materials in the Exclusive Economic Zone.

The Government may, on application, give its consent to the exploitation of natural resources of the seabed and its subsoil located in the EEZ and to exploration aimed at such exploitation or to carrying on of other activities aimed at the economic exploitation of the zone. This could apply for e.g. dredging. Natural resources refer here to minerals, rock materials and other non-living resources of the seabed and its subsoil and plants and animals belonging to sedentary species which, at the harvestable stage, either are

[297] Belinskij, Antti & Paloniitty, Tiina 2015: Poikkeaminen vesienhoidon ympäristötavoitteista uuden hankkeen takia, p. 299.
[298] Belinskij, Antti & Paloniitty, Tiina 2015: Poikkeaminen vesienhoidon ympäristötavoitteista uuden hankkeen takia, p. 293.

immobile on or under the seabed or are unable to move except in constant physical contact with the seabed or the subsoil.[299]

If sea-based measures would be carried out in the EEZ as marine scientific research which does not fall under the scope of Section 6 on the right of exploitation, a notification shall be given to the Ministry of Trade and Industry. If the Ministry of Trade and Industry considers that the research project referred to in the notification on marine scientific research falls under the scope of section 6 or section 7 on building, the Ministry shall inform the notifying party of it as soon as possible and no later than four months from receipt of the notification. In other cases, a notified research project may be started at the earliest six months from receipt of the notification, unless the Ministry of Trade and Industry decides that it can be started earlier.[300]

Additionally, the Government may give its consent to the construction and use of installations and structures that may interfere with the exercise of rights which according to international law belong to Finland. Such installations could include the technical device used in larger-scale oxygenation. The consent may be given for a specified period or for an indefinite period. The decision shall lay down conditions which are indispensable for security or the protection of the rights of the state under the Act on the Finnish EEZ.

According to the Act on the Protection of the Marine Environment, constructions outside the Finnish EEZ in the high seas require a permit from the Finnish Environment Institute, and this would be the case for e.g. oxygenation pumps and other special device required by the sea-based measures.[301] It must be noted, though, that there is no high seas areas in the Baltic Sea, so this section does not apply in sea-based measures taken in the Baltic Sea. The permit cannot be given to an activity which is contrary to the ban on degradation in Section 1 of the Act. If the construction extends to the EEZ or the territorial seas, the permit is given by the Regional State Administrative Agency of Southern Finland. In general, a permit is needed also for exploration and exploitation of the seabed and its interior outside the EEZ.[302]

5.5.2.5 Restrictions under the Nature Conservation Act and the Land Use and Building Act

In the framework of sea-based measures, the restrictions provided in the Nature Conservation Act must be taken into consideration. According to Section 13 of the Act, in general any action altering the natural surroundings is prohibited in a national park[303] or strict nature reserve. Thus, it is prohibited to engage in sea-based measures which may have a detrimental impact on the natural conditions and the landscape, or on the preservation of fauna and flora. A special plan must be drafted for the management and use of a national park, as referred to in Section 19 of the Act. As necessary, a management plan may also be drafted for a strict nature reserve or other nature reserve.[304]

[299] Section 6 of the Act on the Finnish EEZ.
[300] Section 8 of the Act on the Finnish EEZ.
[301] Section 10 of the Act on the Prevention of Marine Pollution.
[302] Section 11 of the Act on the Prevention of Marine Pollution.
[303] There are several national parks in Finland that could that affect potential use of sea-based measures, for instance Tammisaaren kansallispuisto, Saaristomeren kansallispuisto, Itäisen Suomenlahden kansallispuisto, Selkämeren kansallispuisto and Perämeren kansallispuisto.
[304] See also Borgström & Koivurova 2014: Environmental Law in Finland, p. 84.

Section 14 provides derogations from protection provisions. Without prejudice to the provisions of Section 13, any action necessary for the appropriate maintenance and use of a nature reserve is permissible in a national park or strict nature reserve, provided this does not jeopardise the purpose for which it was established. For example, the construction, restoration and repair of any buildings, fixed installations and paths necessary for the management of the site; surveillance, research, public orientation, and hiking, or of other visitors' facilities; the upkeep and restoration of natural habitats and natural heritage types; and steps taken to restore the natural ecological balance, are thus permissible. If sea-based measures would be interpreted as appropriate measures to maintain or restore the natural habitats and the potential risks could be handled, or they would not alter the natural surroundings, the measures would not be forbidden even in or close to protected areas.

According to Section 64a of the Act, the ecological values on which the conservation of an area included in the Natura 2000 network is based may not be significantly deteriorated. Emphasis must be laid on the term significantly deteriorated. Again, even sea-based measures would not be strictly forbidden even in the Natura 2000 network if they do not significantly deteriorate the ecological values of the area. However, especially in the early stage of developing sea-based measures, the most suitable areas for the measures would probably not be the protected areas.

According to Section 65 of the Act, if a project or a plan, either individually or in combination with other projects and plans, is likely to have significant adverse effect on the ecological value of a site included in the Natura 2000 network, and the site has been included in, or is intended for inclusion in, the Natura 2000 network for the purpose of protecting this ecological value, the planner or implementer of the project is required to conduct an appropriate assessment of its impact. The same shall correspondingly apply to any project or plan outside the site which is liable to have a significantly harmful impact on the site. The assessment of impact can also be carried out as part of the assessment procedure referred to in Chapter 3 of the Act on Environmental Impact Assessment Procedure.

No authority is empowered to grant a permit for the implementation of a project, or to adopt or ratify a plan, if the assessment procedure or the requested opinion referred to in section 65, paragraphs 1 and 2, indicates that the project or plan would have a significant adverse impact on the particular ecological value for the protection of which the site has been included in, or is intended for inclusion in, the Natura 2000 network.

In terms of the Land use and Building Act, both maritime spatial planning and land use otherwise affect the sea-based measures. The ecosystem approach in maritime spatial planning requires knowledge of the ecology of the ecosystem and ecological entireties. Since the process of drawing up the maritime spatial plans in Finland is only at its beginning, the potential larger-scale sea-based measures could to some extent be taken into account when drafting the plans. However, it seems like actual area reservations will not be made in the maritime spatial plans, rather, the plans will be of a strategic and general nature. Hence, the maritime spatial plans will probably not be of considerable importance or relevance to potential sea-based measures.

In addition, other land use affects the possible locations of sea-based measures. Even though the maritime spatial planning process in only ongoing, territorial plans and territorial reservations by municipalities have already been made in the sea areas. The national land use targets and the plans made by regions and municipalities stand in the territorial waters and might restrict the use of sea-based measures. Hence, the plans in territorial waters should be taken into account when planning the sea-based measures.

5.5.2.6 Summary

While the environmental permit according to the Environmental Protection Act is an instrument to deal with of emissions and pollution control, structural changes caused by water management projects are regulated mainly through the water permit scheme under to the Water Act. In many cases, both water permit and environmental permit are required. However, this only applies to the activities listed in Annexes 1 and 2 of the Environmental Protection Act that require a permit under Section 27(1), and does not apply to sea-based measures. Since they are not listed in the annexes, the need for an environmental permit for sea-based measures arises from Subsection 2 of Section 27 of the Environmental Protection Act: “An environmental permit is required for activities that may cause pollution of a water body, and that the project in question is not subject to a permit under the Water Act.”

Hence, sea-based measures would require a permit under either the Water Act or the Environmental Protection Act. However, if a project subject to a permit under the Water Act causes environmental pollution in a water area or poses a threat of this, the provisions laid down in the Environmental Protection Act on issuing permit regulations shall also apply when issuing the permit regulations under the Water Act. Compensations on damage are partly connected to the permit processes. The larger-scale sea-based measures are likely to require an EIA in accordance with the EIA Act.

When planning a sea-based measure project, in addition to a permit under either the Water Act or the Environmental Protection Act, the possible need for a derogation in accordance with the WFD and the Water Resource Management Act must be taken into account. The fact that the river basin management plans are reviewed only every six years must be taken into account in scheduling the sea-based measures.

Also the Nature Conservation Act, plans by municipalities and regions and maritime spatial planning retain restrictions to the use of sea-based measures. Since the process of drawing up the maritime spatial plans in Finland is only at its beginning, sea-based measures could to some extent be taken into account when drafting the plans.

In Figure 48 below, the process for applying for environmental hearings in Finland is illustrated. It involves several steps and hence requires time. The average time for hearing environmental permits in all Regional State Administrative Agencies in 2015 was 17.2 months.[305] Also possible appeals must be taken into account when setting up the timetable for sea-based measures projects.

[305] Attila, Mikko: Ympäristölupamenettelyn pullonkaulat ja kesto. Ympäristöministeriön raportteja 5/2017, p. 12.

Table 25. Various permits in Finland.

Permit under Water Act (EEZ and territorial waters)	Water resource management projects described in Chapter 3, Sections 2 and 3, of the Act. Also extraction of soil materials in the EEZ. If environmental degradation is caused or may be caused, Environmental Protection Act is applied when permit regulations are given.
Environmental permit (EEZ and territorial waters)	If the project causes a risk of pollution of a water body and permit under Water Act is not required.
Notification on experimental activities under the Environmental Protection Act	Certain short-term experimental activities, but **not** if they entail a risk of water pollution -> in that case, environmental permit is needed.
Permit from the land-owner	If the activity is situated on other's property.
Notification to the Ministry of Trade and Industry	Marine scientific research in the EEZ.
Governments consent in the EEZ	Construction and use of installations and structures that may interfere with the exercise of rights that according to international law belong to Finland. Also exploitation of natural resources of the seabed and its subsoil located in the EEZ.
Permit under the Act on the Protection of the Marine Environment (outside the EEZ)	Constructions beyond Finnish jurisdiction.

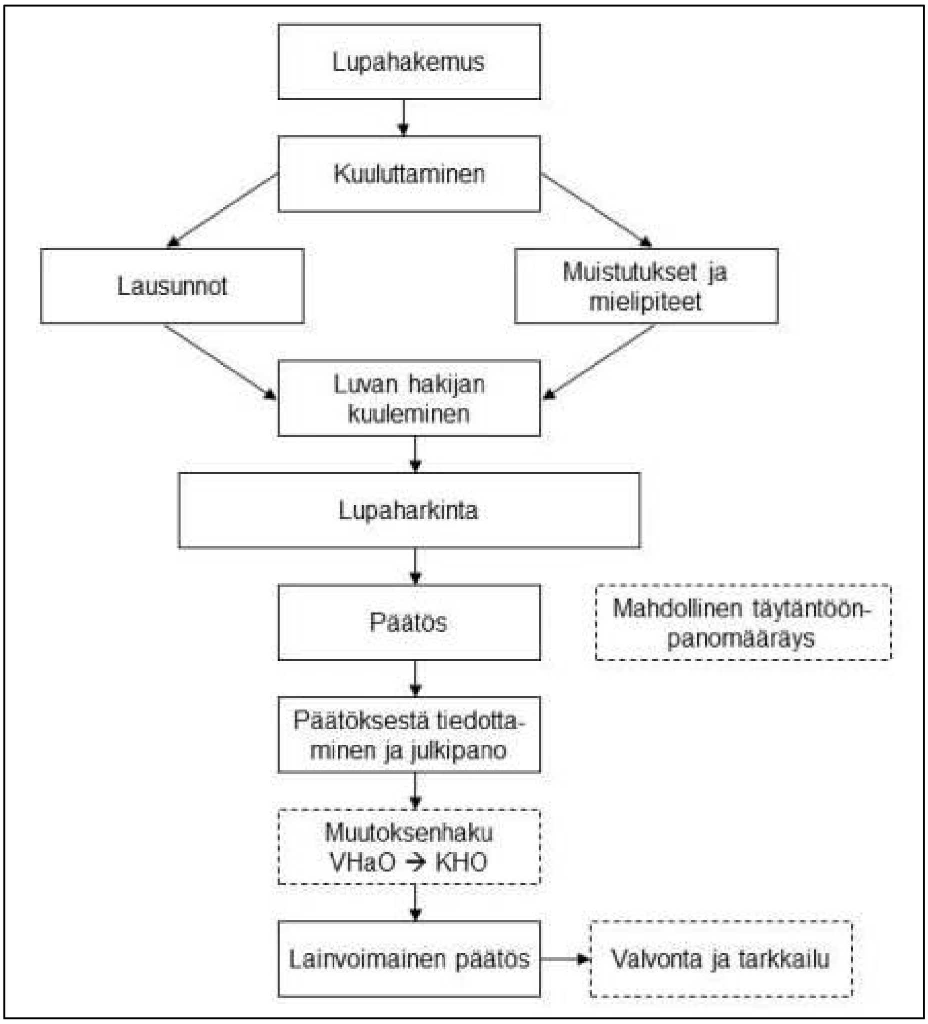

Figure 48. Finnish environmental permit process. Source: http://www.ymparisto.fi/fi-FI/Asiointi_luvat_ja_ymparistovaikutusten_arviointi/Luvat_ilmoitukset_ja_rekisterointi/Ymparistolupa

5.5.3 Procedural rules - Sweden

5.5.3.1 Introduction

The main regulation is the Swedish Environmental Code together with a number of ordinances and other laws specific to certain activities or sectors. The Swedish Environmental Code applies primarily to the Swedish territory, but to some extent also beyond that as regulated by the Swedish EEZ law and the Swedish Law on the Continental Shelf, and in relation to what follows from EU law.

For operators and activities with potential environmental harm, the General Rules of Consideration in Chapter 2, together with different rules and procedures for permits, are the most central provisions. Moreover, all operations that require a permit must assess the effects of the activities in an EIS and EIA, in accordance with Chapter 6 of the Environmental Code and the EU EIA Directive as well as the Espoo Convention as described in Section 5.2.2.3.

There are also other general requirements that need to be discussed more specifically in relation to the sea-based measures, which will be reviewed in the following sections.

5.5.3.2 General procedural provisions for sea-based measures

Chapter 11 in the Environmental Code forms specific requirements for water operations and water structures.[306] As for the Environmental Code generally, the Chapter on water operations and water structures is primarily applicable in the Swedish territory, i.e. in the territorial sea. In addition to Chapter 11, important provisions on water operations and water structures are also found in a specific law, the Law (1998:812) with specific rules for water operations[307] ("*Lag med särskilda bestämmelser om vattenverksamhet*"). Both dredging and the kind of installation that is connected to oxygenation are found among the specific activities regulated in Chapter 11.[308] Dumping, however, is not. It is regulated by the waste management laws in Chapter 15, as described above in the Introduction (section 5.2.5.3.2).

