

ATLAS OF OVEREXPLOITED TERRITORIES

BAŁTYK

SEA

BAŁTYK SEA MASTER THESIS

ECOLE POLYTECHNIQUE
FÉDÉRALE DE LAUSANNE

ATLAS OF OVEREXPLOITED TERRITORIES
BAŁTYK SEA

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← *COVER* *ARCHIPELAGO SEA* (GIS data from Landsat 8, 2014)

All maps are presented on **1**:**8**,**500**,**000** scale

This research aims at an objective understanding of the overexploitation of the Baltic Sea drainage basin

It describes the geomorphological and physical actions taking place in this highly crowded and disputed sea

and questions the impact industries and infrastructural development have on this wide geopolitical space

BAŁTYK
SEA

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FOREWORD

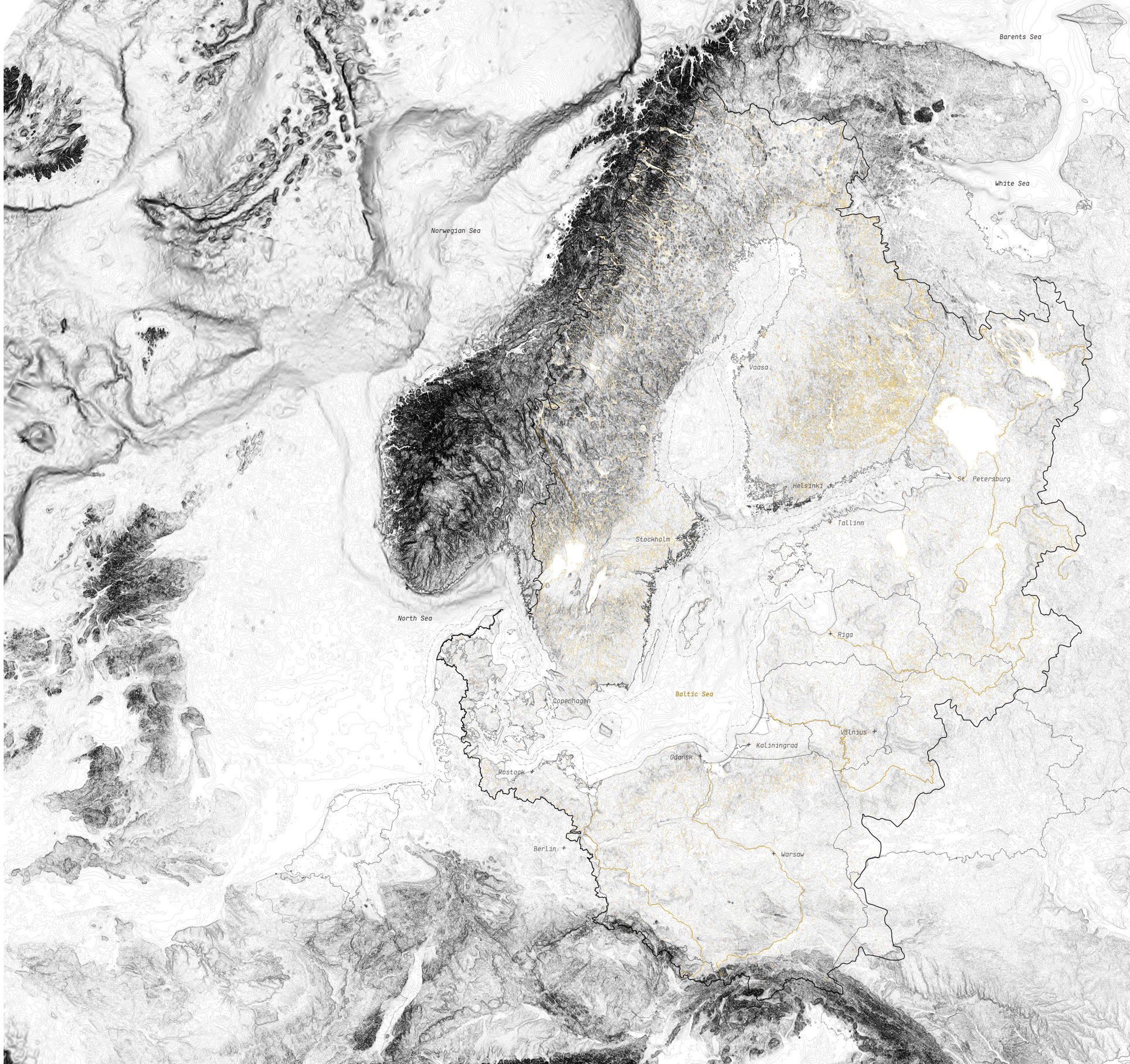
THE BALTIC SEA BASIN COVERS 15% OF ALL EUROPE. ACCOUNTS FOR A LARGE PART OF NORTHERN EUROPE, INCLUDES 14 COUNTRIES, AND HAS A POPULATION OF ABOUT 85 MILLION. IT IS AN AREA WHERE EAST MEETS WEST AND NORTH MEETS SOUTH

BAŁTYK SEA
FOREWORD

	North Sea	Baltic Sea	Barents Sea
Dimensions			
↘ Length	960	1,601 km	1,300
↘ Width	580	193 km	1,080
↘ Depth			
↘ Mean	95	54 m	230
↘ Maximum	700	459 m	500
↘ Volume	94,000	21,205 km³	282,000
Surfaces			
↘ Drainage basin	750,000	329,978 km²	1,405,000
↘ Sea area	850,000	1,633,290 km²	1,464,550
Climate			
↘ Salinity			
↘ Mean	34	7.4 ‰	35
↘ Range	34-35	0-32 ‰	25-35
↘ Temperature			
↘ Average in summer	17	17 °C	10
↘ Average in winter	6	-10 °C	-20
↘ Ice cover			
↘ Annual ice extent	-	12,5-100 %	0-45
↘ Annual ice season	-	5-7 months	5-6
↘ Water renewal	-	50 years	6
Context			
↘ Borders			
↘ Coastal countries	7	9	2
↘ Countries in basin	7	14	3
↘ Population in basin	185,000,000	85,000,000	1,464,550

↑ *FIG.1* ***NORTH ATLANTIC SEAS*** (Data from Wikipedia, 2015)
Comparison of major northern seas

MAP.1 (GIS data from HELCOM, EMODnet) →



BAŁTYK SEA
FOREWORD

SOCIAL FACTS

BELARUS
- → AREA: 207,600 Km²
- → POPULATION: 9,500,000, MINSK 1,900,000
- → GDP PER CAPITA: US$ 8,711 (2015)
- → *BALTYJSKAJE MORA*

CZECH REPUBLIC
- → AREA: 78,864 Km²
- → POPULATION: 10,500,000, PRAGUE 1,300,000
- → GDP PER CAPITA: US$ 17,171 (2015)
- → *BALTSKÉ MOŘE*

DENMARK
- → AREA: 43,094 Km²
- → POPULATION: 5,700,000, COPENHAGEN 569,557
- → GDP PER CAPITA: US$ 52,822 (2014)
- → *ØSTERSØEN*

ESTONIA
- → AREA: 45,200 Km²
- → POPULATION: 1,300,000, TALLINN 428,000
- → GDP PER CAPITA: US$ 17,561 (2015)
- → *LÄÄNEMERI*

FINLAND
- → AREA: 338,000 Km²
- → POPULATION: 5,500,000, HELSINKI 601,035
- → GDP PER CAPITA: US$ 42,732 (2015)
- → *ITÄMERI*

GERMANY
- → AREA: 357,168 Km²
- → POPULATION: 81,100,000, BERLIN 3,500,000
- → GDP PER CAPITA: US$ 41,955 (2015)
- → *OSTSEE*

LATVIA
- → AREA: 64,600 Km²
- → POPULATION: 1,900,000, RIGA 727,800
- → GDP PER CAPITA: US$ 16,836 (2015)
- → *BALTIJAS JURA*

LITHUANIA
- → AREA: 65,300 Km²
- → POPULATION: 2,900,000, VILNIUS 554,192
- → GDP PER CAPITA: US$ 14,560 (2015)
- → *BALTIJOS JURA*

NORWAY
- → AREA: 386,280 Km²
- → POPULATION: 5,200,000, OSLO 623,966
- → GDP PER CAPITA: US$ 80,749 (2015)
- → *ØSTERSJØEN*

POLAND
- → AREA: 312,685 Km²
- → POPULATION: 38,500,000, WARSAW 1,700,000
- → GDP PER CAPITA: US$ 12,920 (2015)
- → *MORZE BAŁTYCKIE*

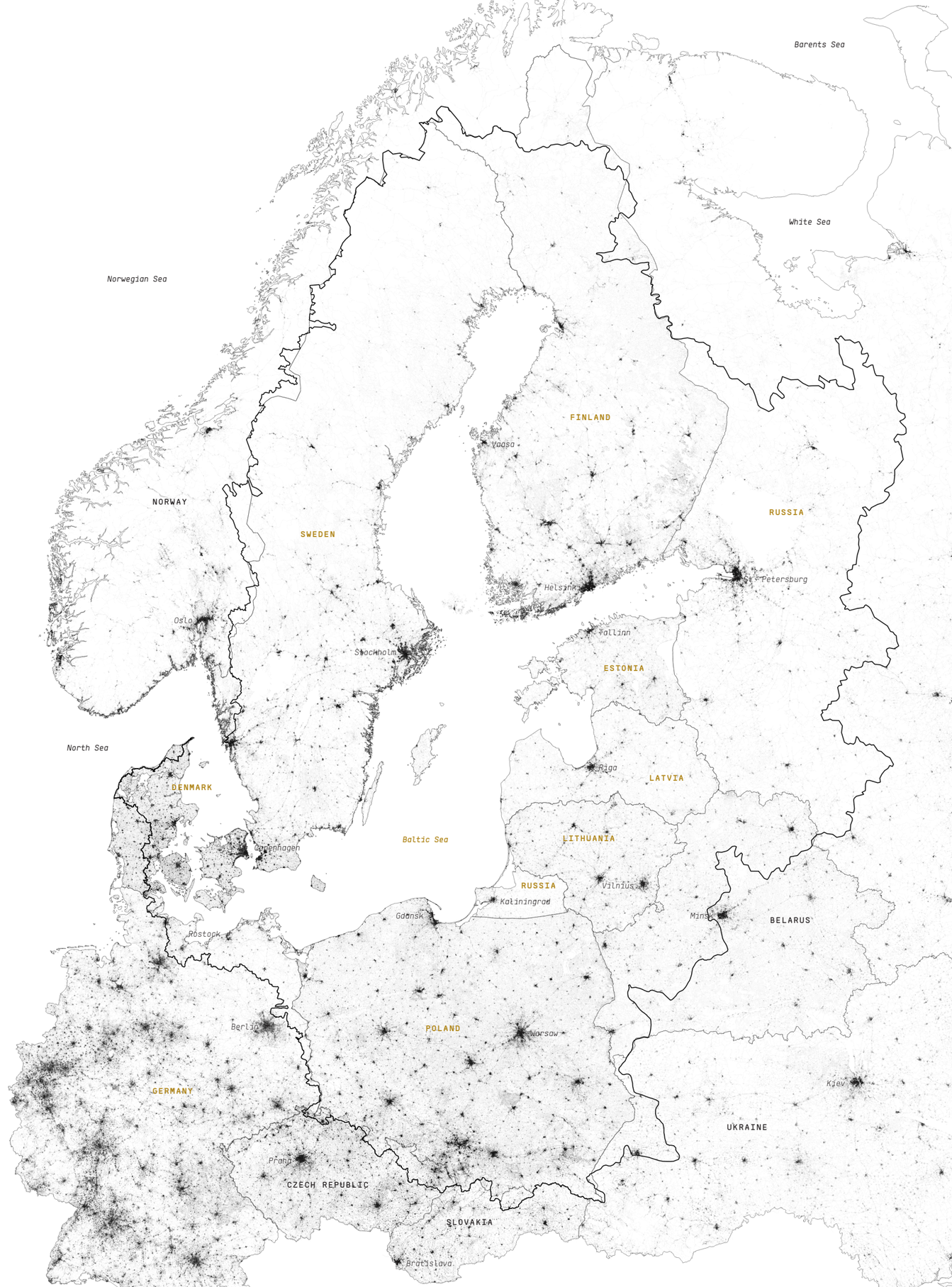
RUSSIA
- → AREA: 17,075,200 Km²
- → POPULATION: 143,900,000, MOSCOW 12,200,000
- → GDP PER CAPITA: US$ 8,184 (2015)
- → *BALTIYSKOYE MORYE*

SLOVAKIA
- → AREA: 49,036 Km²
- → POPULATION: 5,400,000, BRATISLAVA 491,061
- → GDP PER CAPITA: US$ 16,138 (2015)
- → *BALTSKÉ MORE*

SWEDEN
- → AREA: 449,964 Km²
- → POPULATION: 9,800,000, STOCKHOLM 917,297
- → GDP PER CAPITA: US$ 49,582 (2015)
- → *ÖSTERSJÖNH*

UKRAINE
- → AREA: 603,700 Km²
- → POPULATION: 44,400,000, KIEV 2,800,000
- → GDP PER CAPITA: US$ 2,001 (2015)
- → *BALTIYS`KYY*

MAP.2 (GIS data from HELCOM, GEOFABRIK) →



BAŁTYK
SEA
FOREWORD

A MANUFACTURED LANDSCAPE

↓ TERRITORY

The Baltic Sea is a rapidly changing environment that can be perceived as a manufactured landscape. European seas in general have experienced and witnessed the effects of intense human activities all along their existence, often affecting their fragile ecological system in irreversible ways.

The Baltic Sea reassembles multiple layers of exchange, being maritime traffic, underwater gazoducs or cables and dense shipping routes. This intensification process results in an overexploitation of resources and growing extra-territorial claims. It echoes the unprecedented land grab play in action in the Arctic region, where nations are today contesting claims for sovereignty and where the intricacies of deep-sea microbiology and geology resonate at a geopolitical scale.

"The European peninsula is a vast stretch of land shaped by two parallel systems of seas: to the north, an increasing exploitation of mineral and natural resources are undermining the links between sovereignty and the spaces of a growing number of non-state actors. Change in the North Atlantic, the North Sea, the Barents Sea, the White Sea and in the Baltic are realigning the territorial forms of the higher latitudes, moving towards new interconnections and new expert knowledge. These escalatory processes are not only shaping the inhabited spaces and infrastructures but also impacting a wide geopolitical space. Change in this part of Europe is explored as a set of complex interactions between multiple actors, processes and practices."[1]

These territorial claims are directly observable through the growing military activity in the region in addition to the already saturated shipping density. Conflicts are inscribed not only around natural resources but also on the approach executed by different countries in order to handle the question of preservation.

National interests and economical situation are seemingly different and tensions are palpable on these thematics. Two main frameworks or categories oppose each other : on one hand the conflict between aesthetic preservation of the sublime and picturesque landscape and the research of a techno-infrastructural effciency on the other. These approaches materialize the confrontation of two cultures or ideals of society : it marks the limit between the East and the West.

↓ CARTOGRAPHY

Cartography will be be used throughout this research as a medium to depict specific geographical forms, complex informations and data and provide a reading of a continuously changing reality. In this context, a transboundary landscape analysis is needed to evaluate the current overexploitation of the Baltic Sea and investigate the complex and shifting relation between the reshaping of international or supranational influence on the region and forms of the inhabited territories.

"As a resource, territory opens up the possibility to exploit. Comprehensively with mines and fields as well as indirectly with people and their skills. Just like nature, space gradually loses part of its former vital dimension, in order to become fully measurable, quantifiable and exploitable. Territory is from the start inseparable from practices such as survey and cartography that were meant to provide a panoptic overview of what is available, in what quantity and where."[2]

"Is there a degree of control that allows both territorial forces, landform dynamism and human activity to coexist?"[3] Can approaches to territory with changing nature be based on conventional rules of border ? We intend to question the representation and the role cartography can play as a medium of expression of a reality. In this research, maps will describe the changes the Baltic Sea faced in the post-socialist era in terms of economy, infrastructural development as well as geopolitical influence.

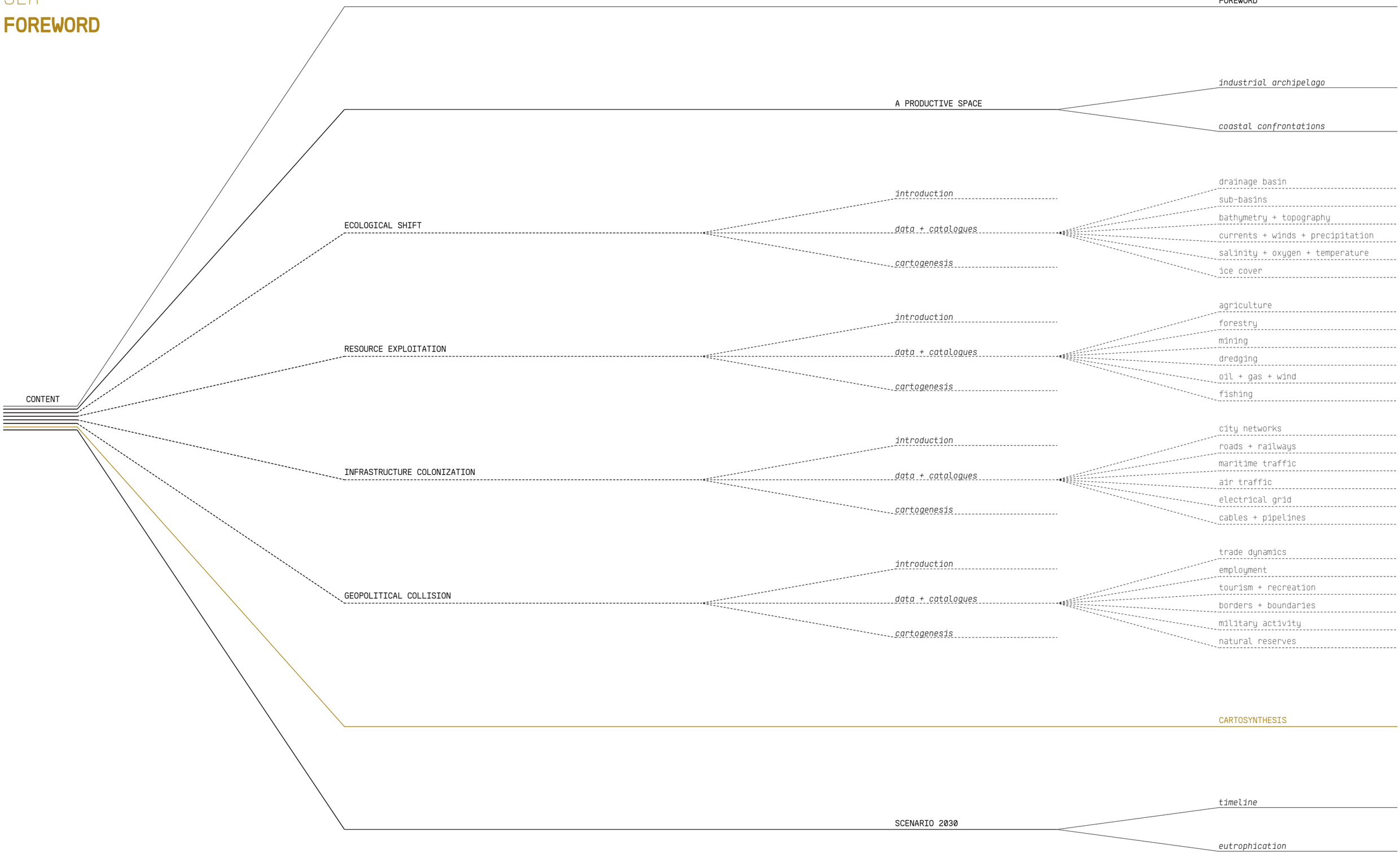
Therefore from a landscape urbanism perspective the project advances possible guidelines which from the Baltic scale to the Europe one engage the ordinary layout in order to deal with the consistent challenges sea territories are passively suffering. The goal is to present a comprehensive view on the Baltic Sea problematic, in order to propose a base for the development of a project in the region.



IMG.1 ORMONDE WIND FARM, IRISH SEA (Photo from Vattenfall) →

BAŁTYK
SEA
FOREWORD

METHOD +
STRUCTURE



BAŁTYK
SEA
FOREWORD

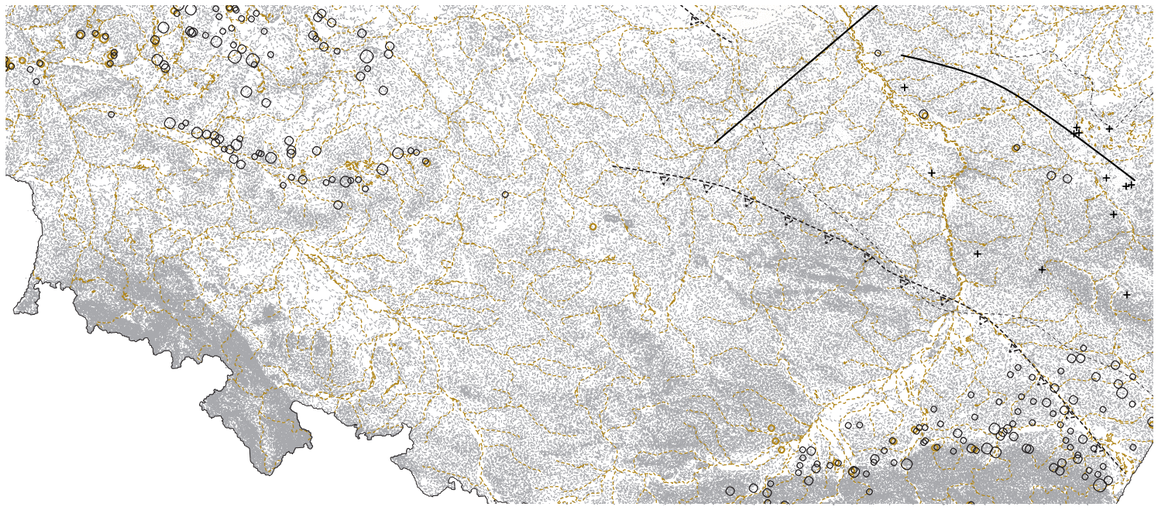
→ INTRODUCTION

- ↘ main problematic
- ↘ characteristic
- ↘ key facts
- ↘ abstraction
- ↘ snapshot
- ↘ landscape
- ↘ aesthetics
- ↘ intentions
- ↘ framing



→ DATA + CATALOGUES

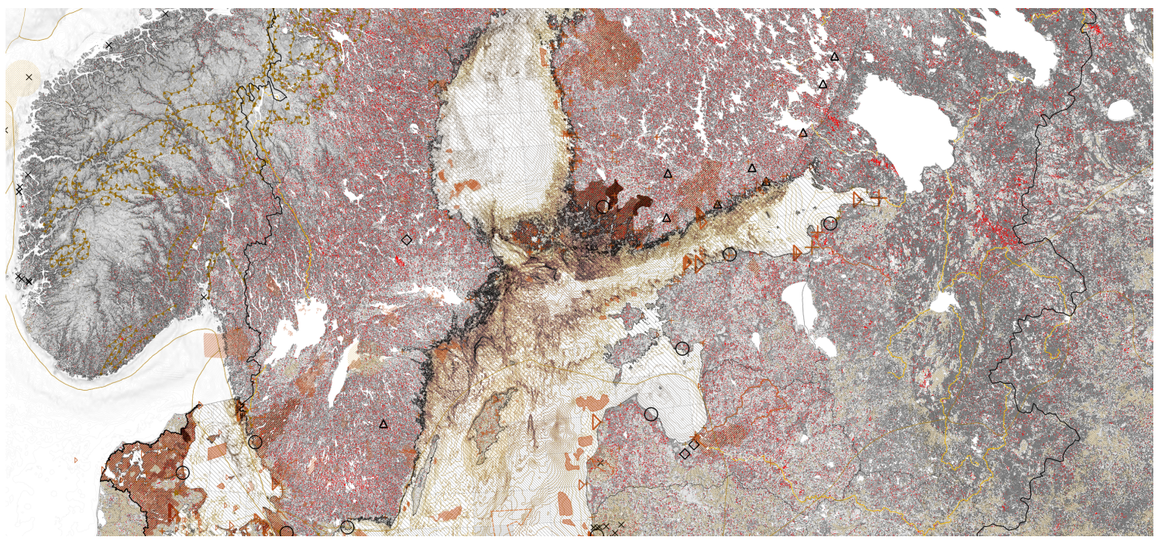
- ↘ classification of systems
- ↘ territorial actors
- ↘ facts and figures
- ↘ specific conditions
- ↘ land formation
- ↘ territorial simulation
- ↘ diagram of transformation
- ↘ regional evolution
- ↘ technical data



→ CARTOGENESIS*

*AALU. LANDSCAPE URBANISM

- ↘ image of the territory
- ↘ system of relations and consequences
- ↘ territorial understanding
- ↘ highlight of specific problematics
- ↘ production of an imaginary
- ↘ spatial construction
- ↘ systems and objects
- ↘ selection and omission
- ↘ reading the real



All maps are presented on **1:8,500,000** scale →

A PRODUCTIVE SPACE

THE BALTIC SEA CONTAINS MULTIPLE LAYERS OF EXCHANGE. IT OVERLAPS IMPORTANT MARITIME TRAFFIC, UNDERWATER GAZODUCS, CABLES, PIPELINES, WIND FARMS AND OFFSHORE PLATFORMS

BAŁTYK
SEA
A PRODUCTIVE SPACE

INDUSTRIAL
ARCHIPELAGO

↓ TOWARDS A NEW URBAN

During the last decades, urban studies have seen important shifts of ideas and concepts as new ideas regarding the role and the definition of cities, and urbanism more generally have been raised. But some concepts are still anchored and grounded in the field. Urbanisation still continues to be a representation or mapping of human settlements and metropolitan areas. This approach was more plausible in the late nineteenth and early twentieth centuries than nowadays. The second wave of industrialisation that came during this period of time has seen large-scale industrial city-regions and suburban areas appear all around the world and was followed by a clear distinction between these major demographic concentrations and the countryside. Classical dichotomies that followed in the twentieth-century urban studies were always grounded on the idea that there was a geographical contrast between both *urban* life and its opposite the *rural*. These assumption that there is a clear separation between the non-urban and cities or, later, *conurbations*, *city-regions*, *urban-regions*, *metropolitan regions* and *global city-regions* was still present among urban theorists during the twentieth-century.[1]

The demarcations separating the nature of *urban*, *sub-urban* and *rural* spaces has remained quite distinct and universal while its definition has alway been changing. The precise nature of cities has been object to numerous different qualification while the *non-urban* realm has always been considered as an *outside* of the *non-urban*. However, this concept is now being redefined and new forms of urbanisation have radically requestioned this urban theory.[2]

"The urban can no longer be understood with reference to a particular "type" of settlement space, whether defined as a city, a city-region, a metropolis, a metropolitan region, a megalopolis, an edge city, or otherwise. Consequently, despite its continued pervasiveness in scholarly and political discourse, the category of the "city" has today become obsolete as an analytical social science tool. Correspondingly, it is no longer plausible to characterise the differences between densely agglomerated zones and the less densely settled zones of a region, a national territory, a continent, or the globe through the inherited urban/rural (or urban/non-urban) distinction. Today, the urban represents an increasingly worldwide condition in which political-economic relations are enmeshed. [...]

This situation of planetary urbanisation means, paradoxically, that even spaces that lie well beyond the traditional city cores and suburban peripheries—from transoceanic shipping lanes, transcontinental highway and railway networks, and worldwide communications infrastructures to alpine and coastal tourist enclaves, "nature" parks, offshore financial centres, agro-industrial catchment zones and erstwhile "natural" spaces such as the world's oceans, deserts, jungles, mountain ranges, tundra, and atmosphere—have become integral parts of the worldwide urban fabric. While the process of agglomeration remains essential to the production of this new worldwide topography, political-economic spaces can no longer be treated as if they were composed of discrete, distinct, and universal "types" of settlement."[3] (Brenner, 2012)

The disintegration of the concept of *hinterland* as an area behind a coast, often referred as the rural area that is tied to the urban catchment of metropolitan areas or agglomerations is part of this shift. This area is now being *functionalised* whether as agro-industrial land-use systems, recreational zones, energy generation grids, resource extraction areas, waste disposal areas or corridors of connectivity that support the expansion of industrial urbanisation is now fully associated with planetary urban networks. This also means the end of the *wilderness* or *nature* as an opposite of the *urban* or *artificial*. All paces are being transformed and degraded through human actions and worldwide urbanisation. In this sense, world's oceans, seas, alpine regions, major desert and the arctic and the atmosphere itself are interconnected with the rhythms of planetary urbanisation at all scales, from the local, regional to the global. The image of the *non-urban*, in our epoch, needs to be fundamentally reinvented.

Are we now in an era of a *complete urbanisation of society* as Henri Lefebvre put radically some four decades ago ?[4] A new conceptual lexicon must be created or adapted to be able to fully comprehend the interrelation between concentrated agglomerations and their *extended operational landscapes* or *hinterlands*.

↓ URBAN CONSTELLATIONS

The concept of constellation linked to urban studies is related to Walter Benjamin's use of the term as a way to combine apparently disparate elements into an intelligible scheme.[5] But this pattern is also clearly recognisable in the forms that urbanisation is taking in most metropolitan areas. This metaphor of the constellation related to the idea of the urban that goes beyond the city as a bonded and limited entity. As we have seen previously, urbanisation has to be taken on a different perspective than this of the dichotomy between urban-rural areas, cultural, political, technological and ecological impacts of urbanisation extend to the most remote regions of the world nowadays. The Baltic Sea region is no different than the rest of the world in this sense and the sea that is usually associated with a physical obstacle is, in this new perspective, seen as a new potential of urbanisation if not already urbanised. The many immaterial flows of materials and people is, in a way, already part of that urbanisation process. More and more oil and gas platforms are appearing in form of floating structures, wind farms colonise entire portions of the sea and this trend is expected to continue to grow. This new context in constant change is drastically shaping the territory, and what was for long a boundary is now a space of opportunities.

"The world is spread over the entire surface of the earth, from one pole to the other including these poles themselves, a world made of quarries and mines, or gigantic powers of production, of gigantic means of circulation and of transport. From quarries, mines or other sources of primary materials to this consummation of products, which will be an act of intelligent distribution, life will be born creating inhabited places, punctuating the surface of the earth, places of transformation of primary or secondary material into consumer goods [...] In the first machinist stage, they were dispersed everywhere perpetrating the mess that exists. It will be more worthwhile, seeing that a century and a half of experience yields us the lesson to force ourselves to discover the principle."[6] (Katsikis, 2014)

Every condition or process of urbanisation is inherently geographical. Human occupation is anchored, but not limited to, a pattern of dense agglomerations but this is now also being requestioned. Spatial relations and opportunities of development are not only - anymore - connected to existing structures. Rapid development in infrastructure, new resources exploration techniques open new territories to opportunities of industrialisation. This idea that emphasises on the extensive transformation in land use and infrastructure systems that include agricultural production, forestry transportation, irrigation infrastructures is not anymore limited to the densely built areas. The sea itself has become a densely used and lived environment and is highly connected to on-shore structures. Are we therefore tending towards an inevitable future condition of complete urbanisation ? Or are these new uses and densities only part of an industrialisation process ?

This flow of both energy, material and population exchange that is taking place in and around the Baltic Sea is one of the new forms of urbanisation that results in a diffuse agglomeration pattern with a dense mesh of infrastructural networks that is as an example of urban metabolism. It suggests an analytical basis for estimating and understanding all these different flows between cities and their *extensive operational landscapes*. *"Metabolic approaches to urbanisation promise to interweave these diverse locational contexts, allowing the investigation of the interactions among social and ecological processes in the production of urban environments, and potentially enabling designers to address a broad array of processes operating at multiple spatial scales."*[7] (Ibanez, Katsikis, 2014)

The Baltic Sea, with its growing maritime traffic, cables and pipelines is a rapidly changing environment where multiple layers interract to create this dense network. New urbanisation opportunities emerge from this perspective shift and it enables the sea to be seen as both a productive space (*hinterland)* and at the same time a possible space for settlement and infrastructure development. But with the expansion of urbanised regions and the densifiying mesh of connectivity and infrastructure, it also faces a series of distinctive and rather splintered urban fabrics. This new urban constellation, or metaphorically speaking *archipelago* formed by an extensive group of industrial *islands* represents the new forms of urbanisation that take place in territories that were until now considered *natural* and *untouched*.

BAŁTYK SEA
A PRODUCTIVE SPACE

When it comes to boundaries, water knows few : an offshore area is always connected to its surroundings or more precisely to its drainage basin. This connection is made where land meets water, river meets sea, a space which has always attracted human settlements : the coastal zone. On this planet, the sea represents a source of life, of food, of energy, of commerce and sometimes of amusement. Used as a highway for international trade, as a playground for tourists and locals alike, as a home for unique ecosystems and people, its water, waves, and wind are all of great interest.

In the past few years, there has been growing awareness among European countries that the seas offer important opportunities for, as well as potential risks to, territorial development. The seas provide resources above and beneath its waters that can be used as the basis for territorial development : it permits the flow of goods, services and people, connecting various parts of world and providing a significant environmental asset that requires careful planning. Indeed, it is clear now that the health of the seas are critical to our common global endeavour against climate change.[8]

Unlike other seas in Europe, the Baltic Sea is surrounded by highly developed societies. There are many claims on its resources and its open spaces are envied areas where various developments, such as wind farms, fishing, dredging and cable laying, are more often than not in conflict. These infrastructures always coincide with the coastal zone and will require, in the years to come, the use of adequate maritime spatial planning.

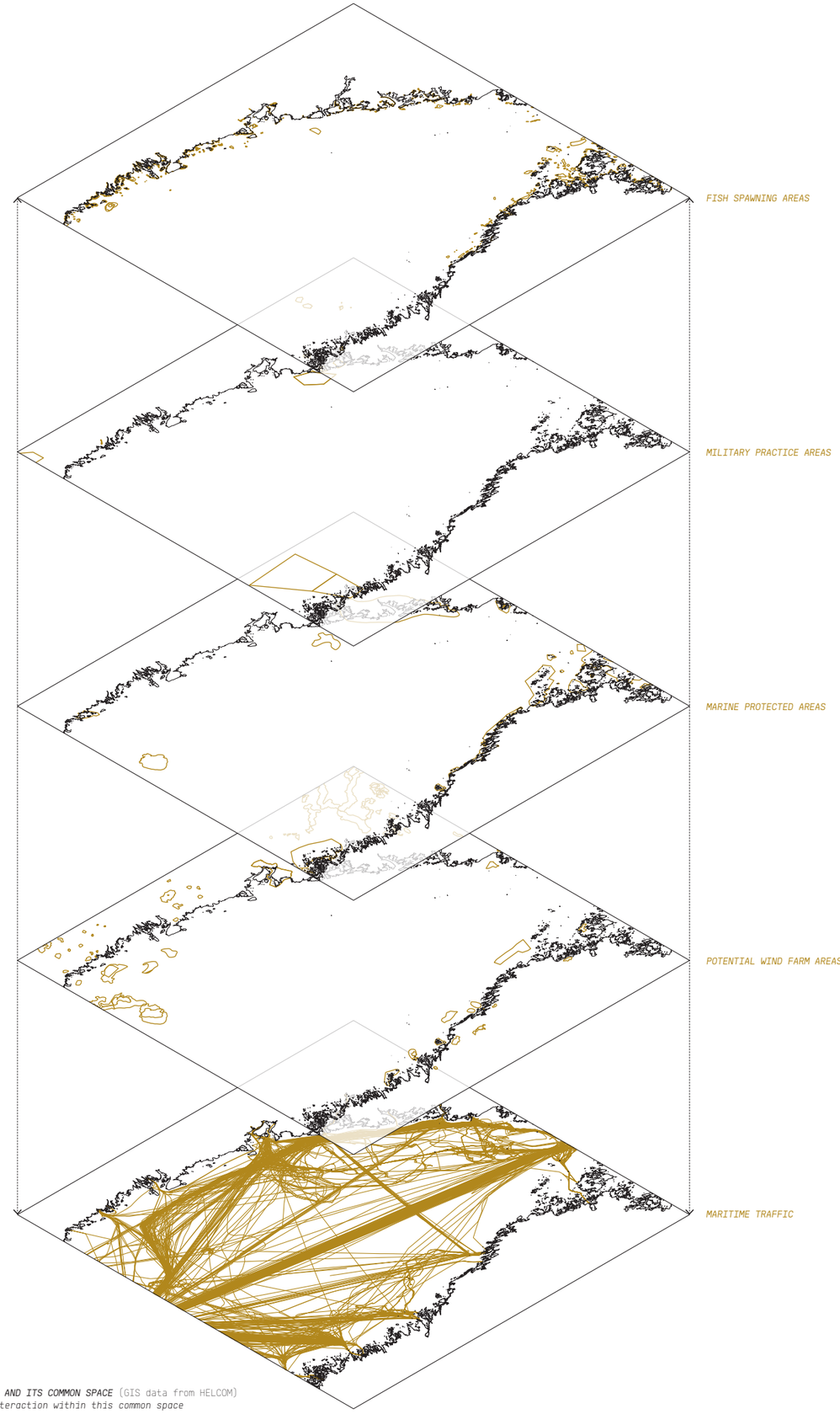
"Like planning on land, maritime spatial planning is a process that has to incorporate ideals of the public good and the various politically-anchored ways to define this, talking in to account private development interests as well as the physical realities of limited natural resources and fragile ecosystems."[9] Indeed, throughout the development of these highly industrial and developed societies, pressures on the Baltic Sea have in the long run created a long list of environmental degradations as well as population reductions of certain species. According to the WWF, the Baltic Sea remains *"the worlds most polluted sea"*.

In the years to come, the volumes of goods transported across the Baltic Sea is predicted to grow exponentially. Newly designed transport systems require that a majority of land transport be moved to the sea in order to be more energy efficient. Parallel to increased shipping activities, developments of existing port infrastructure will need to be secured. In the zones closest to the coast (the coastal zone) as well as in offshore areas, importance will hopefully be given to uses and activities that are beneficial to coastal communities.

Whilst studying the coastal zone as a space of transition, one can notice that the stretched, lineal shape of the Baltic Sea emerges as a continual coastal condition. The coastal zone is large in comparison to the entire area of the sea and is loaded with both ecological and anthropogenic pressures. The coastal zone is thus able to penetrate the central area of the sea and create links across this common space.[10]

Taking into account the planning of this coastal zone, the ecosystem of the Baltic Sea provides at the same time the basis and limitations. This research aims at confronting the classical debates for and against the primacy of economy and employment, against the argument for maintaining landscapes and ecosystems intact. Should we exploit or maintain ? Parallel to this argument exists the discussion around the benefits for local versus national populations, global or European interests. Of course planning is never truly biased, regardless of the efforts by the concerned actors to provide neutrality. In the end, it amounts to a political process linked to a specific paradigm or logic.[11]

Through this book, the raw data is synthesise in order to highlight certain planning issues. *"Whilst there has been growing recognition of the need for improved planning of maritime space, as exemplified by the growth of integrated coastal zone management and marine spatial planning, more broadly little has yet been done to explore the potentials and challenges of planning for these areas, particularly in relation to their transnational and cross border dimensions."*[12] This research hopes to generate more ideas on how the uses of the Baltic Sea could be organised so humans can live side by side with the sea, today and in the future. Planning will become crucial in the Baltic Sea where user pressures are currently relatively manageable but are expected to witness a strong shift in the years to come.



↗ *FIG.1 COASTAL ZONE AND ITS COMMON SPACE* (GIS data from HELCOM)
Multiple layers of interaction within this common space

ECOLOGICAL SHIFT

THE BALTIC SEA HAS A LONG NORTH-SOUTH EXTENSION OF ABOUT 3,000 KM. THIS UNIQUE CLIMATIC CONDITION, WITH GROWING EX-TREMES, ACCENTUATES ITS VULNERABILITY

BAŁTYK SEA ECOLOGICAL SHIFT

↓ A HYDROLOGICAL UNIT

A drainage basin is defined as an *ecogeographical region (Håkanson, 1991)* or a hydrological unit for environmental studies.[1] It extends an area of land without limiting itself to political borders but focusing on the flow of water. In order to understand the ecological shift actually taking place in the Baltic Sea region, it is important to define a specific frame of study. In our case natural limits, instead of national borders, seem more relevant to understand this shift.

"The Baltic Sea drainage basin is one of the six major basins in Europe. The others are the North Sea, the Mediterranean Sea, the Black Sea, the Caspian Sea, the White Sea and the Barents Sea basins."[2] The Baltic drainage basin covers about 15% of the European continent and is inhabited by 85 million people. It covers 1,745,000 km² and 2,250,000 km² when including the Baltic Sea.

"The border of the drainage basin is called the water divide "(Håkanson, 1991). The Baltic *water divide* is very precisely defined because it is limited by high mountains on all sides. Swedish and Norwegian fjell mountains in the North mark the higher latitude limit of the drainage basin.[3] This ridge also defines almost exactly the border between Norway and Sweden.

It is limited in the south by the Carpatian mountains and the mining areas of the Czech and Slovakian republic. The water divide coincides almost with national borders between Poland and its two southern neighbouring countries. In the east, the divide crosses much flatter landscapes, it extends up to sources of the Dvina/Daugava rivers in Belarus. In Germany and Denmark, the divide is found once more on a reletively flat landscape compared to Scandinavian countries.[4]

↓ DRAINING RIVERS

These different industrial areas of southern Poland, western Ukraine and Belarus drain into the Baltic Sea through the Odra and Wisla rivers. It is highly agricultural landscape, as it contains 20% of all arable lands of the catchement area. Poland itself counts for almost half the inhabitants with 38 million people and 41% of all arable lands in the region.[5]

Soil types play a fundamental role when studying water flow. The different types define several degrees of permeability. This is especially important in western Europe where there are intensive agricultral areas and loose soils. They often contain large quantities of chemical fertilisers who are then deported into the Baltic Sea.[6] In areas where soil types are less permeable, these problems have significantly less importance.

Out of all these rivers, of different sizes and scales, draining into the Baltic Sea, ten major rivers account for 58% of the basin surface and 55% of the water inflow. These rivers differ from the north to the south. The rivers in the the north descent higher elevations, they once had important water falls and rapids but are now extensively exploited for hydropower. The rivers in the south are older and flow on more maleable and flatter surfaces. They flow in a much more meandrous way through the landscape. The largest rivers of the basin are the Wisla and the Odra in the south, and the Daugava and Nemunas in the east.[7]

↓ LAKES WATERSCAPE

The drainage basin has an important variety of waterbodies. Rivers account for a vast majority of the transport of goods. In this complex network, lakes play a major role in containing and stocking rain water. Unfortunately, pollutants from highly industrial areas such as the Ruhr region in Germany or open mine fields in southern Poland also end up in these waterbodies.

This rich waterscape is especially present in the northern 2/3 of the region. After the ice dissapeared, the newly forged landscape allowed a large number of lakes and water courses to emerge. Lakes accounts for 6% of the drainage basin surface. Sweden and Finland together account for more than 52% of all inland waterbodies. Sweden has a large variety of larger or smaller lakes with a total of about 86,000 lakes. Russia has some of the largest lakes, including lake Ladoga and Onega.[8]

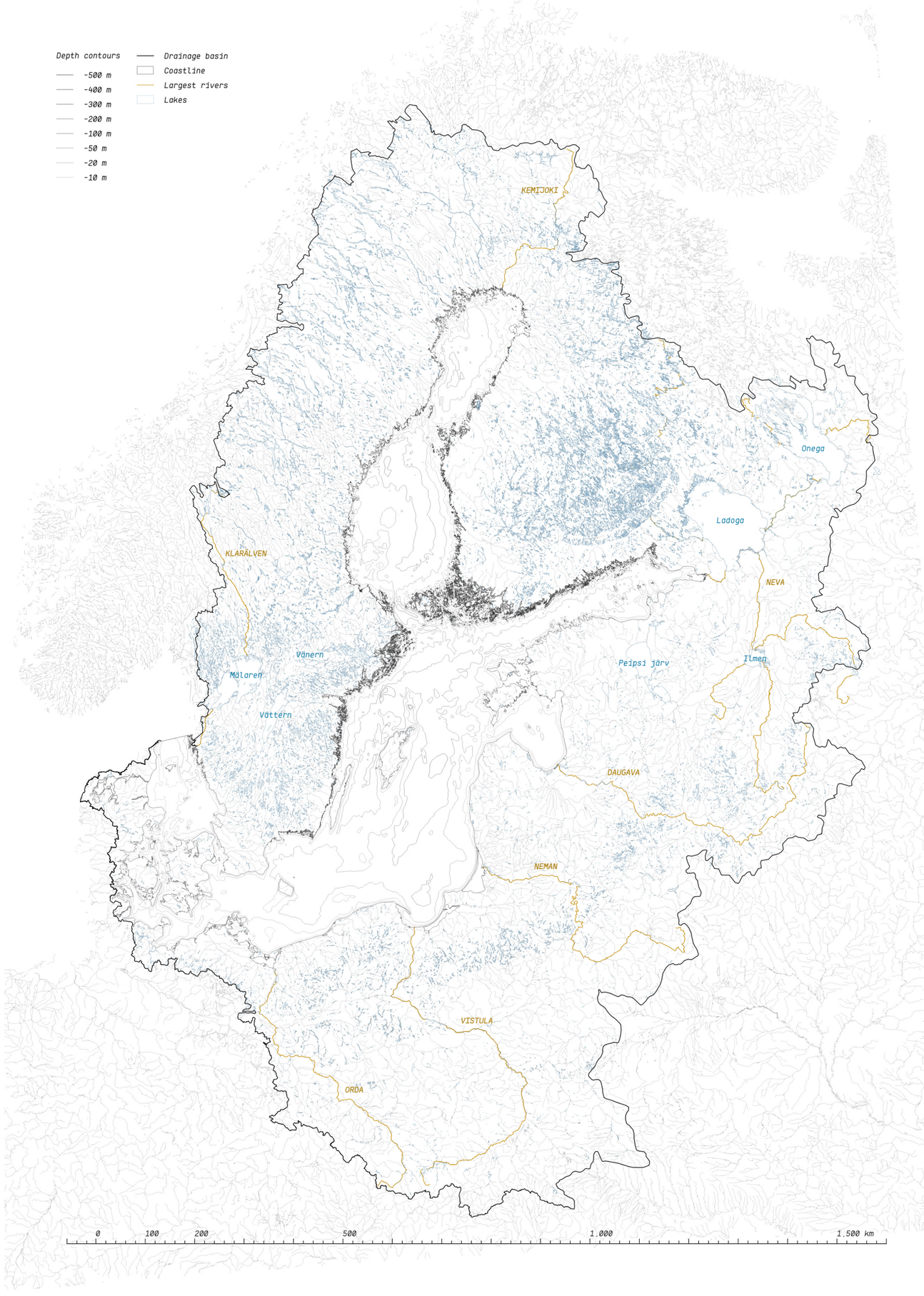
This important variety of waterbodies throughout the basin with rivers, lakes, reservoirs, estuaries and wetlands make it a very heterogeneous area with a common waterflow towards the Baltic Sea. It is an important *hydrological unit* at the European scale.

River	Length (km)	av. Discharge (m³/s)	Basin (km²)
↘ Wisla	1,068	1,065	40,157
↘ Daugava	1,020	659	58,700
↘ Nemunas	937	632	98,200
↘ Odra	860	573	119,000
↘ Kemijoki	600	562	51,127
↘ Torne älv	550	397	40,157
↘ Dalälven	520	370	28,954
↘ Klarälven	460	165	11,820
↘ Neva	74	2,460	284,506
↘ Rhine	1,230	2,900	185,000
↘ Rhône	813	1,710	98,000

↑ *FIG.1 THE LARGEST RIVERS* (Data from Andersson et al., 2003)
In comparison with two of the largest rivers in Switzerland

Lake	Area (km²)	Catchment (km²)	Country
↘ Ladoga	17,800	276,000	Russia
↘ Onega	9,900	51,540	Russia
↘ Vänern	5,648	46,880	Sweden
↘ Peipsi järv	3,100	47,800	Estonia/Russia
↘ Vättern	1,912	4,503	Sweden
↘ Saimaa	1,500	61,054	Finland
↘ Ilmen	1,284	67,200	Russia
↘ Mälaren	1,120	21,460	Sweden
↘ Päijänne	1,110	26,480	Finland
↘ Geneva	580	7,975	France/Switzerland
↘ Neuchâtel	215	2,670	Switzerland

↑ *FIG.2 THE LARGEST LAKES* (Data from Andersson et al., 2003)
In comparison with two of the largest lakes in Switzerland



BAŁTYK SEA **ECOLOGICAL SHIFT**

↓ FUNCTIONAL ZONES

In all enquiries on the Baltic Sea and in order to better understand this ecological shift we are discussing, one needs to show the basin divided into sub-basins. The entire Baltic Sea basin, as well as each of the sub-basins, can also be mapped according to functional zones (see ***FIG.4***).[9] This division into zones, with each their characteristic function – both physical and biological – can be useful when discussing and understanding environmental impact. Overall, there are four different zones.

THE DRAINAGE AREA represents the area of our study (as explained in the previous chapter) and is also called the *catchment area* or the water shed. The rain falling on this area will, in due course, find its way to the Baltic Sea via brooks and larger rivers. The drainage area of the entire basin is 1,745,000 km², which is more than 4 times larger than the entire water area of 415,266 km².[10]

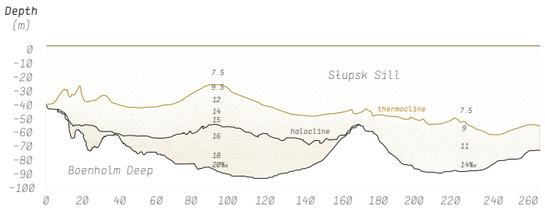
THE COASTAL ZONE is the zone inside the outer islands of the archipelago and/or inside barrier islands. The coastal zone receives the pollutants from land-based activities. The retention time of the water and the characteristics of the different types of pollutants may vary between coastal areas. If the retention time is long the coastal zone acts as a *purification plant* for the open waters. The coast is crucial as it is where many fish species as well as other species reproduce, it is often referred to as the *pantry or nursery* of the sea. The coast is also of special importance for recreation, fishing, water management and shipping. It is thus a zone where different conflicts and demands meet. The natural processes, such as the water transport, flux of material, energy and bio-production, are of utmost importance to the rest of the Baltic Sea.[11]

THE DEEP WATER ZONE consists of the areas beneath the wave base. Within these areas, there is a constant deposition of fine materials. It is the *end station* for many types of pollutants and the areas where conditions of low oxygen concentrations are most likely to occur.[12]

↓ SILLS

Water exchange between the sub-basins is mostly governed by the sills between them. Sill depth is the maximal depth at which water can freely (horizontally) flow between two basins. So, water exchange is effective down to sill depth.[13] A schematic view is given on ***FIG.5*** regarding the inflow of water over sills to inner parts of the Baltic Sea.

In order to obtain an overall view of the topographic features, one needs to observe the areas, volumes and depths in different basins. The Gotland Sea is the largest basin with an area of 151,920 km² or 39% of the total area of the Baltic Sea. The Gulf of Bothnia is the second largest with an area of 115,516 km², a volume of 6,369 km³ and a mean depth of 55 metres. The next in

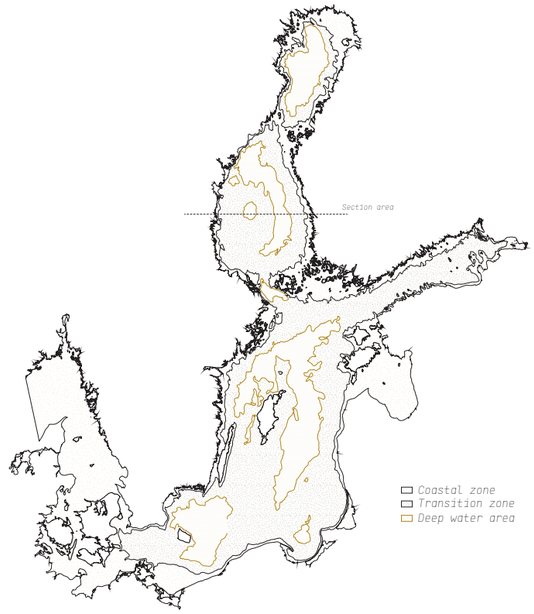


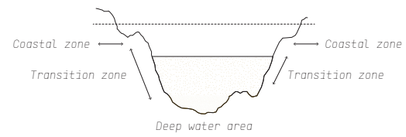
↑ ***FIG.3*** ***POTENTIAL SALINITY*** (Redrawn from Couling, 2015)
The separation in different sub-bassins makes it even harder for the two water layers to mix. Pollutants that are circulating in the in-between layer often take many years to reach another basin. Pollutants therefore hardly dilute in the sea waters

← ***MAP.1*** (GIS data from HELCOM)

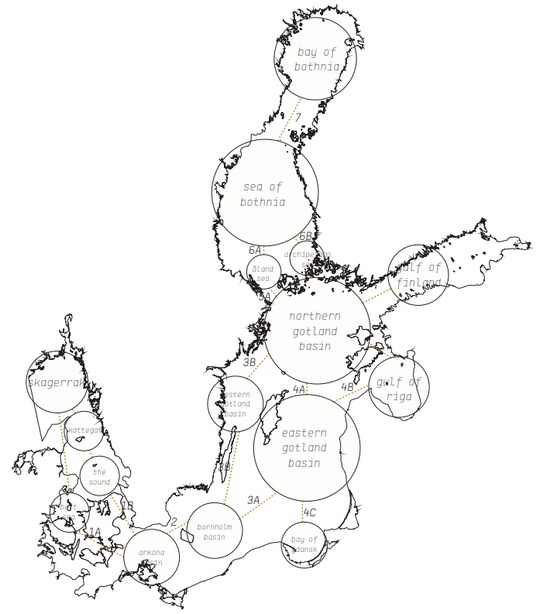
↓ ***IMG.1*** ***EASTERN GOTLAND BASIN*** (Photo by Hiroshi Sugimoto)







↑ ***FIG.4*** ***THE FUNCTIONAL ZONES*** (Redrawn from Andersson *et al.*, 2003)
The zones indicated are the coastal area (light gold hatch), the transition zone (black hatch) and the deep water area (dark gold hatch)



1A Dars Sill	*18 m*
1B Drogden-Flint Channel	*8 m*
2 Hamrare Strait	*45 m*
3A Stolpe Channel	*60 m*
3B Hamrare Strait	*40 m*
4A Förö Sill	*115 m*
4B Irbe Strait	*20 m*
4A Gdansk Sill	*100 m*
5A Åland Sill	*70 m*
5B Gotska Sandö Sill	*100 m*
5C Väinameri	*5 m*
6A Southern Quark	*100 m*
6B Kumlinge Sill	*18 m*
7 Northern Quark	*25 m*

↑ ***FIG.5*** ***BALTIC SEA SILLS*** (Redrawn from Leppäranta *et al.*, 2009)
Schematic view of sills between different basins in the Baltic Sea

	Area (m²)	*Mean depth* (m)	*Max. depth* (m)	*Volume* (km³)
Kattegat	22,287	23	130	115
Baltic Sea	392,978	54	459	21,205
Southwestern Baltic Sea				
↘ Danish Straits	20,121	14	81	287
↘ Belt Sea	17,821	15	81	260
↘ Öresund	2,300	12	53	27
↘ Arkona Basin	19,068	23	53	442
↘ Bornholm Basin	38,942	46	105	1,780
Gotland Sea	151,920	71	459	10,824
↘ Gdansk Bay	25,234	57	114	1,439
↘ Eastern gotland Basin	63,478	77	249	4,911
↘ Northern Gotland Basin	28,976	71	150	2,056
↘ Western Gotland Basin	34,232	71	459	2,418
Eastern and northern gulfs				
↘ Gulf of Finland	29,498	37	123	1,098
↘ Gulf of Riga	17,913	23	51	405
↘ Gulf of Bothnia	115,516	55	293	6,369
↘ Åland Sea	5,477	75	301	411
↘ Archipelago Sea	8,893	19	104	169
↘ Sea of Bothnia	64,886	66	293	4,308
↘ Bay of Bothnia	36,260	41	146	1,481

↑ ***FIG.6*** ***BALTIC SEA BASINS*** (Redrawn from Leppäranta *et al.*, 2009)
The dimensions of the Baltic Sea basins and the Kattegat

BAŁTYK SEA ECOLOGICAL SHIFT

	Catchment (km^2)	Inflow (km^3/year)	Main river
Sub-basins			
↘ Baltic Sea proper	584,000	114	Orda
↘ Bothnian Bay	261,000	98	Kemijoki
↘ Bothnian Sea	230,000	91	Kemijoki
↘ Gulf of Finland	421,000	112	Neva
↘ Gulf of Riga	132,000	32	Daugava
↘ Kattegat & Belt Sea	101,000	37	Klarälven

↑ *FIG.7 INFLOW OF FRESH WATER* (Redrawn from Andersson et al., 2003)
Inflow of fresh water to the various sub-basins of the Baltic sea for the period 1950-1990 and their respective catchment areas

size is the Bornholm Basin with an area of 29,498 km^2 (8% of the Baltic Sea), a volume of 1,098 km^3 (5% of the Baltic Sea) and a mean depth of 37 metres, which is reasonably less than that of the entire Baltic Sea. The Gulf of Riga, the Danish Straits and the Arkona Basin have relatively smaller volumes.[14]

↓ WATER BALANCE

A majority of the fresh water entering the Baltic Sea and its sub-basins originates from river input. The precipitation on the Sea itself is much smaller than the river input and of similar magnitude as the evaporation from the water surface. There is a constant exchange of water between the different sub-basins.[15] The most important exchange is the one through the Danish straits with Kattegat.

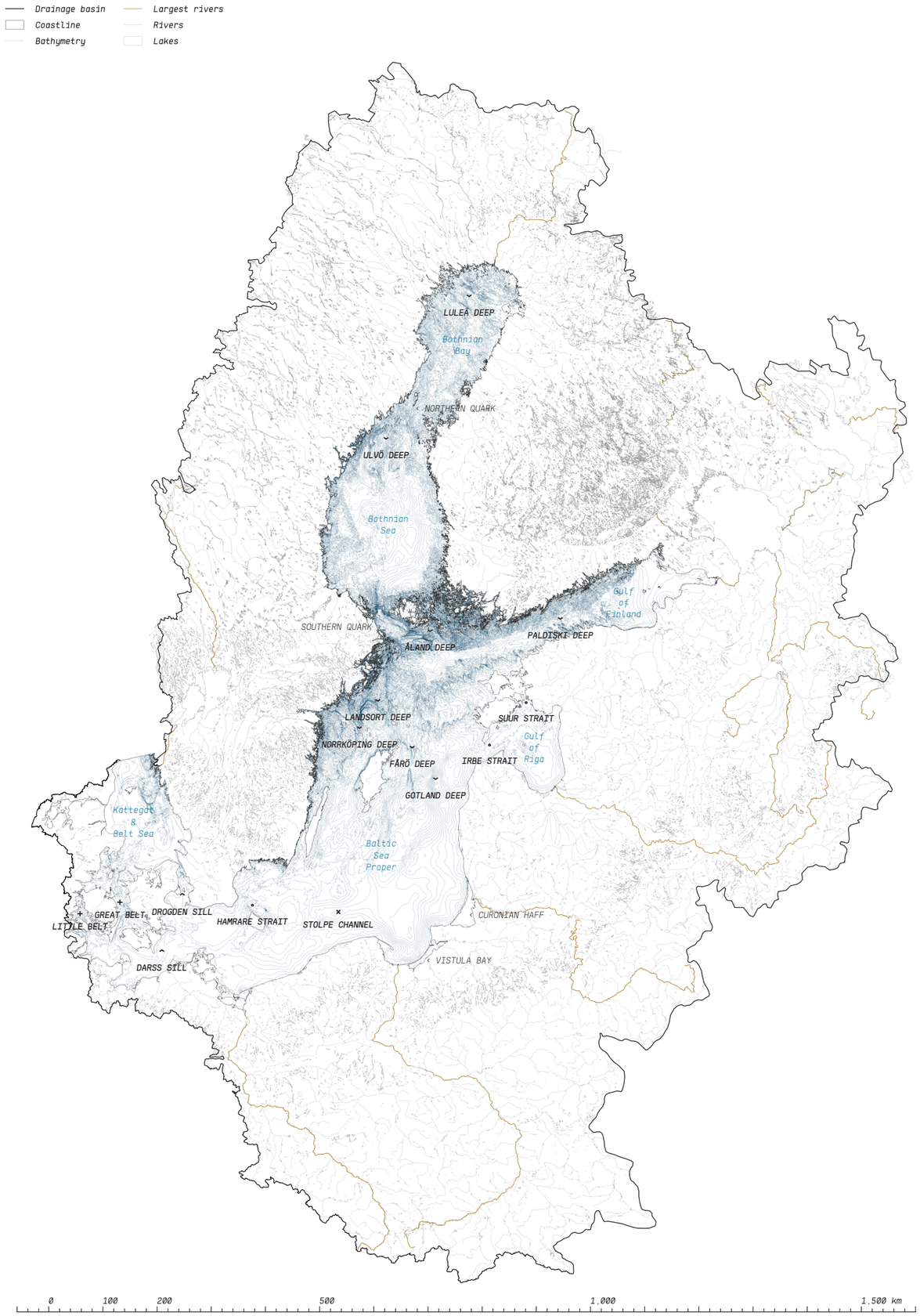
Excess freshwater flows through the Danish Straits, the Sound and the Belts. Large quantities of salt water flows in the opposite direction into the Baltic Sea. The physical properties and the biological life of the Baltic Sea are both shaped by this inflow of salt water.

The *half-life* of water in the Baltic Sea is 25 years, which corresponds to 30 metres of water depth on the average. However, due to the salt water inflow the total exchange of water in the Baltic Sea is significantly larger than the net outflow. This is also applies to the exchange of water between the different basins in the Baltic Sea. The water exchange remains however reasonably small, which results in both water staying brackish and a slow dilution of pollutants.[16]

↓ *IMG.2 ÅLAND SEA. BETWEEN FINLAND AND SWEDEN* (Photo by Fanny Schertzer)



MAP.2 (GIS data from HELCOM) →



BAŁTYK SEA **ECOLOGICAL SHIFT**

↓ AN EPICONTINENTAL SEA

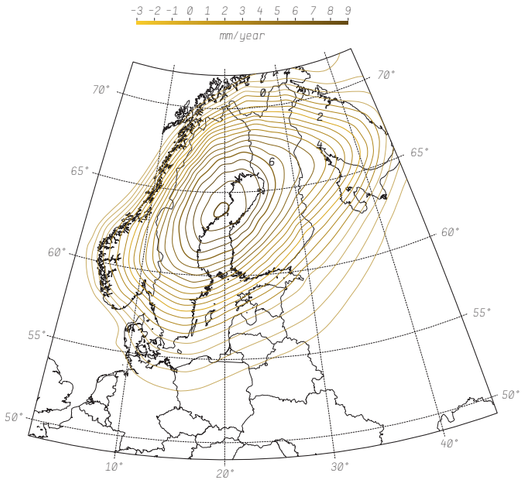
The Baltic Sea is different from deep oceans. It is *epicontinental*, which means situated on a continent. Similar *epicontinental* seas are the North Sea, the Hudson Bay and the Persian Gulf. All these seas are shallow, usually less than a 100 metres deep. Whereas seas between continents are usually more than 2,000 metres deep (for example the Red Sea, the Mediterranean Sea and the Black Sea). An *epicontinental* sea is usually cut off from the oceans, semi-enclosed.[17] In the Baltic Sea, one of the shallowest areas is near the Danish archipelago, where narrow straits prevent ships with a draft over 12.5 metres from entering the rest of the Baltic Sea.[18]

The bathymetric map of the Baltic Sea is crucial in the understanding of water circulation, nutrient flows, sedimentation and pollution. From the bathymetry, one can observe that water circulation is easily restricted between the different sub-basins, from the Bothnian Bay in the north to the Kattegat in the west.

