2019-2020

Delft University of Technology

SYNCHRONIZING
HABITAT

Risk adaption by co- evolution
of environment and society

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Graduation Project
MSc. Urbanism

Colofon

Synchronizing habitat:
Risk adaption by co- evolution of environment and society

Master Thesis P5 Report
M.Sc. Architecture, Urbanism and the Building Sciences

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AR3U023 Theories of Urban Planning and Design
AR3U013 Analytical Methods of Urban Planning and Design
AR3U100 Graduation LAB

2nd July 2020
Delft, Netherlands.

SYNCHRONIZING HABITAT

Risk adaption by co- evolution of environment and society

Fig. 1 Vista of the Wadden Sea, Lower Saxony.
(taken by author, 2019)

ACKNOWLEDGMENTS

I would like to thank my mentor duet- **Luisa Calabrese** and **Daniele Cannatella**- for their wonderful support and guidance throughout the thesis. Despite the challenges the Corona pandemic presented for our teamwork and personal lives, my mentors never ceased to inspire me with their words and insights on the project.
Heel erg bedankt!

I also grateful to my parents for teaching me the sensitivity and mindfulness I required for this project (especially regarding the sea); to my sister for giving me perfect advice and always cheering me up; and to my boyfriend for his unconditional patience, care, and readiness to solve my most ridiculous problems.
Muchas gracias! Vielen Dank!

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Chapter

1

PREFACE

INTRODUCTION

In this short chapter the personal reasons and significance that have led to the development of this project in the Transitional Territories studio will be exposed, followed by a summary of the main ideas and notions exposed in the studio Symposium 2019.

[CONTENT]

- MOTIVATION

- EXECUTIVE SUMMARY

MOTIVATION

As an architect and soon to be urbanist, one develops a sensitivity for spaces, or as E. Bacon states "the awareness of space as experience" (Bacon, 1976). I grew up with sea salt tangled in my hair, soothing music of waves retrieving from a sandy shore and memories in the form of freckles on my skin from the burning sun. The sea has moved me with the most extraordinary landscapes and has brought me calmness in contemplating its powerful synergies. Unlike other marvelous landscapes, the sea makes me feel present, alive and connected to this planet's natural systems.
Throughout this first year of masters, I was surprised to discover that this landscape I considered in a state of 'natural purity', is in fact the most vulnerable and most affected by anthropogenic activities. Since then I feel an obligation to protect and to assure these valuable spaces operate as a safe, just, and healthy habitat.

As a citizen of one of the most dangerous cities of the Global South (Caracas, Venezuela) I have learned the value of safety and security. It is these feelings that allow you to experience a sense of freedom and empowerment. To me, urban space should always emanate these principles in order to activate social interaction and development.

My personal motivation to work with maritime dynamics combined with the urgent need of a spatial revision of coastal ecosystems due to the dichotomy of climatic change and economic development influenced my choice for the Transitional Territories studio (see Chapter 2 'Reflection').

Fig. 2 Observing the seascape
(taken by Mark Hartenstein, 2019).

'The empty vistas on the coast give us an experience of infinity and freedom, and hereby enable us to distance ourselves from everyday life [...] Infinity goes in hand with the temporal, the transience of life, contact with the elements of nature.'

Dirk Sijmons & Van Dorst in The emotional landscape, 2014.

Fig. 3
Infrastructural obsolescence
(taken by author, 2019).

Fig. 4
Hybridization
(made by author, 2019).

Fig. 5
Manufacturing externalities
(taken by author, 2019).

INTRODUCTION

Executive summary

The extreme character of human activities and hard infrastructures in combination with the continuous variation of the climate has triggered an unprecedented fast rate of alterations in the environment. Hereafter the anthropogenically magnified climate change is increasing stress on ecosystems; especially interfaces such as coastal areas are at significant risk. Considering that the North Sea is one of the most urbanized seascapes, we can draw upon its susceptibility to three hazards: inundation, sea temperature rise, and growing harbors. Although an ambiguity will prevail concerning the magnitude and rate of transformations, certainly inundation will cover and drown habitats, as well as move large amounts of formations and sediments; that sea temperature rise will attract invasive species and decrease water quality due to habitat depletion; in addition to the demand on expanding ports which implies more pollution by ship traffic, big industrial areas, spills, and maintenance, hence the accumulation of externalities in the sea bottom. One of the most sensible as well as affected territories concerning these hazards is the Wadden Sea region, which consists of a large intertidal zone surrounded by high productivity areas and rich marine ecosystems shared by three countries (Netherlands, Germany, and Denmark). Recalibrating the Wadden Sea region could mean enhancing the exhausted North Sea ecology to embrace climatic risk, store externalities, and set an example for the management of other conservation areas at risk.

Our spatial measures have developed from the exploitation of ecology (the 1900s) to its conservation (1960s), currently (2000s) we are looking towards shepherding nature by integrating them into our constructed systems. However, this spatial management perspective overlooks the innate benefits resulting from the synergy by cohabitation of human life, non-human life, and the environment. The proposed project recommends looking into a partnership with nature to join the intrinsic dynamics this planet offers, instead of trying to dominate them. This suggested cohabitation could be a chance to synchronize with the changing processes of our environment, which might lead us towards adapting progressively to them.

The project claims to regenerate the multi- equilibria state of marine ecosystems and develop an evolutionary adaptation through an ecosystem succession approach(Davoudi et al., 2013; Hale et al., 2009; Munang et al., 2013). This entails the gradual transformation of constantly obsolete infrastructures towards hybrid evolving systems consisting of Infrastructural Ecologies (Belanger, 2009; Brown, 2019; Reed & Lister, 2014). The idea is to use a mixture of soft and hard infrastructures that reintegrate the biodynamics of ecology so that it can be colonized by socio-ecological elements. Hence the interplay of the anthropic designs and environmental processes would support the creation of habitats that allow a shared expansion space for dissimilar activities to meet (ecotone enhancement). To propose such infrastructures it was necessary to understand the dynamics of the different marine ecosystems in terms of time cycles, longevity, and interdependencies. The consideration of this temporal dimension of socio-ecological elements in the design, allows the proposed changes to eventually be coupled to the pace of environmental processes. Hereafter ecosystems could be able to embrace climatic risk since they no longer present a hazard, but a trigger of transformation.

Chapter

2

FUNDAMENT

CONTEXT & CONFLICTS

The chapter '*Fundament*' contains the discussion of problematics, dichotomies and potentials of the territory and region that lead to the research questions and early assumptions of the project.

[CONTENT]

- PROBLEM FIELD
- PROBLEM STATEMENT
- RESEARCH QUESTIONS
- HYPOTHESIS

PROBLEM FIELD

North Sea: An extreme habitat

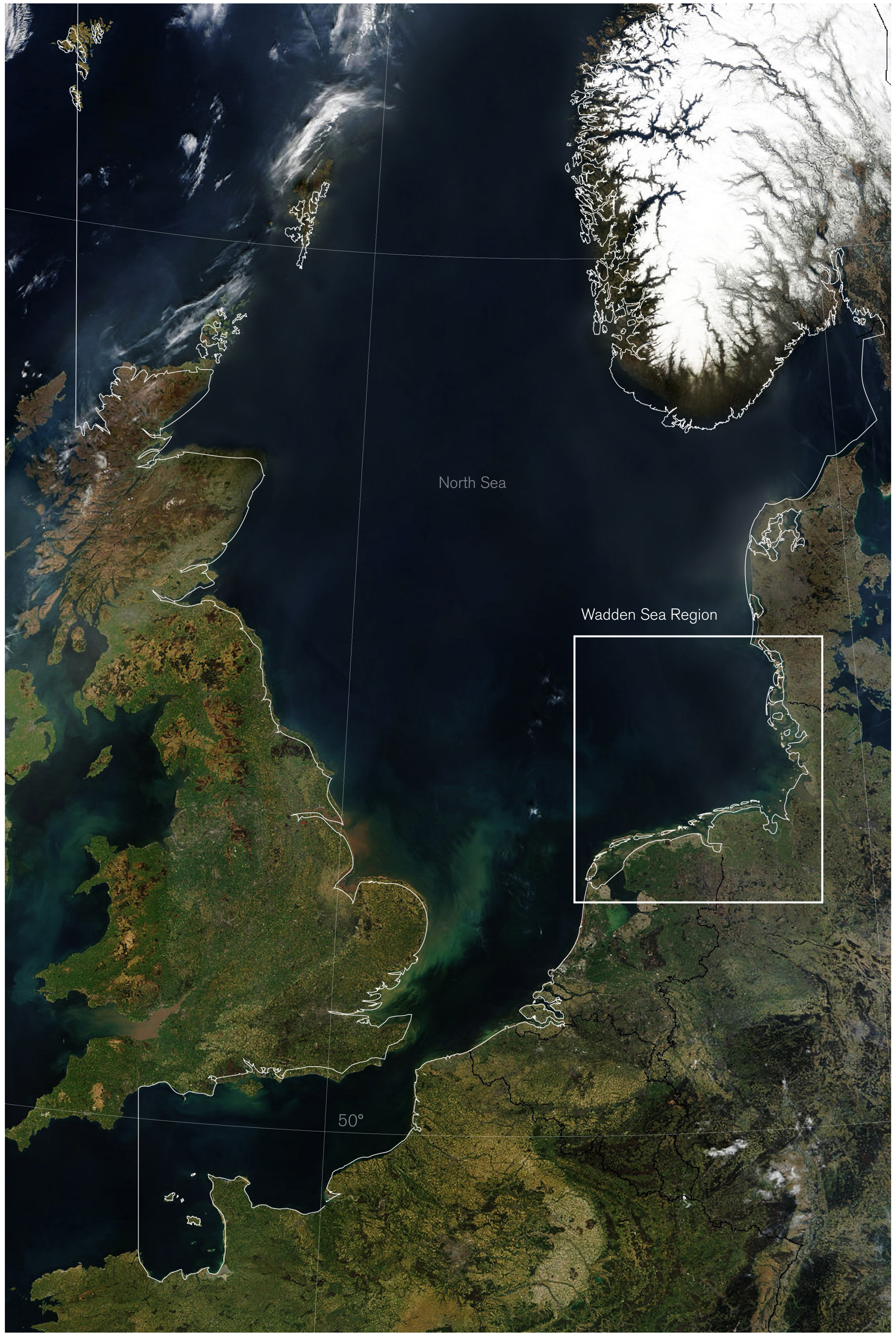
Despite its dynamic climatic variability, a high resource availability and trade opportunities triggered the urbanization and intensive use of the coastal landscapes of the North Sea (McGranahan et al., 2007).With the occupation of the sea through oil platforms; lighthouses; windmills; fishery equipment, and aquaculture, activities and infrastructure around coasts (mainly as an interface between land and water) intensified. Nevertheless, the heavy infrastructure imposed on this landscape remains mostly static, and therefore vulnerable to the hydrodynamic character of the coast. Hereby we can assume that developing extreme climatic conditions catalyzed by the anthropogenically magnified climate change will be more visible and rapidly affect the coastal areas of the North Sea.

Although currently guarded by costly and constantly renewed coastal defenses, human settlements around the coast are at risk of flooding due to the increasing mean sea level rise. If unattended harbor cities, important socio-economic drivers, will suffer substantial damage that will especially affect systems the community relay upon (McGranahan et al., 2007). This means human population and land vegetation will retrieve towards continental grounds, which will also increase the cultural distance towards the seascape already developing as a side effect of traditional economic growth by mass tourism, port trade, and storage activities. Recent discoveries of nature-based solutions could become a chance to adapt fragile coastal communities to climate variability maintaining important systematic synergies (Vikolainen et al., 2014)

The rapid shift of weather patterns is also causing biotic life-supporting ecosystems function to slowly move towards the Arctic Circle region due to sea temperature rise (IPCC, 2018). The abandonment of habitats by cold-water species jeopardizes the health of the marine ecosystem of the North Sea and the overall function of its landscape such as carbon storage and fauna & flora production. Allocating incoming warm water alien species while considering the needs of remaining endemic species (against dangerous invasive alien species) requires the creation of new habitats (Narayanaswamy et al., 2010).

Since the era of the Anthropocene is drastically accelerating the decline of resource availability in marine landscapes, and as one of these extremely exploited territories, the North Sea is continuously harvested to serve in function of land necessities, nonetheless not cultivated enough to restore to its previous resource-rich state. This means that the leading linear economic model that manages resource extraction, production, and consumption is not aligned to the capacity and pace of the regeneration of biotic, abiotic, and cultural systems. Hereafter the North Sea is rapidly becoming a space of accumulating "consumed' resources, that due to their mismanagement trigger processes of mostly hazardous events. These resources could pose a chance either to replace 'virgin material' or to rebuilt habitats that restore fragile ecosystem functions (Belanger, 2009; Hale et al., 2009).

Fig. 6 North Sea
(taken by NASA, 2006)

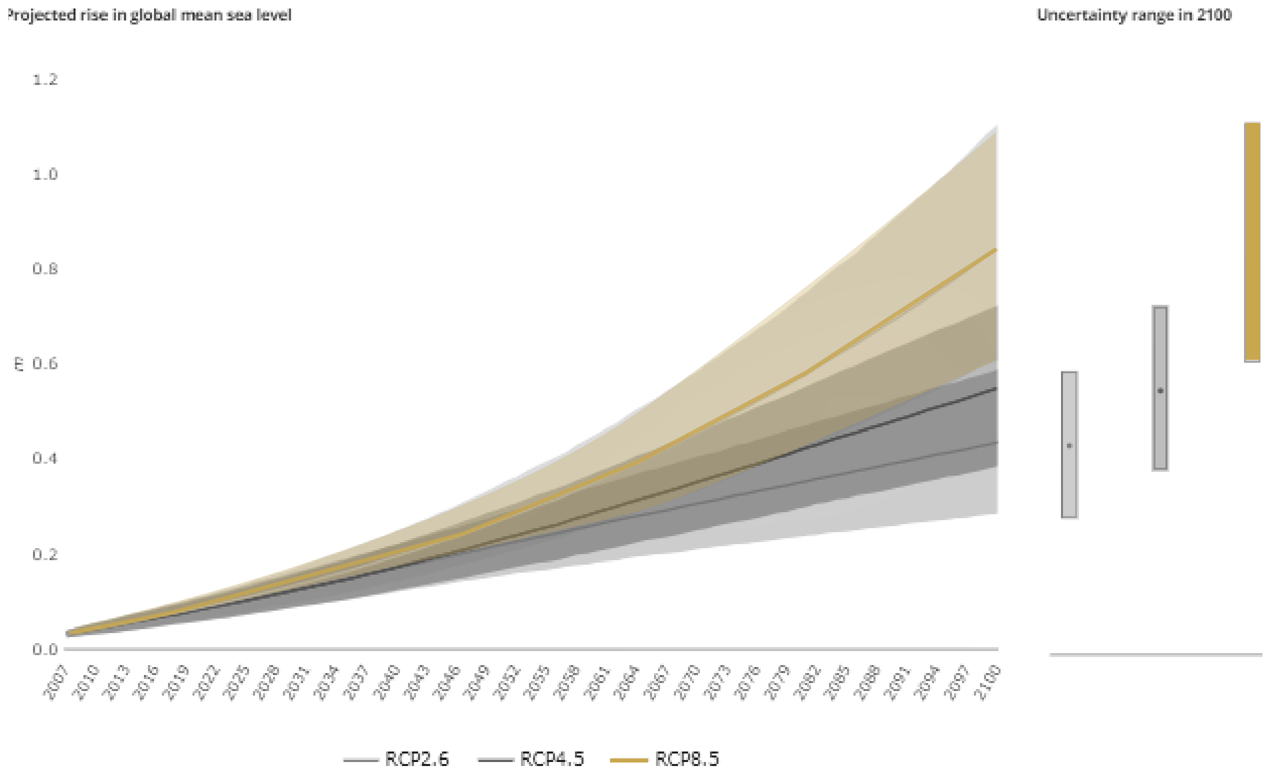


PROBLEM FIELD

RCP 8.5 Future Scenario: Sea Level Rise

As visualized in the graph when it comes to flooding we are relying on uncertainty since different scenarios depict very varied rates of global mean sea-level rise. In this project, the worst-case scenario serves as a base to understand the extends of the risk. The future scenario described by the IPCC (IPCC, 2014, 2018) RCP 8.5 by 2100 is illustrated in the map of the North Sea, showing the range of the inundation mostly in the lowest southern coasts (Netherlands, Germany, Denmark, Belgium, and the UK). Sea level rise will also affect the edges of important rivers that travel far into the continental western European landscape (Quante & Colijn, 2016).

Fig. 7 The projected rise in global mean sea level (taken from EEA, 2017. Modified by author).



North Sea- Sea Level Rise

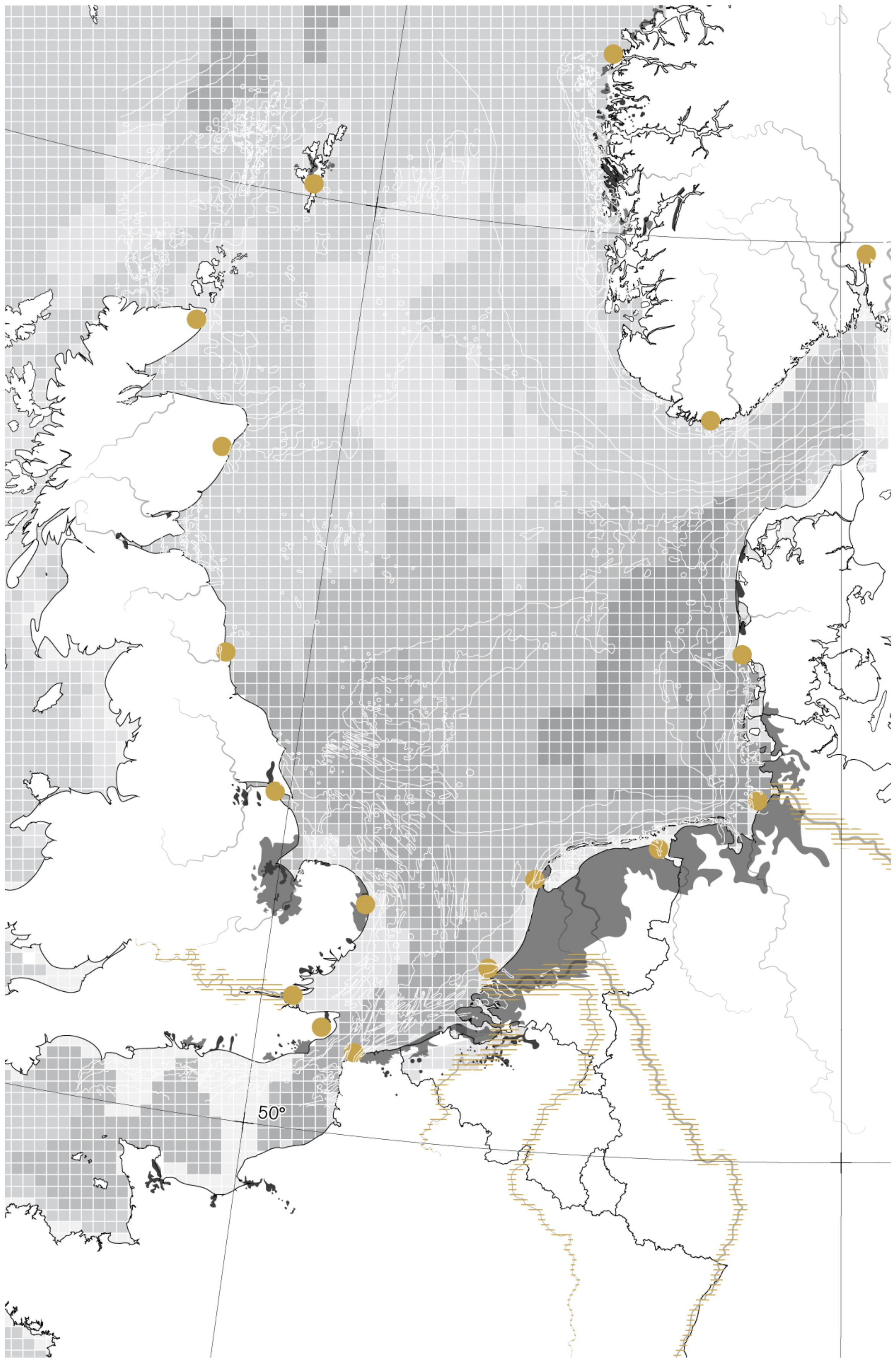
If the system of hard infrastructure should fail, a sea level rise of maximum 60 cm will suffice to cover most of the southern low and subsiding coast of the North Sea, its barrier islands and affect ground water levels and delta rivers.

Relative SLR
(8.5 RCP) by 2081-2100

- 0,5- 0,6 m
- 0,4- 0,5 m
- 0,3-0.4 m
- 02,-0,3 m

- Flooded area (1m SLR)
- High Chance of river flooding
- Frenquently flooded coastal area

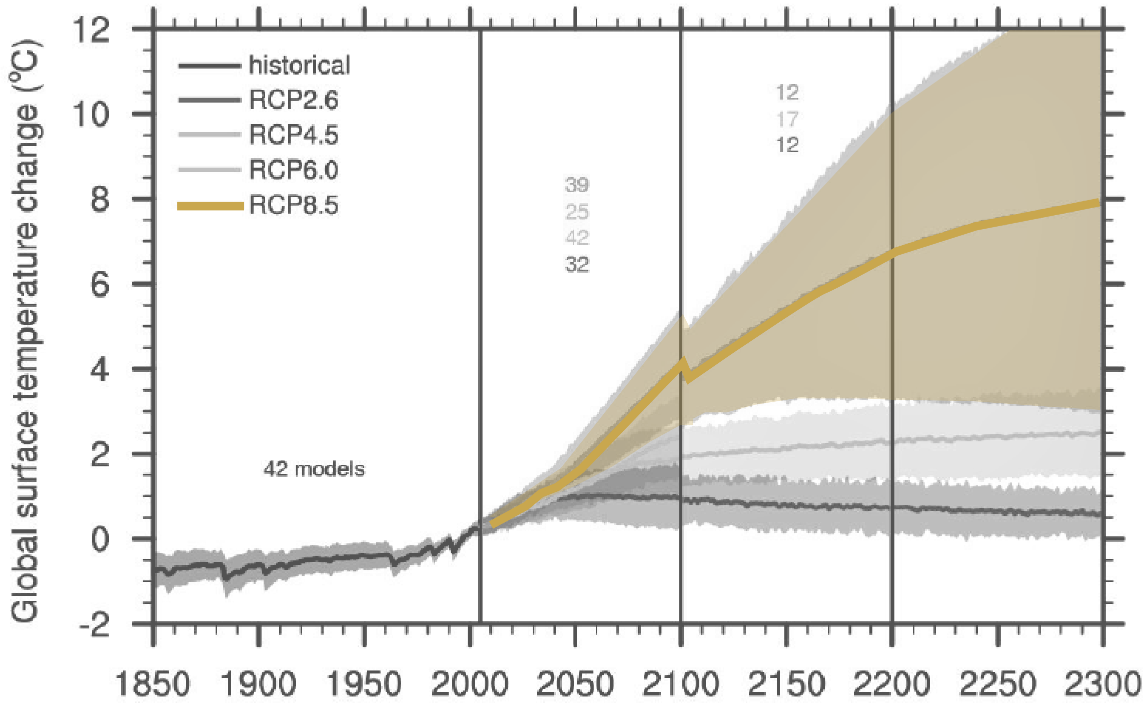
Fig.8 North Sea Sea Level Rise
(made by author)
(Data from Transitional Territories Studio, 2018; EEA, 2017 ; Climate Central, 2018)



PROBLEM FIELD
RCP 8.5 Future Scenario: Sea Temperature Rise

The delicate relation between atmospheric temperature and sea regulates many climate interactions such as precipitation, winds, oxygenation, salinity, vertical and horizontal particle exchange and currents, within other dynamics. In the projected RCP 8.5 scenario for 2100 the North sea atmospheric temperature could increase to a maximum of 7 degrees Celsius, and a sea temperature increase of 4 degrees Celsius. These speculative scenario questions if these extreme changes would also influence other less susceptible dynamics such as current movements since it is certain it will affect wind dynamics, vegetation bloom, and seasonal changes (Quante & Colijn, 2016).