Water operations or structures at larger scale, or with more significant impact for the environment and for sustainable development, could also be subject of the Government's consideration of permissibility for certain matters established in Chapter 17 of the Environmental Code, as described in the introduction section 5.2.5.2.[309] It is possible that a large-scale installation for oxygenation could match those criteria, both because its permanent and large-scale impact, its general purpose with regard to sustainability, and since it includes similarities to some of the operations that are more specifically included in the provisions of Chapter 17. If a matter is the object of such permissibility, it will still need to go through a permit procedure where the conditions of the permit will be established.

The regulation of water operations and water structures sets out certain main criteria for their permissibility. The main criterion, which could be interesting in this context, is that the water operation shall be assessed from a cost-benefit analysis. It can only be considered for a permit if the benefits for both private and public interests overrides the costs, as well as the potential harm that it might bring.[310] The latter part of this criterion is interesting in relation to sea-based measures since some of these measures might be costly, although these costs should also take into account potential damage to the surrounding environment, and other indirect costs etc. However, it is also established in the preparatory works that operations that might be non-beneficial from a pure economic point of view shall still be considered permissible, if they bring obvious benefits for, *inter alia*, the

[306] Env. Code, Chapter 11, Section 1.
[307] Unofficial translation.
[308] Env. Code, Chapter 11, Section 3, p. 1 and p. 4.
[309] Env. Code, Chapter 17, Section 3.
[310] Env. Code, Chapter 11, Section 6.

environment. Still, this means that the costs must be balanced against the value that the different measures brings.[311]

The main principle for water operations and water structures regulated by Chapter 11 in the Environmental Code is that such operations and structures require a permit.[312] Some exceptions from this main rule are however established. One such exception is found in Section 12, where it is stated that license for an operation or structure is not needed if its effects on the environment do not harm public or private interests. However, such effects on the environment that a water operation could cause to private and public interests includes *inter alia* impairment or degradation to the ecological or chemical status.[313] Hence, the kinds of activities, or operations, related to sea-based measures are probably not within this exception since they all entail a risk of affecting ecological or chemical status. Although, of course, this also depends on where the operation is taking place and whether the area has been classified or not. Another exception that must be taken into account in this context is if the water operation aims to recover a water area that temporarily has changed from its natural state.[314] At first glance, this sounds like it may apply to highly eutrophic areas and the methods that aim to restore them, but this exception only applies if the change really is temporary and, therefore, would probably not be applicable to a situation where eutrophication is the problem since it is more of a permanent situation. However, exactly how this rule is to be assessed is not a clear cut issue.[315] If a permit is required by the rules established by the Birds and Habitats Directives for Natura 2000 sites, none of the exceptions are applicable.[316]

Given that the general exceptions from the permit requirement are not clearly applicable, it is likely that most of the sea-based measures under review will require a permit. An application for such permit shall be given to the Swedish Land and Environment Court.[317] A prerequisite for a permit and for any water operations or water structures is a that the operator has to have some right to the water.[318] The person who owns a property where the water is located has such right.[319] However, if the purpose of the water operation or structure is in the interest of environmental or health benefits, then also the state, the municipality and the local water board ("vattenförbund") are considered to own such right to the water.[320]

For a water operation or water structures to be permitted, the activity or the structure must meet a number of requirements established in the Environmental Code. Especially the requirements in the general rules of consideration, in Chapter 2, have to be applied. This includes different forms of precautionary and preventive measures, and rather strict requirements on localization, which is an interesting matter in this context. Sea-based

[311] Michanek, G. & Zetterberg, C., pp. 323–327; Preparatory of the Environmental Code – Prop. 1997/98:45, del 1, p. 369.
[312] Env. Code, Chapter 11, Section 9.
[313] Michanek, G. & Zetterberg, C., p. 322; Preparatory of the Environmental Code, Regeringens proposition 1997/98:45, Miljöbalk, del 2, Författningskommentar (Prop. 1997/98:45, del 2), p. 134.
[314] Env. Code, Chapter 11, Section 15.
[315] See the Preparatory of the Environmental Code – Prop. 1997/98:45, del 2, p. 137. See also for example the case MÖD 2007:32, from the Swedish Land and Environment Court of Appeal.
[316] Env. Code, Chapter 11, Section 9.
[317] Env. Code, Chapter 11, Section 9b.
[318] Law (1998:812) with specific rules for water operations, Chapter 2, Section 1.
[319] Law (1998:812) with specific rules for water operations, Chapter 2, Section 2.
[320] Law (1998:812) with specific rules for water operations, Chapter 2, Section 5.

measures must generally be placed where the problems are apparent, but these could also be areas that are more sensitive to different forms of disturbance.

When considering the localization, also the general provisions for management of land and water areas, Chapters 3 and 4 of the Environmental Code, must be taken into consideration. These rules for management include a differentiation between different land and water areas, meaning that some areas must be prioritized or protected for different purposes. Hence, depending on the chosen localization, restrictions on the land/water use in that area may be found in the provisions of these Chapters which then provide a kind of balancing tool for how these areas are to be used, and which will impact the possibilities and conditions for a permit. Chapter 4 also provides the basis for the implementation of the MSPD.

The maritime spatial plans work in a similar way to the management plan for land and water in Chapters 3 and 4, but are more general. The municipalities have the competence to plan the water areas and their usage in the whole territorial sea, which overlap with the geographical scope of the MSPD. The planning of water areas by municipalities is based on the general Planning and Building Act (2010:900) ("*Plan- och Bygglagen*"), which also refers in part to Chapters 3 and 4 of the Environmental Code. On the more overarching level, the Swedish government has directed the coordinating of maritime spatial plans to SwaM. Moreover, Chapters 7 and 8 of the Environmental Code contain rules on nature protection and restrict the use of those areas. Depending on the level of nature protection, exploitation in such areas will be restricted or even forbidden. Chapter 7 also implements the Habitats Directive and the Natura 2000 framework and thus evokes the same rules on requirement of permits if the activity could have adverse effects on the protected area.

However, the fact that an area is protected or prioritized for a certain purpose, either in the nature protection law, Chapter 7, or through the general provisions for management of land and water areas, Chapters 3 and 4, does not mean that any other activity is directly banned. All of these provisions include different balancing principles. The balancing can be based on different conditions. One way this could be done is basically that there is a direct balancing of interests (land/water use), where the interest that is most in line with a sustainability perspective should prevail. Another possible outcome – probably the most common – is that the balancing results in sufficient amount of preventive measures so that the activity or operation planned for (the land/water use) is not in conflict with other interests and that the protected area will not be harmed.

5.5.3.3 Permits for hazardous activities

The Environmental Code also holds other principles and rules on permits. The main regulation for what operations that require a permit is found in Chapter 9. Chapter 9, Section 1, defines what environmentally hazardous activities are in the scope of the Environmental Code. All operations that are defined as environmentally hazardous activities do not automatically require a permit. There are also different kinds of permit procedures depending primarily on the size or scale of the environmental hazard. Some operations do not require a permit but should still be announced through a notification to the responsible authority. More specific rules on whether an operation requires a permit and which procedure that applies are found in ordinances issued under the Environmental Code, particularly the Ordinance on Environmental Assessment. The permit sets out the scope of the activity concerned and must include the conditions under which the activity may be carried out.[321]

The general rules of consideration apply also in this permit procedure, and provide the basis for determining whether and, if so, under what conditions a permit can be issued. It is often the case that specific types of conditions are required, e.g. conditions setting out emission limits or conditions concerning how emissions must be monitored. In principle, the permit stipulates that an activity, e.g. the production of a certain quantity of a specified product, the use of a certain amount of a specified product for a certain purpose etc., is subject to certain conditions. The conditions set out in the permit vary depending on the activity in question.[322]

If a water operation or water structure falls within the definition of 'environmentally hazardous activities' according to Chapter 9, Section 1, it is regulated also by those requirements. Among sea-based measures, the pumping installation appears to be the only one that could meet the criteria for hazardous activities, since it is the only one of the measures that is based on a (semi-)permanent installation or structure, which thus will have impacts on the surrounding environment. This does not in itself mean that it falls within the requirement of a permit connected to Chapter 9. The activities that require a permit are listed in the Ordinance on Environmental Assessment.[323] This list only includes commonly known activities, with certain expected levels of risks for the environment, which is what also determines where a permit is to be applied for, or whether it is even only requiring a notification to the concerned authority. Since a pumping installation was not foreseen by the legislator when listing activities, it does not require a permit according to the general rule. However, there is a possibility for the supervisory authority to require that an operator applies for a permit even when it is not listed, if it is likely to cause significant harm to the environment.[324] Since the structure of oxygen pumping – if established in the territorial sea or internal waters – would be subject to a permit procedure according to Chapter 11, it is however likely that an authority would not require an additional double permit procedure for the operation.

If the pumping installation would instead be placed in the Baltic Sea deep basins, in the EEZ, then it would be subject to permit review according to the EEZ law. Moreover, such installation could also be the subject of the government's own consideration. It is a possibility that such an installation could fall under the governments consideration even if performed in the territorial sea and more close to the coast, but the prerequisite for such consideration by the Government is that it likely to cause significant effect and have important impact for the goals of the Environmental Code, so it is more likely that this would become an issue for a more large-scale installation in a more sensitive area.

5.5.3.4 EQS and the implementation of the WFD

With certain limited exceptions, permits, approvals and exemptions cannot be granted for activities which are likely to lead to non-compliance with the EQSs. The permit authority

[321] See also: Swedish Environmental Protection Agency (*Naturvårdsverket*), Report 6790, p. 24.
[322] Swedish Environmental Protection Agency (*Naturvårdsverket*), Report 6790, p. 24.
[323] Env. Code, Chapter 9, Section 6.
[324] Env. Code, Chapter 9, Section 6a.

may revise a permit for an activity with respect to the permissible volume of production or the scope of the activity, alter or cancel conditions or other provisions, or issue new provisions where the activity is to a significant extent responsible for an infringement of an EQS.[325] The regulation on EQS in Chapter 5 also to a large extent incorporates the WFD into the Swedish law.[326] Hence, for a permit procedure for sea-based measures, these rules have significant impact, since it is possible that they will have adverse effects on the EQSs. The implementation of the Weser Judgment will further limit the possibilities to receive a permit in certain areas.

5.5.3.5 Activities in the Swedish continental shelf and the EEZ

For sea-based measures taking place beyond the Swedish territorial sea, the Act on the Swedish EEZ and the Swedish Continental Shelf Act are also central in addition to the Environmental Code. According to the Swedish Continental Shelf Act, the right to explore the continental shelf and to extract its natural resources shall vest in the Swedish State.[327] The Government or such authority as it may designate (Geological Survey of Sweden, SGU) can grant a concession to another party to explore the continental shelf by means of geophysical measurements, drilling or other methods, and to extract its natural resources.[328] However, it is important to note that this does not mean that the state consequently also owns the right to the water, as is a criteria for water operations under Chapter 11 and regulated in Law with specific rules for water operations.[329] To explore the continental shelf by means of geophysical measurements, drilling or other methods and to extract its natural resources is what the idea of dredging for extracting phosphorus as a natural resource would be classified as and, thus, such activity would need a requirement according to the Continental Shelf Act, if performed in the EEZ.[330]

When such concession is being considered, Chapter 2 and Chapter 5 (Section 3), of the Swedish Environmental Code provide the frame. Chapter 2 provides the General Rules of Consideration, including a number of requirements on precaution and preventive measures, with the aim to make sure that all aspects of the activity are taken into account. Chapter 5, Section 3, however, is a requirement for state authorities to ensure that EQS, where identified, are being met. This means in practice that also such licensed activities that can be carried out to extract natural resources in the continental shelf must meet the requirements set out by potential EQS, including those that are connected to the WFD as explained in the previous Section 5.5.3.4. The general provisions for management and use of land and water, Chapters 3 and 4 of the Swedish Environmental Code, shall also be considered.[331]

Another rule found in the Continental Shelf Act that interesting in this context is Section 3b, which states that in the case of an application for concession for mining activities at

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[325] Swedish Environmental Protection Agency (*Naturvårdsverket*), Report 6790, p. 19; and Env. Code, Chapter 2, Section 7; Chapter 5; Chapter 24.
[326] Env. Code, Chapter 5, Sections 10-12.
[327] The Continental Shelf Law, Section 2.
[328] The Continental Shelf Law, Section 3.
[329] Michanek, G. & Zetterberg, C., p. 317.
[330] Cf. Sand mining along the Coast of southern Sweden which was requested by Ystad Municipality, and found permissible by SGU Decision 440-1632/2010.
[331] The Continental Shelf Law, Section 3a.

the continental shelf of different kinds of minerals etc., the current need of the material to be extracted shall be balanced against the damage that such mining would cause to animals and plants, and the environmental water status generally. How such a balancing of values would play out in relation to extraction of phosphorus is difficult to assess at a general level, due to the sensitivity of the ecosystem in the Baltic Sea. However, given that it would also have the upside of reducing the internal reserve from the very same substance with the benefit of also reducing some that internal reserve which is also contributing to the degrading of the ecosystem, it is not likely to cause a hindrance to such activity.

The Act on the Swedish EEZ includes environmental requirements on certain other activities, acknowledging that the right to explore the floor of the continental shelf in the EEZ and to exploit the natural resources of the continental shelf are primarily regulated with the Swedish Continental Shelf Act. However, the EEZ Act states that a license is required for, *inter alia*, investigation, extraction and other utilization of such natural resources and the establishment and utilization of installations and other equipment for commercial purposes.[332] The activities identified are such that they could, for example, match installations, and other equipment may be translated as referring to the kind of technical pumping installation that are necessary for oxygenation. Whether such installation would be for commercial purposes, however, is more uncertain. This depends whether it would be for research purposes only or whether it would be financed and carried out by a private actor in a way that would be considered as part of its regular operation. However, as stated above, even if a permit would not be required the General Rules of Consideration, the rules regulating EQSs shall still be taken into account.

A license for such activities in the EEZ is given by the Government or a designated authority, and may be restricted in time. It shall be combined with the conditions necessary to protect human health and the environment from harm, and to promote sustainable management of land and water and other natural resources.[333] To this end, the license can also be conditioned with economical insurance sufficient for the cost of remedying the site and uninstall potential installation when the activity ends. However, state run operations, or activities licensed for County boards or Municipalities etc., are excluded from this obligation.[334]

The activities that require a license, as described above, shall apply to the General Rules of Consideration in Chapter 2 of the Swedish Environmental Code.[335] The General Rules of Consideration include, as described above, *inter alia* the precautionary principle[336] – with emphasis on taking preventive measures but also including the precautionary aspect – and moreover the principle of best available technique[337] and the polluter pays principle[338.] The EEZ law furthermore refers to other rules in the Environmental Code and thus implies that they are applicable also in the EEZ and in parallel to the general requirements stated there.[339] Some of the more interesting rules of the Environmental

[332] The Act on the Swedish EEZ, Section 5.
[333] The Act on the Swedish EEZ, Section 5.
[334] The Act on the Swedish EEZ, Section 5b.
[335] The Act on the Swedish EEZ, Section 2.
[336] Env. Code, Chapter 2, Section 3.
[337] Env. Code, Chapter 2, Section 3.
[338] Env. Code, Chapter 2, Section 8.
[339] The Act on the Swedish EEZ, Section 3.