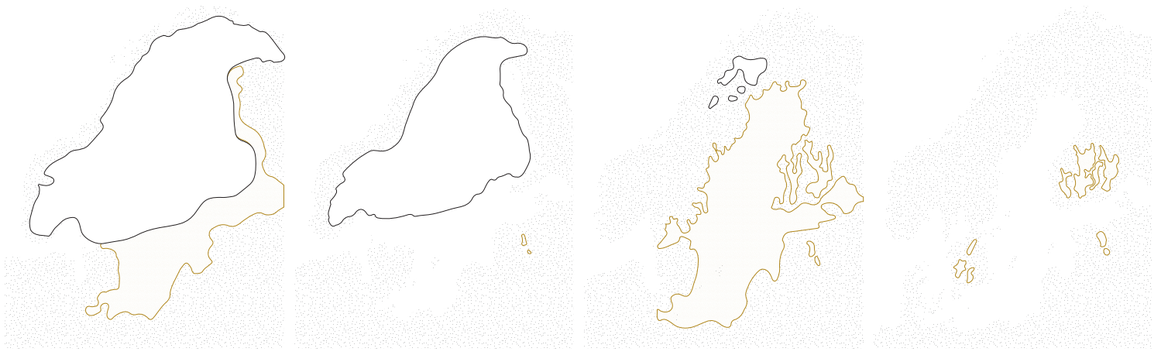
↓ LAND UPLIFT

In order to understand the bathymetry of the Baltic Sea and the topography of its region, one would need to go back a million years. Indeed, the Baltic Sea area has had at least three large inland ice ages or *glaciations*. Back then, the ice cap was up to 3,000 metres thick. The underlying bedrock was polished, scratched and depressed by the unimaginable force released by this mass of ice. The Baltic Sea region landscape is largely carved and formed by glacial activity and isostatic *land uplift* (the land mass rising after being depressed by the inland ice). Through this *land uplift* phenomenon, entire coastal and archipelago areas, as well as new islands, have emerged since the Middle Ages. Today, results of the last ice age are still visible (as accounted by end moraines and ice margin deposits). These formations are scattered around the countryside within areas of central Sweden, southern Finland and along the entire southern Baltic area (such as Poland and Germany). The particle size of the material is of decisive important for soil fertility, water permeability and groundwater formation.[19]

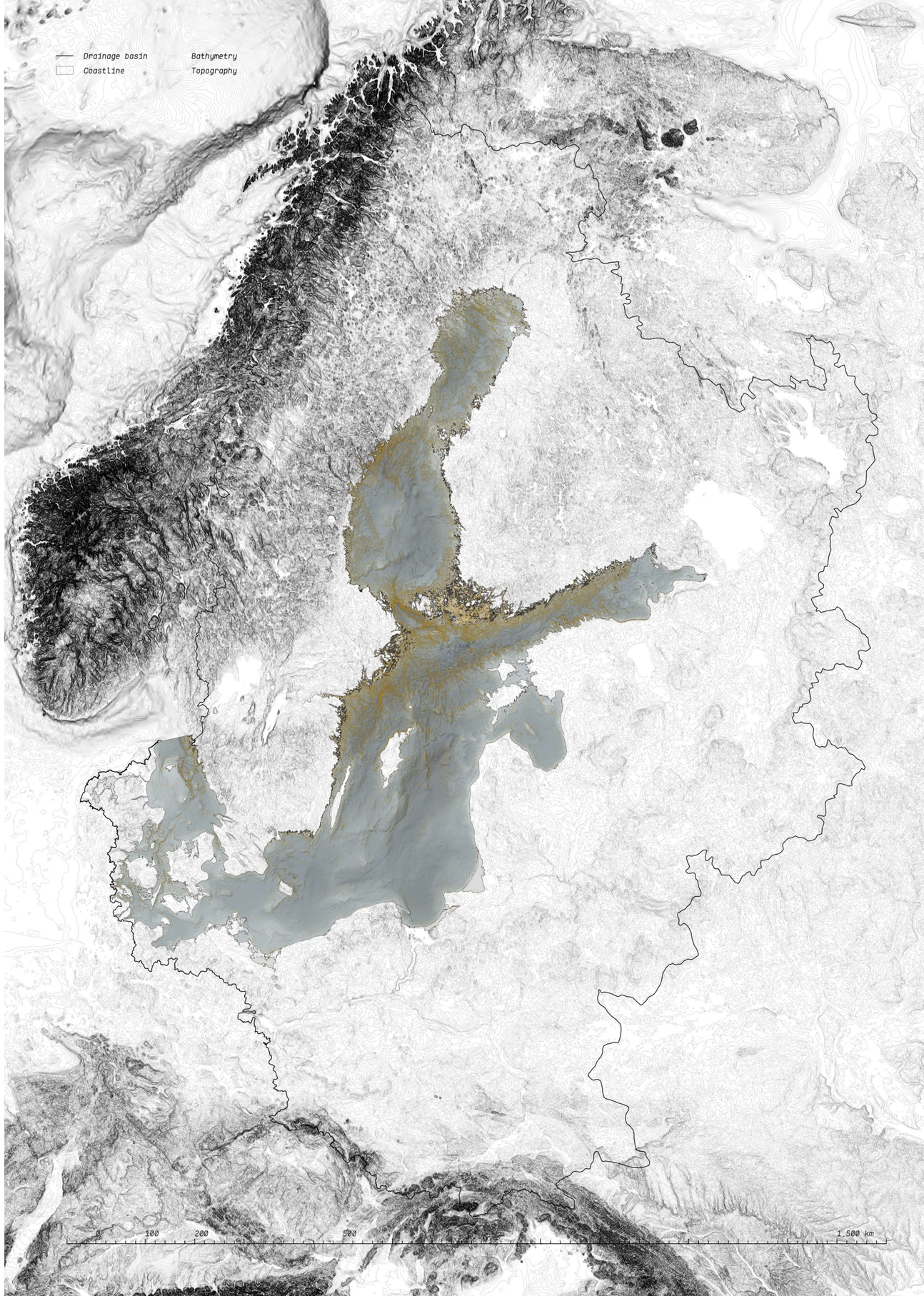
Even after the recession of the ice ended, some 8,000 years go, the land in the Baltic Sea area is still rising (although much less dramatically). The present day isostatic *land uplift* is most visible in the northern part of the region. In the Bothnian Bay, it amounts to 90 centimetres per 100 year, and decreases to zero in the central part of the Baltic Proper (from Öland to Latvia). With the submergence in Germany, it even reaches negative values. This process is of significant importance for many ecological and sedimentological processes.[20]



↑ *FIG.8* ***LAND UPLIFT*** (Redrawn from Ågren et al., 2007)
Contour lines (mm/year) for the land uplift



↑ *FIG.9* ***THE MAIN POST-GLACIAL STAGES*** (Redrawn from Andersson et al., 2003)
From left to right: the Baltic Ice Lake up to 10.000 years BP, the Yoldia Sea 10.000-9.400 years BP, the Ancylus Lake 9.400-8.000 years BP, and the Littorina Sea from 8.000 years BP, which gradually changed into the Baltic Sea



BAŁTYK SEA ECOLOGICAL SHIFT

↓ COASTAL PHYSIOGRAPHIC FEATURES

The coastal area in the northern Baltic region, which is still gently rising, is largely cut into solid ancient bedrock. This combination of rock type and uplift makes the coastline here highly fretted (meaning that it is deeply cut into by erosion). Often the coast rises remarkably high above sea level, forming outstanding scarps in places. Such intricate and greatly dissected shorelines are particularly typical in the area where Precambrian crystalline rocks crop out.[21] Most people visit or live on and by the coast. The coast is thus an important cultural and natural resource. It is also a resource for shipping, sailing, fishing, aquaculture, recreation, and industries. Often leaving the coastal zone as a receiving system for emissions of different types of pollutants.[22]

ROCKY COASTS AND FJORDS The rocky coasts, found along large areas of the northern Baltic Sea, Bothnian Sea, and Bothnian Bay, are formed from areas with naked bedrock and no or little quarternary deposits after the glaciation. Fjords are long faults in the bedrock. Although fjord is used in the name of some bays of the Baltic Sea, these have a different origin and are not proper fjords. The fjord coasts provide good natural harbours but make inland communication and agriculture difficult.[23]

ARCHIPELAGOS OR SKERRIES Archipelago is a common name for an accumulation of islands that have been formed by different processes. The archipelagos in the Baltic Sea are also referred to as skerries. The main archipelago areas in the Baltic Sea are the archipelagos between the Åland Islands and the Finnish mainland, and the Stockholm archipelago, one of the largest in the world with its more than 11,000 km^2 and 24,000 islands and islets. Archipelagos are also found along the Swedish east coast in Blekinge, Östergötland, and Luleå. Traditionally they have provided fish to inland communities. Today the archipelagos are important for tourism and recreation, as well as for aquaculture.[24]

CHALK CLIFFS AND PLAINS, KLINT COASTS These coastal types are found along a long chalk stone formation which stretches across the entire Baltic Sea from northern Estonia in a south-west direction over the Estonian island Hiiuma, over Gotland and Öland to Bornholm. The chalk is an important natural resource. The three large cement factories in the Baltic Sea region are found in Kunda in northern Estonia, Slite on Gotland, and Degerhamn on Öland. The coastal position makes shipping of cement to the entire region as well as further into Europe possible.[25]

MORAINIC CLIFF COAST The profile of the cliff coast depends on its geological formations. Cliffs are exposed to sometimes impressive erosion. The erosion depends on cliff construction, sea action, and groundwater inflow. Cliff coasts are abundant, where postglacial material, clay, and fluvioglacial sands, were located as a highland much higher then the present sea level. The cliff is created on the steep side of this formation. There are cliffs in many places of south Baltic Sea coast.[26]

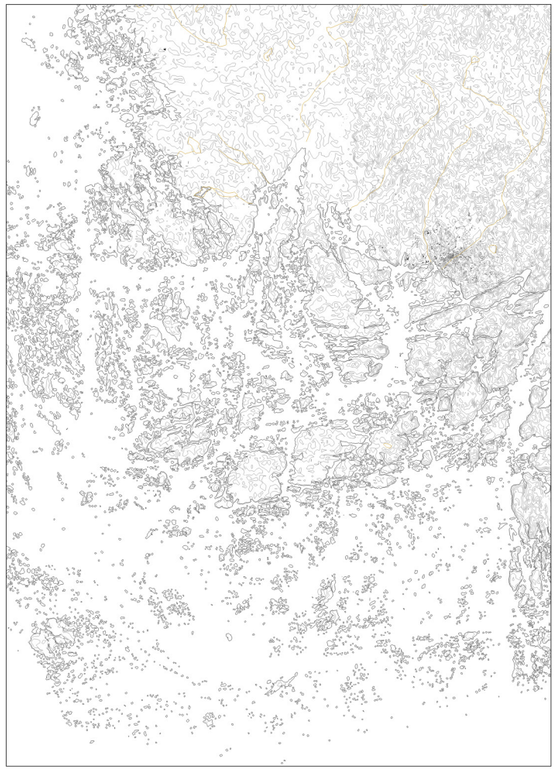
← *MAP.3* (GIS data from HELCOM, EMODnet)

↓ *IMG.3 LAGOONS AROUND BARHÖFT NEAR STRALSUND, GERMANY* (Photo of Klugschnacker)





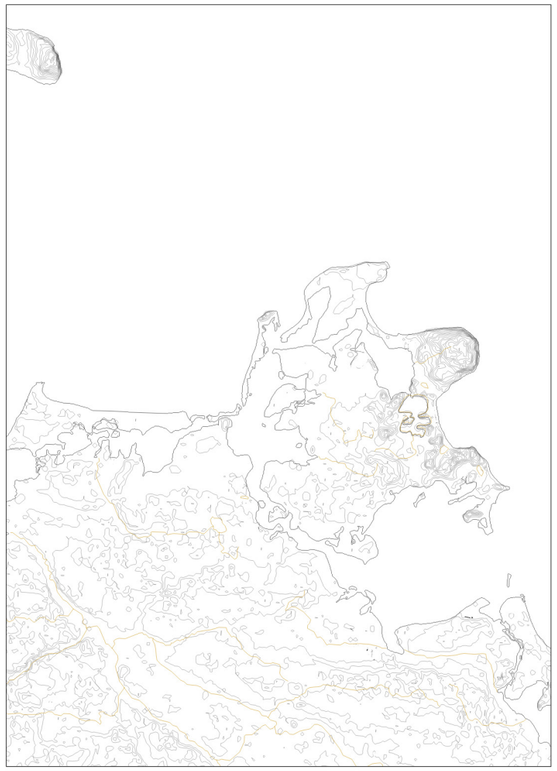
↑ *FIG.10 LAGOON FEATURE* (GIS data from HELCOM)
Haff-sand-bar coast in the former east Prussia



↑ *FIG.11 ARCHIPELAGO FEATURE* (GIS data from HELCOM)
Schärenhofküste in south-western Finland



↑ *FIG.12 FJORD FEATURE* (GIS data from HELCOM)
Fjärd-Schären coast in the middle of Sweden



↑ *FIG.13 BODDEN FEATURE* (GIS data from HELCOM)
Bodden coast in northern Germany

BAŁTYK SEA **ECOLOGICAL SHIFT**

BODDENS Boddens are shallow coastal areas with a depth of a couple of metres below sea level. Bodden areas were created in places where the postglacial plain was covered due to a fast rising sea level. Some parts of the lowland plain, usually front moraines, formed islands a bit above present sea level. Moraine islands have been strongly modified by past and present coastal processes, while the inner lowland coast was in this case protected against wave action by these islands. This is the reason why coasts inside boddens are mainly low, flat, and covered by vegetation.[27]

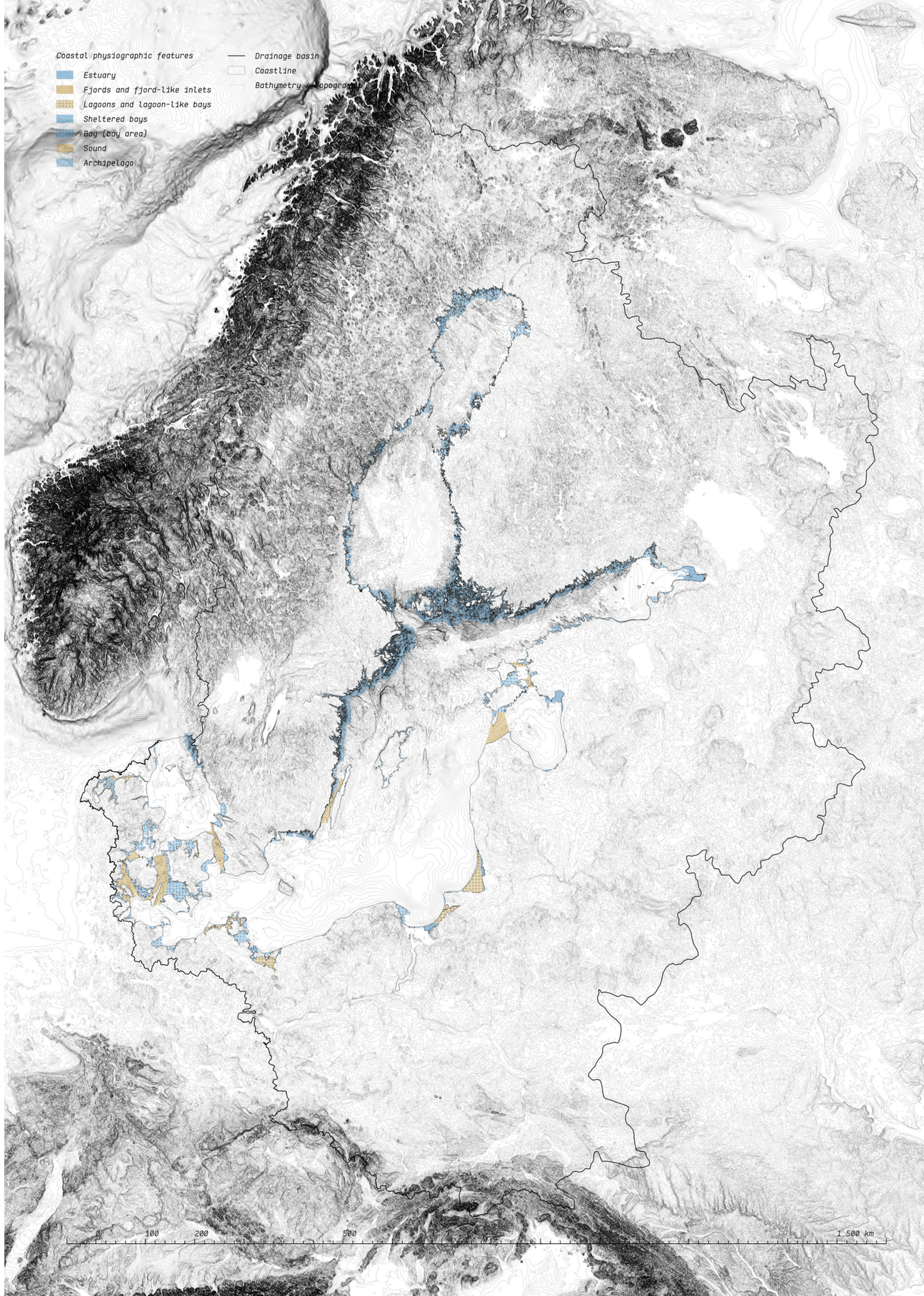
DUNE COAST If exposition to the wave action is right and sand supplied from neighbouring coasts or shallow bottom, the coastal processes create sandy beaches with dunes. Dune coasts are found in places where post-glacial material was deposited as a lowland plain or wide valley at a bit higher or at about sea level. When thereafter the wind collects part of the sand, foredunes are formed at the border of the beach and the lowland plain. The sizes of the dune coasts depend on exposure time and speed of the waves and the amount of sand from the coast. On most of the German coast and on about 80% of the Polish and the Lithuanian coasts there are dunes.[28]

LAGOONS Lagoons are shallow lakes usually created by groundwater, streams, or rivers along dune coasts. There are two typical examples of this process: the Vistula Lagoon at the Polish-Russian border and the Curonian Lagoon at the Lithuanian-Russian border, where the barrier is open constantly. Lagoon coasts are related to dune coasts.[29]

↓ IMG.4 *CHALK CLIFF AT JASMUND NATIONAL PARK, GERMANY* (Photo by Luca Locatelli)



MAP.4 (GIS data from HELCOM, EMODnet) →



BAŁTYK SEA **ECOLOGICAL SHIFT**

↓ WIND CONDITIONS

The Baltic Sea has a large variety of climates. As it extends over 3,000 km from South to North, there are important differences in temperature and precipitation. The North with its higher latitudes has an average temperature of 0°C while the south offers milder conditions with 8-12°C.[30] These temperature variations also coincide with fluctuation in atmospheric pressure. Not only do these differences influence the climate, but on a larger scale the Baltic Sea has external and larger scale links to Northern European climatic variations.

Wind conditions change according to seasons. However, dominating winds come from the west. These winds often carry air pollutants coming from as far as England or the Ruhr industrial region in Germany. The winds also change radically in speed, not only direction. Winter (March - May) has the strongest winds with an average ranging from 8 to 10 m/s. The blowing direction from south to west is called westerly circulation of *zonal circulation*.[31]

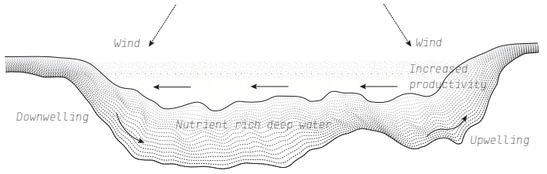
Spring (March - May) has the stablest atmospheric boundary layers and very low cyclonic activity, winds are therefore lower with an average of 6 m/s. In summer (June - August), the wind blows on average from west towards north-west with very low speeds from 5 to 6 m/s. In autumn (September - November), cyclonic activities intensifies again and wind speed increases to 7-8 m/s with a direction blowing from south to west. 50% of the wind speeds are between 5-9 m/s during the year, but on rare occasions (less than 5%) it goes over 17 m/s (strong wind). In 15% of the cases, it is of very low intensity 0-3 m/s.[32]

↓ PRECIPITATIONS

Air pollution is an important issue in the Baltic Sea region, it affects both human and ecosystem health. As a whole, the drainage basin receives 450 km³ of precipitations annually. This represents 40 cm of water/year if evenly spread on the territory.[33] The distribution of precipitation is directly related to geographical location and topography. Most of the precipitations are carried to the north where the evapotranspiration is low and precipitaions high (3,000 mm annually).

It results in an abundance of water resources directly visible when looking at the important number of lakes and rivers Finland and Sweden have combined. The south on the other hand has low precipitations (300 mm annually) and high evapotranspiration limiting the agriculture in large regions such as Poland.

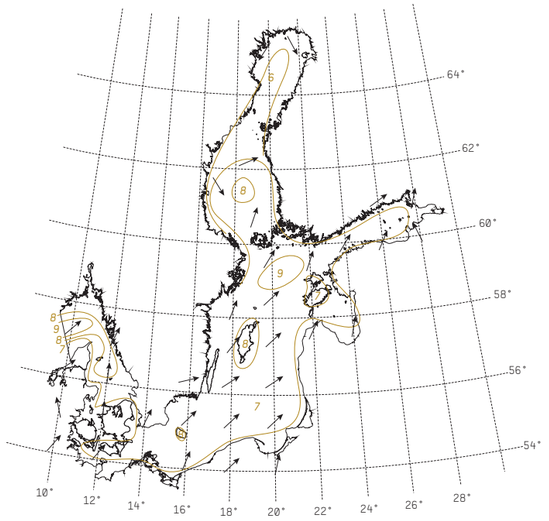
Monthly precipitation is usually between 20 and 100 mm in the Baltic Sea basin, the largest values are reached in late summer and in autumn. They are more frequent over land than over sea in this period of the year due to the low sea surface temperature. In winter and spring, values reach their smallest peak. The largest amount of precipitation is estimated to be between 1,500 and 2,000 mm/year and take place most often in the Scandinavian



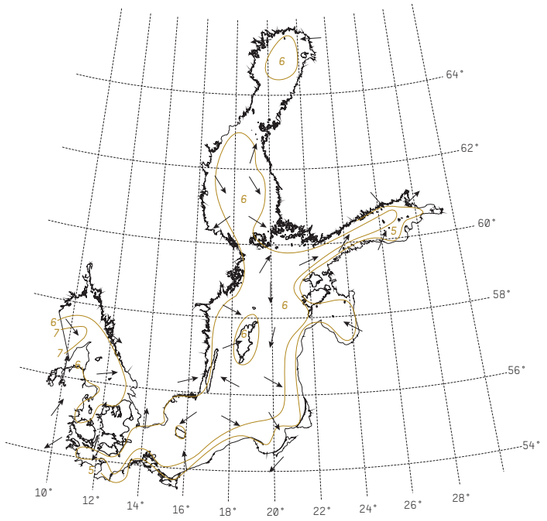
↑ *FIG.14 UPWELLING AND DOWNWELLING* (Redrawn from Backer *et al.*, 2013)
Wind induces coastal upwelling while there is a downwelling movement close to the coastlines. Water movement is perpendicular to the direction of the wind due to the Ekman transportation phenomenon

↓ *IMG.5 THUNDER AND RAIN OVER THE SEA* (Photo by Anu Wintschalek)

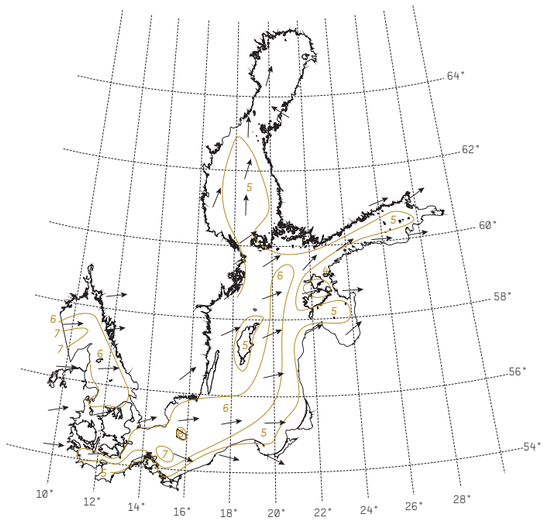




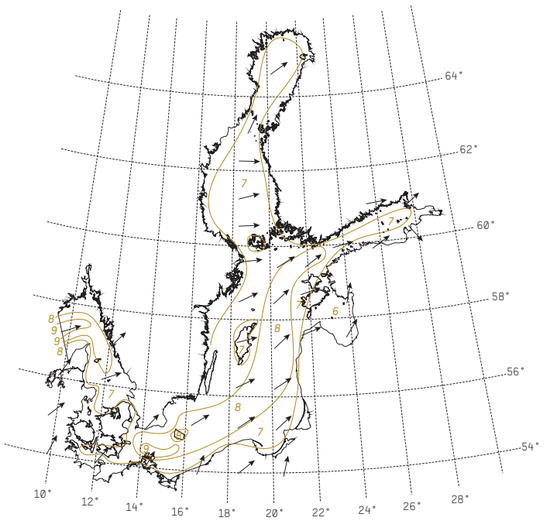
↑ *FIG.15 WIND SPEED AND DIRECTION* (Redrawn from Leppäranta *et al.*, 2009)
Mean data for January



↑ *FIG.16 WIND SPEED AND DIRECTION* (Redrawn from Leppäranta *et al.*, 2009)
Mean data for April

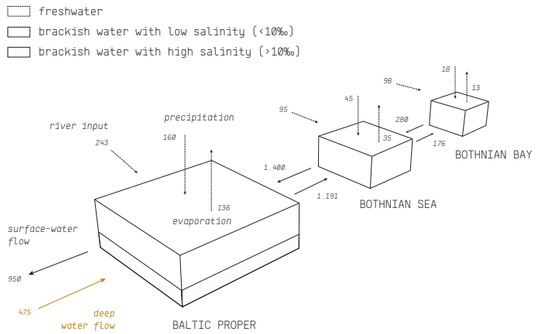


↑ *FIG.17 WIND SPEED AND DIRECTION* (Redrawn from Leppäranta *et al.*, 2009)
Mean data for July



↑ *FIG.18 WIND SPEED AND DIRECTION* (Redrawn from Leppäranta *et al.*, 2009)
Mean data for October

BAŁTYK SEA ECOLOGICAL SHIFT



↑ *FIG.19 WATER EXCHANGE* (Redrawn from Andersson et al., 2003)
The Baltic Sea is divided in three major sub-basins, the Bothnian Bay, the Bothnian Sea and the Baltic proper, which includes the Gulf of Finland, the Gulf of Riga and the Belt Sea. The left side of the diagram shows the water exchange with Kattegat and the North Sea through the Danish Belts and the Sound. All data are in km³/year

mountains. From this point on, as you go south, the amounts of precipitation get smaller. Southwestern Sweden amounts between 1,000 and 1,200 mm/year. In the central basin, it reaches 700 to 800 mm/year.[34]

The runoff is also quite variable from north to south. In the north, water is trapped in water or snow during Winter. Mountain peaks are always covered with snow/ice in Norway and Sweden and the mean temperature hardly goes over -4°C. In spring, there is a peak of water runoff with the melting of ice/snow. In the southern region of the basin, there are not much interseasonal variations except for the Tatras and Carpatians moutains where in spring an immense volume of water is released compared to the rest of the year. These geographical variations also affect how the regions are impacted by air pollutants. When wind direction/speed is added to precipitations, the north clearly has the most important part of damage from acid rain. Sulphur contained in oil and coal is released in the air when burned, it then turns into sulphur dioxide particles and is transported in the air. The large temperature variations from south to north form a cold trap over the northern regions of the basin, transforming precipitation into acid rain. This process of acidification not only kills life in many lakes but it also damages the growth of trees.[35]

↓ CURRENTS

Due to its specifities, the Baltic Sea currents vary depending on the depth, geographical location and season. The surface water is constantly in circulation while bottom/deep waters are more stable. There is a dominating circulation observable in the three largest basins (the Bothnian Bay, the Bothnian Sea and the Baltic proper) that circulates in an anti-clockwise direction. This direction of circulation is formed by the rotation of the Earth which drives water to the right in the northern hemisphere. When a river enters the Baltic Sea, its water is pushed to the right due to this effect.[36]

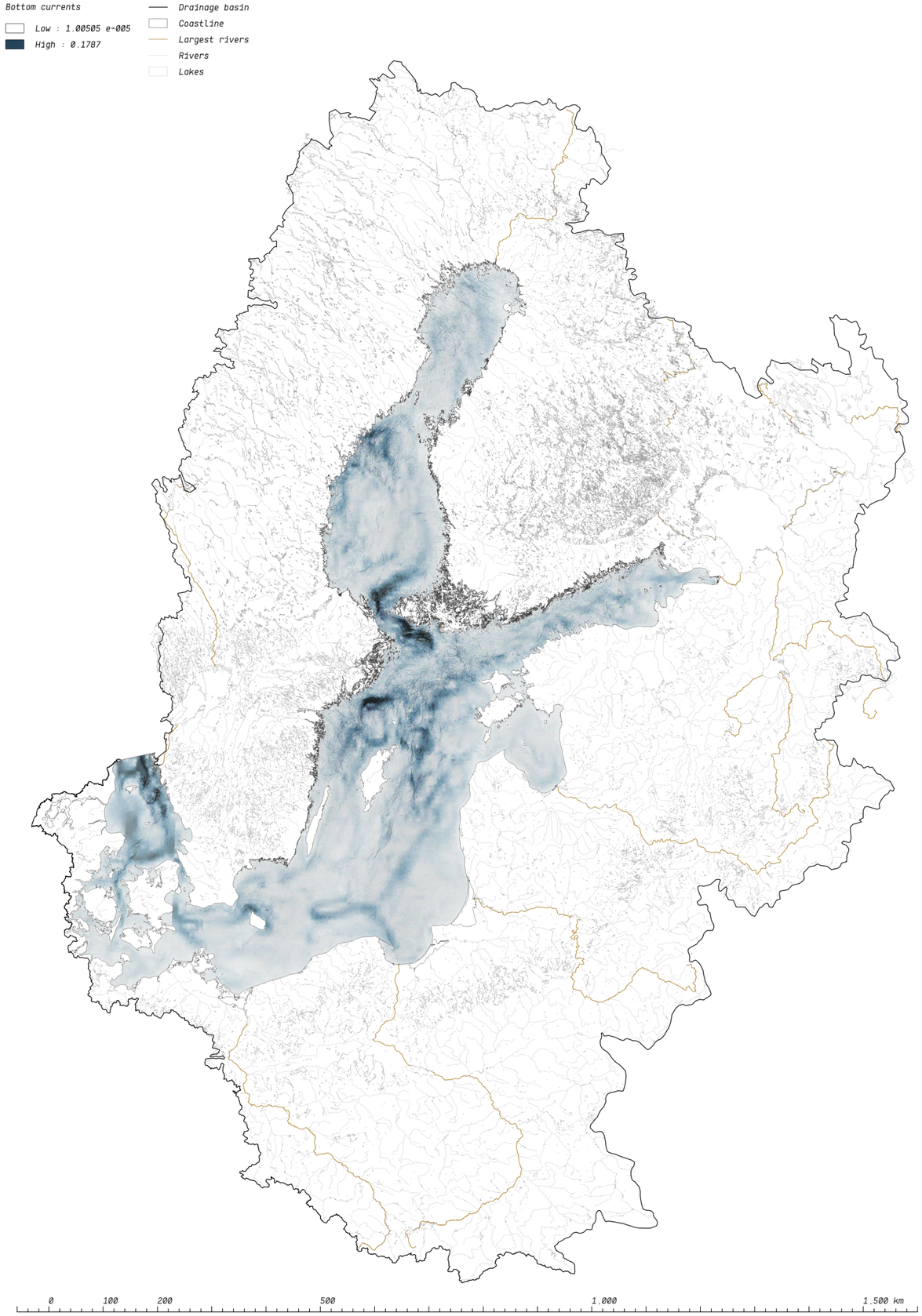
The circulation pattern is not constant though. There are rather strong currents towards the coastline while they are weaker in the center of the basins. These currents also form an enclosed system, water moves to the north on the east side of the Baltic Sea and to the south on the west along Swedish coastline. As a result pollution emanating from southern regions travels towards north. Most often oil spills hit Gotland and the Swedish coasts rather than the rest of the Baltic Sea.[37]

Due to its very complex bottom bathymetry, the Baltic Sea has important variations in wave types. The presence of ice also affects the wave patterns in winter. There are areas of convergence and concentration where waters are not deep and coastline shallow and where occasional wave energy concentration form. This is usually also closely connected to wind circulation patterns that may augment the wave amplitude. These areas may offer interesting points for the development of tidal energy generation.[38]

↓ *IMG.6 STORM OVER THE BALTIC SEA* (Photo by Anastasiya Berezina)



MAP.5 (GIS data from HELCOM) →



BAŁTYK SEA **ECOLOGICAL SHIFT**

SALINITY + OXYGEN + TEMPERATURE

	Salinity (‰)	*Temperature* (°C)	*Precipitation* (m/a)
Sea		surface/bottom	
↘ Red sea	40	23/21.7	0.12
↘ Eastern Mediterranean sea	39	20/12	0.2-1.5
↘ Ocean seawater	33-37	17/1	-
↘ Black sea	20	20/9	0.5-1.0
↘ North sea	35	12/9	1.3
↘ Baltic sea	7-30	11/7	0.7-1.2
Clear water			
↘ Limit of Agri. irrigation	2	-	-
↘ Drinking water	0.1	-	-

↑ *FIG.20 SALINITY COMPARISON* (Data from from Leppäranta et al., 2009)
The diagram shows the specifity of the Baltic Sea in terms of saline concentration. It makes it neither totally a Sea, neither a lake

↓ THREE PARAMETERS

The Baltic Sea has very special characteristics that makes it one of the largest brackish water bodies in the world. It is composed neither entirely of marine waters nor fresh waters. It is therefore between a sea and a lake. There are very few species that are adapted to live in the Baltic Sea. This low level of biodiversity makes it significantly sensitive to any ecological impact. Most of the fresh water that enters the Baltic Sea comes from the draining rivers. It is then mixed with highly concentrated salt water coming from the Straits to form this very unique situation. The salt concentration of a fully marine environment is 35‰ (or 3.5‰) and fresh water has almost no salt.[39] In the case of the Baltic Sea, we find both situations depending on the surface area, season or depth. The north is characterized by low values and high values can be found especially in the Belts. Deep water has a higher concentration at any site. These disparities are especially high when comparing the Bothnian Bay (2-4‰) and the Kattegat, Skagerrak (20-30‰). Intermediate values can be found in the Bothnian Sea (4-6‰) or in the Baltic proper (6-8‰).[40]

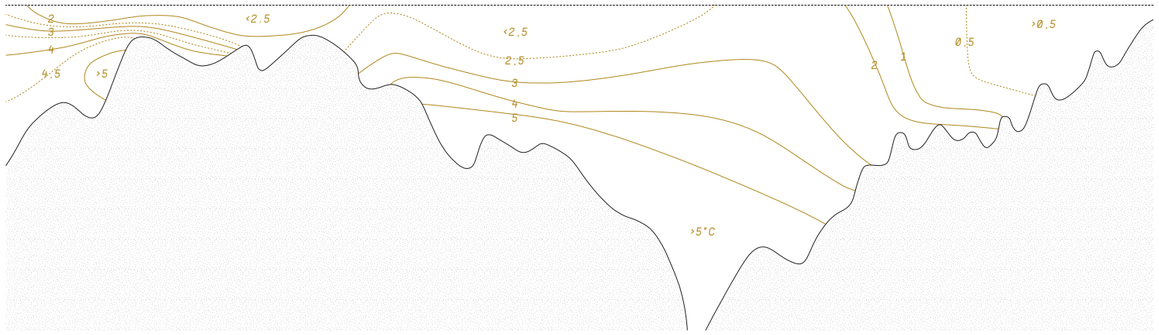
Salinity is not the only fundamental paramater that needs to be taken into account when analyzing the Baltic Sea. What also plays a crucial role is the water temperature and oxygen concentration. There are different layers of specific concentration of all three components. Surface water and bottom water are separated by the *thermocline* (depth between 20 and 70 meters). There is a drastic fall of temperature after the depth of around 25 meters. This means that in summer, the water is less saline and warmer on top of colder water with similar salinity. Below this, is saltier and warmer deep water. During winter, the cold water then reaches the surface, the temperature increases constantly from about 20°C at the surface to 4°C at the bottom.[41]

↓ WATER STRATIFICATION

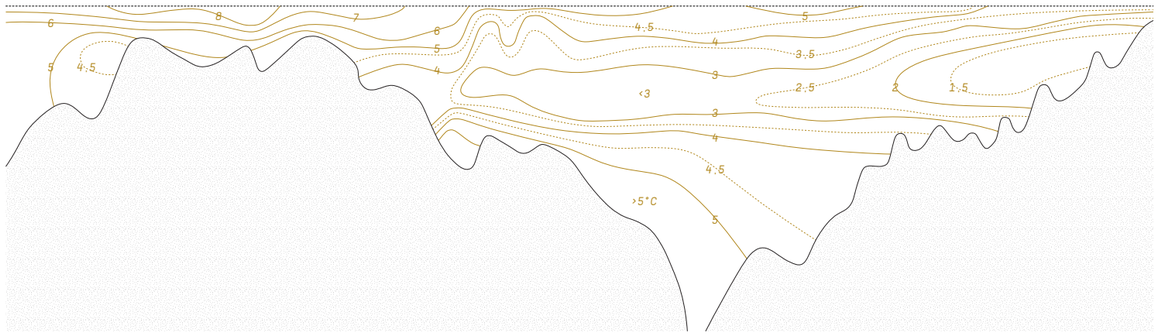
These two boundary layers (*thermocline and halocline*), play an important role. They define two very separate layers where water hardly mixes. It also acts as two intermediate bottoms, or glide surfaces that transport a layer or water and often also various pollutants. The surface water is constantly in circulation while the bottom waters are more often stable. This separation in two layers, with specific and changing charateristics, makes it hard for pollutants to be diluted. They are often in circulation in the in-between layer and are therefore very hard to catch and treat. In addition to the layering, there are observable differences of salinity concentration in time not only space. These may vary considerably on the scale of a few years or even shorter periods. These phenomena of salt water inflows have been studied by many marine institutions around the Baltic Sea. This phenomena is called *inter-annual variation in the deep layers*. It is caused by the major saltwater inflows from the Skagerrack-Kattegat area that supplies the deep stagnant layers.[42]

↓ *IMG.7 BRACKISH CURONIAN LAGOON* (Photo by Niall Corbet)

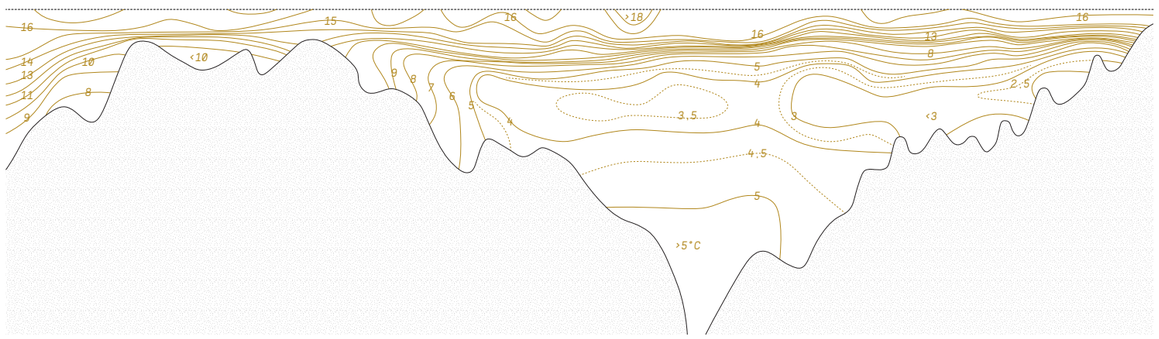




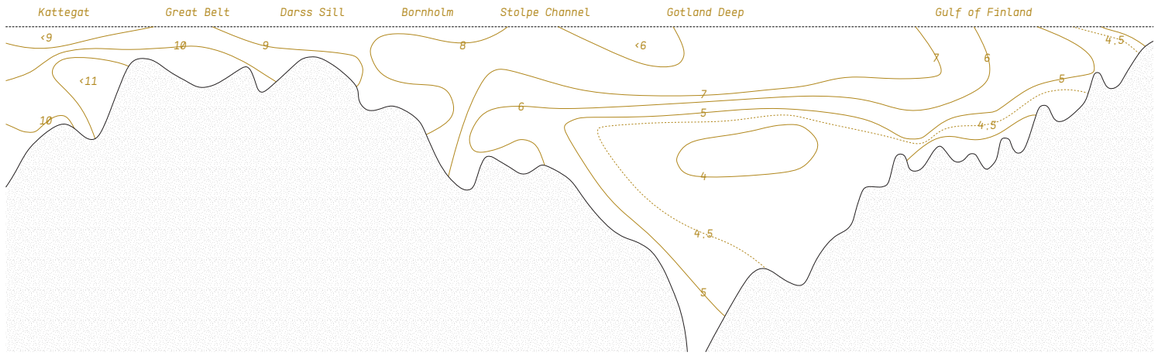
↑ *FIG.21 CROSS-SECTION TEMPERATURE PROFILE* (Redrawn from from Leppäranta et al., 2009)
Stratification condition in January



↑ *FIG.22 CROSS-SECTION TEMPERATURE PROFILE* (Redrawn from from Leppäranta et al., 2009)
Stratification condition in May

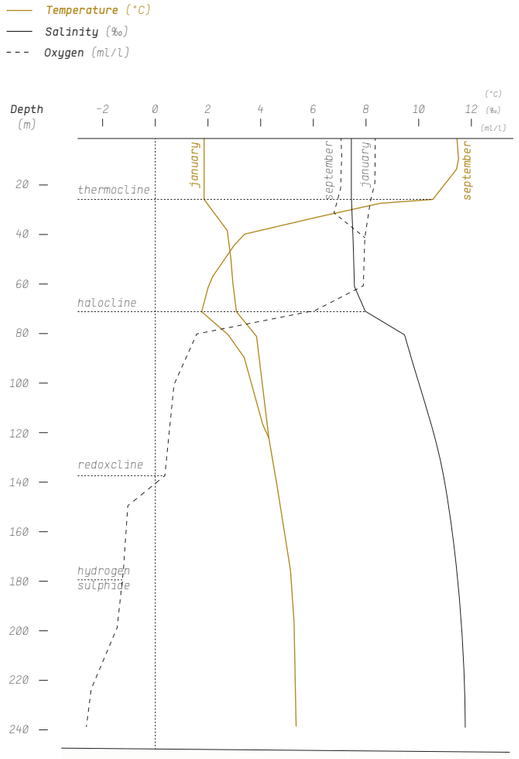


↑ *FIG.23 CROSS-SECTION TEMPERATURE PROFILE* (Redrawn from from Leppäranta et al., 2009)
Stratification condition in August



↑ *FIG.24 CROSS-SECTION TEMPERATURE PROFILE* (Redrawn from from Leppäranta et al., 2009)
Stratification condition in December

BAŁTYK SEA **ECOLOGICAL SHIFT**



↑ *FIG.25* ***VERTICAL PROFILES*** (Redrawn from Andersson et al., 2003)
Data for September and January in the Gotland Deep in 1987

There is a positive freshwater balance, meaning that there is usually more water flowing out of the Baltic Sea than into it. Usually, there is a constant bidirectional exchange at the Belts. However on a few occasions saline water penetrates heavily enough to mix in the deep layers. These situations affect the whole equilibrium of the Baltic Sea and cause many other smaller reactions that might affect the marine life. This layering or stratification process depends of various elements depending of the location.[43]

Salinity is the dominating force in the Kattegat and Skagerrak while it is the temperature that usually divides the most the waters in the Baltic proper. The *halocline* is usually defined by the fresh water input and also by bathymetric data. It is usually around 50-70 metres deep in the Baltic Sea, with a rather homogeneous and low saline surface water. It varies the most in the Kattegat and Skagerrak area with a depth at around 10-20 metres deep.[44]

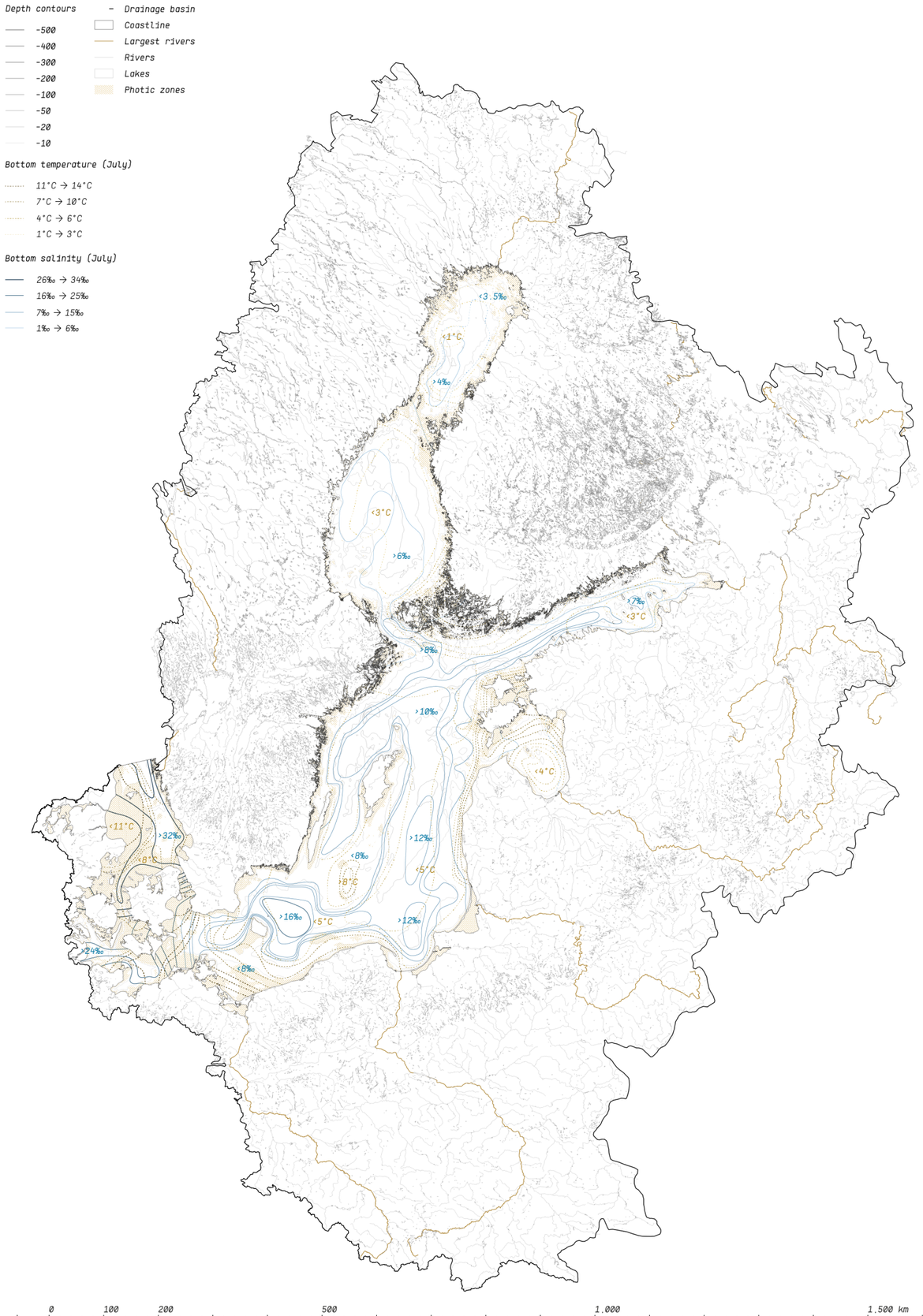
↓ FRAGILE BALANCE

Climatic changes are of major importance for the ecosystem. Very little variations in temperature affect oxygen and salt concentration that then affect a whole cycle of marine life. It is in very rare situations that the bottom water of the Baltic Sea obtain large additions of oxygen-rich salt waters from the Kattegat. This occurs only on specific and unusual conditions. All these climatic and biological reactions show that the Baltic Sea is very much linked to higher and larger climatic factors. Any significant change in precipitation or water inflow would be able to shake the whole system.[45]

↓ *IMG.8* ***ALGAL BLOOM IN SUMMER*** (Photo by Niall Corbet)



MAP.6 (GIS data from HELCOM, University of Helsinki) →



BAŁTYK
SEA
ECOLOGICAL SHIFT

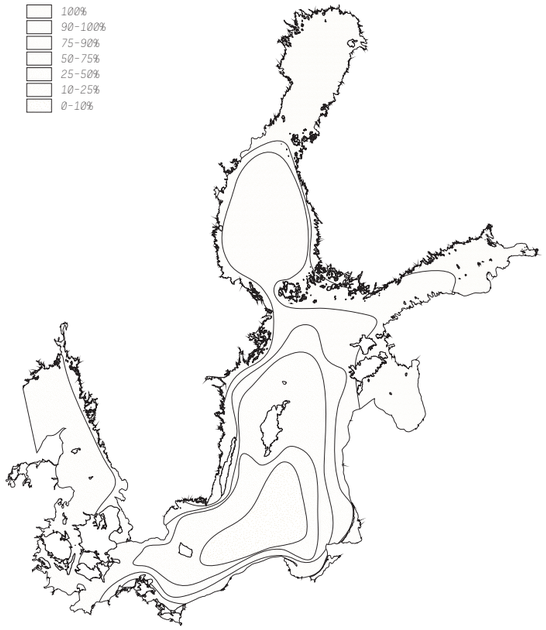
ICE COVER

↓ ICE SEASON

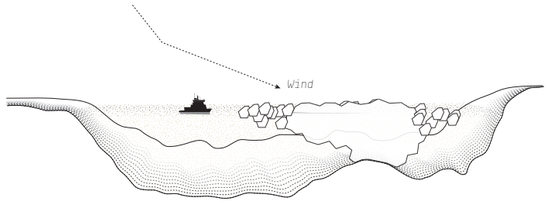
Sea ice has an important role in the annual course of physical and ecological conditions in the basin. It forms in the Baltic Sea annually and can be found there for seven months of the year. The Baltic Sea is unique for being such a large body of brackish water influenced by ice. It is one of the key physical features of this basin and plays a significant role in the Scandinavian climate system.[46] The map on the right shows the mean distribution of the maximum and minimum ice extent in the Baltic Sea (from 1960 to 1964 and 2005 to 2009). It illustrates large areas that are covered by ice each winter. The centre of the Baltic proper is usually ice-free, while the Bothnian Bay is normally ice-covered.[47]

Sea ice acts as a buffer to surface water temperature right up to freezing point. The process of ice melting has a significant impact on surface water salinity: it kick-starts stable spring stratification which has further consequences for the spring algal bloom (including eutrophication, which will be elaborated in a following chapter). The presence of ice has an influence on the transfer of momentum and light to the water and on the air-sea exchange of water and heat. It also influences the hydrological flow, the sedimentation processes and the shore vegetation. Since water temperature, together with salinity, is an important *abiotic* parameter regulating bioproduction, it is important to recognise the significance of water temperature and ice for the plants and animals that constitute the Baltic Sea ecosystems.[48]

Ice plays also a dominant role in human living conditions, particularly when it comes to maritime traffic. At the time of sailboats, winter shipping was cut off entirely during the ice season. Today a fleet of 20-25 icebreakers ensures there is a workable marine transportation system giving access to all the principal harbours of the Baltic Sea.[49]

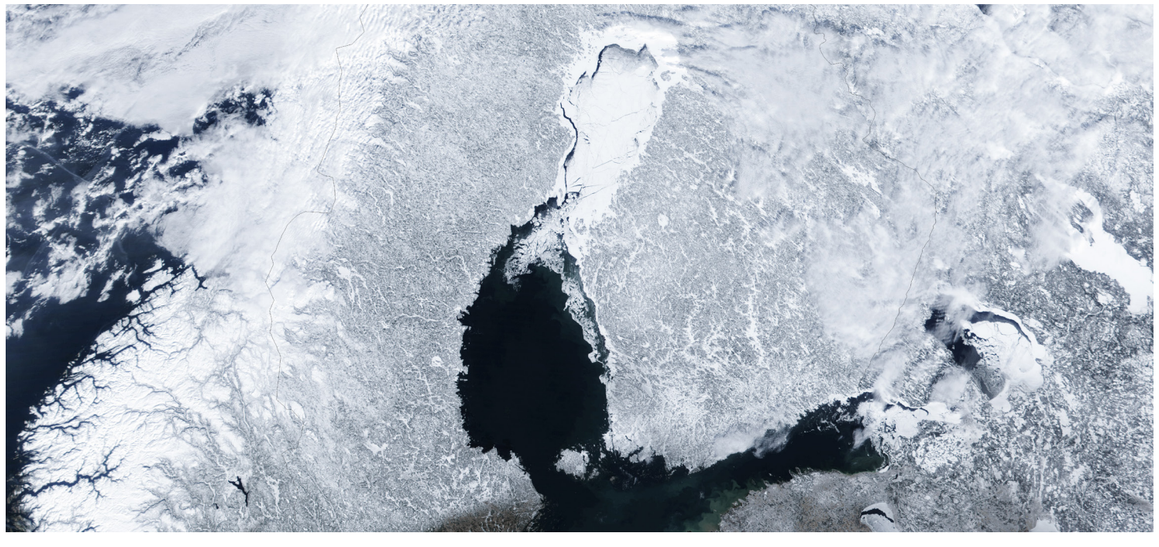


↑ *FIG.26 ICE COVER* (Redrawn from Leppäranta *et al.*, 2009)
The probability of annual ice occurrence in the Baltic Sea

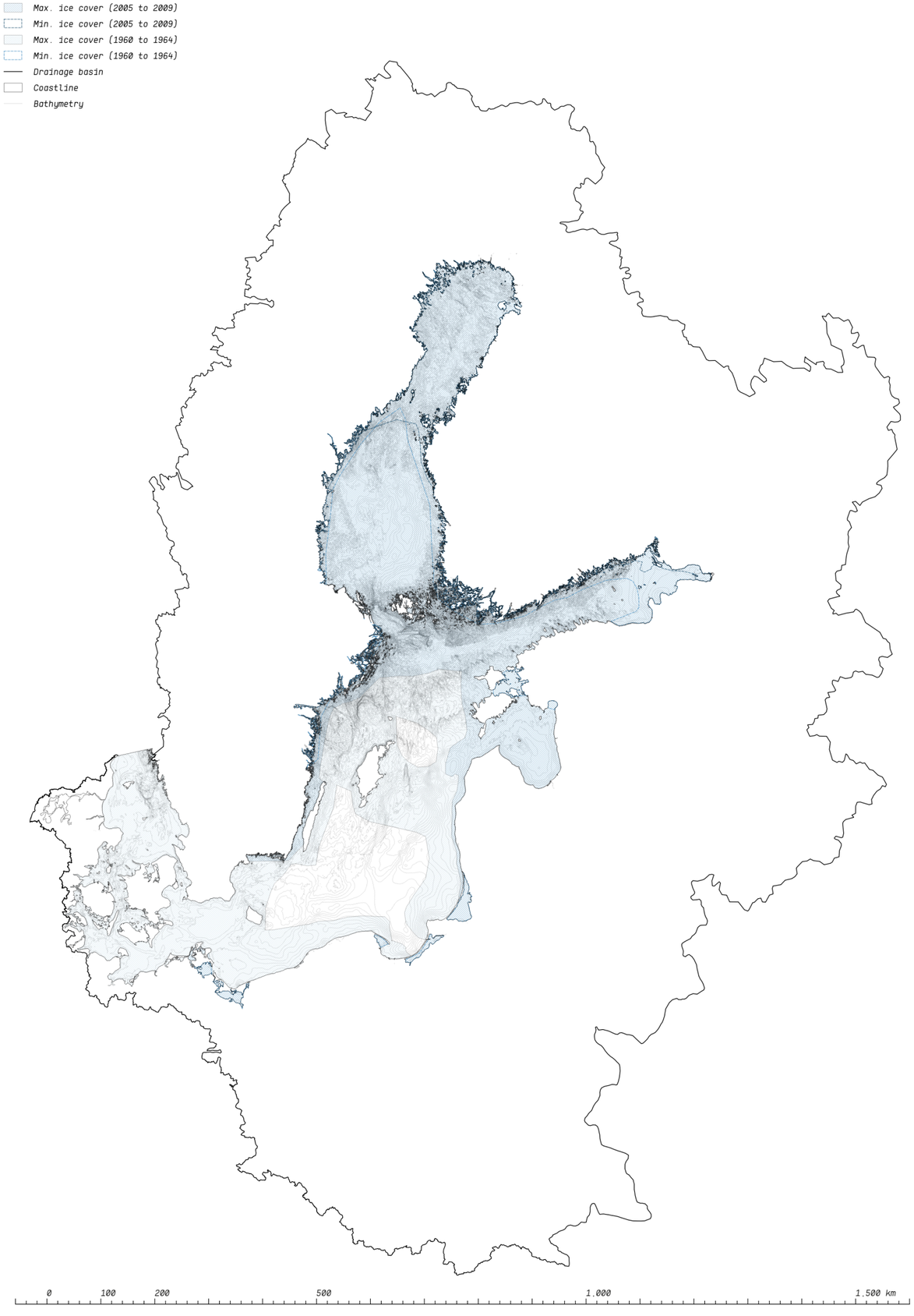


↑ *FIG.27 PACK ICE* (Redrawn from Backer *et al.*, 2013)
Drift ice, consisting of loose ice floes moved by wind, often aggregates to ridged ice (also called pack ice). Such ice ridges have commonly a vertical thickness of 5-15 m

↓ *IMG.9 BOTHNIAN SEA ICE COVER* (Satellite image from MODIS, 2002)



MAP.7 (GIS data from HELCOM) →



BAŁTYK SEA
CARTOGENESIS

→ DRAINAGE BASIN

Drainage basin

Coastline

A drainage basin is defined as an ecogeographical region or a hydrological unit for environmental studies. It extends an area of land without limiting itself to political borders but focusing on the flow of water. In order to understand the ecological shift actually taking place in the Baltic Sea region, it is important to define a specific frame of study. In our case natural limits, instead of national borders, seem more relevant to understand this shift.

→ SUB-BASINS

Largest rivers

Rivers

Lakes

This specificity of the Baltic Sea plays a fundamental role as it defines specific compartiments that interact one with another in a very slow process. Water exchange between the sub-basins is mostly governed by the sills between them. Sill depth is defined as the maximum depth at which water can freely flow between two basins. There are several major and observable sills that form underwater barriers that make it difficult for water to freely circulate. The general shallowness of the sea coupled with the compartimentation into sub-basins results in water staying brackish and therefore slowly diluting pollutants.

→ BATHYMETRY + TOPOGRAPHY

Topography

Bathymetry

There are clear limits in the North with the Norwegian Fjell moutains and in the South with the Carpatians moutains. These topographical features result in many rivers draining towards the Baltic Sea and carying pollutants from several different industries ranging from agricultural fertilisers to heavy metals produced from mining processes. Topograhy also defines a very specific kind of landscape, varying from South to North. The South is very much flat with many larger rivers draining towards North. This last, on the other hand is much more hilly and has much more smaller rivers and large amounts of lakes.

→ CURRENTS + WINDS + PRECIPITATION

Bottom currents

High

Low

Due to its specifities, the Baltic Sea currents vary depending on the depth, geographical location and season. The surface water is constantly in circulation while bottom/deep waters are more stable. There is a dominating circulation observable in the three largest basins (the Bothnian Bay, the Bothnian Sea and the Baltic proper). The circulation pattern is not constant though. There are rather strong currents towards the coastline while they are weaker in the center of the basins.

Because of its very complex bottom bathymetry, the Baltic Sea has important variations in wave types. The presence of ice also affects the wave patterns in winter. There are areas of convergence and concentration where waters are not deep and coastline shallow and where occasional wave energy concentration form. This is usually also closely connected to wind circulation patterns that may augment the wave amplitude.

→ SALINITY + OXYGEN + TEMPERATURE

Bottom salinity

26 → 34 ‰

16 → 25 ‰

7 → 15 ‰

1 → 6 ‰

Photic zones

A majority of the fresh water entering the Baltic Sea and its sub-basins originates from river input. The precipitation on the Sea itself is much smaller than the river input and of similar magnitude as the evaporation from the water surface. There is a constant exchange of water between the different sub-basins. The most important exchange is the one through the Danish straits with Kattegat. Salinity, temperature and oxygen are three parameters that work closely linked one with another. If any variation is observed in one of the three, they others will adapt in consequence. This therefore has important consequences in terms of aquatic life change, it is the main driving element for the development of algae and euthrophication.

→ ICE COVER

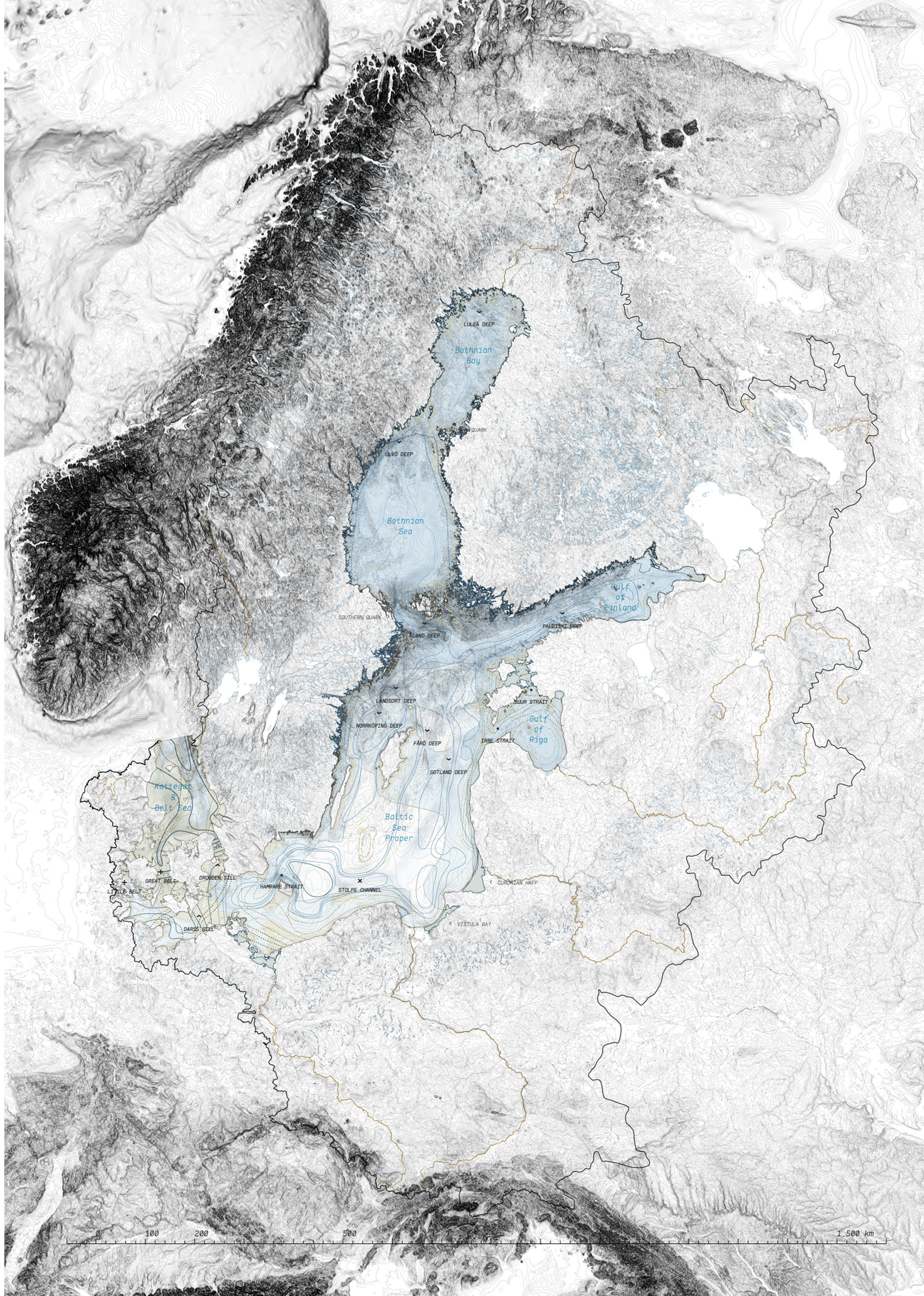
Min. 1960 to 1964

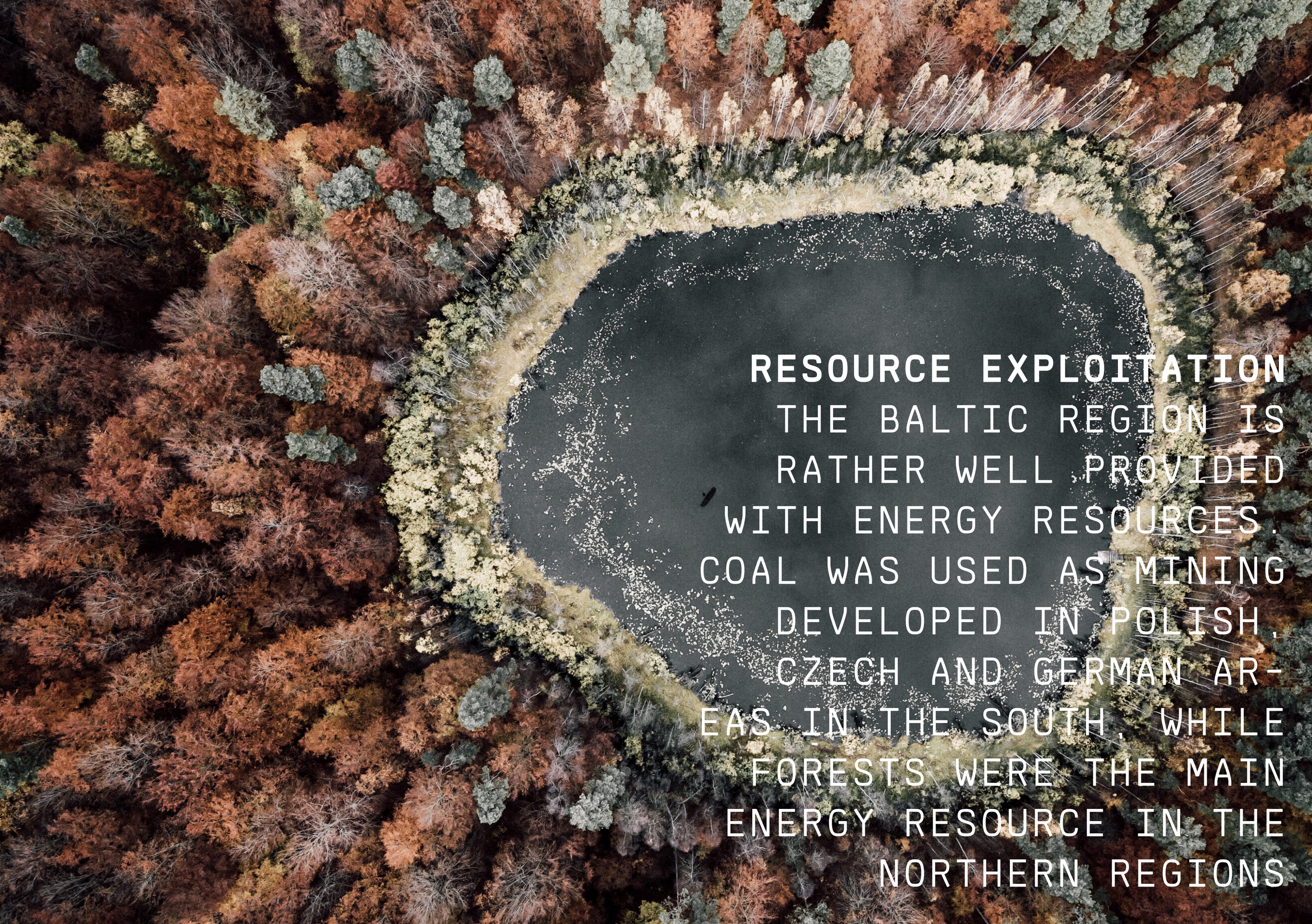
Max. 1960 to 1964

Min. 2005 to 2009

Max. 2005 to 2009

Sea ice has an important role in the annual course of physical and ecological conditions in the basin. Sea ice acts as a buffer to surface water temperature right up to freezing point. The process of ice melting has a significant impact on surface water salinity: it kick-starts stable spring stratification which has further consequences for the spring algal bloom (including eutrophication, which will be elaborated in a following chapter). The presence of ice has an influence on the transfer of momentum and light to the water and on the air-sea exchange of water and heat. It also influences the hydrological flow, the sedimentation processes and the shore vegetation.