Fig. 9 Global surface temperature change.
(taken from Oost et al., 2017. Modified by author)



North Sea- Sea Temperature Rise

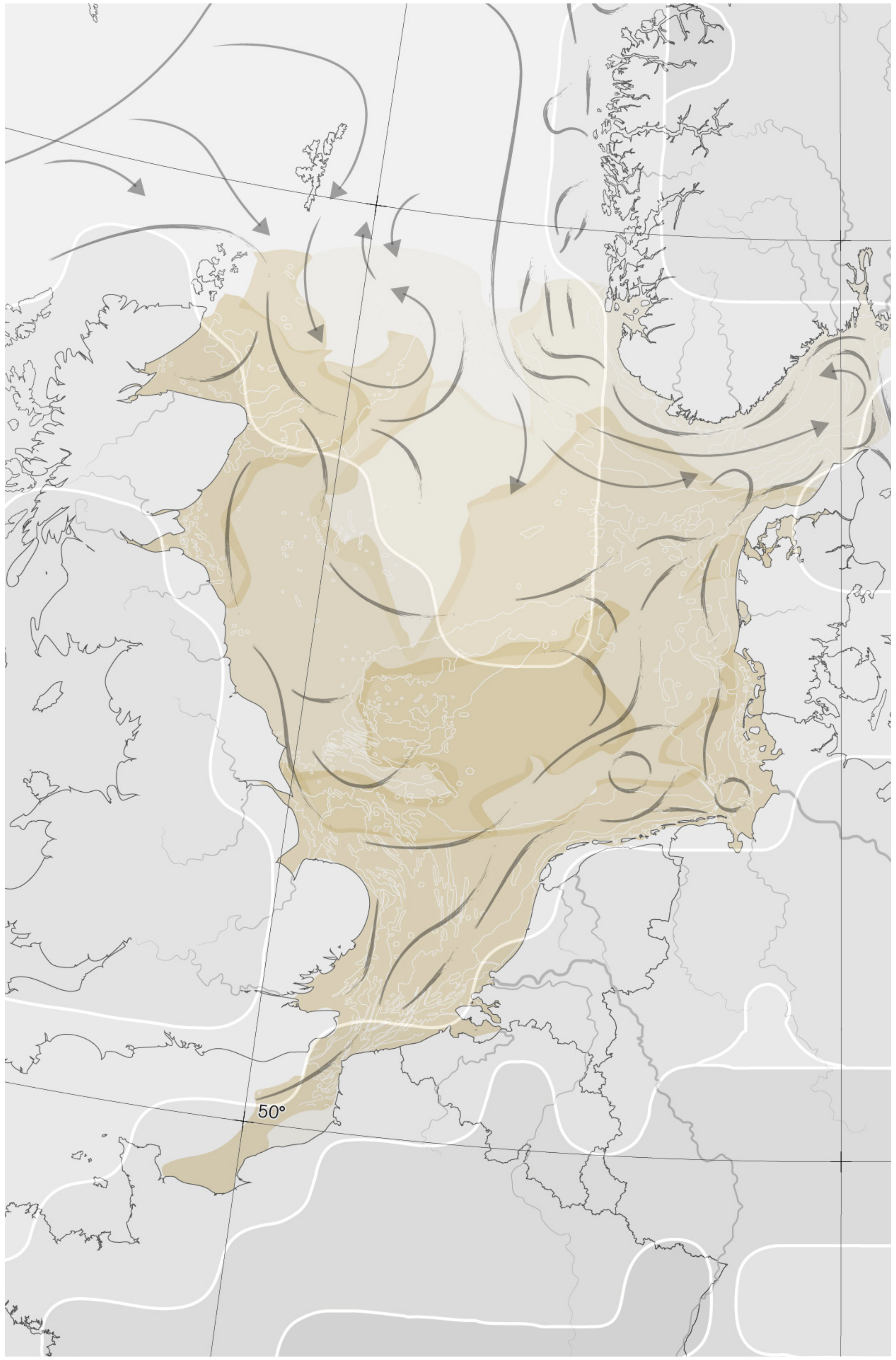
Warm currents from the Atlantic enter the North Sea through the English Channel and from Scotland towards the south. The Norwegian current continues north towards the Arctic attracted by colder waters.

Relative Sea Temperature (8.5 RCP) by 2081-2100
- 19°C [15 + 4 °C]
- 18°C [15 + 3 °C]
- 17°C [15 + 2 °C]
- 11,5°C [7,5+ 4 °C]
- 10,5°C [7,5+ 3 °C]
- 9,5°C [7,5+ 2 °C]

Atmospheric Temperature (8.5 RCP) by 2081-2100
- Mean Difference in Air Temp. Increase 6 - 7ºC
- Mean Difference in Air Temp. Increase 5 - 6ºC
- Mean Difference in Air Temp. Increase 4 - 5ºC
- Mean Difference in Air Temp. Increase 3 - 4ºC
- Mean Difference in Air Temp. Increase 2 - 3ºC
- Mean Difference in Air Temp. Increase 1 - 2ºC
- Mean Difference in Air Temp. Increase 0 - 1ºC

Currents

Fig. 10 North Sea Sea Temperature Rise
(made by author)
(Data from Transitional Territories Studio, 2018; SEOS-project. 2018; Quante, M., & Colijn, F. 2016)

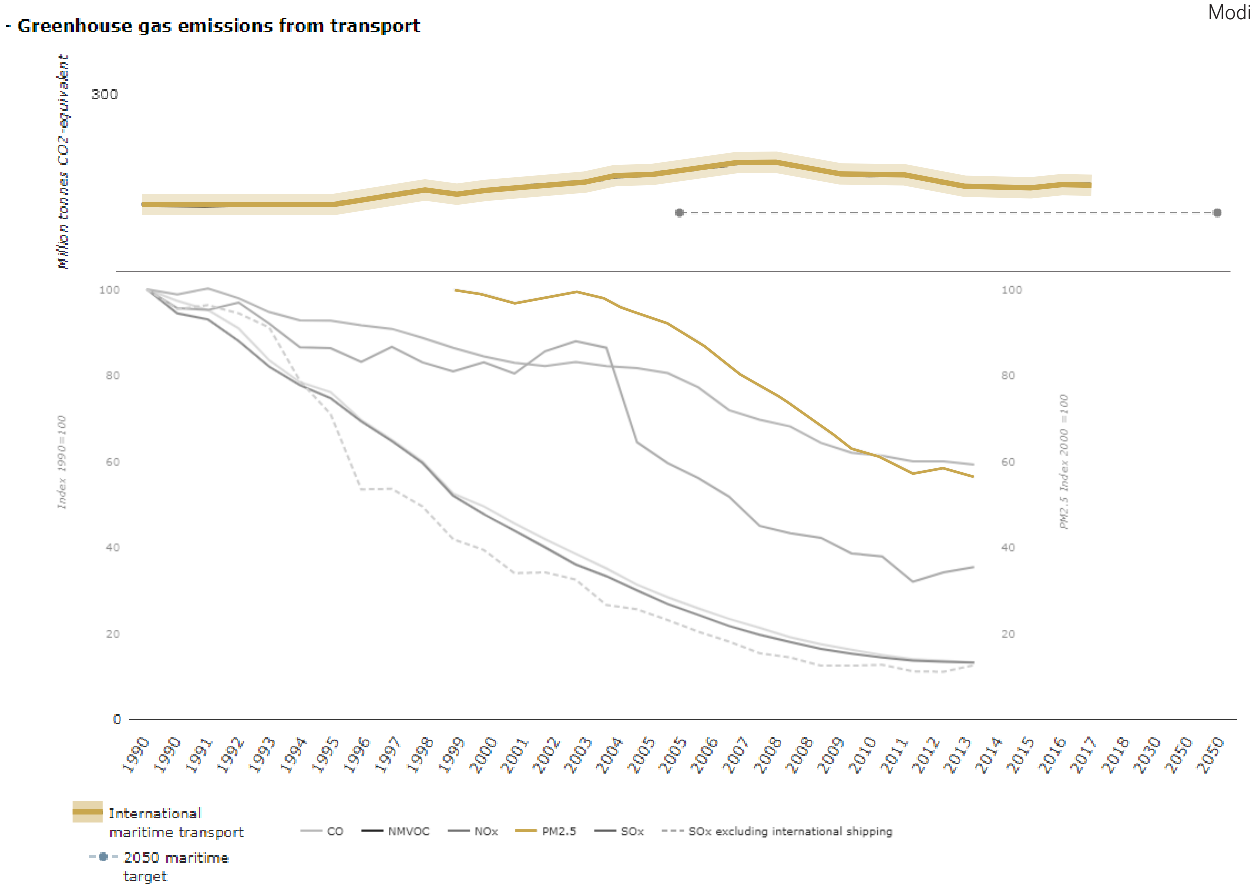


PROBLEM FIELD

RCP 8.5 Future Scenario: Water pollution by port activity

Shipping is the third biggest emission producer by traffic after the vehicle and airplane. It contributes largely to the emissions of sulfur dioxide, nitrogen, and carbon dioxide in the North Sea. In the projected scenario RCP 8.5 for 2100 following the current trend shipping and industrial areas will continue to deposit 3.55 to 44.15 E-15 kg m-2 sec -1. Furthermore, deposition of nitrogen in the atmosphere both as a gas and as rain will stretch over the current 44.15 E-15 kg m-2 sec -1 (Transitional Territories Studio, 2019).

Fig. 11 Greenhouse gas emissions from transport.
(taken from EEA,2017.
Modified by author)



North Sea- Water Pollution by port activities

Water pollution is also caused by the metal, coal, waste, chemical, medicine, fertilizer & pesticides, fisheries and car manufacture industries, which spill, pour or loose chemicals, heavy metals and waste in solid form or by combustion (OSPAR, 2017).

Concentration of various water, ground & air pollution

High

Low

Water pollution by port activities

- Growing ports
- Ports
- Port Industry
- Oil Rig

Heavy Metals

- Hg _Mercury
- Pb_Lead
- Cd_ Cadmium

Chemicals

- PAH
- Oil spills concentration
- PCB
- Chemical spill

Shipping Emissions

- CO_2 emissions
- NO_x emissions contributing to PM2.5
- Ship routes

Fig.12 North Sea: Water Pollution
(made by author)
(Data from Transitional Territories Studio, 2018; SEOS-project. 2018; Quante, M., & Colijn, F. 2016)

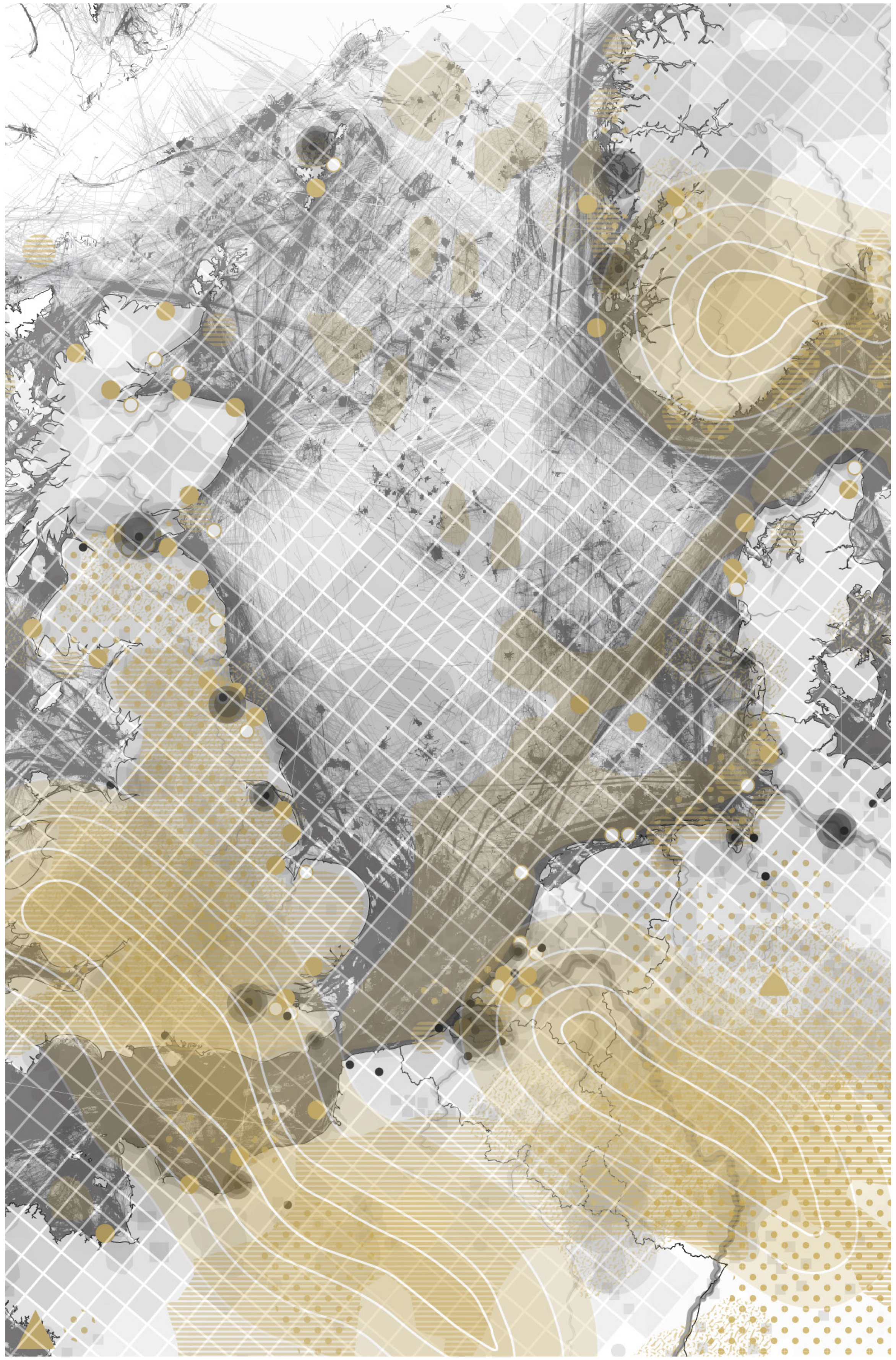
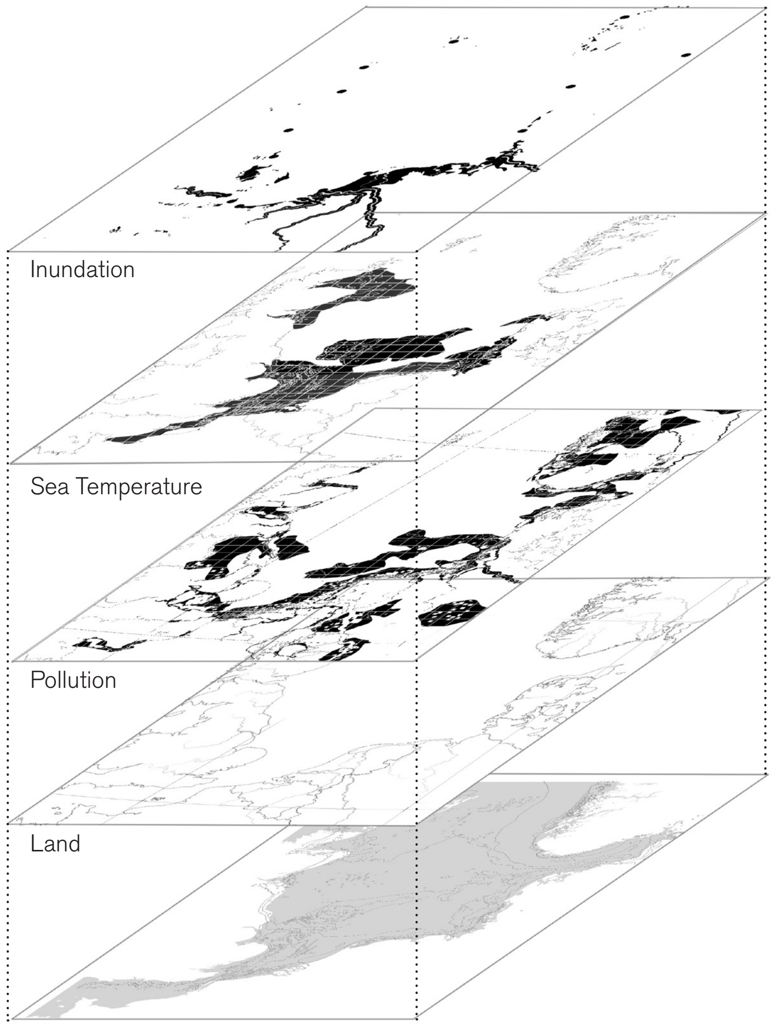


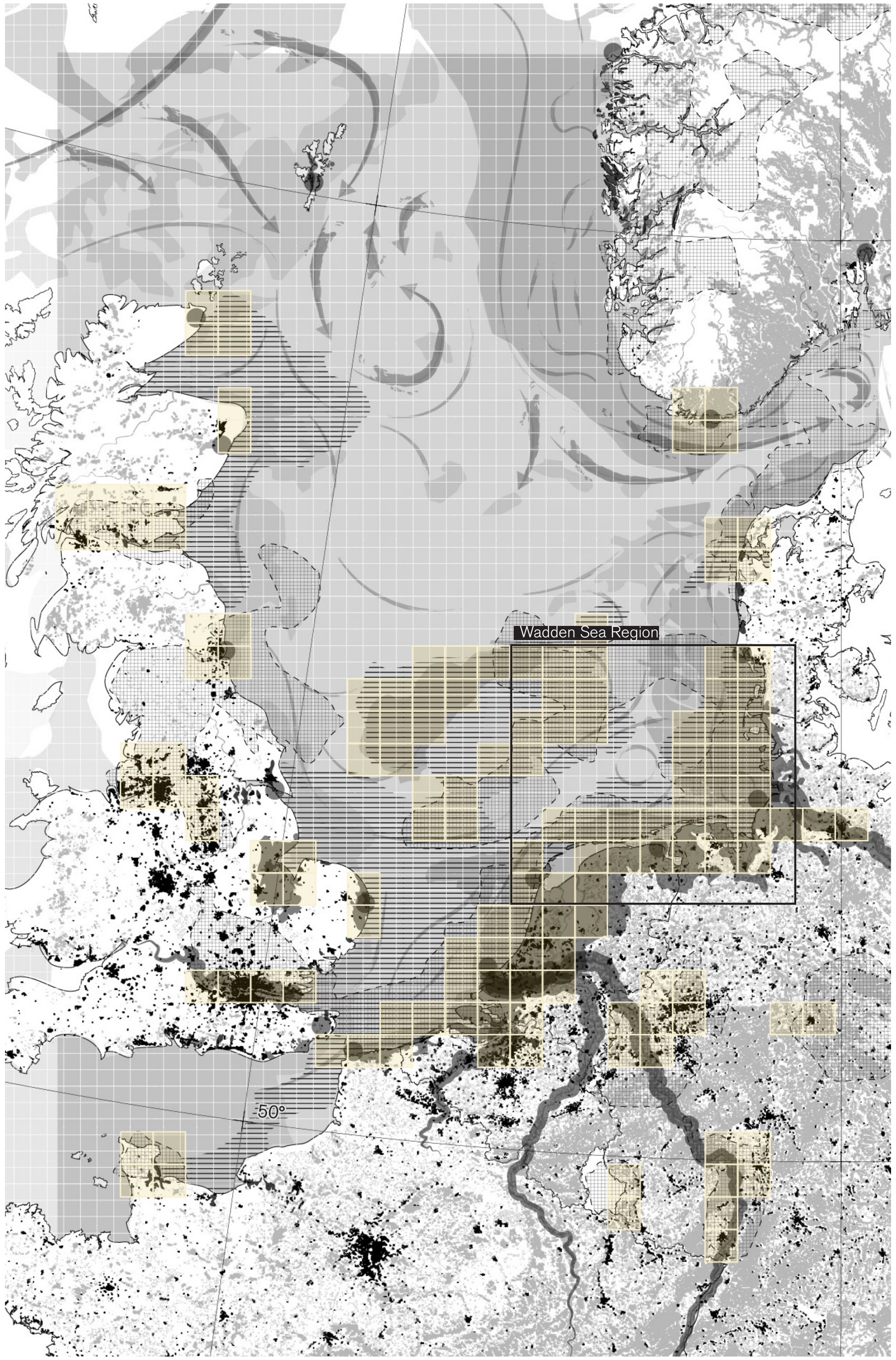
Fig.14 North Sea vulnerabilities.
(made by author)
(Data fromTransitional Territories Studio, 2019; EEA,2017 ; EEA Corine Land Cover, 2016; EMODnet, 2016 ; Climate Central, 2018; SEOS-project, 2018 ; Quante, M., & Colijn, F. 2016)

With the use of a layer- approach, it was possible to overlay the selected hazards as described in the RCP 8.5 scenario for 2100 with habitat clusters (including human settlements) on land and sea. This allowed me to determine which areas are most susceptible to most of the extreme projected conditions, and therefore at risk.

Fig. 13 Hazards layer approach.
(Made by author,2019)

■ Areas with intesified hazard magnitude





North Sea Map- Vulnerabilities

Through the combination of sea temperature rise, inundation and pollution hazards we can identify different vulnerable locations across the North Sea. Within the most affected areas we can depict the southern North Sea; with the Wadden Sea Region as one of the most urgent locations to evaluate.

Habitat Land
- Urban Fabric
- Forest
- Agricultural fields
- Grassland
- Wetland

Habitat Sea
- Deep Sea Mud
- Shallow Sandy Mud
- Deep Coarse Sediment
- Deep Mud
- Deep Sandy Mud

- Most affected areas
- Pollution
- Inundation
- Sea Temperature Rise
- Currents

Wadden Sea region: A complex cultural heritage site

The south coast of the North Sea consists of a series of large wetlands surrounded by high productivity areas, rich marine ecosystems, and a large dynamic intertidal zone known as the Wadden Sea region. This valuable region shared by three countries (Netherlands, Germany, and Denmark) expands over 500 kilometers along the coast, is home to 3.5 million inhabitants, and nesting habitat for millions of migrating birds and benthic communities. The Wadden Sea region entails an extensive intertidal area protected by a barrier of 25 mostly uninhabited islands and a complex cultural mainland. This area has gradually changed from its development after the last Ice Age to the current UNESCO World Heritage Site, from an 'intertidal wasteland from an agricultural perspective and an often threatening stormy sea towards a natural wetland of global importance and towards a sea threatened by pollution and other human impacts' (Kabat et al., 2012)

The conflicting management of natural and built systems in the Wadden Sea area is currently susceptible to the future climatic changes of sea-level rise, sea temperature rise, and changes in water properties by pollution. The natural environment although benefiting from the protection of international policies like Natura 2000 and UNESCO World Heritage Site against exploitation of resources is also restricting development in the area that could cope with the coming dynamic stress by climate change and economic development (shrinking area). Harbour cities (built environment) located mainly in the German coast are contributing to strengthening these pressures on the protected areas. Although they are profiting from the trade, industrial activities, and tourism, these port cities such as Bremerhaven are equally vulnerable to the future pressures of sea-level rise and resource scarcity by sea temperature rise and water pollution (growing area).

Fig. 15 Current trend of the Wadden Sea region (made by author,2019)

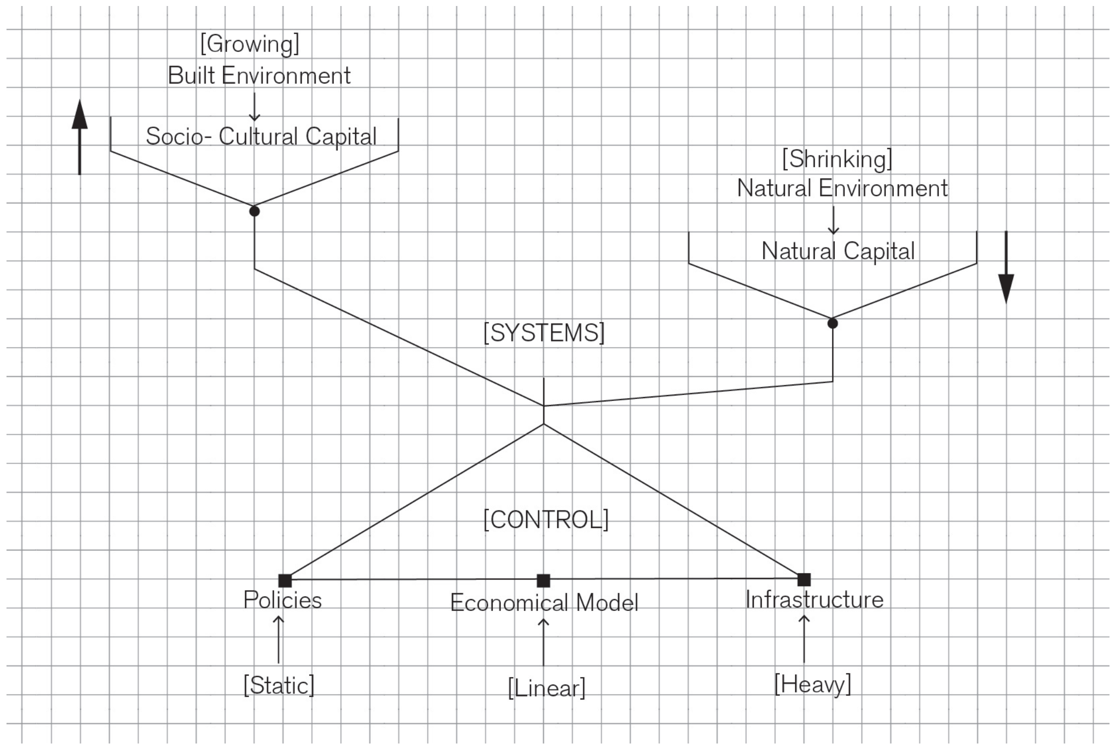


Fig. 16 Wadden Sea Region (made by author, 2019) (Data taken from Earthstar Geographics SIO,2020 ; Common Wadden Sea Secretariat, 2018)