Code that the EEZ law refers to are the rules concerning protected areas, according to the Natura 2000 regulation and the Birds and Habitats Directives, as implemented by Sweden.

To such activities that require a license according to the Swedish EEZ law, the rules in Chapters 2–4 and certain parts of Chapter 5 in the Environmental Code, regarding EQS, are also applicable, implying that also for these activities and when considering permits, EQS have priority and must be taken into account.[340] An application for a license shall also produce an EIS and an EIA in accordance with the requirements in Chapter 6 of the Environmental Code.[341] Moreover, the regulation of such licensed activities in the EEZ law can also, by decision from the Government or from such authority as the Government determines, be subject to special ordinances on safety zones – which is in line with the requirements found in UNCLOS regarding installations.[342]

Last, the EEZ law also states that marine scientific research in the EEZ may not be carried out by foreign citizens without specific consent by the Government or from such authority as the Government determines.[343]

5.5.3.6 Summary

The main permit to consider for sea-based measures in Sweden is a permit according to the rules for water operations and waters structures, found in Chapter 11 of the Environmental Code. In some cases, an environmental permit according to Chapter 9 might also be required, but even if the general definition of environmentally hazardous activities applies, it does not automatically mean that the activity must be regulated by a permit or is included in the more specific Ordinance on Environmental Assessment. Dumping is regulated separately in accordance with the regulation on waste and is then, as a main rule, prohibited. However, if an environmental assessment shows that dumping does not cause harm to the environment, an exemption can be granted.

If the measures are pursued in the EEZ, other rules apply. For any activity taken – in all marine zones – the General Rules of Consideration shall apply. Hence, rules on precaution and knowledge on both direct and indirect environmental effects need to be considered and the effects limited.

5.5.4 Conclusion on the national procedures

Under both national legal systems, many parallel procedural rules and conditions apply. It follows from above that almost all activities need some form of permit, irrespectively of in what sea areas they are placed. However, it is not possible – at a general level – to assess whether permit requirements would apply, or if other rules or notification procedures would instead be a possible way. In some cases, there could also be opportunities for a government or authority to consider the permissibility of activities on a case-to-case basis.

[340] The Act on the Swedish EEZ, Section 6.
[341] The Act on the Swedish EEZ, Section 6a.
[342] The Act on the Swedish EEZ, Section 7.
[343] The Act on the Swedish EEZ, Section 9.

Dumping seems to be the only case where no permit is necessary or considered under either Finnish or Swedish law, but where the main regulation instead prohibits such activity. In such cases exemptions must be granted instead.

Whether the matter relates to a permit, exemptions, or other rules of consideration, an assessment of the potential adverse effects on the environment is the key to the level of control and conditions for any such measures to be accepted. Hence, knowledge of such effects is crucial for any legal assessments also at the national level. A key instruments here then, in both Sweden and Finland, are EIA and EIS, such which provide a basis for most environmental assessments in relation to legal procedures.

From an ecosystem point of view, the resilience of the marine ecosystem should not be reduced either in a long-term or short-term perspective. However, there is no available legal practice for cases comparable to sea-based measures where there would have been a risk of temporarily weakening the state of the sea through a measure that in the longer perspective makes the state better. In managing the risk of environmental degradation, the permit regulations or conditions are significant. Again, in order to know how the risks for the water environment and ecosystem can be managed and removed, the operator shall have enough information about the risks themselves.

Regarding the general need for knowledge about the environment, the technical process and the environmental effects also in a wider perspective, in order to fulfil the requirements and assessments, it seems as if more knowledge is needed. While this lack is an obstacle to a full legal review, it does emphasize the quest for further research, also in the national context. Small-scaled sea-based measure projects have already taken place and given permit to in both Sweden and Finland, and some lessons could be learned from them.

On the other hand, in both countries, water resource management projects require a permit where a general assessment shall be made of the benefits and losses caused to public and private interest. In this assessment, also other values than environmental values must be assessed.

From the point of view of environmental degradation, it could be argued that it is better to remove the phosphorus rather than to merely bind it to the seabed. This talks for dredging, but still, the technical feasibility is the key in choosing the appropriate sea-based measure. In any case, the environmental risks of sea-based measures must be known and managed in order for the permit to be granted.

5.6 Relevant actors, responsibility and liability

5.6.1 Introduction

This section addresses briefly the division of responsibilities for the key actors involved, including the 'operator' of the sea-based measure, the authority that issues the permit, the state etc. The aim is to identify different forms of responsibility for the players involved, including the responsibility for acting in the first place, for taking precautionary measures, the procedural responsibilities involved as well as identifying the responsibility for controlling the activities and assuming liability for potential harm caused by the activity. Here, too, relevant legislation exists at many levels, but EU law (section 5.6.3) and national laws (section 5.6.4) remain most relevant, apart from the question of states' responsibility under international law, which is governed by public international law (section 5.6.2). The policy positions of the key players involved relating to responsibilities and reparation of damage are finally listed in section 5.6.5.

5.6.2 International law

5.6.2.1 Introduction

This section briefly addresses the responsibility of states for harm to the marine environment, for example caused by sea-based measures. UNCLOS Part XII does not offer much guidance on state responsibility. Article 235(1) merely provides that "states are responsible for their fulfilment of their international obligations concerning the protection and preservation of the marine environment. They shall be liable under international law." Yet, the rules relating to responsibility and liability are not well-developed under international law.[344] There are no international conventions in these area, but the UN International Law Commission has issued a number of reports and draft articles on both the responsibility of states for unlawful conduct (irrespectively of any damage caused) (section 5.6.2.2) and on the principles for repairing environmental damage for lawful activities (section 5.6.2.3). The former rules are more widely accepted and have in part been consider representative of customary international law.

5.6.2.2 State responsibility

The main principle under the Articles on Responsibility for states for Internationally Wrongful Acts, adopted by the ILC in 2001,[345] is that responsibility arises for every "internationally wrongful act of a state". Under Article 2, there is an internationally wrongful act "when conduct consisting of an action or omission: (a) is attributable to the state under international law; and (b) constitutes a breach of an international obligation of the state."

As to the first criterion, attribution, a state does not assume responsibility for all individual entities under their jurisdiction. Only a limited number of entities that are deemed to

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[344] The term responsibility here refers to secondary responsibility while the term liability refers to a duty to make reparation. Whereas responsibility presupposes a wrongful act, liability does not. See Rachael Lorna Johstone, Offshore Oil and Gas Development in the Arctic under International Law: Risk and Responsibility (Brill 2015) pp. 232ff.

[345] UN General Assembly resolution 56/83 of 12 December 2001, as corrected by UN document A/56/49(Vol. I)/Corr.4.

represent a state for this purpose have been enumerated in Articles 4–8 in the State Responsibility Articles.[346] Activities undertaken by the operator of sea-based measures would normally not fall into any of those categories and would therefore normally not be attributed to the state. That does not exclude, however, that state may be held responsible for acts of other entities, but in that case it would be for having failed to take appropriate measures to prevent the act, which is a separate failure that is attributable to the state. The relevant standard of care required by the state is that of 'due diligence'. A state, in other words, will only have committed an international wrongful act if the state itself has failed to exercise due diligence; activities by private entities will not as such give rise to such responsibility. The ICJ has further clarified held that due diligence "is an obligation which entails not only the adoption of appropriate rules and measures, but also a certain level of vigilance in their enforcement and the exercise of administrative control applicable to public and private operators, such as the monitoring of activities undertaken by such operators."[347] In the context of sea-based measures, this would notably involve the duty of states to exercise caution in the permit process or in controlling the effects of such measures.

The second main criterion under the Articles on state responsibility is that state responsibility only arises where there is a breach of an international obligation. Article 12 of the Articles provides that "there is a breach of an international obligation by a state when an act of that state is not in conformity with what is required of it by that obligation, regardless of its origin or character." In our case, the relevant obligations are usually linked to prevention of harm to the marine environment or consist of more general marine environmental protection obligations. The mere fact that harm has been caused to the environment does not necessarily trigger responsibility. The obligation is one of conduct (to exercise due diligence), rather than one of result.

However, the duty to prevent environmental harm has been considered to entail a positive duty for states to maintain the necessary administrative apparatus to monitor the conduct of private entities, including a legal framework and a permit system, and a forum that can provide remedies.[348] Providing a permit for a hazardous activity without safeguards could be an example of a breach of such positive obligations, and it is not necessary under the rules to identify exactly which state entity has failed. 'Anonymous' or 'cumulative' culpa could suffice to evidence institutional failure by the state as a whole.[349] A certain degree of activeness is required by the state in this regard, that there must be a certain effort on the side of the state.[350]

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[346] These include: acts of organs of the state (art. 4); non-state entities exercising elements of governmental authority (art 5); agents of the state (persons or entities acting on the instruction of or under the effective control of a state organ (art. 7). In addition a state can bear responsibility if its government 'acknowledges and adopts' conduct of non-state actors as its own (art 11).
[347] ICJ, Pulp Mills para. 197.
[348] Johnstone p. 240.
[349] See e.g. Alexandre Kiss 'State Responsibility and Liability for NuclearDamage, 35 Denver Journal of International Law and Policy, 2006-2007, p. 78 and See Rachael Lorna Johstone, Offshore Oil and Gas Development in the Arctic under International Law: Risk and Responsibility (Brill 2015) p. 241.
[350] SDC, para. 110: "The sponsoring State's obligation “to ensure” is not an obligation to achieve, in each and every case, the result that the sponsored contractor com- plies with the aforementioned obligations. Rather, it is an obligation to deploy adequate means, to exercise best possible efforts, to do the utmost, to obtain this result. To utilize the terminology current in international law, this obligation may be characterized as an obligation “of conduct” and not “of result”, and as an obligation of “due diligence”.

The level of diligence required from the state also depends on the nature of the obligation concerned. Very vague obligations will entail difficulties to specify the conduct required by states and vice versa, and it has been suggested that the standard of diligence required has to be more severe for riskier activities.[351] In the case of dumping, for example, the very straightforward prohibitions of the London Convention and Protocol may very well give rise to responsibility for a state if its failure to maintain appropriate control mechanisms can be linked to a particular dumping incident, and the more serious the pollution is, the more stringent standard of care will be applied.[352]

For the purposes of sea-based measures, it may be assumed that it will be a failure to live up to the procedural elements of the obligation to prevent harm to the marine environment that are most likely to trigger international responsibility.[353] As noted above, these procedural obligations include the duty to evaluate potential environmental impact and to monitor those impacts once the activity is on-going. While the impact assessment obligations are limited to transboundary impact and a certain level of potential harm (significant harm to the marine environment), the monitoring obligations outlined in UNCLOS Article 204 entail no such qualifications.

State responsibility may arise even without any physical damage to the marine environment. Wrongful acts may be committed even without any such consequences. Harm is accordingly not a prerequisite for responsibility in the case of a breach of an obligation to exercise due diligence. By contrast, for a state to be responsible for harm, hence triggering duties of restitution and compensation, the causal link between the harm and the wrongful conduct of the state has to be proven by the claimant.[354] It must, in other words, be shown both that had the state not acted wrongfully the operator would have acted diligently, and had he done so, damage would not have occurred.

A final question is who may invoke this responsibility against the state. The general rule is that any state to whom the responsible state owes the obligation in question is an 'injured' state and may invoke responsibility.[355] However, in the case of damage to the marine environment, the obligation of prevention is not limited to neighbouring states, which raises the question as to whether any state may invoke the responsibility for such erga omnes obligations. Article 42 of the State Responsibility Articles does foresee such a situation, in cases where the breach of the obligation either "specifically affects that state" or "is of a character as radically to change the position of all the other states to which the obligation is owed with respect to further performance of the obligation."

Procedurally, claims invoking the responsibility of states for failing its marine environmental obligations would most likely be addressed through the dispute settlement procedures under UNCLOS Part XV, which includes a broad variety of options depending on the choices made by the states in question at the time of ratification. However, it needs to be borne in mind that states have generally been very reluctant to invoke such claims against other states.

[351] ITLOS Case 17, SDC, para. 117.
[352] See, however, Birnie, P., Boyle, A. and Redgwell, C., International Law and the Environment, 3rd Ed., Oxford University Press, Oxford, 2009, p. 431, noting that in practice the state responsibility for dumping appears to remain unresolved.
[353] See also due diligence N. Matz Lück & E. van Doorn, 'Due Diligence Obligations and the Protection of the Marine Environment', *L'Observateur des Nations Unies*, 2017-1, vol. 42, pp. 169–187.
[354] ITLOS Case 17, SDC, para. 182.
[355] ILC state responsibility articles, article 42.

5.6.2.3 State liability for lawful activities

Various efforts have been made for international law also to regulate the liability of states to compensate for environmental harm that is caused without any wrongful act by the state, i.e. where state has acted diligently, but damage has nevertheless occurred. In 1996, Draft Articles were prepared by the ILC on this topic, based on the idea that states should provide residual compensation in the event the operator could not provide adequate compensation to avoid that victims of pollution would have to carry the risks and losses.[356] Such liability regimes would not constitute an alternative to state responsibility, but rather a complement to it, but the focus of such regimes has been on transboundary harm only, which means that they fail to address the duty of states to protect the marine environment per se, including within its own territorial waters and EEZ. These instruments, however, have not achieved widespread acceptance in practice of states or recognition in subsequent case law.[357]

Instead, financial liability of environmental damage caused by lawful acts is governed by a certain legal void in international law. Some environmental damage will thus remain outside any compensation regime for states, if the pollution involves no breach of an international obligation. To fill that void, certain specific conventions have been adopted to deal with specific fields, such as damage caused by space objects, nuclear damage or pollution from ships. However, no such international liability regime exist for matters of relevance in this study.

The compensation of damage for sea-based activities that involve no internationally wrongful act is thus left to civil liability rules under domestic (or EU) law. UNCLOS Article 235(2) provides in this regard that "all states shall ensure that recourse is available in accordance with their legal systems for prompt and adequate compensation or other relief in respect of damage caused by pollution of the marine environment by natural or juridical persons under their jurisdiction."