RESOURCE EXPLOITATION

THE BALTIC REGION IS RATHER WELL PROVIDED WITH ENERGY RESOURCES. COAL WAS USED AS MINING DEVELOPED IN POLISH, CZECH AND GERMAN AREAS IN THE SOUTH, WHILE FORESTS WERE THE MAIN ENERGY RESOURCE IN THE NORTHERN REGIONS

BAŁTYK
SEA

RESOURCE EXPLOITATION

↓ GREAT EUROPEAN PLAIN

The Baltic Sea drainage basin has an important variety of land uses, but agriculture still remains the most important force driving land use.[1] Almost half of the total land area is devoted to agriculture *(Green et al., 2005)*. There are large variations of utilised agricultural areas (*UAA*) in-between the regions (see ***FIG.1***). The Southern parts of the basin with Germany, Poland and Denmark have the highest proportions of agricultural surfaces (see ***FIG.2,3***). Climate are hydrology are optimum in this area of the basin for agriculture and the average cereal yields in these regions are more than 60% above the world average.[2]

These areas are part of a bigger productive territory called *"the great European plain extending from South-East England through France, Benelux, Germany, Poland, Hungary, Ukraine and Belarus to Russia."*[3] This territory is the largest mountain-free landform in Europe and is home to important drainage basins of Europe. On the other hand, Nordic Countries have usually less than 10% of cultivated land due to important seasonal variations in day length, duration of growing season and early frost seasons.[4]

Not only has the basin important variations in crop yields, there is also a diversity between more technically advanced countries *(Oomen et al, 1998)* and countries where agriculture is still mostly pre-industrial.[5] Poland still has no clear separation between the separation of animal and crop production leading to lower inputs of artificial fertilisers and a higher diversity of both productions. Countries with more intensive and specialised agriculture such as Sweden, Finland and Denmark have a much greater impact on the nutrients leaks (see ***FIG.4***). According to *HELCOM*, intensive agriculture accounts for almost half of the total nutrients load in the drainage basin.[6]

↓ INDUSTRIALISED AGRICULTURE

Agriculture has faced an important shift and acceleration after Second World War in Europe with as result a dramatical increase of environmental impacts. This process of industrialisation has largely shaped the actual landscape. The introduction of non-organic herbicides, pesticides and fertilisers had, and still has profound effects on soil conditions, waterbodies and also directly into agricultural products.[7]

LANDSCAPE SHAPING through the use of large-scale machinery, mono-functional fields created by the drainage of wetlands have considerably modified the landscape in the basin.

FOSSIL FUEL used in almost all machinery still nowadays marks a great dependance towards this form of energy. Large-scale industrial farming uses important amounts of energy, and this is also true for the production of nitrogen fertilisers.

NON-ORGANIC FERTILISERS have, since the 1960's, been used on a very large scale in the region and in Europe in general. These

UAA : utilised agricultural area	*Total land (1000 ha)*	*Agriculture (1000 ha)*		*Grassland (%)*	*Cereal land (%)*
Country			*% of total*	*% of UAA*	*% of UAA*
↘ Denmark	4242	2676	63	8	55
↘ Estonia	4239	948	22	31	39
↘ Finland	30,408	2291	8	1	29
↘ Germany	34,877	16,704	48	28	30
↘ Latvia	6229	1805	29	35	38
↘ Lithuania	6268	2772	44	22	54
↘ Poland	30,633	15,709	51	20	44
↘ Sweden	41,031	3073	7	15	31

↑ ***FIG.1*** ***UTILISED AGRICULTURAL AREA*** (Redrawn from Krug *et al.*, 2015)
Proportion of used land for agricultural purpose. Shows great variations between Nordic countries, with less than 10% of cultivated land, and countries of the Great European plain such as Poland with more than 50% of agricultural lands

↓ ***IMG.1*** ***HAYSTACK FIELD*** (Photo by Mark Finney)





↑ ***FIG.2*** ***ARABLE LANDS*** (GIS data from HELCOM)
The great European plain that extends from South-East England up to Russia is clearly visible when looking at this map of arable lands. There are great variations from Poland that has very fertile soils (70-100%) to Norway and Sweden that vary from 30-50%

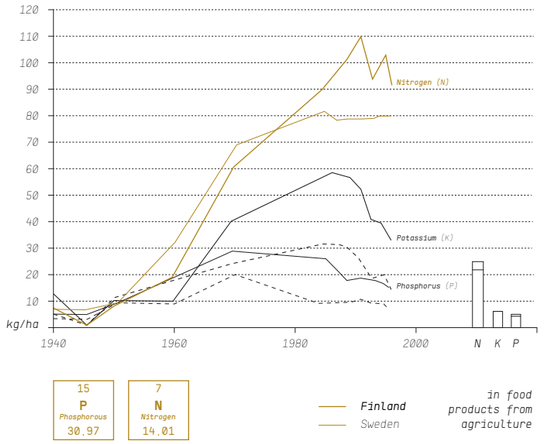


↑ ***FIG.3*** ***PASTURE LANDS*** (GIS data from HELCOM)
Grazing represent an important part of what is considered as utilised agricultural areas (UAA). The difference between northern and southern parts of the drainage basin is still as visible as previously

	Denmark	*Sweden*	*Finland*	*Poland*	*Lithuania*	*Latvia*	*Russia*	*Belarus*	*Estonia*
Landuse (% of UAA)									
↘ Arable land	69	41	60	72	45	42	31	58	72
↘ Forage plants	17	33	28	6	26	23	-	21	6
↘ Permanent grass and meadows	7	15	1	19	26	28	69	21	19
↘ Fallow	7	10	11	1	3	6	-	0	1
Livestock (head/ha)									
↘ Dairy cows	0,14	0,13	8	0,21	0,18	0,14	-	0,22	0,15
↘ Pigs	3,68	0,58	0,64	1,42	0,48	0,33	-	0,46	0,46
Consumption (kg N/ha)									
↘ Mineral fertiliser	74,0	51	74,2	68,2	-	25,9	-	55	26,3
↘ Manure	72,2	25,4	42,9	38,3	27,2	17,9	-	42	25,7
↘ Nutriets load	62,240	175,610	146,560	229,990	35,560	54,070	53,720	-	32,990
Nutrients load (t/year)									
↘ Nitrogen	53,000	121,000	79,000	152,000	28,000	59,500	107,600	-	20,400
↘ Percentage (%)	8	19	12	24	4	9	17	-	3
↘ Phosphorus	1,520	3,730	3,490	10,240	1,240	2,800	4,070	-	790
↘ Percentage (%)	5	13	12	36	4	10	14	-	3
Level of sewage treatment (%)									
↘ Primary (sedimentation)	2	0	0	2	33	2	0	-	2
↘ Secondary (chemical precipitation)	50	6	0	35	6	35	50	-	34
↘ Tertiary (biological filtration)	0	86	80	34	18	33	0	-	34

↑ ***FIG.4*** ***CROP TYPES AND NUTRIENTS LOAD*** (Redrawn from Krug *et al.*, 2015)
Not only is the proportion of arable land very different from a country to another, but also the amount of Nutrients that are released from industrialized agricultural systems. Poland is by far the most polluting one with Scandinavian countries

BAŁTYK SEA
RESOURCE EXPLOITATION



↑ *FIG.5 MINERAL FERTILISERS* (Redrawn from Granstedt *et al.*, 2004)
Output of inorganic fertilisers in agricultural products such as milk, meat and grain bread in the example of countries with highly industrialised agriculture

chemical products, usually nitrogen, phosphorous and potassium (see ***FIG.5***) linger in the soils and leak in the form of nitrates. This affects groundwaters for decades, but not only, it also has effects in the Baltic Sea aquatic ecosystems through the draining rivers. A study has showed that synthetic nitrogen fertilisers can still be found in soil organic matter even after 30 years (*Sebilo, 2013*) and may probably continue to leak in low amounts for 50 years. These chemicals are one of the main contributors of eutrophication in fresh waters.

ANIMAL PRODUCTION as the rest of agricultural production has become very specialised and mono-functional. Large scale production units of pigs and cows produce important emissions of ammonia resulting in the acidification of soils, waterbodies and also affecting human health. South-western Sweden, in the region of Kategatt has for a long time, received large amount of nutrients through run-offs, that has led to the introduction of maximal allowed amounts of animals per hectare nowadays.

BIOCIDES as fertilisers have been introduced in the 1960-70s to combat pests and fungus in crop fields. These toxic chemicals have for long been used without any controlled condition, important leaks to the soils have been observed in the eastern part of the basin where there aren't any management of these substances still nowadays.[8]

The region is expected to face an increase in agricultural production in the next years in Poland, Estonia, Latvia and Lithuania. Without a proper management of the question, the annual input of waterborne nitrogen and phosphorous will continue rising.[9] Large amounts of these chemicals have still been leaked in the Baltic Sea between 2001 and 2006, with an estimated 641,000 tonnes of nitrogen and 30,000 tonnes of phosphorous.[10]

↓ GEOGRAPHICAL SHIFT

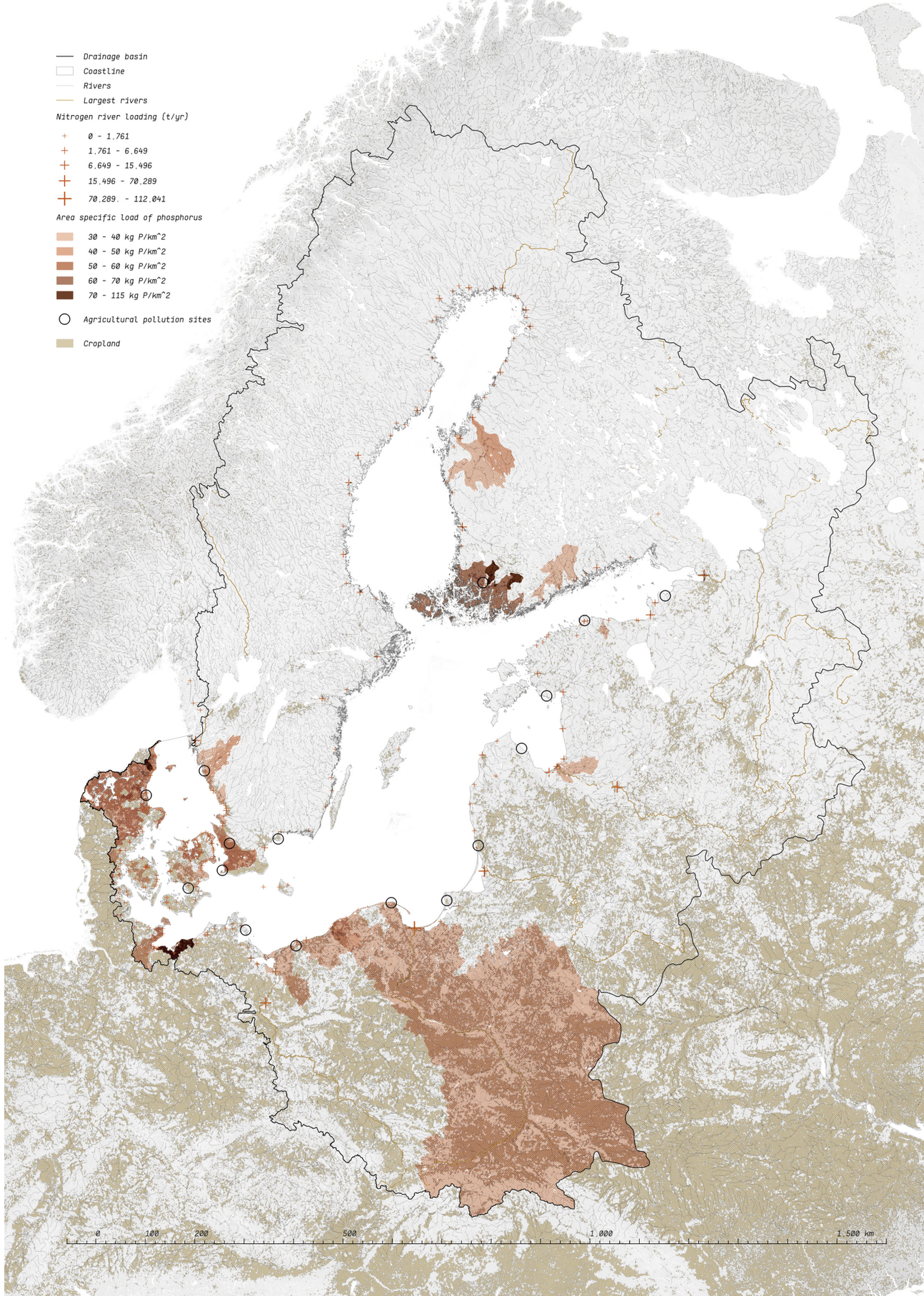
The region is facing an important climatic shift. Climate change does not only affect negatively as we could imagine, but the effects of the upcoming shift are reversing the actual productive balance. Northern Europe is expected to benefit from positive effects of climate change, for both summer and winter.[11] Recent changes have been observed in precipitations and temperature patterns and long period of drought, floods and storms will increase in the upcoming years. The climatic factors in the North will result in land-use potential openings in the future with an increase in productivity as well.[12]

Southern and Eastern parts of the drainage basin are going to experience more negative impacts of climate change. Longer drought seasons and floods will impact the production, adaptation is therefore an obligation. Future agriculture in the basin must therefore adopt agro-ecological techniques, diversify the production and improve water-management in areas where it is expected to improve irrigation systems.[13]

↓ *IMG.2 WETLANDS AND FIELDS* (Photo by Peter Gray)



MAP.1 (GIS data from HELCOM, EEA, Landsat) →



BAŁTYK
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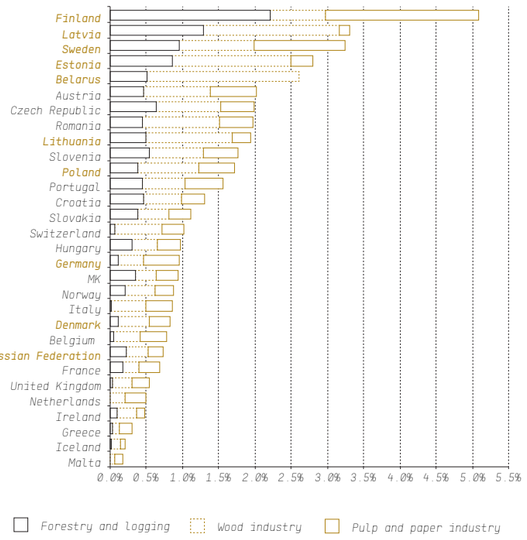
↓ FORESTRY IN SCANDINAVIA

As seen in the first chapter, when the glaciers receded only 10,000 years ago they shaped the soils in Sweden and Finland. Land, which is not agricultural land, has a low productive capacity in these regions, with a predominance of coniferous forest and relatively slow vegetation growth. This is explained by this short geological history and the fact that the countries are located so far north. As one probably noticed through the previous chapters, there is a reasonable variation in climate due to the large nouth-south extent of the countries. Forest land, particularly in Sweden and Finland, is characterised by a high abundance of lakes and wetland areas.[14] *"A short growing season and low nitrogen supply are the main factors limiting forest growth in the boreal forests, whereas low water availability periodically limits forest growth over large areas in the temperate southern parts of the Baltic Sea basin."*[15] In total, the area of forest and other wooded land in the Baltic Sea basin (excluding Russia) is approximately 82 million hectares. This area is dominated by two native species: Scots pine (*Pinus sylvestris*) and Norway spruce (*Picea abies*). Both of these species account for more than 70% of the total stem volume (with is about 11,290 thousand cubic metres).

For centuries, forests were a scarce resource, large areas of Sweden and Finland lacked wood to heat homes and cook food. One of the main factors, with the farmer's practice to burn the forest, was the increasing need for charcoal for an expanding iron industry. Today wood is also largely used for industrial purposes and adapts to a constantly evolving market and demand. Back then, iron production required large amounts of wood and charcoal. In the 1700s, Sweden monopolised 30% of the world's iron production. Obviously one of the main reason for this dominance was the easy access to wood. Slowly however, the role of Swedish iron production decreased when Russia entered the market with its consequent forest resources and when charcoal was inevitably replaced by black coal.[16]

Firewood and charcoal were not the only by-products of forests, in the medieval times the Baltic Sea region was the world's leader in producing tar. During the 1900s the region say an increase in timber production and planks for export and for the continuously expanding industry. This forest in northern Sweden and Finland were brought to use in order to make this shift possible. Rivers were used to float the wood from these isolated regions to the coast, where sawmills and ports were located. Through this booming economy, wood production in Sweden practically doubled from 20 million cubic metres in 1850 to 40 million cubic meters in 1990.[17] However, most parts of southern and central, as well as large parts of northern Sweden, were rapidly deforested. Laws had to be enforced to put a stop to the uncontrollable purchase of land and the logic of cutting without replanting. This obviously led the lumber companies to move more to the east and south, in Finland, Russia and the Baltic states, where history quickly repeated itself.



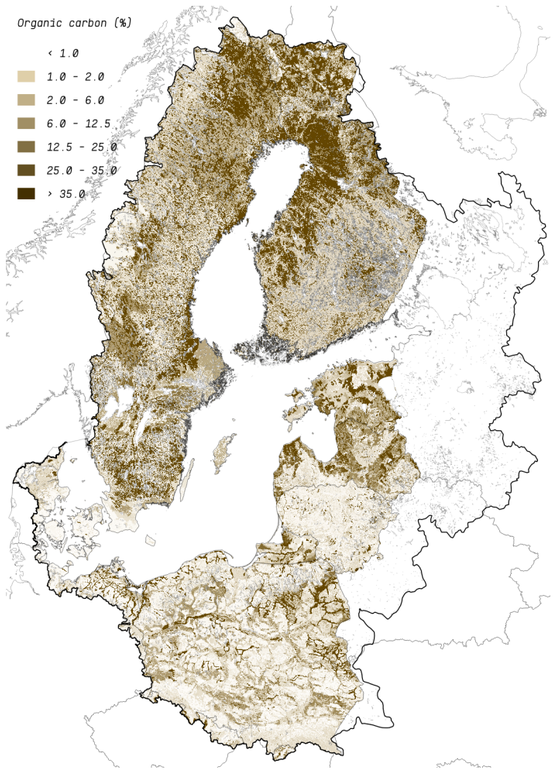
↑ *FIG.6 FOREST SECTOR AND GDP* (Redrawn from Michalak et al., 2011)
Contribution of the forest sector to GDP in selected countries (percent of GDP)

↓ *IMG.3 WOOD WAITING TO BE PULVERIZED AND PELLETIZED* (Photo by Christopher Boyer)

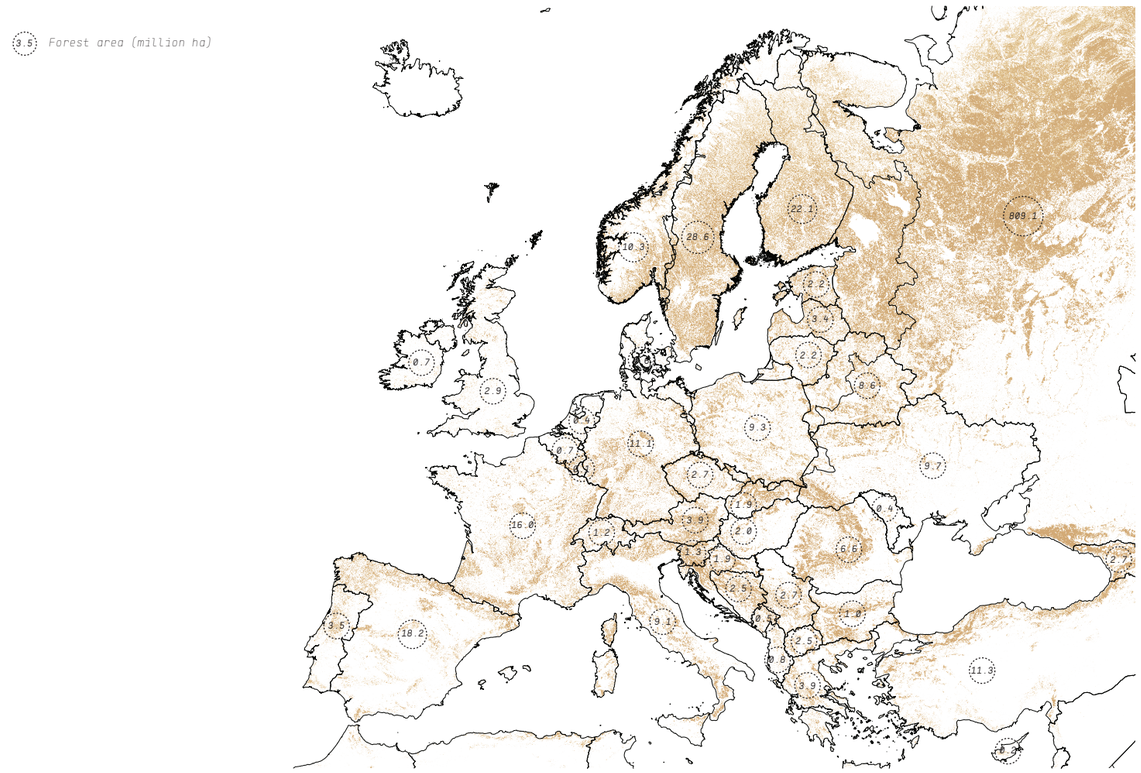




↑ *FIG.7 FOREST COVER IN THE BALTIC SEA REGION* (GIS data from HELCOM)
Sweden and Finland benefit from the most forest cover

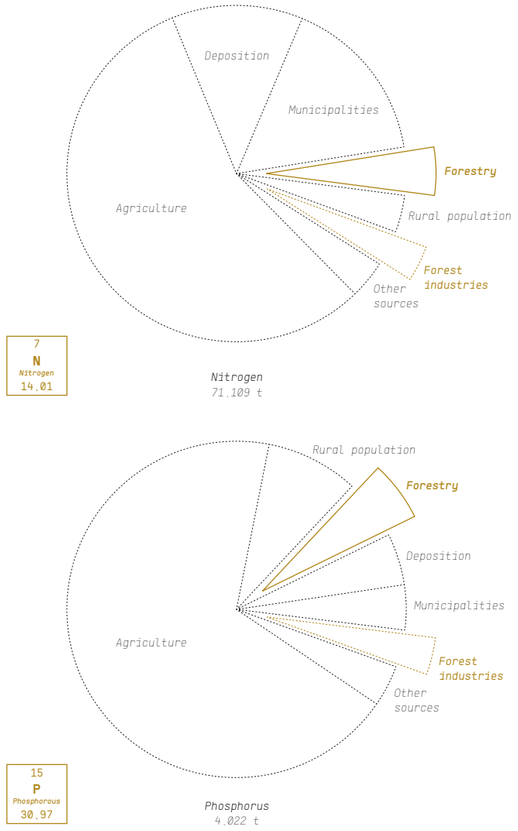


↑ *FIG.8 TOPSOIL ORGANIC CARBON CONTENT* (GIS data from HELCOM)
Tree diversity and density affect topsoil organic carbon content



↑ *FIG.9 SHARE OF FOREST AREA* (Redrawn from Michalak et al., 2011)
Forest area (million ha) by country in 2010

BAŁTYK SEA RESOURCE EXPLOITATION



↑ *FIG.10 WASTE WATER DISCHARGE* (Redrawn from Ylitalo et al., 2013)
Waste water discharge of phosphorus and nitrogen by emission source, 2012

In Russia, the industry did not establish as successfully as in Scandinavia or in the other Baltic states. Indeed, the fact that many rivers in Russia had their outlets to the North and the harbours were mostly clogged by ice for the major parts of the year, made the transportation of timber a complicated and costly affair. Since then, the forest of Sweden and Finland have been highly valued as natural resource assets.[18]

↓ VALUE AND CHANGE

Today, Sweden has about 22 million ha of forest land and Finland 20 million ha. Denmark, on the other hand, has only 0.5 million ha of forestry land. *"The trend for the standing volume of forest cubic metres is positive: in Sweden alone, the increment is close to 120 million forest cubic metres each year."*[19] In Europe, Sweden and Finland are the most active countries in producing and trading forest products.

On the global arena, both countries are also the second and third largest overall exporters of paper, pulp and sawn timber (close to countries like Canada). With new developments in fuelwood production, Sweden has become the world leader in wood pellet production and consumption. Back in 2005, the Swedes used more than 1.6 million metric tons of wood pellets for heating purposes and production of electricity. There is also a fast growing market demand for wood pellets on the global scale too.[20]

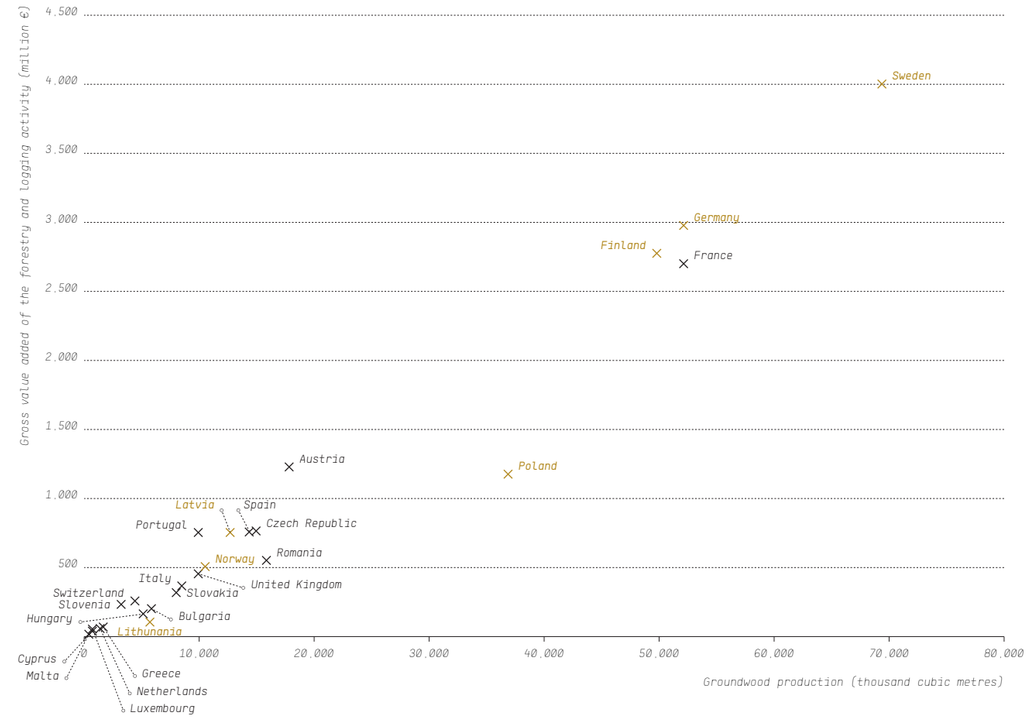
When it comes to ownership, large industrial companies own about 25% of forest land in Sweden and approximately 9% in Finland. Private owners are usually farmers or small family enterprises in both countries. Rural employment as well as rural identity depend mainly on forestry. For both countries, the productive goal is to ensure that the majority of forest land is used cost-effectively, with responsibility for efficient productivity and regeneration. In the case of Estonia, Latvia and Lithuania, all three Baltic states have a similar forest cover to that of the Scandinavian countries. Their species composition consist largely of Scots pine, Norway spruce and birch. These species comprise between 30-50% of the total land area (Estonia being more forested than the two others).

Since the 1990s, all three Baltic countries have witnessed a period of restitution of private forest land to its former owners, a privatisation process which is currently ongoing. Compared to its Scandinavian neighbours, the average private forest holdings are relatively small which makes them difficult to manage (essential forest operations are too fragmentised). Illegal logging has drastically declined since the beginning of the 1990s, new state forest laws and forestry strategies are now in place.

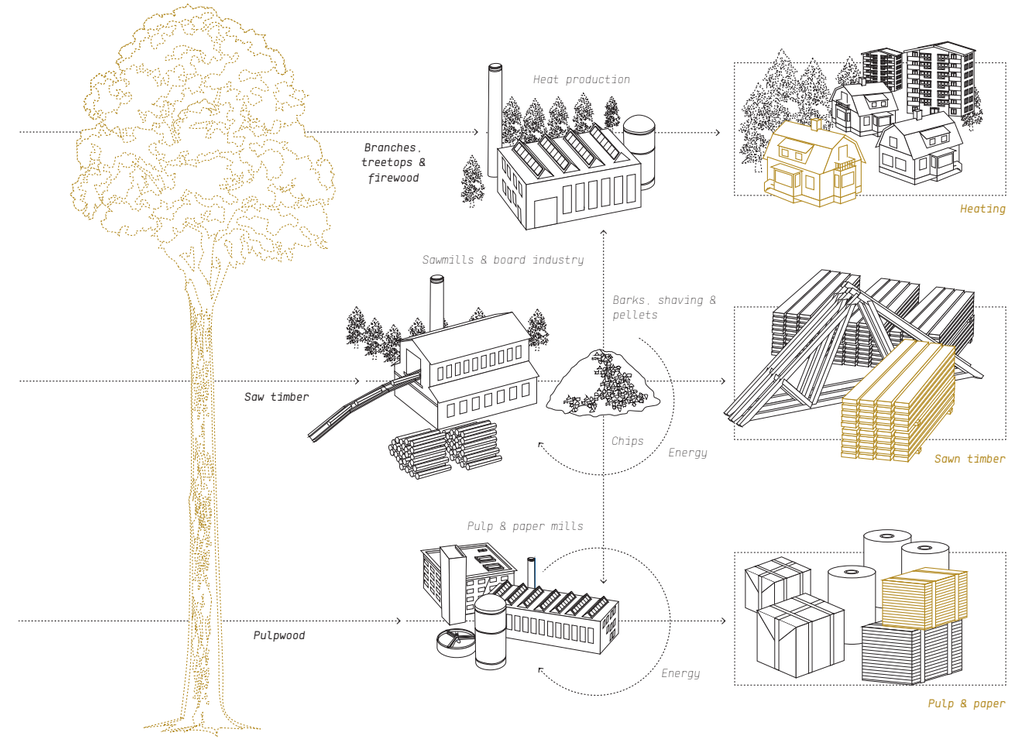
When the three countries joined the EU back in 2004, this led to the implementation of regulations on European and international standards. Today, export values of wood products, such as furniture, paper and assembled wooden constructions, are increasing along with imports of roundwood and sawn wood for further processing in neighbouring countries. Since wages are still much lower, the Baltic states are able to compete with big players, such as Sweden and Finland, in these industries. Of the three countries, Latvia has most export income and the country in which the forest industry has the greatest importance (about 14% of GDP). In the past 10 years, growing stock and protected areas have increased in Latvia. In total, about 4 million hectares of FSC-certified forest can be found in the Baltic states.[21]

Germany and Poland play also a big part in the export of pulp, paper and sawn timber (Germany is the fifth largest exporter). In Germany, about 31% of the total land area consists of forests. Poland follows closely behind at 30%. Germany also imports large quantities of wood: used as raw materials for its industries and as processed wood products. In Poland wood resources have growing steadily for the past 20 years, in 2006 the harvested volume made up 56% of the growth.

Today, the health of forests in south-west Poland is poor, mostly due to industrial activities and other pollution. Nitrogen deposits are usually higher in central Europe than in the North while sulphur deposits are still too high, making soils more acidic in Central Europe. What's important to keep in mind is that higher levels of nitrogen levels in soil and water make trees more susceptible to pathogenic fungi, insects, frosts and collapse under wind or snow.[22]



↑ *FIG.11 ROUNDWOOD PRODUCTION* (Redrawn from Eurostat, 2012)
Roundwood production and gross value added of forestry and logging, 2012



↑ *FIG.12 FOREST RAW MATERIALS AND USAGE* (Redrawn from Thorén, 2008)
The various sub-sectors use different parts of the tree, and they exchange by-products. A large proportion of the by-products are also used as biofuel

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↓ IMPACTS

Due to the ecological shift and industrial landscape of the Baltic Sea basin, the northern part may lead to substantial yield increase in forestry resources, while in the southern part, adaption may be required to counter deteriorating conditions. The ecological shift affects the productivity and vulnerability of forestry systems mainly through changes in precipitation, temperature systems, and changes in the frequency and intensity of risk factors (such as droughts, floods, storms and pest infestations). Simulations show that rising temperature could improve tree growth in the northern boreal zone. Changes in precipitation are unlikely to have a major effect on growth at these latitudes. However, in the south of the Baltic Sea basin, tree growth is heavily water limited. *"Here, an increase in temperature but without an increase in precipitation could further exacerbate the water deficit and thus decrease growth."*[23]

In the economical perspective, the forestry sector remains and will continue to remain important in the local economies of Northern Europe, where it contributes 2.1% to the regional GDP. The forest industry is of particular importance for the economies of Latvia, Finland, Estonia and Sweden, where it can account for up to 6% of the national GDP. However this needs to be weighted with a more hidden and negative aspect of these flourishing trends: the paper and pulp mill industry is a polluting one. These industries are demanding on water, energy and chemicals (the mills make extensive use of chemicals – some 2.8 million tonnes per year). Emissions of nitrogen and sulphur from this sector is quite high and is often found next to the rivers and lakes in their immediate surroundings. *"For many Forest industry companies, soil decontamination has become an environmental issue that calls for considerable effort. The contamination has been caused by on-site activities a long time ago, with technology and environmental legislation of that time."*[24] Production of pulp and paper is energy-intensive and the use of energy generally affects the environment and the climate. Today, 90% of the fuel used by the forest industry is bioenergy, which does not produce net emissions of carbon dioxide. Various regulations have been implemented in order to control, survey and collect information regarding those industries.[25]

↓ *IMG.4* ***PULP AND PAPER MILL IN OULU*** (Photo by Estormiz)



MAP.2 (GIS data from HELCOM, Landsat, University of Maryland) →



↓ METALS IN NATURE

Metals are found everywhere in the ground and the lithosphere. They are not homogeneously distributed along planet Hearth though. Ore deposits in high concentrations that are commercially exploitable are considered as anomalies. They correspond to only a minor amount compared to what is to be found in common rocks, sediments and usual soils, but are on the other hand very hardly exploitable.[26] Generally found as compounds (composite) and ions (electrically charged atoms), metals are naturally present in alsmost all living organisms. Several of them are even essential to some biological functions (see ***FIG.13***)

Living organisms such as plants and animals get their needed amounts of metals for their biological functions through water or food. This natural cycle can't be connected in any way to the situation regarding organic environmental pollutants. These are entirely artificial and they do not have any biological meaning.[27] There presence turned out to be severely damaging to the environment. Toxic heavy metals such as mercury, lead and cadmium constitute one major category of threats to the environment. Even though they can be found naturally in some soils, most of the pollutions emanates from man-made excavations. It is important to understand the nature and magnitude of these geological sources in order to be able to distinguish metal loading contributions emanating from natural or anthropogenic sources.[28]

Metals have for a long time played a fundamental role in the development of societies. The situation has drastically evolved from the first premises to the actual industrialised situation. The average amount of metals a household owned in the mid 19th century was around 8 to 10 kg mainly as jewellery and utensils. These relatively low amounts have drastically evolved since the industrialisation. We now find metals everywhere from the construction of the house itself, kitchen machinery to cars.[29] We consume enormous amounts that are hardly comparable to what discussed previously. It is clear that the flow of metals has terribly increased. Metals take the third position in the large material flows after fossil fuels and macronutrients nowadays.[30]

↓ EXTRACTING METALS

Metal extraction or mining has always been an important industry in the Baltic Sea region. We can find mines that have been exploited for more than 1000 years. Swedish Falun copper mine has produced 2/3 of world copper in the mid 1600s and was considered being the largest of its kind in the world. It was recently classified as a world cultural heritage, and isn't therefore anymore in use. This example, among others, showed how serious point source of environmental pollution mines still are. Copper, gold, lead, mercury and zinc mines are considered to have the greatest impact on the environment worldwide.[31]

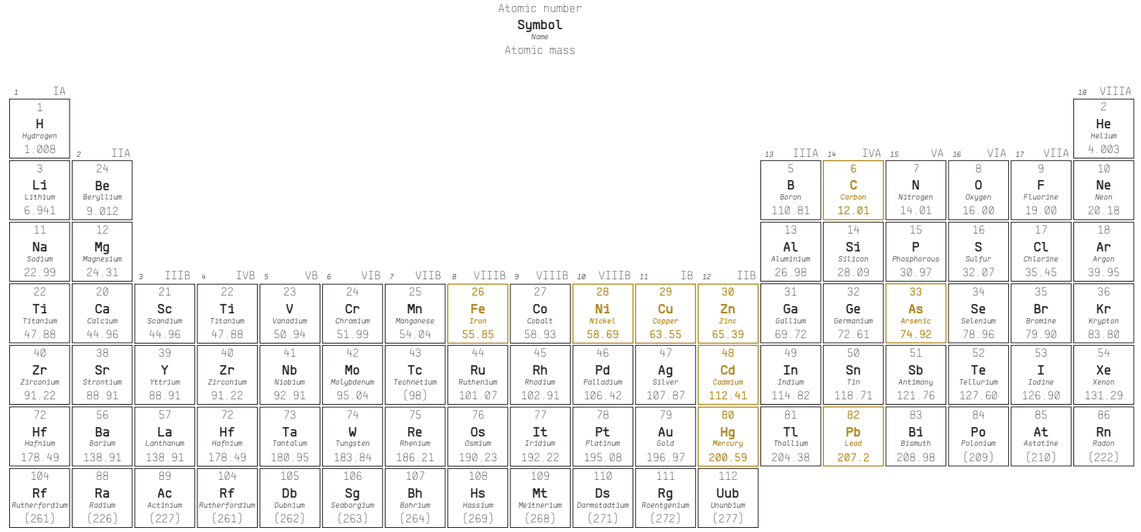
˚The mountains in the north and the south of the basin have been mined since historical times. Sweden has a long history in copper

Heavy metals	Symbol	*Biological role*	*Toxicity*	*Dischage sources*
↘ Iron	Fe	*Essential for all organisms*	*Toxic at drinking water >200 mg/l*	*Industrial plants*
↘ Copper	Cu	*Essential for all organisms*	*Toxic at high doses*	*Mining*
↘ Zinc	Ni	*Essential for all organisms*	*Toxicity low*	*Industrial plants*
↘ Nickel	Mn	*Essential to some organisms*	*Some compounds extremely toxic*	-
↘ Manganese	Mo	*Essential for all organisms*	*Mainly non-toxic*	-
↘ Lead	Pb	*Considered non-essential*	*Toxic*	*Lead mining, vehicles*
↘ Mercury	Hg	*Considered non-essential*	*Very Toxic*	*Industrial plants*
↘ Cadmium	Cd	*May be essential to some animals*	*Toxic*	*Zinc mining, industries*
↘ Chromium	Cr	*Essential to some organisms*	*Cr^{6+} Highly toxic*	*Leakage from waste deposits*
↘ Arsenic	As	*Essential to some organisms*	*Toxic*	*Non-ferrous mining*

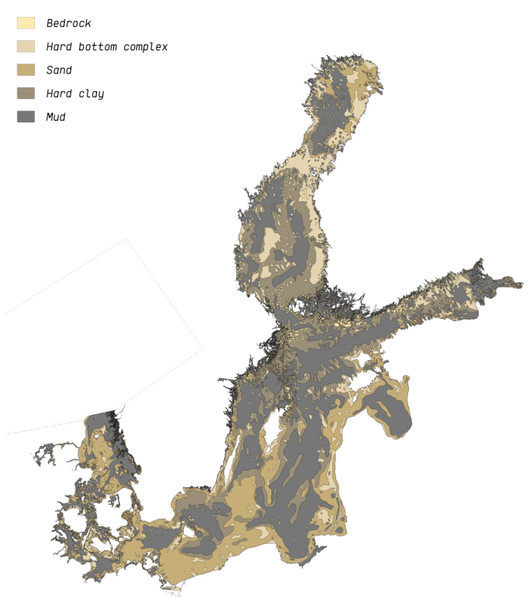
↑ *FIG.13 HEAVY METALS* (Partly redrawn from Selinus et al., 2003)
Most of these elements emanate from industrial processes, mining or waste leakage and are transported into the Baltic Sea through rivers or acid rains. Important concentration are highlighted in gold

↓ *IMG.5 HAMBACH COAL MINE, GERMANY* (Photo by Bernhard Lang)

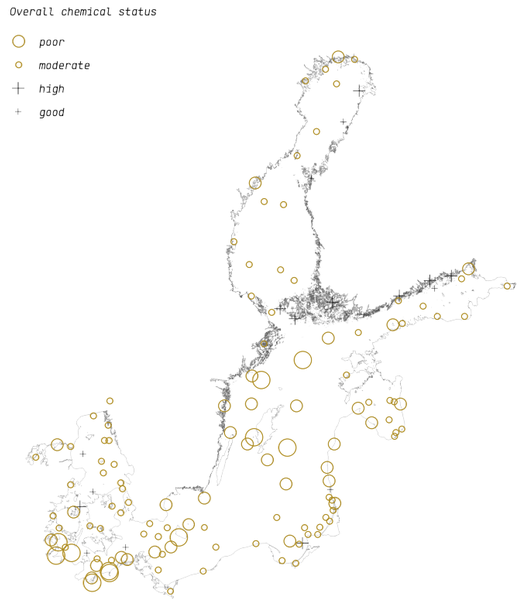




↑ *FIG.14 PERIODIC TABLE OF ELEMENTS* (Redrawn from North Carolina Public Schools, 2009)
Most of these elements emanate from industrial processes, mining or waste leakage and are transported into the Baltic Sea through rivers or acid rains. Important concentration are highlighted in gold



↑ *FIG.15 SEABED SEDIMENTS* (GIS data from HELCOM)
The concentrations of pollutants in sediment depend on the sediment type. Sediments act as a sink for hazardous substances as long as they are not disturbed physically (e.g., dredging or hydrographic changes)



↑ *FIG.16 OVERALL CHEMICAL STATUS* (GIS data from HELCOM)
The southern and south-eastern Baltic seabed is predominantly sandy, many other areas have high organic content in the sediment and thus a larger capacity to accumulate hazardous substances

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Metal		Concentration in soils	Metals mining	In extracted fossil fuels	Mining + fossil fuels
Abundant	Symbol	mg/kg	ktonnes/year	ktonnes/year	
↘ Aluminium	Al	72,000	18,000	34,000	0.05
↘ Iron	Fe	26,000	540,000	34,000	1.47
Scarce					
↘ Zinc	Zn	60	7,300	260	8.31
↘ Chromium	Cr	54	3,800	34	4.62
↘ Copper	Cu	25	9,000	55	23.83
↘ Nickel	Ni	19	800	570	4.83
↘ Lead	Pb	19	3,300	85	11.67
↘ Cadmium	Cd	0.35	20	3.4	4.42
↘ Mercury	Hg	0.09	5.2	10	10.86

↑ *FIG.17 GLOBAL FLOWS OF METAL* (Redrawn from Selinus et al., 2003)
Iron is by far the most mined metal of all. It is about 30 times more than any other metal. Both aluminium and iron are present in relatively high concentration in the soil and are non-toxic. All other metals are mined in amounts that are 2% or less of the two mentonned above

mining as showed with the Falun mine, but iron mining was also very important in this region during the 15th, 16th and 17th centuries."[32] Mining also began very early in southern Poland and in the Slovakian mountains, it then became very important in the 18th and 19th centuries when coal mining was increased"1 (*Håkanson, 2003*) Coal mining in southern and western Poland is very destructive in aras where it takes place. The environmental impacts not only include large amounts of heavy metals reads in the surrounding effluents, but also produces immense amounts of solid waste. The mining area known as the *Black Triangle* covers portions of eastern Germany, southern Poland and northern Czech Republic. Important amounts of heavy metals of sulphates and chlorides are transported into the Baltic Sea though the two large rivers Wisła and Odra.[33] This region is known to be one of the most contaminated in Europe, the soil contains abnormal amounts of heavy metals.

The extraction of metals requires movement of large amounts of other material, that are so called overburden but also clearing and draining the land in the surroundings. Large amounts of solid waste and contaminated water are produced in this process. One tonne of copper requires processing of about 800 tonnes of ore. The ratio between extracted product and solid waste flirts with an astonishing 1 to 799. The amounts are even higher when speaking of gold. For five grams needed for a ring, one cubic meter or 3-5 tonnes or ore are required. This is close to 1 million times as much solid waste as pure extracted metal. These numbers show that mining is still highly destructive for the landscape but that it also needs enormous amounts of energy to be processed. The extraction of copper as showed in the example of the Turów open pit mine is particularly destructive, it leads very often to large intrusions into the landscape, that are scaring and modifying large portions of the territory.[34]

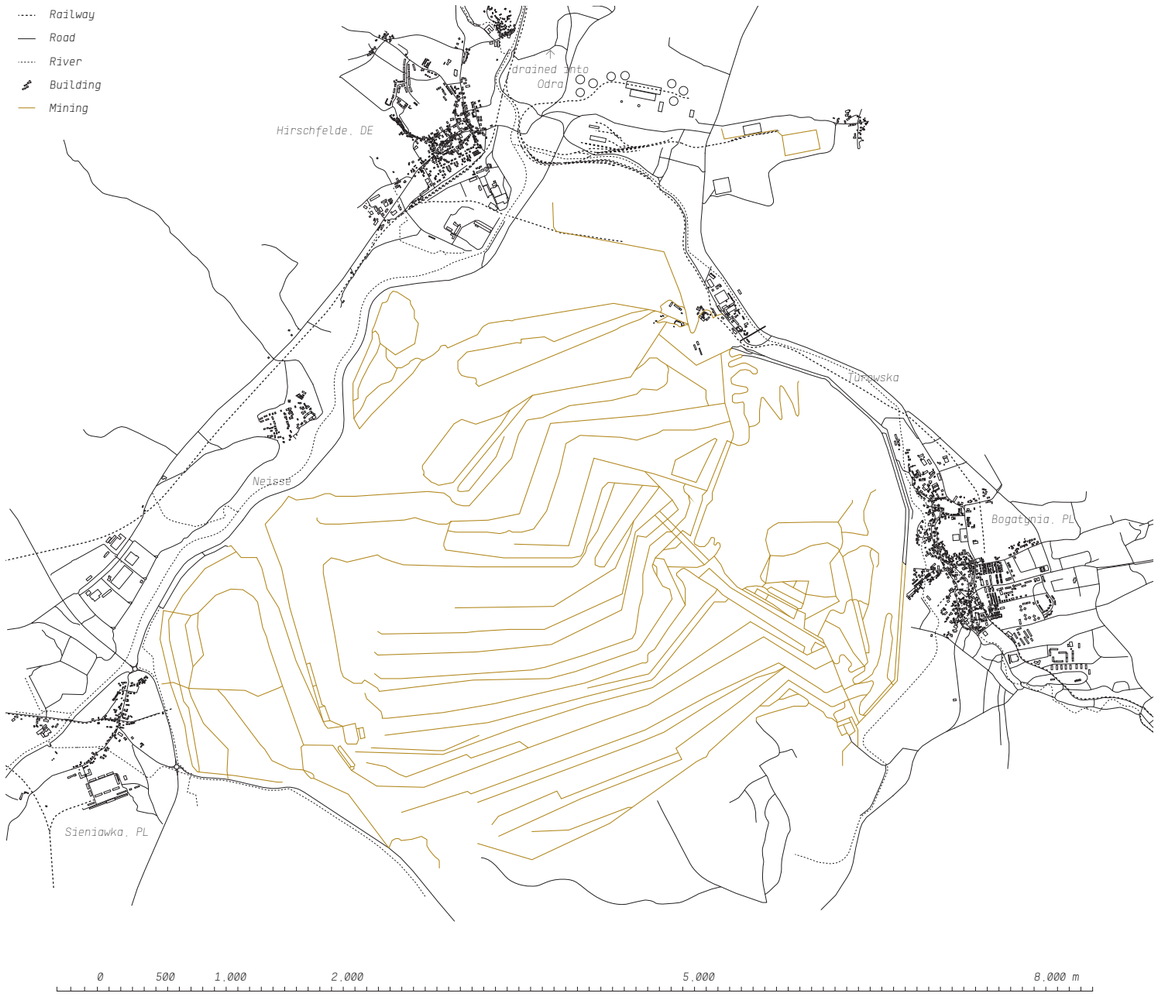
↓ MARINE WATERS POLLUTION

Metals being chemical elements, they never completely degrade. This means that they can't be broken down or metabolised to become harmless compounds such as water. They can be partly washed out, become waste or be stored in landfills but they still remain in the environment.[35] There are different sources of pollution starting from transboundary air pollution, fallout of metal-containing dust and heavy metals carried out by rivers towards the Baltic Sea. Riverine load of heavy metals and pollutants is by far the largest source of pollution, it accounts for nearly 90% of pollution transport. Almost all waters in Europe have an increased level of heavy metals compared to un-polluted waters nowadays and the Baltic Sea is now exception. Concentrations of metals such as copper, cadmium, nickel and zinc are a lot higher in the Baltic Sea than in other comparable marine environments such as the North Sea or the Atlantic.[36]

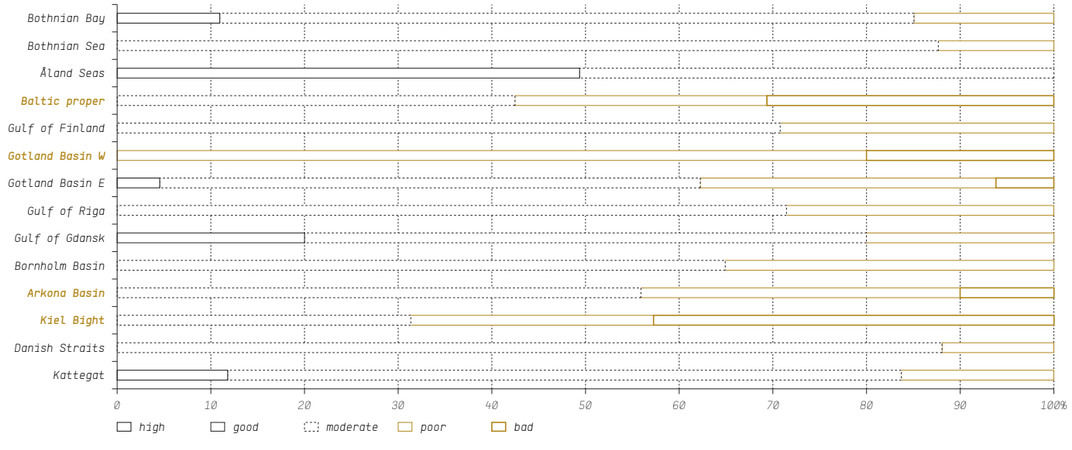
The most affected sub-basin of the Baltic Sea is the Gulf of Finland that receives most of its polluted waters from the Neva

↓ *IMG.6 STRIP MINING MACHINERY* (Photo by Bernhard Lang)





↑ *FIG.18 TURÓW COAL MINE, SOUTHWESTERN POLAND* (Redrawn from Google Maps)
The open pit mine located near Bogatynia is one of the largest lignite reserves in Poland, with an estimated reserve of 760 million tonnes in coal. The annual coal production of Turów is around 27.7 million tonnes. The mine forms a part of an area widely known as the "Black Triangle" due to its past heavy industrial pollution, covering portions of eastern Germany, southwestern Poland and northern Czech Republic



↑ *FIG.19 HAZARDOUS SUBSTANCES STATUS* (Redrawn from Sapota et al., 2012)
There is a tendency for the areas with the poorest status to be located near big cities or ports (Tallinn, Klaipeda) or to be estuarine areas (Ruotsinpyhtää in the Gulf of Finland, Kvädöfjärden in the Western Gotland Basin) or coastal sites (the Kiel Bay area). The areas near large coastal cities are usually classified as having a "moderate" hazardous substances status (St. Petersburg, Helsinki, Stockholm, Riga, Gdansk and Copenhagen)

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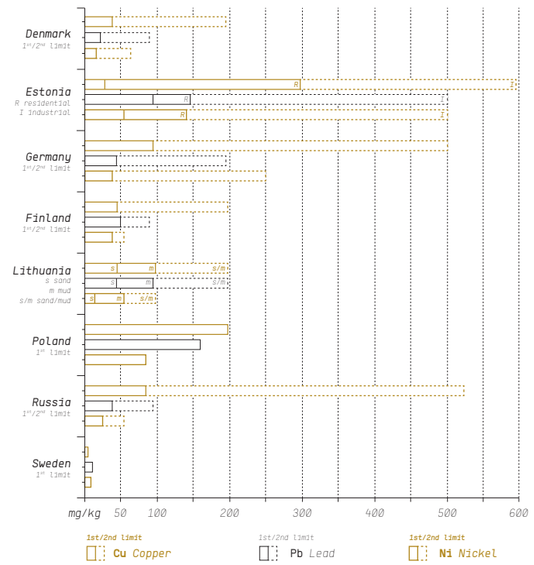
river draining all waters from industrial plants in Russia. The other heavily polluted area is the Bay of Gdansk where the Wisła river loads all kinds of heavy metals discharges. In 1995, this rivers which is draining 40% of Poland deposited 1,455 tonnes of zinc, 173 tonnes of lead, 177 tonnes of copper, 13 tonnes of cadmium and 67 tonnes of mercury. These pollutants originate from different sources but one of the main source of heavy metal pollution remains mining. The levels of metals are always higher near the shores than in deep sea.[37] When discharges in the waters of the Baltic Sea, heavy metals tend to deposit in sediment layers, they do not mix with the water. It is therefore more convenient to analyse metals in sediments than water itself because the concentrations are usually much higher. Sediment analyses can also provide information of metal levels in the past, that help us understanding the sources of metal pollution.[38]

↓ SEDIMENT DEPOSITS

Sedimentation contains different levels of concentration. It has been found that the upper sediment layers in the Baltic Sea contain over 10 times more cadmium and mercury than the deeper sediment layers. This demonstrates the continuous increase of anthropogenic load of these metals. For lead and zinc concentration is three to five times higher. For arsenic, copper and cobalt they are approximatively 1.5 to 2 times higher.[39] These concentrations also depend on the nature of the sediments themselves and the location. Southern and south-eastern Baltic seabed is mostly sandy, but many other areas have high organic content in the sediment and therefore a larger capacity to accumulate hazardous substances.[40]

An other problem that points out to be very important in the Baltic Sea region is that there are no uniform rules for the research methods as seen in ***FIG.20***. Sampling techniques, chemical analysis and depth of sediment layer differ from a country to another. Since there are no standardised system for limit values of pollutants each country has introduced their own.[41] Countries with important mining industries adapt their acceptance level of pollution release in the environment in order not to harm the economy and this leads to catastrophic effects in the whole of the Baltic Sea. There is a huge improvement possible in this direction. Standardised research methods and limits could improve the overall heavy metal discharge.

Limit values often give two limits. The first one is defined as a target value showing the limit of concentration of a dangerous substance in a soil in order not to be considered a threat to human health and/or the environment. Sediments are considered as contaminated when limits overpass the second limit, they therefore cannot be dredged. Some countries have introduced limit values separate for residential or industrial zones or even for the different types of sediment.[42]



↑ *FIG.20 LIMIT VALUES FOR TRACE METALS* (Redrawn from Sapota et al., 2012)
As you can see approach to determine limit values of individual pollutants is very different in the Baltic Sea region. Both ranges of limit values, counting methods and the used terminology are very different. Also, not all countries have specified limits for the same range of contaminants

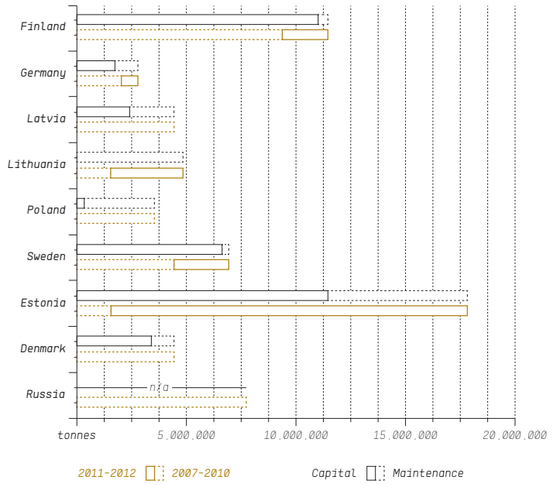
↓ *IMG.7 VATTENFALL'S WELZOW-SÜD MINE, GERMANY* (Photo by Luca Locatelli)



MAP.3 (GIS data from HELCOM, USGC, EEA, Landsat) →



BAŁTYK
SEA
RESOURCE EXPLOITATION



↑ *FIG.21 TYPES AND AMOUNTS OF DREDGED MATERIALS* (Redrawn from HELCOM MONAS, 2013)
All countries are expanding and maintaining their port facilities. Some such as the Baltic countries are in a large phase of construction of ports. There are importance variations from a country to another in regard of dredging volumes

↓ DREDGING SEDIMENTS

As for surface mining, dredging is an activity that consists of excavating underwater in shallow seas with the purpose of gathering bottom sediments.[43] The main purpose of dredging in the Baltic Sea consists of keeping waterways navigable, as we have seen that this particular sea is very shallow with an average depth of 50 metres. Dredging mainly happens along the coastline to maintain harbours as well as for the development of port facilities.[44] There are different types of dredging with different purposes:

CAPITAL DREDGING serves navigation. It ensures the passage of commercial vessels by enlarging or deepening the existing channels and/or port areas or creating new ones. This form of excavation usually involves hard material or high-volume of excavation, it is done using cutter suction dredgers or large trailing suction hopper dredgers (see *FIG.23*).[45] With these techniques, the lower end of the suction pipe is trailed at speeds around 1-2 knots across the seabed. This approach generates very important shallow furrows on the bottom sediment layer.[46]

MAINTENANCE DREDGING ensures that channels or construction works are maintained at their designed dimensions.[47] Port infrastructure usually coincide with important river streams along the Baltic Sea. These carry suspended sand and soil along with them as they flow towards the sea. The velocity of the water decreases when it enters the sea, non-floating materials then drop to the bottom of the channel. These sediments can be of different types: clay, sils, sand or gravel. In still waters and harbours, these sediments tend to settle out and build shallow spots on the bottom. Shoals are an important threat to navigation vessels since it causes the bottom to become shallower than what is shown on nautical charts. The vessels and their cargo can be damaged if they strike the shoal causing important environmental threats. It is therefore required to perform maintenance in navigation channels and harbours.[48]

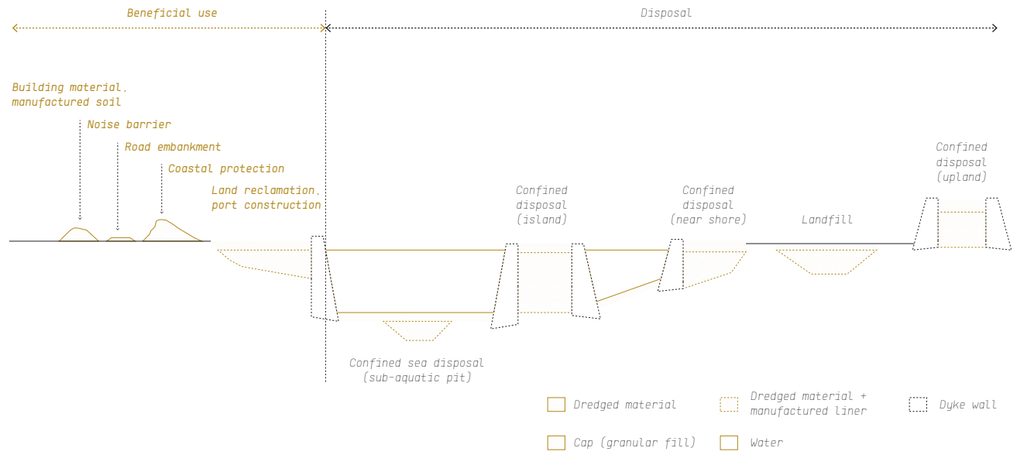
CLEAN-UP DREDGING is also more and more important in the Baltic Sea. It serves the purpose of removing contaminated materials (see MINING) that tend to be deposited on the bottom layer of the sea.[49] All of these methods to handle dredged sediments also serve another purpose when excavated. They usually serve as material for land reclamation, beach nourishment or more generally construction material.

↓ ECOLOGICAL EFFECTS

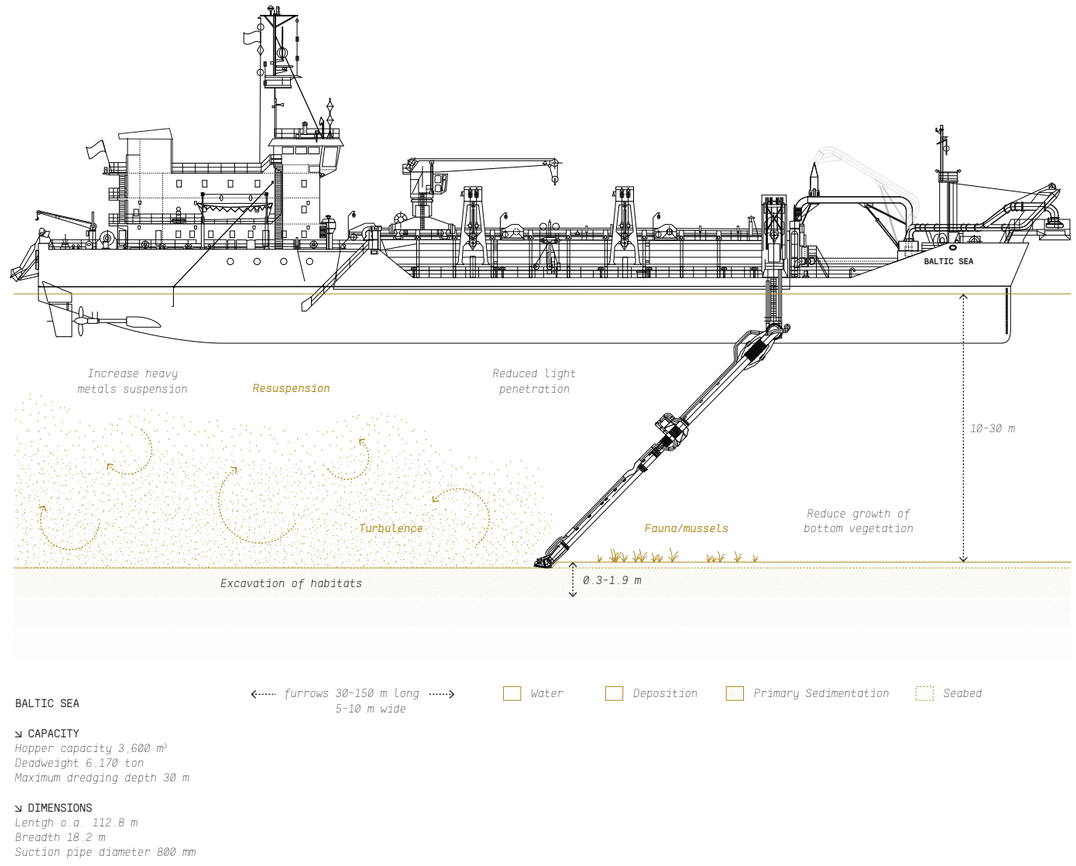
There are many observed effects that dredging creates on aquatic ecosystems and others that are supposed but not yet enough documented. The first and most visible effects on the environment are the physical ones: Cutter suction dredgers create large and long furrows. These may take up to a year to recover. The length of the furrows vary from 30 to 150 metres, and a width from 5 to 10 metres. Their depth also varies depending on the type of sediment and machinery that is used, it ranges from 0.3 to 1.9

↓ *IMG.8 DREDGING VESSEL* (Photo by US Army Corps of Engineers, Norfolk District)





↑ *FIG.22 HANDLING POSSIBILITIES FOR DREDGED SEDIMENTS* (Redrawn from Mousavi et al., 2013)
There are different handling types for excavated sediments. It is mostly used in landfills, construction of infrastructure and as construction material



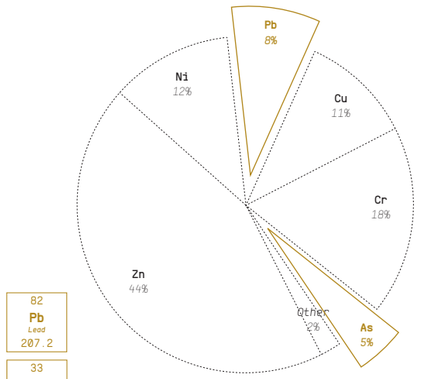
BALTIC SEA

↘ CAPACITY
Hopper capacity 3.600 m³
Deadweight 6.170 ton
Maximum dredging depth 30 m

↘ DIMENSIONS
Length o.a. 112.8 m
Breadth 18.2 m
Suction pipe diameter 800 mm

↑ *FIG.23 TRAILING SUCTION HOPPER DREDGER* (Partly redrawn from Jan de Nul Group)
Shows the effects and scale of this type of dredging

BAŁTYK
SEA
RESOURCE EXPLOITATION



↑ ***FIG.24*** ***DREDGED HEAVY METALS*** (Redrawn from *HELCOM MONAS, 2013*)
Main contaminants disposed at sea with dredged material for 2012. Other consists of Cd, Hg, PAH9, PCB7, TBT, TPhT. Oil products, Mn, V, Co, etc.. are not included in this diagram. A total of 17.845.241 was dredged in 2011

metres. With non-static dredging, but bottoms are perturbed on a larger scale but take less time to recover than static dredging. This specific type of excavation forms pits of diameters from 20 to 70 metres with an average depth of 4 metres (see ***FIG.23***).[50]

In both types of dredging, there is in increase in turbidity that affects certain aquatic metabolism and interferes with spawning. As seen before (see **FISHING**) spawning usually takes place along coastlines in shallow waters, it is therefore important to control periods of spawning and allow suction dredging only in specific time frames. Many other species that live directly on the bottom layers of the seabed are also directly affected by dredging. Excavation of their habitats reduce the growth of certain species and this may affect the whole aquatic ecosystem. Since the Baltic Sea is very specific in terms of species variety and adaptability even a slight change affects the whole system.