☐ Important ports
UNESCO World Heritage Areas

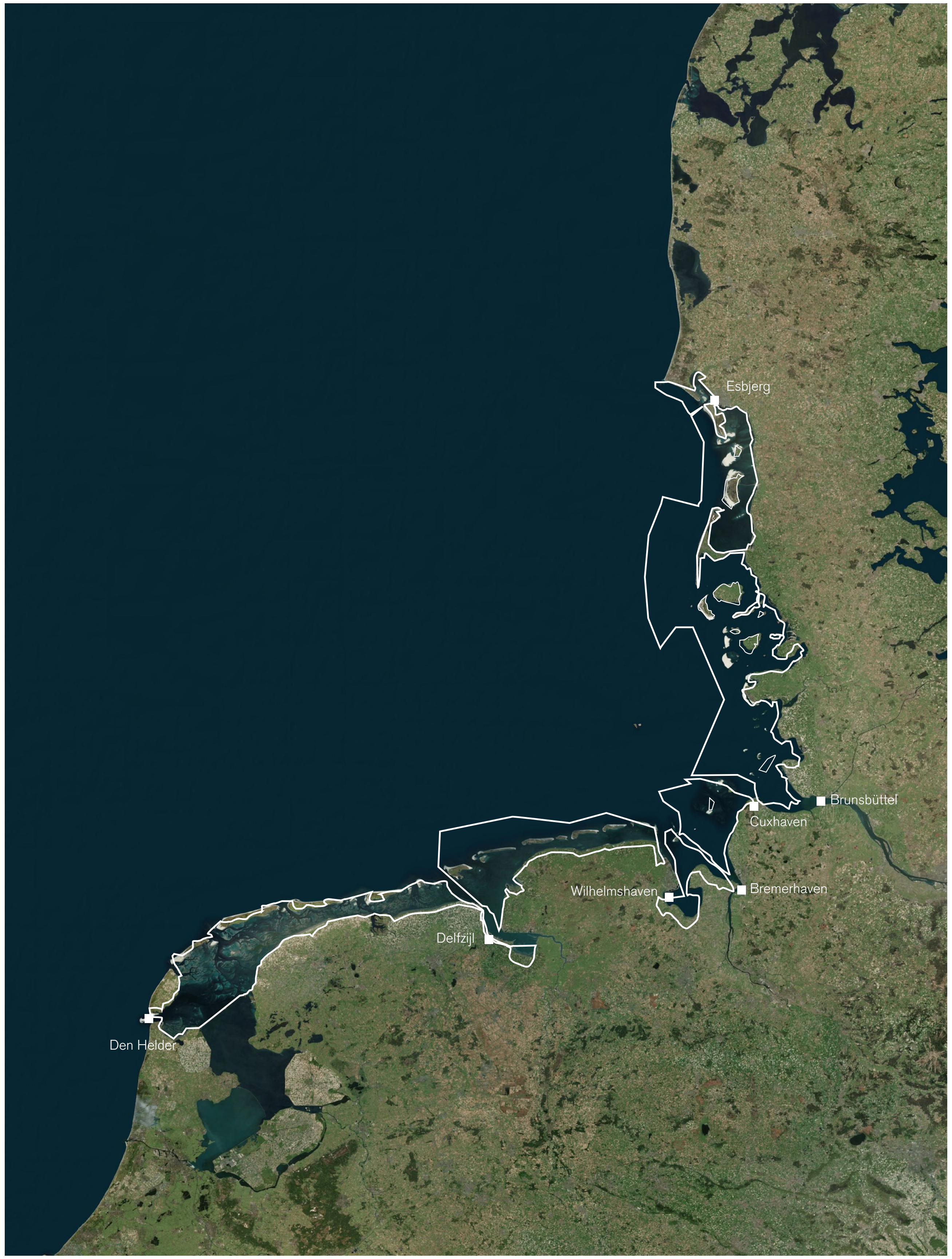


Fig. 17 Timeline: Geomorphological and socio- cultural dynamics of the Wadden Sea Region.
(made by author, 2020)
(Data from Bazelmans et al., 2012; Meier, 2012; Oost et al., 2017; Wikimedia Foundation, 2018)

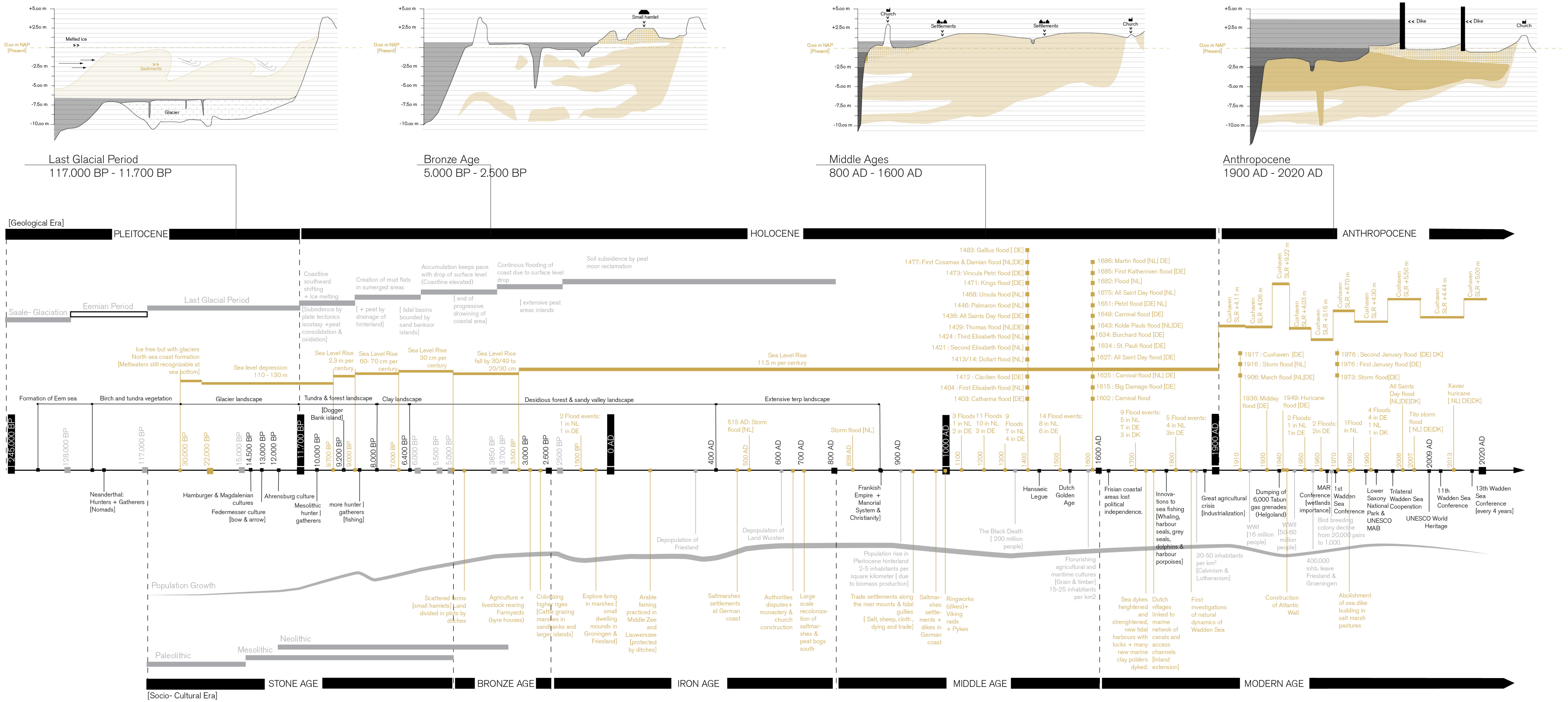
PROBLEM STATEMENT

Wadden Sea region: Historical precedents & Identity

Although belonging to three different nations, the Wadden Sea is considered a region, not only because of the territorial extension of intertidal mudflats with similar dynamics but also because of a similar and interconnected socio-cultural development that transcended national boundaries. The following timeline denotes the evolution of environment and culture, where we can depict the increasingly accelerated pace of socio-cultural systems concerning morpho- and hydrodynamic systems.

0 | 4 km

- Extreme High Water
- Mean High Water
- Mean Low Water
- Peat
- Tidal marsh
- Tidal flat
- Pleitocene & older deposits



PROBLEM FIELD

Wadden Sea region: Future pressures & risks

Although the Wadden Sea region is extensively experienced in drastic vicissitudes of built and natural systems (see Fig. 16 Timeline), climatic change and economic development simultaneously pose a great challenge to the preservation of the current state of the territory. In this project, I address three of the most significant hazards that will affect the coastal ecosystem of the Wadden Sea: sea-level rise, sea temperature rise, and water pollution by port activity.

Sea Level Rise

The Wadden Sea region consists of the lowest-lying coast of the North Sea, that additionally receives the freshwater runoff of several important estuarine rivers such as Elbe, Weser, and Eems. Hereafter it is a territory that will constantly deal with the risk of inundation, making this vulnerability a priority. A rising concern is the uncertainty of sea-level rise, which will not only permanently inundate current intertidal areas important for fauna and flora but could challenge the coping capacity of the dike systems that protect the mainland structures, that are additionally subsiding due to peat oxidation. These factors pressure the unceasing vertical construction of coastal defenses, which demand high investments and would further disconnect the coast and hinterland. Sea level rise could also 'cause [s] the barrier islands to move towards the mainland and displace their massive volume of sediment towards the tidal basin' (Kabat et al., 2012), an event that would put urban and marine ecosystems in jeopardy (Becherer et al., 2018).

Sea Temperature Rise

Even though ambiguity will persist regarding the magnitude and rate of transformations the effects of sea temperature rise will increasingly distress the benthic habitat composition, triggering the change of distribution patterns of species and subsequently the interspecies relations. This will allow southern species, currently alien and invasive, to colonize these habitats. With the upscaling of transoceanic trade and aquaculture, the introduction of non-endemic species could occur rapidly. The interaction of alien and endemic species "will permanently create novel and unique eco-evolutionary development and ecosystem functioning alterations and may affect fisheries and touristic use of the Wadden Sea ' (Kabat et al., 2012).

Water Pollution by Port Activity

The Wadden Sea region is also susceptible to the discharge of rivers, its neighboring and embedded industrial ports, and incoming currents from the Atlantic Ocean. Most of the polluting externalities are regulated by local and national policies, as well as sporadic cleanup actions (Slob et al., 2016). Considering the consistent linearity of urban waste management, expanding industrialized fisheries, and the growing amount and size of vessels for tourism and trade that enter the ports, which relates to an escalating amount of visitors, traffic, and chances of accidental cargo loss; pollution will remain a persistent problem. Massive amounts of externalities will continuously end up at the outer coast of the island barrier or trapped by the meet- up point between north-south traveling and south-north traveling currents coming from the Atlantic ocean. Furthermore 'economic activities like fishing, agriculture, and tourism are subject to international competition and might lead to changes in production locations, scale, and other tourist destinations' (Kabat et al., 2012).

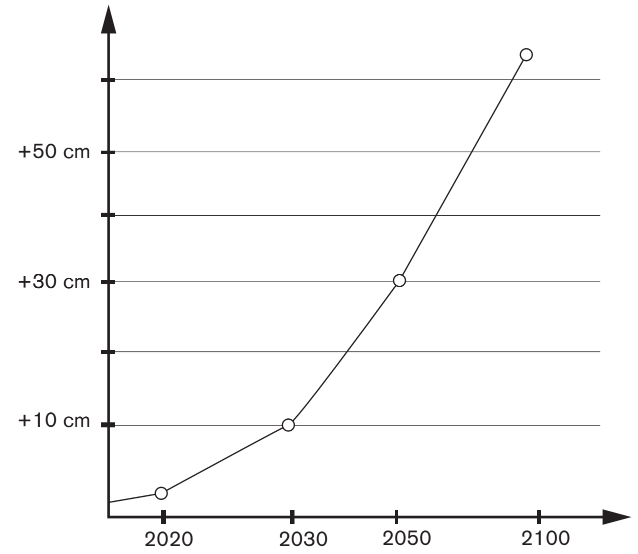


Fig. 18. Sea Level Rise Projection Wadden Sea (Made by author) (Data from: Oost P., et al., 2017)

(M. Stock, 2019)

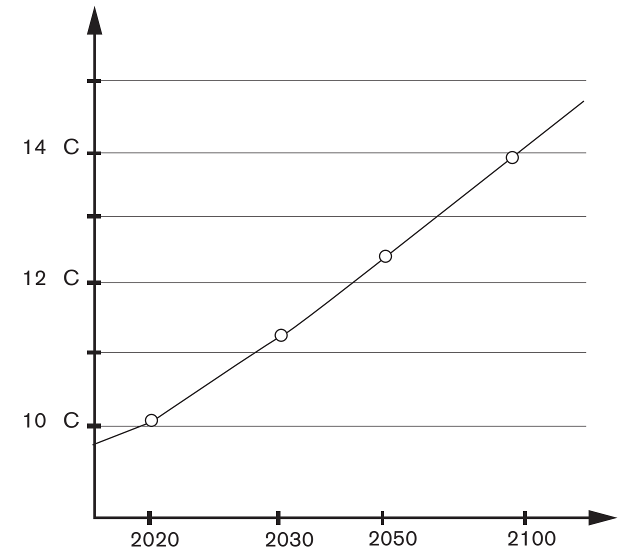
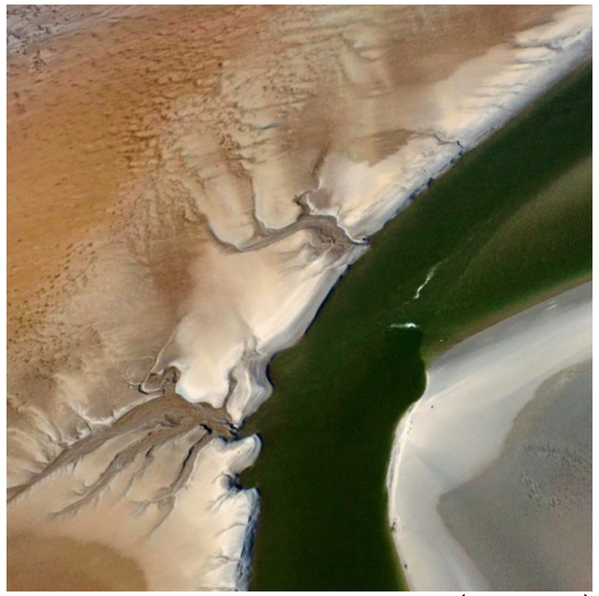


Fig. 19. Sea Temperature Rise Projection Wadden Sea (Made by author) (Data from:Oost P., et al., 2017)



(dpa, 2019)

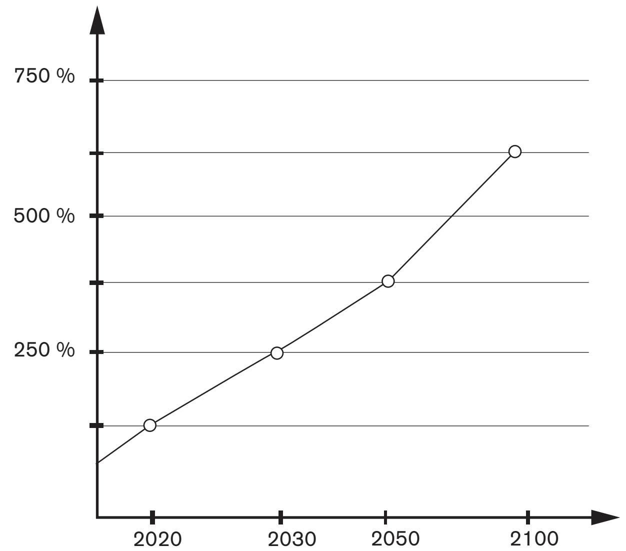
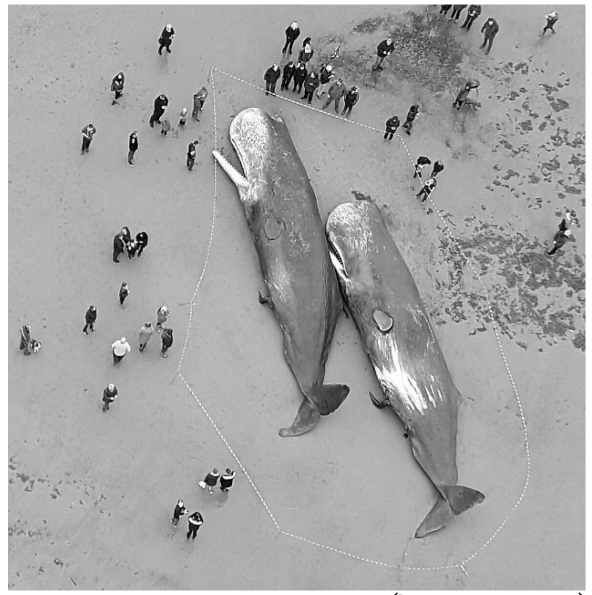


Fig. 20. Traffic (1000 tonnes) in Ports Projection Wadden Sea (Made by author) (Data from Balke C., 2017)



(kns.news, 2016)

RESEARCH QUESTION

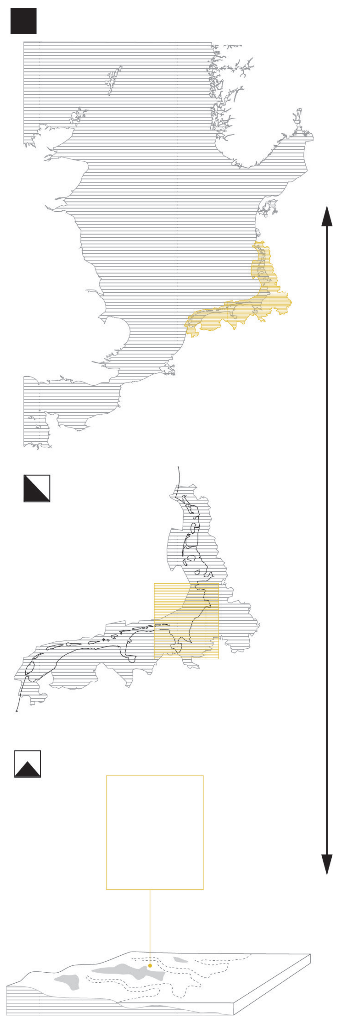
Objectives of the project

After understanding the present and future challenges of the Wadden Sea Region, it is implicit that different scales have to be taken into account in the research development. Therefore the following research questions address different subjects, objects, and flows related to three different scales: a process scale connected to the architectural space, a network scale linked to the urban dynamics, and a system scale in relation to the region and territory.

Main research question
Can an ecosystem succession approach trigger the cohabitation of human-nature systems of the Wadden Sea region to develop an evolutionary adaptation?

Aim: To achieve the transition 'from an exclusively naturally formed system towards a system that is the result of a combination of natural change and progressive anthropogenic influences' (Kabat et al., 2012) and enhances a safe, healthy, and connected habitat.

Fig. 21 Scales
(made by author,2019)



System [Regional] Scale

To what extend can we multi- balance socioeconomic and environmental interests in the Wadden Sea region considering the future pressures of climate change?

Aim: To transition from traditional conservation of the landscape towards a climate risk inclusive protection that synchronizes the cultural and ecological values of the Wadden Sea region.

Network [Urban] Scale

Which strategies would enhance the necessary links and elements of the Weser Estuary ecosystem so its ecological succession results in an evolving adaptation?

Aim: To augment the capacities of biotic life (human and non- human) to embrace risk by climate-related hazards, so that its well-being can thrive and its livelihood can last.

Process [Local] Scale

Which hybrid infrastructures would allow the necessary flexibility to adapt to flooding, temperature rise, and water pollution by port activity in the Weser Estuary over time?

Aim: To increase the dynamism of static infrastructures (hard and soft) through connections to different socio-ecological processes of the Weser Estuary ecosystems.

HYPOTHESIS

The dichotomy between exclusively built and protected natural environments within the Wadden Sea region is preventing the ability of the coastal ecosystem to adapt to future risks of climate change and port growth. To enhance a resilient future, hybrid infrastructures supported by an ecosystem succession approach need to be implemented to decrease the risk of desertion, unproductivity, and detachment and improve the safety, health, and accessibility of the coastal area of the Weser Estuary.

Through the evaluation of vulnerabilities such as fragile or inhibited coastal ecosystem functions, different adaptive strategies can be determined that can act in different moments in time. When a systemic strategy exceeds its regenerative limits, a succeeding system will be able to take over the valuable function, possibly advancing on the knowledge from the previous system and hereby forming an evolutionary capacity. Hereby the project would enable:

(I) Safety by managing water risk through hybrid infrastructures with ecological responsiveness.

(II) Health by creating habitats that maximize an ecosystem's regulatory, productive, informative, and sheltering functions.

(III) Connectivity through flexible and dynamic encounter spaces (ecotones) that relate and synchronize socio- ecological cycles to make opportunities out of risk.

Chapter

3

STRUCTURE

METHODOLOGY

The chapter '*Structure*' demonstrates and discusses the exploration, combination and application of different methods, notions and concepts withdrawn from literature or taught at the studio and lectures.

[CONTENT]

INTRODUCTION

The conflict between natural and built environment development in the Wadden Sea region is specifically noticeable between harbor areas and conservation areas, and the possible risks in terms of flooding, sea temperature rise and water pollution by port activities. In order to dive into water risk management of the coastal area of the Wadden Sea Region, and more specifically of the Bremerhaven (Germany), we need to revise and constrain this complex and broad problem field by reflecting on possible theories, concepts, methods and approaches linked to it. In this chapter I will explain and link notions to actions of the project, to build a structure for the research. This means I will particularly delve into the points of 'Methodology' and 'Methods' shown in the research framework diagram (Fig.22). The purpose is to define the different frameworks related to theories, concepts, approaches, and methods to achieve a proposal for a resilient synchronization of environmental and societal systems.

After a quick revision of the problem, questions, and aims, I will address the implications of these fundamental components and clarify the steps to be taken to achieve a design proposal. Moreover, I will advance on the related terms such as risk, ecosystems, and human-nature relationships with the help of theories in the theoretical framework, to understand what they stand for in the context of spatial planning and design. This will allow me to explain what is to be considered for an 'ecosystem-based adaption' and how can it be applied in the project. The resulting conceptual framework will help me set the parameters for the analysis. The analytical framework will be aiming for the values of safety, health, and accessibility, while keeping in mind the governance system these have to act within (conservation policies and cross border cooperation) and the timeframes that need to be noticed (past, present, and future). Hereafter I continue explaining the possible methods to be used within the research that range from literature reviews to vision building, which will serve for different purposes in each stage of the thesis. Finally, I will reveal how these steps and variables will be organized in nine months to achieve a set of goals related to the values of safety, health, and accessibility. To conclude I evaluate the proposed process and expose the overall relevance of synchronizing coastal habitats through an 'ecosystem- based adaption' (Hale et al., 2009).

Fig. 22 Graduation Project Overview: Research Framework.
(made by author, 2020) (inspired by Balasubramanian, 2018)

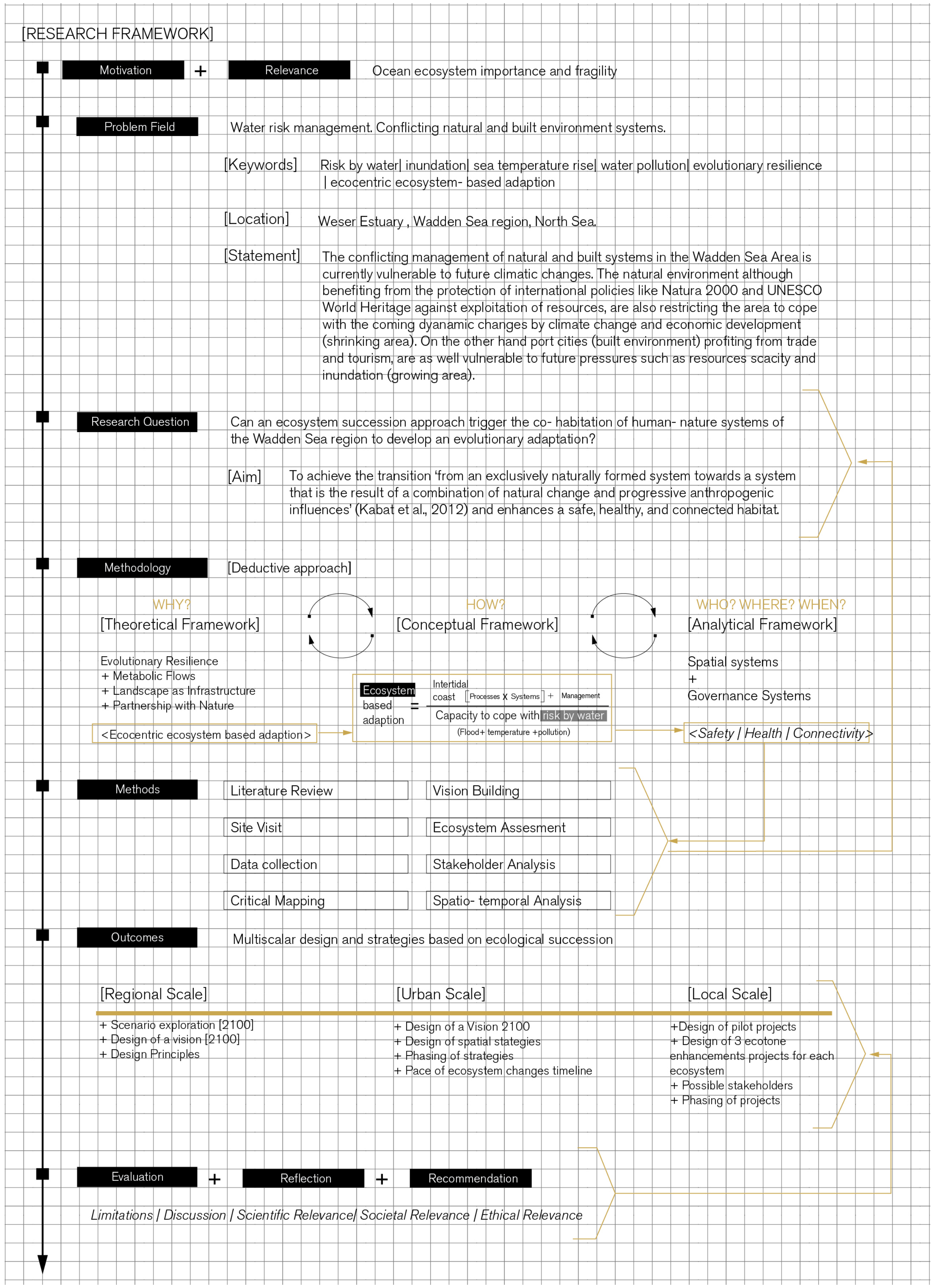


Fig. 23 From fundaments to projection: Methodology.
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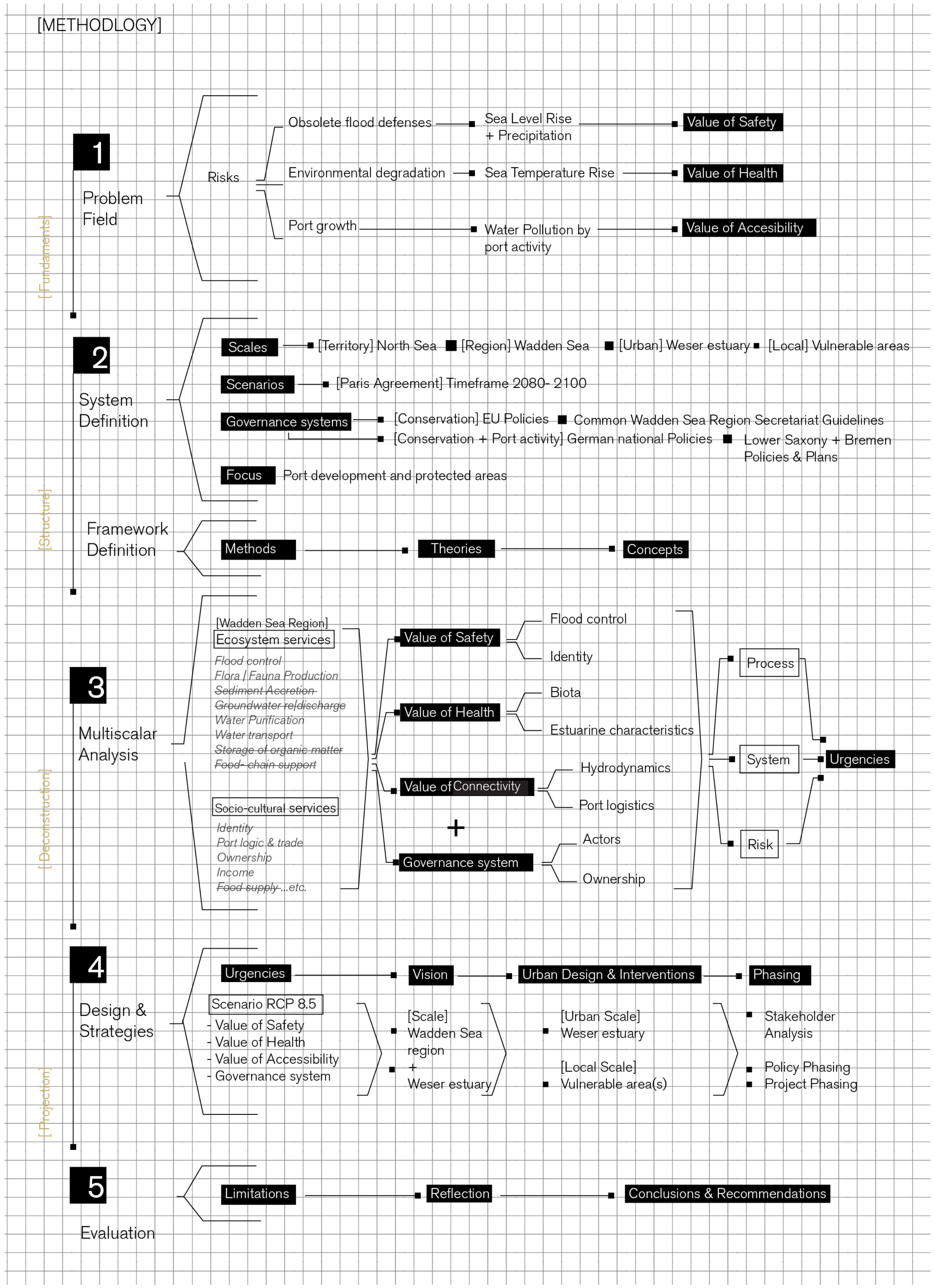


WHAT?