5.6.2.4 Summary

States may be responsible for their acts or omissions in the context of the operation of the sea-based measures. This is particularly so with respect to failure to meet the more procedural aspects of the planning, permitting and monitoring of the activities, and such responsibility does not necessarily even presuppose that the activity has resulted in environmental damage. However, responsibility presupposes that states have committed an internationally wrongful act, which in reality means that they are found to have failed in their duty to exercise due diligence in ensuring various obligations to protect the marine environment. By contrast, states are not likely to have financial responsibility under

[356] 1996 ILC Draft Articles on International Liability for Injurious Consequences Arising out of Acts Not Prohibited by International Law. The project subsequently split into two parts, both of which resulted in sets of ILC Draft Articles of their own: the 2001 Articles on Prevention of Transboundary Harm from Hazardous Activities (UN Doc. A/56/10) and the 2006 Draft Principles on Allocation of Loss in the Case of Transboundary Harm Arising out of Hazardous Activities (UN Doc. A/61/10.

[357] ITLOS Case 17, SDC, para. 209.

international law for activities that does not involve any breach of legal obligation, even if the activity causes transboundary pollution.

5.6.3 EU law

The Directive on environmental liability with regard to the prevention and remedying of environmental damage (ELD) establishes a framework based on the polluter pays principle to prevent and remedy environmental damage.[358] The ELD is based on the powers and duties of public authorities, as distinguished from a civil liability system for "traditional damage" (damage to property, economic loss, and personal injury). The ELD does not give private parties a right of compensation as a consequence of environmental damage or of an imminent threat of such damage occurring. Instead, a key role in implementing and enforcing the ELD is given to competent authorities designated by member states. Competent authorities will, for instance, be in charge of specific tasks such as assessing the significance of the damage and determining which remedial measures should be taken (in co-operation with the liable operator).

Under its Article 3(1), the ELD provides for two different liability regimes. First, operators of certain activities deemed to be of actual or potential concern, listed in Annex III to the Directive, can be held liable, essentially through a non-fault liability regime, in the event of damage to protected species and natural habitats, water damage and land damage. Sea-based measures are no included in the list in Annex III, but some of the activities could nevertheless have relevance to the operation of such measures, including waste management operations (para. 2) and "the discharge or injection of pollutants into surface water or groundwater which require a permit, authorisation or registration in pursuance of [the WFD]" (para. 5).

Second, the ELD also applies to damage to protected species and natural habitats caused by any occupational activities other than those listed in Annex III,[359] and to any imminent threat of such damage occurring by reason of any of those activities, but this is only to the extent the operator has been at fault or negligent.

The operator liable under the ELD, which in essence is the holder of the permit to carry out the sea-based measures,[360] must bear the cost of the necessary preventive or remedial measures, which are quite broadly defined.[361] The ELD also requires member states to take measures to encourage the development of financial security instruments and markets with the aim of enabling operators to use financial guarantees to cover their responsibilities under the Directive.

According to the Directive “environmental damage" is damage to protected species and natural habitats, which is any damage that has significant adverse effects on reaching or maintaining the favourable conservation status of such habitats or species, related to other

[358] ELD, Art 1.
[359] Under Art. 2(7) ‘occupational activity’ is defined as meaning “any activity carried out in the course of an economic activity, a business or an undertaking, irrespectively of its private or public, profit or non-profit character".
[360] Under Art 2(6) the ‘operator’ is defined as meaning " any natural or legal, private or public person who operates or controls the occupational activity or, where this is provided for in national legislation, to whom decisive economic power over the technical functioning of such an activity has been delegated, including the holder of a permit or authorisation for such an activity or the person registering or notifying such an activity".
[361] See also Annex II on remedying environmental damage.

community legislation such as the Habitats and the Birds Directives,[362] but it also includes "water damage", which is damage that significantly adversely affects the ecological, chemical or quantitative status or the ecological potential, as defined in the WFD, or the environmental status of the marine waters concerned, as defined in the MSFD.[363]

In conclusion, the Directive places a potential burden on the operator of the activity in question, notably in relation to the competent (state) authority which may require the damage to be remedied and repaired. The regime's applicability to sea-based measures is not obvious, as the key activities listed in Annex III focus on discharges of pollutants and do not fit well to most categories of sea-based measures, and as only damage that "significantly adversely" affects water status will be covered. With respect to damage to protected species and natural habitats, however, the Directive places potentially very far-reaching remediation and reparation obligations on the operator, but this presupposes that the operator has been at fault or negligent.

5.6.4 National laws

5.6.4.1 Finland

In Finland, civil liability for environmental damage is based on different legal rules. The general law of torts is codified mostly in the Tort Liability Act (412/1974). Under the Act, it must normally be shown that the damage has been caused either intentionally or negligently.[364] Unless otherwise provided in the Act on Compensation for Environmental Damage, the Tort Liability Act applies to compensation for environmental damage.

General legislation on the subject includes the Act on Compensation for Environmental Damage (737/1994) and the EU Environmental Liability Directive on the prevention and remediation of environmental damage. Additionally, compensations are also an integral part of permit procedures under specific laws: As mentioned earlier, *inter alia*, the Environmental Protection Act and the Water Act provide rules on determining compensation for damage anticipated and assessed in advance as part of the permit procedure. In these cases, the Act on Compensation for Environmental Damage is applied substantively, but not procedurally as no civil law suit is concerned.[365]

The Act on Compensation for Environmental Damage is the general law concerning environmental impairment liability and contains provisions on compensation for environmental damage. The Act applies to compensation for losses caused by environmental damage, or other similar disturbances to the environment. Compensation shall be paid for a loss defined in the Act as environmental damage, caused by activities carried out in a certain area and resulting from pollution of the water, air or soil; noise, vibration, radiation, light, heat or smell; or other similar nuisance.

According to the Act on Compensation for Environmental Damage, the operator whose activity has caused the environmental damage is strictly liable for compensation (as

362 ELD, Art 2(1)(a) and ELD 2(3).
363 ELD, Art 2(1)(b).
364 See more: Borgström, Suvi & Koivurova, Timo 2016: Environmental Law in Finland, pp. 141–144.
365 Borgström, Suvi & Koivurova, Timo 2016: Environmental Law in Finland, p. 142.

opposed to the general rule of intention or negligence in the Tort Liability Act). Furthermore, persons comparable with the operator, taking into account consideration control, financial arrangements and other comparable matters, also have strict liability.[366] The liability applies to bodily injury and material loss, in accordance with Chapter 5 of the Tort Liability Act, and economic loss if the loss is not minor.[367] Further, compensation is paid for the costs of measures needed to prevent environmental damage, for restoration costs caused to the authority, and for the costs of investigations that prove unavoidable whilst carrying out preventive measures or restoration.

The EU Environmental Liability Directive is implemented in Finland through the Act on Remediation of Certain Environmental Damages (383/2009) and related changes in other legislation (i.e. Environmental Protection Act, Nature Conservation Act and Water Act). Based on the Act, the Government has also issued a Decree on the Remediation of Certain Environmental Damages (713/2009). The Act includes provisions on necessary measures related to the remediation of significant damage to protected species, natural habitats and waters, and on the liability to pay the costs of such measures.

It is notable that the term 'liability' in the directive and thus the national legislation based on the directive does not refer to traditional economic compensation for damage, as the directive aims to prevent and remedy significant environmental damage according to the 'polluter pays' principle.[368] The principal aim is to restore the environment to the state in which it would be, had no environmental damage occurred. In case this is not possible, other complementary and compensatory measures shall be taken in order to remedy any damage to natural resources. The implementation and costs of these measures are mainly borne by the operator responsible for the environmental damage.

The Environmental Protection Act and the Water Act also contain provisions on how, in accordance with the Act on Remediation of Certain Environmental Damages, the authorities may issue orders to remedy significant environmental damage caused by activities falling within the scope of application of these acts. Provisions to be applied in such cases are those which relate to administrative enforcement proceedings set out in the Act concerned.[369]

5.6.4.2 Sweden

5.6.4.2.1 Responsibility for the operator

According to Swedish environmental law, the operator is responsible for his or her activity. This is one of the most fundamental principles both of the Finnish Environmental Protection Act and Water Act, and of the Swedish Environmental Code.[370] The operator of an activity must prove that the obligations arising out of the Code are complied with. This responsibility can also be related to the precautionary principle which is also one prominent

[366] Wetterstein, Peter: The Liability of Salvors. In Rak, Henrik & Wetterstein, Peter 2007: Shipwrecks in National and International Law, p. 80.
[367] Section 5 of the Act on Compensation for Environmental Damage.
[368] Borgström, Suvi & Koivurova, Timo 2016: Environmental Law in Finland, p. 143.
[369] Borgström, Suvi & Koivurova, Timo 2016: Environmental Law in Finland, p. 144. See also: Reports of the Ministry of the Environment of Finland 2/2012: Remediation of Significant Environmental Damage.
[370] Swedish Env. Code, Chapter 2, Section 1.

rule in the Environmental Code, obligating anyone who pursues an activity to take all necessary environmental precautions in order to limit the impact on human health and the environment.[371] It is important to note also that the operator is continuously held responsible for any environmental damage caused by the operation activity until the damage stops and is remedied.[372]

As in international law, important instruments to guarantee that all precautions and preventive measures are assessed and implemented are EIS and EIA. Such assessments are required at least for any activity that requires a permit (see section 5.4.4.2) but also for some other activities.[373]

Chapter 10 of the Environmental Code provides more detailed rules on what can be required by an operator if responsible for a polluted area, in terms of remediation and financial responsibility.[374] The Chapter primarily refers to damage as a result of pollution, or imminent threat, and provides rules on both practical remediation and how the financial responsibility is distributed between several potential operators.[375]

Moreover, there are different ways for the supervisory authority to enforce the rules and conditions given an operator. If a permit holder does not follow the conditions set out in the permit, for example, or in any other way breach the provisions or environmental laws, the supervisory authority may order him to rectify the matter.[376] The supervisory authority may order an operator to submit information required for the supervision.[377]

5.6.4.2.2 Compensation and environmental damages

Rules concerning compensation and environmental damages are found in Chapter 32. These provisions, however, concern liability and damages for injury and loss caused by pollution, noise, vibration and other similar disturbances. Hence, they do not apply to environmental damage as such.

5.6.5 Policy perspectives on responsible actors

The policy review conducted as part of the study (section 5.3.2 above) included some questions on who should bear the responsibility if sea-based measures were to be introduced in practice. Most of the respondents emphasized that the responsibility for such measures, especially if carried out large-scale, should be with the state. Some respondents (incidentally representing state authorities), however, considered that given the available permit procedures and the risk assessment connected to such procedures, it would be sufficient and natural to let the operators bear the responsibility for their measures, including the financial costs and liability for damage.

[371] Swedish Env. Code, Chapter 2, Section 3.
[372] Swedish Env. Code, Chapter 2, Section 8.
[373] Swedish Env. Code, Chapter 6; Swedish Environmental Protection Agency (Naturvårdsverket), Report 6790, p. 19.
[374] Swedish Env. Code, Chapter 10, Sections 2, 4, 5, 5a and 6.
[375] Swedish Env. Code, Chapter 10, Section 1.
[376] Swedish Env. Code, Chapter 24, Sections 3 and 5.
[377] Swedish Env. Code, Chapter 26, Sections 19–20.

The important role of HELCOM as a governing organization in this work was emphasized by several respondents. At the same time, it was noted that HELCOM might not have the instruments or mandate to manage such large scale and long term operation. One suggestion was that a special body for this purpose should be crated. Similarly, it was proposed that the political responsibility should lay at HELCOM or on an upgraded version of HELCOM. It was finally noted that whatever level a permit would be adopted for such measures, and regardless the level of responsibility, such measures and operations would need a careful EIA and continuous monitoring.

5.6.6 Conclusions

Different responsibility regimes target different players. International law targets states, while EU and national law tend to focus on the responsibilities of the operator. These liability regimes are not alternatives and may well be implemented in parallel.

As for states, international law provides that international responsibility may be invoked against them, even if no damage has occurred. It suffices that the state has failed to meet its due diligence obligations in relation to the protection and preservation of the marine environment, and this is most likely to be the case in the context of procedural aspects of sea-based measures, i.e. the planning, permitting and monitoring of the activities. By contrast, states are not likely to face a financial responsibility under international law for activities that do not involve any breach of a legal obligation, even if the activity causes transboundary pollution. International law in this field has not yet developed into a stage that would create reparation obligations on states, apart from specific fields covered by special agreements.

EU law, on its part, includes no responsibility for states but targets the responsibilities and liability of the operator in case of environmental damage. The applicability of the ELD to sea-based measures is not obvious, as the key activities listed in Annex III focus on discharges of pollutants and do not fit well to most categories of sea-based measures. With respect to damage to protected species and natural habitats, the Directive places potentially very far-reaching remediation and reparation obligations on the operator, provided the operator has been at fault or negligent.

5.7 Conclusions

Sea-based measures can be divided into different substantive legal categories, which makes it easier to analyse and discuss applicable laws. Different laws and legal assessments apply (at least to some extent) to the different categories. The geographical dimension also plays a role in the legal assessment as different laws apply in the different jurisdictional zones, which affects the applicability of international law as well as national legislation.

In an effort to summarize the legal review in a single picture, the Table 26 below indicates the most relevant laws that apply in Finland for different measures in different areas.

Table 26. Applicable laws in different sea areas for different measures (the Finnish situation).

		Chemical treatment	**Oxygenation**	**Dredging**
Internal waters	**National (FIN)**	EPA, WRMA, NCA, LUBA	EPA, WA, WRMA, NCA, LUBA	EPA, WA, WRMA, NCA, LUBA, Waste Act
	EU	WFD, Waste Proced.: EIA, Habitats/Birds	WFD Proced.: EIA, Habitats/Birds	WFD Proced.: EIA, Habitats/Birds
	International	LC/LP, HELCOM Espoo Conv	HELCOM Espoo Conv	HELCOM Espoo Conv
Territorial sea	**National (FIN)**	EPA, WRMA, NCA, LUBA	EPA, WA, WRMA, NCA, LUBA	EPA, WA, WRMA, NCA, LUBA, Waste Act
	EU	(WFD 1 or 12nm), MSFD, MSP, Waste Proced.: EIA, Habitats/Birds	(WFD 1nm), MSFD, MSP Proced.: EIA, Habitats/Birds	(WFD 1nm), MSFD, MSP Proced.: EIA, Habitats/Birds
	International	UNCLOS (principles, etc.) HELCOM, LC/LP, CBD Espoo Conv	UNCLOS (principles, innocent passage, etc.), HELCOM, CBD Espoo Conv	UNCLOS (principles, CS) HELCOM, CBD Espoo Conv
EEZ/CS	**National (FIN)**	EEZ Act, EPA, WRMA, NCA, LUBA	EEZ Act, EPA, WA, WRMA, NCA, LUBA	EEZ Act, EPA, WA, WRMA, NCA, LUBA, Waste Act
	EU	MSFD, MSP Proced.: EIA, Habitats/Birds	MSFD, MSP Proced.: EIA, Habitats/Birds	MSFD, MSP, Waste Proced.: EIA, Habitats/Birds
	International	UNCLOS (CS, EEZ), HELCOM, LC, LP, CBD Espoo Conv.	UNCLOS (principles, due regard, installations), HELCOM, CBD Espoo Conv	UNCLOS (principles, CS), HELCOM, CBD Espoo Conv.