Other effects of dredging are impulsive underwater noises which are an additional harmful factor for marine organisms.[51] It also suspends particules that were previously laying on the bottom of the Sea which affects water transparency and therefore the amount of solar energy bottom species need to grow.

↓ POLLUTANTS RELEASE

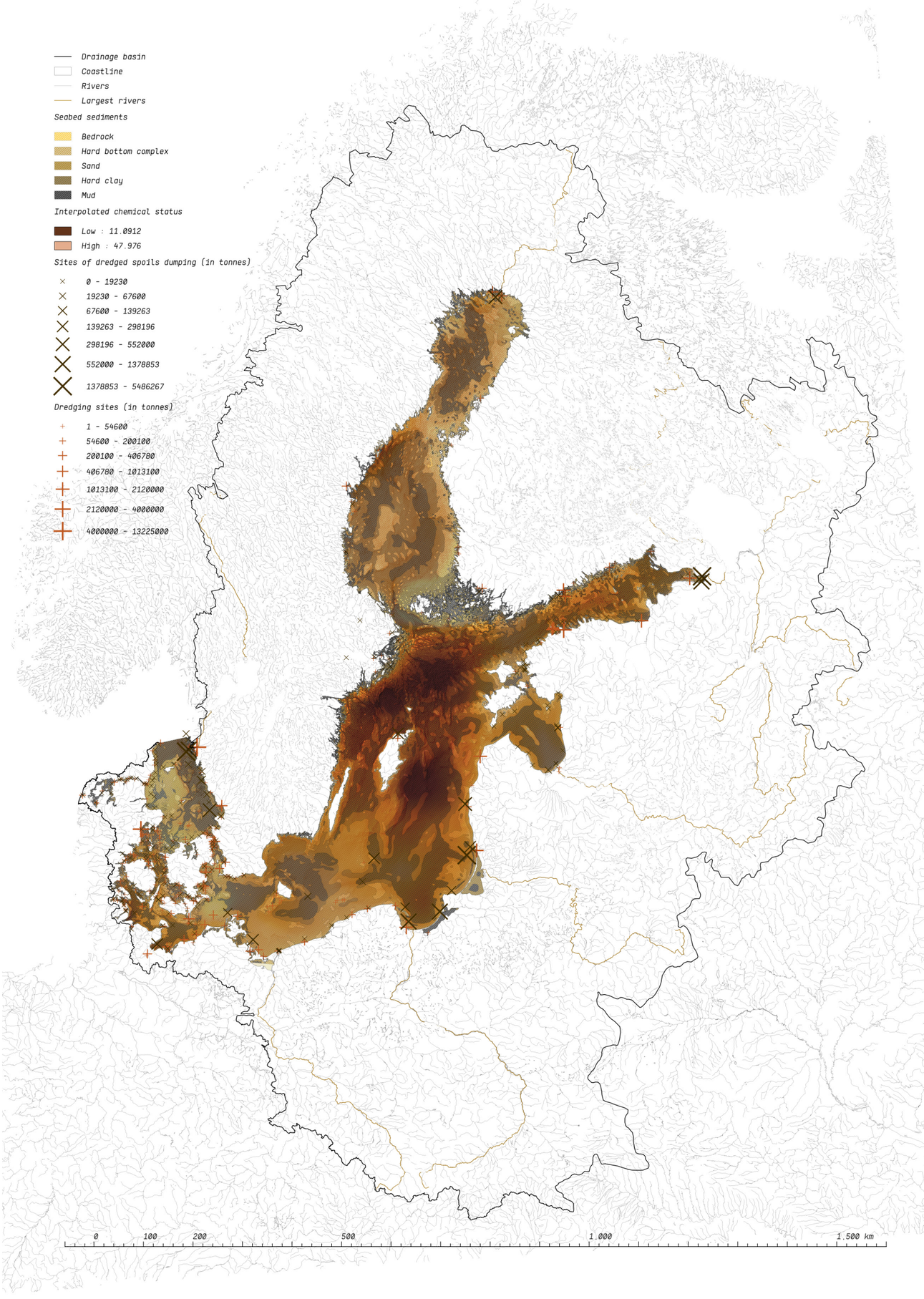
Sediments act as a sink for different substances such as heavy metals or biochemical products related to agriculture (see **AGRICULTURE**, **MINING**). As long as they are not disturbed these particles with heavier mass than water are disposed on the seabed. They never mix with water so they lay within sediments.[52] Physical disturbance creating by the activity of dredging resuspenses these hazardous substances and may increase their availability to be mixed in biological processes.[53] Some of these metals that result from several different industrial activities are extremely harmful for marine life.

Heavy metals (see ***FIG.24***) are still the main contaminant contained in dredged material.[54] These contaminated sediments must usually be treated before being used in road construction or landfills. There are emerging treatment technologies that make it possible to consider the use of contaminated sediments in construction.[55] The so called stabilization/solidifacation method can improve technical propertiese of the material while reducing its environmental impact. This remediation technology relies on the reaction between a binder and soil to reduce the mobility of hazardous contaminants. It enables a beneficial use of what is still nowadays considered as solid waste while saving costs and natural resources.[56]

↓ ***IMG.9*** ***STATIONARY DREDGING*** (Photo by Dave Rauenbuehler)



MAP.4 (GIS data from HELCOM) →



BAŁTYK SEA
RESOURCE EXPLOITATION

↓ OIL AND GAS EXTRACTION

There are four oil platforms in the Baltic Sea. They are located in the south-eastern part of the region in the oil fields of Kravtsovskoye and B-3. Of these four platforms, three are Polish (*Baltic Beta*, *Petro Baltic* and *PG-1*) and one Russian (*MLSP D-6*). The reserves in both oil fields are estimated to last until 2030. Interest in oil extraction in the Baltic Sea is increasing and drilling has confirmed that there is more oil to be extracted. Several hundred million barrels of oil are estimated to lie in the seabed southeast of Gotland (50 kilometres from the existing Polish oil platforms).[57]

In the deeper underground of the Baltic basin, important resources are mostly composed of oil, gas, geothermal energy and reservoir formations which can be used as storage sites for natural gas, CO2 or compressed air. In the 1940s oil extraction began in the area of Kinnekulleverken on Gotland, in the 1970s in the onshore area of Lithuania and the Kaliningrad district and in the 1980s in the Polish offshore economic zone. The Baltic basin remains a proven hydrocarbon province, about 40 hydrocarbon accumulations have been discovered. A vast majority of these accumulations are oil, but gas fields are also present in the offshore sector of Poland. In 1975, oil production began in the Kaliningrad district, where today 5-6 Mbbl per year are produced. In the second half of 2004, production from the offshore platform MLSP D-6 started. In Lithuania, onshore oil production initiated after the restoration of independence in 1991 and reached a peak production in 2004 with 2.8 Mbbl. In the Polish sector there is light oil and gas production, in Gotland (northern part of the basin) there is a small-scale oil production and in Latvia there are several small oil accumulations that were discovered.[58]

Based on statistics, the number of oil spills per offshore platform and year is 2.79. For example, the Russian MLSP D-6 platform contributes a yearly leakage of around 140 tonnes of oil, which are mainly caused by operational spills and discharges, failure of pipelines caused by anchors passing over the pipe, corrosion or breakage and blowouts from oil wells. The D-6 platform is located 22.5 kilometres away from the coastline and about one third of all oils spills reach the coast. Based on the duration and the size of the spill, the length of the polluted coastline can vary from 5 to 75 kilometres.[59]

↓ SHALE PLAYS

Following the North American shale gas production boom, geologists have identified within European basins dark shale formations with a potential for shale gas accumulations. The oldest of these shales are the so-called alum shale rocks, which have potential for unconventional oil and gas exploration. They are mainly found in Sweden, Denmark, Norway, Poland and Estonia.[60] *"The EIA has assessed that Eastern Europe may hold as much as 250 trillion cubic feet of shale gas, with Poland's Silurian Shale plays boasting 187 trillion cubic feet of that total."*[61]

↓ *IMG.10 SHALE RIG IN POLAND* (Photo by John Guillemin)

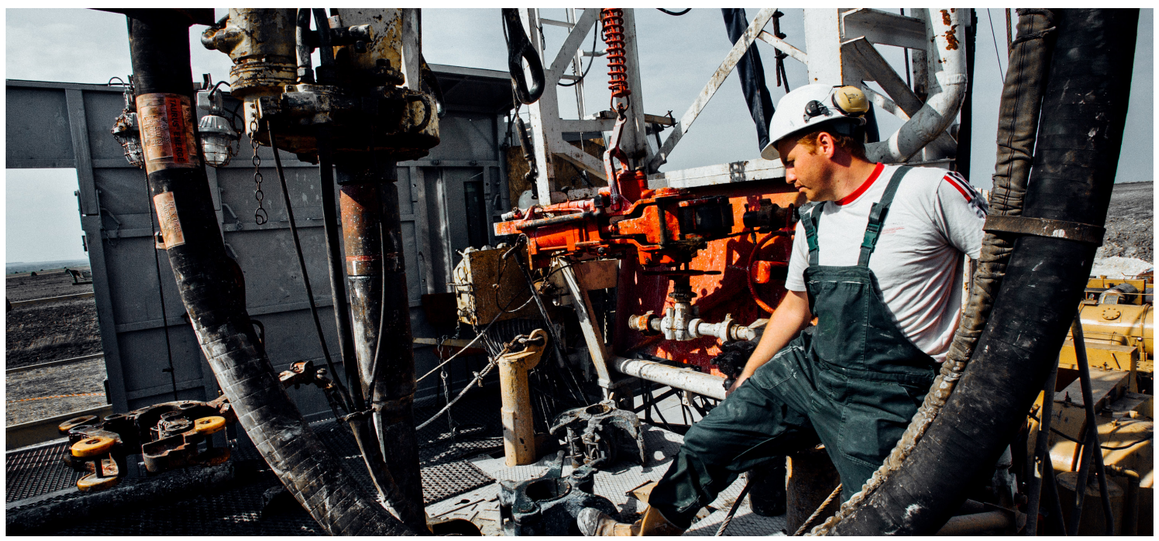
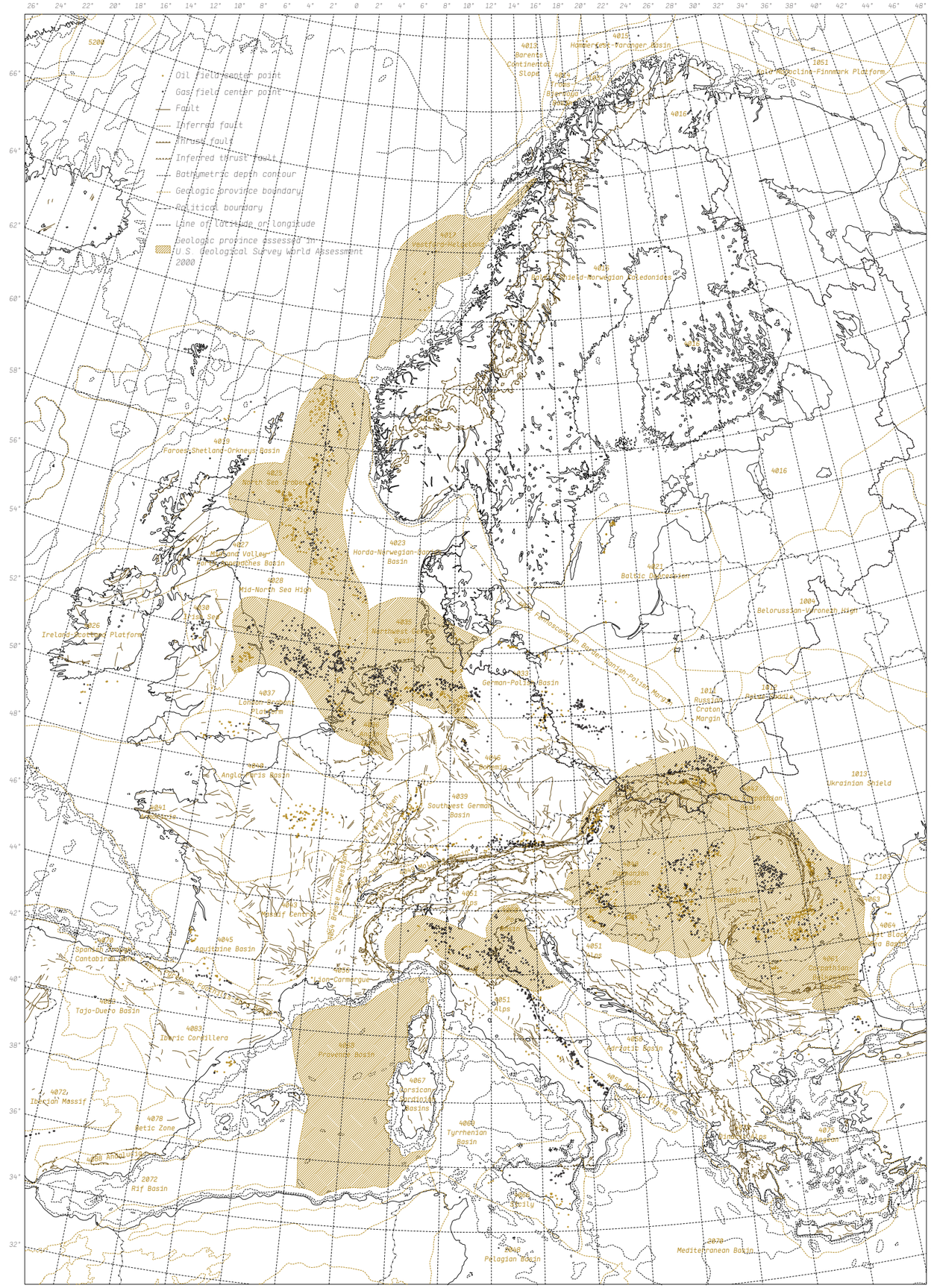
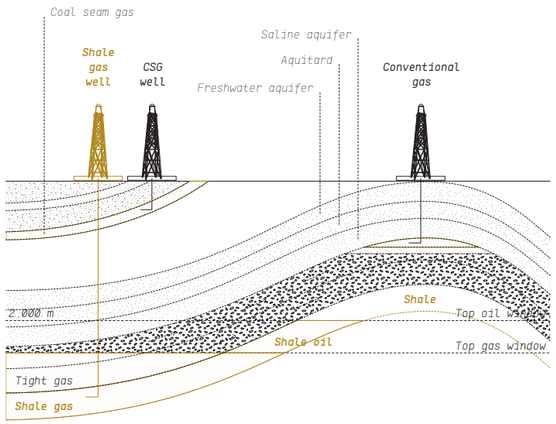


FIG.25 GEOLOGIC PROVINCES, OIL AND GAS FIELDS (Redrawn from USGC, 2002) →



BAŁTYK
SEA

RESOURCE EXPLOITATION



↑ *FIG.26 CONVENTIONAL/UNCONVENTIONAL GAS* (Redrawn from Cook et al., 2013)
Shale gas, sometimes together with shale oil, occurs in very fine-grained low permeability organic-rich sediments, such as shales mudstones and silty mudstones, usually in deeper parts of basins. Gas was formed when the organic matter within shales was subjected to high temperatures and pressures, but unlike in conventional deposits, the gas or oil remained within the impermeable shale

Poland's potential shale resources could reduce Europe's dependence on natural gas imports, especially when we take into account that Russia currently supplies 25% of Europe's natural gas. The future exploitation of these reserves remains uncertain but the 85 million people living in around these Shale plays will have a strong claim to energy independence as its projected reserves corresponds to about 300 years of domestic consumption.

Poland is considered the first country in Europe to have begun the exploration and development of shale gas resources. Although estimates vary quite a lot according to sources, it has been estimated that recoverable shale gas resources in Poland are between 3 to 5 billion cubic meters. Following these estimates, oil and gas companies have drilled more than 60 exploratory wells in Poland and performed 25 operations of hydraulic fracturing. Poland is the leader in Europe when it comes to the number of wells aimed at determining unconventional gas resources. However due to unstable environmental regulations and lack of support for the industry on both the national and European level, the pace of exploration is now slow. *"The number of exploratory concessions granted in Poland dropped to 80 as of early March this year from the record 115 in 2012."*[62] Hundred of companies, including *ExxonMobil* and *Chevron*, have drilled test wells in Poland, in hopes of grabbing a share of Poland's gas concessions. Although some of those early tests produced decent flows, others showed quite different results compared to what was produced in the US. Based on these outcomes, *ExxonMobil* concluded that it could not justify commercial production in Poland and that the poor flow made development unprofitable. However, the drilling of testing wells has not stopped, in 2011 22 exploration wells were started and 13 wells were completed by 2012. *"14 new exploration wells were planned for late 2012 and as many as 123 wells are planned by 2017."*[63] The Polish government strongly believes shale gas could help reduce the nation's energy dependency on Russia. It also believes it could help cut greenhouse gas emissions by slowly replacing the coal-based electricity generation industry. *"Poland's Treasury Minister said the country may be producing one billion cubic meters of shale gas per year by 2014."*[64]

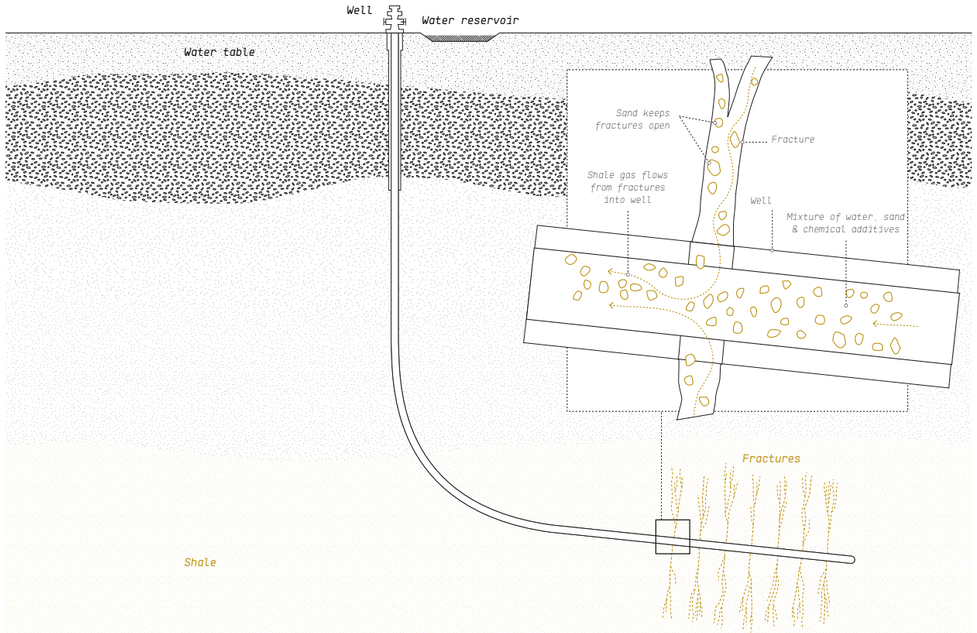
Finding sufficient water supply for shale gas drilling remains one of the key challenges. Approximately 17 million litres of water are needed per well and Poland has one of the lowest renewable water resources per capita in Europe.[65] Water used in hydraulic fracturing comes from surface waters (lakes and rivers), groundwater (wells and aquifers), municipal supplies and from wastewater from previous fracking activities. Effectively managing the volumes of wastewater generated is also a challenge. The composition of the mix used in shale gas fracturing is usually 99.51% of water and sand and the remainder consisting of chemicals that fulfil various purposes. This has an impact on the water quality by producing high TDS (Total dissolved solids) levels which poses problems in terms of water reuse in further operations and treatment to create freshwater.[66]

↓ *IMG.11 WEJHEROWO SHALE GAS CONCESSION IN POLAND* (Photo from PGNIG)





↑ *FIG.27 CONVENTIONAL/UNCONVENTIONAL GAS AND OIL* (Redrawn from Allingham et al., 2012)
Map showing shale gas basins, with existing shale gas drilling wells, combined with existing conventional gas and oil explorations



↑ *FIG.28 HYDRAULIC FRACTURING* (Redrawn from Bickle et al., 2012)
Fracturing fluids are injected under pressure to stimulate fractures in the shale. The fractures are propped open by sand contained in the fracturing fluid so that shale gas can flow out of the shale into the well

BAŁTYK SEA RESOURCE EXPLOITATION

Country	Electricity demand 2020 (TWh/a)	Offshore targets NREAP 2020 (MW)	Offshore installed 2010	Offshore yet to be installed
↘ Denmark	37.7	1,339	1,268 (incl. 400 C/C*)	71
↘ Estonia	10.9	250	0	250
↘ Finland	101.6	900	0	900
↘ Germany	561.9	10,000	3,007 (incl. 2,887 C/C*)	6,993 (699 in the BSR*)
↘ Latvia	13.9	180	0	180
↘ Lithuania	8.7	0	0	0
↘ Norway	115	Assumed small	2	0
↘ Poland	169.8	500	0	500
↘ Russia	n/a	Assumed small	0	0
↘ Sweden	154.6	182	133	49
↘ Total BSR	1,174	13,351	4,410	8,943

↑ *FIG.29 2020 TARGETS FOR OFFSHORE WIND* (Redrawn from Neubauer et al., 2012)
This table shows the expected offshore wind capacity in each country in accordance with the NREAPs, and similar estimates for Norway and Russia

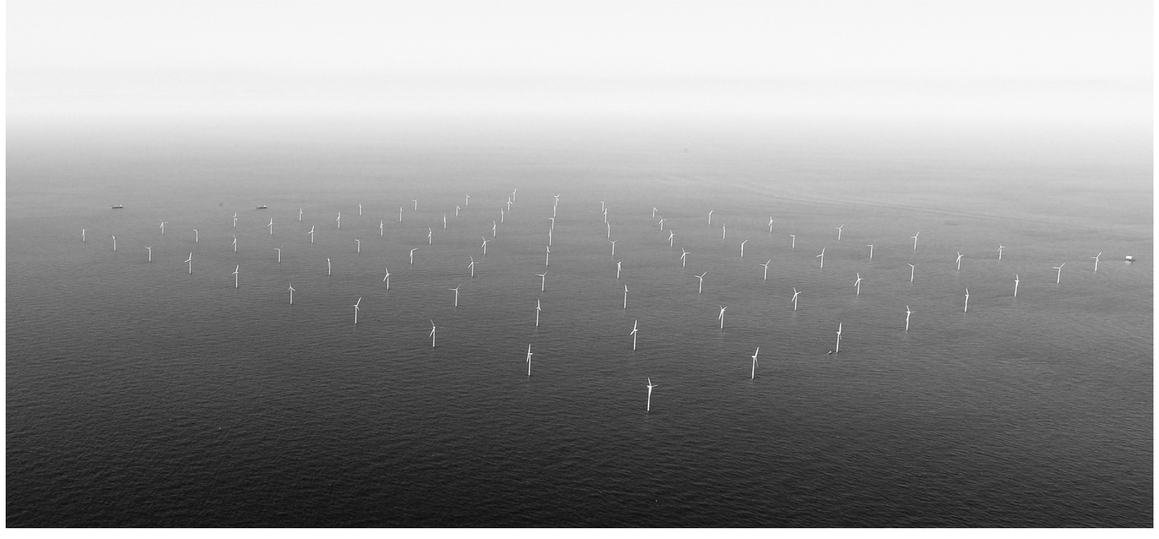
↓ WIND ENERGY

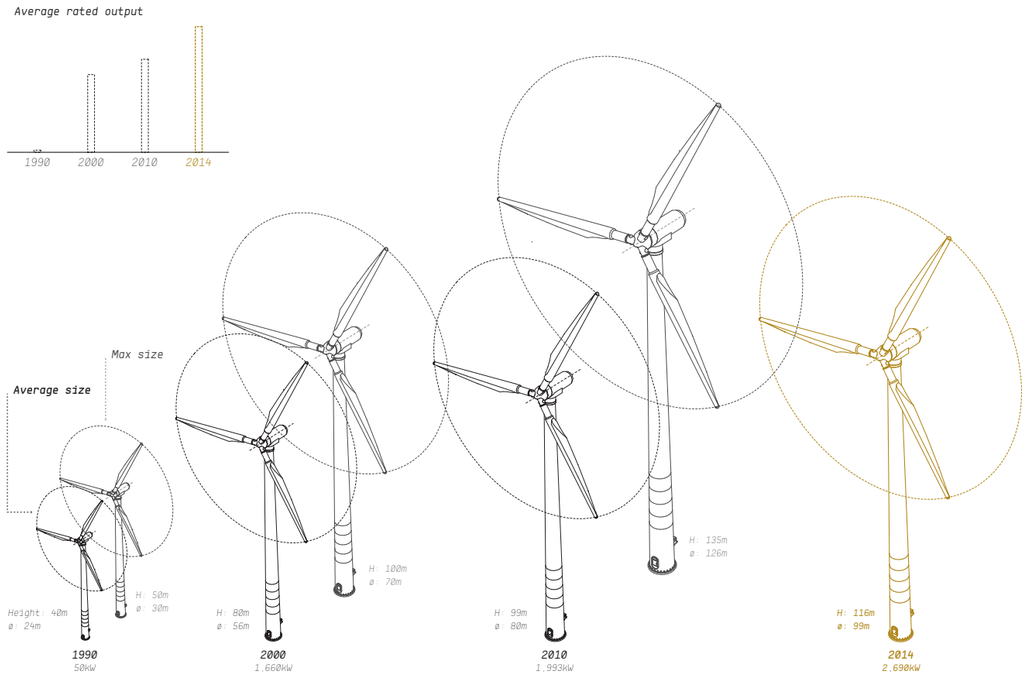
The Baltic Sea Region includes countries which differ greatly when it comes to the experience they have in the deployment of wind power, ranging from wind energy's home of Denmark through to the *sleeping giant* of Russia. The political strength of environmental policy, international directives, natural resources of both wind and competitive fuels, electricity market structures and markets are all factors that influence the different levels of progress between these countries.[67] The offshore wind energy sector has experienced strong growth over the past few years. In the last decade the trend has been visible in all of the Baltic Sea Region. With a total capacity of about 436 MW, there are currently 13 wind farms in the Baltic Sea, situated in Denmark, Germany, Sweden and Finland. Until 2020, there are plans for 29 new offshore wind farms in the region. According to the EU climate and energy package, the EU Member States have agreed to produce 20% of the total EU electricity demand from renewable sources by 2020. Of this 20%, 12% of the renewable energy should come from wind energy. The 29 new offshore wind farms have a planned total capacity of 10,843 MW, which is an increase of about 25 times compared to current production levels.[68]

The Baltic Sea region can be divided into six sub-groups of countries. First, there is the pioneering nations of Denmark and Germany. With high wind energy penetrations in their electric grid, they are now concentrating their efforts on increasing production offshore. Second, there is Sweden and Finland, which until a few years ago had only low levels of wind deployment, with a majority of their electricity coming from hydro and nuclear power. Recently, changes to support mechanisms have accelerated wind energy development activities, especially onshore. Next there is Norway, which is also a hydro power based electricity producer and benefits (like Finland and Sweden) from wood biomass resources. However it remains special due to its huge oil resources and its small Baltic Sea coastline south of the country. Fourth, Poland is a current hotbed of European onshore wind development. Rather than being blessed with strong hydro resources, Poland remains dependent on carbon intensive domestic coal reserves. Fifth, the countries of Estonia, Latvia and Lithuania have comparatively small electricity systems. Market liberalisation is ongoing and en efficient integration of their grids and markets with Europe remains a priority. Wind power however, has only seen limited deployment in these countries up to this day. Last but not least is Russia, which is not bound by any European treaties concerning renewable energy targets. Nevertheless it has drafted its own wind energy plans since it has a consequent untapped potential for both onshore and offshore wind power (only a relatively small part of that potential lies in the Baltic Sea).[69]

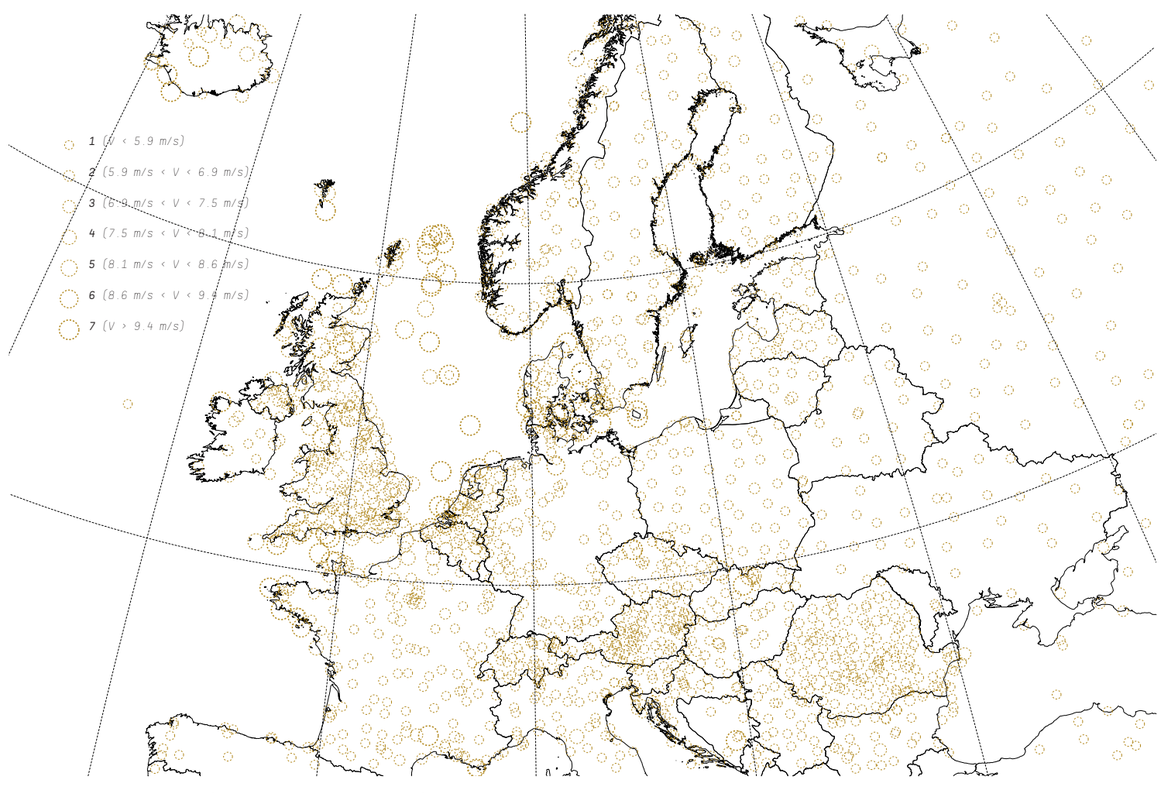
An important question with respect to a future strategy for offshore wind development in the Baltic Sea Region is the question of location: where to put the new offshore capacity that would lead to the fulfilment of the EU regulations like the NREAP

↓ *IMG.12 THE 160MW HORNS REV OFFSHORE WIND FARM* (Photo from Vattenfall)





↑ *FIG.30 DEVELOPMENT IN SIZE AND POWER OF WIND TURBINES, 1990-2014* (Redrawn from Morris et al., 2015)
Wind turbines 40 times more powerful today than 20 years ago



↑ *FIG.31 WIND CLASSES AT 80 M* (Redrawn from Archer et al., 2005)
Map of wind speed extrapolated to 80 m and averaged over all days of the year 2000 at surface and sounding stations

BAŁTYK SEA RESOURCE EXPLOITATION

(*National Renewable Energy Action Plan*) objectives? Up to date there are no supranational authority to decide in which areas and countries within the Baltic Sea Region the offshore wind capacity should be positioned.[70] Most current wind farms contain up to 20 turbines but the planned and projected wind farms will be larger in size than current farms. They are projected to contain up to 500 turbines. The Hiiumaa Estonian wind park, planned to be in operation by 2020, which will contain 250 turbines will have a total capacity of 1,000 MW. *"This park alone will produce more than double the current total capacity of the whole region".*[71] The sea area needed by a wind farm that produces 100 MW, based from the plans of three of the future offshore wind farms, is on average 10 km². *"Assuming that the proportions between size and MW is applicable for all wind farms in planned for the next 20 years, an area of about 2,500 km² will be needed to accommodate all planned farms in the Baltic Sea. This would mean that, including the existing wind farms, the wind energy sector will in 2030 cover an area equal to the size of the Estonian island of Saaremaa or the Swedish island of Gotland."*[72]

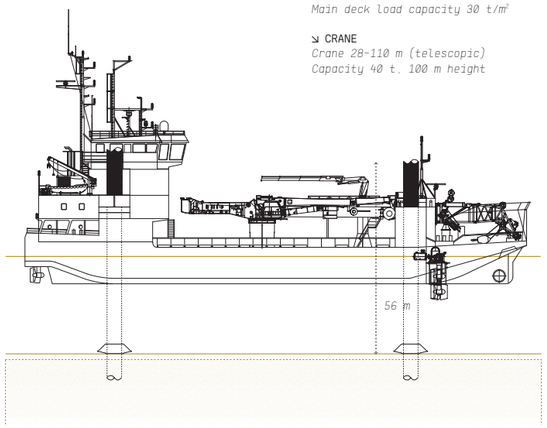
↓ IMPACTS

Wind farms use vast areas of the sea and will require better planning collaboration between the different Baltic Sea countries and industries. Indeed, large scale offshore wind farms are a source of conflict as they often collide with other interests such as shipping, fishery, extraction of sediment, laying of cables and pipelines and military activities. They also impact the seascape, which may affect tourism and recreation in a negative way. Since most wind farms occupy shallow sea areas, that are home to some highly sensitive ecological phenomenons, it may result in conflicts with nature conservation.

"It is important to note that the surface area wind farms occupy extends further than the physical structure. There is, for example, usually a safety zone of 500 metres around wind farms, with restrictions for shipping. There is usually also a buffer zone of 500 metres around the cables, which prohibits anchoring of vessels."[73] So far knowledge about the ecological impact of wind farms remains relatively low. According to research they can interfere with hydrological processes of the sea by altering transportation of sediments, water currents and the natural movement of drifting marine organisms. On the other hand, offshore wind turbines have also been observed to act as artificial reefs. They attract several marine species of flora and fauna and can sometimes act as sanctuaries for fish.[74]

↘ CAPACITY
Maximum payload 220 ton
Main deck area 430 m²
Main deck load capacity 30 t/m²

↘ CRANE
Crane 28-110 m (telescopic)
Capacity 40 t, 100 m height



↑ *FIG.32 WIND TURBINE INSTALLATION VESSEL* (Redrawn from DBB J/U)
Self-elevating offshore support unit for the offshore wind turbines construction

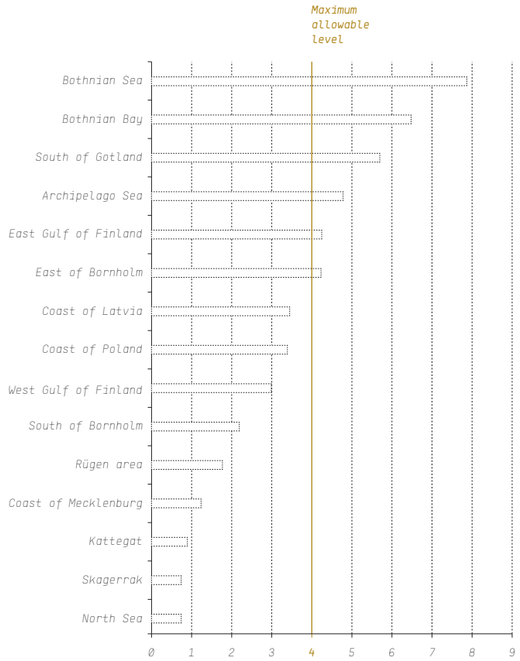
↓ *IMG.13 PETROBALTIC PLATFORM OFF THE COAST OF POLAND* (Photo from LOTOS)



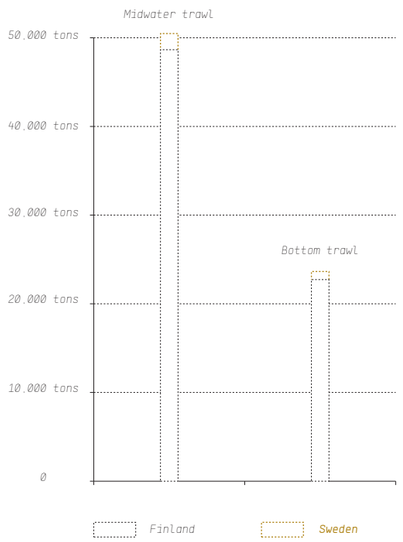
MAP.5 (GIS data from HELCOM, USGC, Landsat) →



BAŁTYK SEA RESOURCE EXPLOITATION



↑ *FIG.33 DIOXIN CONTENT IN HERRING* (Redrawn from Backer et al., 2013)
WHO tcdd/-teq, ng/kg wet weight



↑ *FIG.34 AVERAGE CATCH OF HERRING* (Redrawn from Backer et al., 2013)
Difference in catch, in tonnes, of Baltic herring between Finland and Sweden (through 2007 to 2009)

↓ LIFE IN THE BALTIC SEA

The Baltic Sea was and is still very rich in fish, in fact one of the richest in the world. Until the early 1990s it had a yearly catch close to 1,000 million tonnes. The Baltic Sea is special not least because of its fauna and flora. Since its formation about 7,000 years ago, or since its salt concentration was fixed to the levels of today about 3,000 years ago, its brackish water has blocked the immigration of a large variety of species. The Baltic Sea is thus *species-poor* but the species present are often in considerable numbers.

However, this makes the Baltic Sea more sensitive to pollutants. The ecosystems are often not robust enough since there are often no reserve species than can replace a damaged species. Today, populations of cod and salmon have been fished too intensely. The means to improve the situation include both regulation and environmental protection. Luckily the Baltic Sea environment has been studied for a long time now. Monitoring records cover the longest period of time of any sea. The effects on the Baltic Sea flora by excess nutrients (especially the coastal algal belt), by excess fertilisers from agricultural fields and exhaust from power production and car traffic, have been researched carefully.[75]

The fish's role as a consumer of plankton and benthic invertebrates and food for marine top predators plays a crucial part in the Baltic Sea ecosystem. As explained in the previous chapters, the Baltic Sea is the world's largest body of brackish water, in which both saltwater and freshwater organisms are found side by side. In some sub-basins like the Bothnian Sea, cold temperatures, long months of darkness and very low salinity make life challenging.[76]

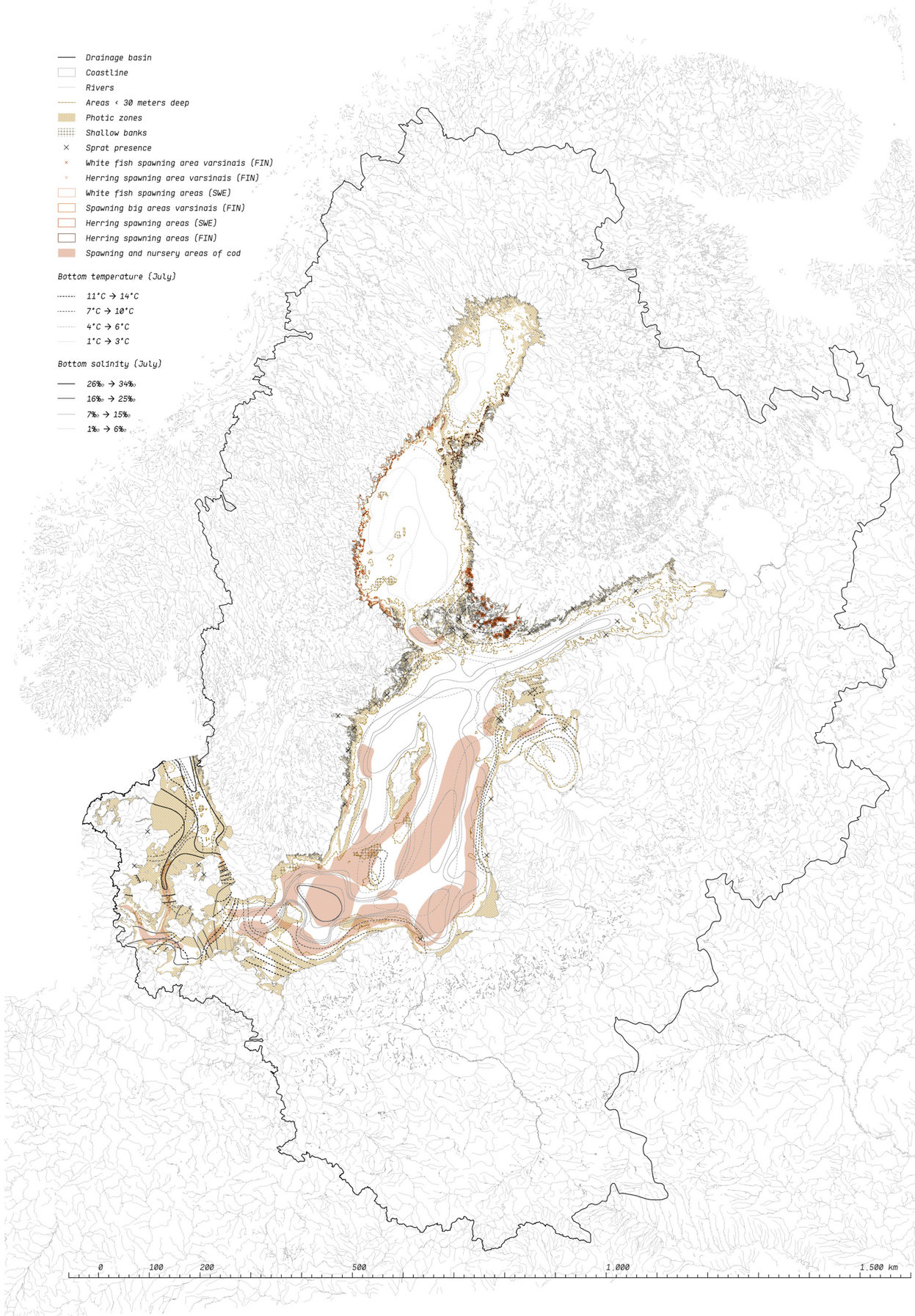
↓ PHYSICAL PARAMETERS

SEDIMENTS The bottom of the Baltic Sea is composed of various sediments (bedrock, hard bottom complex, sand, hard clay and mud). The sediments reflect what is happening in the water mass and on the bottom. They affect the conditions in the water via resuspension processes, so-called internal loading and by the fact that the animals living in the sediments play a fundamental role in the ecosystem. The sediment composition of the seabed is considered essential in marine landscape production as it is one of the primary parameters influencing the biogeographic distribution of marine benthic species. It also a primary component in shaping the physical structure and function of marine habitats. Areas with various sediment types ranging from mud, sand, gravel and boulders will contain higher number of species in comparison to areas with only one or two sediment types.

The difference of food availability in the different sediments is a key parameter in the geographical range of distribution of fish species. The ability to bury oneself in order to avoid predators and reserve energy is also another important factor. In recent years, the deterioration of sediments by drifting mats of filamentous algae and trawling activity, decreasing the availability of nursery habitat for juvenile flatfish, has been considered an increasing problem, especially in eutrophied areas.[77]

PHOTIC ZONE Light (*irradiance*) is a measure of the amount of energy falling on a flat surface. From an ecological point of view, available light is one of the primary physical parameters influencing and structuring the biological communities in the marine environment. It is the driving force behind the primary production by providing the energy for the *photosynthesis* (energy that is transferred to other organisms not capable of *photosynthesis*). The depth of the photic zone is usually defined, for benthic plants, as the depth where 1% of the surface *irradiance* (measured just below the water surface) is available for *photosynthesis*. Light is a crucial parameter in shaping the geographical zones of biological communities. Marine organisms in the Baltic Sea are therefore ultimately dependent upon the primary production from a relatively constrained zone of the sea surface layer.[78]

OXYGEN One of the many special properties that marine animals have is the capacity to extract dissolved oxygen from water. Oxygen can be dissolved in a concentration of about 10 milligrams oxygen per litre of water. Animals are therefore ably to *breathe* in the water. However if the oxygen content decreases thy may suffocate and die. Oxygen is usually not a limiting factor in the upper part of the water column, but may be at larger depths.[79]



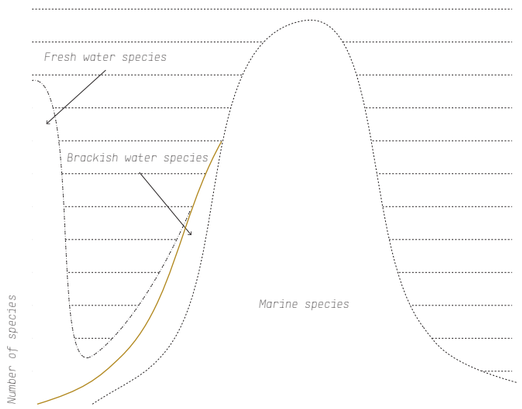
BAŁTYK
SEA
RESOURCE EXPLOITATION

SALINITY With its low salinity, the brackish Baltic Sea has a relatively low diversity of both flora and fauna. The number of marine species found decreases dramatically as one goes through the Danish straits into the Baltic Sea proper. They are 1,500 species of macroscopic animals found on the the Norwegian coast compared to the approximately 70 found in the central parts of the Baltic Sea. Of about 320 macroalgal species, some 90 remain the northern part of the Baltic Sea proper, the Gulf of Finland and the Bothnian Sea. Few species are capable of living and growing the Bothnian Bay. Due to low salinity levels, the proportion of freshwater species is high.[6] Species with floating eggs, notably cod, are especially negatively affected by the low salinity, and due to *eutrophication*, the low oxygen concentrations sometimes occurring in the deepest parts of the Baltic Sea. Indeed due to the low salinity, there is a decreased growth rate observed compared with the Atlantic cod populations.[80]

TEMPERATURE Temperature also plays a role in the life of the Baltic Sea. The annual insulation in the winter of the Bothnian Bay is about 30% and the number of degrees-days in the depth interval (mean 0 - 10 metres) is 65% of the value estimated for the southern part of the Baltic proper. The low salinity gradient is paralleled by a short productive season of only 4 to 5 months. In the far north of the Bothnian Bay there is up to 6 months of ice cover, while the productive season in the souther sounds and Kattegat is 8 to 9 months. In some instances temperature rather than salinity is the factor limiting any further penetration of marine organisms into the Baltic Sea.[81]

↓ SALMON

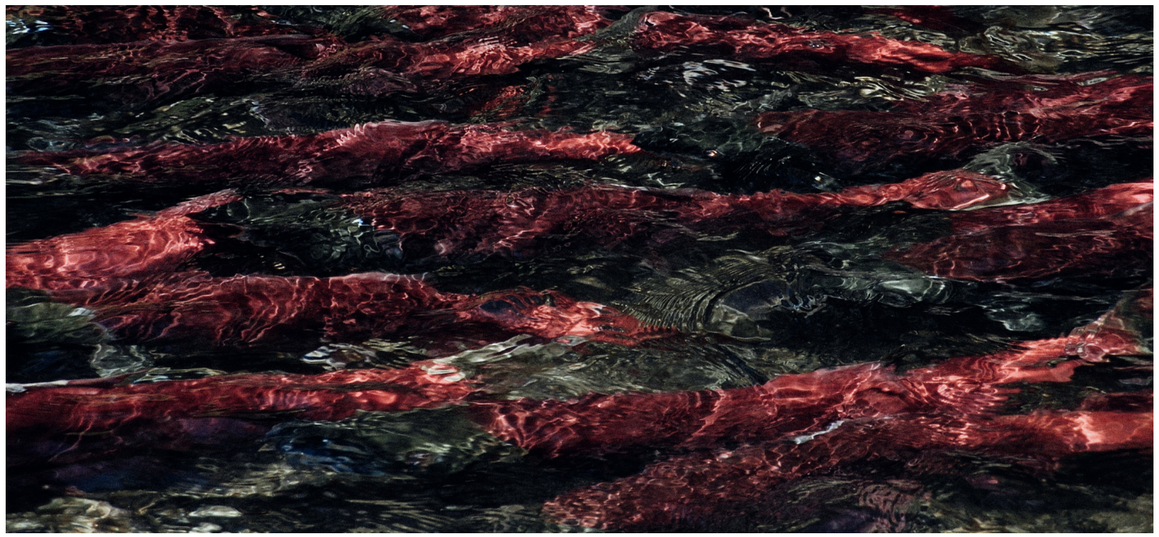
The population of salmon in the Baltic Sea belongs to the Atlantic salmon species. After hatching, the young salmon usually remains up to 5 years in the river, before migrating in May/June to spend up to 4 years in their feeding areas, largely in the Baltic Sea basin. In September/November they return to spawn in the rivers. The Swedish stocks of salmon are mainly native to the big rivers in the northern part of the country. At one point in history, some 50 Baltic Sea rivers accommodated spawning salmon populations. Since then an important factor has changed the game : the building of dams in connection with power plants from the 1940s (different categories of dams, from passable to non-passable, are represented on the map on the next page). It has reduced the salmon populations drastically. It has only been possible to keep a certain level of reproduction by establishing compensator hatcheries with mass rearing of smolts at each river. Smolts are then released into the river each year from theses hatcheries.[9] Mass rearing of smolt for release into blocked rivers has been accepted as a means of compensation for the loss of natural reproduction. About 90% of the yearly smolt production in the Baltic comes from hatcheries.[82]

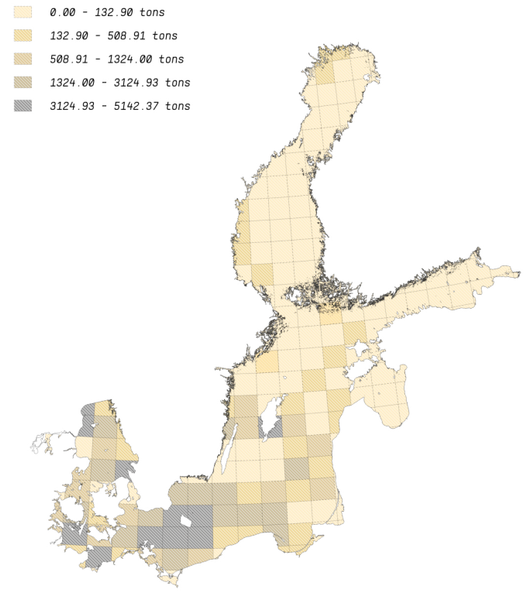


↑ *FIG.35 SPECIES DIVERSITY AND SALINITY* (Redrawn from Andersson et al., 2003)
Diversity, the number of species (vertical axis), in aquatic environments is critically dependent on salinity of the water (horizontal axis). The largest number of species is found in fresh water and marine environments of high salinity, while brackish waters are species-poor

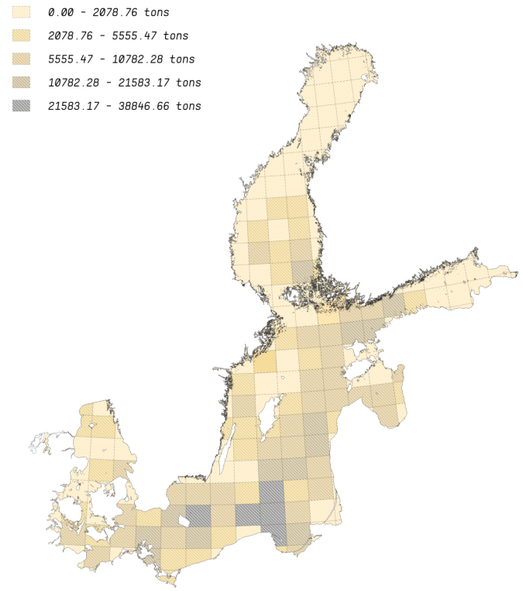
← *MAP.6* (GIS data from HELCOM, University of Helsinki)

↓ *IMG.14 SALMON MIGRATING UPSTREAM TO SPAWN* (Photo by Jennifer Griffiths)

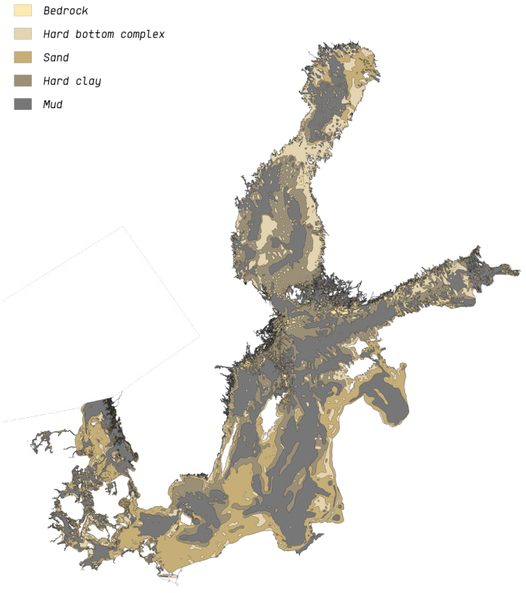




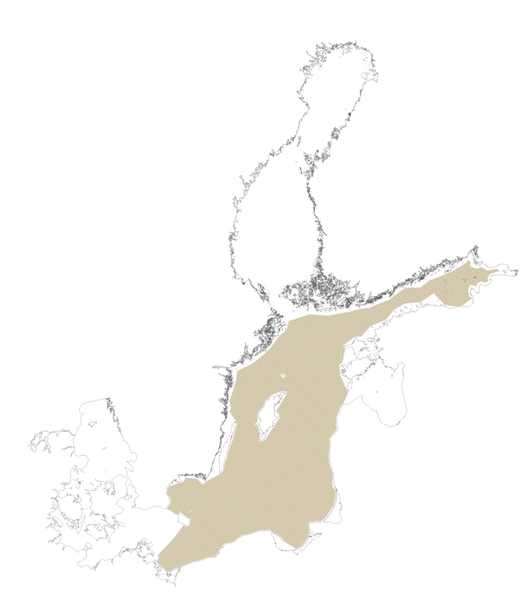
↑ *FIG.36 BOTTOM TRAWLING CATCH* (GIS data from HELCOM)
Catches are given per ICES rectangle as total values, all values are in tons



↑ *FIG.37 COMMERCIAL FISHERIES CATCH* (GIS data from HELCOM)
Catches are given per ICES rectangle as total values, all values are in tons

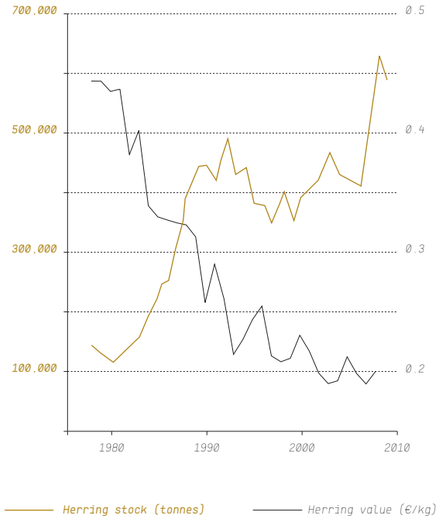


↑ *FIG.38 SEABED SEDIMENTS* (GIS data from HELCOM)
Seabed sedimentation of the Baltic Sea



↑ *FIG.39 OXYGEN* (GIS data from HELCOM)
Average oxygen debt below halocline

BAŁTYK SEA RESOURCE EXPLOITATION



↑ *FIG.40 STOCK AND VALUE OF HERRING* (Redrawn from Backer et al., 2013)
Variations in stock and value of Baltic herring through 1980 to 2008

↓ FISHING SECTOR

Fishing remains one of the most traditional activities at sea. The area covered by fishing activities in the Baltic Sea is hard to estimate. The Baltic Sea is a rich sea, it has traditionally provided it's surrounding population with a comfortable share of their intake of protein. Commercial fisheries are intensive in the whole basin, but fishing pressure remains especially high in the southern parts. Herring, sprat, cod and salmon are the most present species but some 20 other species are also important locally.[83] These three species make up over 90% of the total catch from the Baltic Sea.

Fisheries in the Baltic Sea are managed by the European Union and by national political decisions. EU allocates fishing quotas, and thus the less fish there are in the sea, the more sea area the fishing vessels will need to cover to reach their quotas. Simultaneously, the number of commercial fishermen and fishing fleets has considerably decreased due to overcapacity in the sector and shrinking fish population after several years of overfishing.[84] Denmark, Sweden and Poland are responsible for the largest cod catches, with Denmark who has one of the highest share of cod in Baltic Sea statistics. In comparison, only small amounts of cod are landed by Finland, Russia and Estonia. Among scientists, the suggested large catches of sprat and herring are relatively uncontroversial since their populations are relatively big. However, the increased catch of cod has been questioned. If a new stagnation period in the Baltic Sea water exchange emerges, there is risk that the cod stock may be badly overfished again.[85]

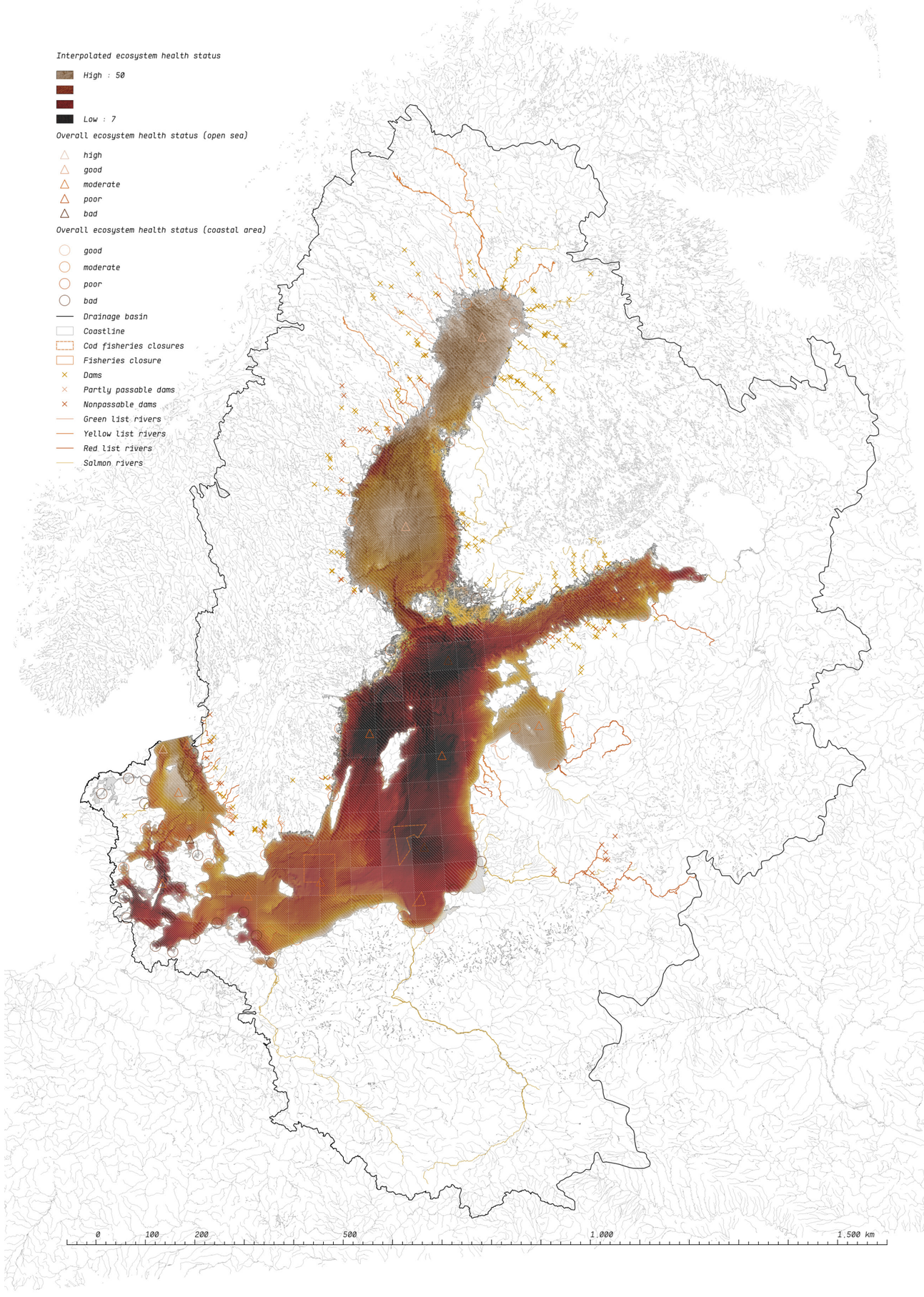
Overall, if the quotas are set too high, the fish stocks in the Baltic Sea will eventually collapse, which will result in a more long-term decrease in fishing activities. Recent forecasts made by the EU predict that the number of fishing vessels will continue to decrease. However this does not necessarily mean that a smaller area of the Baltic Sea will be exploited by fishing activity. As fishing pressure seems to be maintained by EU's quota levels, a decrease in fleet number may only imply increased quotas and wider areas to fish for lower number of vessels.[86]

What's important to keep in mind is that the fishing industry is probably also facing substantial challenges in the future with an important ecological shift (through changes in temperature, oxygen, salinity, etc..) leading to considerable changes in fish population distribution and movement. One should also take into account recreational fishing as it is steadily growing in the Baltic Sea region. In the future, fishing will be competing for space with wind farms and increased maritime traffic. Commercial fishing remains a vulnerable sector since it depends on the fish stock's survival and growth and consequently a healthy ecosystem that is not overexploited.[87]

↓ *IMG.15 SMALL FISHING VILLAGE IN SWEDEN* (Photo by Ola Ericson)



MAP.7 (GIS data from HELCOM) →



BAŁTYK SEA CARTOGENESIS

→ AGRICULTURE

Load of phosphorous

High

Low

Cropland

Polluting sites

Agriculture accounts for a large part of the pollutants released in the Baltic Sea. The majority of it comes from the use of chemical and non-organic fertilisers to increase production and productivity. These chemical products, usually nitrogen, phosphorous and potassium linger in the soils and leak in the form of nitrates. This affects groundwaters for decades, but not only, it also has effects in the Baltic Sea aquatic ecosystems through the draining rivers.

→ FORESTRY

Treecover

Treecover loss

Polluting sites

The paper and pulp mill industry is extremely polluting the regions where forestry is manufacturated extensively. These industries are demanding on water, energy and chemicals (the mills make extensive use of chemicals – some 2.8 million tonnes per year). Emissions of nitrogen and sulphur from this sector is quite high and is often found next to the rivers and lakes in their immediate surroundings. Not only is it polluting its surrounding soils but it is also a major source of nitrogen leaks into the Baltic Sea.

→ MINING

Mining waste

Riverine mercury load

High

Low

Riverine lead load

High

Low

There are different sources of pollution starting from transboundary air pollution, fallout of metal-containing dust and heavy metals carried out by rivers towards the Baltic Sea. Riverine load of heavy metals and pollutants is by far the largest source of pollution, it accounts for nearly 90% of pollution transport. Almost all waters in Europe have an increased level of heavy metals compared to un-polluted waters nowadays and the Baltic Sea is now exception.

Concentrations of metals such as copper, cadmium, nickel and zinc are a lot higher in the Baltic Sea than in other comparable marine environments such as the North Sea or the Atlantic. These heavy metals are deposited on bottom sediments and continue polluting their surroundings without being dissolved into water. It poses serious problems to capture these elements since they are whether suspended into water, whether in sediments.

→ DREDGING

Dredging sites

High

Low

Sediments act as a sink for different substances such as heavy metals or biochemical products related to agriculture. As long as they are not disturbed these particles with heavier mass than water are disposed on the seabed. They never mix with water so they lay within sediments. Physical disturbance creating by the activity of dredging resuspenses these hazardous substances and may increase their availability to be mixed in biological processes. Some of these metals that result from several different industrial activities are extremely harmful for marine life. Heavy metals are still the main contaminant contained in dredged material.

→ OIL + GAS + WIND

Offshore platforms

Offshore wind farms

Oil/gas discoveries

Oil/gas fields

Geologic province

Large scale offshore wind farms are a source of conflict as they often collide with other interests such as shipping, fishery, extraction of sediment, laying of cables and pipelines and military activities. They also impact the seascape, which may affect tourism and recreation in a negative way. Since most wind farms occupy shallow sea areas, that are home to some highly sensitive ecological phenomenons, it may result in conflicts with nature conservation. So far knowledge about the ecological impact of wind farms remains relatively low. According to research they can interfere with hydrological processes of the sea by altering transportation of sediments, water currents and the natural movement of drifting marine organisms.

→ FISHING

Commercial fishery

High

Low

Fisheries closure

Most polluting rivers

Fishing remains one of the most traditional activities at sea. The area covered by fishing activities in the Baltic Sea is hard to estimate. The Baltic Sea is a rich sea, it has traditionally provided it's surrounding population with a comfortable share of their intake of protein. Commercial fisheries are intensive in the whole basin, but fishing pressure remains especially high in the southern parts. Herring, sprat, cod and salmon are the most present species but some 20 other species are also important locally. Overall, if the quotas are set too high, the fish stocks in the Baltic Sea will eventually collapse, which will result in a more long-term decrease in fishing activities.