METHODOLOGICAL FRAMEWORK

From fundaments to projection

Problem Statement

As the first step in this research (The Fundaments) I have defined the problem field in terms of three risks of the North Sea region that seem to maximize around the Wadden Sea region. It is noticeable that although accustomed to change, the intertidal coastal wetland will undergo several transformations due to flooding by sea-level rise, sea temperature rise, and water pollution by growing harbors (Kabat et al., 2012). Flooding control is still mostly depending on hard infrastructure, which will not be able to keep up with the uncertain rate and magnitude of sea-level rise and precipitation pattern prediction (Becherer et al., 2018; Oppenheimer & Glavovic, 2019). Sensible marine habitats and cold water species will migrate north, affecting the food chains around the Wadden Sea region, as well as soft flood protection infrastructures and water quality, considering that sea temperature will rise (CPSL, 2010; Narayanaswamy et al., 2010). The resulting variables or system changes such as invasive species are not considered in conservation policies, protecting only the current state of the environment and livelihoods (Giebels et al., 2013; Kabat et al., 2012). On the other hand, port development is continuous but equally threatened by their linear economic model, since externalities of water pollution act counteractively for water transport (erosion and accumulation) and water quality needed for industries and marine biotopes. Henceforth it may be said that this conflicting management of natural and built systems in the Wadden Sea region is currently vulnerable to future climatic changes, affecting the value of safety, health, and accessibility.

Research Question

Research Aim

Therefore I raise the question of to what extent can an ecosystem system succession approach trigger the co-habitation of human- nature systems of the Wadden Sea Region to develop an evolutionary adaptation; and am aiming for a hybrid system that regenerates but also enhances new habitats, as well as regulates and copes with port expansion besides climate change.

To approach this challenge, as a second step (The Structure) I am implementing a systematic approach that includes revising the fractality of the problem in different scales (territorial to local), deciding on one of the proposed scenarios (the worst-case scenario of 5th edition of IPCC, RCP 8.5), and determining a focus on the co-evolution of port development and protected habitat areas (See Fig. 23.). These decisions have to lead me to the possible implementation of certain methods, required the understanding of different theories and their combination to develop concepts.

These concepts will set the base and methodology on how to analyze the site and its interactions. In the Deconstruction phase, I initially selected which ecosystem and socio-cultural services relate to the problem field and organized the different related aspects to analyze in four categories inspired by the values the project is striving for. All these aspects will be analyzed in terms of processes, systems, and risks in order to determine the most urgent locations and affected subjects. Given that these urgencies are maximized in the RCP 8.5 scenario, the project can hopefully develop a robust vision in two scales (regional and urban scale) that will inspire an urban design and strategic interventions for the most vulnerable areas. Due to uncertainty, the project needs to consider the variable of time, as well as evaluate its feasibility. As the last step, I propose to evaluate the whole process reflecting on it as well as indicating limitations and aspects which could need further development.

WHY?

THEORETICAL FRAMEWORK

From notions to theories

In the project, I make use of several terminologies and concepts originating from different fields of knowledge, that need to be understood and properly defined. I decided to use the theoretical framework and academic paper as an excuse to explore these notions and their implications in terms of spatial planning and design.
Since the project is focusing on water risk management in the academic paper I deconstructed the notion of risk based on the formula coming from the field of engineering (see Fig. 24, Notion 1).
This has allowed me to identify urgent hazards (events), exposure (scenario-dependent rate and magnitude), and vulnerabilities (livelihood dependencies) in the Wadden Sea region. I coupled this term and recognition with the theory of 'evolutionary resilience', which argues for adaptability in form of a progressive transformation as the key to adjust systems to risk (Davoudi et al., 2013).

Risk is often defined as the possible struggle of a system to cope with the rate and magnitude of a given hazard, it is highly exposed or sensitive to (vulnerability).

ACADEMIC PAPER

'In 'evolutionary resilience' theory, human and nature are considered co-dependent systems, which adds complexity, but addresses their mutual ability to self-organize, adapt, and transform in different paces and scales when disturbed. In this framework a system's resilience depends upon what it has learned from past experiences of stress (preparedness); on its rooted relations with the particular values of the setting or sub-systems (persistence); on the flexibility of its substantial structures and processes (adaptability), and on its capacity to embrace or accept change (transformability) (Davoudi et al., 2013).'

(Garcia Vogt, 2019)

Ecosystems are defined as ecological constellations of structures and flows, that through certain processes create particular conditions to sustain several forms of life (Alberti, 2008).

Since this theory is inspired by the capacity of socio-ecological systems to cope with risk, I decided to link it to ecosystems, considering that the project is placed on one of the most vulnerable once, a coastal marine ecosystem. I identified fragile hard and soft structures as defined by the concept of 'landscape as infrastructure' (Belanger, 2009; Reed & Lister, 2014; Waldheim, 2016); different resource flows affected by the linear economic model and inaccessibility with the help of 'urban metabolism' theory (Ahern, 2007; Alberti, 2008; Belanger, 2009) ; different types of processes considered as ecosystem services (Folmer et al., n.d.; MEA, 2005)and a demand for flexibility in the trilateral governance system. Hereafter I arrived at the concept of 'ecosystem-based adaption'.

Anthropocentric
According to the '*stewardship of nature'* perspective humans should perceive responsibility for natural systems. It support the idea that humans are part of nature, but not equals, as we supposedly stand above it. This position we achieved, because we are able to 'dominate' them. As 'stewards' we carry a responsibility: the chance to decide on leaving 'enough nature intact for future generations' (de Groot and Drenthen 2011, p.4).

ACADEMIC PAPER

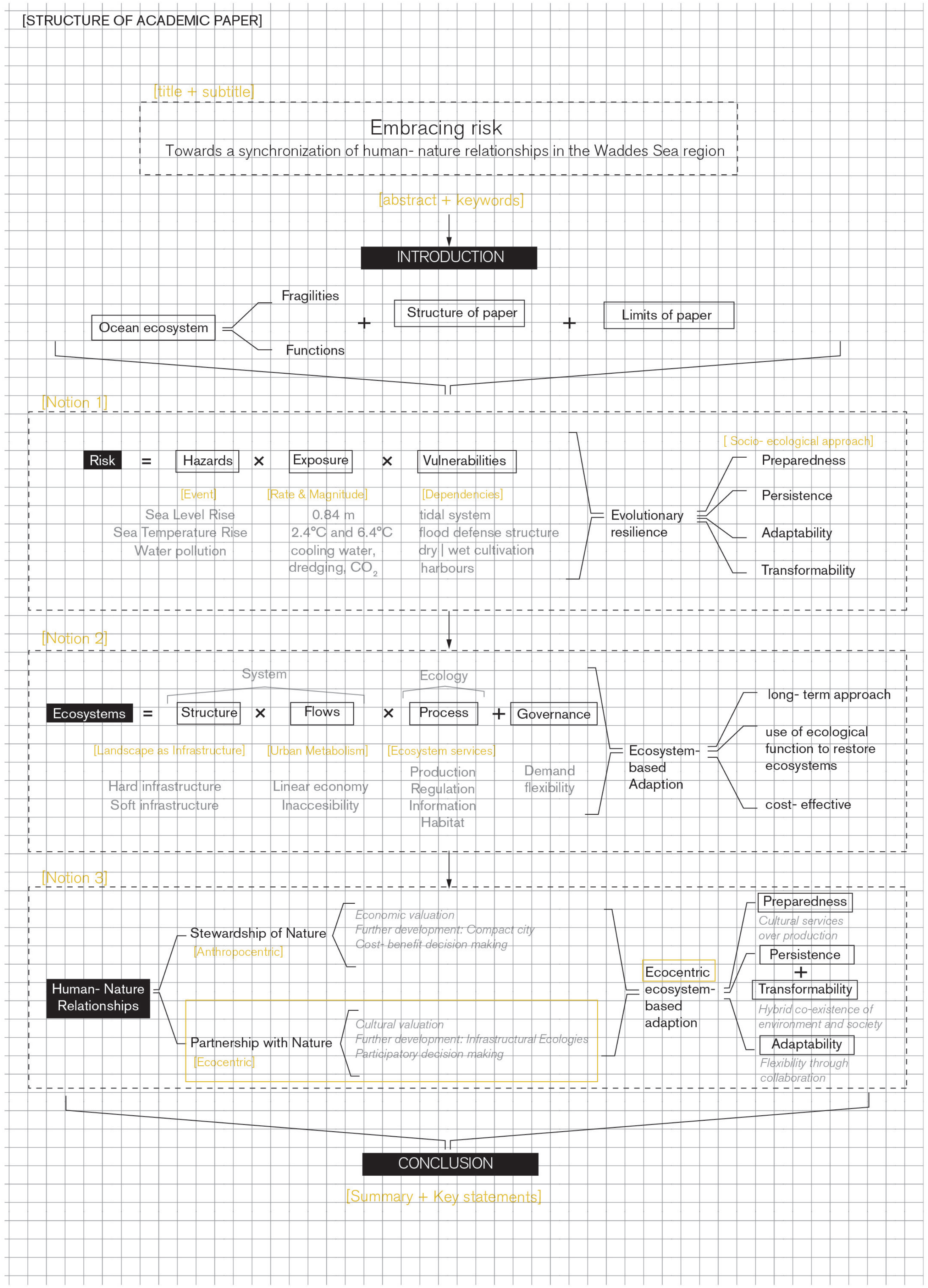
'Ecosystem-based adaption' could be seen as an approach that summarizes, integrates, and is aligned to the above-mentioned ideas of a circular economy, infrastructural landscapes, and flexible policies. It is a long term vision strategy, that uses ecological functions to restore ecosystems and reduce the vulnerability of their dependent forms of life. It is encouraged by the fact that it is cost-effective because the maintenance of structures over time is almost self- regulated thanks to the adaptive character of its ecosystems. This socio-ecological approach towards adaptation also acknowledges that ecosystems are territorial and dynamic entities that hardly respect administrative or national boundaries. Thus strategies insist on collaborations across different scales and actors (Hale et al., 2009; Munang et al., 2013).'

(Garcia Vogt, 2019)

Ecocentric
On the other hand humanity could embrace the ecocentric perspective of building *a 'partnership with nature'*. In contrast with 'stewardship', this relationship with nature considers human and nature as equals. Therefore a dichotomy between nature and humans is non- existent, since natural systems are also looking forward 'to grow, prosper and develop, just like humans do' (de Groot and Drenthen 2011, p.4)

Since the idea of the project is to synchronize the environment and society, it was important to understand the different types of relations humans could have to nature from a sociological point of view (M. de Groot & Drenthen, 2011). This allowed me to take a position on which perspective could guide us towards a co-evolution; arguing that an ecocentric rather than an anthropocentric ecosystem-based adaption would go for strategies more in tune with hybridization, instead of compaction.

Fig. 24. Theoretical Framework. Overview of topics of the academic paper. (made by author,2019)



Embracing risk

- Towards a synchronization of human- nature relations in the Wadden Sea region -

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[ABSTRACT]

Coast habitats are particularly exposed to anthropogenically magnified climate change impacts. In this paper we address the risk by sea level rise, sea temperature rise and water pollution that predominantly affect a vulnerable area of the South North Sea called Wadden Sea region. In order to adjust to the uncertainty of these predicted risks, *adaption* is considered the path to reach an 'evolutionary resilience'. Within this framework we choose to advance on the concept of 'ecosystem- based adaption', which relates to the notions of 'metabolic flows' and 'landscape as infrastructure'.

Although it consists of a socio- ecological approach, 'ecosystem- based adaption' is not considering the important paradigms questioning what role should humans take in relation to nature, which would trigger different results in terms of strategies and design. This paper re-examines the concept of 'ecosystem- based adaption' in relation to anthropocentric and ecocentric perspectives, focusing on 'stewardship of nature' represented by the idea of 'compact cities' and 'partnership with nature' supported by 'infrastructural ecologies'. It concludes that an ecocentric 'ecosystem- based adaption' would lead to preparedness, persistence, transformation and flexibility which are key to achieve a co- evolution of nature and society in the context of the Wadden Sea region.

Keywords: Coast habitat, risk, 'ecosystem- based adaption' ,human- nature relations, Wadden Sea region.

INTRODUCTION

The extreme character of human activities and hard infrastructures in combination with the continuous variation of the climate, has triggered an unprecedented fast rate of alterations in the environment. This means that the anthropogenically magnified climate change is increasing stress on ecosystems, which have proven to provide the essential services that support livelihood (Adger et al., 2003; IPCC, 2014; Munang et al., 2013). Hence oceans, our planets biggest and most vital ecosystems, are under severe pressure; their ability to sustain life through the regulation of the climatic regime, absorption of atmospheric carbon dioxide and production of oxygen is compromised (Hale et al., 2009; MEA, 2005). As part of the oceanic ecosystem, coastal communities are increasingly exposed to hazards such as sea- level and temperature rise, as well as water pollution (Hale et al., 2009; McGranahan et al., 2007). To depict what risk means, we exemplify each of its components in one of the most vulnerable coastal habitats, the Wadden Sea region, 'an intertidal ecosystem of global importance' (Alberts, 2015).

This paper proposes to revise the concept of 'evolutionary resilience' as a way to explore further developments in the region, that are in tune with the dynamics of the changing environment. 'Evolutionary resilience' theory suggest that *adaptability* in form of a progressive transformation is the key to adjust systems to risk (Davoudi et al., 2013).

After a quick revision of the ideas of 'urban metabolism' and 'landscape as infrastructure' linked to the definition of *ecosystems* as understood in urban planning, we will advance on the concept of 'ecosystem- based adaption'. 'Ecosystem- based adaption' addresses the use of ecosystem services to enhance co-benefits between built and natural systems (Munang et al., 2013; Hale et al., 2009). Although this notion is usually linked to measures of restauration, conservation and focused management (MEA, 2005; Munang et al., 2013; Secretariat of the Convention on Biological Diversity, 2009) the design and planification of strategies strongly depend on the perspective on the future relation between humans and nature. The debate consists on whether the role of human kind should co- evolve towards a 'guardian of nature'

(anthropocentrism) supported by the theory of 'compact cities' (Burton et al., 2003) , or a 'partner of nature' (ecocentrism) in line with the ideas of 'infrastructural ecologies' (Alberti, 2008; Belanger, 2009; Brown, 2019; Reed & Lister, 2014).

On the basis of the aforementioned notions and presented dichotomy, we discuss which point of view would better enhance a synchronization of human- nature relations in the Wadden Sea region to guide an 'ecosystem- based adaption' (Alberts, 2015; Bazelmans et al., 2012; Meier, 2012).

'EVOLUTIONARY RESILIENCE' AS A PATHWAY TO COPE WITH RISK

Risk is often defined as the possible struggle of a system to cope with the rate and magnitude of a given hazard, it is highly exposed or sensitive to (vulnerability). Therefore risk assessment initiates by studying the 'real but highly uncertain' hazards (Adger et al., 2003 ,p.179), continues evaluating the exposure of life supporting structures, and ends up addressing vulnerability based on the dependency of living communities on the affected systems. Additionally Adger et. al. argue that the level of vulnerability also depends on constructs like ownership and resourcefulness, since these could limit the possibility of a community to use an alternative system (Adger et al., 2003).

In the context of the North Sea we can identify several hazards related to climate change that range from heat waves to storm surges, but the most significant in terms of drivers of physical changes for coastal habitats are sea level rise , sea temperature rise and sea water pollution due to port activities (Emeis et al., 2015) . The combination of these three hazards seem to intensify in the south North Sea, especially in the Wadden Sea region, since morphologically it consists of the lowest coastal point and its hinterland suffers from glacio-isostatic subsidence,; it is part of the entrance of warm currents from the Atlantic Ocean, and it allocates the most important German harbours within the UNESCO World Heritage site (Alberts, 2015; Bazelmans et al., 2012; Meier, 2012).

An incredible uncertainty around the rate and magnitude of these risks have led to the publication of different scenarios, where we decide to depict on the RCP 8.5 scenario (IPCC, 2014). According to this scenario the intertidal wetland will be exposed to a mean sea level rise of 0.84 m (Oppenheimer & Glavovic, 2019) and surface sea temperature will elevate between 2.4°C and 6.4°C (CPSL, 2010) globally by 2100. Additionally several national plans concerning the development of further structures in the North Sea (Bahlke, 2017; Zijlstra et al., 2019), will probably influence the expansion of industrial areas around harbours, involving 'the use of cooling water, the dredging of access channels to bring coal and CO_2 emissions' that would expose water bodies to more pollution (Kabat et al. 2012, p.11).

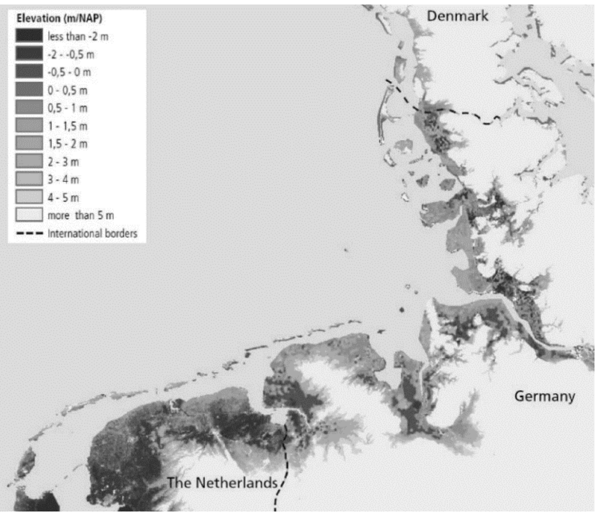


Figure 1. Wadden Sea region low lying areas.(CWSS 2010, p.9).

Most of the exposed areas to these threats encompass structures of the built environment, like dykes, houses, and entire port areas, that besides livelihood also sustain activities such as trade, agriculture, tourism and fisheries. Furthermore the extend of the exposure also comprises structures of the natural environment, like the barrier islands, salt marshes and fragile seagrass landscapes, that support even more lives, and boost processes such as flood protection and storage of organic matter, etc. (Becherer et al., 2018; CPSL, 2010; Kabat et al., 2012). As a region dependent on the existence of a tidal system, harbours, dry or wet cultivation areas and flood defence structures, its vulnerability is increasing with time.

In order to deal with such an exponential and progressive evolution of risks, most conveyed research point towards developing resilience. The initial concept of resilience, originating from engineering, was described as a predictable pathway that a system follows to return to an equilibrium after it was stressed. However this was challenged by biologists Holling and Gunderson (Fig.2), since their study on ecosystems reveals that the ability of organisms to deal with disturbances demands a persistent process of function change that will eventually achieve a multi equilibria state (Alberti & Marzluff, 2004).

Nevertheless both of these concepts are hardly applicable for risks related to climate change since they count on reaching a type of stability over time. Climate change will continuously destabilize this planets processes and systems (anthropological activities are adding to the velocity of this change) so to keep up with this phenomenon a socio- ecological approach to resilience was introduced. In 'evolutionary resilience' theory, human and nature are considered co-dependent systems, which adds complexity, but addresses their mutual ability to self-organize, adapt and transform in different paces and scales when disturbed. In this framework a systems resilience depends upon what it has learned from past experiences of stress (preparedness); on its rooted relations with the particular values of the setting or sub-systems (persistence); on the flexibility of its substantial structures and processes (adaptability), and on its capacity to embrace or accept change (transformability) (Davoudi et al., 2013).

As the word *evolutionary* indicates, resilience is only keep through an ongoing process of evaluation of the aforementioned conditions, and constant transformation. Recognizing this, is practically embracing the adaptive cycle of growth, conservation, creative destruction and reorganization that structures and functions of ecosystems experience (Holling & Gunderson, 2002). Hence adaption strategies after the UN Climate Change Conference in 2008 are insisting on an approach based on *ecosystems* as a new way to embrace climatic risks (Hale et al., 2009; Munang et al., 2013).

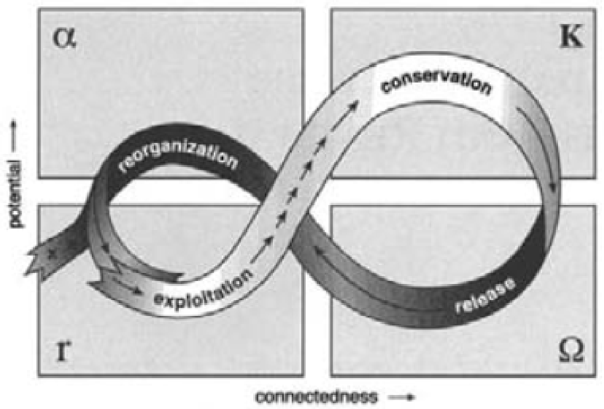


Figure 2. The adaptive cycle (Holling and Gunderson 2002, p.6)

ADJUSTING TO OCEANIC RISK: 'Ecosystem- based Adaption'

Ecosystems are defined as ecological constellations of structures and flows, that through certain processes create particular conditions to sustain several forms of life (Alberti, 2008). To understand this in terms of spatial planning and design, we can draw upon these mentioned components of ecosystems (structures, flows and processes) and deconstruct them with the support of theories.

If we see *structures* as biophysical constructs that accommodate dynamics and activities, we are able to differentiate between hard and soft infrastructures. The traditional way of building environments, specially in areas prone to climatic variability such as coasts, are dominated by hard infrastructure that can range from dams to canals. This was a way to reclaim land and territories against (and even from) the sea (Bazelmans et al., 2012). It not only involves the destruction of many ecosystems, but also the fragmentation of habitats and the demand of continuous high expenses for their maintenance and reinforcing. Additionally climate change is challenging the further development of these structures as hard infrastructures, since their inflexible character clashes with the high level of uncertainty of its impacts (Kabat et al., 2012).

Therefore new developments around coastal areas in Northern Europe are considering the use of soft infrastructures as an alternative to invite flexibility. Soft infrastructures, as defined in the field of landscape architecture, originate from the idea of conceiving landscape as an empirical infrastructure (Waldheim, 2016). In contrast to hard infrastructure, landscapes can absorb certain amounts of features coming from the impact, since 'climate works as a conditioner rather than a constraint' (Belanger 2009, p.449). 'Landscape as infrastructure' has also pushed design and strategies to think in terms of temporalities and multiple scales, that include the dynamics of climatic and geological regimes; a mapping task that was exclusive to geography practices (Reed & Lister, 2014).