The table illustrates that some difference exist with respect to the laws that apply the different measures, e.g. that the Water Act applies to dredging and oxygenation measures, but not to chemical treatment as long as the measures do not involve structural alterations. It also illustrates that when moving seawards from the limits of the territorial sea, certain additional laws come into play.

Yet, in the end, neither the substantive nor the geographical categorization eventually seems to be decisive for establishing the legal rights and obligations involved in sea-based measures. None of the categories of measures can be ruled out or accepted without having regard to their environmental impact. The geographical categorization under the law of the sea (as reflected in UNCLOS) is not of crucial relevance either, since there is considerable jurisdiction for states for this type of activities in all of their maritime zones. Perhaps surprisingly, the geographical distinction that appears to be most relevant for determining the rights and obligations involved emanates from EU law, through the difference in applicability of the EU marine directives, which is not linked to the limits under the law of the sea.

Instead, what transpires from the legal review in this chapter is that the legality of any kind of sea-based measure, in any sea area, in the end depends on the risks they present – in the short and longer term – balanced against their longer-termed benefits. In view of this, a particular category of measures cannot be legally preferred over another without having regard to their performance and environmental impact. If a particular measure improves the marine environment without much risk, it is legally easy to justify, while, conversely, a measure with uncertain benefits and large risks meets resistance in a variety of applicable legal rules and principles at many levels.

The problem for sea-based measures is that their potential impact in this regard is disputed. There is no certainty or consensus among researchers as to what the likely outcome of the sea-based measures will be, in particular for large-scale measures. This, in turn, highlights the need for more knowledge and the availability of a proper national procedure for evaluating the proposed measures based on best available scientific knowledge.

In reality, the balancing of interests will take place at national level during the permit process. This process will therefore be where the relevant rules and standards are implemented most concretely, on a case by case basis. In this process, the permit regulations, in the form of implementing obligations and conditions, are of crucial relevance. Any kind of sea-based measure is subject to a permit in Finland and Sweden and this will accordingly be the procedural framework in which short-term and long-term risks and benefits will be weighed against each other, on the basis of applicable law. This law includes principles to deal with scientific uncertainty, notably in the form of the precautionary principle, but not even that principle can be applied without regard to the facts and information available in the individual case. For large-scale measures, potentially affecting the sea areas of many or all Baltic Sea states, there is currently no multilateral permit process in place, though a recent HELCOM Ministerial Declaration has indicated an interest to study that option for larger-scale sea-based measures.

A relevant example of how the precautionary principle has been operationalized in the face of new measures aimed at environmental protection is found in the amendments of the London Protocol relating to marine geo-engineering measures which are not yet in force but ratified by Finland.

It may finally be noted that it is in the context of procedural obligations, such as assessing, permitting and monitoring sea-based measures, that states are most likely to be exposed to state responsibility under international law. However, the financial liability for damage caused by such measures will normally be channelled to the operator.

6 Conclusions and roadmap

Eutrophication development of the Baltic Sea

The Baltic Sea has suffered from eutrophication for decades. It is caused by excessive external nutrient inputs released mainly from anthropogenic activities. The significant decrease in phosphorus discharges from cities and industrial plants since the 1980s has improved water quality in the vicinity of cities, most recently in the Gulf of Finland. Nevertheless, the state of the Baltic Proper is still unsatisfactory.

The Baltic Sea annually receives a total of 36,900 tonnes phosphorus and 910,000 tonnes nitrogen from the catchment area (inputs in 1997-2003, HELCOM 2013). Almost half of the nutrients originating from land-based sources (18,300 tonnes phosphorus and 423,900 tonnes nitrogen) enter into the Baltic Proper. The GOF receives some 7,500 tonnes P and 116,300 tonnes N, the Bothnian Sea 2,800 and 79,400 tonnes and the Bothnian Bay 2,700 and 79,400 tonnes, respectively. The largest proportion (45 %) of land-based phosphorus input comes via rivers and originates from diffuse sources such as agriculture, forestry and dispersed settlements as well as storm water runoff from built-up areas. Point sources (municipal and industrial wastewaters and fish farming) cover 20 % of P load. Diffuse sources cover 45 % and point sources 12 % of the land-based nitrogen load. The remaining proportion originates from transboundary load, unspecified river load and natural background sources. Although the proportion of point sources is relatively low, it can be spatially and temporally higher. Since the nutrient input from point sources is the easiest to reduce, a marked reduction in nutrient input from i.e. municipal wastewater plants has been achieved during the last decades (Furman et al. 2013, HELCOM 2017).

Malmaeus and Karlsson (2012) estimated that the total amount of mobile P in the entire Baltic Proper sediments below 65 m water depth is between 55,000 tonnes and 156,000 tonnes representing the maximum amount of P that could possibly be released to the water column from these areas. The potential of internal P leakage is therefore clearly higher than the input of P from the catchment.

During the last century, both the extent of hypoxic sea bottom areas, as well as the duration of hypoxic periods, has increased in the Baltic Sea. Bottom sediments transform from phosphorus sinks to phosphorus sources when the state of the sediment-water interface changes from oxic to anoxic, although also various other local conditions in the sediments and at the sediment-water interface affect this balance. High levels of phosphorus are maintained in the water by the combined impact of external loading and phosphorus release from sediments in anoxic conditions.

It is evident that the recovery of the Baltic Sea will take a substantial time. Model simulations indicate no or only little improvement in water quality of the Baltic Sea despite of the decrease in nutrient loads in recent decades. Due to complex and non-linear processes, including counteracting impacts from climate change, it is challenging to predict the path of its recovery. According to the model simulations (HELCOM 2017), significant improvements will be seen a few decades after the land-based nutrient reduction targets defined in the HELCOM Nutrient Load Reduction Scheme have been fulfilled. Concentrations of dissolved inorganic nitrogen in winter begin to diminish after 20-30 years and achieve the target level after 100 years. Concentrations of dissolved inorganic phosphorus begin to diminish immediately and achieve the respective target level in 100 years.

The main sink for hazardous substances in the aquatic environment is in sediments, although they are also found in water and biota. Some compounds are present in higher concentrations close to their discharge points, whereas some are more evenly distributed in the sediment across the Baltic Sea. The sea-based restoration solutions presented in this study may release harmful substances from sediments, which has to be taken into account in risk analysis and implementation of the measures.

Speeding up the ecological recovery of the Baltic Sea?

In this assessment we have studied:

- sea-based restoration measures aiming at enhancing the phosphorus (P) binding capacity of the sediment, which includes oxygenation of anoxic bottoms and chemical binding and
- extraction of nutrients from the sea by dredging (conventional bulk dredging and more sophisticated thin-layer dredging).

Other possible measures include biological measures, such as removal of phosphorus and nitrogen from the sea by fishing fish with low or no economic value, harvesting algae and mussel farming. These measures have not been studied in this project.

Oxygenation of restricted water bodies (lagoons and bays) has been successful in decreasing benthic phosphorus release - at least as long as the treatment is on-going - although there have also been drawbacks in some pilots for different reasons (e.g. due to insufficient pumping capacity). At the moment, limited information exists on long-term impacts of oxygenation. The technique is mature enough for continuing local projects in coastal areas and inner archipelagos to gain local benefits, better understanding of the short and long-term effects on ecology and to further improve the technology. Even though the ecological effects are not thoroughly known, risks in local projects can be controlled. The feasibility, including technical requirements, hydrogeography as well as geochemistry of each area should be carefully analysed to avoid risks and failure of oxygenation. For example, in order to successfully bind phosphorus to the sediment, it is critical that there is enough Fe(III) to bind the phosphorus. The potential benefits, risks and costs of each project should be carefully assessed before implementation and ecological monitoring should be continued after treatment. Large-scale oxygenation in open sea areas requires more research and gained experience from several local projects.

Aluminium treatment has been implemented in a marine bay in Sweden, which took place in 2012-2013. Monitoring after the treatment continues and according to the monitoring results the ecological status of Björnöfjärden is improving. The technique is mature enough for continuing the field experiments to gain more information on the reactions taking place in the sediment during and after the treatment. In lake environments, the measure is regularly applied. The results suggest that the risks of small-scale treatments can be controlled. Yet, aluminium treatment is not considered a very attractive measure in the marine environment due to the high chemical costs and bioavailability of aluminium at alkaline and acid pH. The monitoring of long-term impacts of the treatment for the whole ecosystem needs to be continued.

Clay bombing and marl treatment are promising measures, although at the moment these have been tested with appropriate analysis only at the laboratory scale. In practice, clay bombing takes place in many dredging projects that dispose of dredged material into the sea.

Selective sediment dredging that removes only a thin layer of biologically active top sediment and nutrients from the sea bottom could be a suitable option in anoxic areas with high oxygen demand of bottom sediments. Its effect on oxygen conditions in bottom waters and on benthic nutrient release needs more research. The feasibility of the treatment depends on e.g. the possibilities of utilizing the dredged sediment.

As an overall conclusion, there is a rather good understanding and experience of some of the measures and their short term effects in coastal waters; e.g. oxygenation and aluminium treatment. For other methods, such as sediment removal and especially more novel methods like clay bombing and marl treatment, more research is needed. In coastal waters, risks can be minimized to a satisfactory level already now and local pilots and trials should be continued to gather knowledge on long-term effects and to further develop methods. Sea-based measures are most likely to be successful when the bottom and current conditions as well as chemical nutrient retention capacity are favourable, and when the differences between brackish and lake conditions are taken into account in the planning of mitigation measures. Cost estimates of the application of the measures vary from a few euros to hundreds of euros per removed kg of phosphorus and can be very case dependent. Therefore it can be concluded that the feasibility of local sea-based measures is very case dependent.

It is also important to understand that local measures only have local impacts on the targeted area and immediate vicinity of it. Local measures have little or no significant impact on the larger-scale problem in the open sea and the Baltic Proper.

There are knowledge gaps and much more uncertainty and greater risks related to larger scale applications of sea-based measures. There is a potential risk that large-scale technical measures to manage internal nutrient reserves could have widespread and possibly irreversible negative effects on the marine environment of the Baltic Sea (see Table 2, Table 3 and Table 4). Hence, further research and piloting are needed to add to existing knowledge, which in turn makes the scaling up of the applications more possible and less risky.

Mapping of potential areas and feasibility studies of planned measures

For small-scale testing of potential sea-based measures, closed eutrophied water bodies in coastal waters might be good from both communication and practical perspectives. There may be challenges to find optimal closed bays where effects are measurable. Potential places for application could be found e.g. in areas outside Porvoo, Tammisaari, and in the Archipelago Sea.

Local positive impacts are very much site specific and costs, results, risks and positive effects should be assessed case by case. Feasibility studies, which are usually needed to get financing for projects, should cover all these aspects.

Regional plans for river estuaries and other areas as well as preliminary site selection could boost development of projects.

Systematic monitoring and documentation of results is important, as they provide information that can be learned from. Monitoring should be continued also in the long-term to get a better understanding of longer-term impacts.

Communication

Communication about the implementation of sea-based measures should take into account that both citizens and decision-makers might feel concerned about the use of unfamiliar new technologies. The communication must be open and mutual and it is important to highlight that possible risks are being considered, and that the process is carefully monitored.

It is also vital to identify potential pitfalls in communicating about sea-based measures. Communication should emphasize that possible risks related to sea-based measures need to be taken into account. Communicating about sea-based measures should not be simplified too much, i.e. they should not be presented as an easy and fast solution. On the other hand, it is also important to avoid causing unnecessary alarm.

In communication, the topic could be tied in with the dead zones on the sea floor, as they are a captivating image and a symbol of the sea's poor condition. Dead zones could thus provide a good angle for reporting on internal nutrient storage and leakage, as long as the connection between the two phenomena is adequately explained and justified.

Local residents are presumably keen on improving the condition of their home environment, therefore, they might have a generally positive attitude towards trying out new kinds of sea-based measures. Proper communication is nevertheless of great importance in gaining common acceptance.

When implementing measures at sea, it is important to minimize the lack of knowledge or false information, and the resulting risks for project implementation. Local residents and stakeholders must be involved in projects from the very beginning and already at the planning stage. Transparency as well as adequate and timely communication is vital. This is particularly important in the vicinity of the coast and in the archipelago where people live.

More research is needed

More research, tests and trials are needed on internal nutrient leakage and sea-based measures, combining science, common knowledge, strategy and implementation in order to gain common acceptance for the measures.

More research is needed, especially to obtain a better understanding of the internal nutrient recycling processes in the Baltic Proper and Gulf of Finland. There are still major knowledge gaps in understanding basic phenomena of the ecosystem. For example, there is significant uncertainty regarding estimates of the magnitude, trend, dynamics, and bioavailability of phosphorus fluxes from internal sources (sediment and other reserves) and affecting factors. Microbial processes and reactions between carbon, nitrogen, manganese, iron and sulphur, that couple the cycling of phosphorus to redox reactions in sediments and concretions (iron manganese), are not fully understood either.

Different models show very different scenarios of impacts of reducing the leakage of phosphorus from internal sources and recovery of the Baltic Sea solely by implementing measures to restrict inputs from land-based sources. This calls for model comparisons. One criterion a model must fulfill, to be considered reliable is that it can describe the P content in the Baltic Proper from the 1950s to the present time.

More research is needed to understand which measures can be used, and where, in order to achieve full recovery of the Baltic Sea to a good status, and whether that could safely be speeded up. Also, it is crucial to holistically understand the short and long-term risks and impacts of different proposed sea-based measures on the marine ecosystem and humans.