INFRASTRUCTURE COLONIZATION

THERE ARE MORE THAN 200 COMMERCIAL PORTS IN THE BALTIC SEA REGION. IN 2008 THESE PORTS ALL TOGETHER RECEIVED MORE THAN 800 MILLION TONNES OF CARGO AND 91 MILLION PASSENGERS

BAŁTYK
SEA

INFRA-STRUCTURE COLONIZATION

↓ HUMAN SETTLEMENTS

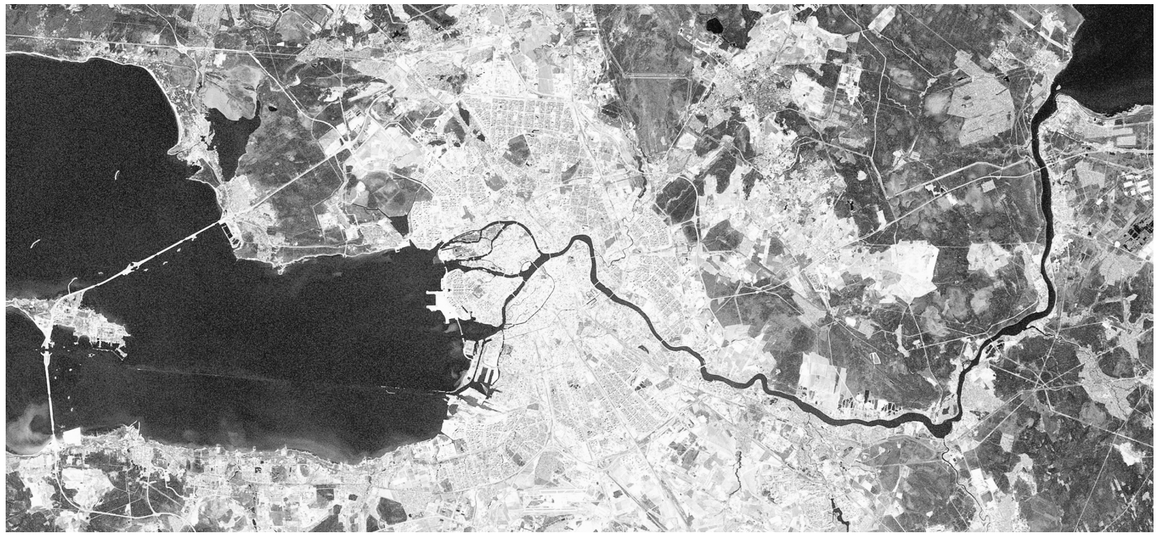
Agriculture helped shape the sedentary style of life that developed in the Baltic Sea region. *"Villages became prevalent from the Iron age and farms in the modern sense have been found since the Viking age. Villages and farms continued to be the dominating form of habitation up to our century. In these settlements, the environmental impact was relatively small, and resources brought in were recycled to the environment locally."*[1] During Viking times, cities developed as centres for trade and at the time of state formation, as centres for power. These pre-medieval or medieval cities were initially relatively small, with only a few thousand inhabitants. Up to 1800, only some 2-3% of the population in the region lived in cities, and more than 80% worked in agriculture. The medieval cities were, on the other hand, used by many more than the people living directly in them. During annual markets, the population of some important trade cities grew several fold. In other places religious events were an important factor for attraction. Other resources for the region were the administration, court processes, schooling and education that existed within cities. Therefore the town hall, the church, the fortress and the market place were the centres and also the function of cities.

"Cities developed slowly up to about 1800. In the cities, many of the inhabitants were in fact busy a large part of the year outside the city limits growing food and taking care of their provisions for the rest of the year. There were often very unhealthy conditions within the city walls. Streets were muddy, and removal of household and toilet waste was not well organised. There were also quite a few animals. Pigs and chickens were common. Cows were located at points where milk could be taken into the city, and of course horses were used for all kinds of transport. All these animals required fodder and produced substantial amounts of manure. Heating of homes was accomplished with individual furnaces. When fired with either wood or coal, they polluted the air with smoke and particles, both quite unhealthy."[2] The concentration of humans living in cities constituted an environmental problem on the site itself since the very beginning. However, when it came to the environment and landscape in general, the cities were neither numerous nor large enough to become a real problem.

↓ URBANISATION

Industrialisation drastically changed the situation. *"Factories required a large number of workers at one place. England was the first country where industrialism seriously changed the society and also the place where a new wave of urbanisation took shape. Already in the mid-19th century some 40% of the inhabitants of England lived in cities. It is also here that the serious environmental impacts of the extreme concentration of individuals and activities typical of cities become overwhelming. Sewage, waste, energy and pollution became acute problems in the English cities."*[3]

↓ ***IMG.1*** ***ST. PETERSBURG, RUSSIA*** (Satellite image from Landsat 8)



MAP.1 (GIS data from HELCOM, NASA Earth Observatory, 2012) →



BAŁTYK SEA
INFRA-STRUCTURE COLONIZATION

During the second half of the 19th century industrialisation started rapidly in the Baltic Sea region. The frontrunners were Germany and Poland. Later came the northern regions, with the exception of St. Petersburg who developed quite early into an important industrial centre. *"St. Petersburg, for example, suffered a bad cholera epidemic in 1896. Air pollution was serious, e.g. in Polish cities where hard coal was used for heating homes. Smog was rampant in Krakow in southern Poland, both due to the industries in the city and the heating of homes, with serious health consequences. Still today the number of children with respiratory diseases is far above national averages in cities in Silesia in southern Poland and the several places in eastern Estonia, and most likely in all other cities with bad air."*[4] Cities grew larger when industrialisation arrived. They also formed the required infrastructure to support it such as railroads, roads and energy distribution networks. At the end of the last century, a wave of urbanisation, spurred by industrialism and building of railroads, occurred in the Baltic Sea region. Important industrial centres formed in many cities around the coast, connected to their hinterland by railroads (or rivers) and to the rest of Europe or even the world through ports and the Baltic Sea.

In 1950 and 1975 a new wave of urbanisation took place in the Baltic Sea region. In this wave, cities grew by depopulating the countryside instead of absorbing the population increase like in the previous phases. This time, rather than developing themselves, cities grew through suburbanisation and an increase of communication (especially car traffic). Existing cities became much bigger but the real megacities, who were typical for the South, do not exist in the Baltic Sea region. Currently, there are about 53 cities in the Baltic Sea region with over 200,000 inhabitants, around 7 cities with over 1 million and only one city, St. Petersburg, at 4.9 million. *"The degree of city dwelling is today close to 90% in many areas in Sweden, Denmark and Germany, and 65% or more in Finland and Eastern and Central Europe."*[5]

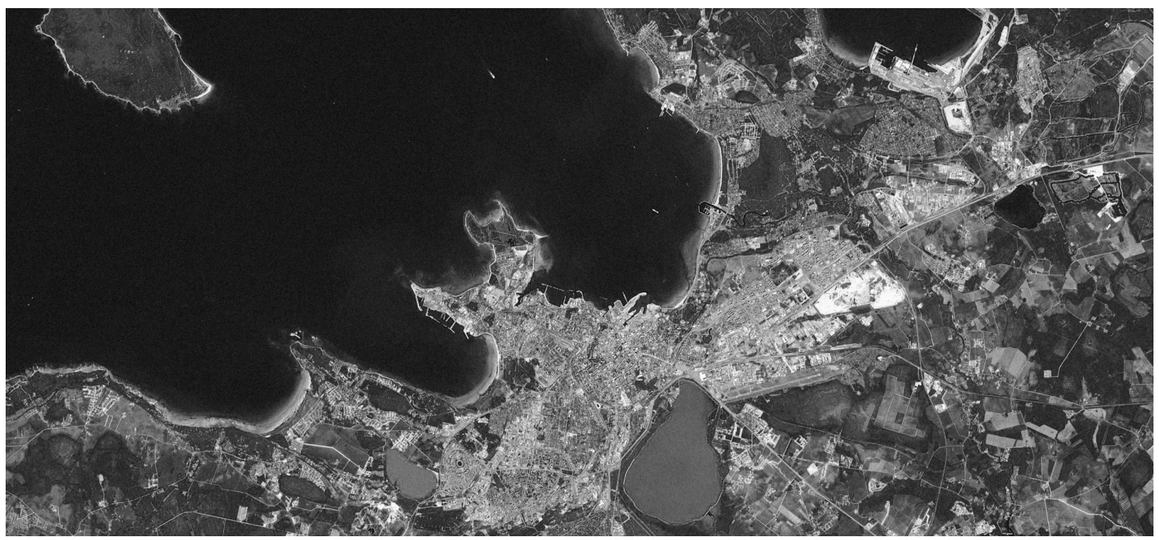
↓ INDUSTRIALISATION

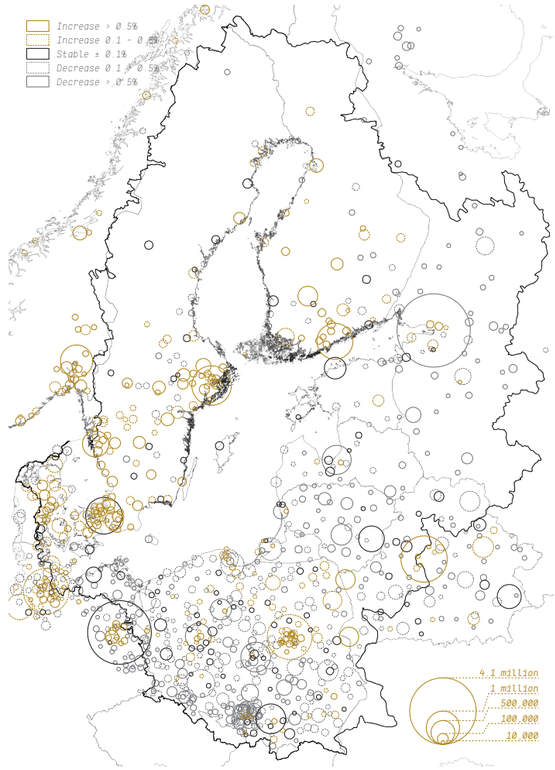
"During the later part of the 1800s industrialisation developed in the region and requirements for the centralisation of resources, including workers, led to the expansion of cities. [..] The most important industrial branches in the Baltic region include food, pulp and paper and forest industry, mines and steel works. Other important industrial branches are manufacturing and the metallurgic and galvanic industry."[6] Most of them were big on pollution. Eastern Germany, southern Poland, Riga, the St. Petersburg region, north Sweden and mid-Sweden became important industrial cities and centres. Around 1970, when manufacturing industry had its peak in western countries, close to 70% of the work force was still in industry. Currently this figure is still below 20% in the Nordic countries. This is mostly due to the collapse of several industrial branches such as the steel industry and ship building and the increased productivity through the

Location	Companies in region in numbers	Total sales in bil €
Denmark		
↘ Copenhagen	5	68.48
↘ Aarhus	1	4.61
Finland		
↘ Helsinki	8	103.74
Germany (BSR part)		
↘ Berlin	3	14.51
↘ Hamburg	1	5.23
Norway		
↘ Oslo	6	49.38
↘ Stavanger (not MEGA)	1	57.85
Poland		
↘ Plock	1	11.81
↘ Warszawa	2	5.46
Russia (BSR part)		
↘ St. Petersburg	2	56.03
Sweden		
↘ Gothenburg	2	34.59
↘ Stockholm	12	135.86
↘ Outside MEGAs	2	8.68

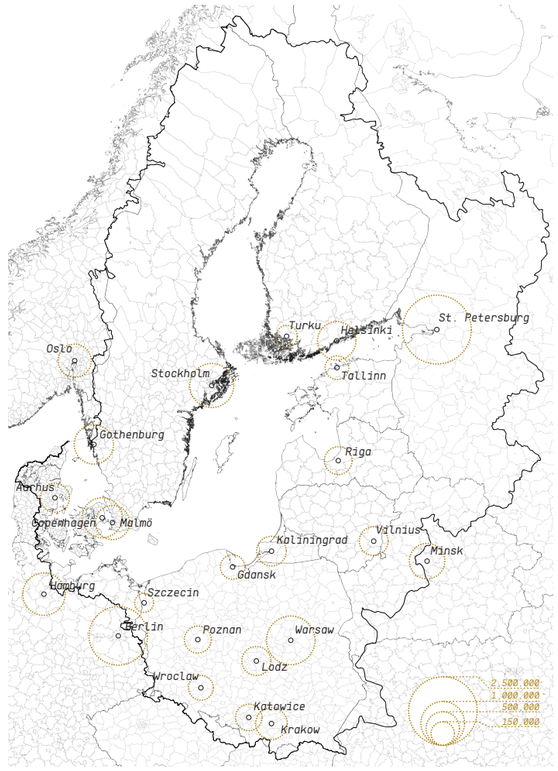
↑ FIG.1 HEADQUARTERS OF INTERNATIONAL ENTERPRISES (Redrawn from Schmitt et al., 2008)
Headquarters of enterprises on the FORBES 'The World's 1000 Largest Public Companies'

↓ IMG.2 TALLINN, ESTONIA (Satellite image from Landsat 8)





↑ FIG.2 ANNUAL AVERAGE POPULATION CHANGE (Redrawn from Schmitt et al., 2008)
Overall population change in Baltic Sea Region cities (2002-2006)

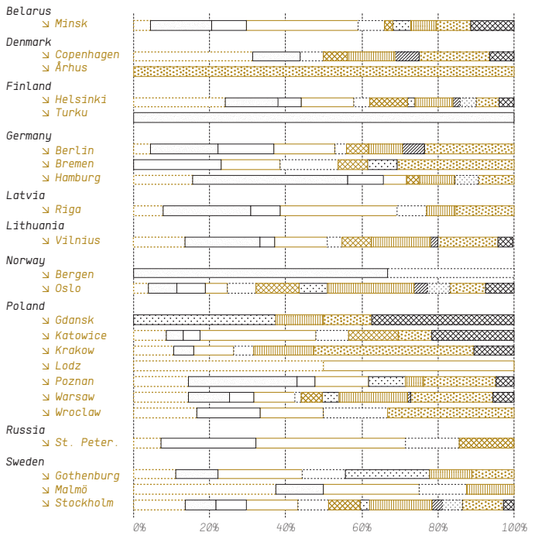


↑ FIG.3 LARGEST METROPOLITAN AREAS (Redrawn from Schmitt et al., 2008)
Size of circle is relative to total number of employed persons in the region in 2006

Top 25 companies	Industry	Location	Market value in €b
↘ OAO Gazprom-neft	Oil & Gas Operations	St Petersburg	199.41
↘ Nokia	Technology Hardware & Equipment	Helsinki	94.68
↘ StatoilHydro	Oil & Gas Operations	Stavanger	63.93
↘ H&M Hennes & Mauritz	Retailing	Stockholm	30.43
↘ A.P. Møller - Mærsk A	Transportation	Copenhagen	29.68
↘ Novo Nordisk	Pharmaceuticals & Biotechnology	Copenhagen	27.72
↘ Volvo Group	Capital Goods/ Industrial Engineering	Gothenburg	26.36
↘ Nordea Bank	Banking	Stockholm	25.61
↘ Fortum	Utilities/ electricity	Helsinki	24.24
↘ TeliaSonera Group	Telecommunications Services	Stockholm	23.37
↘ Telenor	Telecommunications Services	Oslo	22.61
↘ LM Ericsson	Technology Hardware & Equip	Stockholm	22.44
↘ Danske Bank Group	Banking	Copenhagen	17.11
↘ VTB Bank	Banking	St Petersburg	16.83
↘ Sandvik	Capital Goods/ Industrial Engineering	Sandviken	13.18
↘ Beiersdorf	Household & Personal Products	Hamburg	13.17
↘ DnB NOR	Diversified Financials	Oslo	12.79
↘ Scania	Capital Goods	Stockholm	12.68
↘ Atlas Copco	Capital Goods/ Industrial Engineering	Stockholm	12.47
↘ Vestas Wind Systems	Capital Goods/ Industrial Engineering	Aarhus	12.39
↘ Vattenfall Europe	Utilities	Berlin	11.82
↘ PKO Bank Polski	Banking	Warsaw	11.78
↘ Svenska Handelsbanken	Banking	Stockholm	11.39
↘ Norsk Hydro	Conglomerates	Oslo	11.26
↘ SEB-Skand Enskilda Bank	Banking	Stockholm	11.20
Top companies in remaining countries			
↘ Eesti Telekom	Integrated Telecommunication Services	Tallinn	1.09
↘ Rytø skirstomieji tinklai	Electric Utilities	Vilnius	0.68
↘ Latvijas Gâze	Oil & Gas Storage & Transportation	Riga	0.41

↑ FIG.4 LARGEST COMPANIES AND LOCATION (Redrawn from Schmitt et al., 2008)
Largest companies in the Baltic Sea Region by market value in 2008

BAŁTYK SEA
INFRA-STRUCTURE COLONIZATION



↑ *FIG.5 RESEARCH CENTRES OF EXCELLENCE* (Redrawn from Schmitt et al., 2008)
Research centres of excellence in 2008 (public and private)

level while the birth rate has decreased. "*The political problem is now an inverse population pyramid, with too few young persons having to support too many elderly. The crucial question now is not population increase but how much resources each individual uses.*"[7] Modernisation is usually referred to the time of industrialisation and urbanisation. A post-modern society has now come to replace this phase. The service sector is now at the core of the economy of this new society. Today, less than 5% of the population works in the agriculture sector and 20% in the industrial sector. High tech branches, composed of information technology and biotechnology companies, dominate the manufacturing industry. "*The ratio between GDP and resource use, increasing in the western world since about 1970, is an early sign of a future dematerialisation of the societies.*"[8] While a large part of the world has not yet entered into industrialisation and does not have access to basic needs, such as running water or electricity, the Baltic Sea region is at the forefront of this scheme.

↓ GROWING AND SHRINKING CITIES

There is a spatial polarisation of population towards the capitals, larger agglomerations and higher order urban centres that can be observed in most parts of the Baltic Sea region. It is followed by increasing suburbanisation, notably in and around most the metropolitan areas. Furthermore, a number of small and medium- sized cities and towns on the fringes of these metropolitan areas have quickly expanded their populations on the basis of strong in-migration. Therefore, the key drivers of population change remain : strong migration surpluses for the Western part of the Baltic Sea region and large natural losses in the Eastern part (with distinctive national and regional variations). While looking at the Baltic States, negative population trends can be observed. Only Vilnius and Tallinn, inW addition to some of the smaller cities in the suburban hinterland of Klaipeda (Lithuania), boast a stable development. This is partly due to negative natural population change and to negative net migration.

On the Russian side, the metropolitan areas of Kaliningrad and St. Petersburg (and their larger hinterlands) show a dynamic performance in terms of attracting migrants. However, it is important to mention that the entire NW Russian territory is witnessing a significant natural population decrease. In the Nordic countries, the picture of natural population change and net migration is generally the same over the different territories. "*Only in mid-sized Swedish cities does strong positive net migration prevail over negative natural population development.*"[9] In Denmark however, the most dynamic places are not always the larger cities but mostly the mid-sized cities surrounding the larger units such as Aarhus or Copenhagen. "*With specific regard to developments in the Baltic Sea region's cities, one can however detect a north-south divide. Specifically Polish cities, but also in many cities belonging to the German part of the BSR are suffering from high unemployment rates.*"[10]

↓ *IMG.3 OULU, FINLAND* (Satellite image from Landsat 8)



MAP.2 (GIS data from HELCOM, GEOFABRIK, EEA) →



BAŁTYK
SEA

INFRA-STRUCTURE COLONIZATION

ROADS + RAILWAYS

Country	Vehicles (per 1000 inh.)	CO_2 emissions (kt)	Rail lines (km*)	Roads (km)	Highway (km)
↘ Denmark	480	45,698	2,011	73,929	1,143
↘ Estonia	476	15,951	801	58,412	115
↘ Finland	612	53,568	5,905	454,000	863
↘ Germany	572	734,599	34,128	644,480	12,917
↘ Latvia	319	6,652	2,374	71,300	1,651
↘ Lithuania	560	12,838	1,771	84,166	309
↘ Poland	537	298,905	19,429	423,997	1,553
↘ Sweden	520	43,598	9,957	579,564	2,050

*irrespective of number of tracks

↑ *FIG.6 INFRASTRUCTURE FIGURES* (Data from The World Bank, 2014)
Shows the disparities between Eastern and Western countries of the Baltic Sea region. Germany has up to ten times more roads than the Baltic states

↓ INFRASTRUCTURE DEVELOPMENT

There has been a continued and dramatic expansion of the built environment in the last century that has led to important environmental impacts in the Baltic Sea region. Only 2 to 3% of the population in this region lived in cities in the 19th century (see CITY NETWORKS).[11] When industrialisation developed in the region, there has been an increase of centralisation with industries and workers. This has led to large expansions of cities. With it also came the car and the railway. Both were developed by the industry itself but also served it. It increased the efficiency and boosted industrialisation. Roads and railways started expanding intensively with direct connection to the Baltic Sea shipping. The last wave of urbanisation occurred after the 1950s when the countryside moved into cities as agriculture required less workforce. Cars became accessible for a larger part of the population and this has led to suburbanisation.[12]

Not only were cities important for the development of infrastructure but large scale industries have led to important manoeuvres in terms of railway development. Large scale manufactures and industries started becoming important in the mid-19th century and were developing on strategic places not necessarily close to cities.[13] Access to natural resources was the main factor, access would then adapt to it. Very large industries started growing around mines and at the river mouths where forest or agricultural products could be transported (see MINING)[14].A very rapid and important increase in infrastructural demand occurred with the need for bigger and heavier products to be transported on larger distances, railway played a very important role in this regard. This radical change in transport systems has led to the building of cities in completely new areas, the inland behind large waterbodies became new opportunities of urbanisation.[15]

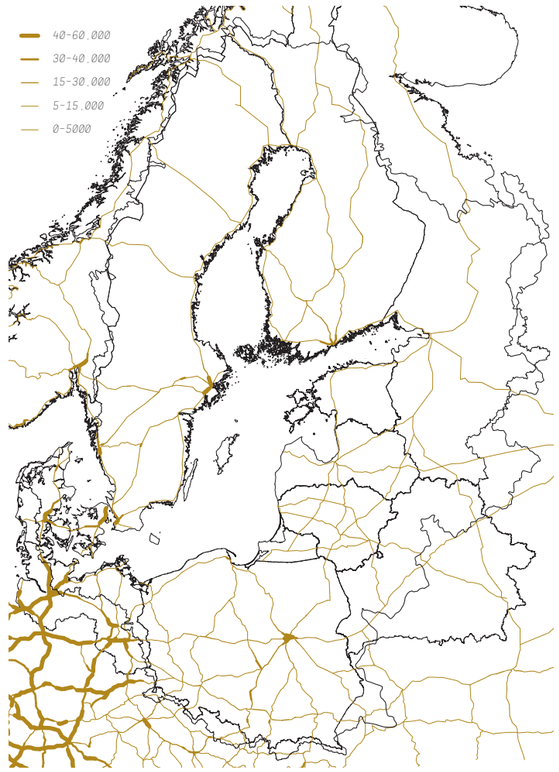
Today, we face a new phase of expansion for the railway network. More railways are being built that ever before. Fast trains are the main reason for the phenomena, these new connections require more bridges, tunnels and stations terminals to be adapted since they do not accept any crossing with roads. The development of double tracks has also heavily increased the spatial invasion of infrastructure in the landscape.[16] Simultaneously with the development of railway infrastructure, the first motorcars were developed based on the combustion engine. The building of roads was slower in the beginning but started expanding enormously in western countries with the mass automobiles from the 1960s.[17]

↓ EUROPE/RUSSIA

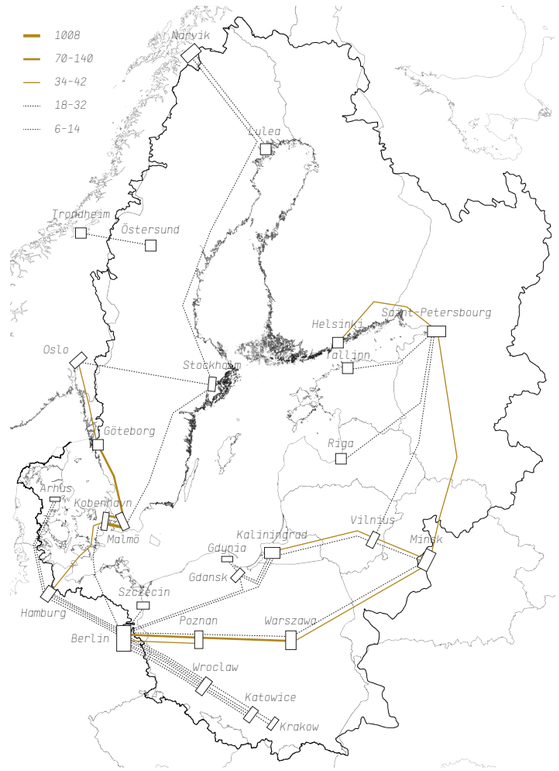
For a long time, the situation was very unbalanced in the region. In the western area the exchange of goods and passengers has always reflected the very high level of economic cooperation within countries in the region. The traffic between east and west is still very disparate, and quite insignificant compared to the western one.[18] People of the Baltic Sea region have always had close relationships throughout trade, migration or

↓ IMG.4 *FREIGHT STATION IN BRUNSCHWICK, GERMANY* (Photo by Gerald Grote)

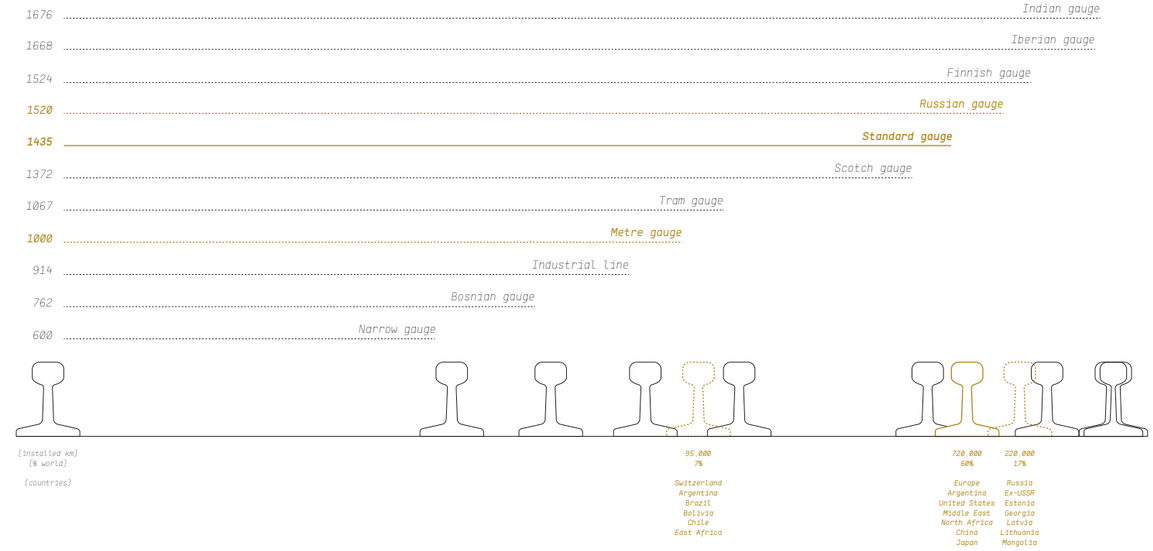




↑ *FIG.7 CAR TRAFFIC VOLUME* (Redrawn from Schmitt, 2008)
Shows the clear disparities in road traffic densities between the different countries, but also around bigger cities such as Helsinki, St-Petersburg, Stockholm and Warsaw



↑ *FIG.8 CROSS-BORDER RAIL FREQUENCY* (Redrawn from Schmitt, 2008)
The Copenhagen-Malmö rail connection is clearly the most used in the region, but a clear line also connects Helsinki to Berlin via the Baltic states



↑ *FIG.9 RAIL TRACK GAUGES* (Redrawn from Wikipedia, 2015)
In rail transport, there are many different track gauges. Every country or transport mode has developed its own. All vehicles on a network must therefore have running geat that is compatible with the track gauge, and we can see that there are slight differencies between Europe and Ex-USSR countries. This incompatibility can now be solved with double-gauge tracks but it limits very much the developement of highspeed train connections between the Baltic states, Russia and the rest of Europe

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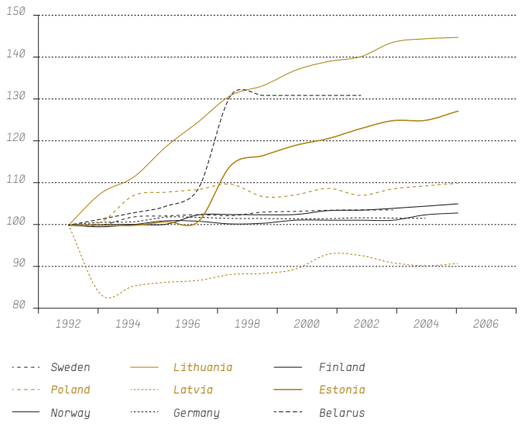
conquests. The Geopolitical situation during the last 50 years had a negative effect on the free flow of passengers, goods and informations between neighbouring countries. With the decline of communism, the former relationships tend to be reestablished and former USSR countries are now moving towards west. *"West European infrastructure has been developed as a cohesive system for all transport modes. The system is well maintained and is adequate for serving the present day transport."* (*The Nordic Council, 1992*) On the other hand east european infrastructure is inadequate and very poorly maintained. There are some capacity problems in the west as well but they are confined to single spots, the east lacks of investment in infrastructure and the system is therefore very limited.[19]

But not only are political differences a factor of these variations. There are some differences technically speaking as well. Russian and European rail gauge sizes vary (see ***FIG.9***). This does not affect much goods transport but high speed trains connecting the west and the east are impacted. The Baltic Sea region is located on a very specific buffer zone and it might play a primary role in the future in serving the transport flows between the European union, Russia and the Fast East countries.[20] In order to achieve these cross-border connections, better cooperation in-between neighbouring countries is needed. As already explained before, there are still some inefficient portions of infrastructure especially in the eastern part of the Baltic Sea region. *"Fragmented motorway sections and lack of electrified double-track railway lines significantly hinder the mobility of goods and persons in the North-South direction between the Baltic States and Poland, and in the East-West direction between the Baltic States and Russia."* (*Szydarowski, 2009*).

↓ SECONDARY NETWORKS

As explained previously, the absence of infrastructure in some parts of the Baltic Sea region limits the development of interactions between cities and regions. On a larger perspective this is often related as a lack of reliable and compatible connections between the different national transport networks.[21] Even if some problems have been found in the coordination between the systems, we can still see that the terrestrial transportation network in this region is rather dense and it connects all parts of the region. The densely populated parts of the Baltic Sea region such as Denmark, Poland and Germany have very important amounts of roads per capita.[22] Germany is the country in the region with the highest car density, with 1 car per 2 inhabitants that represent some 20 million cars.[23]

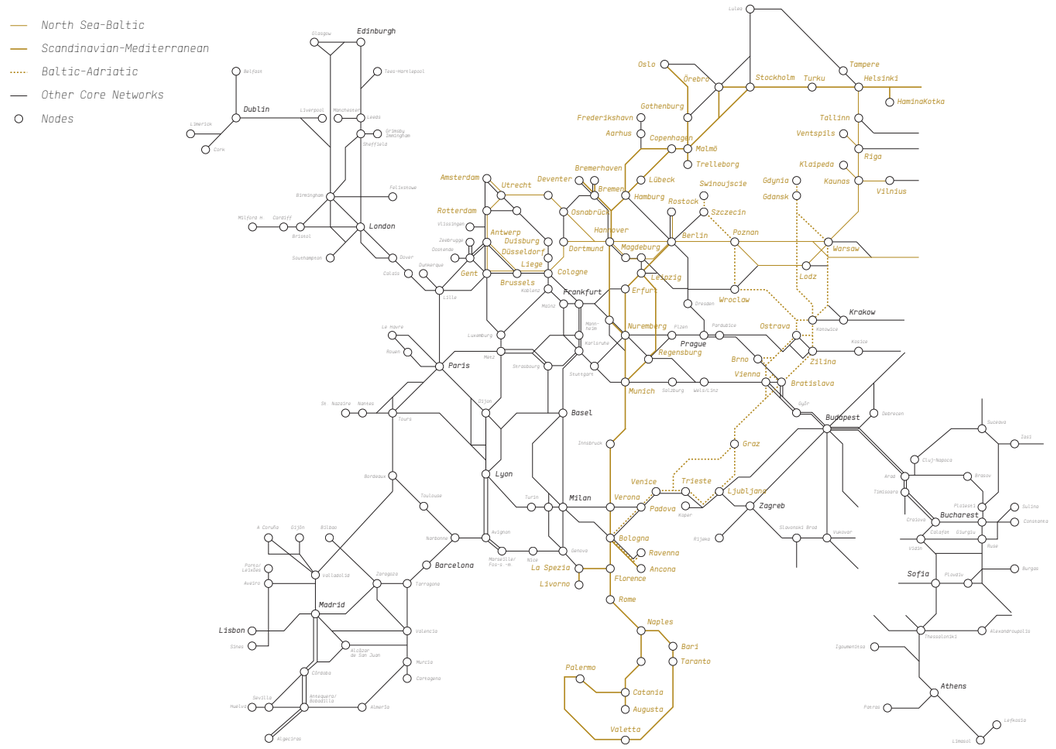
But the contrast is quite important with the northern parts of the region: Norway, Sweden and Finland including North-Western Russia. These areas are considered as sparsely populated, there are long distances between each settlement. But even with a lower density, the road and railway network still covers the main small and medium-sized towns.[24]



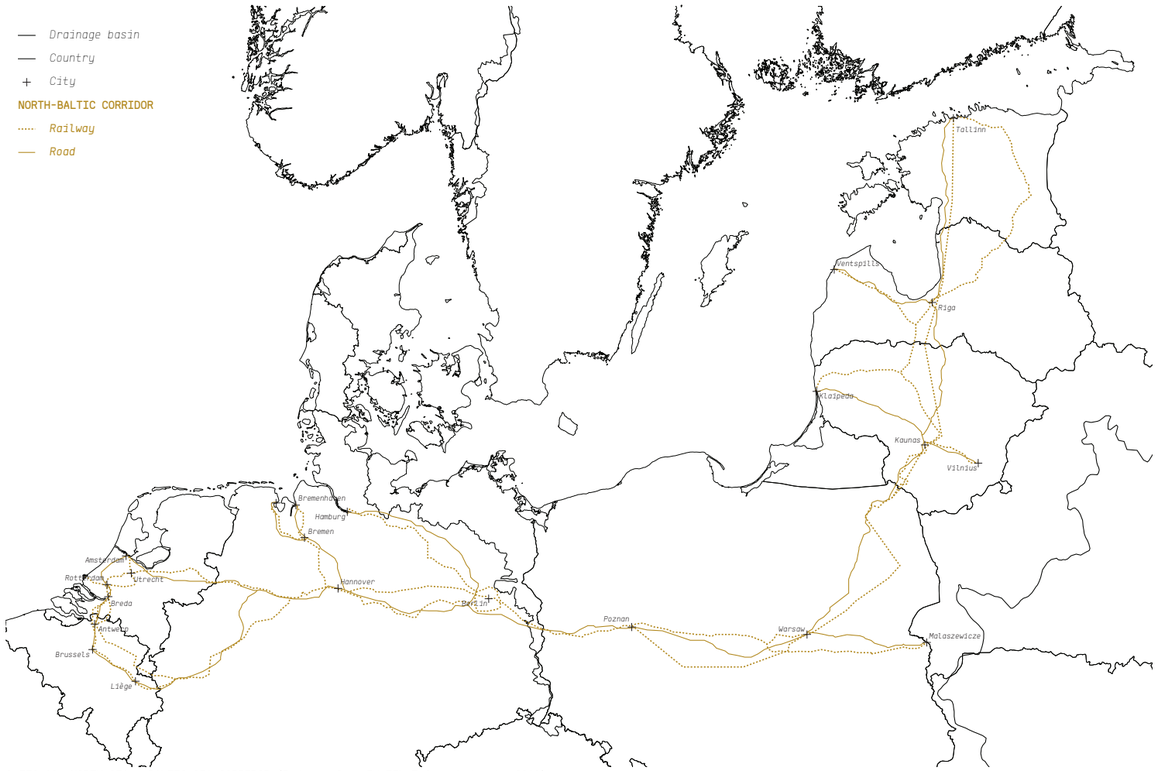
↑ ***FIG.10 SECONDARY ROAD INFRASTRUCTURE*** (Redrawn from Schmitt, 2008)
Shows the rapid growth in secondary infrastructure in the Baltic states

↓ ***IMG.5 NARVIK TO LULEÅ TRAIN*** (Photo by Bernd Zimmermann)





↑ ***FIG.11 TRANS-EUROPEAN TRANSPORTS NETWORKS*** (Redrawn from EU TEN-T Core Network, 2013)
Several EU projects that integrate the whole of Europe as an entity for transport development. The Baltic States occupy a place of choice since they are part of three development projects that extend the connection towards the Arctic and the Mediterranean Sea



↑ ***FIG.12 NORTH SEA – BALTIC SEA CORRIDOR*** (Redrawn from EU TEN-T Core Network, 2013)
Rail Baltica is one of the prority projects of the EU: Trans-European Transport Networks (TEN-T). The projects proposes a link that goes up to Finland through the Baltic States and Poland.The route is estimated to be completed by 2024

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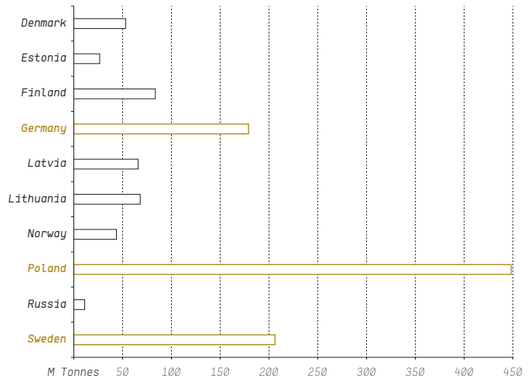
It is therefore important to analyse not only high capacity infrastructures such as highways, motorways or double-track railways but also secondary networks. This kind of networks corresponds to the largest part of the transport networks and is important intra-regional travel as well as enabling connections between each region and the primary network system. There has been important changes in the recent years in regard of infrastructure. Changes have been observed in total length of road networks. Construction of new infrastructure have filled the missing links and the upgrade of existing links have optimised or corrected certain bottlenecks.[25]

There are two main dynamics actually in action. *"Lithuania, Belarus and Estonia belong to the category of countries that have substantially improved the extent of their secondary road network. From 1993 to 2005, Lithuania augmented its secondary road capacity by more than 40%, Belarus nearly 30% and Estonia by 25%."* (*Schmitt, 2008*) This trend goes toward the improvement of existing infrastructure by higher standards that allows an increase in cars and goods density. Other countries around the Baltic have minor changes when it comes to secondary road networks. Nordic countries and Germany, which already had high quality standards in terms of their road network have not increased their road system (see ***FIG.13***).[26]



↑ ***FIG.13 LAND-BASED FREIGHT TRANSPORT 2030 ESTIMATE*** (Redrawn from Meriläinen, 2013)
This estimation is based on the Baltic Transport Outlook study (BTO 2011). The largest land-based (road and rail) growth is estimated to occur in Poland with an increase of about 400 million tonnes that represent a 52% growth. This is mainly expected from economic development and road, railway infrastructure extensions

↓ ARCTIC CONNECTION

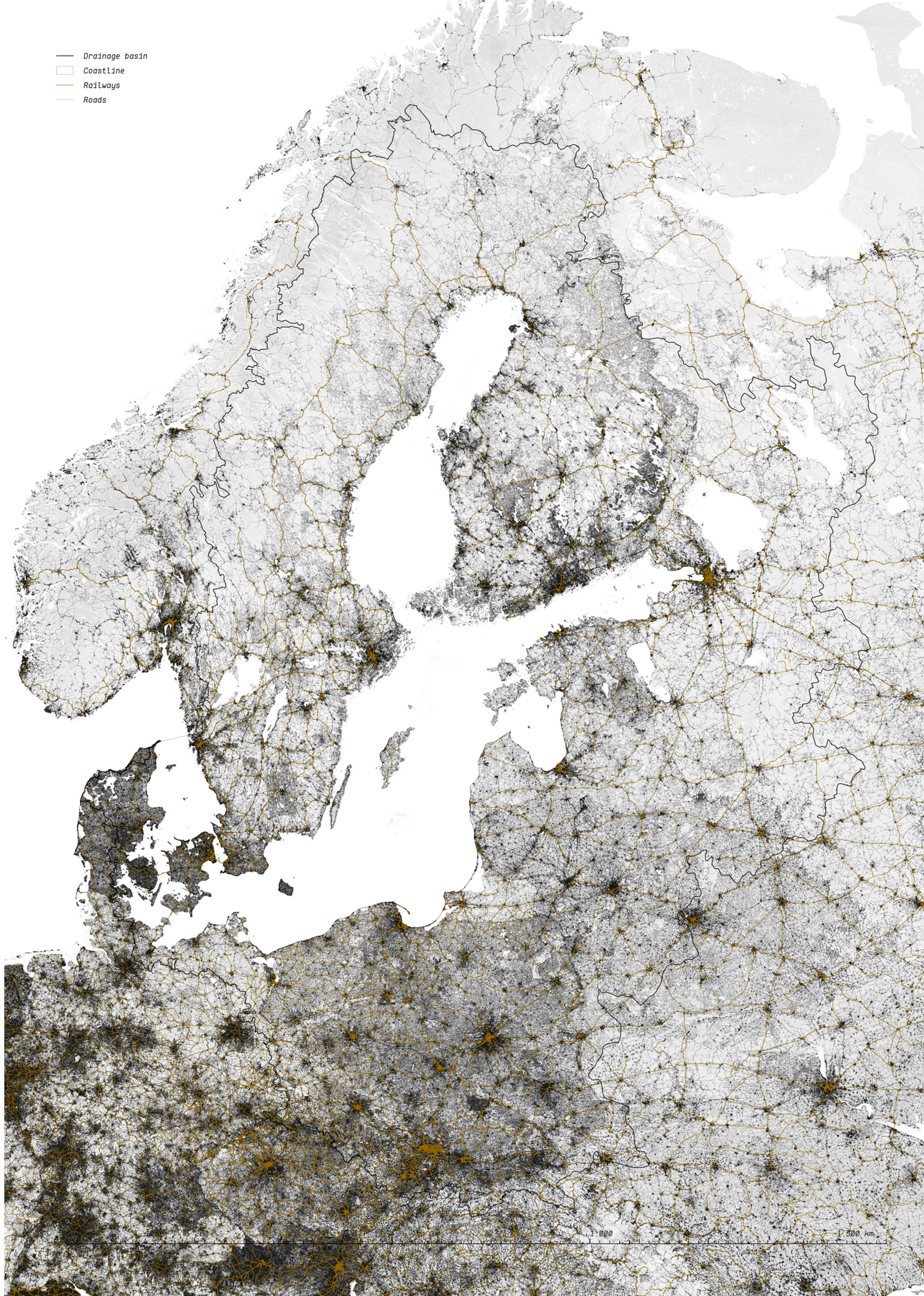
The Baltic Sea region has become one of the fastest growing areas in Europe, thanks to a dynamic economic growth and export-profiled production. Its strategic position between the east and the west makes it one of the most prolific areas of infrastructural development. The European Union has developed project of coordination of spatial planning since the 1980s.[27] Projects such as the Rail Baltic corridor connecting Saint-Petersbourg, Finland, Estonia, Latvia, Lithuania and Poland with western EU Member States is see to become the backbone for the integrated railway system in the eastern part of the Baltic Sea region.[28] This project is not only seen as of prime importance for the region but it forsees the future exploitation of natural resources in the arctic region. It places the whole Baltic region as of primary importance in these future transport and resources handling.

Improvements in the connections between North and South are also on the table with the North-South routes from Scandinavian countries via central Europe to the Adriatic Sea. But not only are projects of development of rail networks on the table nowadays, road connecting and border crossing infrastructure on the external EU borders are as well being promoted. And finally, *"the East-West routes in the northern periphery area such as Barents Link, North-East Cargo Link and Northern Maritime corridor are planned to connect the natural resources rich Barents Region with European mainland."*[29] Many opportunities therefore emerge and it replaces the Baltics in a more central condition in Europe.

↓ ***IMG.6 RAIL CONSTRUCTION*** (Photo by Katia Chubaci)



MAP.3 (GIS data from HELCOM, GEOFABRIK) →



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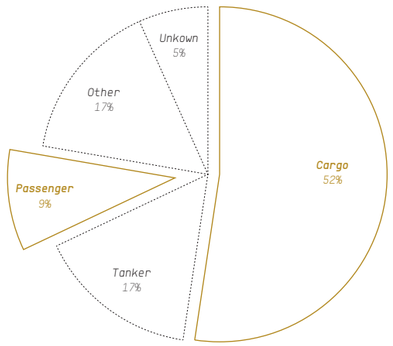
MARITIME TRAFFIC



Number of ship crossing
350.392

↑ ***FIG.14 SHIP CROSSINGS BY TYPE*** (Redrawn from Meski, 2013)
Data shows the total amount of ship crossings in the Baltic Sea for 2013. The majority of ships are transporting freights and containers. In this category there are two types of bulk and non-bulk transport. Then only come in forth place passenger transport but this is a very important share for the Baltic Sea. Boat is often associated with leisure and easy access to different cities all along the coastline, especially in Scandinavian countries

↓ PHYSICAL OBSTACLE

The Baltic Sea acts as a physical obstacle for the development of transport networks across the baltic Sea region. As seen in the previous chapter, road and rail connections are physical elements that form a network, this system of lines is in opposition with what constructs maritime and air transport. This last is a system of nodes, a point-to-point system, in which lines are immaterial and nodes (ports and airports) are of highest importance for the whole system.[30] In order to fully implement the transport of goods and people, maritime and air transport are essential for bridging transnational interactions. Maritime transport especially acts both as an important space of interactions with to so-called motorways of the sea axis.

There are various types of ships cruising in the Baltic Sea. The majority of it is devoted to transport of goods and materials such as oil. Cargo and tankers represent almost 70% of all ships (see ***FIG.14***). Cruise ferries also play an important role in the region by providing direction connections in-between big cities or European capitals. They are also a transpiration of choice for many tourists in the region. These leisure trips or commuting journeys represent 9% of the total traffic and enable a large amount of people to reach the many islands the Baltic Sea has.[31]
"The fact that many countries are only separated by a narrow sea channel increases the possibilities of using maritime transportation on a cross-border basis. In relation to these specific geographical contexts, maritime transportation becomes the most cost-efficient and reliable means of transportation: distances are too short to use air connections, and the building of bridges or tunnels would be, if feasible, too expensive and not profitable enough." (Schmitt, 2008)

Helsingborg in Sweden and Helsingor in Denmark (see ***FIG.19***) are the closest points between the two countries and have strong interactions between them for few centuries already. Ferry connections are also very well developped between Germany and Denmark with the Puttgarden-Rødby route that comes as fourth most frequent in the region. Ferry connections between the different countries enhance the ongoing economic integration and develop important culutural crossings.

↓ SHIP ACCIDENTS

As already seen, the Baltic Sea has one of the densest maritime traffic in the world. There are more than 2,000 ships cruising at any given time on this rather small water body. Different factors also makes it one of the most dangerous to navigate. A combination of heavy shipping traffic, shipping lanes crossing each other, narrows straits (see ***FIG.15***), shallow waters (see DREDGING) and long ice cover periods (see ICE COVER) makes it a difficult area for navigation.[32] Shipping accidents occur on a regular basis. There were 149 accidents reported in 2013 out of which 6 caused pollution by leaking transported material.[33] Even if this number is relatively low (represents 4% of all ac-

↓ ***IMG.7 SWEDISH ARCHIPELAGO*** (Photo by Maria Swärd)



FIG.15 GENERAL NAUTICAL CHART (Redrawn from SJÖFARTSVERKET) →



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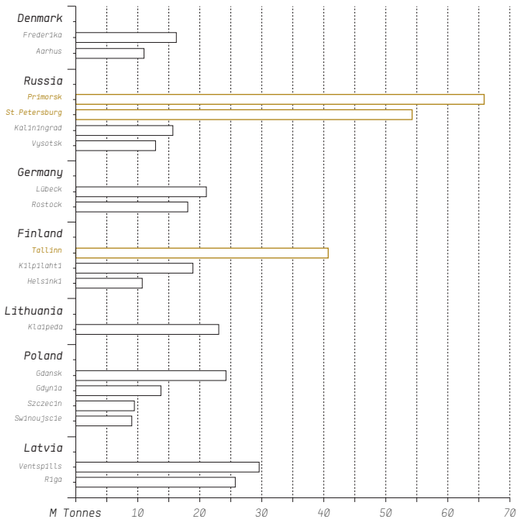


↑ *FIG.16 CARGO HANDLING VOLUME BY PORT* (Data from Baltic Port list, 2015)
When looking at cargo freight, Russian ports clearly are the biggest ones. There is a gravitational shift depending on the type of shipping we focus on. There is a clear difference between cargo and passenger shipping

cidents), consequences might be disastrous. A major spill caused by a tanker would damage considerably the whole ecosystem in the Sea and in its surroundings. Even if tankers represents a relatively low amount of all ships cruising in the Baltic Sea, the total amount was still important when taken separate. There were 61,193 crossings accounted in 2013.[34]

Collisions are the main type of accidents that happened in the recent years, they account for 38% of the total accidents. Out of which 20% were contacts and 18% collisions. This is mainly due to path crossings in areas where manoeuvre is very restricted and difficult. Groundings represent 29% of accidents, this is mainly due to dredging maintenance failures or human errors. Other types of accidents such as fire and explosions are also part of the total reported.[35] A major part of these accidents happen in port or port approach, accounting for 45% and 34% of them happen in open sea.[36]

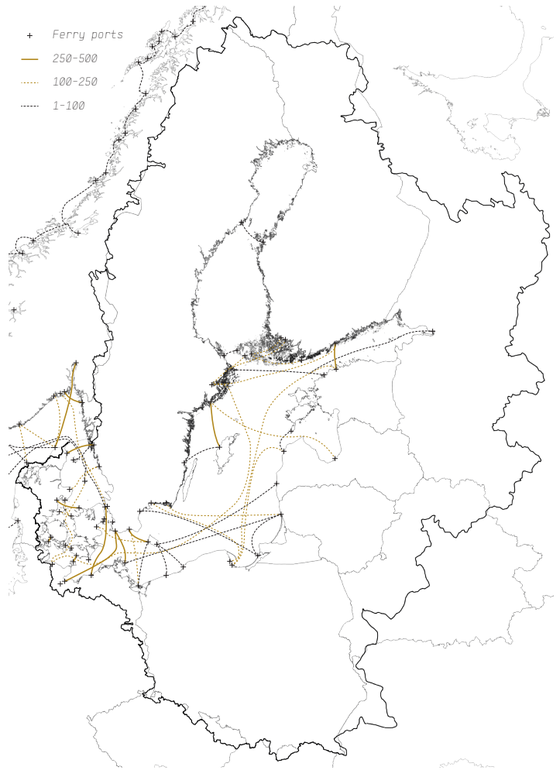
This shows again how important maintenance dredging is for port facilities. But accidents that happen in open sea are still an important part. And these can be avoided with a better monitoring in-between all the countries. Tools such as the Automatic Identification System might help prevent this kind of accident. It is of great importance to provide this kind of tools considering the increase of oil tankers navigating in the Baltic Sea and the difficulties encountered responding to oil spills in icy conditions.[37] This especially when knowing that it takes up to 50 years for the waters to be renewed.

Not all areas of the Sea have the same type of coastline or shallowness (see BATHYMETRY + TOPOGRAPHY). The southwestern Baltic Sea that included the Danish Straits, Skagerrak and Kattegatt have been one of the hotspots for collisions. This is mainly due to the important amount of islands, shallow straits and very high traffic density between Scandinavian countries. In 2013, the number of collisions in this area reached 31 direct collisions, which accounts for 54% of all collisions of this given year.[38] As said previously, there was a significant increase of maritime oil transport. Ships transported 160 million tonnes of oil and this amount is anticipated to increase to 250 million tonnes in 2016.[39]

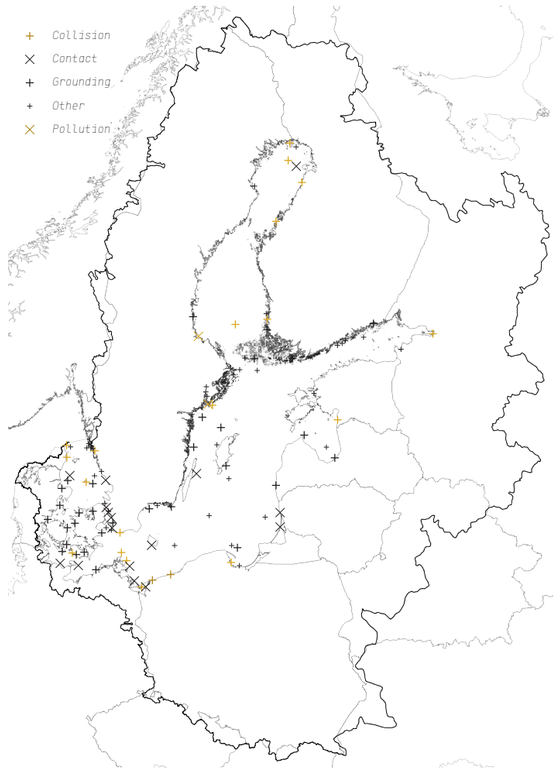
This trend results of the high oil price of Russian export ambitions as well as an increase of economic activities between former Soviet Union countries such as the Baltics. Oil tankers of the Baltimax category have reached significant dimensions that are flirting with the maximum limits allowed for the passage in the Great Belt route. Danish islands and straits limit ship size to a length of 240 metres, a height of 65 metres and a draft of 15,4 metres that represent 100,000 metric tonnes deadweight. But even these limits are bypassed by certain ships such as the *B-Maxcrude oil tanker* with more than 205,000 tonnes deadweight and the *Maersk Tripe E* class container ship that measured 400 metres.[40]

↓ *IMG.8 HELSINKI-STOCKHOLM FERRY* (Photo by Vestman)





↑ *FIG.17 MAIN FERRY ROUTES* (Redrawn from Nordregio, 2008)
Main ferry routes connect Denmark, Sweden and Norway. These clearly appear as the heavier ferry traffic. But more and more connections towards the Baltic states are being proposed nowadays, especially with Capital cities



↑ *FIG.18 SPATIAL DISTRIBUTION OF ACCIDENTS* (Redrawn from Meski, 2013)
A majority of accidents happen in the Danish straits, and most of them are grouding of collisions. The geomorphological specificity of this location makes it one of the most difficult to navigate due to very shallow straits and dense traffic of boats

Departure	Route	Return port	Countries	Weekly services route
↘ Helsingborg	Helsingør	Helsingborg	Sweden-Denmark-Sweden	945
↘ Esbjerg	Nordby Havn, Fanö	Esbjerg	Denmark	560
↘ Helsinki	Tallinn	Helsinki	Finland-Estonia-Finland	392
↘ Rødby	Puttgarden	Rødby	Denmark-Germany-Denmark	336
↘ Tårs	Spodsbjerg	Tårs	Denmark	252
↘ Helsingborg	Rostock	Helsingborg	Sweden-Germany-Sweden	154
↘ Gedser	Rostock	Gedser	Denmark-Germany-Denmark	154
↘ Ystad	Rønne	Ystad	Sweden-Denmark-Sweden	140
↘ Aarhus	Odder	Aarhus	Denmark	140
↘ Gothenburg	Frederikshaven	Gothenburg	Sweden-Denmark-Sweden	133
↘ Fynshav	Bøjden	Fynshav	Denmark	112
↘ Frederikshaven	Vesterø Havn, Laesø	Frederikshaven	Denmark	98
↘ Nynäshamn	Visby	Nynäshamn	Sweden-Denmark-Sweden	84
↘ Hirtshals	Oslo	Hirtshals	Denmark-Norway-Denmark	84
↘ Aarhus	Kalundborg	Aarhus	Denmark	84
↘ Trelleborg	Rostock	Trelleborg	Sweden-Germany-Sweden	80
↘ Frombork	Sandefjord	Frombork	Poland-Norway-Poland	77
↘ Stockholm	Mariehamn	Stockholm	Sweden	70
↘ Trelleborg	Sassnitz	Trelleborg	Sweden-Poland-Sweden	70
↘ Frombork	Baltiysk	Frombork	Poland-Russia-Poland	56
↘ Stockholm	Turku	Stockholm	Sweden-Finland-Sweden	56
↘ Malmö	Travemunde-Lübeck	Malmö	Sweden-Germany-Sweden	56
↘ Elblag	Baltiysk	Elblag	Poland-Russia-Poland	56
↘ Trelleborg	Travemunde-Lübeck	Trelleborg	Sweden-Germany-Sweden	49
↘ Kristiansand	Hanstholm	Kristiansand	Norway-Denmark-Norway	47

↑ *FIG.19 TOP 25 WEEKLY FREQUENCIES OF FERRY ROUTES* (Redrawn from NORDREGIO Report, 2008)
Scandinavian countries are clearly leading when it comes to leisure/ferry routes. Spatial characteristics also help in this regard, many cities of middle to big importance are very close to each other and separated only by a narrow water body

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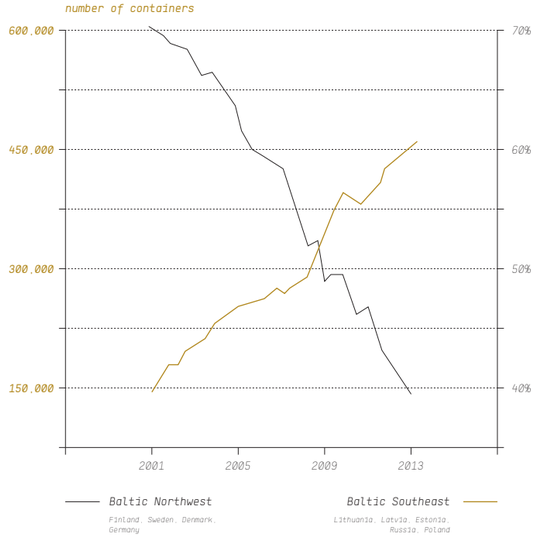


↑ *FIG.20* ***CARGO HANDLING BY REGION*** (Data from Port Gdansk, 2015)
There is clear shift operating between Eastern and Western countries in the Baltic Sea region in terms of cargo shipping. Baltic states are fast growing economies and are therefore rapidly increasing in this sector

↓ GREEN CORRIDOR

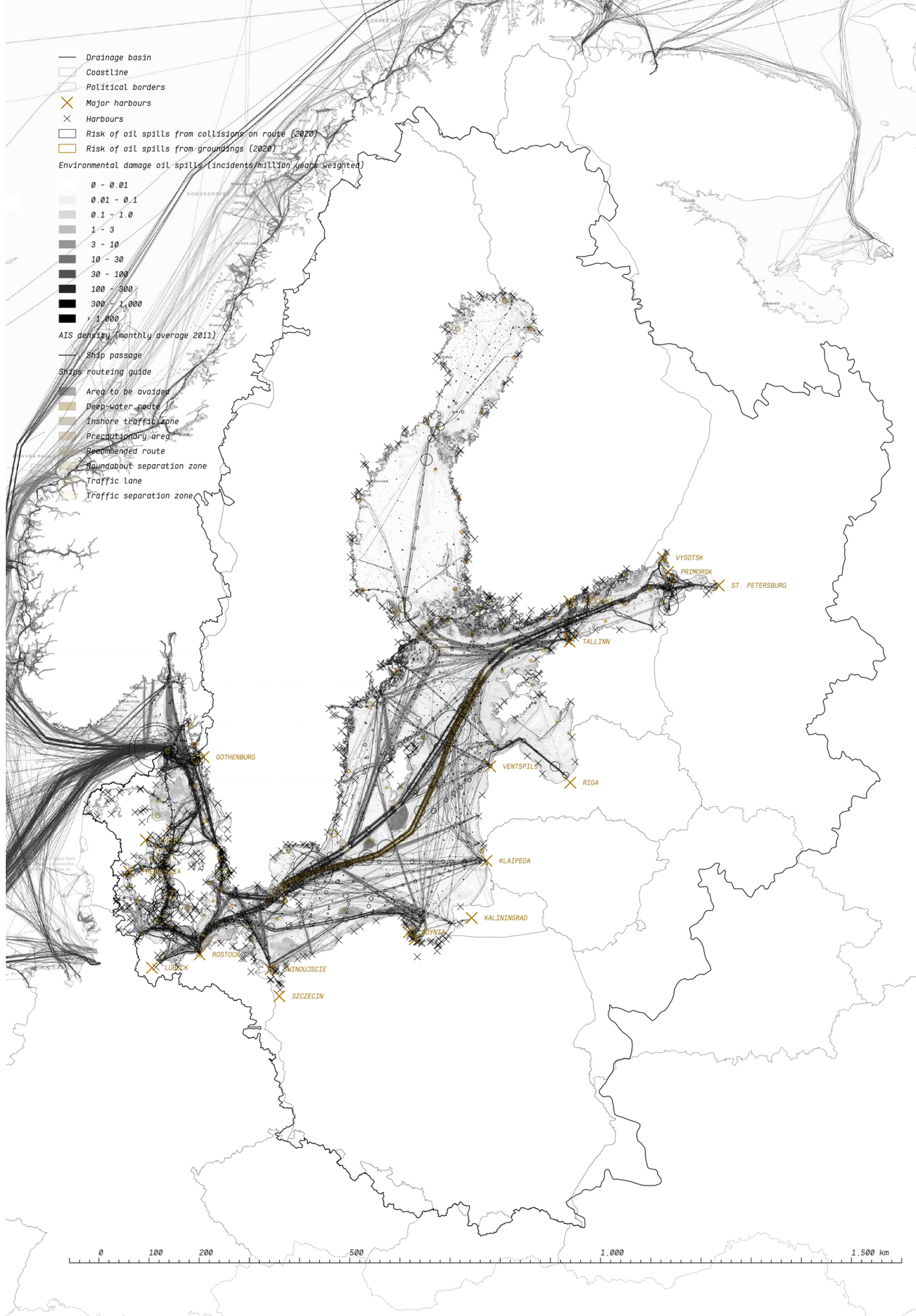
This concept was introduced in 2007 by the European Commission EU as a Freight Transport Logistics Action Plan. It goes towards the development of an efficient, safe and environmentally-friendly transportation system of freight. It integrates a better management in-between different countries that share the same waters and innovative technologies to control the traffic. The transport is expected to grow significantly in the next 20 years.[41] The Baltic Sea is already quite dense in terms of maritime traffic, solutions must therefore be found to integrate a better cooperation between the BSR countries. Appropriate infrastructure should be developed to offer the necessary capacity for this expected growth as well. According to the Baltic Transport Outlook forecast, total cargo transportation throughout the ports will increase by 30% from 2010 to 2030 to reach an estimated volume of 228 million tonnes. There is an observable increase in the container segment while a negative tendency will be observed for liquid bulk such as oil.[42] This is mainly due to the pipeline projects that are being developed nowadays (see CABLES + PIPELINES).

The cargo volume that has been handled in the Baltic Sea region ports is estimated to increase from 757.1 million tonnes (2010) to 984.8 million tonnes in 2030. Most of this cargo freight will be handled by Russian ports, which are already on the highest ranks of total volume handling in the Baltic Sea. Russian ports together with the development and growth in Estonian, Latvian and Lithuanian ports represent up to 53% of this estimated growth. Poland has the highest growth rate with an increase of its ports capacities expected to reach almost 50% of the actual handled volume.[43] This shift is extremely clear when looking at the recent trend in cargo transport (see *FIG.20*). Former Soviet Union countries are becoming more and more important in the transit of goods and people in the region, and this trend is still going on nowadays. There are still some infrastructural nodes (ports and docks) that must be improved and/or extended to be able to handle these newly important amounts of containers, but the way that it marks is very important for the region.

↓ *IMG.9* ***LEAVING ST.PETERSBURG PORT*** (Photo by underthesun)



MAP.4 (GIS data from HELCOM) →



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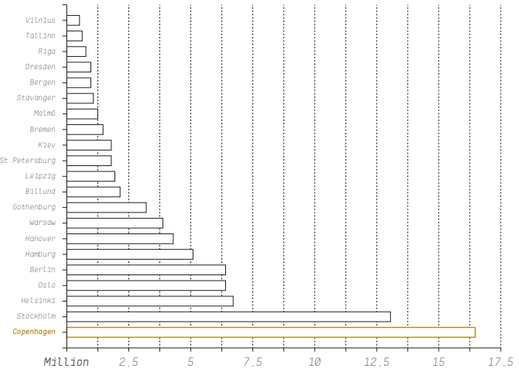


↑ *FIG.21* ***INTERNATIONAL AIR TRAFFIC*** (Redrawn from Matthiessen, 2004)
Copenhagen is very clearly the most important international hub in the region. It is an airport that permits international connection from smaller airports all around the Baltic Sea

↓ INTENSITY OF INTERACTIONS

When looking at a bigger scale, air transport sticks out as being the most important medium for people and high value goods transport. It has a strategic significance for global accessibility.[44] Connections are facilitated in regions such as the Baltic Sea where the geographical characteristics are acting as natural obstacles for terrestrial connections. It therefore forces the development of complementary strategies and way to overcome it.[45] Even with very good road and rail infrastructure, it is of great importance to integrate maritime and air transport to it and implement well developed hubs. These two last means of transport are central in sustaining future expansions of transnational mobility patterns, both for goods and transport (see **MARITIME TRAFFIC**). *"Air and maritime transport are undeniably intangible connections, but they depart and arrive to very tangible infrastructure points: the ports and seaports are the necessary infrastructure to develop air and maritime connections from any location."* (*Schmitt, 2008*).