To clarify these terms, we can once again look at the Wadden Sea region where we can identify a network of hard infrastructures consisting of 1249 square kilometres of dikes, dams and their 121 sluices and locks, that function as heavy coastal defence system (Zijlstra et al., 2019). On the other hand this territory benefits from soft infrastructural flood control by the beaches and dunes of the barrier islands of the west and north- east. Some parts of the German states of Lower Saxony and Schleswig- Holstein are not privileged with barrier islands, therefore salt marshes are highly valued, since one of their many functions is to prevent coastal erosion (van Loon-Steensma, 2015). Both of these soft infrastructures in the Wadden Sea region are stimulated by the natural dynamics of wind and currents coming from the North Sea that supply sediments(Meier, 2012; Wang et al., 2012).

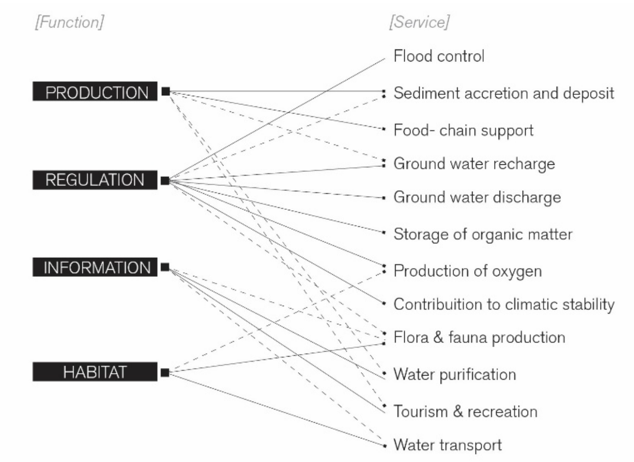
Such *flows* can be studied from the perspective of 'urban metabolism', which addresses all environments as ecosystems. Metabolism theory argues that urban fabrics can be compared to other types of ecosystems since they all rely on materials and energy, as well as generate or absorb emissions and waste. Henceforth it acknowledges human constructs and flows the same way as ecological ones (Alberti, 2008; Belanger, 2009). Thus metabolic flows are movements of biotic, abiotic or cultural resources and commodities that, if not hindered or shifted towards an external path (externalities), will offer the system the right services (Ahern, 2007).

As the most extensively connected intertidal area worldwide, the Wadden Sea region experiences several changes induced by the interaction of diverse flows (Hale et al., 2009). The most prominently related to the risks of sea level rise, sea temperature rise and water pollution are the movements of sediments and minerals; freshwater; waste and contaminants; people, biota and goods (Folmer et al.,2010). Flows like waste, contaminants, freshwater, sediments and minerals are currently trapped in a linear model that in combination with soil subsidence and finite extraction grounds, are causing negative effects through their accumulation in the seascape. The second group of flows consisting of goods, people and biota indicate problems in terms of spatial connectivity, because several habitats are becoming

inaccessible, evacuation routes are limited and waterways are often clogged. 'Urban metabolism' suggests that the recognition of the difficulties in function and relations of these vital substance flow to spatial developments, should lead to shifts in their process to enhance circularity and give chances for vitality. Circularity implies that 'we stop thinking about waste and start thinking about commodities '(Project Atelier Rotterdam 2014,p.10) and emulate the way feedback- loops of ecosystems work (Alberti & Marzluff, 2004; Belanger, 2009).

If in theory all environments are ecosystems, the optimal outputs of metabolic flows are ecosystem services. Ecosystem services are valuable conditions and *processes* that will offer the requested commodities for different animal and plant life to mature in 'pristine' environments ; 'directly provide human services in non- urbanized areas, and indirect services in urbanized areas.' (Alberti and Marzluff 2004 p.5). This term is often related to the designation of socio- economical value to ecological functions, which forgets to include the benefits ecological functions bring to other forms of life besides human populations (Chan et al. 2012; MEA 2005).

If we look into coastal habitats and their respective ecosystem services, we can expect a great variety and range of them, since we are located in the interface of the territories of land and sea. We can classify marine ecosystem functions in terms of production, regulating, information and habitat (Folmer et al., 2010; MEA, 2005). Production functions encompass all processes that lead to the provisioning of resources such as food, water, fibre, amongst others. Furthermore regulating functions are ecological dynamics which set the conditions of floods, climate or diseases. Information services are all flows that evoke recreational, emotional, cultural and spiritual experiences. Moreover habitat functions provide forms of life with support and shelter. The following diagram (Figure 3) illustrates the classification of functions of the Wadden Sea region.



Since climate change is going to affect the development of important coastal ecosystem services of fragile habitats, adaptation measures are demanding the restoration, connection or stimulation of vulnerable ecosystems through co-existing processes to become resilient (Chan et al., 2012; Munang et al., 2013). Nevertheless they are challenged by national and international conservation policies since most of them restrict direct anthropogenic changes in vulnerable areas (Vikolainen, Bressers, & Lulofs, 2014). However these polices forget that climate change will subdue the territory to modifications despite this protection. Allowing changes in protected areas is also defied by variances between different national nature conservation policies. A change in one area will trigger a process in another, which might cross one or several borders because ecosystems expand beyond,, as well as do not follow, administrative boundaries (Sepulveda Carmona, 2019).

In this respect the Wadden Sea region has developed as an positive example for coastal management of conservation areas, since it enjoys the nomination of World Heritage site (2009) and the supervision of the Common Wadden Sea Secretariat, a trilateral cooperation between the Netherlands, Germany and Denmark (1987). This area 'has also evolved from a static and defensive (purely 'conservation) strategy, towards, a more dynamic and positive strategy aiming at sustainable development' (Kabat et al. 2012, p.9). Yet climate change, as mentioned before, is posing additional tests to preserve the physical state of important structures.

So instead of protecting the present bio-physical structures of the Wadden Sea region, conservation should look into what particular values need to be maintained that help the system reach multi-equilibria phases (Alberti, 2008). Kabat et al. insist on flexibility in policies to match them to uncertainty. This means embracing the most pessimistic risk predictions, to produce legal bases, while keeping an open and expectative setting for more accurate or updated scenarios. Thus policies are inclined to integrate scientific advances of the matter, in order to keep up with the technological developments that are constantly evaluating several socio- cultural, economic and environmental aspects in different scales (Kabat et al., 2012).

'Ecosystem- based adaption' could be seen as an approach that summarizes , integrates and is aligned to the above mentioned ideas of circular economy, infrastructural landscapes and flexible policies. It is a long term vision strategy, that uses ecological functions to restore ecosystems and reduce the vulnerability of their dependent forms of life. It is encouraged by the fact that it is cost- effective because the maintenance of structures over time is almost self- regulated thanks to the adaptive character of its ecosystems. This socio- ecological approach towards adaptation also acknowledges that ecosystems are territorial and dynamic entities that hardly respect administrative or national boundaries. Thus strategies insist on collaborations across different scales and actors (Hale et al., 2009; Munang et al., 2013). However this approach based on ecosystems and ecological concepts, is often implemented and described through an anthropocentric view of humanand nature relationships. In the following section we debate if this approach should continue its development inspired by this perspective, or if an alignment with an ecocentric perspective would be more suitable.

HUMAN- NATURE RELATIONS: Anthropocentric or ecocentric adaption?

'Ecosystem- based adaption' involves creating measures that most probably will bring a new relationship between humans and nature forward. So far this relation has been mostly driven by the extreme abuse of natural systems by human population. The intensity of our influence and desired domination over natural regimes has left so many traces that geologists are conceptualizing this as a new era called the Anthropocene (Seppelt & Cumming, 2016). This behaviour is so deeply rooted in our social, economical and environmental imaginaries, that in order to deal with them in a different way, it is vital to evaluate towards which perspective it will advance on, to truly evolve towards resilience. From the four perspectives on human- nature relationships proposed by environmental ethics ('master of nature', 'stewardship of nature', 'partnership with nature', and 'participation in nature') and given the broadness of the approach (but judging by its principles) 'ecosystem- based adaption' strategies and designs could be aligned to two: the anthropocentric 'stewardship of nature' or the ecocentric 'partnership with nature' (M. de Groot & Drenthen, 2011).

According to the 'stewardship of nature' perspective humans should perceive responsibility for natural systems. It support the idea that humans are part of nature, but not equals, as we supposedly stand above it. This position we achieved, because we are able to 'dominate' it. As 'stewards' we carry a responsibility: the chance to decide on leaving 'enough nature intact for future generations' (de Groot and Drenthen 2011, p.4). This anthropocentric view applied on risk assessment would result in prioritizing change in areas where human lives are vulnerable. Thus the use of ecosystems services will concentrate on adding value to human society, which has led to 'expressing the value of ecosystem services in monetary units' (de Groot et al. 2012, p.51). Hereby resources that enable these processes of production and regulation are referred to as capitals: natural and socio- economical. The valuation of services based on capital resembles the estimation of resources that has led to the overexploitation of territories (Chan et al., 2012). Hereafter we could hypothesize the dangerous possibility that this could indeed head towards the abuse of services (specially production and regulating services) driven by the eagerness to obtain power over nature, which stewardship is catalysing. However economic valuation of ecosystem services would simplify and effectively accomplish goals like instant environmental 'respect' and maybe even consciousness for our actions, because we loose 'tangible' value which we are accustomed to measure things with (R. de Groot et al., 2012).

As mentioned beforehand, 'stewardship of nature' is also convinced that conservation of "wilderness" is a way to respect and protect us from further risks. This implies that spatial measures should continue setting clear boundaries where urbanization processes are strictly not allowed. Yet natural systems are not necessarily exclusive of these areas; strategies would still look for ways to built new 'green networks' (Ahern, 2007), but only within urban contexts. These ideas will probably guide us to condition urban ecosystems to adapt to climatic change based on the notions proposed by 'compact city' theory. 'Compact city' theory advocates for sustainability by limiting urban sprawl with densification; thus shielding 'pristine environments', while applying nature- based solutions within the confines of a city system (Burton et al., 2003). We could assume that 'ecosystem- based adaption' principles are used 'to provide a concentration of socially sustainable mixed uses, […]reduce the need to travel, thus reducing vehicle emissions.[…], more energy efficient land use planning […] (and) to make the provision of amenities and facilities economically viable , enhancing social sustainability.' (Burton et al. 2003, p.3-4). An illustrative example of these measures is the urban planning of the Randstad and the Green Heart in the Netherlands. The Randstad concentrates all densely urbanized cities around a green extensive recreational area (Green Heart) where further urbanization of the rural areas was prohibited. Great efforts are put into the integration of green, blue corridors in urban environments and keep the Green Heart intact (Plambeck & Wijnakker, 2019).

Furthermore the support of adaption guided by an anthropocentric perspective will also have effects in decision- making processes. The creation of duality in space by distinguishing the 'wild' from urbanization added to the valuation of ecosystem services in monetary terms could eventually promote two- sided discussions. This means that, while the process might stay democratic, the notion of winners and losers when reaching a decision will prevail. Nevertheless cost-benefit evaluations would help making decisions and policy making quicker and easier, and given the urgency to embrace adaption, the sooner the better (de Groot et al., 2012).

On the other hand humanity could embrace the ecocentric perspective of building a 'partnership with nature'. In contrast with 'stewardship', this relationship with nature considers human and nature as equals. Therefore a dichotomy between nature and humans is non- existent, since natural systems are also looking forward 'to grow, prosper and develop, just like humans do' (de Groot and Drenthen 2011, p.4). In this regard components of both systems are analysed the same way to determine vulnerable and potentially affected areas. An ecocentric perspective acknowledges important

ecosystem functions for all forms of biotic life, which is linked to the recognition of their value in terms of culture. Valuation by culture concentrates more on the tangible and intangible benefit of information and habitat functions of ecosystems. Intangible values are related to sensations of identity, morality and experience perceived by human societies. Since sensation are specially related to body experiences and feelings towards the environment, a sensible appreciation of ecosystems functions invites us to think other- oriented and holistically in respect to nature (Chan et al., 2012). Moreover a valuation oriented by culture, does not necessary mediate change through economic reasons, but motivates it through the promise of knowledge. A 'partners with nature' perspective would sympathise with the trend of an information eager society, where data collection rather than position and consumption of goods, is a symbol of power.

Besides looking ways to distance ourselves from the capitalistic view on values, an ecocentric spatial planning perspective seeks ways to hybridize human and natural ecosystems in order to address the projected growing numbers and demand of space of both systems (Reed & Lister, 2014). Hybridization does not need to take over whole territories, but it is suggested where two ecosystems present vulnerabilities. When it comes to interventions in space the theories on 'infrastructure ecologies' (Belanger, 2009; Brown, 2019) 'hybridize infrastructural function and ecological responsiveness by diverting waste resources from industrial operations '(Reed and Lister 2014, p.21). The idea is to use a mixture of soft and hard infrastructures that reintegrate the biodynamics plus the operational intelligence of ecology and allow a shared expansion space for dissimilar activities to meet. As vivid example of such 'ecologically responsive, socially expedient, culturally relevant and fiscally effective' (Belanger 2009, p.443) 'infrastructural ecologies' we can mention the experimental projects by the Building with Nature program. Building with Nature was initiated by the Ecoshape Foundation in 2008 and looks for the integration of uses, infrastructure and dynamics of the natural system to improve their own state and the one of other systems. Their proposal 'The Sand Motor' for example consists of an "artificial' sand peninsula that nourishes its neighbouring coasts through wave and current power to protect the hinterland from flooding as well as avoid the use of sand dredging for approximately 20 years while providing a changing recreation area (Ecoshape et al., 2014).

Consequently we can imagine that an ecocentric 'ecosystem -based adaption' acquires different dynamics in decision- making processes. As mentioned before, we assume the possibility that ecocentric measures will set values in knowledge and data generation. Thereafter to asses a project multidisciplinary collaboration between different stakeholders should be encouraged. Making such adaption projects feasible will require the 'dismantling and decoupling of bureaucratic land use controls' (Belanger 2009, p.459), including conservation policies like Natura 2000 (Vikolainen et al., 2014). The disadvantage in these type of procedures is that they take long periods of time to reach conclusions, since they rely on the thorough data analysis and experiments of several experts and reviewers, as well as consultations and surveys (Chan et al., 2012).

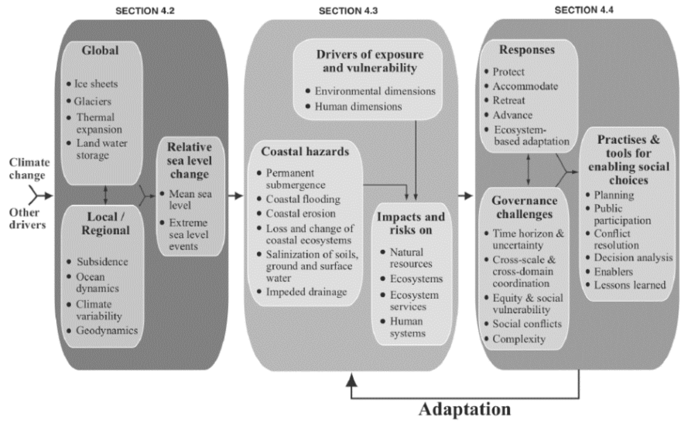


Figure 4. Interconnection of themes related to sea level rise

(Oppenheimer and Glavovic 2019,p.4)

After reflecting on these two perspectives on human and nature relations and how they will possibly develop different measures under the framework of an 'ecosystem-based adaption' approach, we could argue that an ecocentric perspective is more synchronized to the further development of the Wadden Sea region. We present three reasons:

1. In the Wadden Sea region ecosystem services should not be esteemed by economical benefits, instead they should be valued by culture. Experience has shaped the Wadden Sea environment and taught communities how to be prepared. Cultural services rather than production is what has characterized this region, its nomination as World Heritage site stands as proof (Bazelmans et al., 2012).
2. The development of infrastructure even in protected areas should be allowed in the Wadden Sea region. Deciding on setting boundaries on development between nature and human ecosystems in this area, in the long run would probably mean the loss of the tidal mudflats. Replacing the activities related to these areas within urban ecosystems would be a great challenge and require big investments. Hybridizing is seeing change as an asset and adapt by embracing coming risks. The Wadden Sea region is a perfect location to demonstrate that combined nature and human systems are not dangerous but more robust (Alberti, 2008). This area is extensive researched so that proposing a systems just has to notice or include a set of variables that understand the dynamics of the place. Hereby evolution becomes cooperative and joins the desire to preserve this region.
3. Decision- making in the Wadden Sea region should consider long- term planning and trust cooperation. Adaption in form of individual evolution

(just adapting urban ecosystems) is entirely trusting engineering and nature to preform exceptionally. Trusting in cooperation is creating synergies between systems and different actors and voices. The trilateral collaboration of the Wadden Sea region could hardly be sustained by only working on an uninfluenced conservation, it would also be ignoring the warnings by scientific investigations about what values we are loosing by not taking action. Including flexibility in current conservation policies will have to find a balance between more or less control; a balance hopefully inspired by a multidisciplinary assessment (Giebels et al. 2013; Hale et al. 2009; Munang et al. 2013).

CONCLUSIONS

In this brief academic paper we have indicated the importance of coastal ecosystems and discussed their fragility by highlighting the implications of risk. The severe pressure of climate change and the extreme character of human activities that coastal habitats are subdued to, has allowed us to advance on the concept of 'evolutionary resilience' (Davoudi et al., 2013). This notion of resilience acknowledges a constant transformation as a way to adapt to risk. In addition theories on 'metabolic flows' and 'landscape as infrastructure' invited us to understand how ecosystems are understood in the field of urban planning and design(Belanger, 2009; Waldheim, 2016). Through the decomposition of ecosystems in the vulnerable Wadden Sea region we understood that we need to decide on types of structures, flows and processes to reach an 'ecosystem-based adaption' (Hale et al., 2009; Munang et al., 2013). Hereafter we noted that strategies in tune with 'ecosystem- based adaption' change depending on the targeted perspective of human- nature relations(M. de Groot & Drenthen, 2011) and concluded that the Wadden Sea would benefit in three aspects from an ecocentric perspective: cultural valuation to enhance *preparedness*, hybridization to *persist* and *transform* and cooperation to be *flexible* (Davoudi et al., 2013).

The idea of ecocentrism in respect to cultural valuation might be seen as naïve, and the notion of capitalistic eagerness in a anthropocentric view exaggerated; however this paper wanted to explore the possible outcomes of such a view assuming that the scattered occurrences of 'ecosystem-based adaption' approaches of this 21st century will be globalized. Furthermore is to be noted that most of the introduced theories posse greater depth (an perhaps more alignments) than presented in this brief discussion, nevertheless the intention was to shortly evaluate their applicability and practicality to understand a given context. Perhaps this paper should have also elaborated on the feasibility of the described ecocentric approach and further explored what flexibility entails from policy (Giebels et al., 2013; Slobet al., 2016).

Overall, this paper will certainly help further research for the thesis, since the decomposed elements through theories will guide the analysis and frame the research, and more attention will be placed on value to add to the question of what forms of life will the project address. In closing it may be said that the purpose of this paper was to explore seeing risk as an opportunity to try to change our relation with nature.

Words: 4406

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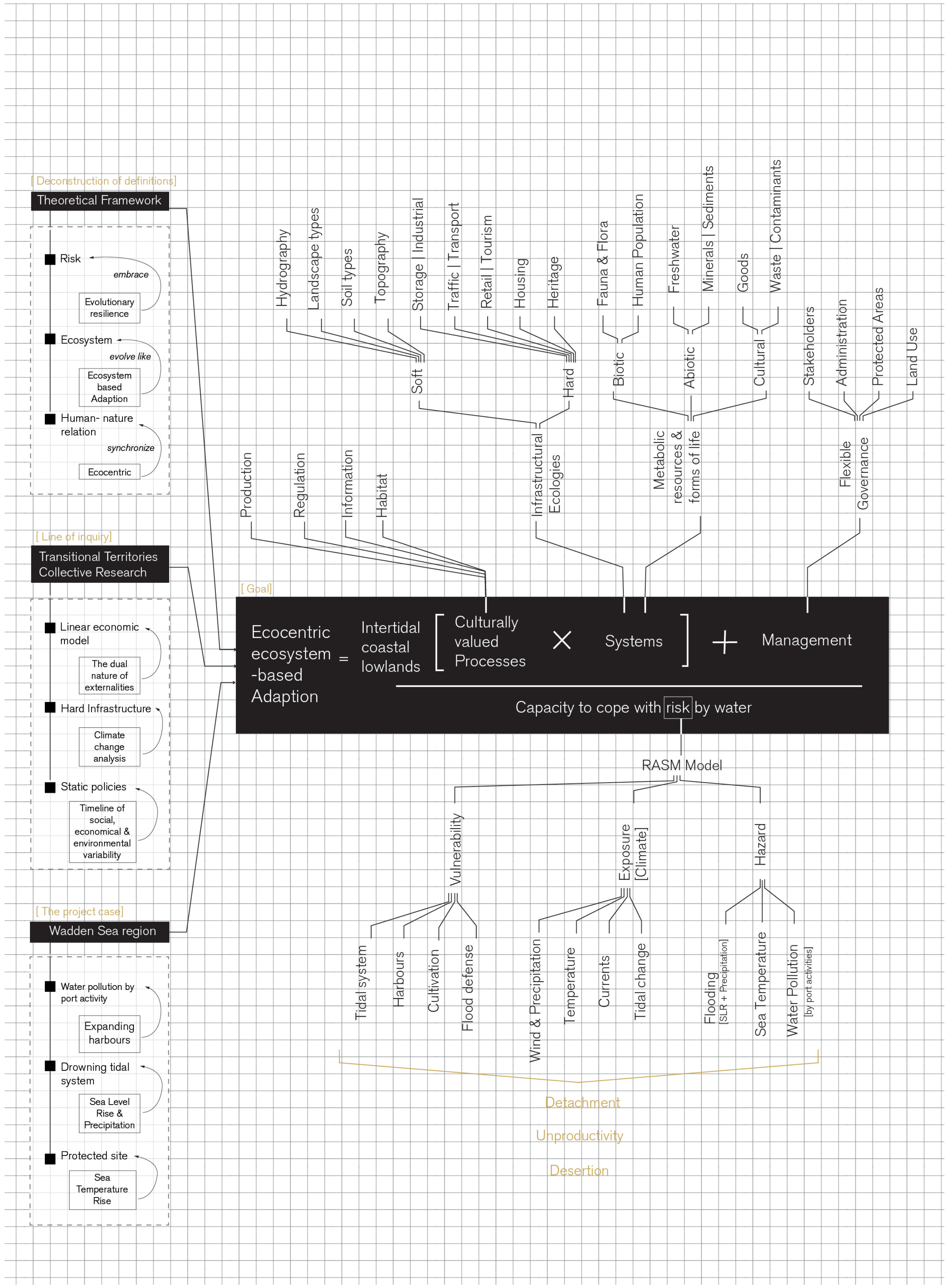
Fig. 25 Conceptual Framework.
(made by author,2019)



HOW?

CONCEPTUAL FRAMEWORK

From theories to applicable concepts

The conceptual framework is formed by the knowledge sustained by theories and notions (see page 40-41); by the analytical conclusions of the collective research of the studio, and the specific problems of the project case.

-Through the notions deconstructed in the academic paper I decided and reflected on embracing risk instead of fighting it to cope with the unstoppable nature of the anthropocentric magnified climate change; to adapt to evolve like (and with) ecosystems, and to synchronize human- nature relations aiming for an ecocentric vision.

- From the collective research based on the analysis the North Sea as a territory, I extracted the ideas of the dual nature of externalities caused by a linear economic model; the incapability to withstand uncertain climatic changes of hard infrastructures, and the static character of climate-related policies in contrast with the paces of social, economical and environmental changes. Hereby I could also conclude that the southern North Sea encompasses the areas most prone to be affected by climate change.

- This led me to set the project case in the Wadden Sea region. Moreover, I decided to focus on three urgent aspects of the region: a protected area threatened by sea temperature rise, a drowning tidal system due to sea-level rise and precipitation, and a port expansions based on an expensive linear model.

I indicated that the path to embracing water-related risk is enhancing an 'ecosystem- based adaption'. In Fig. 25 I have applied this concept to the Wadden Sea region. To reach the goal of an 'ecosystem- based adaption' the project needs to transform the intertidal coastal lowland into an ecosystem consisting of culturally valuable processes of production, regulation, information, and habitat (MEA, 2005) and of systems that combine Infrastructural Ecologies (soft and hard) (Belanger, 2009; Brown, 2019) with biotic, abiotic and cultural Metabolic Flows (Ahern, 2007). These ecosystems should be supported by encounter spaces using a mixture of nature-based designs that will hopefully enhance their capacity to cope with risk by water and prevent detachment, unproductivity, and desertion of the Wadden Sea region. Consequently, the articulation of all parts will result in the combination of ecosystems with society, economy, and ecology, which are aiming for an accessible, healthy, and safe habitat.

'This notion integrates landscape as one fundamental infrastructure and combines design with ecosystem services, often called nature-based solutions.'
(Garcia Vogt, 2019)

Infrastructural Ecologies
(Brown, 2019), (Belanger, 2009)

'The interpretation of anthropogenic urban fabrics as ecosystems, could allow us to create robustness of built and natrual environments by undestanding the functionality of complex flows and shifting them to become reciprocal or cyclical.'
(Garcia Vogt, 2019)

Metabolic flows
(Alberti, 2008), (Ahern, 2007)

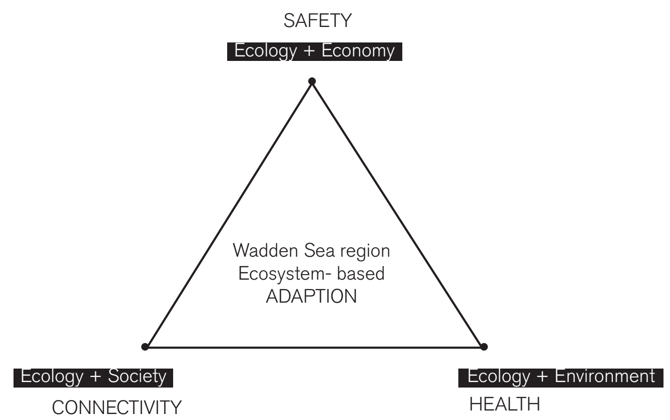


Fig. 26 Conceptual framework. Outcome values.
(made by author,2019)

WHO, WHERE & WHEN?