The Baltic Sea area can act as a science forerunner by making the shift from descriptive science towards advanced, result-driven science. In such a new paradigm, the focus is shifted from merely measuring and describing the Baltic Sea's ecological status towards collecting data to aid decision-making that is required for active restoration of the ecological balance of the sea. This requires not only collecting relevant existing data, but also developing new analysis and financing tools, verification of models, and advancing free and open collaboration with the global oceanographic and aquatic sciences communities. The Baltic Sea could serve as a model area for modern integrated science, which can subsequently be applied globally. This paradigm shift could create a scientific center and community of global significance. Also open research programmes, where research groups in several countries compete for the resources, can provide good results. Both are needed.

Legal, political and institutional measures

The policy approach towards sea-based measures has so far been a national matter. International or EU marine policies or strategies do not take a position on how to manage internal nutrient reserves in the sediments. Finnish and Swedish authorities and institutions tend to have a fairly positive approach towards sea-based measures, at least for the purpose of learning more about them, while other states in the region hesitate, mainly on grounds of the uncertain environmental impact of such measures and the implications for other (land-based) measures to combat eutrophication.

National authorities have and will continue to have a key role in deciding on whether or not to approve sea-based measures in their waters. No sea-based measures can, under applicable rules and procedures, take place without a permit of the relevant public authority (government, regional or local authority, depending on the location and nature of the operation). Yet, there appears to be an increasing acknowledgment of a need for coordinating the general principles to this effect at Baltic Sea level. HELCOM has recently indicated a formal political interest in the matter, notably through the Ministerial Declaration adopted in March 2018, which opens up a possibility for a regional deliberation of the matter.

On the basis of the policy survey undertaken (see section 5.3.2), it appears clear that more knowledge of the benefits and risks of sea-based measures is needed before policy positions on the matter can crystallise within the region. For securing political acceptance for the matter, it would seem important that the more progressive states assure their partners that their initiatives relating to sea-based measures will not distract attention (in terms of effort or funding) from land-based measures. Some sort of formal commitment to this effect may be helpful.

If sea-based measures are to move beyond very small-scale local experiments, it seems advisable to agree on the main principles relating to national assessment and implementation framework at HELCOM level. A Baltic Sea wide coordination of the matter would ensure some consistency of policy, but could also contribute to a degree of transparency of the measures and their outcome, which seems to be essential for obtaining the policy approval by all coastal states in the region. The principles could be laid down in such general terms that they could be applied with respect to any sea-based measure and irrespective of their location and magnitude. The principles could include guidance on matters such as the purposes, location and methodologies of the activity, information needed for issuing a permit, assessment of risks, monitoring of progress and sharing of information on the results. For larger operations, such collaboration, monitoring and transparency are even mandated by various international and EU-rules.

More knowledge about the benefits and risks of sea-based measures is not only relevant in itself, and for allowing stakeholders to form their opinion on the matter, but is also crucial for assessing the lawfulness of the measures in the first place. It has been shown above that the effects on the marine environment are crucial elements in deciding, for example, whether or not a particular activity is to be considered as 'dumping', 'pollution of the marine environment' or 'marine geo-engineering', and on the extent to which different environmental obligations and principles come into play. The lawfulness of the measure, in other words, depends on the short-term and long-term effects of the measures, and on the consequences of non-action. Yet, scientific certainty is lacking for all these key issues.

International environmental law has developed rules on how to deal with scientific uncertainty. On the one hand, international law calls for caution in approving activities the full effects of which are not known and this is reflected, *inter alia*, in Article 3(2) of the Helsinki Convention. On the other hand, more knowledge about risks and benefits, including risks of non-action, cannot be obtained without experience of implementation of sea-based measures in practice.

For the reasons discussed above, it seems justified for public authorities to focus on measures aimed at learning more about sea-based measures, instead of paving the way for the implementation of large-scale facilities involving uncertain risks. In order to secure region-wide participation, the proper place to establish the framework is HELCOM that has recently indicated a political interest in bringing the matter forward. An interesting blueprint for a potential assessment framework is the one adopted for marine geo-engineering measures in the context of the London Protocol in 2013, which could be – and needs to be – adapted for the different challenges posed by sea-based measures in the Baltic Sea. For large-scale research in this field, it may be justified to coordinate the research itself, and the permit processes, at Baltic Sea level. In view of the many environmental, political and legal uncertainties involved, a speedy implementation of common research projects in this area would be welcome.

Roadmap

The proposed actions are presented in a roadmap (c.f. Figure 49) that illustrates the proposed order of main actions and the roles of different players for implementing the most effective measures for speeding up the recovery of the Baltic Sea.

The following actions are recommended:

- Regional mapping of potential coastal water areas for local sea-based measures should be conducted and, based on the mapping, action plans for implementation of the measures should be drawn up. The work could be carried out country by country and it could be combined with regional coastal area and river basin management planning work.
- The main stakeholders for the sea-based measures are typically local municipalities, water protection associations, service providers in the tourism sector, fishers, scientific community and NGOs. The actions are typically taken by private sector actors and non-governmental organizations. The implementation of projects needs financing. Research and new innovations can be tested by R&D project financing. Current R&D project financing mechanisms and instruments are available and effective enough for this purpose. However, the monitoring period in projects should be extended to reveal long-term effects. Separate financing of long-term monitoring projects should be considered.
- Financing of projects applying mature technologies need financing from local interest groups. Co-financing, and possibly new financing instruments, are needed for larger scale applications, especially if scaling up to cross-border projects in open sea areas.
- A combination of ministries should negotiate with Business Finland to open an innovation financing programme aiming at cutting the internal nutrient leakage with different emerging measures. A similar programme could be also financed at EU level.
- Careful ecological, technical and economic feasibility studies, including assessment of risks and positive effects should take place prior to every sea-based restoration project. Monitoring during and after the implementation of the measures is important for assessing whether the actions have been successful. The monitoring should be planned with, and the results made available for use by, the scientific community.
- Experiences from the projects shall be reviewed systematically, regularly and independently. With enough knowledge, a decision support tool could be developed for identifying and selecting suitable and cost-effective measures, which is essential for implementing the right measures at the right scale and place.
- It is proposed that a temporary (e.g. 5-10 years) or a permanent “Baltic Sea Scientific Centre of Excellence on sea-based measures” would be established. It would not only provide information to help fill the knowledge gaps, but could also be highly interesting and unique globally, since largish marine areas that are considered as one ecosystem, and possible remedy technologies, are not intensively studied or piloted elsewhere in the world. Research needs to be open

and financers should ensure that research is independently reviewed and that the results are publically available and transparent.

- International cooperation between researchers and technology developers is vital. Multi-country teams should be supported, like Interreg, BONUS and Horizon are doing. Sea-based measures could be included in research themes. Many of the projects have been led mainly by Finnish and Swedish research institutes with smaller roles for experts from other countries. Increased involvement of Estonian, Lithuanian, Latvian, Polish, German, Danish and Russian research institutes in the new research projects could be useful, because in order to proceed with sea-based measures in Baltic Proper, the contribution of a wider scientific community would accelerate necessary actions compared to the current situation, where the research work is primarily carried out by Swedish, Finnish - and to a lesser extent - by Danish research teams.
- It would make sense to rely on existing international co-operation platforms and e.g. to agree on the main principles relating to implementation of sea-based measures at the HELCOM-level. An acceptance, in principle, of action in this direction, including the development and application of a risk assessment framework, has already been adopted by ministers in the HELCOM Ministerial Declaration of 6 March 2018. The principles to be elaborated should be laid down in such general terms that they could be applied with respect to any sea-based measure, irrespective of their location and magnitude. The principles should include a harmonized approach for issuing permits, carrying out risk-assessments, monitoring and information sharing. Widespread exchange of information throughout the Baltic Sea region should be encouraged from the earliest stages of operation. For larger operations, such collaboration, monitoring and transparency is even mandated by various international and EU rules.

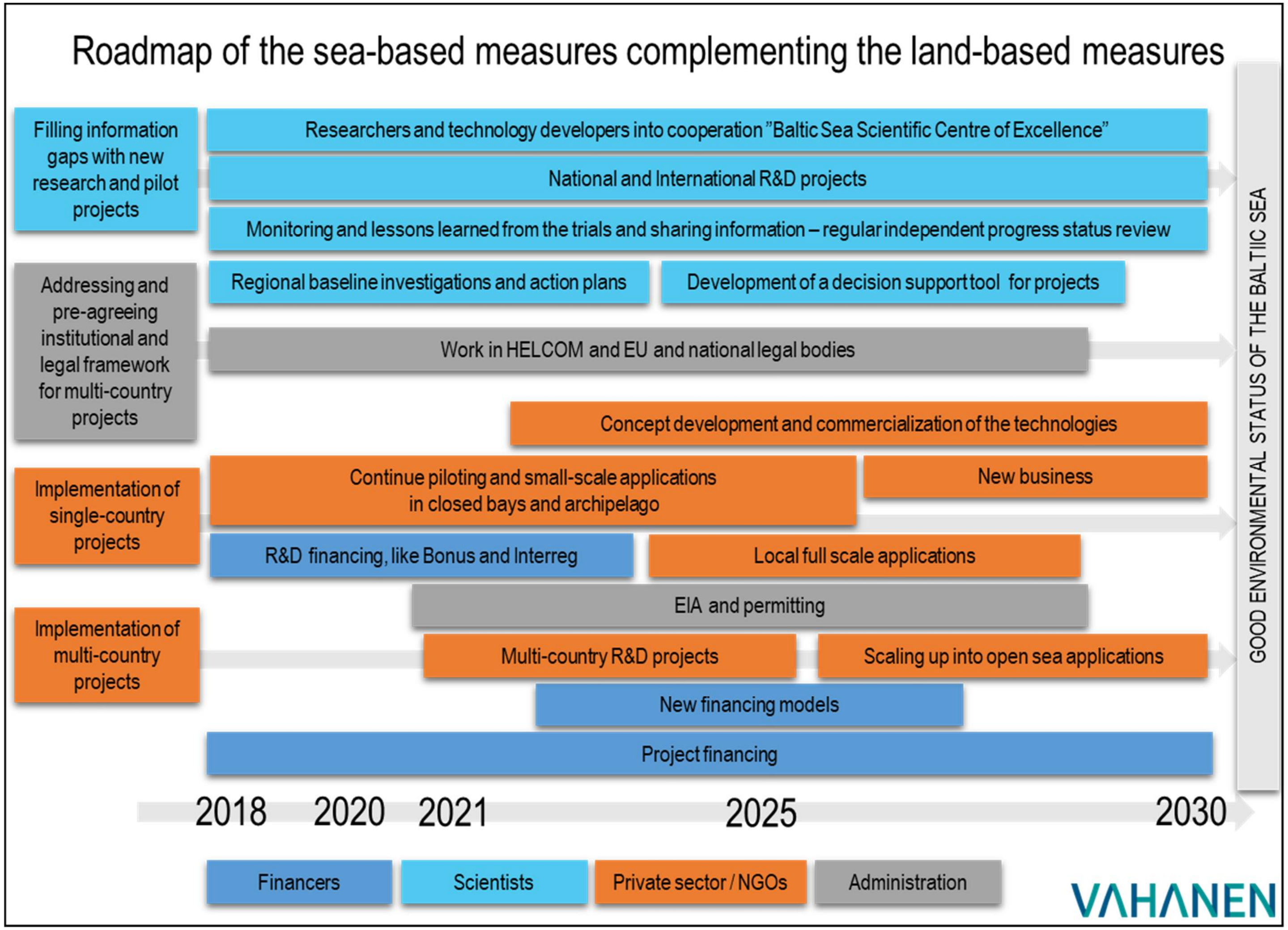

Figure 49. Road map of the sea-based measures complementing the land-based measures.

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Annex 1 Interviews for the policy part of the study

The following interview questions were sent to different organisations mostly in Finland and Sweden in order to get their input on the policy part of the study. The interview questions were sent to the following organisations:

- HELCOM
- NEFCO
- Ministry of the Environment of Finland
- Ministry of the Environment and Energy of Sweden
- Ministry of the Environment of Latvia
- Swedish Agency for Marine and Water Management (HaV)
- Finnish Environment Institute
- Centre for Economic Development, Transport and the Environment of Southwest Finland (ELY)
- Regional State Administrative Agency of Southern Finland
- Marine Spatial Planning at the Regional Council of Southwestern Finland (V-S)
- Baltic Sea Action Group BSAG
- John Nurminen Foundation
- Baltic Sea 2020
- Coalition Clean Baltic CCB
- World Wildlife Fund WWF
- Stockholm University Baltic Sea Center

The following persons in the interviewed organisations were contacted and/or participated in writing the respective answers:

- Nefco: Dennis Hamro-Drotz and Anja Nysten
- Ministry of the Environment of Finland: Laura Saijonmaa, Hannele Pokka, Eeva Gustafsson, Maria Laamanen, Sanni Turunen
- Ministry of the Environment and Energy of Sweden: Martin Larsson
- Ministry of the Environment of Latvia: Baiba Zasa
- Swedish Agency for Marine and Water Management: Robert Almstrand
- Centre for Economic Development, Transport and the Environment of Southwest Finland: Risto Timonen
- Regional State Administrative Agency of Southern Finland: Ville Salonen, Riitta Ikäheimo and Ilona Joensuu
- Marine Spatial Planning at the Regional Council of Southwestern Finland: Heikki Saarento and Timo Juvonen
- BSAG: Mathias Bergman

- John Nurminen Foundation: Marjukka Porvari and Miina Mäki (phone interview)
- Coalition Clean Baltic Mikhail Durkin, Lennart Gladh and Gunnar Norén
- Stockholm University Baltic Sea Center: Bo Gustafsson and Gun Rudquist

Additionally, Monika Stankiewicz from HELCOM contributed with documents on the topic.

Some of the answers have been transcribed and/or translated from Swedish or Finnish to English.

Interview questions and answers

1. What is your general approach to using sea-based measures to address the release from internal nutrient sources? What are, in your view, the main benefits, risks and challenges?

CCB: Precautionary principle. Main benefits for the Baltic Sea in general unknown, maybe short term in enclosed coastal areas. Risks unknown for more large scaled measures. Unclear who should pay for "old sins" and unclear from political and technical point of view how the most affected areas should be dealt with.

BSAG: Considering the magnitude of the internal load, BSAG's view is that if we want to restore the ecological balance of the sea, we have to address the issue. The benefits are potentially very big, and the risks can be managed by careful planning and testing. The main risks concern hazardous substances. The costs (i.e. monetary, life quality, life in the sea, biodiversity etc) of non-action are and will be very high. The challenge is to design efficient funding mechanisms. But this, to be honest, is a matter of human priorities and (political) will.