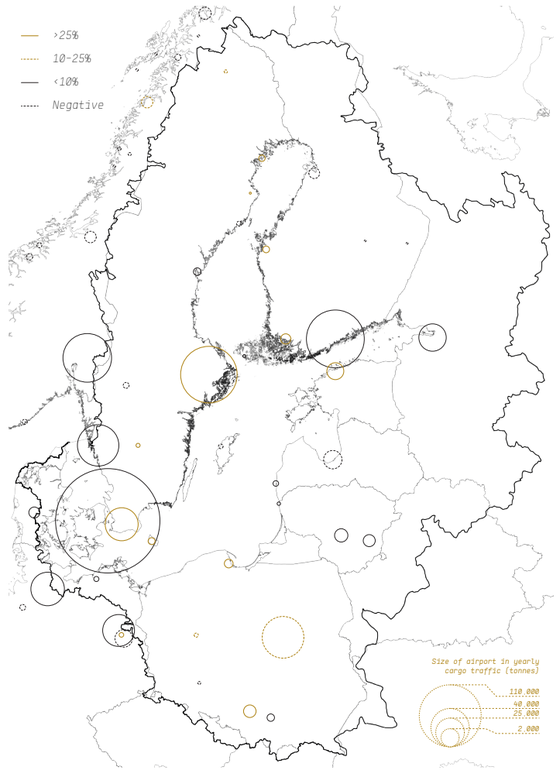
International air transport has immensely developed since the 1990s and is still in constant growth. With the collapse of the Communist regimes in Eastern Europe, and the shift in economies that followed, the Baltic Sea region became an important centre of air traffic due to its geographical location.[46] Air transport is not a sector that is limited to transport only. The infrastructure that result of its development serve many purposes including the development of regional productivity and international competitiveness. It is a significant background factor for economic and spatial developments of cities and regions.[47] Out of all the centres of international transport such as London, Paris, Frankfurt and Amsterdam follow a second category of airports that act on a more European scale. These are Brussels and Zurich followed by Copenhagen and Stockholm that act as the next layer of large centres between a number of important cities. At the level below these, we can find Helsinki, Oslo, Berlin and Hamburg.[48] The busiest intercontinental links are Stockholm-Chicago, Stockholm-New York and Copenhagen-New York with more than 200,000 annual passengers. Copenhagen has the best position in terms of interaction with cities on other continents (see ***FIG.21***). It is also the only intercontinental hub in the Baltic Sea region, non of the others including Berlin and Hamburg have any significant connection with other centres outside of Europe.[49]

↓ CARGO PORTS

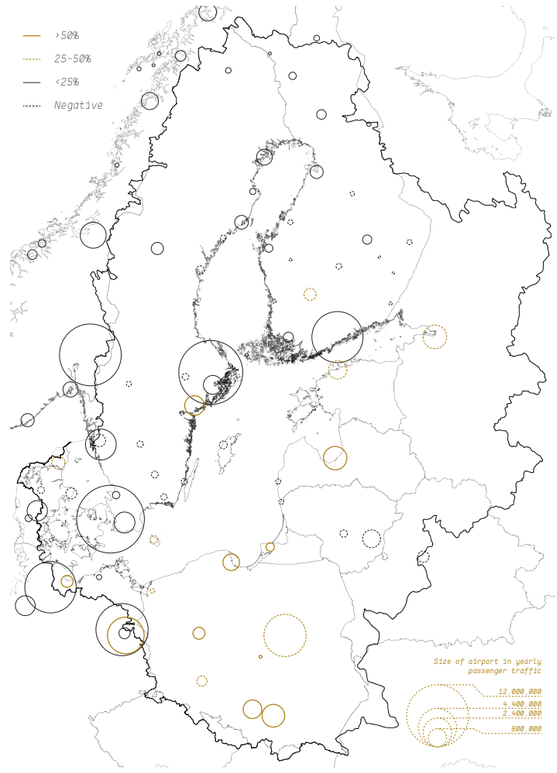
There are around 290 civil airports in the Baltic Sea region, out of which 176 have regular scheduled traffic.[50] As seen previously Denmark has the main hub despite a strong competition from Germany, Sweden and Norway. But the main share of traffic that Copenhagen airport has is for the transport of people. When looking at cargo traffic it ranks seventh in terms of total number of cargo flights (see ***FIG.25***). German airports are much more important in terms of goods transport by air. Frankfurt, with its two airports takes a large part of the total volume of cargo

↓ *IMG.10* ***TEMPORARY AIRSTRIP, NORTHERN SWEDEN*** (Photo by Bernd Zimmermann)

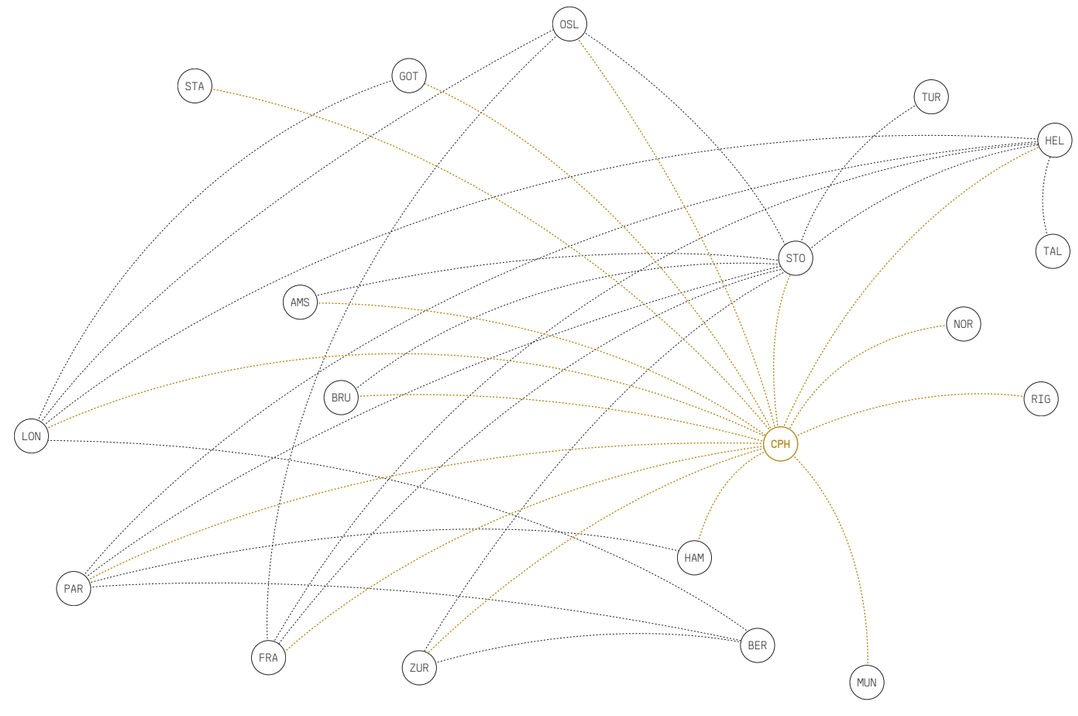




↑ *FIG.22* ***MAIN CARGO AIRPORTS*** (Redrawn from Nordregio, 2008)
Shows the importance of Copenhagen in terms of cargo transport. As explained in the text we know that there is a clear correlation between international passenger connections and size of cargo air transport



↑ *FIG.23* ***MAIN PASSENGER AIRPORTS*** (Redrawn from Nordregio, 2008)
Importance of airports within the Baltic Sea region only. The importance of Copenhagen as the only and most important international one is lowered when looking at inner connections only



↑ *FIG.24* ***MAJOR INTERCITY INTERNATIONAL LINKS*** (Redrawn from Matthiessen, 2004)
There are more than 1.500 roundtrip flights per year (2000-2001). Copenhagen is again clearly a central hub for the region

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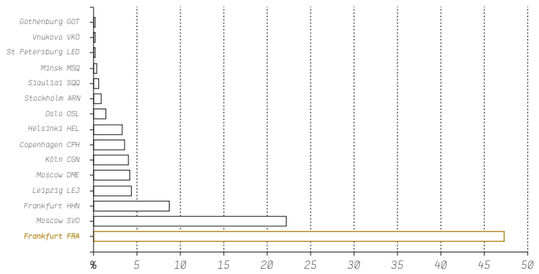
transport in the region. About half of all cargo flights in the Baltic Sea region go through Frankfurt. One reason for that shift of importance is the connectivity with road and rail networks. Frankfurt sits on a very advantageous positions since it is very well connected with these terrestrial means of transport. Germany also has developed a very strong air cargo market that relies on these major hubs. Cargo ports are usually concentrated on already existing airports which have intercontinental passenger flights.[51] These airports are typically capital airports such as Copenhagen, Stockholm or Helsinki.

The situation in the Baltic states (Estonia, Latvia, Lithuania and Belarus) is thus very different than the one in the Western part of the Baltic Sea region. There are a total of 22 airports in the Baltic states, out of which only ten have regular scheduled flights. None of these have intercontinental connections, they therefore completely rely on Copenhagen or Frankfurt for cargo freight.[52] Since the condition of an existing intercontinental infrastructure is the basis for the development of cargo transport, there is still a long way to go for these countries to develop in this sector. These regional airports act isolated and can therefore hardly be integrated within the global network.[53] There is a need for the development of better railway-maritime connections in the first place. Since the air cargo generates a significant part of revenues for the airline companies that operate intercontinental flights, it could profit highly to these countries that are growing economies.

↓ FROM HUB TO GATEWAY

The function of a hub is mainly attractive as it contributes to economic growth for the city or metropolitan area in which it is implanted. Once the transport sector is complemented with the hub function we talk about a gateway.[54] It then becomes a cluster or a gravity point for corporate services or head offices of multinational companies. The development into a gateway requires the construction of durable and effective infrastructure. This requires long-term perspectives and planning. In this respect, such projects are state-driven and require intensive capital investments that are similar to oil fields (see OIL + GAS + WIND) or shipyards.[55] Air transport is, in this regard, classified in different hierarchies ranging from intercontinental gateways to regional hubs. Intercontinental gateways are the 10 largest air transport centres, but the Baltic Sea region has none. Large international gateways include some 20 large centres, Copenhagen is one of them. And finally the majority of airports in the region belong to the two last categories that are the small international gateways and the regional hubs.[56]



↑ *FIG.25 DISTRIBUTION OF CARGO FLIGHTS* (Redrawn from Matthiessen, 2004)
Germany and Russia take the lead when it comes to cargo air transport. Copenhagen is an important airport for the region in terms of passenger traffic and as an international hub, but it doesn't have the capacity for import/export that German airpots have

↓ *IMG.11 FLIGHT OVER STOCKHOLM, SWEDEN* (Photo by Bernd Zimmermann)



MAP.5 (GIS data from HELCOM, GEOFABRIK, Landsat, OpenFlights) →



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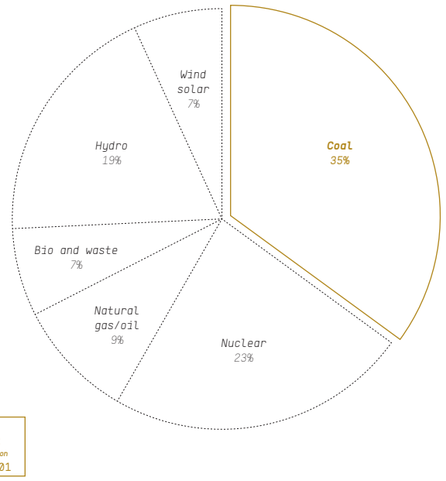


↑ *FIG.26 MAIN ENERGY SOURCES* (Redrawn from Anger, 2012)
Energy sources for electricity generation in the Baltic Sea Region in 2010

↓ ENERGY

Energy resources are generous and well provided in the Baltic Sea region, but not all of them are sustainable and renewable. On a per capita basis, traditional agriculture used about 10% as much energy as that used today. Back then, resources were local and dependent on crops and forests. *"Coal was used as mining developed in Polish, Czech and German areas in the south around 1600, while forests were the main energy resource in the north. Estionia has been independent in energy resources for a long due to its oil shale mining."*[57] In the 1900s, hydropower plants and adjoining reservoirs were constructed in the northern part of the region. After World War II a rapid expansion of energy use occurred, with imported oil as main resource. Russia and Norway later became the main providers of oil. Fossil fuels constantly changed and evolved from coal to oil and then oil to natural gas. This remains an improvement environmentally since less carbon dioxide is needed for each unit of energy. Nuclear power was then quickly developed in countries such Sweden, Germany, Finland and the earlier Soviet Union in order to decrease dependency on fossil fuel. In terms of impact on the environment the energy sector remains a major concern due to global climate change, air pollution the hazards of nuclear production and the intrusion of landscape changes that result today from hydropower and wind power stations.[58]

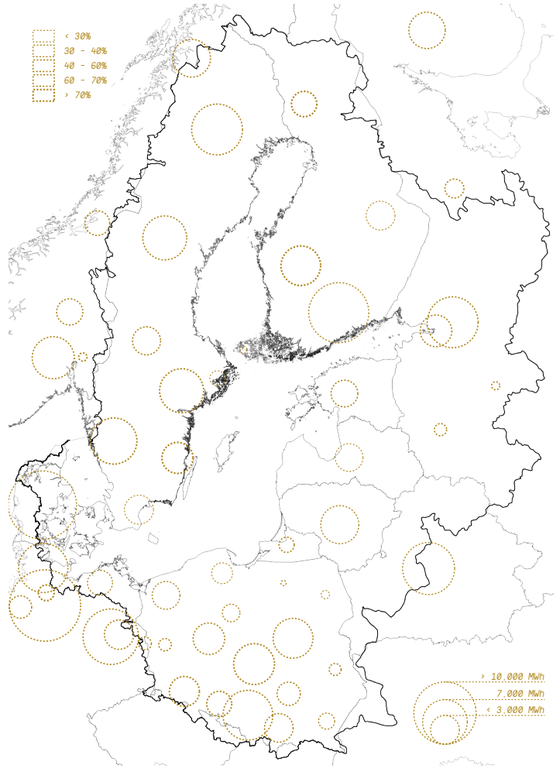
"Energy issues have become central to spatial development policies. Access to energy is necessary in order to pursue economic and social development across the Baltic Sea region."[59] In the case of the Baltic Sea region, the issue of energy is not entirely linked to the development of integrated infrastructure. The interoperability of existing and future energy facilities and networks are of course crucial in order to create a shared energy market, as well as the integration of transmission grids and pipelines, but it is not sufficient in itself. Indeed, energy issues are impregnated by national interests and thus the development of a shared energy strategy needs to creation of a new regulatory framework and the foundation of an interest shared by all participants of the Baltic Sea region. *"Ideally, the elaboration and implementation of energy-efficient spatial development policies in the Baltic Sea region should focus on reducing the consumption of energy, without hampering the potential for the economic development of its regions."*[60]

↓ PRODUCTION OF ENERGY

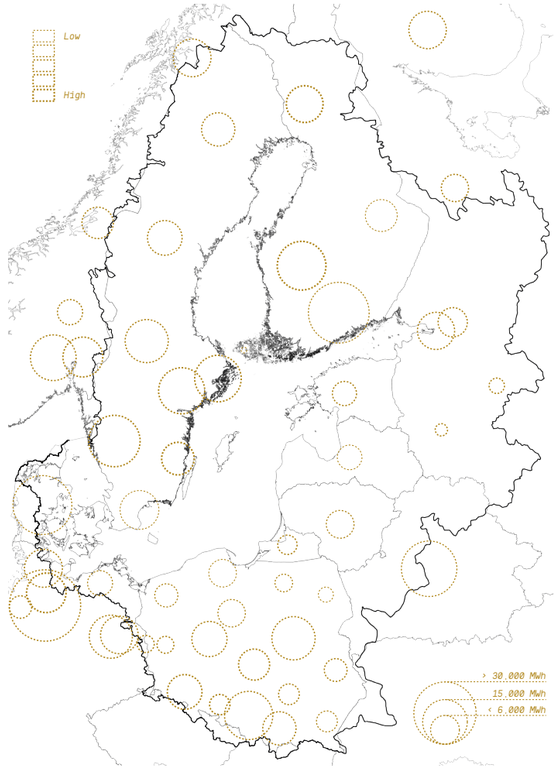
Securing access for industries, businesses and the population to the energy required to perform their daily activities usually guides the elaboration and implementation of energy strategies for national policymakers. In general these strategies address the issues of production such as finding new sources of energy and how to adapt the consumption of energy to the national production capacity and its economic development. Therefore, the territorial capital of a country or region is an important factor in defining these strategies. Indeed, the availability

↓ *IMG.12 WIND PARK IN KIRUNA, SWEDEN* (Photo by Thomas Nilsen)





↑ *FIG.27 % OF USE FOR ELECTRICITY PRODUCTION* (Redrawn from Schmitt et al., 2008)
Electricity production capacity in 2005



↑ *FIG.28 CONSUMPTION OF ELECTRICITY* (Redrawn from Schmitt et al., 2008)
Total Consumption of electricity (GWh) per GDP (million of PPS) in 2005

	Indigenous production of energy							Energy trade, in ktoe			
		% generated from source									
	Total production in ktoe	Coal	Oil + Gas	Nuclear	Hydropower	Renewable energies	Electricity + heat	Export	Import	Net exports	Total primary energy supply (TPES) in ktoe
↘ Belarus	3,802	14.4	52.2	0.0	0.1	33.3	0.0	15,004	37,711	-22,707	26,590
↘ Denmark	31,301	0.0	90.7	0.0	0.0	9.3	0.0	24,383	13,859	10,524	19,610
↘ Estonia	3,722	80.8	0.0	0.0	0.1	19.2	0.0	511	2,000	-1,489	5,096
↘ Finland	16,560	12.9	0.5	36.6	7.2	42.4	0.4	5,376	24,884	-19,508	34,961
↘ Germany	134,505	42.0	14.0	31.6	1.3	11.2	0.0	41,208	255,677	-214,469	344,746
↘ Latvia	2,294	0.1	0.0	0.0	12.5	87.4	0.0	1,151	3,944	-2,793	4,716
↘ Lithunia	3,927	0.4	5.8	69.8	1.0	18.8	4.3	7,843	12,715	-4,872	8,587
↘ Norway	233,704	0.4	94.0	0.0	5.0	0.6	0.0	206,152	5,710	200,442	32,125
↘ Poland	78,633	87.6	6.1	0.0	0.2	6.1	0.0	19,650	36,327	-16,677	92,969
↘ Russia	1,184,857	11.7	83.1	3.3	1.3	0.6	0.0	553,314	21,948	531,366	646,680
↘ Sweden	34,781	0.9	0.0	54.2	18.0	26.1	0.8	12,595	32,702	-20,107	52,174

	Total production in ktoe	Industry	Transport	Residential use	Commercial + public services	Agriculture + forestry	Fishing	Non-specified
↘ Belarus	16,335	33.4%	12.4%	35.8%	10.2%	6.3%	0.0%	2.0%
↘ Denmark	15,488	18.3%	34.7%	28.5%	12.7%	4.5%	1.2%	0.1%
↘ Estonia	2,801	23.2%	26.5%	33.2%	13.5%	3.6%	0.0%	0.0%
↘ Finland	24,783	46.3%	19.9%	19.6%	7.0%	2.9%	0.2%	4.0%
↘ Germany	235,662	24.6%	26.9%	27.0%	10.3%	1.1%	0.0%	10.1%
↘ Latvia	4,043	20.7%	25.3%	35.9%	15.5%	1.9%	0.6%	0.0%
↘ Lithunia	4,514	22.1%	32.2%	30.7%	12.6%	2.3%	0.0%	0.1%
↘ Norway	18,642	35.2%	27.0%	20.4%	13.2%	1.7%	2.4%	0.1%
↘ Poland	57,073	27.4%	22.1%	32.2%	10.4%	7.8%	0.0%	0.0%
↘ Russia	387,260	33.0%	24.5%	28.5%	8.9%	2.5%	0.1%	2.3%
↘ Sweden	33,065	36.1%	26.2%	22.1%	13.0%	2.3%	0.1%	0.1%

↑ *FIG.29 PRODUCTION AND CONSUMPTION OF ENERGY BY TYPE AND SECTOR* (Redrawn from Schmitt et al., 2008)
Production of energy in the Baltic Sea Region by type and energy consumption in Baltic Sea Region countries by sector in 2005

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Nuclear power plants	Existing (expected shutdown)	Under construction (commercial operation)	Planned (commercial operation)
↘ Denmark	–	–	–
↘ Estonia	–	–	by 2023
↘ Finland	Loviisa 1 (2027)	Olkiluoto 3 (Aug 2014)	Olkiluoto 4 (2020)
	Loviisa 2 (2030)		
	Olkiluoto 1 (2039)		
	Olkiluoto 2 (2042)		
↘ Germany	Greifswald 1-4, 5 (shutdown)		
	Brunsbuttel (shutdown)		
	Stade (shutdown)		
	Brokdorf (2021)		
↘ Latvia	–	–	–
↘ Lithuania	Ignalina (closed)	–	Visaginas (2021)
↘ Poland	–	–	by 2030
↘ Russia	Kola 1, 2, 3-4	Leningrad II-1 (2013)	
	Leningrad 1, 2, 3, 4	Leningrad II-2 (2016)	
		Baltic 1/Kaliningrad (2016)	
↘ Sweden	Oskarshamn 1, 2, 3		
	Ringhals 1, 2, 3, 4		
	Forsmark 1, 2, 3		

↑ *FIG.30 NUCLEAR POWER PLANTS* (Redrawn from Wilk, 2012)
Nuclear power plants in the Baltic Sea Region

on site of natural resources is a crucial determinant for most types of energy production. For example, renewable energies and hydropower are usually energy sources that need to be exploited and transformed into electricity on-site. Whereas oil, coal and uranium offer more flexibility and can be transported in order to feed conventional thermal or nuclear power plants.[61]

Russia, Denmark and Norway base most of their production of energy on the extraction of oil and gas. In Poland and Estonia, coal extraction accounts for the largest share of energy production (more than 80%) while in Sweden and Lithuania, it is the production of nuclear energy that holds more than half of the total national energy production, respectively 54.2% and 69.8%. The production of energy by combustible, renewable and waste represents 87.4% of the total energy production in Latvia, which is quite unique in the region. Three countries demonstrate a balanced mix of energy in their national production, including Germany that produces mainly coal (42.0%) and nuclear energy (31.6%), Finland with mainly renewable energies (42.4%) and nuclear (36.6%) and Belarus with essentially oilg and gas (52.2%) and renewable energies (33.3%).[62]

In many countries, however, the national production of energy is only a small part of the energy that is actually consumed in each country. With the exception of Norway, Russia and to a lesser extant Denmark, all Baltic Sea region countries are net importers of energy. Which implies that those countries are highly dependent on energy imports in order to meet their daily needs of energy. Therefore, energy dependence is now one of the most crucial subject of energy policy at both the european and the national level.

"[..] the lack of integration in respect of the region's electricity systems (with the exception of the Nordic countries) prevents the import and export of large amounts of electricity."[63] Therefore, the domestic production of electricity remains of utmost importance when it comes to ensuring the required levels of supply to cover the daily needs of industries and individuals. While in all the Baltic Sea region, oil and its by-products are mainly directed to the transport sector, electricity is a strategic source of energy elsewhere due to its cross-sectorial importance : it is of importance to the industrial sector, as well as in the residential, commercial and public service related sectors.

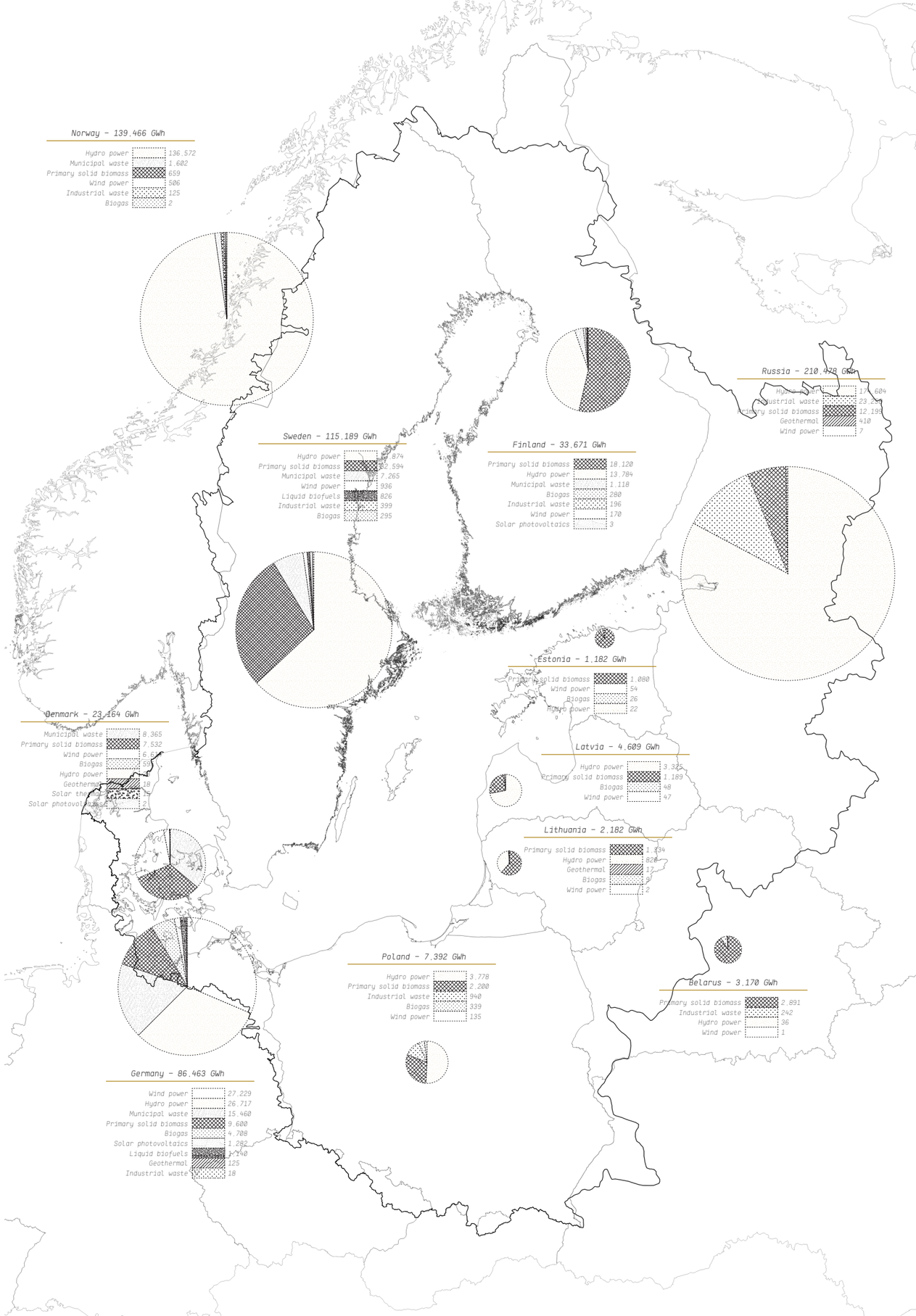
↓ INTEGRATED ENERGY NETWORK

"Energy dependency is one of the most important topics for the Baltic Sea region, since with exception of Russia, Norway and to a lesser extent Denmark, all Baltic Sea region countries are net importers of energy."[64] It is a crucial argument for developing integrated and shared energy networks and markets – seeking to enable regulations of supply and demand patterns across borders – following the trail blazed by the Nordic countries in that field.

↓ *IMG.13 FRIMMERSDORF COAL POWER PLANT, GERMANY* (Photo from Breaking Media)



FIG.31 PRODUCTION OF RENEWABLE ENERGY (Redrawn from Nordregio, 2008) →



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In June 2009, the memorandum of understanding on the Baltic Energy Market Interconnection Plan was signed by the eight Baltic Sea Member States and the European Commission, it was a step in that direction. Currently, few connections exist between the transmission grid systems of the Western and Eastern shore of the Baltic Sea region and this weak number increases the vulnerability of the system to the possible temporary disruptions at some specific nodes. "*In the context of energy dependency and climate change, it seems necessary to better exploit the own territorial energy capital of the Baltic Sea region.*"[65]

Focus should be shifted towards the potential of renewable energies (just like Germany as done for the past few years) and improving energy efficiency by reducing the amount of energy required for providing services. Countries should catalyse and support the production of regionally-based, renewable energy sources and raise the awareness on the potential for each region to contribute to the effort. As an example, the creation of a joint energy body, Nordel, ensured the compatibility of the electricity transmission systems between the Nordic countries involved. It achieved this by defining joint technical standards and by developing joint regulatory frameworks.

This integration of the Nordic electricity networks enabled providers to use the shared technical framework to connect the various electricity facilities (hydropower stations, thermal power plants, nuclear power plants, etc.) to the consumers notwithstanding the location of either. This process permits "*the creation of a shared energy market ensuring access to energy based on the complementary nature of the various countries' policy decisions and natural endowments in respect of the factors of electricity production.*"[66]

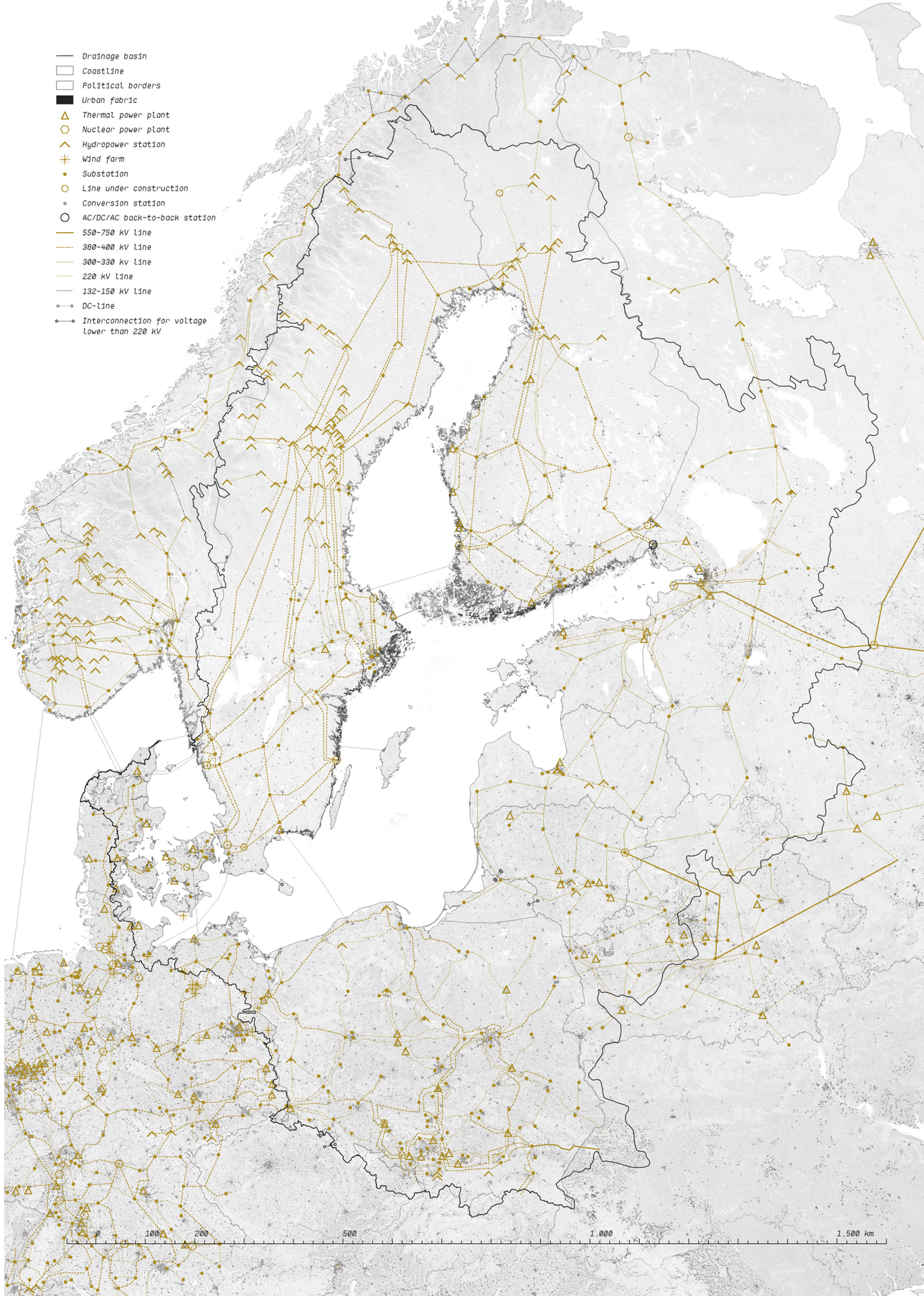
Another interesting example of this shared energy market is the construction of EstLink II in 2012, in the Gulf of Finland, that assured a new powerful energy transmission between the Baltic States and Nordic countries. This second high-voltage direct current interconnection, which was added to complement the existing *EstLink I*, is approximately 170 kilometres long, starting in Anttila in Finland, with around 145 kilometres submarine cable laid, ending in Pussi, Estonia. With its capacity of 650 MW, it increases the total transmission to 1,000 MW.

"*In order to strengthen the integration of the Baltic energy markets with Northern Europe there are also plans to build NordBalt high-voltage direct current (HVDC) Light Swedish-Lithuanian connection with a transmission capacity of 700 MW.*"[67] This project will help develop integration of emerging joint Baltic electricity market with the more developed Nordic and European markets by linking the grid of Baltic States with Nordic countries with a 450 kilometres long cable.

↓ *IMG.14 POWER LINES, GERMANY* (Photo by Alois Grundner)



MAP.6 (GIS data from HELCOM, Landsat, RRG, Nordregio) →



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↓ IMPACTS

The number of cables and pipelines are both increasing in the Baltic Sea. As a consequence of the construction of new wind parks and the willingness to connect national electricity networks, electricity cables are multiplying. Furthermore the market for natural gas has shown a steady increase over the last decade and the construction of gas pipelines in the Baltic Sea is also following this trend (as well as a European and global level). *"Looking at future plans for the region, cables and pipelines of a total length of about 3,810 km are predicted to be laid in the Baltic Sea over the next 20 years (not including cables for the planned wind farms)."*[68] It remains a low estimate since this number is mostly based on plans up to 2020. It is also quite hard to make long term forecasts on plans for cables and pipelines from 2020 and beyond when they are still too vague or non-existent. This is a complicated sector to predict and since the cables and pipelines will inevitably claim a consequential part of the marine space in the future, it is also an important one.

The process of placing cables and pipelines on the sea bottom area is a difficult one and has various impacts on its surroundings. When laying cables and pipelines, a safety zone needs to be established, which temporarily affects fishing and shipping in the area. *"The presence of the cable-laying ship and related equipments may also disturb birds, fish and marine mammals depending on the marine region, the season, and other factors"*[69] Just like dredging activities, the laying of cables also stirs up silt from the sea bottom, which usually affects marine flora and fauna. It also releases toxic substances in the sea that are stored in the bottom sediment layers.

Once the pipelines and cables are in place, they continue to affect the daily life of the fishing sector, for example if the cables are not submerged in the sea bottom, trawling and anchoring are generally forbidden with an area of 500 metres around these cables. Sometimes the cables can also have an impact on certain fish species through the electromagnetic fields that are created by the electric currents inside. Overall, the area used by cables and pipelines are quite large as the safety zone around them demand a wider space than the actual cable. *"Assuming that this sector will continue to grow at the same pace, there will be a net of about 7,000 km of pipelines and cables criss-crossing the Baltic Sea by 2030, including the cables and pipelines of today, and the cables planned for wind farms."*[70]

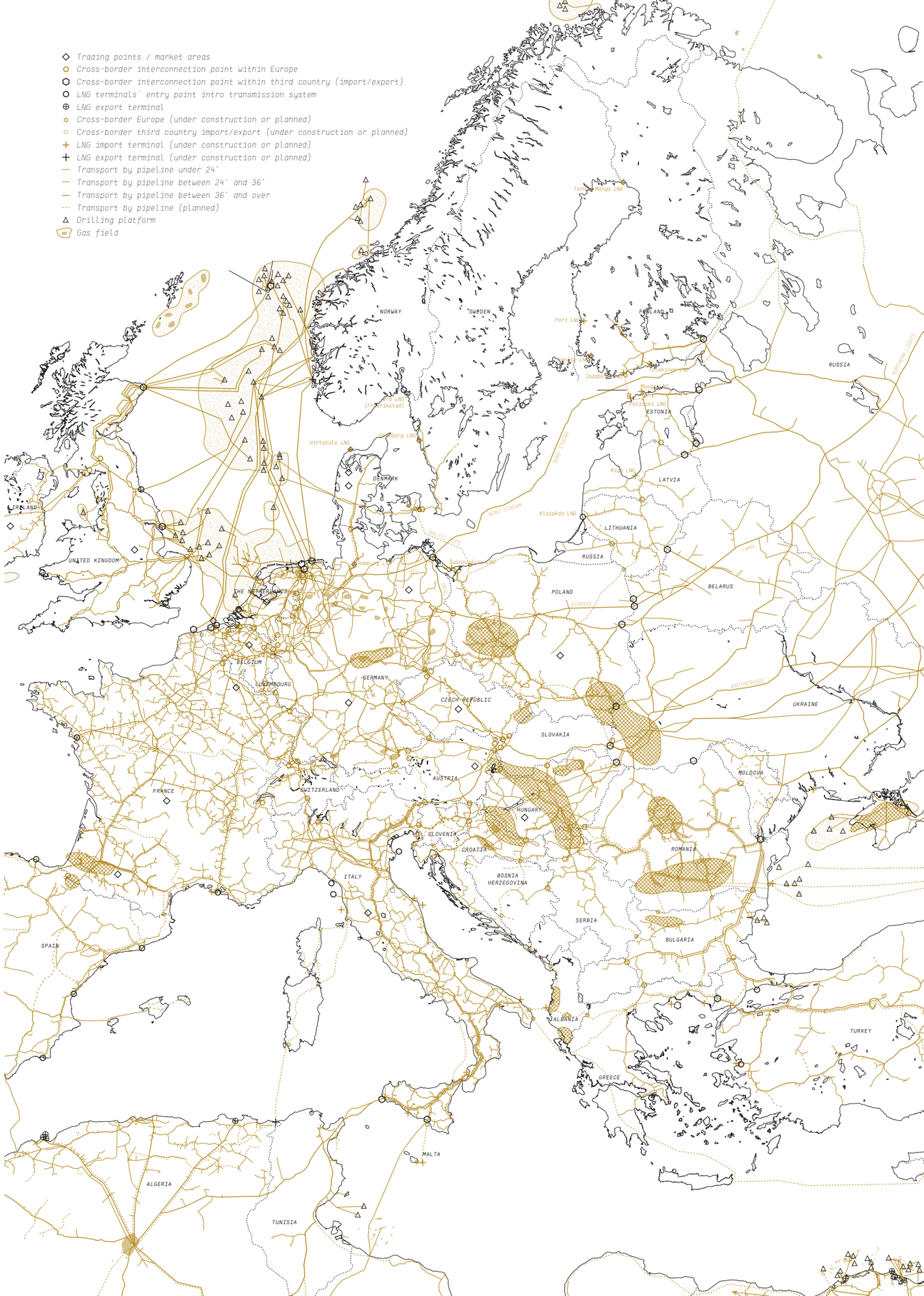
↓ GAS PIPELINES AND TERMINALS

More and more fuels used by the shipping and industry sector will be liquefied natural gas (LNG). This new demand will require an update in the existing natural gas networks, as well as planning for the construction of new LNG terminals within the Baltic Sea region. Since 2011, new projects have been drawn out and undertaken : *Amber*, a gas interconnection between Poland and

↓ *IMG.15 PIPELINE LOWERED ONTO THE SEAFLOOR* (Photo from Nord Stream)



FIG.32 EUROPEAN NATURAL GAS NETWORK (Redrawn from ETCOG,2015) →



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Harbour	Location	Size/Capacity
↘ Brofjorden	Brofjorden, Sweden	1.4 million cubic metres
↘ Bütinge	Bütinge, Lithuania	8389 million tonnes/year
↘ Fredericia	Fredericia, Denmark	18.4 million tonnes/year
↘ Gdańsk	Gdańsk, Poland	34 million tonnes/year
↘ Gothenburg	Gothenburg, Sweden	20 million tonnes/year
↘ Kaliningrad	Kaliningrad, Russia	no data
↘ Kalundborg	Kalundborg, Denmark	1.7 million cubic meters
↘ Klaipeda	Klaipeda, Lithuania	9 million tonnes/year
↘ Liepaja	Liepaja, Latvia	1.6 million tonnes/year
↘ Naantali	Naantali, Finland	4 million tonnes/year
↘ Porvoo	Porvoo, Finland	19-20 million tonnes/year
↘ Primorsk	Primorsk, Russia	12 million tonnes/year
↘ Riga	Riga, Latvia	10 million tonnes/year
↘ Rostock	Rostock, Germany	2.9 million tonnes/year
↘ Sillamäe	Sillamäe, Estonia	5 million tonnes/year
↘ St. Petersburg	St. Petersburg, Russia	12,2 million tonnes/year
↘ ↘ Tallinn	Tallinn, Estonia	2 million cubic meters
↘ Ust-Luga	Ust-Luga, Russia	38 million tonnes/year
↘ Ventspils	Ventspils, Latvia	10 million tonnes/year
↘ Vysotsk	Vysotsk, Russia	11.6 million tonnes/year

↑ *FIG.33 OIL TERMINALS* (Redrawn from Wilk, 2012)
Oil terminals with size and capactiy within the Baltic Sea Region

Lithuania; *Baltic Pipe*, a 230 kilometres long planned submarine pipeline which would connect Denmark and Poland; *Balticconnector*, a proposed natural gas pipeline linking the Finnish, Estonian and Latvian natural gas grid; *JAGAL*, a German section of the Yamal-Europe pipeline transporting Russian natural gas into eastern Germany through Poland and Belarus; *Nord Stream*, a submarine gas pipeline connecting Russian natural gas supplies which consists of two lines that allow the transport of gas for the upcoming 50 years; *OPAL/NEL pipeline*, a natural gas pipeline in Germany, situated alongside the German eastern border; and last but least the *Yamal-Europe pipeline*, which is a transnational gas pipeline passing through Russia, Belarus, Poland and Germany.[71]

Expected to reduce carbon emissions and facilitating transportation, liquefied natural gas is an environmentally friendly fuel which is currently facing an increasing demand. *"Thus, the representatives of eight Baltic ports gathered in Copenhagen to sign a partner agreement related to the project called 'LNG in the Baltic Sea Ports' co-financed by EU TEN-T Multi-Annual Program."*[72] The concerned ports are Helsingborg, Helsinki, Malmö-Copenhagen, Tallinn, Turku, Aarhus, Stockholm and Riga. The main reason for this collaboration is to develop a harmonised planning towards LNG bunkers filling infrastructure in the Baltic Sea region. Today, there are only a couple of working installations for the sector of LNG in the Baltic Sea region. However, in order to increase the diversity of energy supply and to provide alternative supply routes for gas in the Baltic Sea region, many countries are working on projects that will help establish large scale import terminals for LNG. *"Before 2015, large import terminals were expected to come into operation in Tallinn, Klaipeda, Swinoujscie, Lysekil and possibly in Riga, but due to many factors they seem to be delayed."*[73]

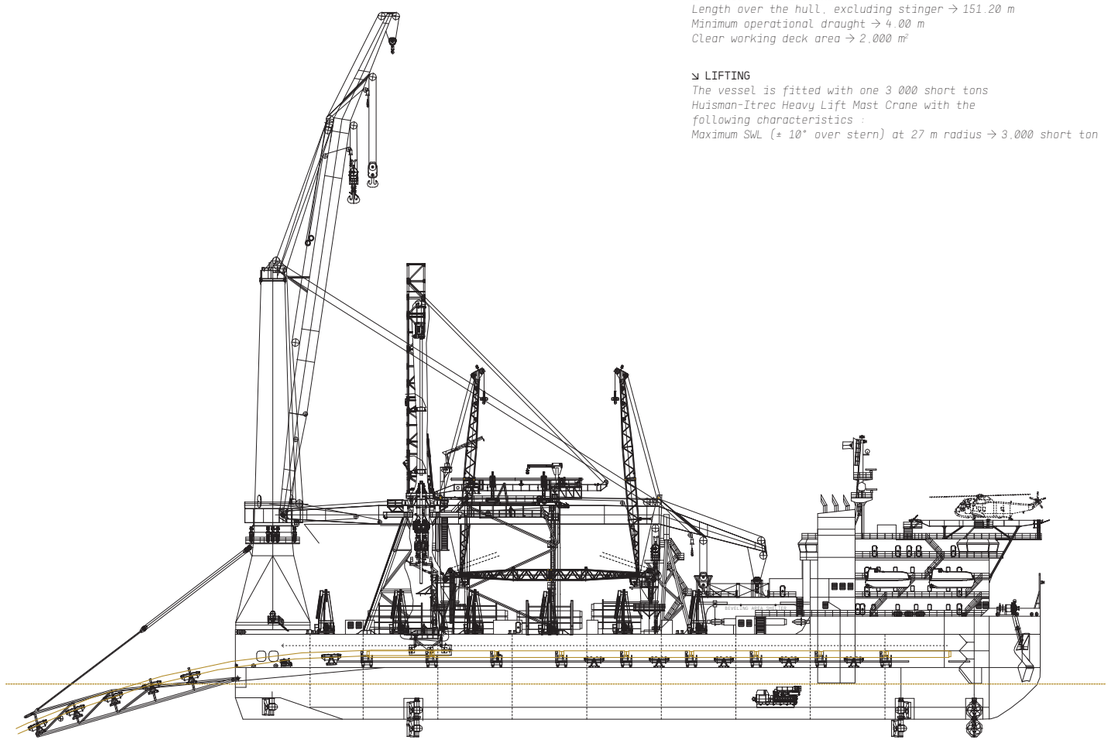
↓ OIL PIPELINES AND TERMINALS

BALTIC PIPELINE SYSTEM 1 The baltic Pipeline system was constructed to move crude oil from the fields of Western Siberia (Timan-Pechora and Volga-Urals petroleum provinces) to a terminal on the coast of the Gulf of Finland for exports. It accounts for the major pipelines of Yaroslavl-Kirishi and Kirishi-Primorks as well as the oil terminal in Primorks, situated in the outskirts of St. Petersburg. However, this pipeline reached its full designed capacity of 1.3 million barrels a day in 2006 (about 65 million tonnes a year).[74]

BALTIC PIPELINE SYSTEM 2 Russia has started exporting crude oil through the Baltic Pipeline System's (BPS) second trunkline, which initiates in the Bryanks region and ends at the Ust-Luga maritime terminal. The oil is then carried onboard tankers, through the Baltic Sea and North Sea, to European customers. The BPS-2 was designed for a total capacity of 50 millions tonnes yearly. In 2013, 30 millions was reached and 38 million in 2014. This pipeline is 1,000 kilometres long with an extra 170 kilometres branch off to Kirishi (approximate construction cost of 4 billion US dollars). The BPS pipelines were mainly designed to reduce Russian reliance on overland transit countries (such as Ukraine) in order to connect directly with Western Europe by maritime route.[75]

DRUZHBA PIPELINE So far this is the world's longest pipeline and remains a leading service for oil transportation to European countries. In 1962, the project was initiated in order to meet the oil needs of Hungary, East Germany, Poland and Czechoslovakia. It transports oil for an impressive 5,327 kilometres. At the time of its construction, each country was in charge of building its own portion, which would then become the country's property. The Former Soviet territory's section is 3,004 kilometres long and was constructed not only to deliver oil to the countries involved in the project but also to ensure stable supplies of oil to processing plants in the western region of Russia as well as exports of oil to other countries through the Baltic port of Ventspils. At Mozyr, in Belarus, the pipeline divides into two routes : one going north through Poland and Germany and one going south through Ukraine, Slovakia, the Czech Republic and Hungary. Both have a capacity of up to 1.4 million barrel of oil a day (about 70 million tonnes a year).[76]

"In addition, Russian company LukOil is planning to build a new pipeline between the port of Primorsk and the marine oil terminal based in the port of Vysotsk. The project is still under discussion and the company is working on technical and economic studies."[77] Once the project is approved, the estimated time for reaching its full capacity is estimated to be around two years. One of the most important oil terminals of the Baltic Sea region



↘ PRINCIPAL DIMENSIONS
Length over the hull, excluding stinger → 151.20 m
Minimum operational draught → 4.00 m
Clear working deck area → 2.000 m²

↘ LIFTING
The vessel is fitted with one 3 000 short tons Huisman-Itrec Heavy Lift Mast Crane with the following characteristics :
Maximum SWL (± 10° over stern) at 27 m radius → 3.000 short ton

↑ *FIG.34 DP II DERRICK PIPE LAY VESSEL SAPURA 3000* (Redrawn from Vuyk Engineering)
Using this vessel, the pipeline is progressively lowered to its designated place on the seabed

NAME OF PROJECT	Cable type	Location	In operation	Length offshore
↘ BALTICCONNECTOR	Gas pipeline	Finland – Estonia	2010	120 km
↘ GREAT BELT	Electricity cable	Denmark	2010	30 km
↘ FENNO-SKAN 2	Electricity cable	Finland – Sweden	2011	200 km
↘ NORD STREAM	Gas pipeline	Russia – Germany	2012	1.200 km
↘ BALTIC PIPE	Gas pipeline	Denmark – Poland	2013	230 km
↘ ESTLINK 2	Electricity cable	Estonia – Finland	2013/2014	140 km
↘ GOTLANDSKABELN	Electricity cable	Sweden	2015 (earliest)	100 km
↘ NORDBALT	Electricity cable	Sweden – Lithuania	2016/2017	350 km
↘ EKOLÄNKEN	Electricity cable	Sweden	2015-2030	700 km
↘ AMBERGATE	Electricity cable	Sweden – Latvia	2015-2030	390 km
↘ (NO NAME)	Electricity cable	Estonia – Sweden	2015-2030	350 km
TOTAL				3.810 km

↑ *FIG.35 CABLES AND PIPELINES* (Redrawn from WWF, 2010)
New cables and pipelines in the Baltic Sea that are either under construction, have been approved or are under consideration during the next 20 years (electricity cables from projected wind farms not included)

BAŁTYK SEA
INFRA-STRUCTURE COLONIZATION

is situated in St. Petersburg where over the past few years the tank farm there has increased capacity to 354 thousands cubic metres. In 2010, there were 108 tank places, 7 wharves, capacity of ships received of 100 thousand tonnes and the terminal capacity of 12.2 million tonnes a year. The main company, Petersburg Oil Terminal, started back in 2011 the implementation of the next stage of its long-term investment program until 2020, which includes building a third 40.000 cubic metres oil product storage tank.

↓ FUTURE TRENDS

"As the Baltic Sea Region is mostly dependent on gas supplies, there has to be a sufficient gas infrastructure provided for countries within the region."[78] Liquefied natural gas terminals and unconventional resources will be the mains actors witnessing this change. As for oil movements within the Baltic Sea region, it is easy to predict a continued domination of Russia through its export of crude and refined oils. Indeed with the Druzhba and Baltic Pipeline System 1 & 2, all the Baltic Sea region countries are heavily influenced by Russian oil supply. As most of these countries remain strongly dependent on oil, there are new oil terminals being planned and constructed in order to enable easier and more efficient exchange. However, the Baltic Sea region countries are slowly but steadily moving away from fossil fuels in order to replace them by more renewables ones. These new energy policies will undoubtedly effect the way pipelines and cables will be planned and constructed in the future.

↓ IMG.16 *MARSHALLING YARD, SLITE, SWEDEN* (Photo from NordStream AG)



MAP.7 (GIS data from HELCOM, Landsat, Harvard) →



BAŁTYK SEA CARTOGENESIS

→ CITY NETWORKS

Population density

High

Low

Urban fabric

Continuous

Discontinuous

With the rise of industrialisation, cities became centres of polarization and started gathering important amounts of poeople at one place. There is a spatial polarisation of population towards the capitals, larger agglomerations and higher order urban centres that can be observed in most parts of the Baltic Sea region. It is followed by increasing suburbanisation, notably in and around most the metropolitan areas. Furthermore, a number of small and medium- sized cities and towns on the fringes of these metropolitan areas have quickly expanded their populations. This urban development has a great spatial impact on the territory.

→ ROADS + RAILWAYS

Railways

The Baltic Sea region has become one of the fastest growing areas in Europe, thanks to a dynamic economic growth and export-profiled production. Its strategic position between the east and the west makes it one of the most prolific areas of infrastructural development. Many opportunities of connecting missings parts along the Baltic Sea or with further connection towars North are opened for development in the upcoming years and decades.

→ MARITIME TRAFFIC

Risk of oil spills

Groundings

Collisions

Oil spills damage

Maritime traffic

Main harbours

Harbours

As the Baltic Sea acts as a physical obstacle for the development of transport networks across the Sea, maritime traffic is of major importance for the transport of goods, people and for many industrial activities such as fishing or for the installation of offshore platforms. The sea is still a place of importance and of opportunities for future developments in many sectors. It also has one of the densest maritime traffic in the world. There are more than 2,000 ships cruising at any given time on this rather small water body. Different factors also makes it one of the most dangerous to navigate. A combination of heavy shipping traffic, shipping lanes crossing each other, narrows straits, shallow waters and long ice cover periods makes it a difficult area for navigation. Many improvements can still be done to strengthen maritime connections across the Baltic Sea.

→ AIR TRAFFIC

Main airports

Airports act as hubs or gateways of transport on a larger scale. Copenhagen is the main transport hub for the whole region Internatonally. Smaller airports permit distant regions to be re-approvisionned and are often closely linked to maritime traffic hubs and railway infrastructure.

→ ELECTRICAL GRID

Thermal power plant

Nuclear power plant

Hydropower station

Wind farm

Line construction

AC/DC/AC station

550-750 kV line

380-400 kV line

300-330 kV line

220 kV line

132-150 kV line

Lower voltage

Securing access for industries, businesses and the population to the energy required to perform their daily activities usually guides the elaboration and implementation of energy strategies for national policymakers. In general these strategies address the issues of production such as finding new sources of energy and how to adapt the consumption of energy to the national production capacity and its economic development. Therefore, the territorial capital of a country or region is an important factor in defining these strategies. In many countries, the national production of energy is only a small part of the energy that is actually consumed, improvements can be done in this regard.

In many countries, however, the national production of energy is only a small part of the energy that is actually consumed in each country. With the exception of Norway, Russia and to a lesser extant Denmark, all Baltic Sea region countries are net importers of energy. Oil, gas and coal are still the main source of energy for most of the countries of the Baltic Sea region. Some countries use nuclear energy production. The production of energy by combustible, renewable and waste represents 87.4% of the total energy production in Latvia, which is quite unique in the region.

→ CABLES + PIPELINES

Oil Terminals

LNG Terminals

Main gas pipelines

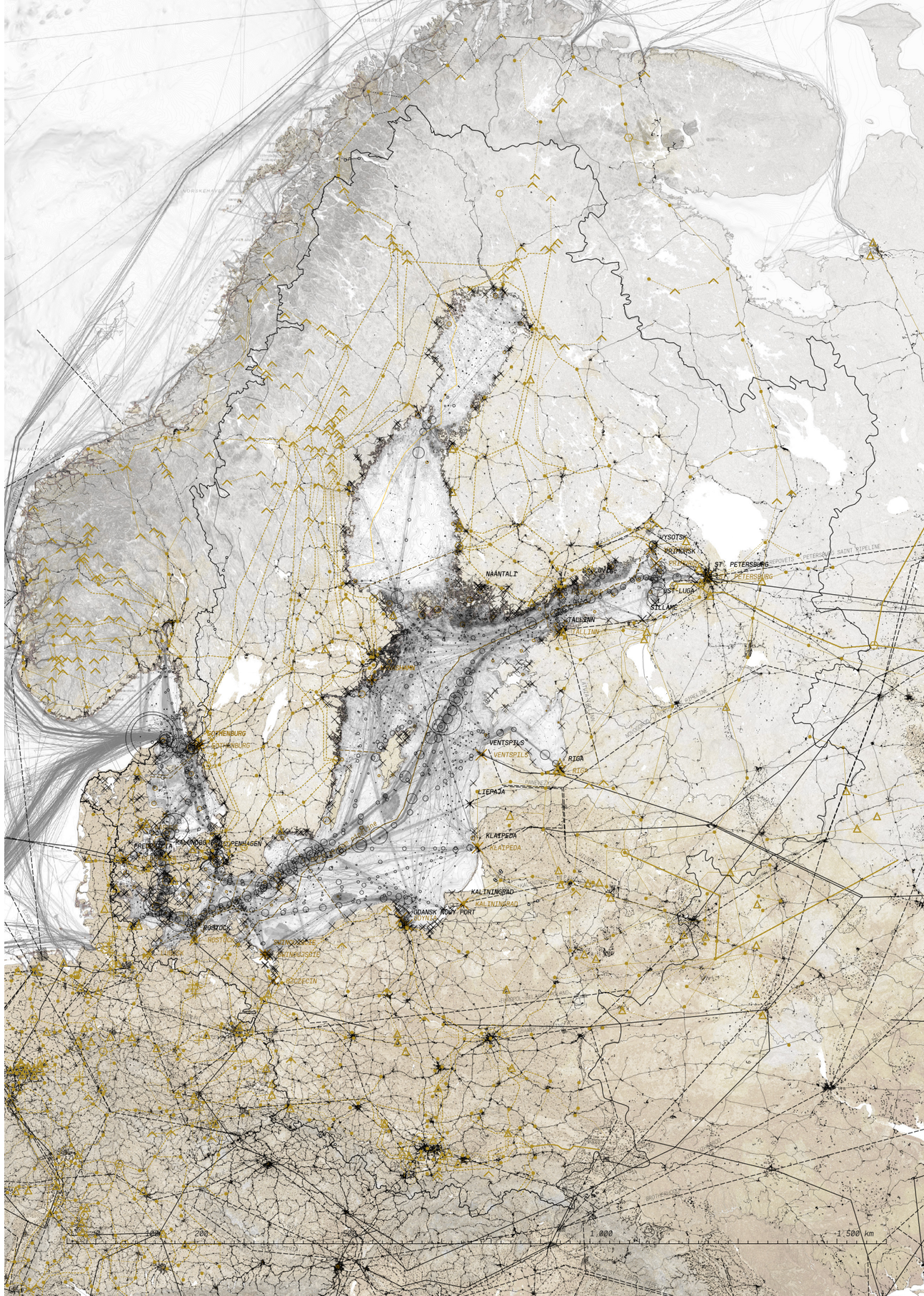
Main oil pipelines

Submarine cables

Planned HDV cable

The number of cables and pipelines are both increasing in the Baltic Sea. As a consequence of the construction of new wind parks and the willingness to connect national electricity networks, electricity cables are multiplying.

The Baltic Sea region countries are now slowly but steadily moving away from fossil fuels in order to replace them by more renewables ones. These new energy policies will undoubtedly effect the way pipelines and cables will be planned and constructed in the future.





GEOPOLITICAL COLLISION

RUSSIA HAS BEEN CONDUCTING NEARLY NONSTOP NAVAL EXERCISES IN THE BALTIC SEA

BAŁTYK SEA GEOPOLITICAL COLLISION

↓ FOREIGN TRADE EVOLUTION

"The foreign trade between the countries located on the shores of the Baltic Sea took place back in historical times. Several cities of the area belonged to the Hanseatic League in the 14th-15th centuries when trade flourished and there were many contacts between the cities."[1] Conditions for foreign trade were very different during the Second World war, when the Iron Curtain divided the area.

The Scandinavian countries integrated into the Western world trade system at various speeds. As part of the Soviet Union, Belarus and the Baltic States were involved mainly in the distribution of production between the republics of that state. Poland, on the other hand, acted as a satellite of the former Eastern bloc and this forged the geographical pattern of foreign trade dominated by the Soviet Union and other East European countries.[2]

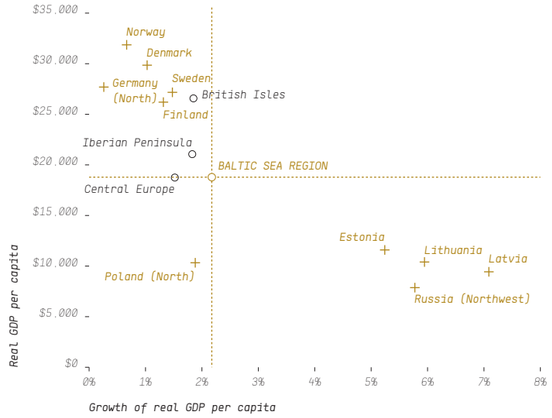
Quick changes also took place in foreign trade when the Soviet economic system collapsed: the Baltic States regained their independence and an important transition occurred in Poland from planned to market economy. The countries that had now transited, orientated their foreign trade rapidly toward Western Europe (with special emphasis on a possible integration with the EU). In response, Russia partly deregulated its foreign trade, while Belarus remained strictly regulated and oriented towards its Eastern neighbour. *"The trade with Baltic Region transition economies achieved a larger share also in the trade balance of Scandinavian countries, but those changes were proportionally several times smaller than changes in the trade balances of those countries."*[3]

↓ GEOGRAPHICAL PATTERNS OF TRADE

In terms of foreign trade patterns and economic development, the Baltic Sea region includes countries with various levels. First of all there are the rich Scandinavian countries such as Denmark, Finland and Sweden. Second there are the transition economies which includes the Baltic States with Estonia, Latvia, Lithuania and Poland. Russia – especially the St. Petersburg area – and Belarus also belong to this second group. Furthermore, the huge gap in welfare and production capacities have a relatively strong impact on foreign trade as well.

In the regional integration process, the countries stated above also differ greatly: the three Scandinavian countries were members of the European Union before the turn of the century (Denmark joined in 1973, Sweden and Finland in 1995), while the Baltic States and Poland, considered accession countries at the time, all joined around 2004.[4]

Until the collapse of the Soviet Union, the exports of the Baltic States countries' trade were completely oriented to the eastern markets, since then significant changes have taken place in their trade orientation. The Baltic Sea region has grown into a closely

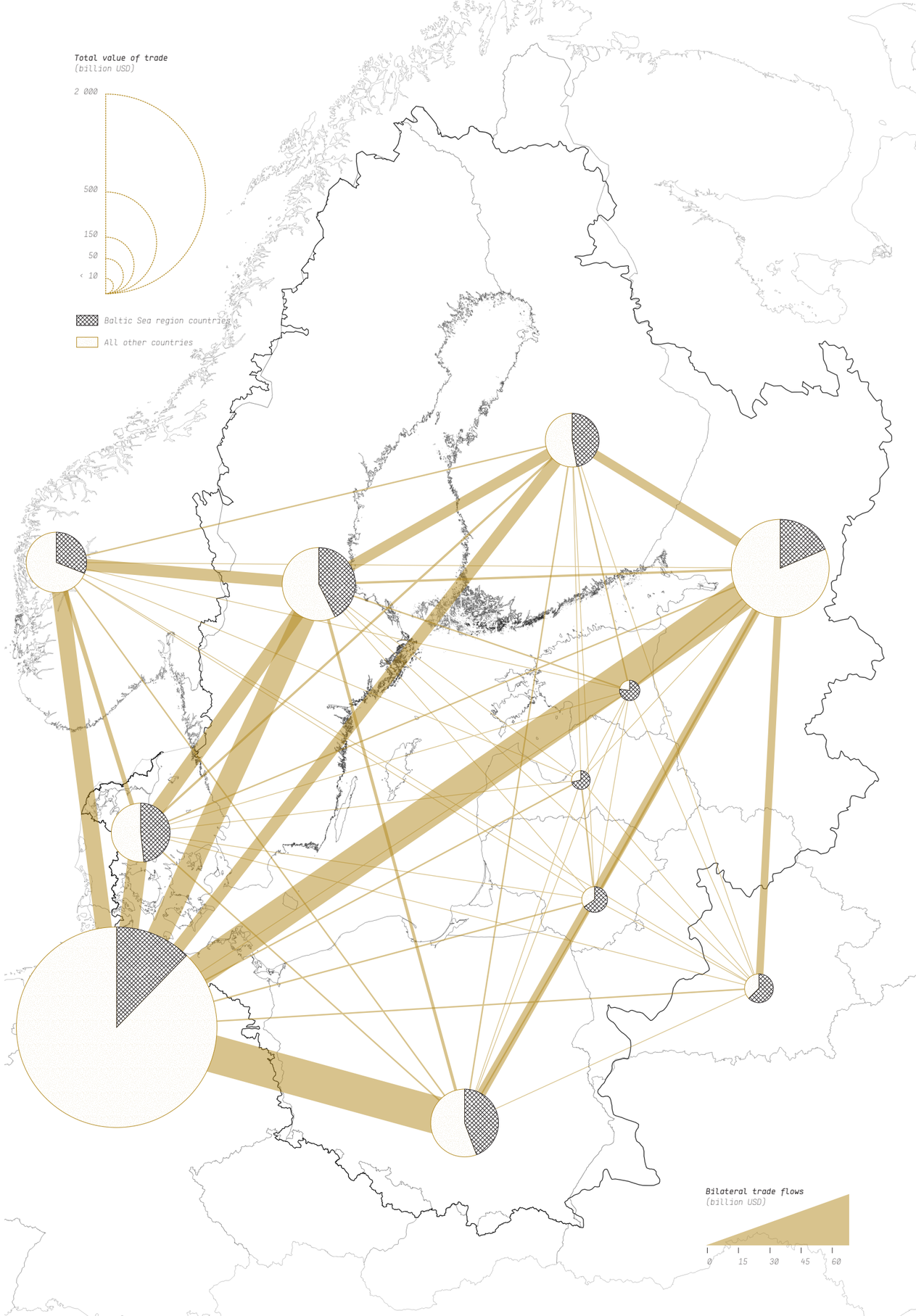


↑ *FIG.1 PROSPERITY BALTIC SEA REGION* (Redrawn from Ketels et al., 2004)
The Region's prosperity level in 2003 was slightly ahead of the Central European Region, lagging the Iberian Peninsula by 10% and the British Isles by 30%. Despite some recent convergence there is still significant heterogeneity of economic performance across the region

↓ *IMG.1 THE LANDFALL OF THE NORD STREAM PIPELINE, GERMANY* (Photo from NordStream AG)



FIG.2 TRADE BETWEEN BALTIC SEA REGION COUNTRIES (Redrawn from NORDREGIO,2006) →



BAŁTYK SEA **GEOPOLITICAL COLLISION**

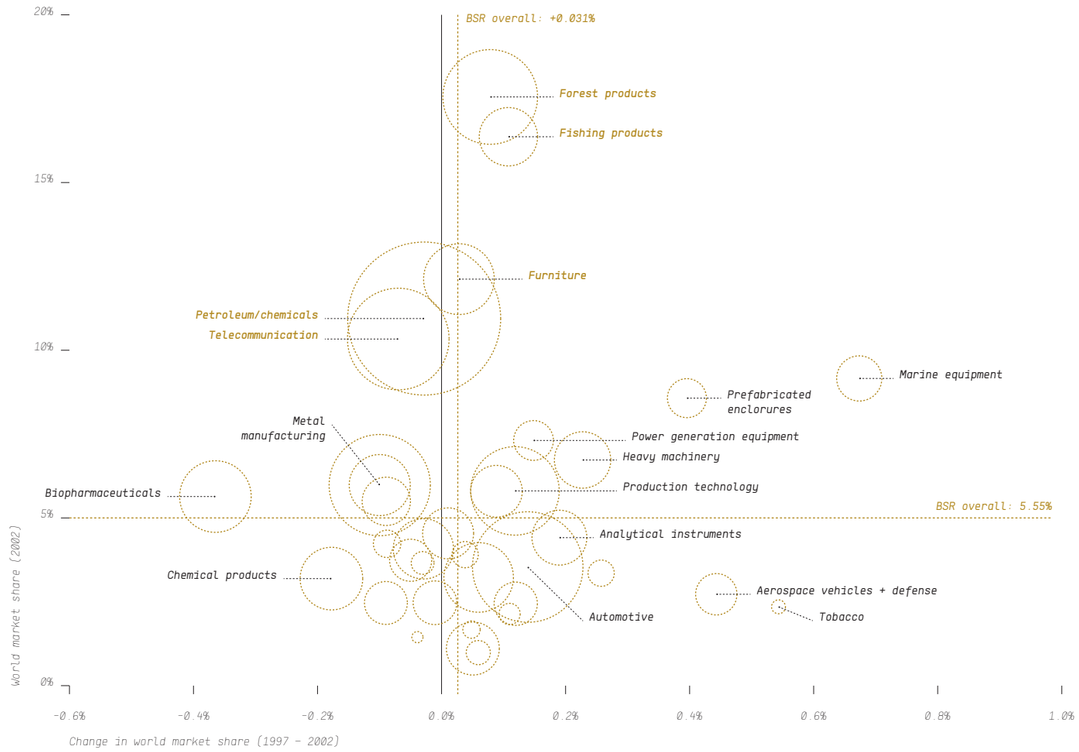
knitted cross-border economic region, where intra-regional trade constitutes an important part of the trade of the individual countries. However, the trade balances of the Baltic States remain in deficit 15 years after the start of transition despite the generally favourable developments. While taking a closer look at the relative trade balance of individual countries, one can notice different trade specialisation patterns along the North-Western and South-Eastern coastlines of the Baltic Sea. *"While the Nordic countries and Germany specialise predominantly in exports of manufactured goods, the Baltic States and Poland record positive relative trade balances mainly in agricultural products and/or raw materials."*[5]

↓ INTERNATIONAL TRADE SPECIALISATION

The main export articles of the Baltic Sea region are petrochemicals, telecommunication equipment, automotive and transport equipment, metal manufacturing, forest products and various production technologies. Sweden is one of the largest exporter in the region: its export consists mainly of aerospace engines, biopharmaceuticals, automotive and forest products. Finland exports predominantly forest products, telecommunication and marine equipment. Denmark is strong in food products, biopharmaceuticals, power generation (wind energy) and footwear. Germany's strengths are in automotive, aerospace and information and communication technologies. Poland's main strength are in manufacture of transport equipment and parts thereof (diesel engine), wood and furniture.