ANALYTICAL FRAMEWORK

From concepts to analytical parameters

Since the theoretical framework presented the most important notions and theories that sustain and give purpose to the research; and the conceptual framework transformed these notions into applicable actions to achieve asset of values at risk in the Wadden Sea region, the analytical framework deconstructs these values into components to be evaluated in the multiscale analysis, as well as to understand who, what and where we are working in the research. This means that the analytical framework is placing limits on the endless possibilities of research about the region, urban fabrics, and neighborhood.

The proposed analytical framework takes in consideration the variable of time, hereafter it suggests to evaluate the past and present of a given system (for example inundation) and its future risk in combination with a related system (such as inundation and wind & precipitation as flood control risk) within the confines of the scenario RCP 8.5 (IPCC, 2018; Oppenheimer & Glavovic, 2019). Additionally, each aspect's past will be analyzed considering structures and flows, to compare to the development of their present process, structures, and flows. The urgencies categorized by values resulting from the combined eight parameters at risk will help me to develop a vision on a regional and urban scale.

Fig. 27 Analytical Framework. Scales
(made by author,2019)

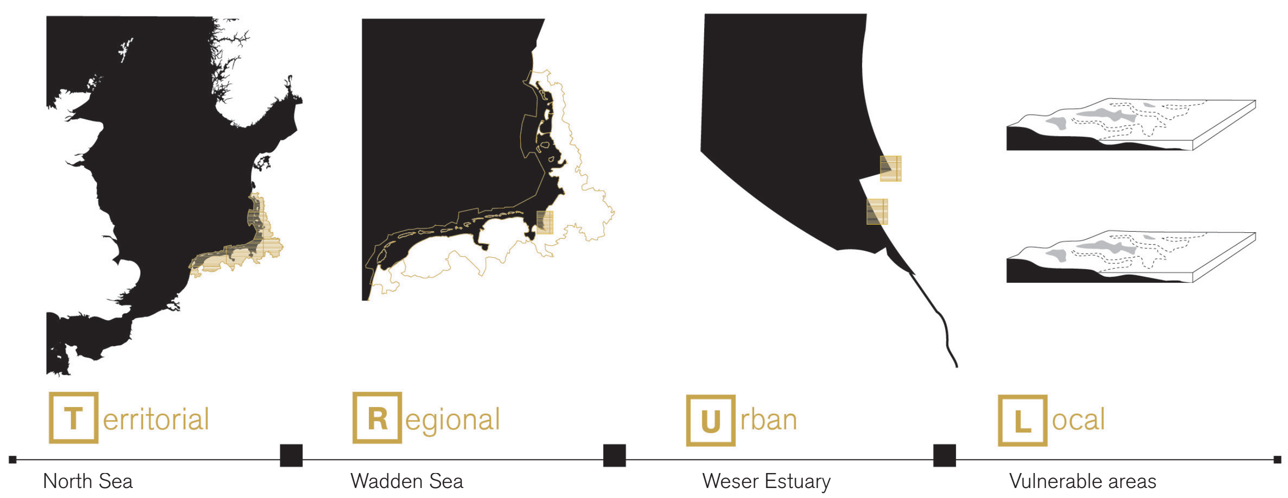


Fig. 28 Analytical Framework. Parameters
(made by author, 2020)

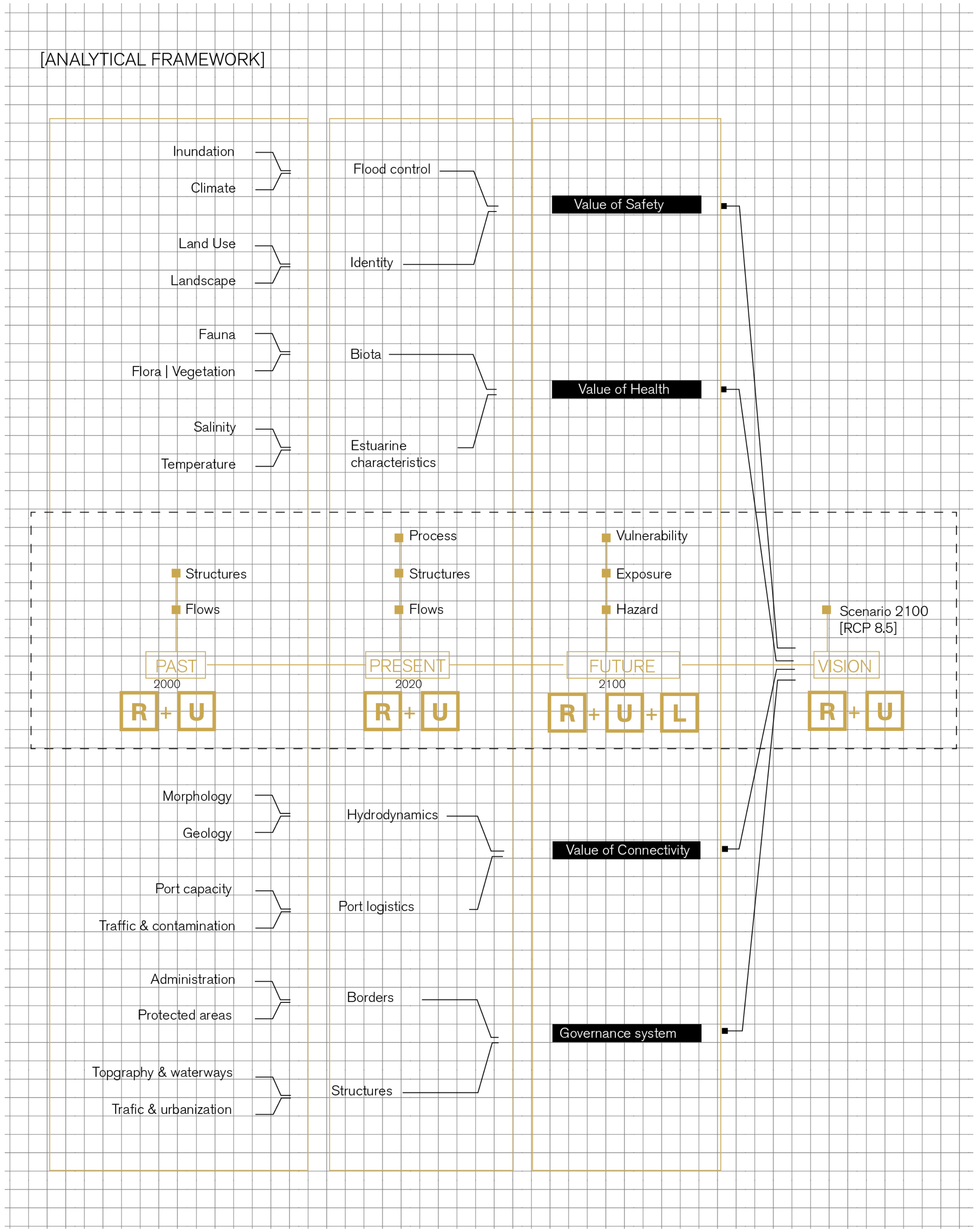
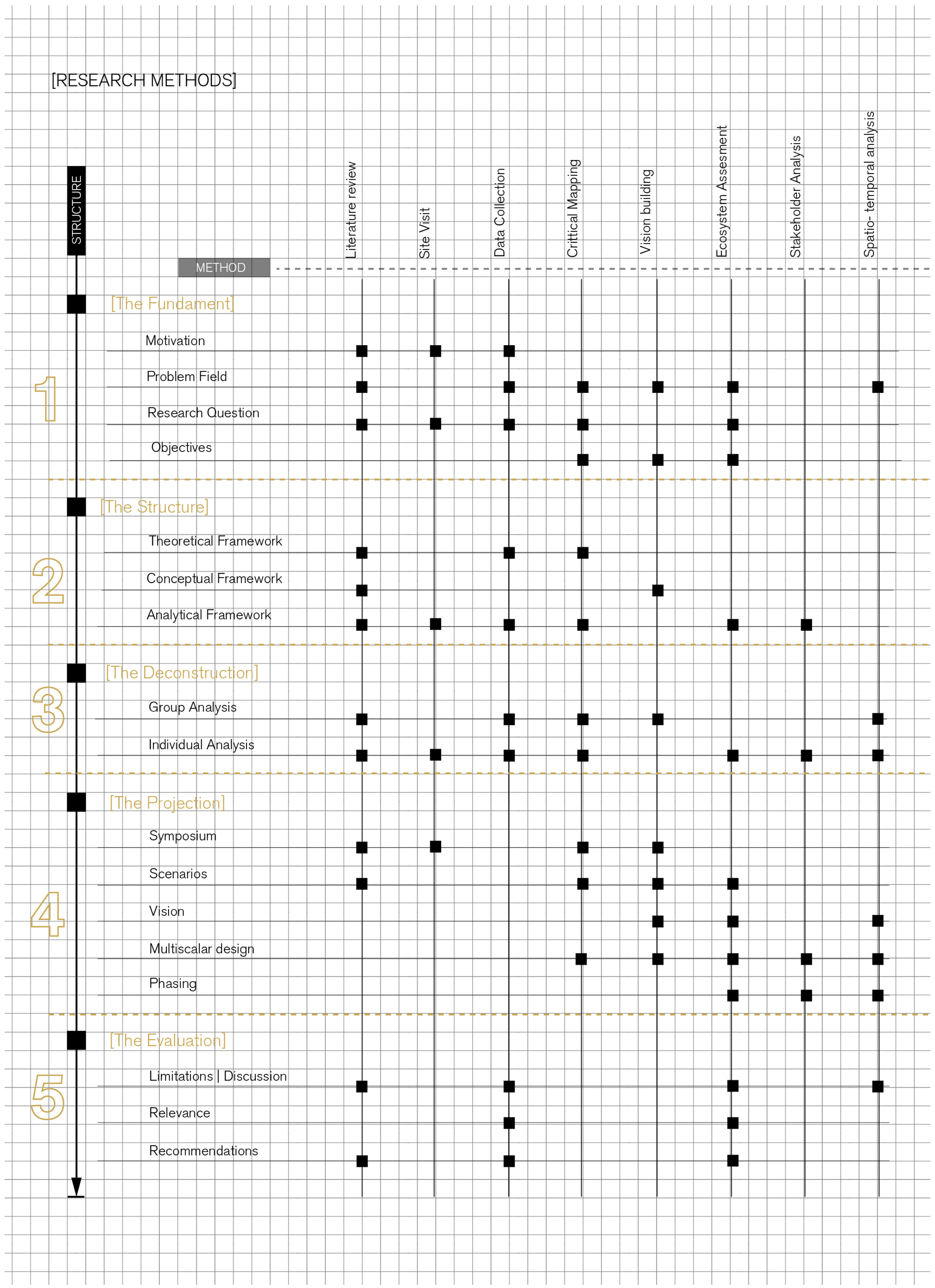


Fig.29. Research methods.
(made by author,2020) (inspired by Balasubramanian, 2018)



RESEARCH METHODS

From parameters to methods

The research approach is inspired by a deductive method, where initial ideas are general, and through the process of research by design become specific. Categorizing, assembling, and reconstructing is expected. Through logical and teleological inquiry, the search for truth is supported by the values of safety, health, and connectivity.

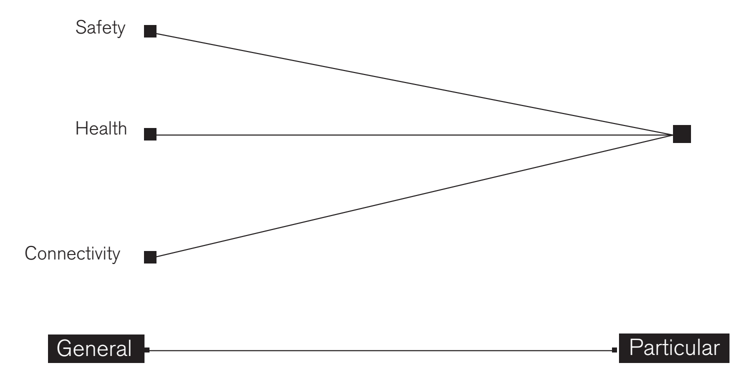


Fig. 30 Deductive Approach.
(made by author,2019)

On the other hand, we can associate the proposed phases (The Fundament to The Evaluation) of the project with eight different types of research methods (see Fig. 29). Besides commonly used methods in the field of urban planning and design such as literature reviews, site visits, data collection, and critical mapping, the project requires the implementation of vision building, ecosystem assessment, stakeholder analysis, and a spatio-tempral analysis in order to respond to uncertainty and adaptivity. Hereafter it is deductible that the research follows a socio-ecological approach, which implies using methods that emit a series of switchable possibilities rather than a unique result or solution. Furthermore, I can elaborate on each of the eight methods to be applied, along with their components and aims.

1. Literature review

Aim

To revise and understand different concepts related to ecosystems, risk adaption, and human- nature relationships from a conceptual, theoretical, and scientific perspective. The different statements linked to the keywords will be evaluated to select the once that argue in tune with the predispositions of the context. These findings will support and guide the opportunities visualized for the research.

Keywords

Ecosystem [*Ecosystem succession- 'Ecosystem-based adaption' – Coastal ecosystems*]
Risk [*Water risk management- climate change uncertainty – evolutionary resilience*]
Human- nature relations [*flexible governance- socio- ecological vulnerability*]

Database

Google Scholar search engine - ResearchGate - Science Direct - SpringerLink and published books.

2. Site visit

Aim

To document the site through visuals (photographs and video) and do an experiential study of the chosen context.

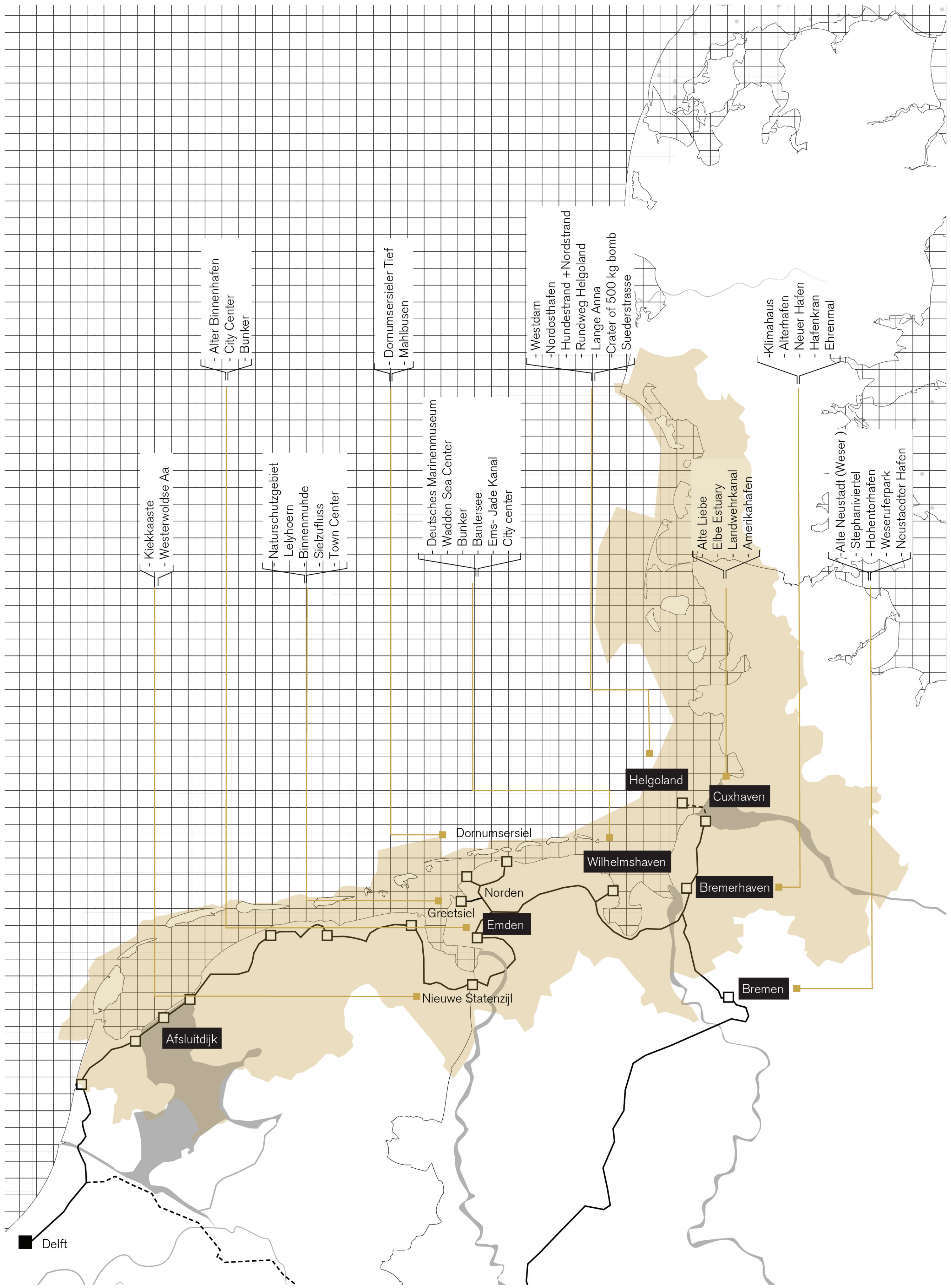
Duration

25. October 2019 to 03. November 2019 [10 days]

Locations

Bremen- Bremerhaven- Cuxhaven - Helgoland - Wilhelmshaven- Berumbur- Dornumsiel- Greetsiel - Norden - Emden - Nieuwe Staatenzijl- Afsluitdijk

Fig. 31 Fieldtrip Overview. Visited and documented locations.
(made by author,2019)



RESEARCH METHODS

3. Data Collection

Aim
To assemble a collection of qualitative information (subjective evidence) and quantitative date (objective material).

Sources
Websites, literature, media, publications, reports, papers and newspapers

Database
North Sea [Helholtz- Zentrum- Geesthacht (CoastDat) - NOAH Maps - EMODnet, Eurpean Atlas of the Seas- SeaDataNet- WWF Artic Maps - ODIS Catalogue - IODE - ESRL - JCOMM - ICES. CIEM - 4C Ofshore - COntours Axismaps - EEA]
Wadden Sea & Northern Germany [GeoSeaPortal - ZeBIS Schleswig Holstein - Norddeutscher Klimamonitor- Norddeutsches Kuesten- und Klimabuero - Geoportal MRH- Wadden Sea Forum - WaddenNatuurkaart- NIOZ- TIDE Toolbox]

4. Critical Mapping

Aim
To understand and determine critical urgencies or vulnerable systems as well as identifying subjects, objects, processes and flows in different scales and moments in time.

Scales
Territorial [North Sea] - Regional [Wadden Sea] -Urban [Weser Estuary] - Local
Past [~2000] - Present [2020] - Future [2100]

Parameters
Safety [*Flood control + Identity*] - Health *[Biota + Estuarine Characteristics*] - Accessibility [*Hydrodynamics+ Port logistics*] - Governance [*Administration + Structures]*.

5. Vision Building

Aim
To explore the implications of a worst case scenario and propose an utopic goal image related to the adaption and management of 'exaggerated' parameters.

Scales
Regional [Wadden Sea] - Urban [Weser Estuary]

Parameters
Vision for 2050 considering IPCC Scenario for 2100 .

	[SED]	
RCP 4.5	RCP 8.5	
		[CC]
RCP 2.6	RCP 6.0	

6. Ecosystem Assessment

Aim
To understand ecosystem synergies, vulnerable elements, longevity and yearly cycle changes.

Scales
Urban - Local

Parameters
Quantitative analysis - Qualitative analysis - Phenological analysis

7. Stakeholder Analysis

Aim
To explore the collaboration between different actors within the proposed strategies, and to evaluate the power and interest of various groups in relation to an intervention to test its feasibility.

Parameters
Public Sector -Private Sector- Civil Society

8. Spatio- temporal analysis

Aim
To comprehend how the design and strategies would develop in time, which policy changes are required, and test if the choreography of projects is synchronized with the changes of socio-ecological processes.

Parameters
Important years 2020- 2050 -2070- 2100 (long term)
Key and pilot projects + goals [deadlines to adapt]

Fig. 32 Research methods & questions.
(made by author,2020) (inspired by Leung, 2018)

[RESEARCH METHODS]

As a way to evaluate the presented methods, I have combined them with the research questions (main and sub-questions) that the thesis wants to answer. The main research question already entails some of the notions depicted in the theoretical and conceptual framework, which are at the same time linked to three sub-questions related to the problems of flooding, sea temperature rise, and water pollution by port activities.

INFRASTRUCTURE

[Theoretical +Conceptual + Analytical framework]
What is ecological succession?

'Ecological succession – the study of how biological communities re- assemble following natural or anthropogenic disturbance – has been a foundation in ecology, (...)In particular, successional studies provide insight into the community assembly mechanisms, including dispersal limitation species (...), pool effects (...), priority effects(...) , abiotic environmental filtering(...) , stochastic processes(...) , biotic interactions(...) , and feedbacks(...). '
(Chang et al, 2019, p.1)

Can an ecosystecosystem succession approach r the co- habitation of human- nature systems of the Wadden Sea region to develop an evolutionary adaptation?

ELEMENTS

[Theoretical +Conceptual +Analytical framework]
What are human- nature systems?

'Ecosystem- based adaption' involves creating measures that most probably will bring a new relationship between humans and nature forward. So far this relation has been mostly driven by the extreme abuse of natural systems by human population. From the four perspectives on human- nature relationships proposed by environmental ethics and given the broadness of the approach , 'ecosystem- based adaption' strategies and designs could be aligned to two: the anthropocentric 'stewardship of nature' or the ecocentric 'partnership with nature' (M. de Groot & Drenthen, 2011).

PROCESS

[Theoretical framework]
What is evolutionary adaption?

In 'evolutionary resilience' theory, human and nature are considered co-dependent systems, which adds complexity, but addresses their mutual ability to self-organize, adapt and transform in different paces and scales when disturbed. In this framework a systems resilience depends upon what it has learned from past experiences of stress (preparedness); on its rooted relations with the particular values of the setting or sub-systems (persistence); on the flexibility of its substantial structures and processes (adaptability), and on its capacity to embrace or accept change (transformability) (Davoudi et al., 2013).

[Phases]

- 1 Motivation Aspects
- 2 Fundament Aspects
- 3 Structure Aspects
- 4 Deconstruction Aspects
- 5 Projection Aspects
- 6 Evaluation Aspects

Sub-research Question 3

Literature review | Data collection | Vision building | Stakeholder analysis
Site visit | Critical mapping | Ecosystem assessment | Spatio- temporal analysis

Which hybrid infrastructures would allow the necessary flexibility to adapt to flooding, temperature rise, and water pollution by port activity in the Weser Estuary over time?

SCALE	PRODUCT	Questions
U + L	Design of two pilots + Ecosystem succession process	-What are hybrid infrastructures? What nature based- solutions enhance ecotones? 2 3 5 - How can we include ecological succession in the parameter of the desgin? 5 6 - What is the predicted pace and extend of these risks? 4 5

Sub-research Question 2

Literature review | Data collection | Vision building | Stakeholder analysis
Site visit | Critical mapping | Ecosystem assessment | Spatio- temporal analysis

Which strategies would enhance the necessary links and elements of the Weser Estuary ecosystem so its ecological succession results in an evolving adaptation?

SCALE	PRODUCT	Questions
R + U + L	Hybrid- multi-scalar strategies & design principles	- Which ecosystems exist in the Weser Estuary? 4 5 - Which possible scenario is in tune with the presented goals? 4 6 - How would possible strategies change under the influence of different scenarios? 4 6

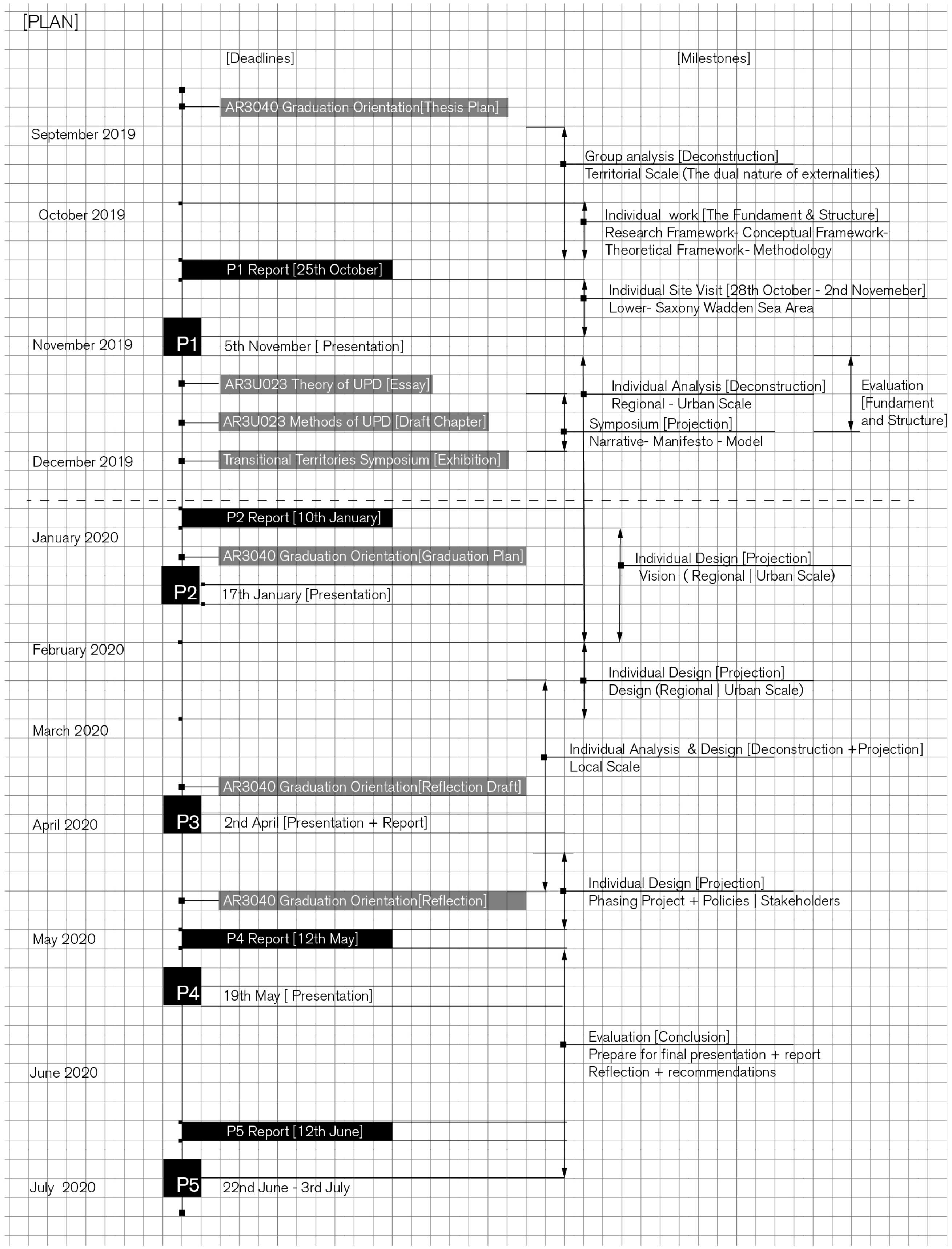
Sub-research Question 1

Literature review | Data collection | Vision building | Stakeholder analysis
Site visit | Critical mapping | Ecosystem assessment | Spatio- temporal analysis

To what extend can we multi- balance socioeconomic and environmental interests in the Wadden Sea region considering the future pressures of climate change?