Env. Ministry Latvia: We are cautious about the use of sea-based measures to address release of nutrients from internal sources. We think that terrestrial/ land-based measures are not exhausted yet to reduce nutrient inputs to the sea. Currently, there is not enough knowledge about nature and dynamics of internal nutrient reserves, as well as effects of sea-based measures. The precautionary principle, as laid down in Article 3 of the Helsinki Convention, should be observed. Effectiveness and effects of sea-based measures depend from method/ technology applied and location where it is applied, however, in general high risks to ecosystem and human health and unpredictable adverse environmental effects and transboundary effects can be expected. Possible negative impacts, such as release of hazardous substances and nutrients, all of which would further deteriorate the environmental status of the Baltic Sea, should be taken into account. Finding an appropriate, safe and marine environmentally friendly technology could be a challenging task. Application of sea-based measures certainly is extremely expensive exercise.

ELY: •Generally, sea-based measures may have potential in reducing internal nutrient reserves and release of nutrients in the sea, but before large-scale use, the feasibility and cost-effectiveness of different methods, and especially their possible harmful effects on the marine ecosystem, must be studied. It is important to keep in mind,

however, that reducing external nutrient load is the principal way to reduce eutrophication
•Main benefits: reducing of internal nutrient reserves/internal load and possibly, as a by-product, suitable material for fertilization and improvement for agricultural fields
•Main risks: technical problems in realization of measures, high costs, release of harmful substances from sediments either to water during the process or to fields, if the removed sediment will be spread over fields
•Main challenges: Technical problems in conducting the measures, to find suitable places in land where to relocate sediment in cases when the sediment is removed from the sea, to get financing for the measures, possible negative attitudes among public and interest groups

AVI: The layout of the question gives room for interpretations. As a permit authority we recognized three perspectives:
a) Permitting the (large-scale) measures for the rehabilitation of the Baltic Sea,
b) Taking account of the benefits of rehabilitation measures as compensation in permits or
c) the implementation of the rehabilitation measures developed in a project, as well as taking them into account in permit applications, and the developing needs of legislation guidance enabling the taking into account of such rehabilitation measures, so that matters can also be taken into account in the permit.

The permit authority will decide upon an application for a permit based on the framework of the legislation. Chapter 3, Section 2 of the Water Act (587/2011) defines the general permitting of the water resource management projects Section 3 the water resource management projects always requiring a permit.

Env. Ministry Finland: According to the Program of Measures of the Marine Strategy 2016-2020, the optimal protection of the Baltic Sea may in future include measures on internal mechanisms, but their benefits and disadvantages must be investigated before large-scale implementation. The study behind this survey is intended to provide more information on the benefits, risks and challenges of the methods in support of decision-making.

John Nurminen (phone interview): We have a project of our own, SeaBased, ongoing for the next three years. The discussion is polarized, the knowledge is scattered and not comparable. It should be possible to discuss on fact basis. The main focus should be in reducing the external load, but the foundation has done it for 13 years not and thousands of tons have been cut down, so now it’s starting to be the time to look at SBM. It remains open whether they are yet timely, and we want to clarify that during the SeaBased project. If some of the SBM would be feasible compared to the land-based measures when it comes to the risks, the costs and the effectiveness, we would be interested in carrying them out in the foundation. They start to be timely when “everything else” (in the reference of John Nurminens activitites and the Gulf of Finland) has been done, and we are starting to get close to that point. There is still a lot to be done in agriculture, so it cannot be said that everything would have been done on land, but the issues that can easily be affected as a foundation have almost been done. There is a need for discussion and science. A social and scientific consensus must be found.

Env. Ministry Sweden: We have for the first time this year allocated funding that is addressed to be used for projects to treat internal loading of phosphorus from lakes and coastal waters. The main benefit is that internal loading locally can be the major source of P causing eutrophication and that it is a cost-effective measure compared to many other measures. In lakes or coastal waters where the extra loading is significant, the main challenge is to address those sources so that the positive effects of the treatment of the internal loading will be persistent.

NEFCO: We are, in principle, supportive of such measures. Measures do, however, need to be carefully tested, progressively increased in size, as well as monitored.
-Main benefits: reducing the internal load which today is one of the largest sources of nutrients in the Baltic Sea and that strengthens the vicious circle created by algal blooms, anoxic bottoms and re-introduction of nutrients into the water column from bottom sediments. Other benefits include rehabilitating dead and anoxic bottoms, potential for circular economy activities (re-introducing nutrients where they are needed = on land) and improved understanding of the mechanisms affecting the Baltic Sea.
-Main risks: Re-introducing nutrients tied to bottom sediments to the water column (for example through uncontrolled dredging activities), unexpected/unknown trickle down effects.
-Main challenges: The scale of the problem, the size and depths of the Baltic Sea and extent of dead sea-floor. Funding the measures, who is responsible, what permits are needed and what is the authority/authorithies responsible are all additional challenges and questions to be addressed. Important to make sure that sea-based measures do not reduce the efforts and obligations to continue with land-based measures.

HaV: Sea-based measures against internal loads should only be taken if their positive effects can be expected to be long-term. In addition, the risks associated with the methods in question must be limited and held for review in e.g. an environmental court. Today's knowledge base makes it difficult to estimate the long-term impact of the measures (and thus also cost-effectiveness) and the extent of the risks they are associated with if they are implemented on a large scale. In addition, large-scale sea-based restoration measures have never been implemented and are therefore associated with major technical challenges. For these reasons, HaV believes that long-term effective measures against internal loads at present are only realistic in lakes and coastal waters with limited open sea water exchanges, where all reasonable measures have been taken to minimize the supply of nutrition from land-based sources.

Baltic Sea Center: a) In general, the potential of sea-based measures is strongly over estimated. There is no method of large-scale sea-based measure that is even close to be scientifically proven to work. A massive RTD (Research and Technology Development) effort would be necessary to develop a method and to perform an environmental impact assessment. Not only does the primary aim of reducing phosphorus concentrations need to be addressed, but also effects on the biogeochemisty and ecology of the system as a whole needs to be described. Our understanding of many of the components of the Baltic Sea system is still limited, not even the primary processes of phosphorus cycling is fully understood.

b) Small scale implementation of sea-based methods has in most cases insignificant benefit on the environment. Only exception might be very enclosed bays with past large local anthropogenic load, but these systems are quite rare in the Baltic Sea.

c) The Baltic Sea countries should focus on better management of natural resources, stop the excess nutrient use in agriculture and improve sewage treatment. This is necessary to overcome future challenges like phosphorus shortage and greenhouse gas emissions anyway.
d) Most recent research shows that the Baltic Sea has shifted from increasing phosphorus reserves to depleting them. This implies that given time (a few decades), conditions should improve and any additional reduction will add to that improvement.

V-S: It is important to look for solutions to make use of the nutrient stocks accumulated on the seabed, and in particular the fact that the internal load can be resolved in a controlled manner.
The most important benefit is to improve the ecological state of the Baltic Sea. Through the improvement of the state, the multiuse and also the economic exploitation of the sea is possible much more than today.The biggest risks are related to the environment. The release of nutrients or harmful substances accumulated in the bottom sediment in the sea when taking sea-based measures. The size of the seabed is a great challenge and difficulty, the scale of the renovation is staggering.
Benefits: Sea-based measures could support and develop the potential for Blue Ecosystem Services and so improve the possibilities for regional development. It could also improve the ecological state of the Sea which as such is prerequisite for sustainable economy and wellbeing.
Risks: Sea-based measures are new and not tested in large scale, so they may cause unforeseen effects and in the worst case even worsen the situation. On the other hand it is necessary to start seriously develop sea-based measures as we do not know if we have already reach the point when the vicious-cycle starts and can not be stopped without sea-based measures.
Challenges: Usually poor cost-effectiveness combined with unsure results is perhaps the main challenge.

2. What is the involvement of your organization in sea-based measures? (E.g. facilitator, operator, regulator, research, policy etc.)

CCB: Mainly policy

BSAG: Facilitator of research, policy and business; communication

Env. Ministry Latvia: None, except of policy and regulatory function.

ELY: VARELY is a coordinating ELY-Centre in implementing Marine Strategic Framework Directive (MSFD) in Finland, and has been centrally involved in drawing up of the Programme of measures of MSFD. In addition, VARELY is a partner in a project SEABASED (Seabased Measures in Baltic Sea Nutrient Management), which is going to pilot different measures to reduce internal nutrient reserves or the release of nutrients from bottom sediments

AVI: Permit authority

Env. Ministry Finland: Responsible Ministry in Finland

John Nurminen: We make projects ourselves, facilitator and operator. No financing to other's projects.

Env. Ministry Sweden: The potential tools we have are to implement different policy instruments including funding.

NEFCO: -NEFCO's role as a financial institution is to finance interesting projects with a positive environmental impact.
-We are looking for measures that are cost-efficient in respect to further nutrient reductions. This is an important criteria.

HaV: We are a central environmental authority responsible for the management of lakes, streams and sea including issues of conservation, restoration and sustainable use of these. Through the action programs in the water and marine environment management, we have inter alia responsibility for investigating opportunities and developing national guidance on internal load measures in lakes, coast and the sea. HaV also represents the public environmental interest in environmental trials in court (when permit is applied under the Environmental Code). We then participate in principally important trials.

Baltic Sea Center: Research.

V-S: As a policy organisation, collaborator, regional planner and developer.The Regional Council of Southwest Finland is involved (in its role) in many tasks related to the Baltic Sea / Archipelago Sea: As a regional development authority, a regional planner and a trustee, as well as a promoter of, for example, circular economy and resource wisdom solutions. The Council is involved, for example, in the Pro Archipelago Sea work and the Protection Fund for the Archipelago Sea. The Council makes the region's maritime spatial plan together with Satakunta Regional Council. The Council coordinates co-operation in national maritime spatial planning.

3. How should possible sea-based measures be taken into account in the marine spatial planning process? What limitations does MSP involve?

BSAG: This is an important issue. As a first step, MSP could designate areas suitable for testing and piloting. As the worst bottom areas of the whole sea (= those best suited for measures) are well mapped and characterized, MSP could designate these as areas to be used for large scale measures. This would a.o. include restrictions for other maritime activities.
I´m not exactly up-to-date on the issue but MSP as it is now might not take anoxic/hypoxic areas into account.

Env. Ministry Finland: Maritime spatial planning and the nature and content of the plan that is being created are still open questions that are currently being clarified among the responsible organisations for maritime spatial planning. Consequently, it cannot be said with certainty at this stage whether plans are to deal with measures concerning the seabed or the inner nutrient stores. At present, measures taken in the sea area are controlled by various sectoral acts and their permit procedures. The Land Use and Building Act is applied in the territorial waters.

V-S: The nutrients of internal load maintain or aggravate the ecological poor state of the sea and prevent sea-related activities and the development of the bio-economy. In other words, it is very important in the development of sea areas that methods can be found to improve the ecological status of the marine area.The formal MSP process is of a general scale and MSP may not be able to take into account very detailed measures.The VELMU process has produced a great deal of national information on the values of underwater marine life, and the work continues. It is also important to include this information in measures related to the restoration of the sea area and their development.

4. In which situations could sea-based measures, in your view, be implemented? (E.g. purpose: research or commercial; limitations: geographic or temporal; operating conditions etc.)

CCB: Still research and in enclosed lo coastal areas and with effects followed up by long term studies for possible negative and positive effects

BSAG: First, the main purpose of the measures is to restore one of the seas of our planet. The measures can then be implemented in other sea areas. Second, high quality purpose driven research is needed to gain the required knowledge of the complex chemistry and dynamics of the sediments. Third, the massive amounts of nutrients in the sediments should be recovered and re-used = the commercial aspect. As we learn more, the commercial activities might provide a sound financing for further research.

Env. Ministry Latvia: Sea-based measures could be applied for research purpose. Limitations in use of sea-based measures: geographic; ecological; operating conditions.

Varsinais-Suomi ELY: Sea-based measures could be implemented in situations and in geographical and local areas in which there exist plenty of nutrient-rich sediments causing nutrient release, implementation of sea-based measures would be cost-effective and the amount of external nutrient load from the catchment area has been reduced, and in which the measures would not have harmful effects on the sea ecosystem.

Env. Ministry Finland: The starting point is that the methods do not replace the reduction of external nutrient load. The report in question is intended to provide additional information on these issues. Research data and small-scale experimentation are needed before extensive methods are applied.

John Nurminen: The point of the SeaBased project is to make pilots locally in a small scale close to the shore and in closed bays, so the results cannot directly be applied in larger-scale projects. Wider international cooperation is needed before we can even think about anything larger. In the SeaBased project, the intention is to find out how local improvements can be done. Before bigger projects, for example in the Bornholm deep, more solid information must be at hand. The techniques are not ready yet for deep-see experiments. All experiments for now have been in lakes or close to the shore. Another question is the funding: Who would give so much money that the Bornholm deep could be oxygenated when there is no knowledge about the effectiveness, the risks and the effects on the ecosystem. Talking about this is still distant and daydreaming, irresponsible from the ecosystem point of view. An international EIA would be needed, that reality is far away, consent would be needed from all the states. The techniques have been started to develop particularly for the deeps, but it’s hard to say if we can get that far and if we can draw conclusions from the tests for the deeps. Everything must be researched and developed further, but we shall see if we ever get that far. Small steps must be taken first: how do the techniques work, and the ecological precautionary principle must be taken into account when we go further. No-one knows what happens if we start to do big things so that the physical etc. consequences are large-scaled. It’s unrealistic to talk about big projects, it must be seen first whether it works in smaller scale.

Env. Ministry Sweden: Our organisation has so far no clear strategy for implementing sea-based measures related to internal loading. However, for research purposes it is definitely supported. If it proves to be a vital measure to improve the situation in the Baltic Sea, our organization would certainly take it into consideration.

NEFCO: -We believe that both research and commercially driven projects could and should be piloted and demonstrated, and implemented. Measures would, however, need to be carefully monitored and consideration given to the premises, scale, operating conditions etc. of such projects. Sea-based measures should primarily focus on areas where anoxic conditions and dead-sea floor exist, as this would limit any potential negative effects and not affect living flora & fauna (=difficult to further destroy something already dead).
-Questions remain in respect to who should be the governing, authorizing, monitoring authority for measures affecting the Sea as a whole? Need for actions to be done in a coordinated fashion, either nationally or regionally, depending on the size, scope and location of projects.

HaV: In lakes and coastal areas with internal load problems where all reasonable measures have been taken to minimize the supply of nutrition from land-based sources. Under these conditions, both actions for research and commercial purposes (eg on behalf of a municipality) are possible. However, long-term monitoring of the results needs to be ensured. However, the above depends entirely on what kind of measure it is and if there are conditions for granting permit for this.