"The North-Western region of Russia is one of the most industrially developed among the Russian regions."[6] Russia's specialisation includes energy production, wood processing, metal and machinery manufacturing (energy technology, marine transport equipment), food processing, ICT and electronics manufacturing. A significant part of the exports of the Baltic States is also the transit of oil from energy rich Russia. Lithuania's strength, besides manufacturing Russian oil, are in transport (railway carriages) and marine equipment. Latvia's exports are mainly wood and furniture, food and textiles. Finally, Estonia's main export specialisation are in telecommunication equipment, electronics, wood processing, furniture and printing.

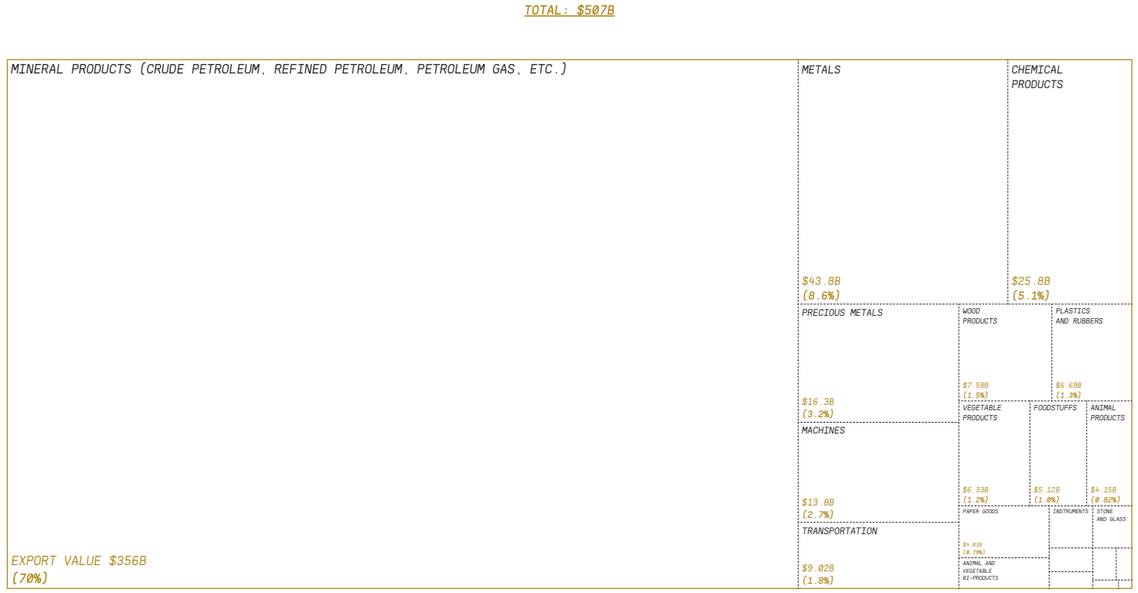
"When assessing the potential for future cross-national co-operation in the region, one should not limit the potential of Russia with its natural resources alone."[7] Amongst the Russian regions, the North-Western region is one of the most industrially developed: it accounts for 9% of Russia's GDP and almost 10% of its industrial production. Furthermore, the region is also rich in human capital and it is only a question of time before the city of St. Petersburg will regain its full glory as a global metropolis. Given its favourable location and the number of universities and research institutes located there, the region remains one of the most attractive in Russia for foreign direct investments.



↑ *FIG.3 BALTIC SEA REGION WORLD EXPORT MARKET SHARE* (Redrawn from Ketels et al., 2005)
Baltic Sea region world export market share by cluster

↓ *IMG.2 SAAB GRIPEN FIGHTER JET IN LINKOPING, SWEDEN* (Photo by Casper Hedberg)





↑ *FIG.4 RUSSIAN EXPORTS* (Redrawn from OEC, 2013)
The tree map of Russian exports clearly shows the signigicant impact of mineral products, such as crude and refined petroleum

BAŁTYK SEA
GEOPOLITICAL COLLISION

↓ TRENDS

Looking at the *intra-regional* trade pattern – trade between countries in the Baltic Sea region – one can observe that the three Baltic States and Belarus in particular show a substantially trade flow within the region. In this respect, Poland and the Nordic countries also show a high degree of integration. *"Due to the large size of Germany and its central location in continental Europe the share of bilateral trade flows to other BSR countries is rather low. The same can be said for Russia [.]"*[8] However, Germany and Russia remain global players in the Baltic Sea region. The Nordic countries and Germany, witnessed through the intensity of flows show on the first map, exhibit strong trade relations with each other. In comparison, large trade flows are also noticeable between Germany and Poland and Germany and Russia. Other important trade partners for Russia in the Baltic Sea region are Finland, Poland and Belarus.

What remains striking is the comparably small flows that are directed to (or respectively from) the Baltic States. This is mostly due to the fact that these national economies are much smaller in comparison to most of the other countries of the region. Furthermore, the fact that many Nordic companies (mostly banks) have established Baltic-based ventures disfigures one's perception of trade and financial integration along the Nordic-Baltic axis. *"On closer inspection one can see, however, that their international trade flows are not only very much focussed on other BSR countries, but also that these flows remain rather balanced as most of the strokes do show the same gauge."*[9] In a dynamic perspective, as trade patterns have been relatively stable, one can notice that the last few years can be characterised as a time of consolidation.

Today, Russia seems to have regained its former position, which it held before the country had to cope with severe economic issues around the turn of the millennium. Since then the pattern of trade flows with other Baltic Sea region countries have grown again: especially due to the increasing demand for oil-related products in the other Baltic Sea region countries. Considering the size and nature of the German economy, the significance of the Baltic Rim as a geographical region decreased in the first few years after the fall of the Iron Curtain, but has steadily grown again since then. As for the three Baltic States, one can anticipate a trade trend which will in the future become rather similar to the one present in the Nordic countries. This will mean that the share of trade flows with other Baltic Sea region countries will decrease further until it stabilises around the level of the Nordic countries (about 40% of their overall international trade).[10]

IMPORT

	DK	EE	FI	DE	LV	LT	PL	SE	RU	BSR9
Denmark	:	0.3%	2.1%	21.4%	0.3%	0.5%	1.8%	13.3%	1.0%	**40.7%**
Estonia	2.4%	:	20.0%	12.4%	4.1%	5.1%	3.2%	9.4%	9.4%	**66.1%**
Finland	5.2%	2.5%	:	16.2%	0.2%	0.1%	0.9%	14.3%	12.8%	**52.3%**
Germany	1.7%	0.1%	1.0%	:	0.1%	0.1%	2.7%	1.8%	2.7%	**10.2%**
Latvia	3.0%	7.0%	6.4%	14.0%	:	12.3%	5.5%	6.2%	8.8%	**63.2%**
Lithuania	3.6%	3.3%	3.4%	16.9%	3.9%	:	7.7%	3.4%	23.2%	**65.4%**
Poland	1.7%	0.1%	1.4%	28.2%	0.3%	0.6%	:	2.8%	7.1%	**42.2%**
Sweden	8.8%	0.8%	6.1%	18.2%	0.4%	0.5%	2.4%	:	2.4%	**39.7%**

EXPORT

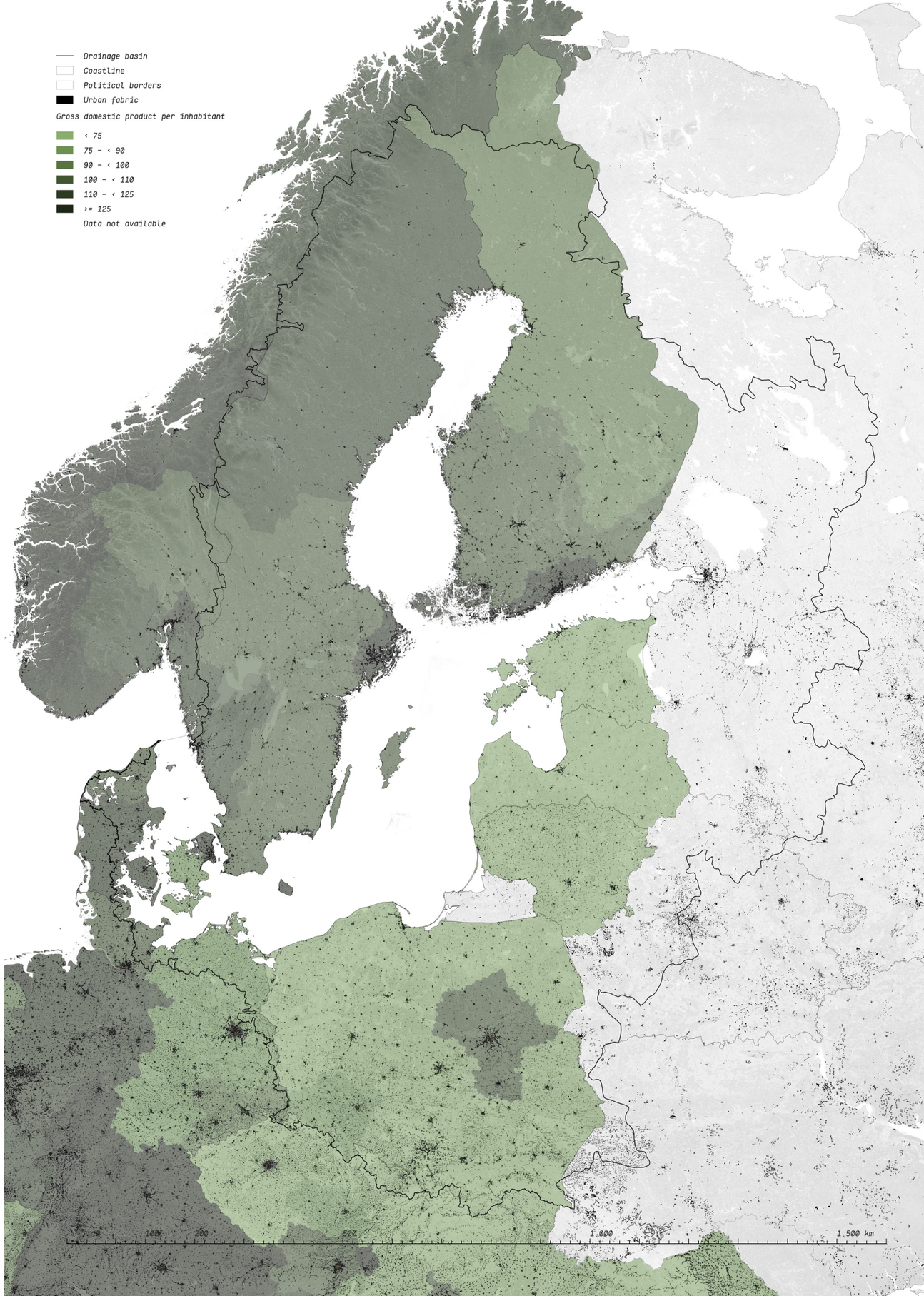
	DK	EE	FI	DE	LV	LT	PL	SE	RU	BSR9
Denmark	:	0.2%	2.9%	18.3%	0.3%	0.4%	1.5%	12.8%	1.3%	**37.7%**
Estonia	3.3%	:	22.9%	8.3%	8.0%	4.4%	1.0%	15.2%	5.6%	**68.7%**
Finland	2.2%	2.8%	:	10.7%	0.7%	0.5%	1.7%	11.1%	8.9%	**38.6%**
Germany	1.5%	0.1%	1.0%	:	0.1%	0.2%	2.6%	2.2%	2.0%	**9.7%**
Latvia	5.4%	8.0%	2.5%	12.1%	:	9.2%	3.6%	10.1%	6.4%	**57.4%**
Lithuania	4.8%	5.0%	0.9%	10.3%	10.2%	:	4.8%	5.1%	9.3%	**50.4%**
Poland	2.2%	0.4%	0.8%	29.9%	0.6%	1.7%	:	3.5%	3.9%	**42.9%**
Sweden	6.4%	0.6%	5.5%	10.0%	0.3%	0.3%	1.7%	:	1.5%	**26.3%**

↑ *FIG.5 INTRA-REGIONAL TRADE* (Redrawn from Tiits, 2006)
Share of the intra-regional trade for individual countries, 2004

↓ *IMG.3 MARSHALLING YARD IN HANKO, FINLAND* (Photo from NordStream AG)



MAP.1 (GIS data from HELCOM, Eurostat, Landsat) →



BAŁTYK
SEA
GEOPOLITICAL COLLISION

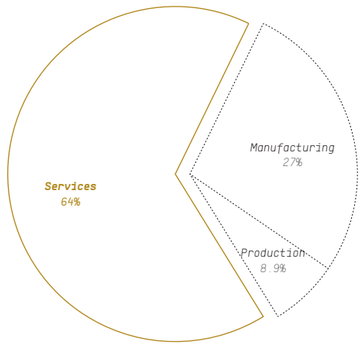
↓ SERVICES LABOUR

The Baltic Sea region has faced important shifts in the past decades. Structural changes happened in the labor market with the fall of the Soviet Union. Some countries such as the Baltic States or Poland have moved from a planned economy with administrative prices to a democratic market economy.[11] Unemployment was not quantifiable at this time since everyone was guaranteed work. The adhesion to the European Union has decoupled the effects of economic growth for these countries. Unemployment followed the drop in production that occurred with this shift of systems, most countries have experienced rates between 8 to 15% of unemployment. In some countries, this figure reaches 20%.[12] But differences are not only visible on a National level, there are big differences between regions within a country.

These differences can be found in the productivity of the labour force within the Baltic Sea region. *'The highest GDP per capita, highlighting the productivity of the labour force, is to be found in the Nordic capital metropolitan areas, in Hamburg, as well as in some of the regions on the Norwegian south-west coast.'* (Schmitt, 2008) These figures are related closely to the locations of big companies (see CITY NETWORKS) or other institutions but do not necessarily correspond to where the GDP is being invested or consumed.[13] But there is a clear difference between rural and urban areas in terms of employment and productivity. Even in countries with higher unemployment rates, exceptions can be found in larger urban agglomerations where the more productive jobs in the service industries and technology firms can be found.[14]

This trend can also be seen through the share in sectors (see *FIG.7*). The employment rate is quite uneven throughout the Baltic Sea region. Not only are national differences directly visible, but this also works on a regional level. A clear concentration of labour is visible in metropolitan areas such as St.Petersburg and Stockholm but also in the southern most populated countries such as Germany, Poland and Denmark. Out of this, is also very clear that the largest source of employment in all Baltic Sea regions is the service sector (see *FIG.6*). Here again there are important regional differences which can be partly related to the degree of urbanisation.[15] *'The higher the urbanisation rate, the higher the share of services'* (Schmitt, 2003). Tourism is one of the most rapidly growing service sector and is becoming more and more important in the Baltic Sea region. It represents a major source of income for many countries and also represents an important part of the service sector employment share.[16]

The overall share of employment in manufacturing has remained quite table in the past decade (27% in 2002, 27,2% in 2006) while the percentage of private/public services has increased (64% now, 62,9% in 2002) while there was an observable decline in production (from 9.9% to 8.9%).[17] These shifts are not constant throughout the regions. The majority of Eastern countries (Baltic States, Poland) have been dominated by primary production.



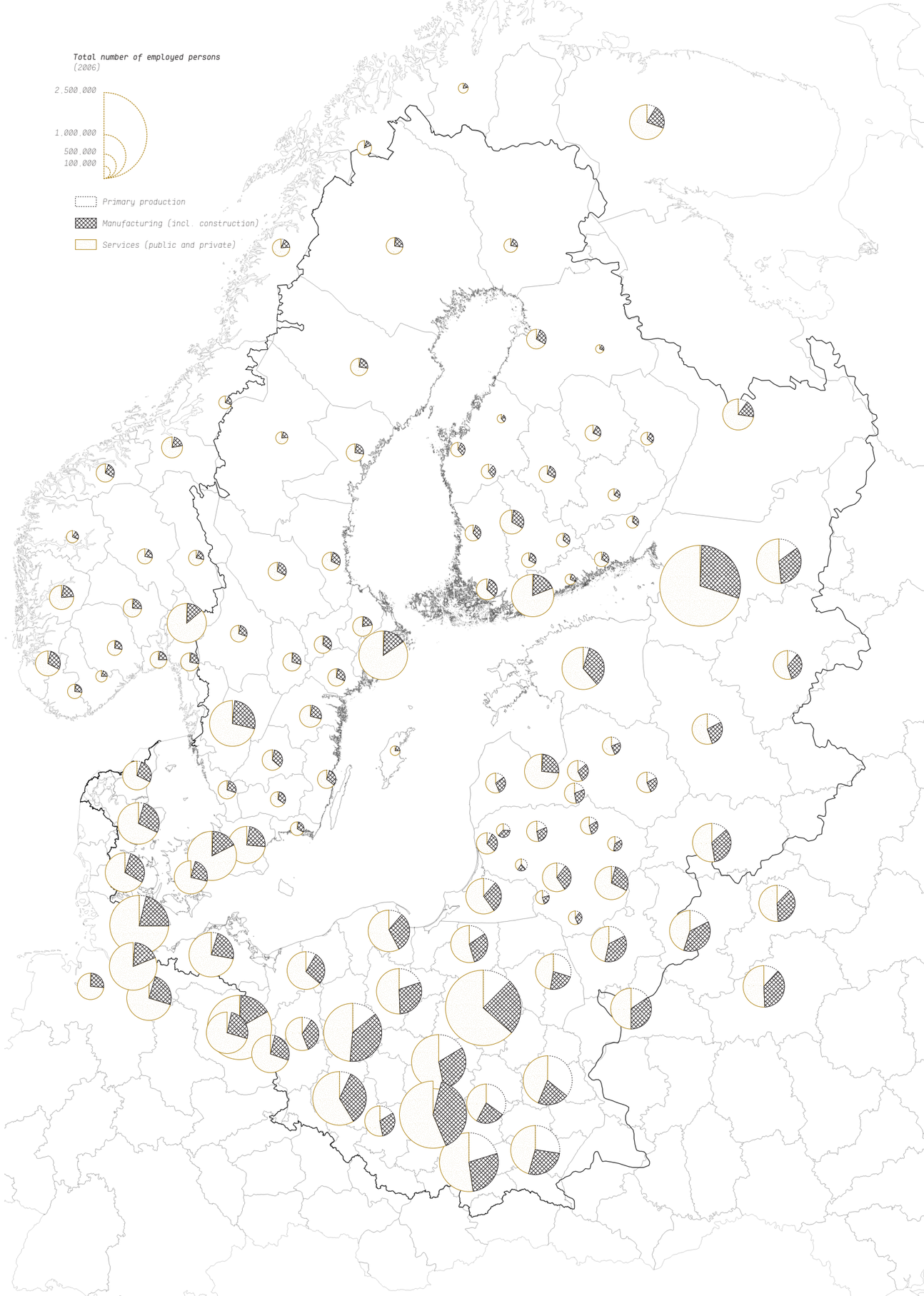
*Sectors
- Primary: production
- Secondary: manufacturing (incl. construction)
- Tertiary: services (public/private)

↑ *FIG.6 SHARE OF EMPLOYMENT* (Redrawn from Schmitt, 2008)
Shows the dominant branch of employment in the Baltic Sea region in 2006. Data based on the average sectoral employment collected from Eurostat, National Statistics Offices, Nordregio estimates and Akershus

↓ *IMG.4 GRAVEL MANUFACTURE, HELSINKI PORT* (Photo by Mikko Miettinen)



FIG.7 DOMINANT BRANCH OF EMPLOYMENT (Redrawn from NORDREGIO,2006) →



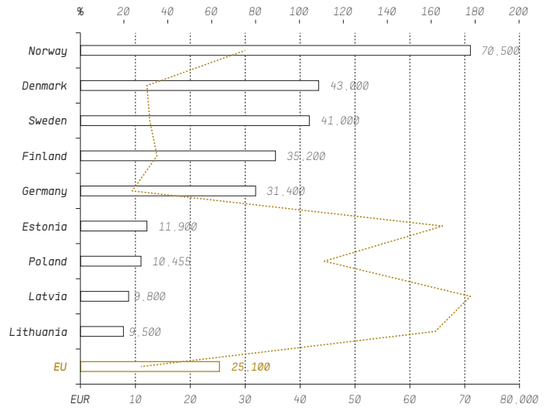
BAŁTYK SEA GEOPOLITICAL COLLISION

Western Poland has increased its manufacturing sector, and it has overtaken the production one nowadays. This can also be seen in Eastern Lithuania and Eastern Belarus. It is also interested to note that almost all Baltic States, except for the Riga region, are dominated by primary production while they where previously dominated by manufacturing.[18] This decrease in agriculture that was observed in Nordic countries in the last two decades has began much later in former Soviet countries.[19] Lithuania has rapidly shifted from a manufacturing sector towards agriculture. This is mainly due to the fact that some people have chosen to go back to cultivate their own small-scale farms instead of becoming unemployed.[20]

↓ KNOWLEDGE-BASED ECONOMY

The Baltic Sea region, as the rest of Europe, has been affected by the recent financial crisis. *'The economies of Finland (-7.8%), Estonia (-14.1%), Latvia (-18%) and Lithuania (-15%) were particularly badly hit. [..] The negative economic effects were less extreme in Germany (-4.7%), Denmark and Sweden (-4.9%), while Norway and Poland were affected by a relatively short period of economic decline which only began in 2010.'* (ScanBalt, 2014) Beneficial effects of the crisis can now be seen in some highly technological and export-oriented macro-economies such as Germany, Sweden and Finland.[21] The recovery is taking longer in the Baltic States, but the crisis has brought favourable restructuring in the economy of these countries. They are now considered having the highest growth rate in Europe (Estonia 7.5%, Latvia 5.0% and Lithuania 5.8%).[22] This growth has developed very positively, since all three countries have strengthened their trans-national cooperation and have started developing infrastructure projects together (see ROADS + RAILWAYS).

The rate of unemployment in the Baltic States has significantly dropped in the past year and slightly in Germany and Finland. The Baltic States are operating a shift towards knowledge-based economies that ressembles the Nordic countries model. This sector provides extraordinary high employment rates in the Nordic countries as it represents more than 50% of all knowledge-based services industries.[23] This success is embedded in a culture of learning, cooperation and innovation that is very specific to Northern Europe and it is interesting to notice that Baltic States are now taking this model more and more. Estonia is becoming an innovation-led country with a significant growth in technology-intensive industries and highly qualified employees. This shift towards European economic models certainly shows a wish to mark the distance with the past and to use full potential of the new highly educated generation.

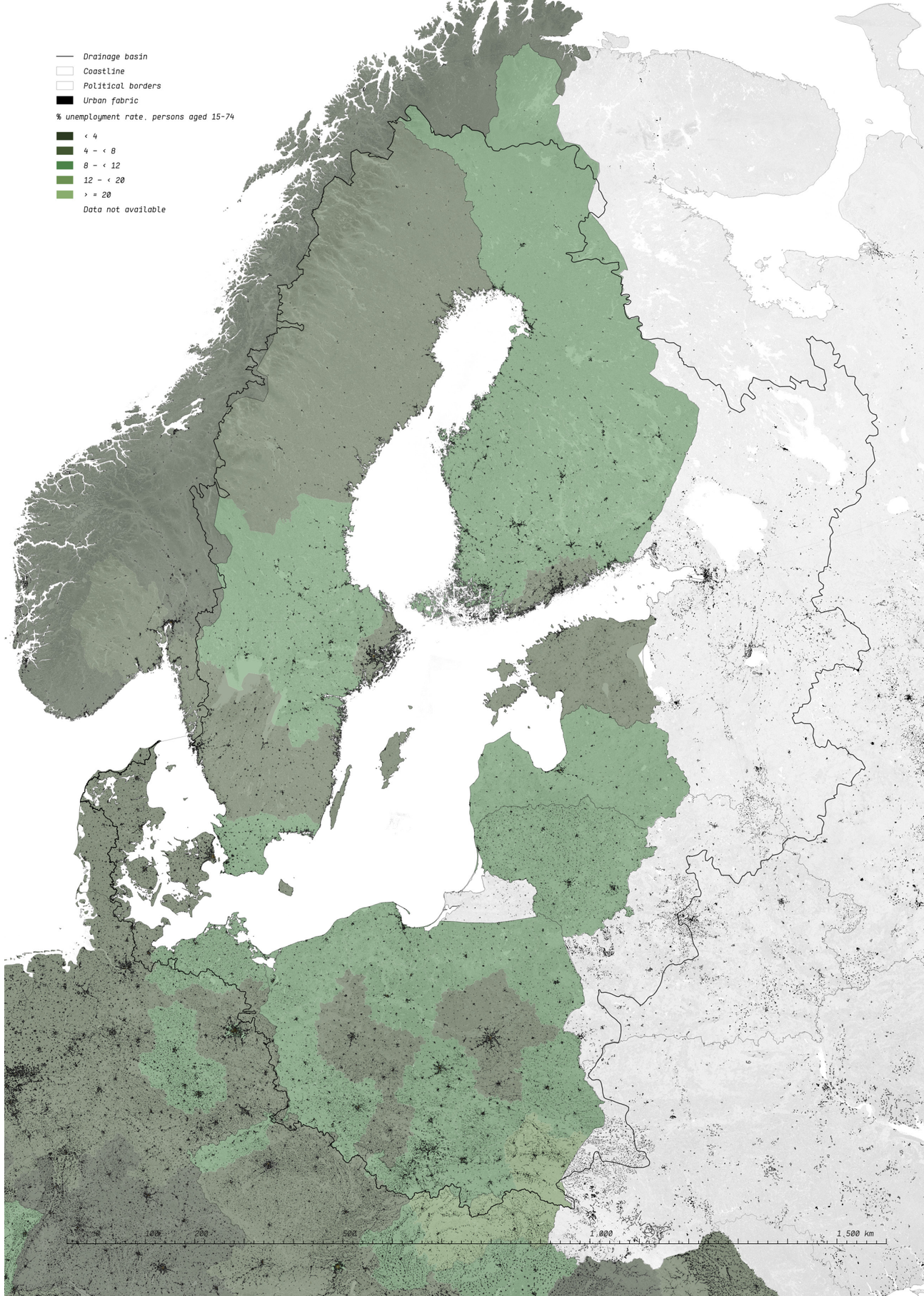


↑ *FIG.8 ECONOMIC HEALTH AND GROWTH* (Redrawn from ScanBalt, 2014)
Shows the important gap between Nordic countries and Baltic States. There is a catch-up process that is happening nowadays with a significant economic growth of former Soviet States such as the Baltics or Poland

↓ *IMG.5 BUSIEST NORWEGIAN PORT, BERGEN* (Photo by Hans Veuger)



MAP.2 (GIS data from HELCOM, Eurostat, Landsat) →



BAŁTYK SEA GEOPOLITICAL COLLISION

↓ TOURISM INDUSTRY

"Tourism is one of the fastest growing industries in the region and although recreation activities mainly take place close to the coast, this sector should be considered by maritime planning."[24] Overall, tourism in the Baltic Sea region contributes 90 billion euros and employs roughly 2 million people. Every year, it constitutes a fast growing destination for tourists and the coastal areas are further exploited to meet the growing demand. By developing tourism related services such as travel excursions, hotels, restaurants, boat trips and cruises, certain regions could boost their local economies. However development should also take into account the safeguard of natural features, as not to put a strain on coastal environments and maintain the unspoiled lands and seascapes that draw visitors to the region.

Tourism in the Baltic Sea region witnesses a stable growth, in line with economic development. It contributes significantly to the economies of the different countries in the region with about 73 million international arrivals in the region (with represents about 7 percent of all international arrivals) it generates growth, wealth and jobs to about 1.4 million people.[25] When it comes to beach tourism (including camping and rental of summerhouses) experts indicate a general increase in demand which has not yet been met by the supply. Today, there has been a trend towards more organised recreational activities. People tend to go fishing on organised trips that offer hotel nights, rather than camping solo. Furthermore, in most Baltic Sea region countries, seniors are living longer and have a larger disposable income compared to precedent generations. It is likely that many will decide to retire at an earlier age and/or have a longer period of activity after their retirement. This will undoubtedly increase the number of senior tourists, which will impact that demand for activities, accommodation and transports (even during the low season).[26]

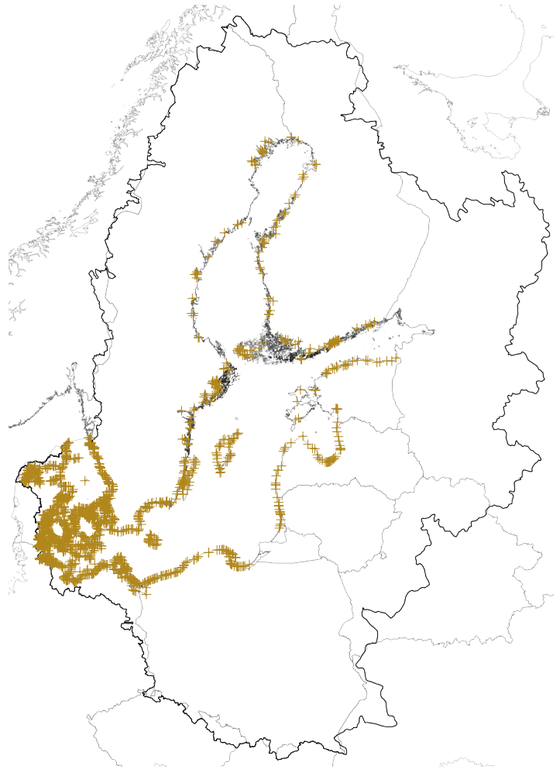
↓ LEISURE BOATING AND CRUISE SHIPS

Leisure boating is a significant maritime form of tourism: in Finland and Sweden it is quite popular and cheap making it accessible to all social classes. People in Finland and Sweden have strong ties to the sea, there is around one leisure boat for every seven people. *"This is 10 times higher than boat ownership in the rest of the EU, excluding Denmark and Norway."*[27] Organised fishing excursions and leisure boating are activities in demand (leisure boating steadily growing at 5 to 6 percent a year). Better grocery supplies and waste management will be required by local infrastructure as these activities bring tourists to sparsely populated areas.

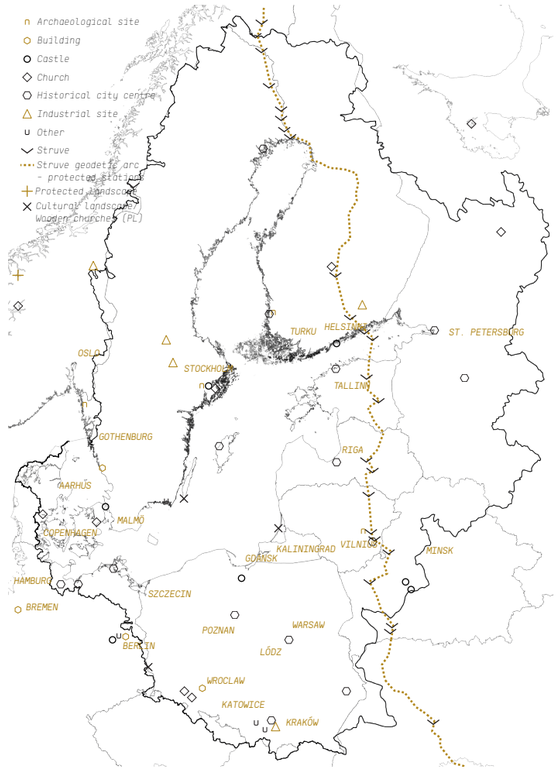
Maintaining leisure harbours and boating routes also requires extensive dredging because of the land uplift around some coasts of the Baltic Sea. Unfortunately this disturbs the sea bottom by harming wildlife and increasing nutrient levels.

↓ *IMG.6 TERMINAL SKANDINAVIENKAI, LÜBECK* (Photo from Lübecker Hafen Gesellschaft mbH)

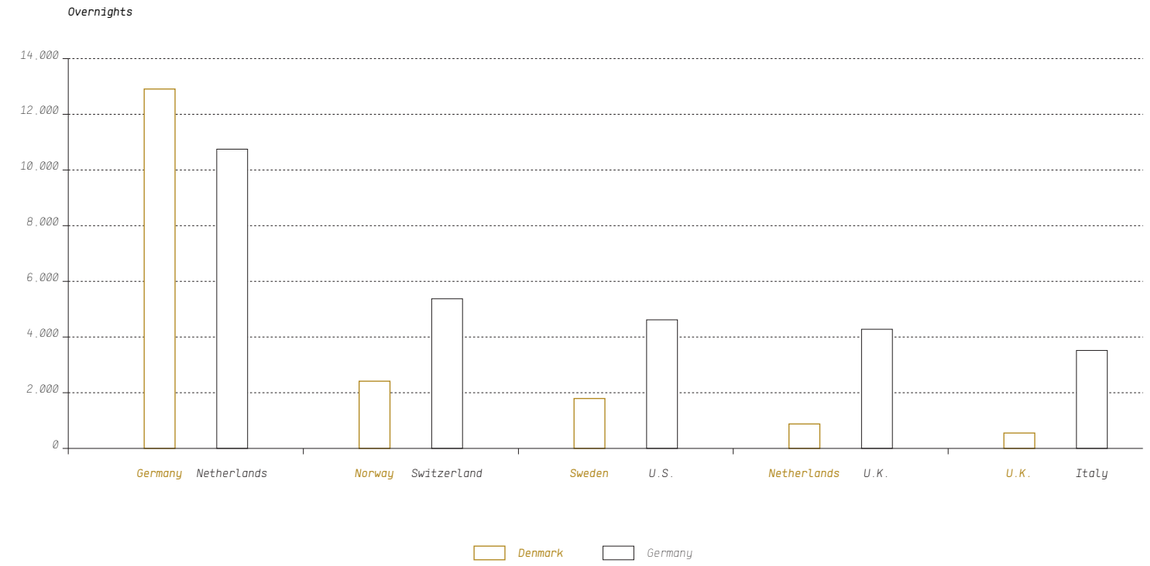




↑ *FIG.9 BATHING SITES* (GIS data from HELCOM)
Concentration of bathing sites around the coast of Denmark, Germany and Sweden. The bathing culture of the Seebad Lubmin is responsible for the increase presence on the German coast

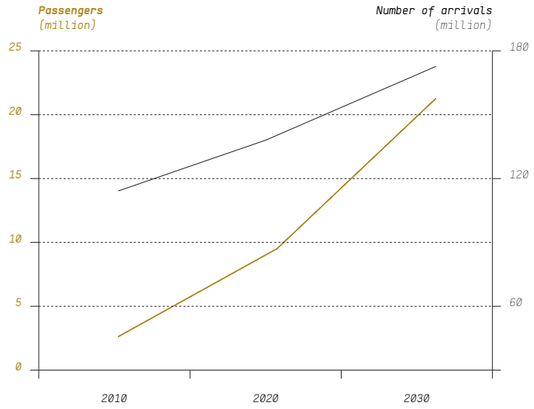


↑ *FIG.10 UNESCO WORLD HERITAGE SITES* (Redrawn from Nordregio,2008)
In the Baltic Sea region there are 54 cultural, 3 natural and 1 mixed sites in 2008. Five of the sites are located between 2 or more countries



↑ *FIG.11 TOP FIVE MARKETS IN DENMARK AND GERMANY* (Redrawn from Jensen et al., 2014)
The number of overnights in Denmark and Germany are relatively high compared to other countries in the Baltic Sea region

BAŁTYK SEA
GEOPOLITICAL COLLISION



↑ *FIG.12 INCREASE IN TOURISM TRENDS* (Redrawn from WWF, 2010)
Scenario for the increase in cruise passengers (gold) and number or arrivals in hotels (black) in the Baltic Sea 2010-2030. Cruise tourism has been increasing by about 12% per year in the region between 2000 and 2010. Assuming the same growth also in the future, the number of passengers would increase by about 600% in 2030

"In addition, cruise tourism is an up an coming, and fast growing, industry."[28] The cruise industry has witnessed a rapid annual growth of 12 percent per year between 2000 and 2010 in the Baltic Sea region. In recent years, in the Baltic Sea, cruising remains one of the fastest growing sector of tourism. However, the Baltic Sea region's popularity remains under pressure compared to other destinations in Northern Europe. The competition from other growing cruise destinations in other regions makes it difficult for the cruise industry to maintain its current market share.

↓ IMPACTS

Combined, the countries located by the Baltic Sea control a large share of the international tourism: in 2012 the Baltic Sea region accounted for 7 percent of the world's tourism (measured by international arrivals) and 13 percent of the european tourism. The tourism industry also accounts for a significant part of the employment in the countries of the Baltic Sea region. By uniting and working together, these countries can raise the politicians' awareness of the importance of the tourism industry and the challenges it currently faces and will face.[29]

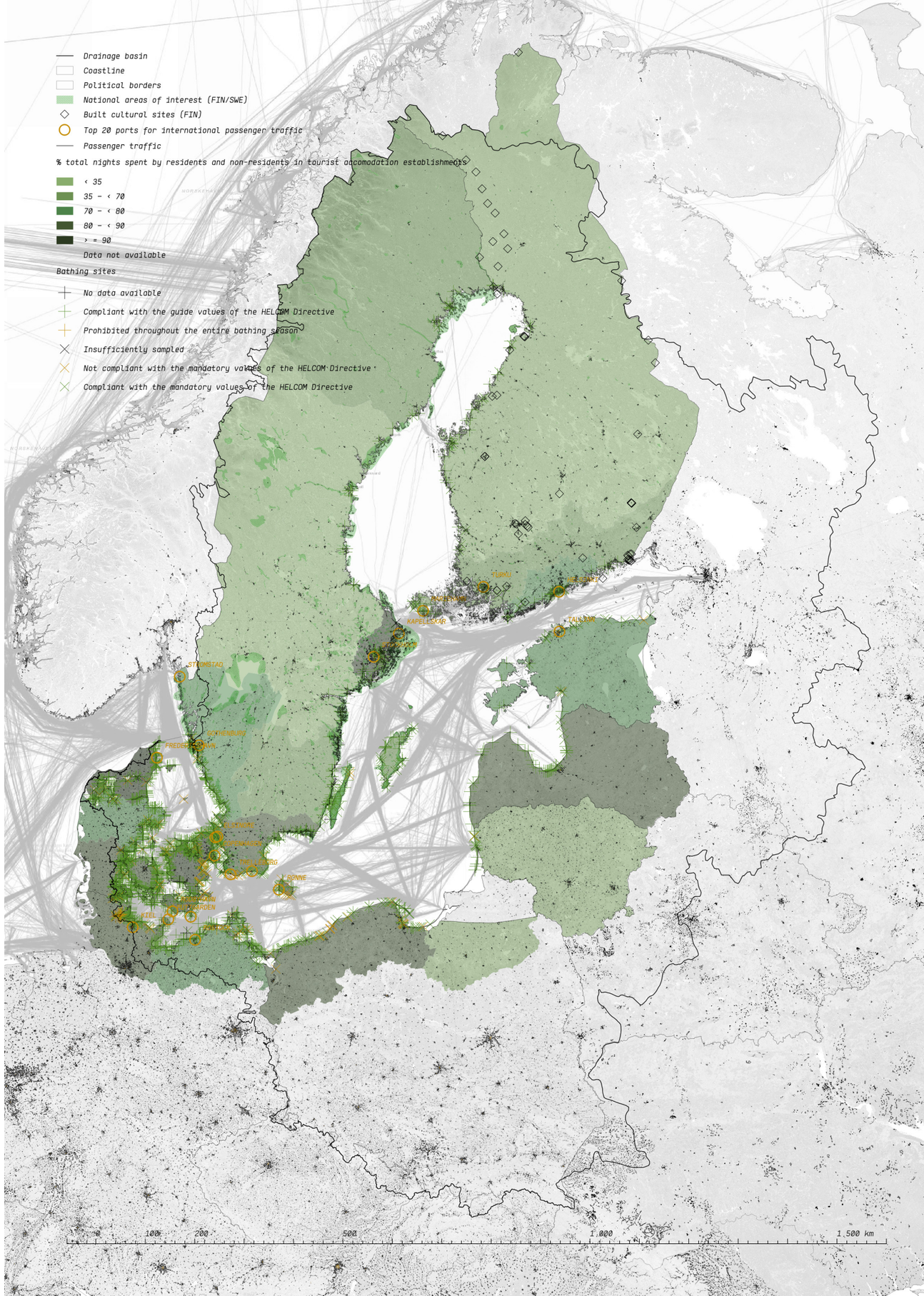
Organising and planning the coasts for touristic purposes has been a source of conflict in most Baltic Sea region countries. It is an ongoing geopolitical debate, on how the coastal areas should be configured and used, between tourism interest lobbies and lobbyist from the fishing, town planning and military sectors. Tourism remains a major environmental actor on coastal areas, which will affect other interest related to nature conservation and fishing. *"Besides land use, its demand for resources such as water and the need for waste disposal facilities puts pressure on water resources and coastal habitats."*[30]

However, pressures caused by tourism related activities is seasonally bound. Indeed, most of the tourism in the Baltic Sea region is only present during the summer months of June and July. Although tourism contributes to environmental pressure, the industry has also been a significant driver for nature conservation in numerous places (especially in areas where ecotourism is practiced).

↓ *IMG.7 SAILING IN THE STOCKHOLM ARCHIPALEGO, SWEDEN* (Photo by Mikael Törnwall)



MAP.3 (GIS data from HELCOM, Eurostat, Landsat) →



BAŁTYK SEA GEOPOLITICAL COLLISION

↓ POLITICAL BORDERS

The concept of National border is one that can already be seen from about 1000 AD with the first state formation in the Baltic Sea region. At this time already, southern and continental European States were better organised and had considerable influence on the region's events. There was a so called "europeanisation" of the Baltic Sea region during the period from 1100 to 1400. Strong states arose after the Reformation, in Scandinavia and the actual Germany.[31] National borders were constantly moving with the wars and alliances. Many changes occurred with and after WWII. USSR annexed or expanded its limits up to Germany. All actual Baltic States were therefore included in this union. These limits did not change for decades after this annexion until the fall of Communism.

We still face a moving condition nowadays, and this is not something that is fixed for ever as we can imagine. Situations in Ukraine make this even more visible, borders are totally artificial boundaries that are a construct of historical and political evolution during time. After WWII, these boundaries were systematically removed to create a common trade zone, that has led to the actual European Union.[32] Economy has always been a driving force for political agreements and cooperation. Even if Russia is considered as a threat for some European States, economical relations still continue to flurish between the two.

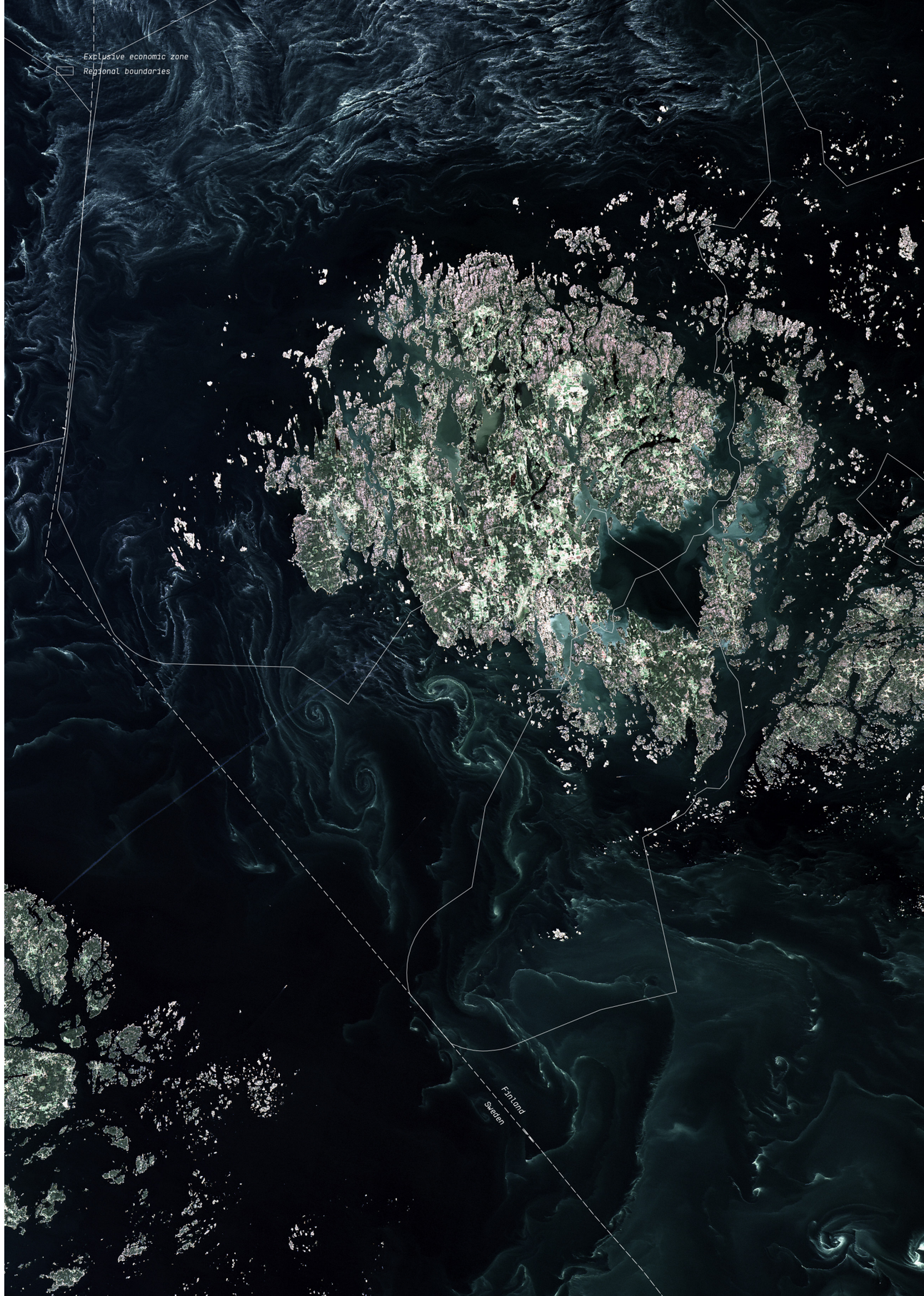
Former USSR countries such as Poland, Lithuania, Latvia and Estonia have now entered EU and have accessed European free market while they still conserve certain cultural and religious links to Russia. This recent change has pushed European borders up to Russia and has conducted to an even more secularisation of Russia. The question of border has now moved from purely physical limits to a more complex interrelation of political alliances. With the introduction of Baltic States in the EU and their acceptance in NATO, Russia has been conducting major naval exercises in and around the Baltic Sea (see **MILITARY ACTIVITY**). These exercises strenghten the image of Russia as an external threat or menace for regional peace. This is also true viewed from the Russian side where the external enemy was always related to the symbol of the boundary and what is beyond. This has, and still, a justification for mobilisation agains "external dangers".[33]

EU's goal of almost erasing national borders is now challenged again with the rise of Nationalisms in European States starting with Russia but also Germany,Poland and Scandinavian States.[34] The Baltic Sea is clearly a region with an increasing economic cooperation, especially with its expansion with former USSR countries but this cooperation is now threatened again. The border remains a symbol, or an icon that still remains a concept with an exceptional socio-psychological meaning for many countries and people. Even if it is completely artificially constructed and sometimes based on some natural elements such as rivers or mountains, it represents the defence line to protect the "*we*" from the hostile "*they*".[35]

↓ *IMG.8 PIASKI-MIERZEJA SAND SPIT* (Photo by Andrzej Sternal)



FIG.13 EEZ SWEDEN/FINLAND, ÅLAND ISLANDS (Photo of USGS/NASA/Landsat 7) →



BAŁTYK
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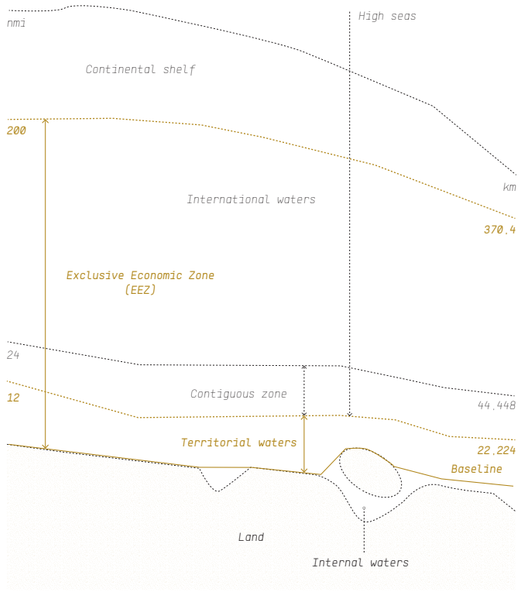
GEOPOLITICAL COLLISION



↑ *FIG.14 SEA AREA IN INTERNATIONAL RIGHTS* (Redrawn from UNCLOS, 2010)
Art.55 The Exclusive Economic Eone (EEZ) is an area beyond and adjacent to the territorial sea, subject to the specific legal regime established in this Part, under which the rights and jurisdiction of the coastal State and the rights and freedoms of other States are governed by the relevant provisions of this Convention

↓ MARITIME BOUNDARIES

There are several different types of boundaries in the International Convention on Sea Laws that regulate the limit of territorial influence on sea, exploitation of submarine resources or passage rights for example. One of the specificities of Baltic Sea is that there are no so called *'International waters'*. The Baltic Sea is divided according to administrative borders, as territories.[36] Since the extension of Finland's *Exclusive Economic Zone* (EEZ) in February 2005, all outer limits of EEZ boundaries meet the corresponding zones of the neighbouring states.[37] (see *MAP.4*) This results in the possibility of entering or leaving Russian ports of the Gulf of Finland (St.Petersburg) without passing through an area under an other state's control.[38] The EEZ corresponds to fishing zone boundaries and grants coastal states juridiction over natural resources, preservation and protection. The passage of vessels is granted in these zones but international standards still apply and polluting activities such as oil spilling (see **MARITIME TRAFFIC**) or fishing quota disrespect (see **FISHING**) are considered violation for the sovereign state controlling the EEZ.

This distinction between territorial sea and exclusive economic zone is very important especially in a narrow sea as the Baltic. Coastal states have sovereign rights for soil exploration and exploitation. This means that all natural resources found within this boundary are under the jurisdiction of the coastal State (UNCLOS, Art. 55).[39] But not only are resources in marine soils property of the coastal State, the EEZ is also the fishing limit. This is often a source of tension between States as migration and spawning areas move during seasons. One of the biggest geopolitical tension that arose from the question of EEZ crossing was and still is the construction of the Nord Stream pipeline that crosses many countries' EEZ (see **CABLES + PIPELINES**). The construction of this specific pipeline was considered as a threat for Baltic States since it is planned as a way to bypass Baltic States to provide energy directly from Russia to Germany. The construction of this pipeline also goes with a rise in Russian military exploration around it, since there are no International waters it means Russian navy would protect the pipeline within the EEZ of other countries (see **MILITARY ACTIVITY**).

As we have seen, the Baltic Sea is a very specific sea in terms of governance. There are several organisms that manage the sea and that try to put all sovereign interests together. But even with this there are tensions in regard of resources exploitation being fishing, offshore wind farms or gas exploitation. Russia has increased its military activity within the sea in the recent years and some Baltic states fear that there would be tensions between them. The construction of future pipelines or wind farms must therefore be regarded on a larger scale and discussed with neighbouring countries especially since all these maritime boundaries are completely artificially created and do not correspond in any way to the situation in waters or in terms of geological formations.

↓ *IMG.9 BORDER SIGNAL* (Photo by Doug Murray)



MAP.4 (GIS data from HELCOM, Landsat) →



BAŁTYK SEA **GEOPOLITICAL COLLISION**

MILITARY ACTIVITY

↓ GEOSTRATEGIC IMPORTANCE

The rapid growth in Russian oil export and shipping routes through the Baltic Sea for energy trade has recently aroused particular concern for countries that share this common space of navigation. The planned pipeline that goes through the sea and therefore bypasses ex-USSR countries of the Baltic States will have a considerable impact on the region's strategic landscape. It is important to know that Russia is the only country along the Baltic Sea that is not member of the EU. With the recent changes that occurred with the fall of Communism in this region, there have been tremendous changes in the political and geostrategical scene. The Baltic Sea is quickly becoming Russia's most important transit route for energy (see **CABLES + PIPELINES**). It account's for almost 40% of all its exports.[40] Russian military activity is very closely linked to these energy-export questions, it's expansion in the control of certain areas of the sea is also closely linked to that.

"The concerns of littoral states are not purely environmental. One reason for Russia's desire to diversify its export routes is the fact that its price disputes with Ukraine and Belarus, which resulted in temporary cut-offs of Russian gas supplies, had knock-on effects on other European customers, raising fears in Europe about Moscow's political use of its gas. In theory, the Nord Stream pipeline would give Moscow the ability to curtail gas deliveries to the Baltic states and Poland while continuing to supply Germany."[41]

The choice for an undersea project suggests that it's not purely an economical choice. There are also security considerations. Russian navy always protects the National energy infrastructure, this would then mean that its influence and protection zone would be extended all along the pipeline, that crosses mainly international waters. It is a way for Russia to mark it's domination over the sea and control diverse shipping routes other than it's one only.

Russia is still perceived as a threat for the surrounding countries, especially the Baltic states that have faced serious threats in the recent years after their independence was proclaimed. An example of the tensions that arose recently is the 2007 cyber-attack on Estonian official institutions. There is still no official statement of Russian government taking responsibility over these attacks but it seems to be closely related to the decision of Estonian government to move a Soviet war memorial out of the centre of Tallinn.[42]

Even if all three Baltic states (Estonia, Latvia and Lithuania) are now members of NATO, they still fear a move that Russia could do towards their borders. These three countries have created militaries from scratch after achieving independence. Even if they are under NATO's protection, their own military effectives are still very small.[43] The size of these countries and their financial status forces them to cooperate regionally (see ***FIG.15***).

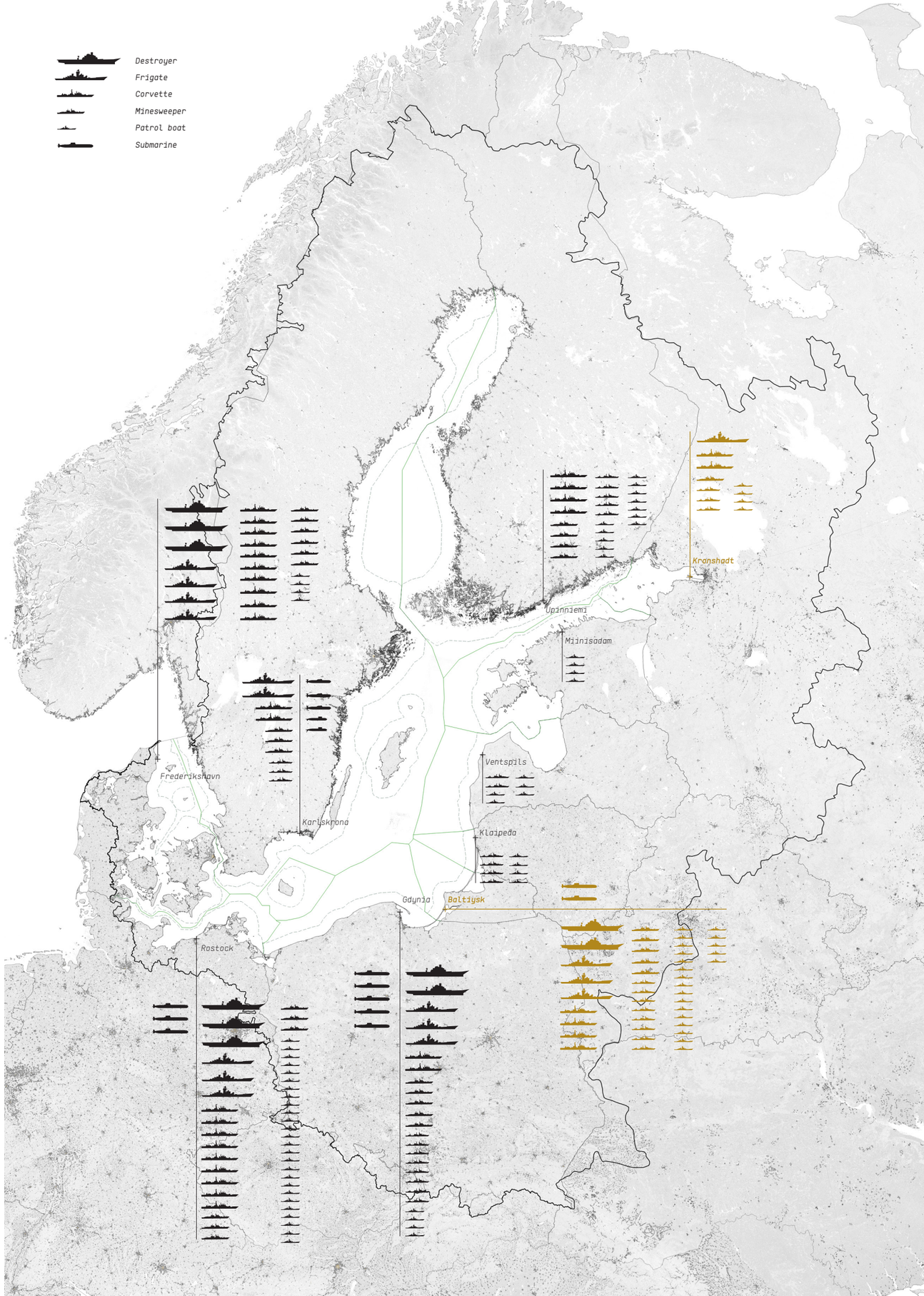
Countries	NATO membership	European Union	Military personnel	Frigate, destroyer	Costal combat ship
	(adhesion)	(adhesion)			
↘ Denmark	1949	1973	17,200	7	9
↘ Sweden	-	1995	15,300	-	22
↘ Finland	-	1995	22,200	-	8
↘ Russia	x	x	771,000	35	84
↘ Estonia	2004	2004	5,750	-	1
↘ Latvia	2004	2004	5,310	-	5
↘ Lithuania	2004	2004	10,950	-	4
↘ Poland	1999	2004	99,300	2	4
↘ Germany	1955	1957	181,550	16	8

↑ ***FIG.15*** ***POWER IMBALANCE AND MEMBERSHIPS*** (Data from IISS, 2010)
Shows the important differences between countries of the Baltic Sea region in terms of military power. The power imbalance has drastically changed in this regiojn with the introduction of the Baltic States in the North Atlantic Treaty Organization

↓ ***IMG.10*** ***SWEDISH MINESWEEPER HMS KOSTER*** (Photo by Marko Saavala)



FIG.16 ***MILITARY PRESENCE IN THE BALTIC SEA*** (Data from Wikipedia) →



BAŁTYK SEA **GEOPOLITICAL COLLISION**

	Bornholm basin	*Gotland deep*	**Total**
Types of Chemical Munitions	*(tonnes)*	*(tonnes)*	*(tonnes)*
↘ Aircraft bombs	*7,896*	*682*	*8,578*
↘ Artillery shells	*768*	*66*	*834*
↘ High-explosive bombs	*314*	*27*	*341*
↘ Mines	*42*	*4*	*46*
↘ Encasements	*1,050*	*91*	*1,141*
↘ Smoke grenades	*65*	*6*	*71*
↘ Containers	*924*	*80*	*1,004*
↘ Drums	*18*	*2*	*20*
↘ **Total**	***10,077***	***958***	***12,035***
Types of Chemical Agents			
↘ Mustard gas	*7,027*	*608*	*7,635*
↘ As-cont	*2,033*	*176*	*2,209*
↘ Adamsite	*1,428*	*124*	*1,552*
↘ CAP	*515*	*44*	*559*
↘ Others	*74*	*6*	*80*
↘ **Total**	***11,077***	***958***	***12,035***

↑ *FIG.17 TYPE OF DUMPED CHEMICAL WEAPONS* (Redrawn from CHEMSEA, 2013)
The Bornholm basin holds over 90% of all the chemical munitions that have been dumped in the Baltic Sea. The majority of these warfare munitions are aircraft bombs and most of them contain mustard gas

A joint Baltic Naval Squadron (BOLTON) was created and is composed of Lithuanian-Latvian-Estonian national ships from their navies. It's based in Estonia and has a long-term goal of border protection and mine countermeasure operation conduct.

A Baltic Air Surveillance Network (BALTNET), this time based in Lithuania has been established in order to strengthen international cooperation between civilian and military authorities in regard of the aviation.

A Baltic Defense College (BALTDEFCOL) has been created in Estonia to manage the cooperation between the three states armies.[44]

↓ CHEMICAL WARFARE AGENTS

Important amounts of chemical weapons were produced during both World Wars. Fortunately, they have never been used in the European Theatres, vast quantities were therefore stored after the wars ended. The handling and destruction of these munitions would have been enormous, the countries that produced them in mass have then decided to dump them in the Baltic Sea. It is by far the largest part of chemical weapons that has been handled this way. German chemical warfare agents were stored in Wolgast on the shores of the Baltic Sea, close to the Bornholm basin. The British, Russian and American forces have dumped at least 50,000 tonnes of these weapons in the Skagerrak Strait, mainly close to Swedish coast. It is assumed that these contained at least 15,000 tonnes of chemical warfare agents. During these dumping operations, complete ships were sunk with their cargo. The most important dumpsite of all in the Baltic Sea are located in the Little Belt, near the island of Bornholm and in the Gotland basin.[45]

The sea floor is a resources that all surrounding countries share. Many recent projects regarding industrial activity have encountered problems with old mines, artillery shells or aircraft bombs that have been dumped in the sea. As seen already in previous chapters (see **DREDGING**, **CABLE + PIPELINES**), numerous projects have connections with the sea floor directly or indirectly. These include submarine cables, offshore wind farms, pipelines, construction of bridges or tunnels and dredging activities in general.[46]

Some of these projects are located near areas at risk of contamination, it therefore still poses important problems nowadays. Some fisherman have also caught non-exploded bombs in their trawling gears. There are restriction zones that have been applied to shipping routes nowadays in order to avoid the contact with this kind of munitions but the problem is not resolved yet since dredging activities are more and more required to maintain shipping routes.

Many of these munitions have been dumped with the rest of the fleet but there are also areas especially in the Gulf of Finland where bombs were thrown overboard in their wooden cases.[47] This

↓ *IMG.11 TANK BATTALION, BALTOPS* (Photo by Rafał Mniedło)



FIG.18 LITHUANIAN EEZ (Photo of USGS/NASA/Landsat 7, Redrawn from Couling, 2013) →



BAŁTYK SEA GEOPOLITICAL COLLISION

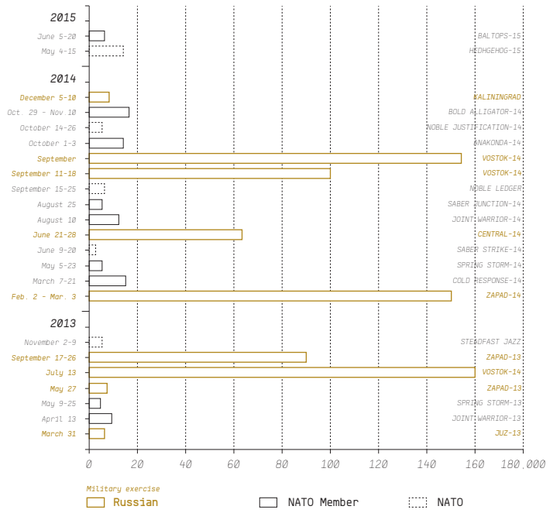
has led them drift around for many nautical miles and it is still hard to find them nowadays because of this. In this region, many dispered objects can be found at the bottom of the sea, and it is hard to make the different between a bomb shell or any other objects. Several risk zones and mine threat areas have therefore been introduced. They pose serious problems to navigation since they almost exactly coincide with all main shipping routes that go from St.Petersburg (see *MAP.5*).

↓ NAVAL EXERCISES

Russian military exercises have recently started to increase. Russia has been conducting exercises over its vast territory - from the high North, far above the Arctic Circle to Japan. NATO's reaction could be seen a few months later where thousands of troops set foot across Europe. After decades of post-Cold War calm, Europe seems to be awaken again by a high military drama according to some experts.[48] Russia has performed huge naval and aviation units exercises in the Baltic Sea region recently (see *FIG.19*). These exercises have led NATO to react again but this time in the Baltic Sea itself. This increase of military activity has led to a certain perception of 'militarisation of the sea'[49] (Couling, 2013). Tensions are palpable in this region where aircrafts and ships from both sides come across each-other on a daily basis.