SCALE	PRODUCT	Questions
R + U	Regional and urban vision for 2100	- What are the urgencies related to safety, health & connectivity? 2 4 - What opportunities and limitations exist to embrace risk? 4 - What values need to be preserved? 4 5

Fig. 33 Overview of Graudation Plan. Nine- month graduation project.
(made by author,2020) (inspired by Leung, 2018)



EXPECTED OUTCOMES

From methods to goals

Early in this chapter, I presented five phases of the projects (The Fundament- The Structure- The Deconstruction- The Projection – The Evaluation), which we now organize within the timespan of nine months. In Fig.33 I am showing when each of these phases and their respective scale should be developed to respect certain deadlines (P1 to P5) given by the four courses that encompass the graduation year.
In order to synchronize the environment and society, I proposed the implementation of an 'ecosystem- based adaption' approach in the Wadden Sea region, which includes the consideration of ecological successions to enhance ecotones. The goal of this graduation project is to enhance *safety* by managing water risk through hybrid infrastructures with ecological responsiveness; *health* by creating habitats that maximize an ecosystem's regulatory, productive, informative, and sheltering functions (ecosystem services)., and *connectivity* through flexible and dynamic encounter spaces (ecotones) that relate and synchronize socio-ecological cycles to make opportunities out of risk. The proposed products to achieve this are a set of design principles or strategies for the region and urban fabric, and the implementation of two of them within Weser Estuary(local scale) to test a multi-scalar design of different adaptive soft infrastructures that integrate ecological and social operations: Infrastructural ecologies (Belanger, 2009; Brown, 2019).

Fig.34 Expected outcomes & products.
(made by author,2020)

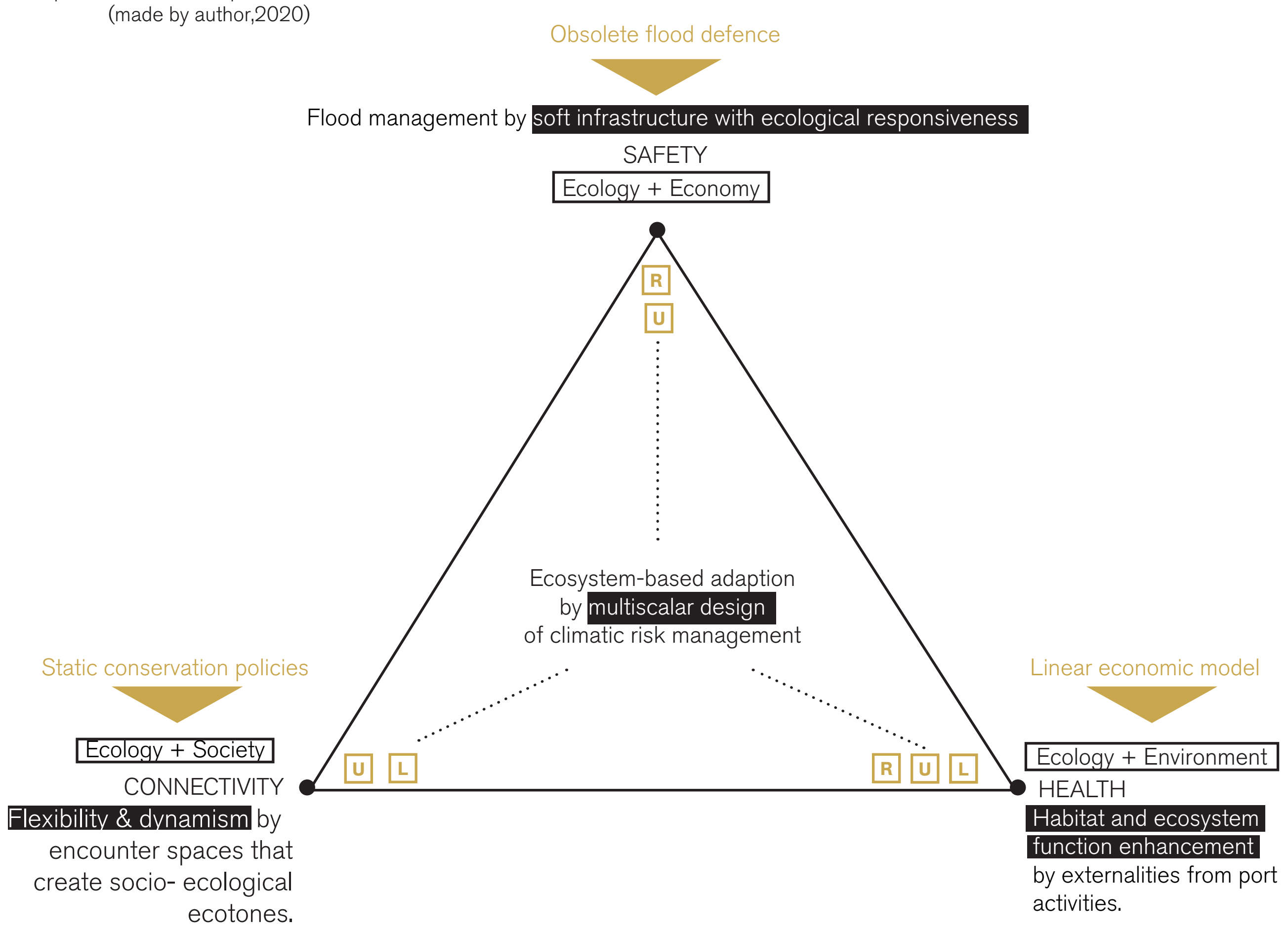


Fig. 35 Dornumsiel, Germany, Wadden Sea region
(taken by author,2019)

CONCLUSIONS

In this chapter ('The Structure') I shortly exposed the vulnerabilities of the Wadden Sea region regarding an obsolete flood defense system, environmental degradation and port growth that will not cope the critical risk of sea-level rise, precipitation patterns, sea temperature and water pollution by port activities, which has led me to wonder to what extent could an ecosystem succession approach trigger a co-evolution of human- nature systems and develop an 'evolutionary adaptation '(Chang & Turner, 2019).
Concerning this question I depict three broad terms: risk, ecosystems, and human- nature relations and constrained them within the 'evolutionary resilience' theory (Davoudi et al., 2013). As a result, I could advance on an 'ecosystem- based adaption' (Hale et al., 2009) that argues for an ecocentric perspective. This concept was deconstructed in the context of the Wadden Sea concluding on three principles: ecosystem functions should be valued culturally (Chan et al., 2012); systems should be constructed by combined infrastructural ecologies and circular metabolic flows (Belanger, 2009; Brown, 2019), and nature-based design is plausible if conservation policies are flexible and climate inclusive. Moreover the set of values that the relation between ecology and society, economy, and environment puts forward, in addition to different scales and time frames, built up the base of the analytical framework. The methods were also by these values, keywords, scales, and climate scenarios in order to support different research sub-questions. Hereafter I will enhance a long term vision supported by a set of design principles to be tested by two interventions in the Weser Estuary.
Henceforth this chapter intended to answer the questions what- why- how- who- where and when of the research, to clarify its boundaries and extend as well as convert notions into actions that were executed in the graduation year.

Chapter

4

DECONSTRUCTION

MULTISCALAR ANALYSIS

The chapter '*Deconstruction*' visualizes filtered data from the past ,present and future in different scales and depicts on the most relevant information that the project needs to address in order to make a design proposition.

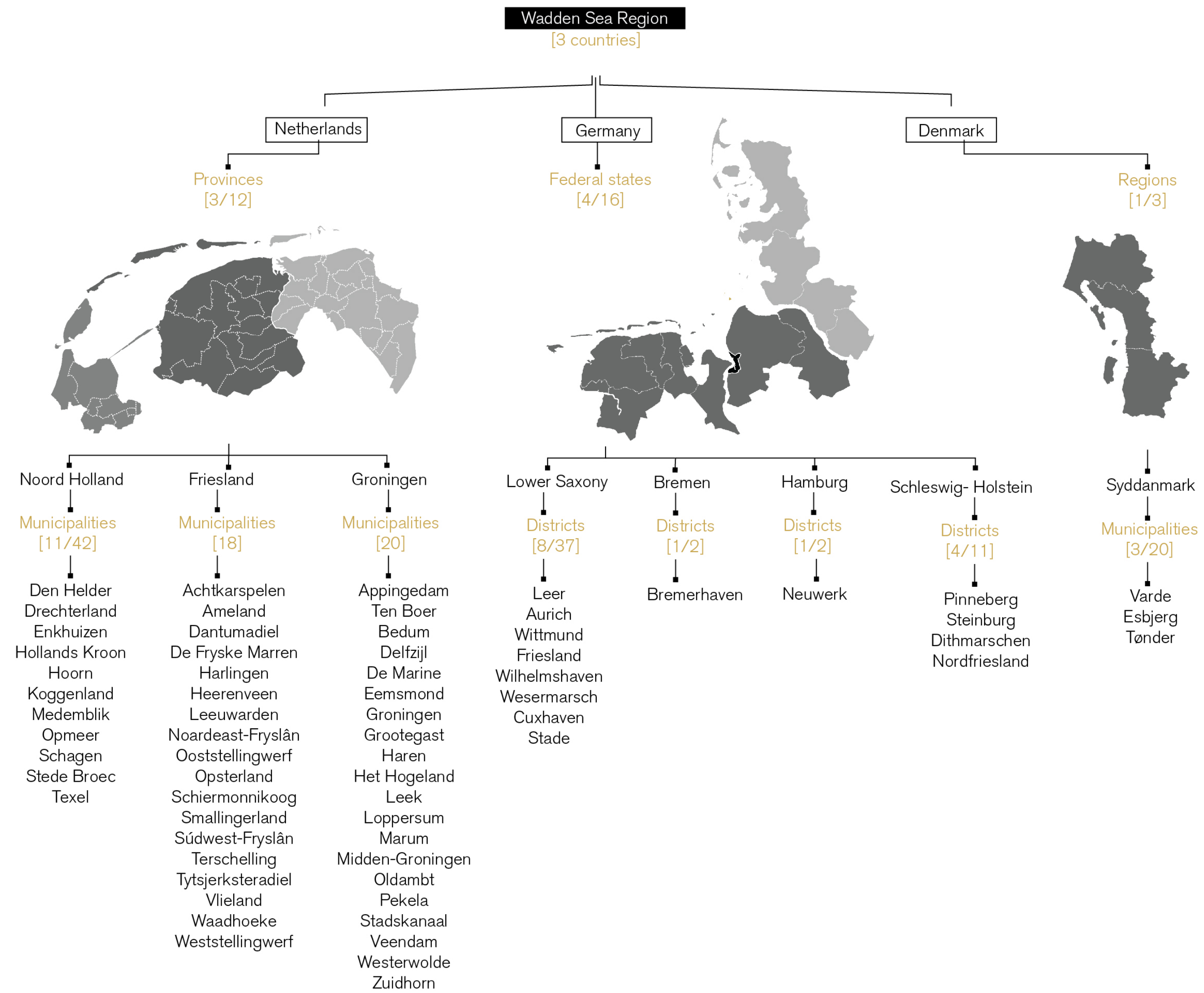
ANALYSIS

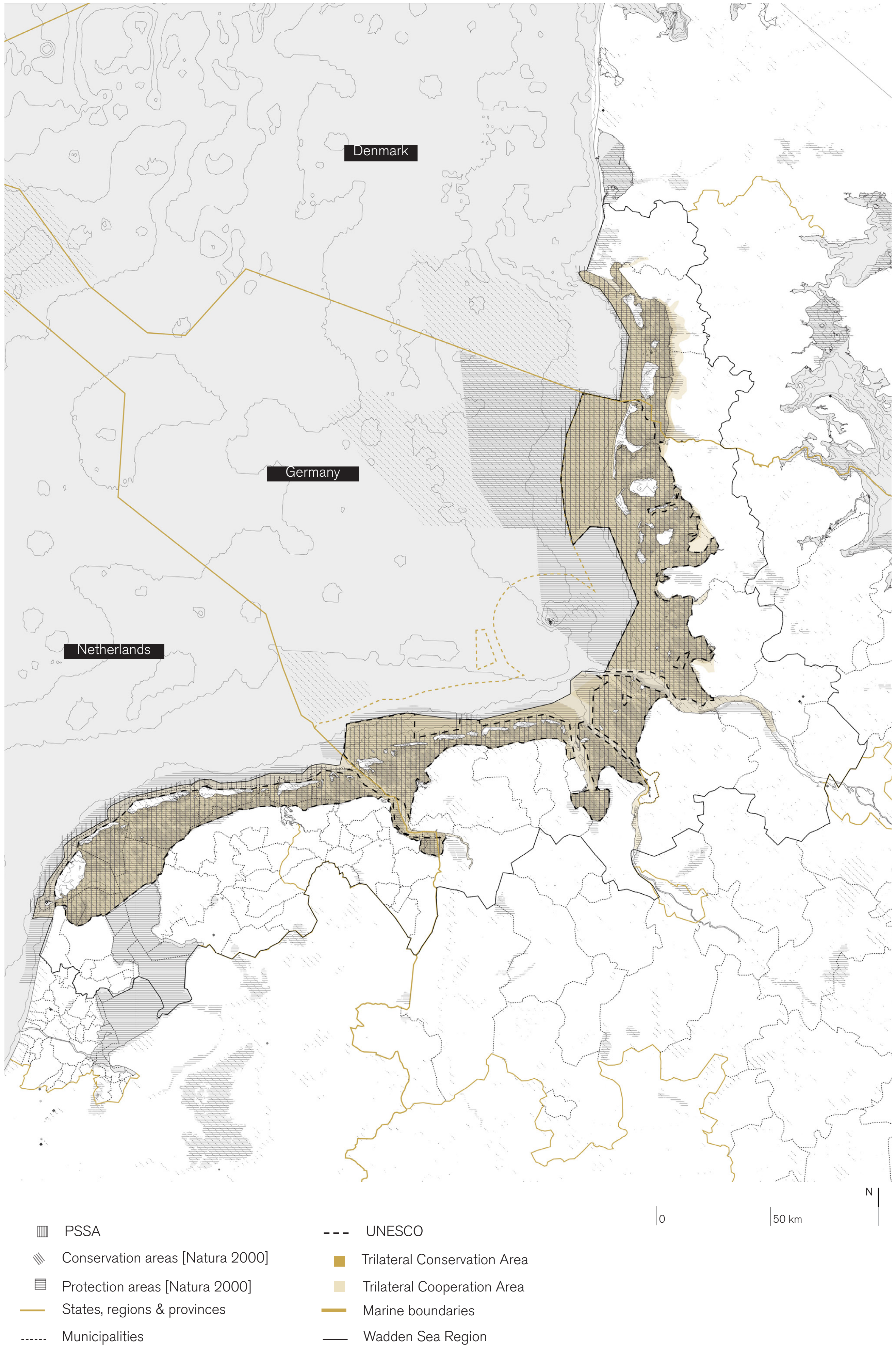
Borders: Administration, Protection & Conservation

The Wadden Sea is a region shared by three nations [Netherlands, Germany & Denmark] and hereafter the administration of the area varies from country to country according to their national law. The Netherlands divides its part of the Wadden Sea in three provinces that are managed by several municipalities due to an agglomeration increase towards the inland. Germany's division of the territory goes from four federal state to a subdivision into districts, whereas Denmark new administrative boundaries (2007) introduced the partition into regions and subsequently fewer municipalities than in the past. In the map we can recognize that this subdivision according to each nation also corresponds to the density of land occupation. Not just the land, but the administrative boundaries of the sea including International and European protection and conservation boundaries differ from each other. We can observe that what is considered part of the Wadden Sea region by UNESCO does not correspond to the area by the Trilateral Cooperation. There is also a difference between PSS Areas (Particularly Sensitive Sea Areas) designated by the International Maritime Organization (IMO), and Special Areas of Conservation (SAC) & Special Protection Areas (SPA) boundaries within the Natura 2000 legislation. Furthermore non of the conservation or protection entities include the inland area of the territory, mentioned in literature as socio-cultural landscape and henceforth considered as a vital part of the Wadden Sea region (Bazelmans et al., 2012; Enemark et al., 2018).

Fig. 36. Administrative border of the Wadden Sea region.
(Made by author, 2020)
(Data from: Wikimedia Foundation, 2020 ; Geobasis-DE/BKG, 2009)

Fig. 37. Organigram about spatial division of territory
(Made by author, 2020)
(Data from: Wikimedia Foundation, 2020)





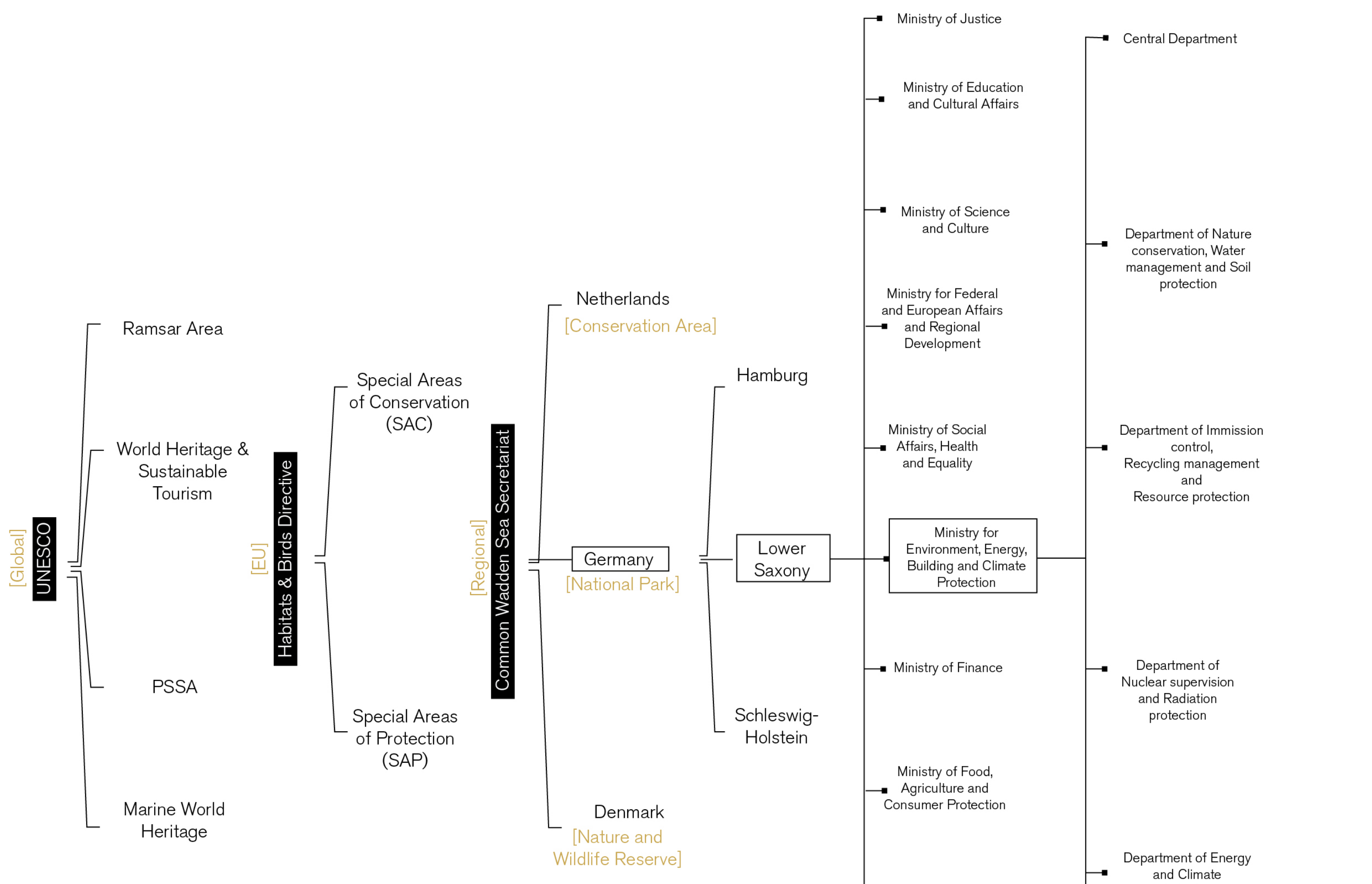


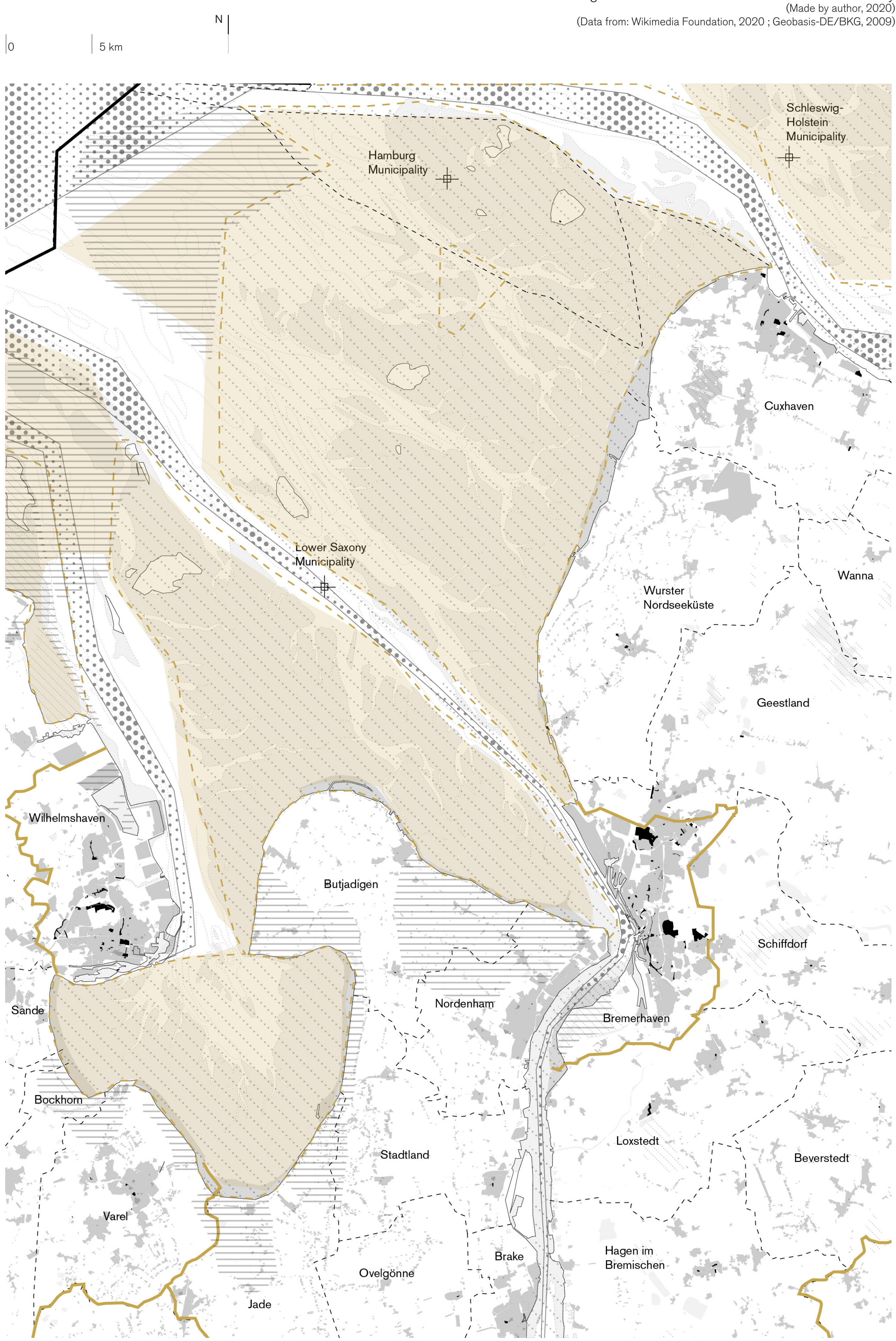
Fig. 38 Governance hierarchy organigram of the Weser Estuary.
(Made by author, 2020)
(Data from: Niedersachsen Landesregierung Portal, 2019)

Weser Estuary - Borders: Administration, Protection & Conservation

Due to its high ecological, socio-cultural and economical value, the Wadden Sea region is protected by many international and national instances. Curiously the most dynamic area of the region (intertidal area) has the most extensive designation of boundaries which is not in tune with the constant and unrestricted natural changes, as well as coping with the benefits sought by the anthropic development.