Baltic Sea Center: e) Possibly in limited areas where a local benefit on the environment can be proven in advance but these systems are quite rare in the Baltic Sea.

V-S: In the beginning, a strong public R & D effort is needed to bring about "system change or breakdown". Also, strong cooperation work between the environmental and permitting authorities is required. In the longer run, with proper permits, the measures could be developed into business.

5. There is uncertainty as to the environmental effectiveness of sea-based measures. How, in your view, should this uncertainty be dealt with, considering the risks involved with action and inaction, when deciding on sea-based measures?

CCB: No large scaled measures without a proper EIA and long term follow-up programme.

BSAG: If we want to restore the ecological balance of the sea, we have to take measures. The only way to get clarity is to perform high level science and to do small scale piloting in several areas using several different techniques (one technique/location of course). In all these activities, careful and accurate measuring of all required entities is required. Globally best available knowledge should be used and all kinds of cross-scientific efforts used (e.g. maining technology, space technology, oil drilling technology, military technology, all kinds submarine technologies etc).

Env. Ministry Latvia: First of all, there is a need for scientific research to assess the nature and dynamics of internal nutrient reserves, as already foreseen by the draft HELCOM Ministerial declaration of 2018, as well as assessment of possible effects on marine ecosystem and effectiveness of such measures, including cost-benefit analysis.

ELY: It is important that enough research on different sea-based measures will be conducted at least of following factors:
o which methods are suitable for which conditions
o what is cost-effectiveness of different measures in different conditions
o what are the risks and potential harmful effects of different measures

AVI: The conditions for granting a permit are defined in Chapter 3, Section 4 of the Water Act. According to subsection 2 of this section, the benefit of the project to public or private interests must be significant in relation to the loss of public or private interests.

Env. Ministry Finland: See the previous answer. Even risks of not doing anything must be recognized.

Env. Ministry Sweden: A thorough analysis is probably needed before implementing large-scale actions. Pilot projects could be realized before applying measures at a large scale to improve the knowledge about the costs and effects.

NEFCO: -Action should be taken. Only by testing and moving ahead can we get more certainty in respect to what actions are effective and which ones are not. Testing should take place, first on a smaller scale, but with technologies and solutions that are scalable.
-Unless action is taken, the risk of inaction is too great, as the internal load currently is one of the biggest challenges, and the only one lacking any type of action to address it.

HaV: Through continued research on phosphorus flows in the Baltic Sea (including effects of sediment biogeochemistry) and the potential and effects of measures. This also includes the effect on higher trophic levels in the ecosystem. Measures should therefore primarily be carried out in well-restricted areas where internal loads constitute a dominant source of nutrition, provided that other conditions enable this and there is no competing environmental interest that is harmed. In addition, the long-term effects need to be evaluated, which means that it is important to follow up for a long time after the implementation of the measures.

Baltic Sea Center: The efficiency needs to be proven and detrimental effects needs to be constrained before any implementation. This is especially important since local implementations might be considered by local stakeholders/officials without appropriate knowledge for critical evaluation. There are numerous examples from around the world of measures for lake restoration with questionable performance sold by companies to various regional and local authorities.

V-S: It requires open cooperation with environmental experts (SYKE, LUKE, ELYs and higher education institutions). Certain risks must also be accepted in order for the trials to be possible, but it is good to note and decide upon rules for the risk together.

6. If sea-based measures were developed, in the short-term, as measures against eutrophication in the Baltic Sea, who, in your view, should be in charge and assume responsibility (and financial liability) for the operation?

CCB: Must be at state level and if large scaled agreed by other Baltic states or /and HELCOM. Well who should pay mil-lions for something that might have no or negative effects that is the question!

BSAG: The simple answer is: all the states surrounding the Baltic Sea. This in turn, equals HELCOM.
HELCOM, on the other hand does not have the instruments or mandate to manage this large scale and long term operation. A special purpose body must probably be designed, having both a strong political and financial mandate. Different private constellations could be foreseen but are not likely to take the full responsibility for the whole sea. The political responsibility should lay at HELCOM, an upgraded version of HELCOM. New Environmental Impact Financing/Bonds might be the solution for the funding.
Overall, the whole operation might not be possible without an honest and quite dramatic paradigm shift in the way society sees and values our living conditions (the so called Environment)

Env. Ministry Latvia: State should take both political responsibility and financial liability.

Env. Ministry Finland: The operator getting the permit has the responsibility.

John Nurminen: Environmental permit process is needed in all activities, even in small-scaled, and that creates the responsibility of the authority. The operators and the projects must be responsible too. Cooperation between the authorities is important. If there are operators with an economic interest, it is not sure if the ecological risks are thought through, so it requires a lot of responsibility and honesty. The authority must have the big picture.

Env. Ministry Sweden: One option is that Helcom would be in charge since it deals with improving the environment of the Baltic Sea and involves all affected countries.

NEFCO: -Primary responsibility is on the project owner.
-Responsibility also on the parties having caused the problem (riparian countries). The external costs (externalities) of pollution should be incorporated on entities, industries,

nations that are the source of the problems (Polluter-pays principle), however so that sea-based measures would not reduce or affect obligations and efforts on land-based measures.
-Also a need to look at the potential opportunities that exist as part of Sea-based measures. This is a way to attract further interest from private and public entities alike.

V-S: Ministry for Agriculture and Forestry and Environmental Ministry finance and decide upon the measures together. SYKE/LUKE/ELY are in cooperation. The operator is likely to be a business with expertise on dredging etc.

7. Assuming that sea-based measures would be more common in the future: How should the regulation for such measures be designed when it comes to rights, duties and liability of different actors and the permit process? What mechanisms/procedures are, in your view, most important for ensuring that sea-based measures are properly governed?

CCB: Helsinki Convention and its fundamental principles (including unanimity decision by all Baltic States and EU).

BSAG: The legal parts of the process can be solved, we believe. The overall regulation and governance must lay at HELCOM or a “more legal and regulatory HELCOM”. A new division of HELCOM?
All this requires a much stronger mandate for HELCOM.
The national and international laws that would cover all the aspects of sea based measures should be compiled and analysed. And then streamlined for best performance, as needed.

Env. Ministry Latvia: Rights, duties and liability of different actors and the permit process should be prescribed by law. EIA procedure, including in a transboundary context (Espoo convention), cumulative impacts assessment and risk assessment should be carried out; maritime spatial plans should be observed.

ELY: First question: ?
Second question: First, a coordinated map/plan of possible areas where sea-based measures in a sea-area would be reasonable, should be compiled. This should be organized by national or regional administration. Before implementation should all planned measures go through a permit process (at least most sea-based measures would need a permission nowadays). Or should the permit process be easier than nowadays?

AVI: The current policy has been working. The cross-border environmental impact assessment is regulated by the so-called Espoo Convention. The Convention States have the right to participate in an ongoing EIA or SOVA (EIA for plans and programs) in another country if the environmental impact of the project, plan or program affect that State. However, permits are granted under the laws of each country, taking into account both interstate and international agreements.

Env. Ministry Finland: The aim of the study at hand is to provide more information even about this for the discussion between the Baltic Sea states.

John Nurminen: there is no legislation for SBM, common procedures and processes should be made if we want to promote them. Now, permits for pilots are being given in Finland and Sweden, and it is possible to learn from them and create guidance. The permit practices must be coherent and the potential problems must be thought through. It's hard to know what all must be taken into account. In the last resort, it comes down to the authority's competence and ability to review the permit application. It has been noted in the planning issues that if there is a lack of competence it is unreasonable to demand that the individual/operator would take everything into consideration.

Env. Ministry Sweden: If there would be a consensus (in for example Helcom) that such measures are beneficial, the financing issue would be one of the key questions. To find a model for the funding would be a process that needs to be agreed upon between the involved parties.

NEFCO: -Project owner / national / regional…
-Transparency and real-time & continuous monitoring

Baltic Sea Center: Sea-based measured shoud not be applied as a substitute for land based measures but a complement, if at all. Land based measures must be done first. No sea-based measures unless an EIA is done.

V-S: The permit process requires multidisciplinary know-how because the measure is brand new but also risky. As a measure, the development of the permit process could be a pilot project, as was the permit process at the Äänekoski biotech plant.

8. If sea-based measures should be taken more-large scale – Who, in your opinion, need to be involved (states, national authorities, regional authorities etc.) and who else can promote measures? Do you see a role for private businesses or foundations in these activities?

CCB: See above private foundations are already involved as donors in same cases. Private business most likely not as there seems to be almost impossible to make this profitable (unless subsidised

BSAG: Most of the answers are above. BSAG sees a strong role for private or state business in the process. But this requires a strong and transparent legislation. And a truly common will.

Env. Ministry Latvia: First of all, states, national authorities and regional authorities (e.g., HELCOM), scientific institutions should be involved. There could be a role for private businesses or foundations, as well (both from technological development and financing point of view).

ELY: National and regional authorities need to be involved e.g. in estimating feasibility of different measures and preparing statements to a authorizing body. Private companies would be appropriate to realize the measurements. Private foundations might be involved as well, e.g. pilot studies and in planning and mapping suitable / feasible sites for measures

AVI: The legislation defines the competent authority.

Env. Ministry Finland: States and national authorities in accordance with the applicable international agreements and national laws. HELCOM is an important political platform. Private companies and foundations can play a role, for example, as technology developers, operatives, circular economy operators and financiers.

NEFCO: -States, national and regional authorities would need to be involved (which one will depend on the location and scale of the projects). We do also see a role for private business and foundations in these activities, as they often are more pro-active and able to operate, finance and take action quicker and in a more versatile way than governmental bodies.

Baltic Sea Center: No opinion but as stated earlier – There is no method of large-scale sea-based measure that is even close to be scientifically proven to work. So therefore, large scale sea based measures should not be counted on for saving the Baltic Sea.

V-S: Permit and environment authorities, ministries, regional councils, Metsähallitus. The operator is likely to be a private company.

9. How do you view the fact that sea-based measures mainly address phosphorus but not nitrogen?

CCB: N is not a major issue as such as P is the key nutrient for solving eutrophication problem in the Baltic

BSAG: This might be related to the fact that the P-chemistry is partly better understood. Also, since nitrogen is always provided from the atmosphere, regardless of human activities, the two elements have different roles in the eutrophication process.
Both must of course be addressed. But this question is probably one of the first ones to put to the scientific community.

Env. Ministry Latvia: Some research suggests that internal leakage of phosphorus is three times larger than leakage from land into the Baltic Sea. Phosphorus is a limited, non-renewable natural resource and therefore retrieval and recycling of phosphorus could be beneficial not only from the environmental point of view but also profitable from economic point of view.

ELY: Dynamics of phosphorus and nitrogen in water ecosystem is different. Phosphorus stays in sediment or water, but nitrogen is more mobile and can be released to atmosphere via microbial denitrification or be fixed into water by nitrogen-fixing cyanobacteria. Internal nutrient reserves and internal load concerns thus especially phosphorus. However, if bottom sediment is removed, in addition to phosphorus, also certain amount of nitrogen is removed.

AVI: Nitrogen and its reduction should also be taken into account better in the projects. However, a case-by-case consideration should be remained depending on the projects and their location.

Env. Ministry Finland: The role of phosphorus as a reducing natural resource is more important, but also the role of nitrogen, as well as of phosphorous binders, in the nutrient cycle processes must be clarified.

John Nurminen: The circulation of nitrogen is different in the sea, and that's why the SBM mainly address phosphorus. Nitrogen evaporates into the atmosphere. Phosphorus is also more essential for bluegreen algae blooming. In treatment fishing and when removing biomasses, both are removed. But phosphorus plays a bigger role, so it's natural to mainly address it.

Env. Ministry Sweden: If P is the main problem it should only address P, otherwise it should also address N. Should it also address Fe?

NEFCO: -Sea-based measures are, naturally, not the only measures that need to be taken. It is, however, the one challenge that today is lacking corrective action altogether. As phosphorous is a driving factor for the negative state of the Baltic Sea, actions should not be hampered because they would only address phosphorous but not nitrogen.

HaV: It is reasonable considering the conditions in the Baltic Sea.

Baltic Sea Center: Before any implementation the full ecosystem perspective must be taken in the proof that the method works and in the EIA. Nitrogen cannot be neglected because of its controlling impact on the ecosystem dynamics.

V-S: It does not matter as P is the limiting factor for algae mass blooming in Baltic Sea.

10. FOR RELEVANT AUTHORITIES: The state normally owns the seabed (continental shelf) and waters in the Exclusive Economic Zone and in (parts of) the territorial sea. Do you see a reason for distinguishing between the policies and approval processes that apply in different maritime zones? Please explain.

Env. Ministry Latvia: Without prejudice to UNCLOS, regulations could differ from country to country. E.g., different regulations can be for use of coastal waters and (parts of) territorial sea. In Latvia rights of the State, as well as rights and obligations for use of the sea are prescribed by the Marine Environment Protection and Management Law. Before the Cabinet issues a permit or licence for use of the sea, it shall, upon an order in each case, determine a certain territory of the sea (the permit or licence area in the sea) for the performance of the activities, by taking into account the conditions provided for maritime spatial planning and the maritime spatial plan.

AVI: The territorial waters and the economic zone and the competent authorities are defined in Chapter 1, Section 4 of the Water Act and in the Act on the Limits of Finnish Territorials (463/1956) and the Law on the Finnish EEZ (1058/2004). The need for change in legislation is not seen.

Env. Ministry Finland: To the full extent of the state, only the territorial waters of the state (external territorial waters = territorial seas) are included. However, states have jurisdiction over both their territorial waters and their exclusive economic zone, in the exclusive economic zone much less than in territorial waters. Legislation applicable in the economic zone is defined in the EEZ.

With regard to the various permit procedures in different maritime areas, they are at least partly a consequence of the provisions of the Convention on the Law of the Sea (UNCLOS). For example, planning legislation is not suitable for the economic zone (instead, the provisions of the Land Use and Building Act for maritime spatial planning are applicable). The exclusive economic zone is also not the municipality's territory as the territorial waters are. It is therefore natural that, in certain respects, the permit legislation differs depending on whether the territorial waters or the exclusive economic zone are spoken about.

Env. Ministry Sweden: This is mayde a question for a lawyer. It might be necessary to distinguish between national and international regulation depending on where the measures are implemented. However, this is a topic where guidance (e.g. developed under the Helcom umbrella) probably would be helpful.

Other comments:

CCB: EU is also of importance as most states around the sea are EU states and as such under the relevant EU directives.
CCB also keeps the same stand as expressed in a joint position with WWF.
In addition, please have a look at a Policy Brief on the matter developed by the Balti Eye, Stockholm University.