A major step towards security in the region was achieved with the introduction of the Baltic States to NATO. A new balance have been found for this region where many changes happened in the last centuries (see **BORDERS + BOUNDARIES**). But not only did Baltic States face importance changes, Poland has face one of the most striking developments since the late 1990s and has become a major actor in Central Europe. Not only is it well positioned to play a crucial role, but it also has the largest population in Central Europe. Russia's approach towards the Baltic States is also slowly changing. It seems that Russia sees a long-term economic benefit for itself from the integration of the Baltic States into the EU since it is heavily reliant on Baltic ports for the transit of goods and especially oil and gas exports that pass through Baltic ports.[50]

But there are still some sources of possible tensions. One of the most sensitive issues is the Russian minority in Baltic States which continues to be a source of friction especially in Estonia and Latvia.[51] With the crisis in Ukraine that continus to unravel, many of the Western countries are worried that this model happens again in the Baltic States.[52] A trend towards a militarisation of the ocean seems to profile itself for the following years as more and more space for military exercises and firing danger areas develop along the Baltic Sea.

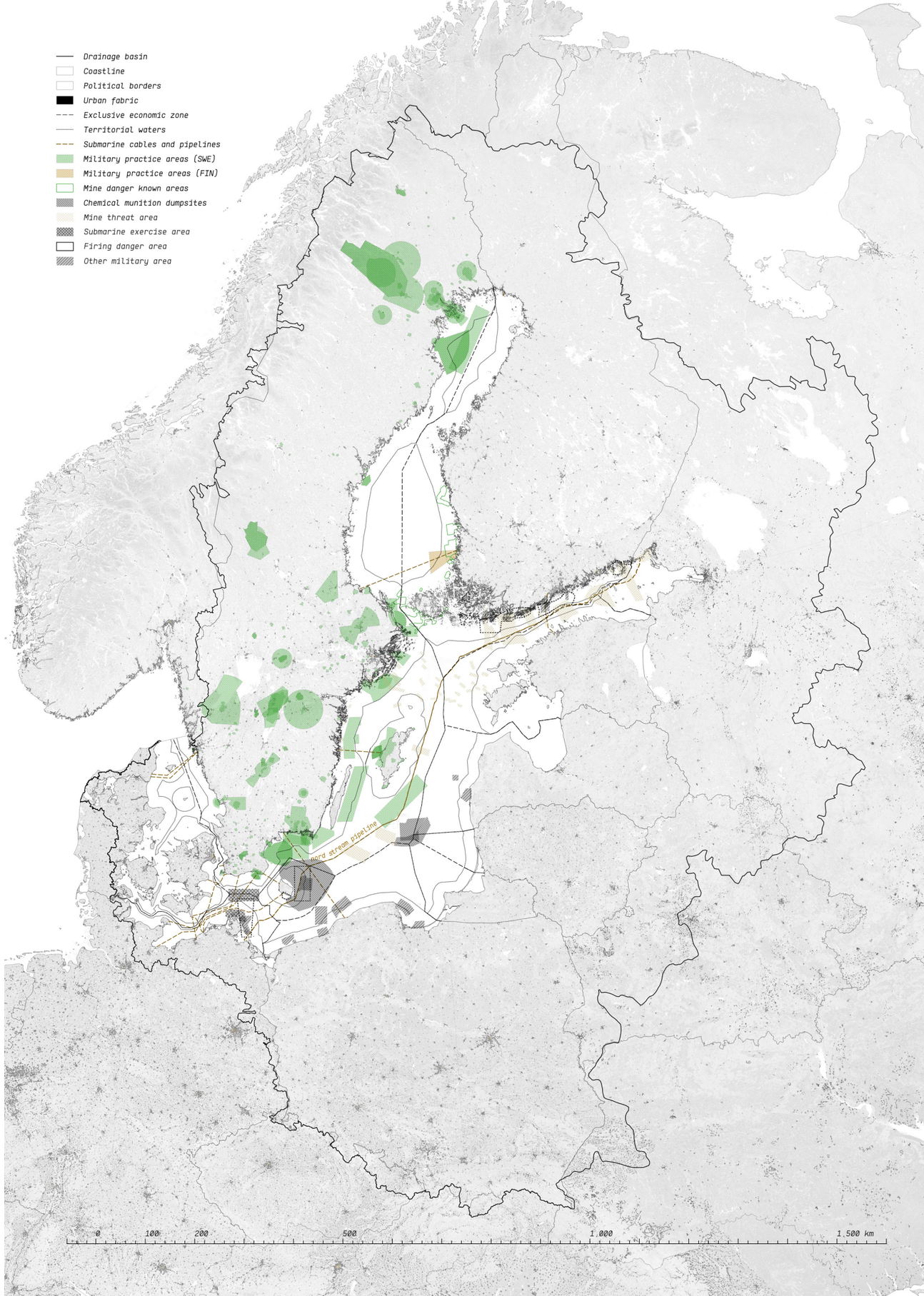


↑ *FIG.19 MILITARY EXERCISES* (Redrawn from ATLANTIC COUNCIL, 2015)
These military exercises are not an exhaustiv indicator of military readiness and capability, but they reflect the seriousness of intent of the different parties. The comparison between NATO's and Russian exercises in the Baltic Sea region reveals an enormous disparity in magnitude that expresses the geostrategic importance Russia puts towards the Baltic Sea

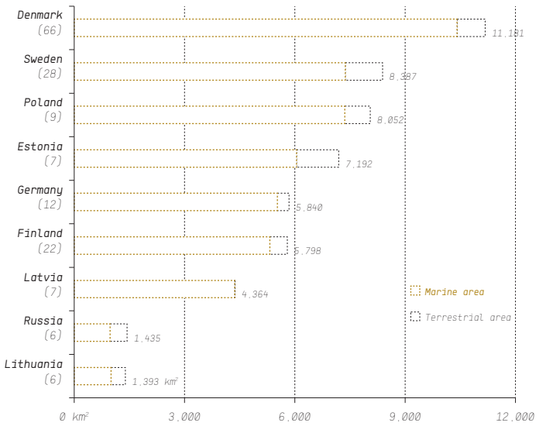
↓ *IMG.12 POLISH ARMY LEOPPARD II, BALTOPS* (Photo by Cpl Madis Veltman, Estonian Army)



MAP.5 (GIS data from HELCOM, Landsat, NordStream) →



NATURAL RESERVES



↑ *FIG.20 BALTIC SEA PROTECTED AREAS PER COUNTRY* (Redrawn from Borg *et al.*, 2013)
Denmark has the largest total area of BSPAs, followed by Sweden and Poland. The total area (km²) is given beside each bar, and the number of BSPAs is given in brackets after the country name

↓ NATIONAL PARKS

"The first national park in Europe was established by Sweden in 1909 : the island and coastal habitat of the 168 ha small Ängsö National Park in the Stockholm Archipelago."[53] This initiative started the trend towards the protection of nature and wildlife in large areas around and inside the Baltic Sea. In 1910, in the north of Sweden, considerable areas in the mountainous regions were given the status of national park. However, it is only after World War II that a concrete policy towards nature conservation truly began through the conversation of the habitats of individual species. Due to these new regulations, a move towards the management of natural environments and integrated planning developed and started efforts for international collaboration while developing criteria and standards. In the Baltic Sea basin, and in Europe in general, the majority of legislative regulations for nature conservation support goals such as : the maintenance of ecological processes and ecosystem stability; conservation of biodiversity; conservation of geological heritage; conservation and long term survival of species and ecosystems; creation of proper human attitudes towards nature; and the rehabilitation of resources and areas of nature to the proper stage.[54]

In the Baltic Sea region, the number of national parks and the total area protected in various categories is different between countries. In Denmark for example, protected land covers 9.8% of the territory while in Finland, a total of 30 national parks cover approximately 8,000 km² (which amounts to 2.3% of its surface area). In Sweden, the surface covered is 6,300 km² (23 national parks). Additionally, around 1,400 established nature reserves represent about 5.5% of the Swedish territory. In Poland, nature reserves are separated intro strictly protected and partially protected areas (where only specific human activities are tolerated). Out of the 1,200 sites, only 110 are strict reserves. In total, the area of protected reserves amounts to 120,000 ha. On the other hand, the 22 national parks cover an area three times this size. In total, less than 1.5% of the Polish territory is under protection.[55]

In order to achieve adequate conservation strategies, an international co-operation and regulations are necessary. *"Many European Union initiatives have been undertaken, such as Natura 2000, seeking the identification of a network for nature conservation across the Member States and beyond."*[56]

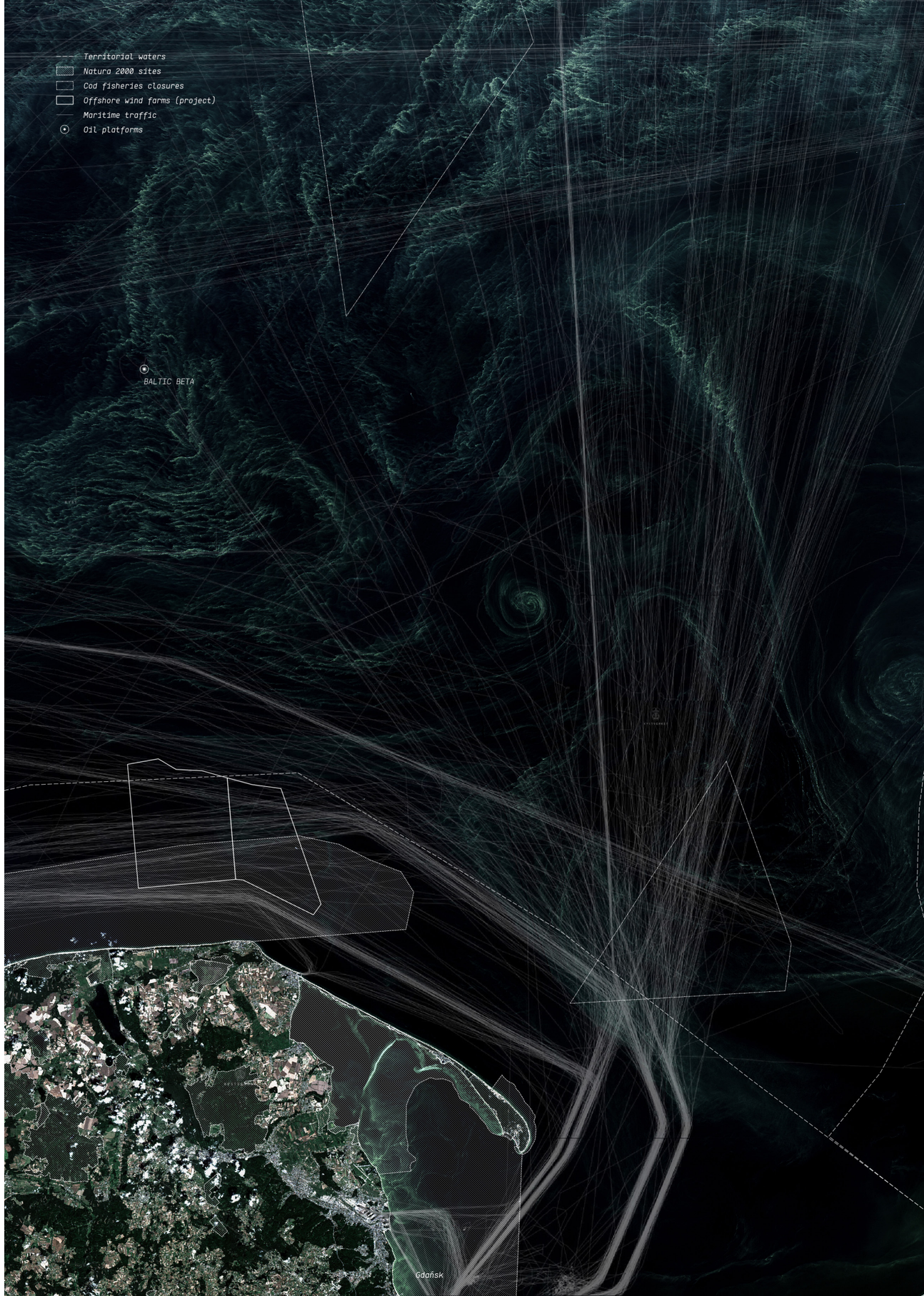
↓ MARINE PROTECTED AREAS

"A marine protected area (MPA) is a marine area, which has been reserved by law or other effective means to protect part or all of the enclosed environment."[57] In various areas, protection varies from the suspension of certain types of humans activities to complete closure of an area. In total, there are two MPA networks in the Baltic Sea : the European Union Natura 2000 network and the Helcom Baltic Sea Protected areas network. According to Helcom, around 12% of the Baltic Sea marine area is currently

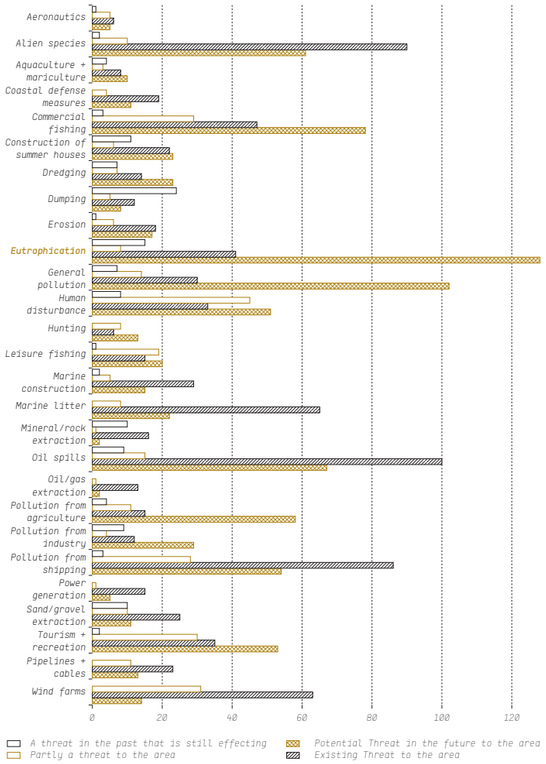
↓ *IMG.13 ENDLA NATURE RESERVE, ESTONIA* (Photo by Abrget47j)



IMG.14 PHYTOPLANKTON IN GOTLAND, SWEDEN (Photo of USGS/NASA/Landsat 7) →



BAŁTYK SEA
GEOPOLITICAL COLLISION



↑ *FIG.21 THREATS TO BALTIC SEA PROTECTED AREAS* (Redrawn from Borg et al., 2013)
The unit on the x-axis is number of entries in the database

covered by these two networks combined. Therefore, the goal of protecting 10% of every ecoregion by 2010 (set by the Convention of Biological Diversity) has now been obtained by the Baltic Sea. However, it is important to mention that although the overall goal has indeed been reached for the Baltic Sea as a whole, this number has not been obtained for all sub-basins, especially the Gulf of Bothnia. The network also remains neither ecologically coherent nor well managed, as a number of designated sites still lack management plans and human activities – such as fishing – are basically never regulated within these sites.

Today, based on scientific recommendations, a minimum of 20% of each habitat in a region needs to be protected in order to ensure a long term survival of the ecosystem. This is also being followed by the European Commission as guiding principle for sufficient protection. Therefore, theoretically, to secure the health of the Baltic Sea ecosystem, 20% of each habitat should be tagged as marine protected areas. "*To establish an ecologically coherent network of MPAs that fulfil the 20% representation target for each habitat would, however, probably require about 30% of the entire Baltic Sea area to be set aside.*"[58] This is a complicated target to achieve as they are many cases of conflicting interests between marine protected areas and various marine related activities. Sectors such as fishing, shipping, tourism, wind farms, pipelines and cables may need to be suspended inside certain protected areas (depending on the species and habitats present on site) in order to respond to the sensitivity of the area and the level of threat. Typically, physical exploitation including sand, gravel and oil extraction are other sectors that are incompatible with marine protection. Furthermore, areas in which marine protection interests conflict with other interests are archipelago and coastal areas which lie in the vicinity of major cities and shallow off-shore banks.[59]

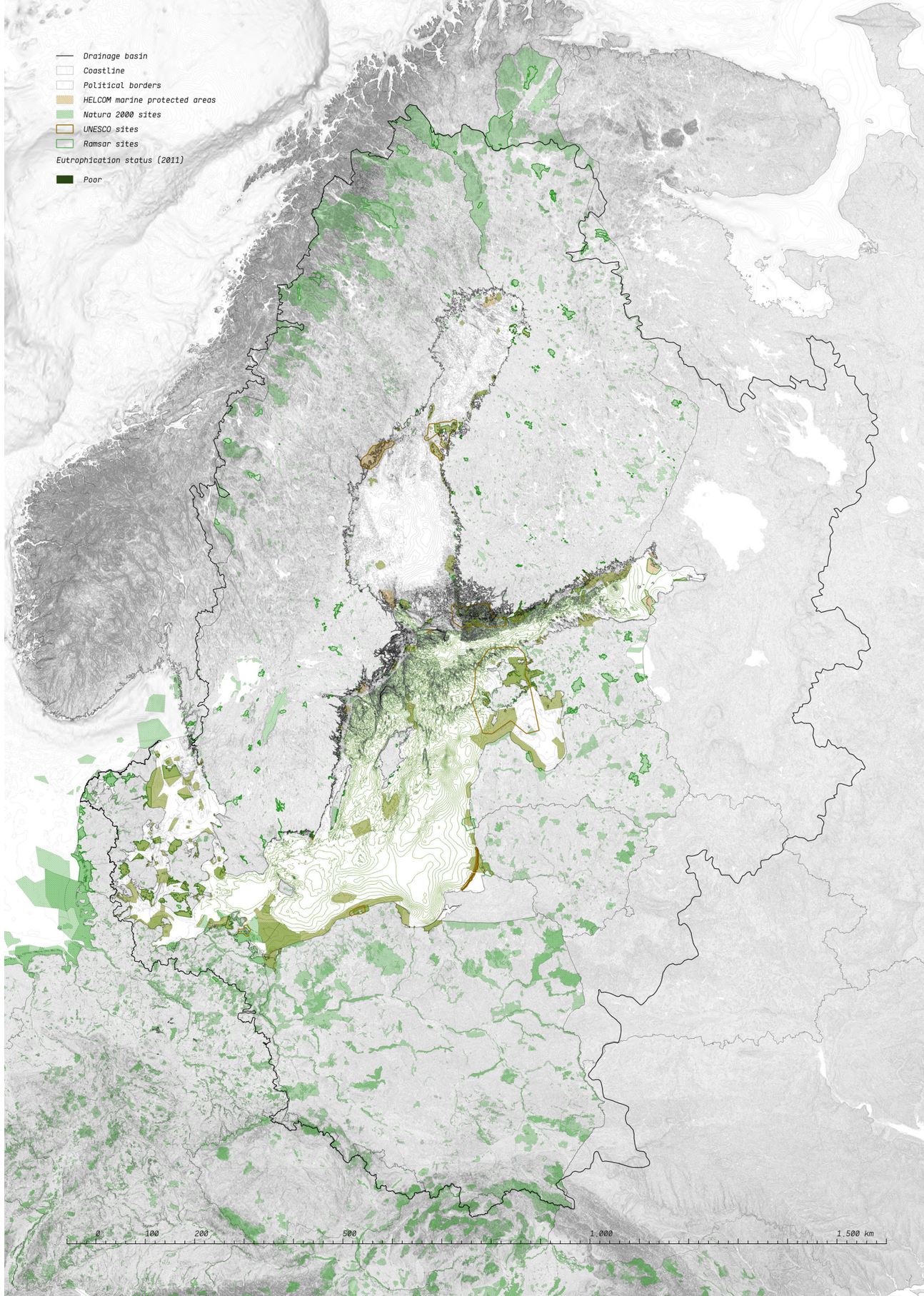
↓ EUTROPHICATION

In terms of danger to the Baltic Sea ecosystem, the most frequently reported existing threat is eutrophication (followed by general pollution and commercial fishing). Today, potential future threats are oil spills, alien species and pollution from shipping. Dumping was considered to be the most prevalent past threat and still has an impact.[60] Agricultural run-off of nutrient is the major cause of eutrophication in the Baltic Sea. Witnessed by intense algal growth, altered communities of flora and fauna, oxygen depleted sea bottoms and the death of fish and benthic organisms. Therefore, commercial and recreational fishing are also affected by eutrophication. Overall, it remains a huge problem for nature conservation since it affects the entire marine ecosystem and extensive or toxic algal blooms also preclude bathing and boating tourism during season heights. The decisions to stop eutrophication are often counteracted by other decisions to increase agricultural habits that have a negative impact on the Baltic Sea.[61]

↓ *IMG.15 JASMUND NATIONAL PARK, GERMANY* (Photo by Peter Lehmann)



MAP.6 (GIS data from HELCOM, EEA, Landsat) →



BAŁTYK SEA CARTOGENESIS

→ TRADE DYNAMICS

In terms of foreign trade patterns and economic development, the Baltic Sea region includes countries with various levels. First of all there are the rich Scandinavian countries such as Denmark, Finland and Sweden. Second there are the transition economies which includes the Baltic States with Estonia, Latvia, Lithuania and Poland. Russia – especially the St. Petersburg area – and Belarus also belong to this second group. Furthermore, the huge gap in welfare and production capacities have a relatively strong impact on foreign trade as well.

→ EMPLOYMENT

The Baltic Sea region has faced important shifts in the past decades. Structural changes happened in the labor market with the fall of the Soviet Union. The situation is now tending to stabilize between the different countries, enormous gaps that we were usued to see a few years ago are now being reduced. All the economies, including former Soviet countries such as the Baltic States are now moving towards an increase of the service sector and a high-educated labour force.

→ TOURISM + RECREATION

Bathing sites

No data available

Guide values respected

Prohibited

Insuffiently sampled

Mandatory values

Not compliant

Compliant

Built cultural sites

Int. passenger ports

Tourism is one of the, if not the, fastest growing industries in the region. The majority of recreation activities mainly take place close to the coast, but this sector should be considered by maritime planning. Overall, tourism in the Baltic Sea region contributes 90 billion euros and employs roughly 2 million people. Every year, it constitutes a fast growing destination for tourists and the coastal areas are further exploited to meet the growing demand.

By developing tourism related services such as travel excursions, hotels, restaurants, boat trips and cruises, certain regions could boost their local economies. However development should also take into account the safeguard of natural features, as not to put a strain on coastal environments and maintain the unspoiled lands and seascapes that draw visitors to the region Tourism in the Baltic Sea region witnesses a stable growth, in line with economic development. It contributes significantly to the economies of the countries around the sea.

→ BORDERS + BOUNDARIES

Territorial waters ----

EEZ

The Baltic Sea is a very specific sea in terms of governance. There are several organisms that manage the sea and that try to put all sovereign interests together. But even with this there are tensions in regard of resources exploitation being fishing, offshore wind farms or gas exploitation. Russia has increased its military activity within the sea in the recent years and some Baltic states fear that there would be tensions between them.

→ MILITARY ACTIVITY

Military planning

Mine threat area

Submarine exercise

Firing danger

Other military area

Military practice

The rapid growth in Russian oil export and shipping routes through the Baltic Sea for energy trade has recently aroused particular concern for countries that share this common space of navigation. The Baltic Sea is quickly becoming Russia's most important transit route for energy. It account's for almost 40% of all its exports. Russian military activity is very closely linked to these energy-export questions, it's expansion in the control of certain areas of the sea is also closely linked to that.

The concerns of littoral states about the militarisation of the sea are not purely environmental. Fears of an invasion, or of territorial claims is still perceivable. Russian increase military activity in the region makes it now one of the most crowded seas in the world in terms of navy vessels.

→ NATURAL RESERVES

Natura 2000 sites

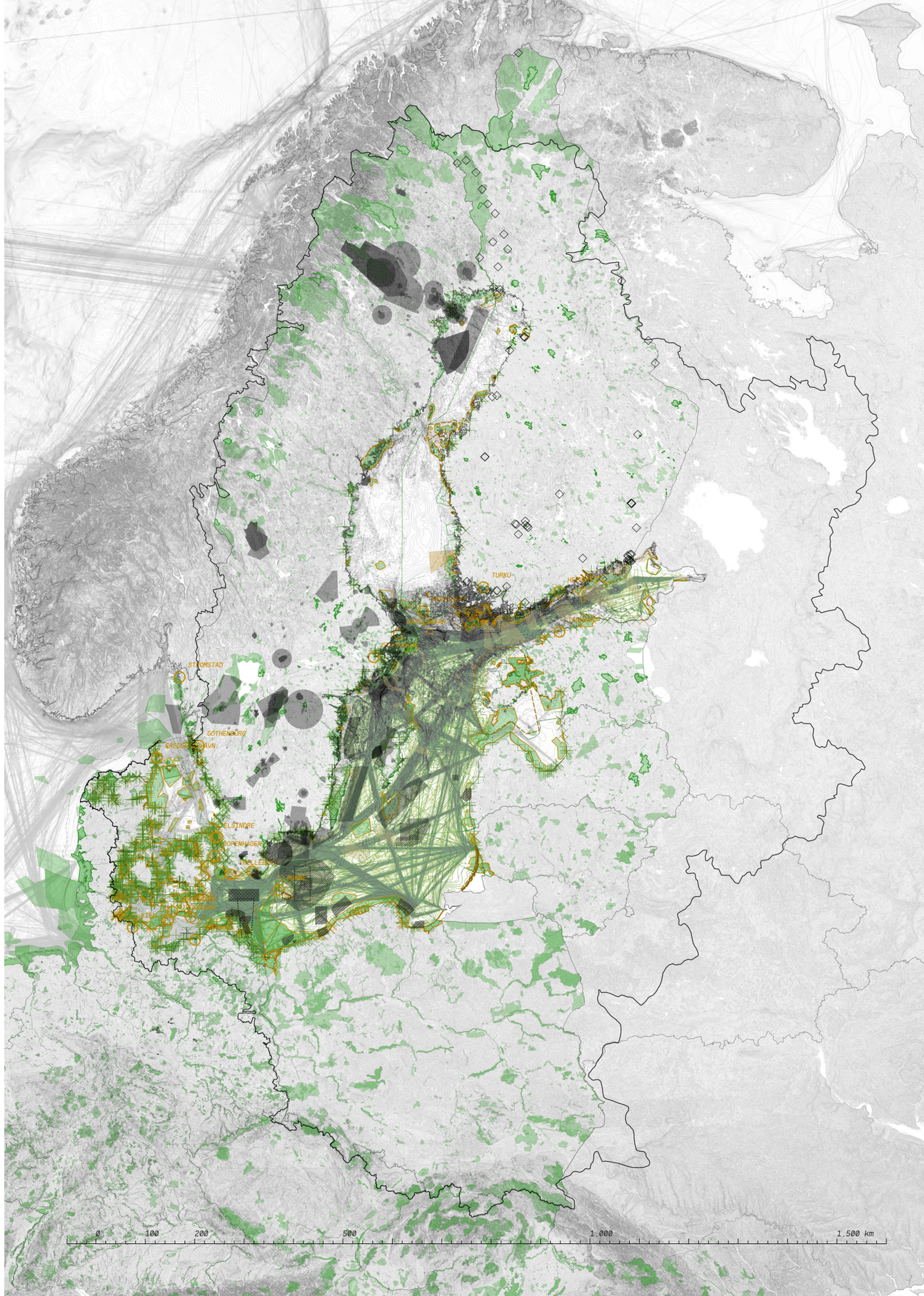
UNESCO sites

Ramsar sites

HELCOM protected

Eutrophication status

In terms of danger to the Baltic Sea ecosystem, the most frequently reported existing threat is eutrophication. Agricultural run-off of nutrient is the major cause of this phenomena. Witnessed by intense algal growth, altered communities of flora and fauna, oxygen depleted sea bottoms and the death of fish and benthic organisms. Therefore, commercial and recreational fishing are also affected by eutrophication. Overall, it remains a huge problem for nature conservation since it affects the entire marine ecosystem and extensive or toxic algal blooms also preclude bathing and boating tourism during season heights.



CARTOSYNTHESIS

IMAGE OF THE TERRITORY THROUGH A SELECTION OF LAYERS IN ORDER TO PRODUCE AN UNDERSTANDING OF THE PROBLEMATICS

BAŁTYK SEA CARTOSYNTHE-SIS

→ ECOLOGICAL SHIFT

Drainage basin
Coastline
Lakes
Topography
Bathymetry
Bottom currents
High
Low
Bottom salinity
16 → 34 ‰
1 → 15 ‰

Based on the readings done in the first chapter, it is likely that the parameters listed on the left will all suffer an important shift in the coming years. Due to anthropogenic reasons, most of these natural phenomenons will be accentuated. Although topography and bathymetry are unlikely to vary, they will however guide the direction in which the ecological system will move. Climate change is bound to increase temperatures in the north and therefore offer new opportunities for systems that were once more south of the drainage basin. On the other hand, in the south, temperatures and deregulations of seasonality will affect the strong agricultural system in place. Through the research completed by HELCOM and other organisations, it is predicted that this ecological shift will not benefit the overexploitation process already in place in the Baltic Sea.

→ RESOURCE EXPLOITATION

Cropland
Load of phosphorous
High
Low
Polluting sites
Treecover
Treecover loss
Polluting sites
Mining waste
Most polluting rivers
Riverine mercury load
High
Low

Agriculture accounts for a vast majority of the pollutants released in the Baltic Sea. This originates largely from the use of chemical and non-organic fertilisers to increase production and productivity. These chemical products, usually nitrogen, phosphorous and potassium linger in the soils and leak in the form of nitrates. This affects groundwaters for decades, but not only, it also has effects in the Baltic Sea aquatic ecosystems through the draining rivers.

The forestry industry is also a significant polluting source, especially in the regions where the pulp and paper mill factories are situated. These industries are demanding on water, energy and chemicals (the mills make extensive use of chemicals – some 2.8 million tonnes per year). Emissions of nitrogen and sulphur from this sector is quite high and is often found next to the rivers and lakes in their immediate surroundings. Not only is it polluting its surrounding soils but it is also a major source of nitrogen leaks into the Baltic Sea.

→ INFRASTRUCTURE COLONIZATION

Urban fabric
Maritime traffic
Risk of oil spills

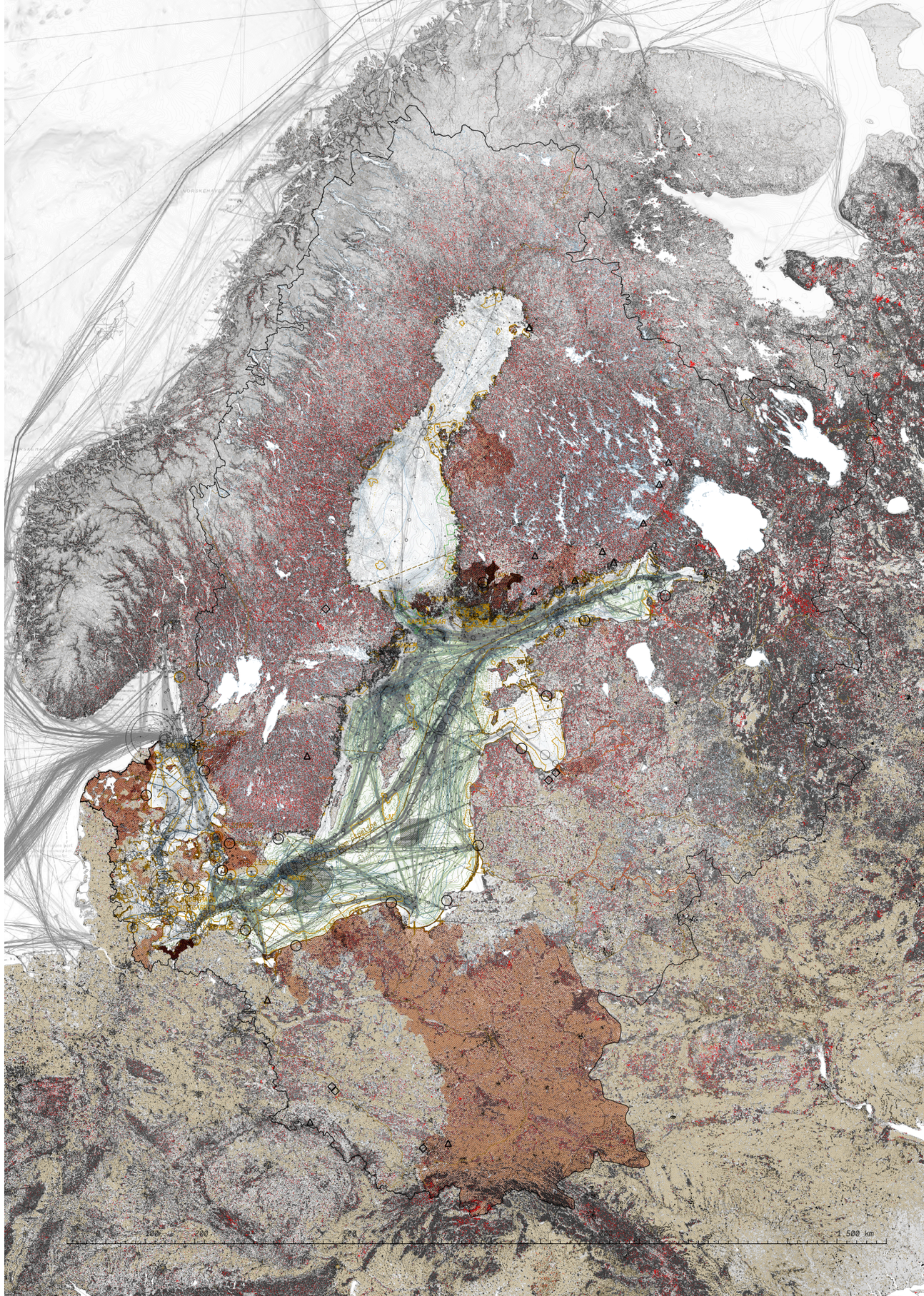
The rapid growth in Russian oil export and shipping routes through the Baltic Sea has recently aroused particular concern for countries that share this common space of navigation. The Baltic Sea is quickly becoming Russia's most important transit route for energy as it accounts for almost 40% of all its exports. Maritime traffic in general is predicted to increase in the years to come and this will be closely followed by the infrastructure needed to cope with this new trend. Oil spills will become more frequent as well as shipping accidents and the need for a tight collaboration in terms of traffic regulations will certainly be an issue to solve.

The intense urbanisation process and population growth will also impact the coastal zones of the Baltic Sea and will undoubtly increase the amount of pollutants and waste present.

→ GEOPOLITICAL SHIFT

Territorial waters
EEZ
Int. passenger ports
Mine threat area
Chemical munition dump
UNESCO sites
HELCOM protected
Eutrophication status

In terms of danger to the Baltic Sea ecosystem, the most frequently reported existing threat is eutrophication. Agricultural run-off of nutrient is the major cause of this phenomena. Witnessed by intense algal growth, altered communities of flora and fauna, oxygen depleted sea bottoms and the death of fish and benthic organisms. Therefore, commercial and recreational fishing are also affected by eutrophication. Overall, it remains a huge problem for nature conservation since it affects the entire marine ecosystem and extensive or toxic algal blooms also preclude bathing and boating tourism during season heights.



SCENARIO 2030

A MANUFACTURED LANDSCAPE, INTERACTING WITH A SPACE IN TRANS-FORMATION

BAŁTYK SEA SCENARIO 2030

TIMELINE

→ 2016. April 4	Noticeable rise of temperature in northern Finland and Sweden
→ 2017. April 17-19	New land-use potentials for agriculture around the Bothnian Sea
→ 2017. October 14-28	Nordic countries meet in Helsinki to decide on common agriculture regulations in terms of chemical fertilisers
→ 2019. November 9	Scarcity of water resources is limiting tree growth in the south of the drainage basin, particularly in the great European plain
→ 2020. March 3	Poland and Russia raise their limit values for nitrogen and phosphorus riverine loads
→ 2020. August 18	Lack of proper storage leads to an important leak of nitrogen stocks from ex-USSR countries in the Baltic Proper
→ 2023. February 5	The Baltic States annual timber yield witnesses a significant decrease. Low unemployment percentages affect regional political elections
→ 2023. July 17	Finland and Russia increase their timber and agricultural production in the northern part of their territory, new infrastructure is built to cope with new traffic of goods
→ 2024. June 13	Inauguration of Rail Baltica project in Tallinn. Helsinki is now connected to Berlin through this new railway
→ 2026. October 23	Due to intense forestry production, Nordic countries' energy consumption increases tenfold
→ 2027. January 8	A hard winter touches the northern part of the Baltic Sea, the ice cover reaches the 1967 maximum extent
→ 2027. June 16	German and Polish beaches face an exceptional closure due to dense algae blooms. Tourism industry is severely hit
→ 2029. August 20	The Gulf of Finland witnesses a record level of phosphorus concentration. HELCOM warns Baltic States to lower their nitrogen emissions
→ 2030. February 12	HELCOM launches an international competition to find new and innovative ways of dealing with eutrophication



BAŁTYK SEA SCENARIO 2030

EUTROPHICATION

↓ EXCESS NUTRIENTS

Caused by excessive inputs of nutrients to the marine environment, eutrophication remains one of the principal threats to the biodiversity of the Baltic Sea. It is driven by a surplus of the nutrients nitrogen and phosphorus in the sea: these nutrient over-enrichment then cause elevated levels of plant growth and algal, oxygen depletion, increased turbidity, changes in species composition and nuisance blooms of algae. *"The main pathways of nutrients to the sea are riverine inputs, atmospheric deposition of nitrogen to the water surface and direct waterborne discharges to the sea from coastal point sources, run-off from diffuse sources in coastal areas or discharges from ships. In addition, excess nutrients stored in bottom sediments can enter the water column and enhance primary production."*[1]

Through the eutrophication process, decaying organic material consumes and depletes the oxygen in the water. This causes a number of secondary impacts including fish kill, formation of unwanted substances (such as methane), hydrogen sulphide, ammonia, odour and taste producing substances, organic acids and toxins. It can also cause mortality in livestock through freshwater toxins from cyanobacteria. Furthermore, eutrophication is also an issue for terrestrial environments : excess nutrients to land area causes plants favoured by higher nutrients to overtake those favoured by poorer ones. Acidification will also take place due to ammonia being oxidised to nitrous or nitric acid. In the end these effects are of considerable significance to forest ecosystems.

↓ ANTHROPOGENIC ENRICHMENT

Human influence on the eutrophication process is now clearly established. Nutrients such as nitrogen and phosphorus that are mainly used in biochemical fertilisers, chlorine that is massively used for the production of paper and sewage waters from metropolitan areas around the Baltic Sea are the main factors of pollution. Agriculture itself accounts for more than 70% of all phosphorus leaks and 55% of nitrogen runoffs. Chemical inputs from cities account for a large part as well. Some countries around the Baltic Sea still use older and less efficient filtration techniques (see AGRICULTURE) that reject sewage waters with high levels of chlorine and PCB's. These chemicals do not mix with water and are therefore deposited on bottom seabeds, which are constantly being moved either from dredging activities or with bottom-trawling fishing.

But not only are human activities causing eutrophication in the Baltic Sea, the characteristics of the sea itself produce favorable conditions for aquatic hypoxia. Hypoxia is defined as an oxygen depletion in marine environments. This phenomena occurs when dissolved oxygen in the water reaches low levels (between 1-30%) and becomes detrimental to aquatic organisms (<30%). Oxygen is a parameter that is closely linked to water salinity and temperature (see SALINITY + OXYGEN + TEMPERATURE).

Point sources

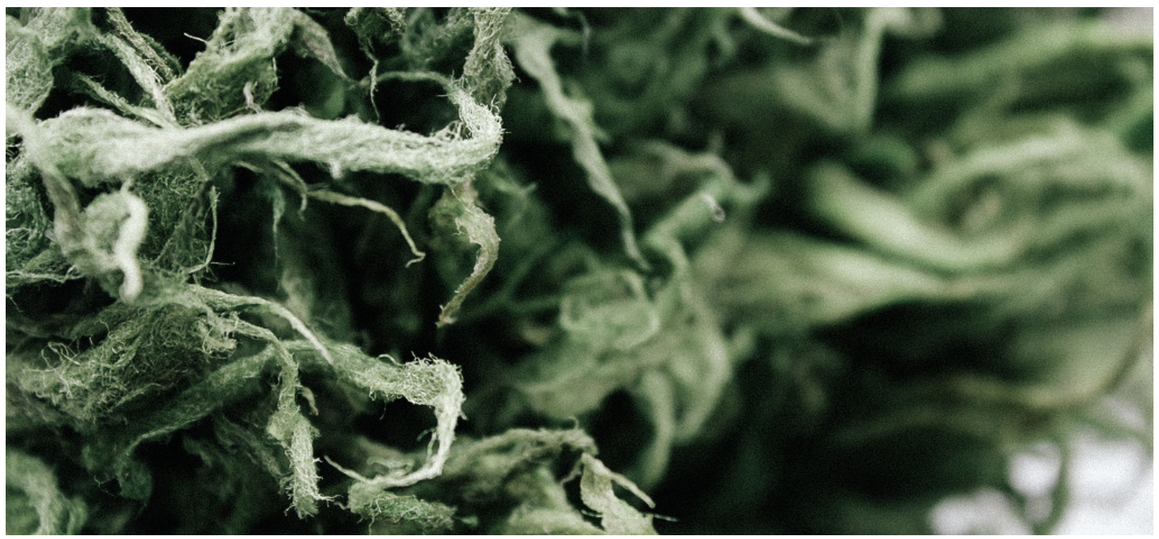
- ↘ Wastewater effluent (municipal and industrial)
- ↘ Runoff and leachate from waste disposal systems
- ↘ Runoof and infiltration from animal feedlots
- ↘ Runoof from mines, oil fileds, unsewered industrial sites
- ↘ Overflows of combined storm and sanitary sewers
- ↘ Runoff from construction sites less than 20.000 m²
- ↘ Untreated sewage

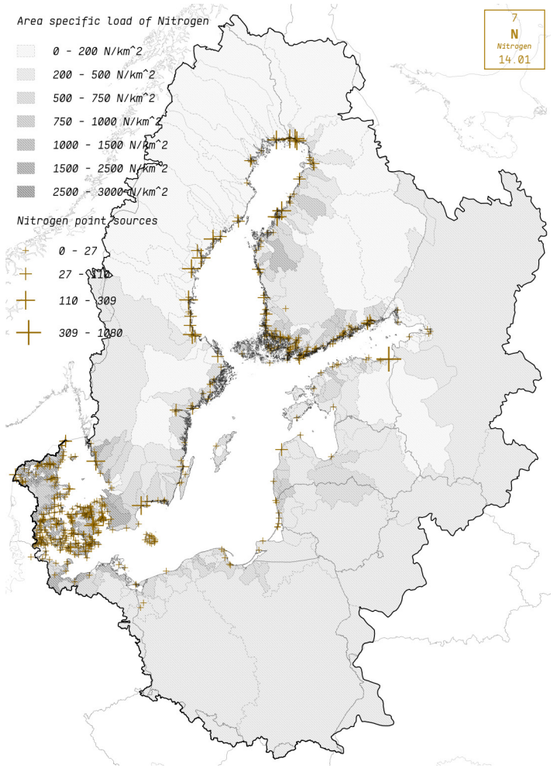
Nonpoint sources

- ↘ Runoff from agriculture/irrigation
- ↘ Runoff from pasture and range
- ↘ Urban runoff from unsewered areas
- ↘ Septic tank leachate
- ↘ Runoff from construction sites > 20.000 m²
- ↘ Runoff from abandoned mines
- ↘ Atmospheric deposition over a water surface
- ↘ Other land activities generating contaminants

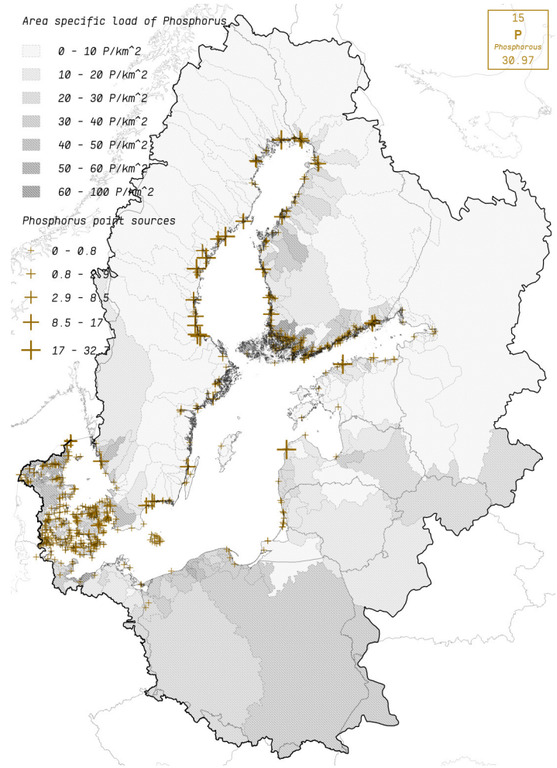
↑ *FIG.1 POINT AND NONPOINT SOURCES OF CHEMICAL INPUTS* (Redrawn from Novonty, 1994)
Specific sources that contribute to nutrient loading can be identified. There are two common sources of nutrients and organic matter: point and nonpoint sources

↓ *IMG.1 GREEN ALGAE, PRODUCT OF THE EUTROPHICATION PROCESS* (Photo by Mia Mäkelä)





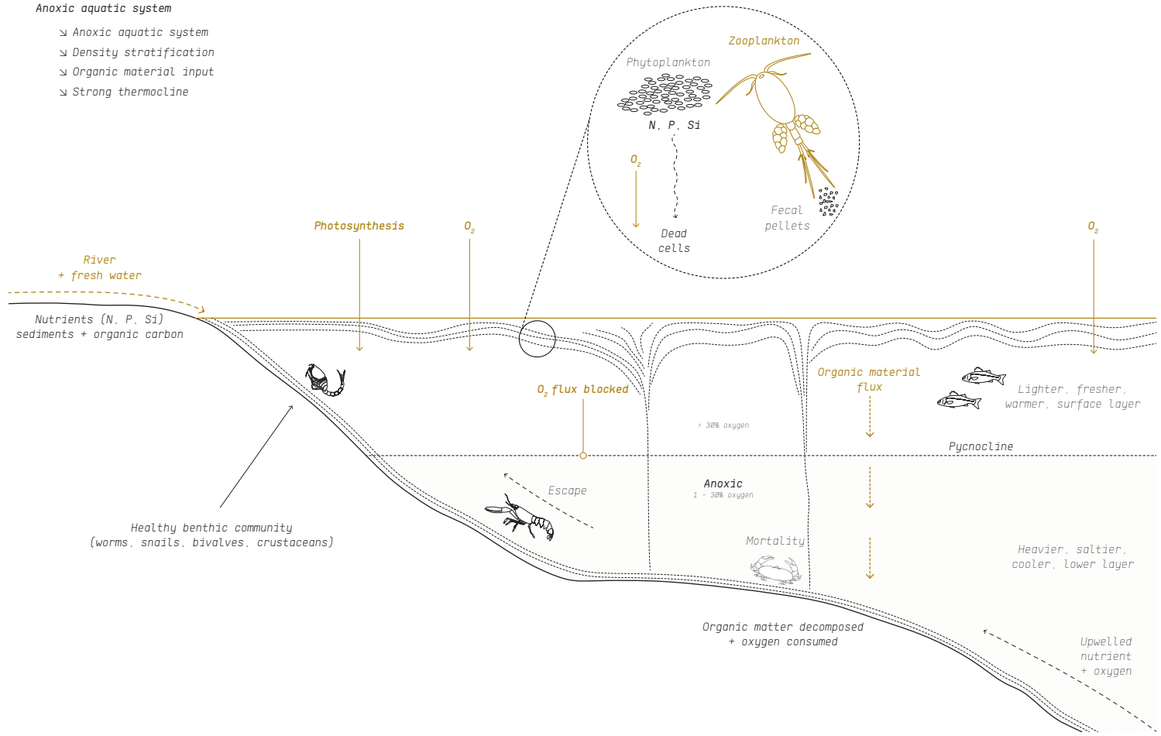
↑ *FIG.2 NITROGEN LOAD SOURCES* (GIS data from HELCOM)
An important aspect of the leakage of nitrogen is the improper use of manure, which accounts for a major part of the leakage. A considerable amount of nitrogen from non-point sources is derived from car exhausts and the burning of fossil fuel as well as biomass for the production of energy



↑ *FIG.3 PHOSPHORUS LOAD SOURCES* (GIS data from HELCOM)
The main consumers of phosphorus in most countries are the agro-ecosystems, which import these nutrients in fertilisers, fodder, sludge, food products, and in chemicals, e.g., washing products

Anoxic aquatic system

- ↘ *Anoxic aquatic system*
- ↘ *Density stratification*
- ↘ *Organic material input*
- ↘ *Strong thermocline*



↑ *FIG.4 EFFECT OF EUTROPHICATION* (Redrawn from Hillewaert, 2006)
Eutrophication results in an increase in the ecosystem's primary productivity (excessive plant growth and decay), and further effects including lack of oxygen and severe reductions in water quality, fish, and other animal populations

BAŁTYK SEA **SCENARIO 2030**

These three parameters influence water density and ice formation. When salinity levels are higher, temperature and oxygen usually follow a descending curve. This phenomena is clearly visible when ice forms on the Sea since it is usually followed by important algal blooms. The water layering that is created by these differences of salinity and temperature can also result in hypoxic conditions. As waters does not mix vertically, the bottom layer has restricted oxygen supply from the surface. Most fishes need 30% of oxygen concentration in order to survive (see *FIG.4*).

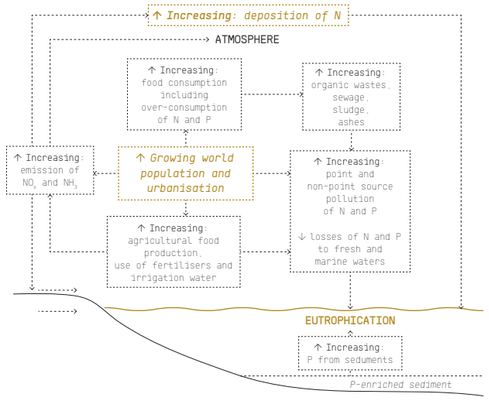
Algal block (blue/green algae) is harmfull for commercial fishing and maritime traffic in general. These blooms ca also be toxic and they often lead to closure of recreational waters. Tourism being one of the major sources of income for many countries, this issue has to be treated seriously. Especially since the nthropogenic pollution is expected to continue to rise in the following years.

There are solution to use algae to produce renewable energy or to produce algae-based fuels (diesel, gasoline). Some countries such as Estonia already use waste to produce energy and this solution is very promising for the future, it is an interesting way of using industrial waste as a benefitial product. These solutions are based on the idea that nutrients runoffs will continue rise and that algal blooms will happen on a more frequent basis. A more ecofriendly solution is based on the restoration of shellfish populations as some oyster species remove nitrogen from water and filter suspended solids.[2]

↓ OUTLOOK

According to HELCOM, a vast majority of the Baltic Sea has been assessed as being affected by eutrophication, even despite measures put in place during the past few years to reduce external inputs of nitrogen and phosphorus. Only a few coastal areas have been classified with a convenient ecological status (according to the WFD criteria of the EU) : the inner and outer coastal Quark, outer coastal Bothnian Bay, outer coastal Bothnian Sea (SWE), outer coastal Quark (FIN) and the Orther Bucht (GER). "*The Baltic Sea is not yet on a path of recovery to its previous state even though inputs of nutrients have decreased. This is due to the long time-scales of biogeochemical cycles and because the ecosystem structure and functions have changed.*"[3]

Today, it is also unclear how climate change will impact the general trend of eutrophication. A HELCOM study (HELCOM 2013c) advocates that the runoff and nutrient inputs is linked to temperature and that the predicted warming of the sea will be associated with lower runoff in southern parts of the Baltic Sea drainage basin compared to higher runoff in the northern regions. Overall this study shows that the Baltic Sea is facing a serious ecological shift that needs to be faced with planning measures, especially since worldwide trends, noticeably climate change, will not help the cleaning process along.

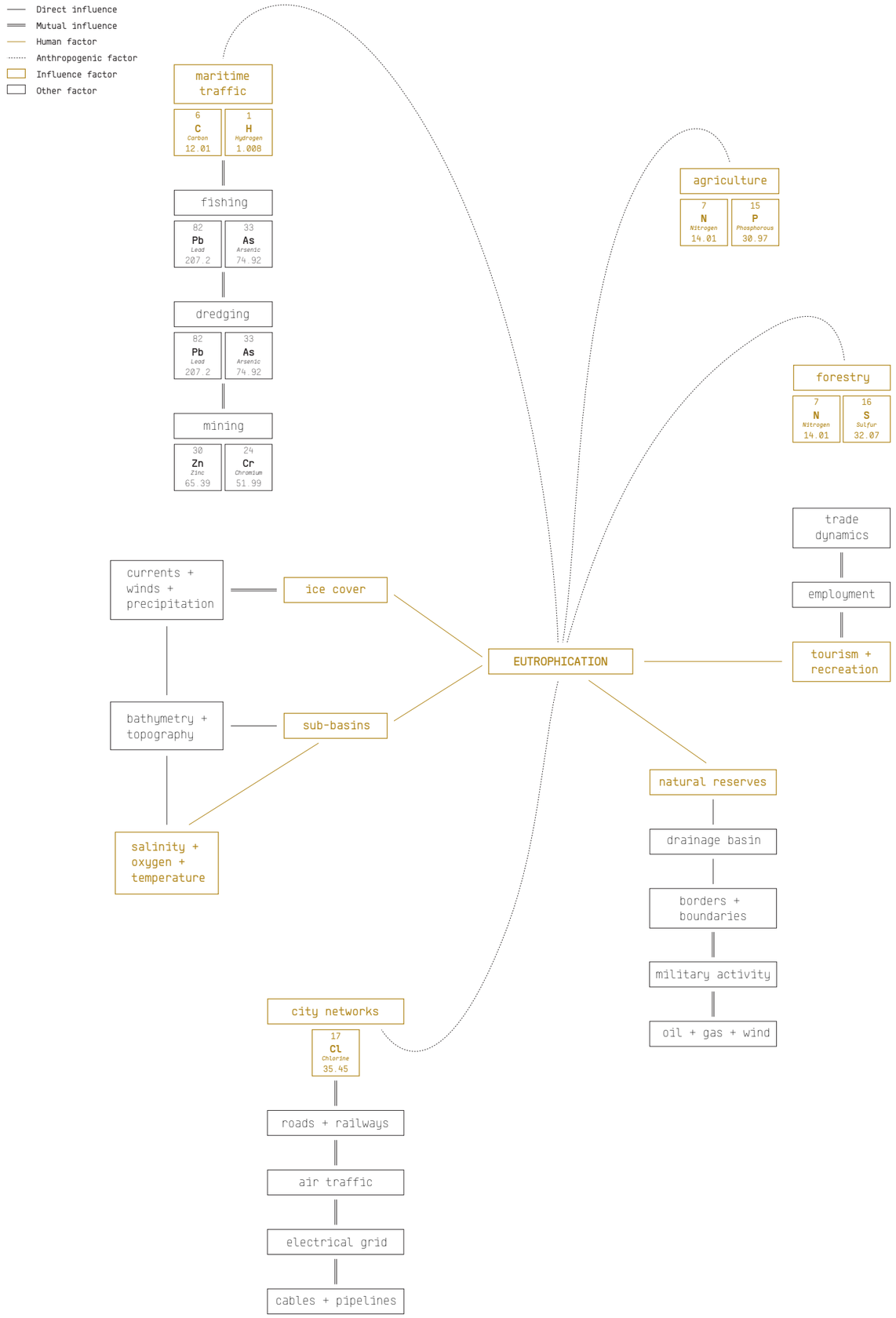


↑ *FIG.5 GROWING WORLD POPULATION AND URBANIZATION* (Redrawn from Rydén, 2003)
The consequence is an increased flux of nutrients from land to water and increased eutrophication

↓ *IMG.2 ALGAL BLOOM OFF THE COAST OF FINLAND* (Photo by Rebecca Löfgren)



FIG.6 EUTROPHICATION EQUATION →

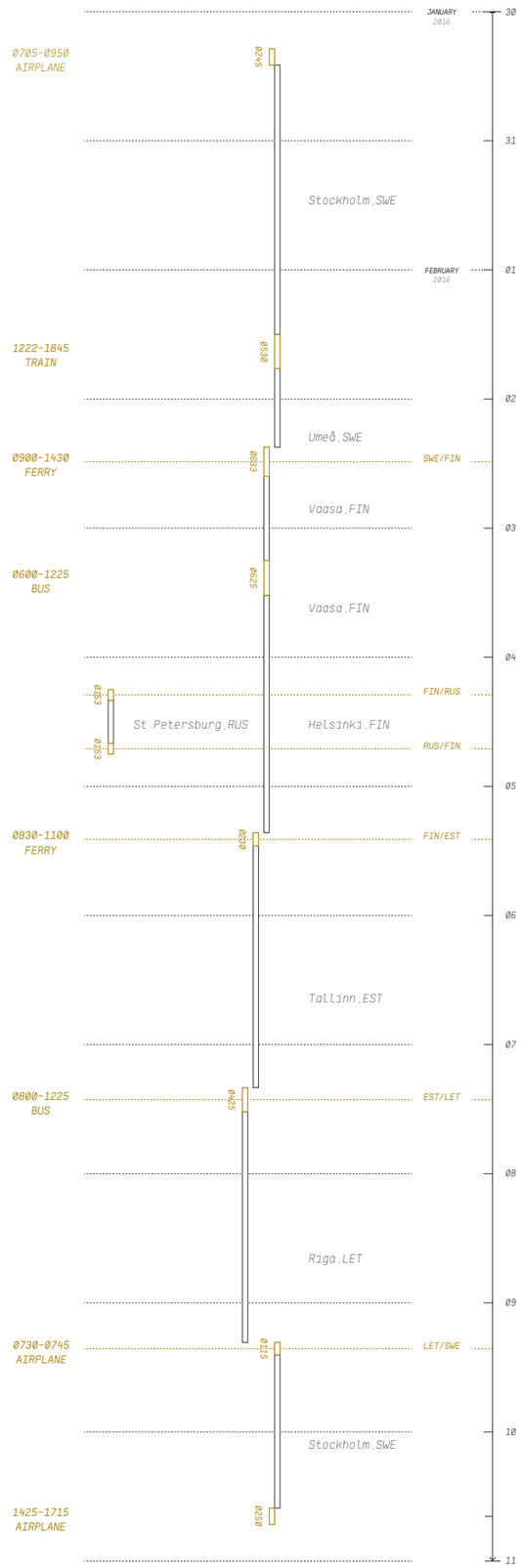


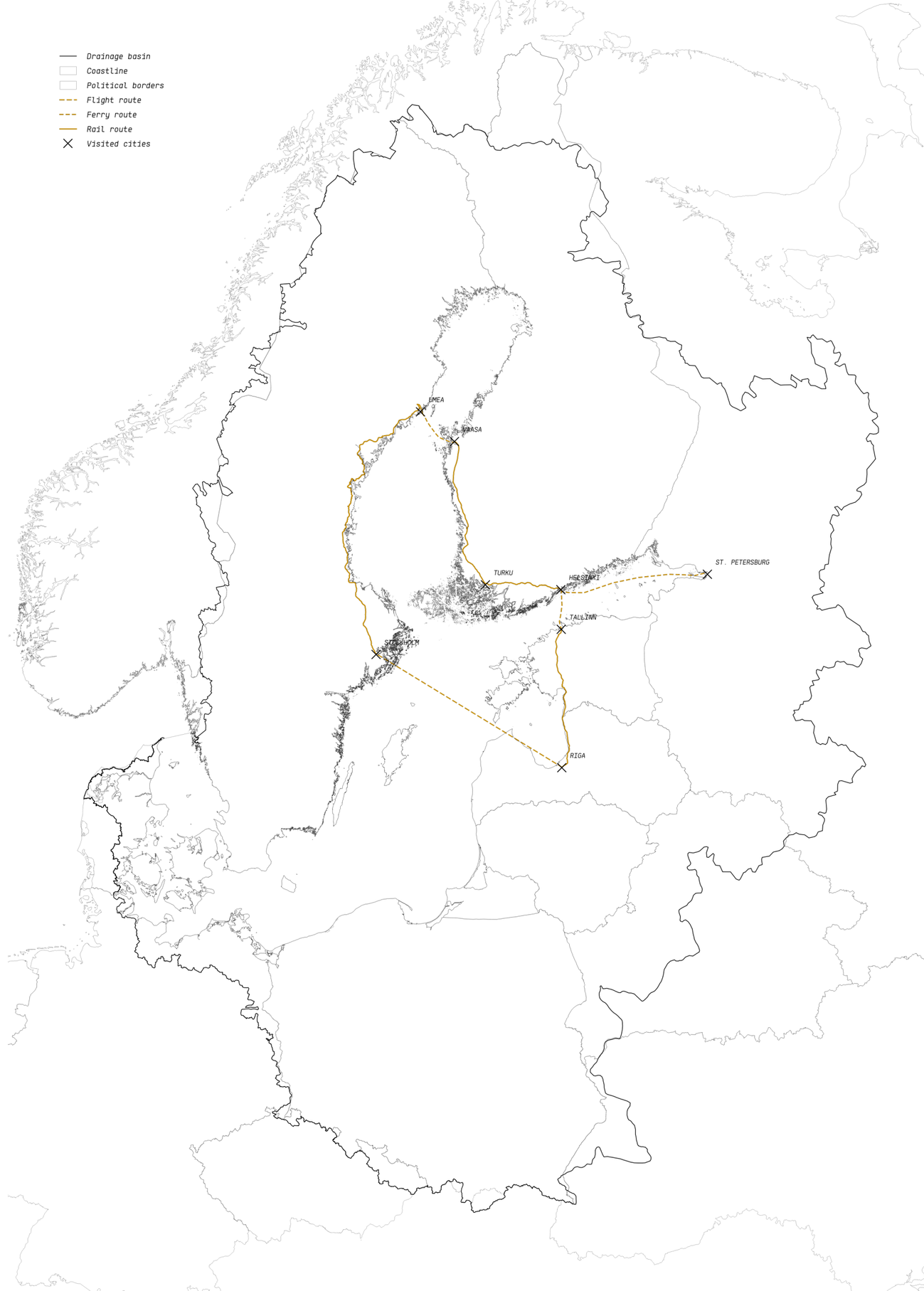
STUDY TRIP

WE CONFRONT THE THEO-
RETICAL RESEARCH WITH
A PERSONAL EXPERI-
ENCE OF THE PLACE AND
SCOUT THE LOCATION FOR
A SPECIFIC SITE OF IN-
TERVENTION WHERE WE
WILL PROPOSE AN ARCHI-
TECTURAL / URBAN DE-
SIGN PROJECT

BAŁTYK SEA **STUDY TRIP**

SCHEDULE





BAŁTYK SEA NOTES

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A MANUFACTURED LANDSCAPE

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2 ibid

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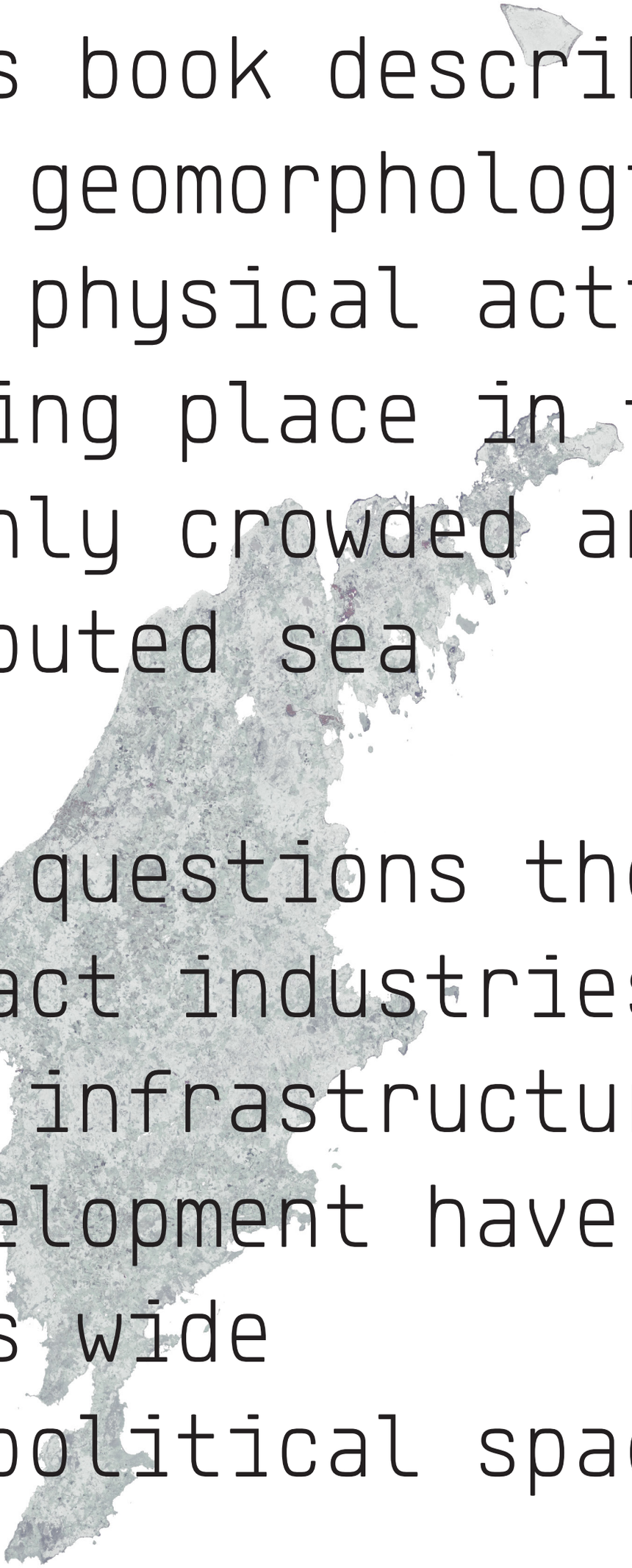

This book describes the geomorphological and physical actions taking place in this highly crowded and disputed sea

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