- PSSA
- Conservation areas [Natura 2000]
- Protection areas [Natura 2000]
- Municipalities
- Districts
- UNESCO
- Trilateral Conservation Area
- Trilateral Cooperation Area
- Marine boundaries
- Wadden Sea Region

Fig. 39 Administrative borders of the Weser Estuary
(Made by author, 2020)
(Data from: Wikimedia Foundation, 2020 ; Geobasis-DE/BKG, 2009)



ANALYSIS

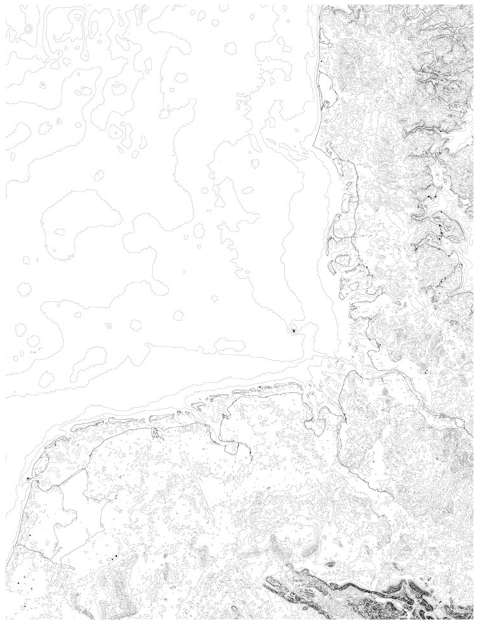
Contours: Spatial Structures

Although we are in the age of the Anthropocene, when looking at the combined topography and bathymetry, we can still depict on the formation of the territory by the action of northern glaciers in the Pleistocene. These shifed most of the sediment towards the south, creating 'small' hills such as the Harz area, an extensive flatland (intertidal wetland) and the several water inlets such as the Ems, Weser and Elbe river. The biggest agglomerations of humans are found near these inlets, which catalysed the creation of a traffic network following water paths in the land and a more trivial structure at sea.

Fig. 40 Structures of the Wadden Sea region.
(Made by author, 2020)
(Data from: BSH, 2020; Open Street Map, 2018)

Fig. 41. Combined structures of the Wadden Sea region.
(Made by author, 2020)
(Data from: BSH, 2020; Geofabrik, 2020; Open Street Map, 2018)

Topography| Balthymetry



Water

Urban form

Traffic

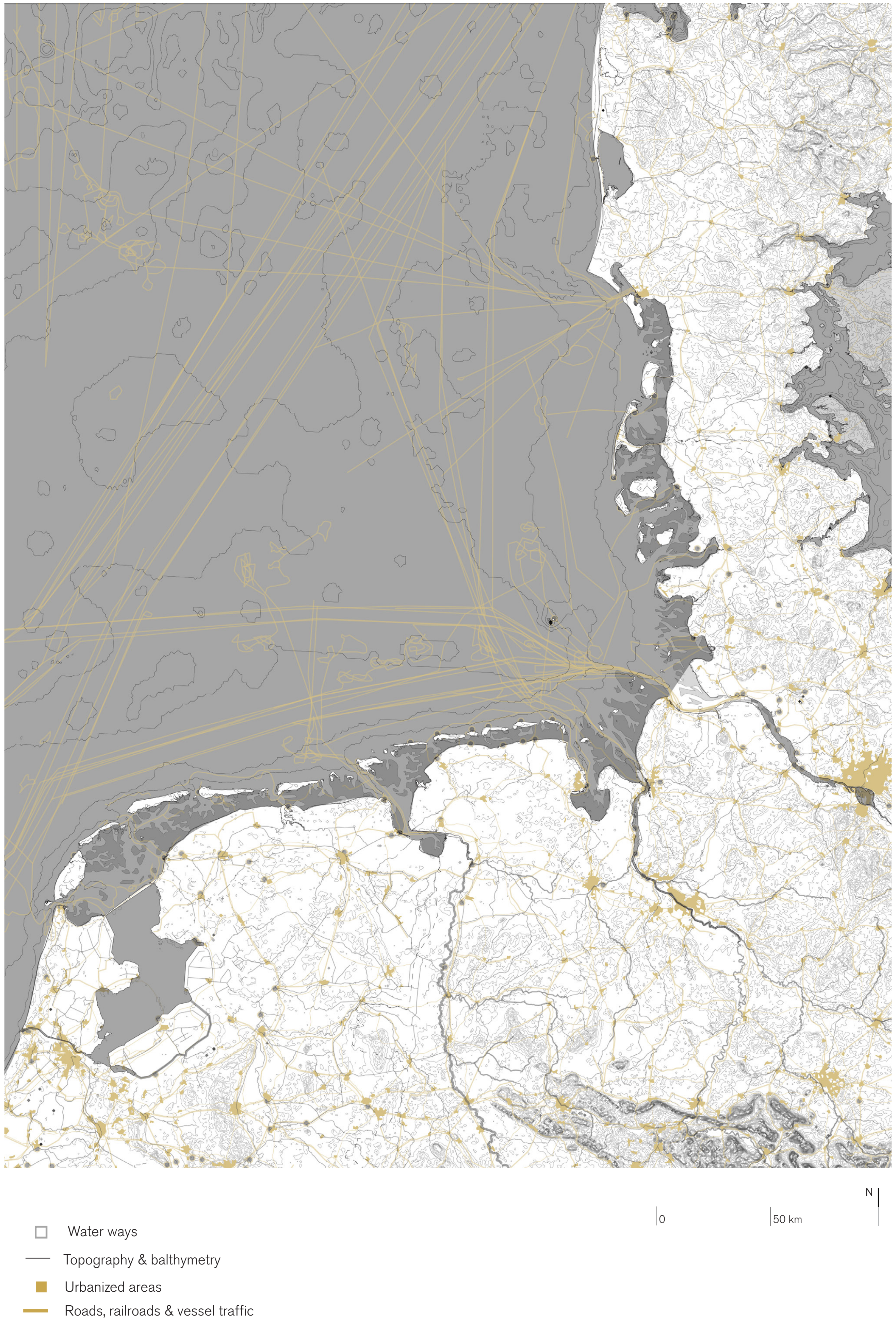


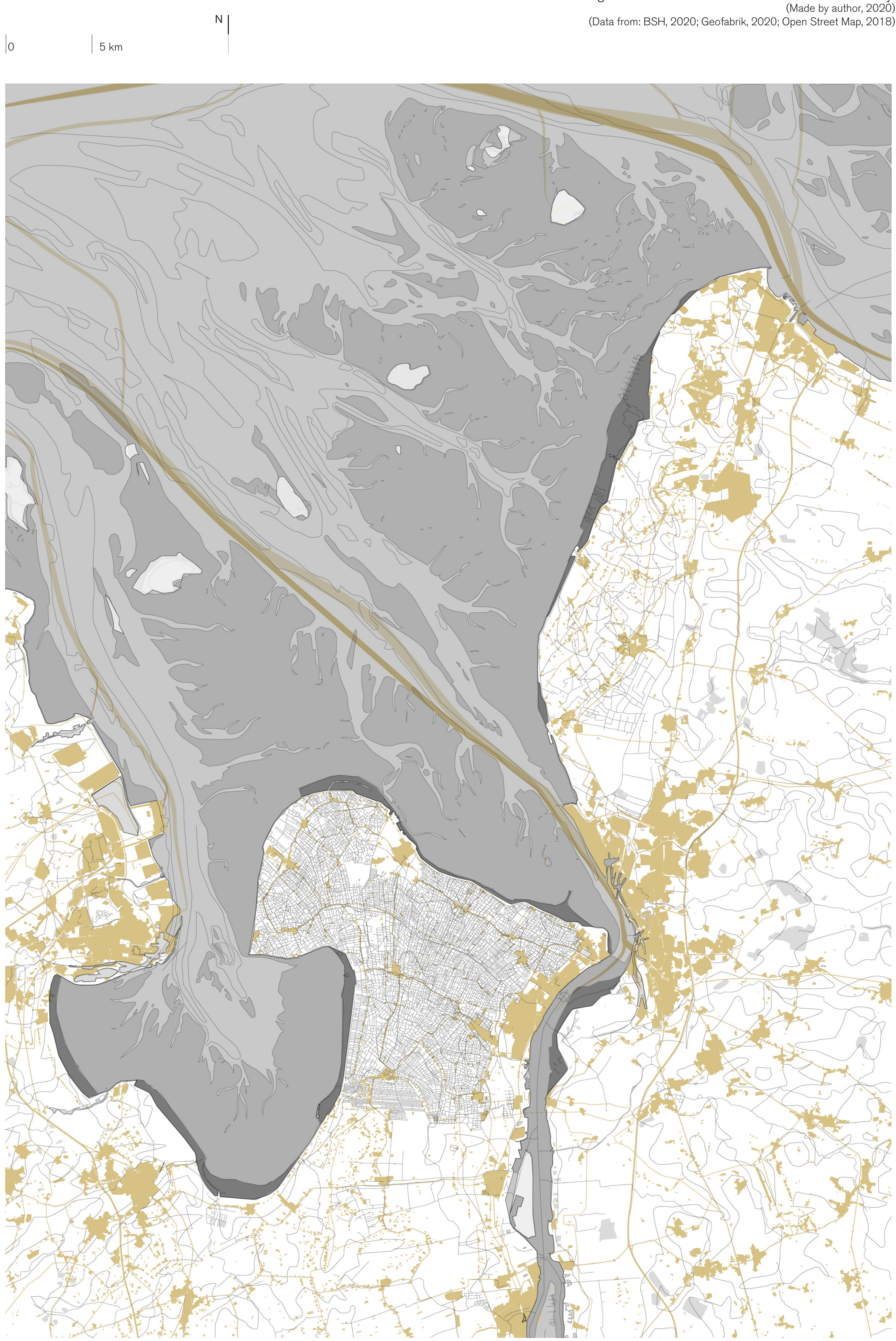
Fig. 42 Structure of the Weser Estuary.
(Made by author, 2020)
(Data from: BSH, 2020; Geofabrik, 2020; Open Street Map, 2018)

Weser Estuary - Contours: Spatial Structures

Since no barrier islands formed around the area and its more inland location, the Weser estuary has an easier access towards the North Sea. Hence compared to the other rivers, the Weser estuary hosts two important international harbours (Wilhelmshaven & Bremerhaven) located nearby the delta inlet.

- Water ways
- Topography & balthymetry
- Urbanized areas
- Roads, railroads & vessel traffic

Fig. 43 Combined structures of the Weser Estuary.
(Made by author, 2020)
(Data from: BSH, 2020; Geofabrik, 2020; Open Street Map, 2018)



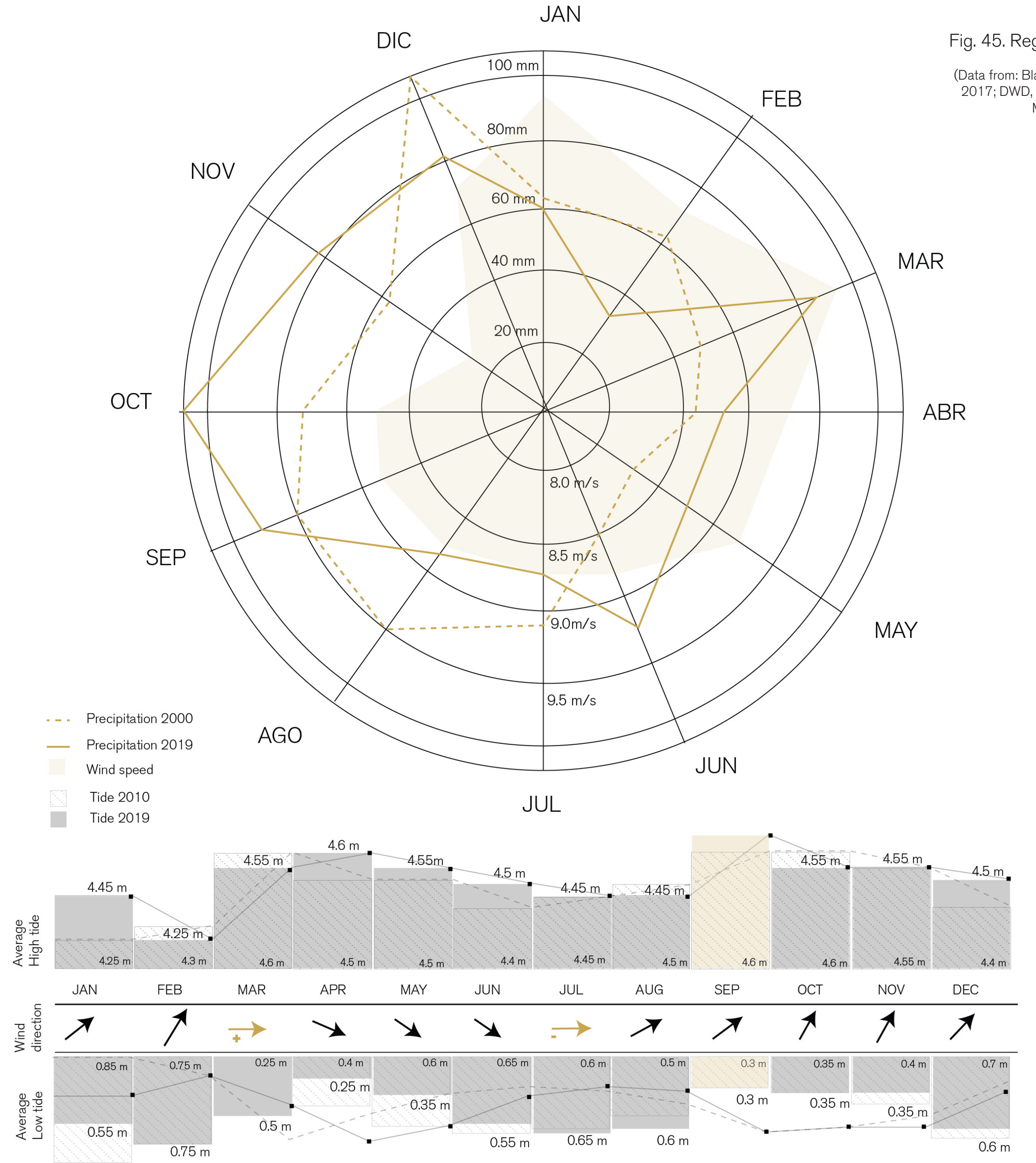
ANALYSIS

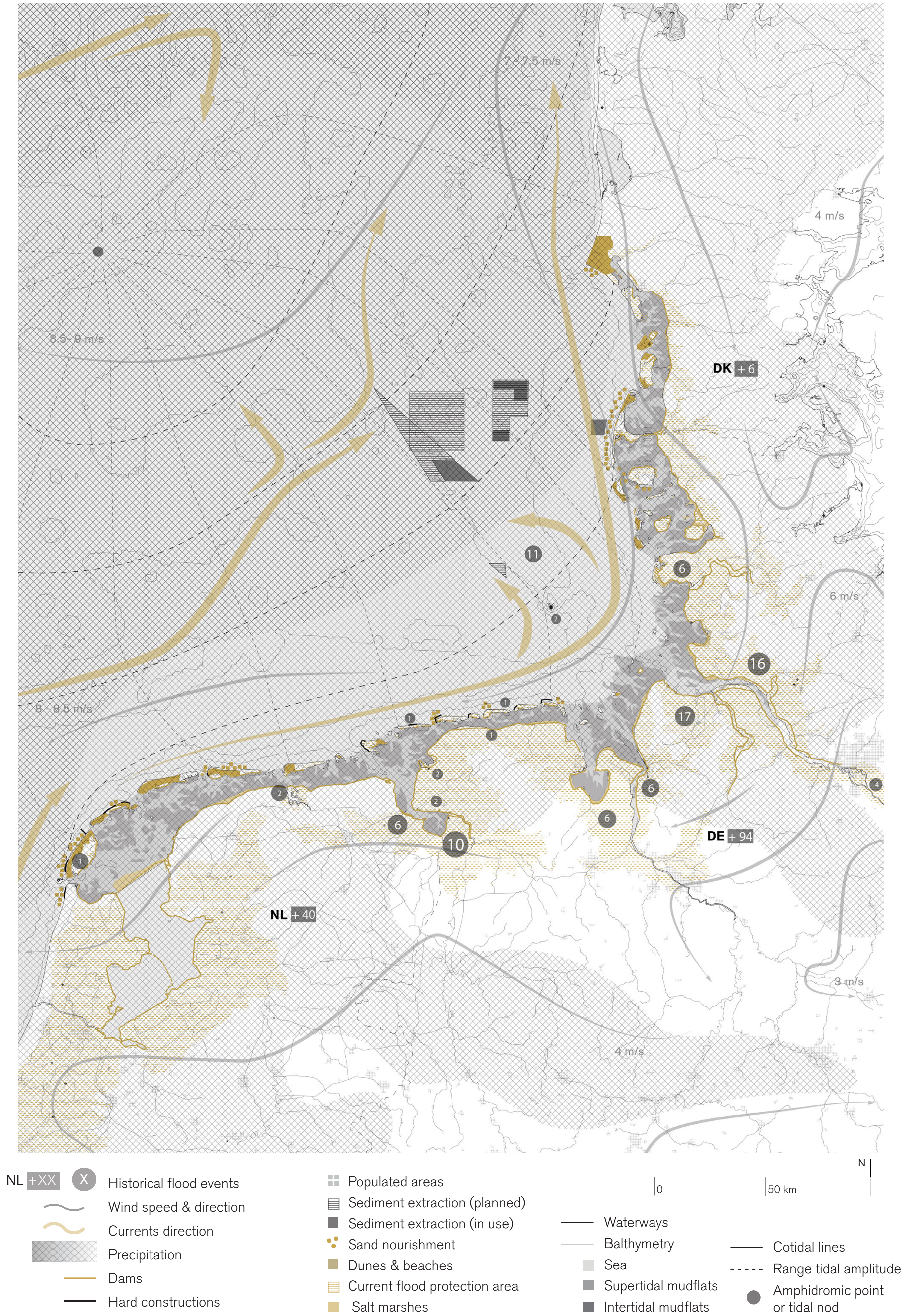
Flood management & climate

Great changes in the climate of the Wadden Sea region are visible when comparing data from precipitation, wind, and tidal amplitudes form the year 2000 and 2019. Although precipitation is still intensive in September-December, the summer period of July- August present less rain than in the year 2000. Wind patterns are more irregular when coming from west to east and increase speed from January to March. The low tide amplitude has shifted from March to April whereas high tidal amplitudes are more or less 0.1 m higher than in the past. In the map, we can notice that most historical floods in this area have occurred along the more southern German coast due to the lack of extra protection from barrier islands and the currents direction change from west-east to the north(Oost et al., n.d.).

Fig. 44. Climate Bremerhaven.
(Made by author, 2020)
(Data from: Gehzeiten Fisch, 2019; Wetterkontor, 2019; Windfinder, 2019)

Fig. 45. Regional Flood management.
(Made by author, 2020)
(Data from: Blatter & Roux, 2016; de Groot et al., 2017; DWD, 2015; Geobasis- DE/ BKG, 2020; Mapbox, 2019; Zijlstra et al., 2017)





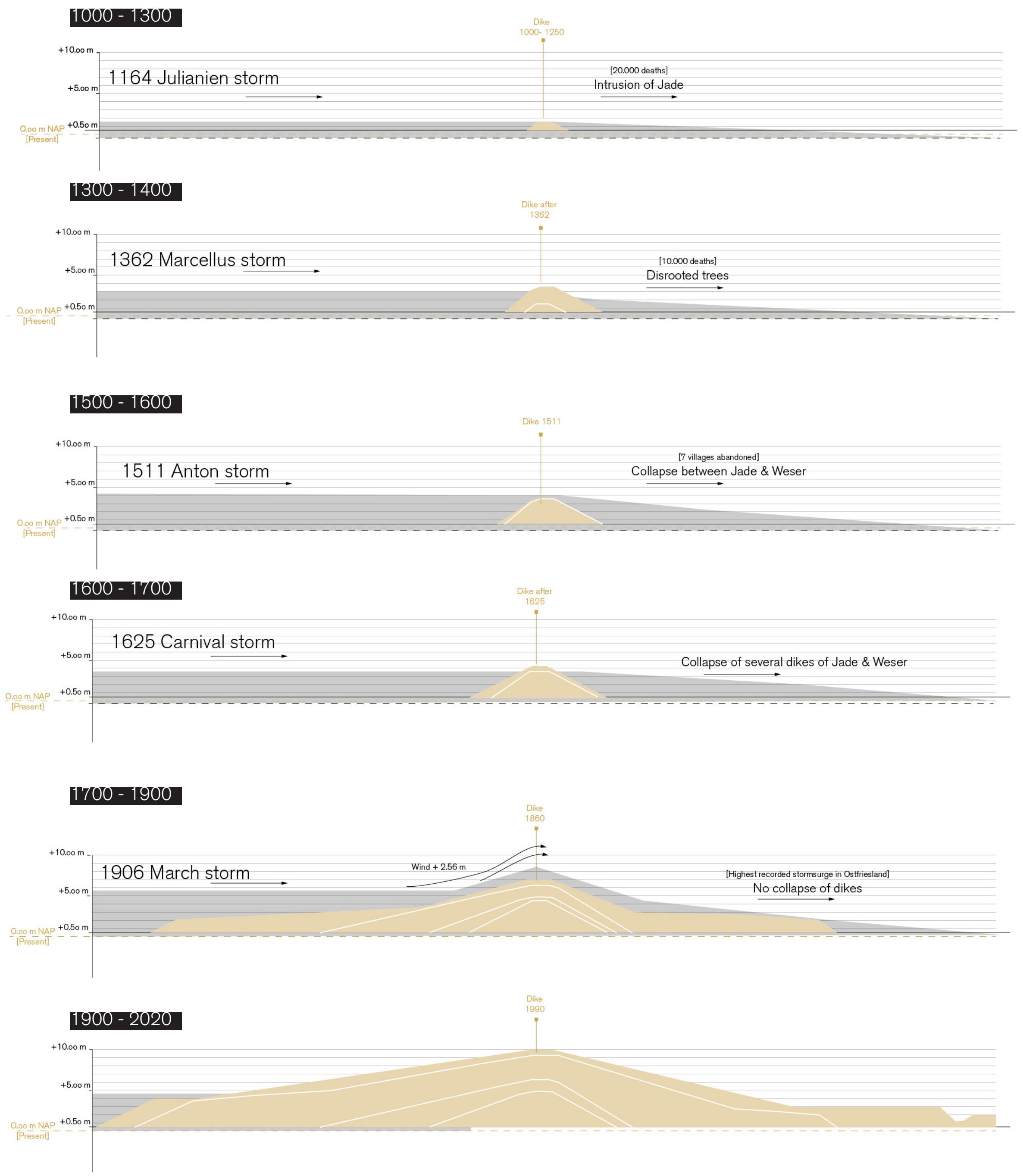


Fig. 46 Evolution of dike construction
(Made by author, 2020)
(Data from: Meier, 2012; Niedersächsischer Landesbetrieb für & Wasserwirtschaft, Küsten- und Naturschutz, 2007)

Weser Estuary - Flood Management & Climate

Flood protection has increased over the years due to the augmented height of inundation events. These have led to the extensive reclamation of land mostly around the Jade Bight and Weser estuary visible on the map.

- Wind speed & direction
- Currents direction
- Precipitation
- Current dams & dikes
- Old dams & dikes
- Sluices & locks
- Populated areas
- Sediment extraction (in use)
- Sand nourishment
- Dunes & beaches
- Salt marshes
- Current flood protection area from storm 1962
- Historical flood events
- Low tide
- High tide
- Waterways
- Balthymetry
- Sea
- Intertidal mudflats

Fig. 47 Urban flood management
(Made by author, 2020)
(Data from Blatter & Roux, 2016; de Groot et al., 2017; DWD, 2015; Geobasis- DE/ BKG, 2020; KÜNO, 2013; Mapbox, 2019; Meier, 2012; Ulrich Lamm, 2014; Zijlstra et al., 2017)

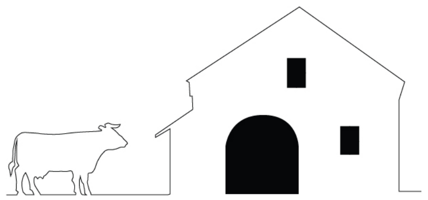
ANALYSIS
Cultural identity & activities

The Wadden Sea region was traditionally used for agricultural and maricultural purposes, mostly consisting of livestock farming (cattle & pigs) and mussel farming (blue mussel & oysters). 'During the 20th century, several invertebrate fisheries collapsed because of overexploitation (e.g. oyster, lobster) or ceased because of declining markets (e.g. clam, sea moss, sea star)' (Lotze, 2004). Hereafter in 2013, some areas of the Wadden Sea region were closed for shrimp fishing. Other fishing practices such as bottom trawling in the outskirts of the Wadden Sea region are still seriously damaging the seafloor and catching unwanted species (bycatch) (Baer & Smaal, n.d.).

Fig. 48. Land Use Activities.
(Made by author, 2020)
(Data from: Bahlke, 2017; BSH, n.d.; Landesamt für Statistik Niedersachsen, 2016b, 2016a)

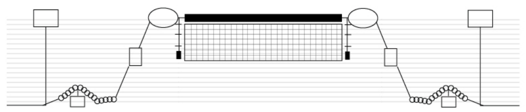
Fig. 49. Regional Cultural identity.
(Made by author, 2020)
(Data from: BSH, n.d.; EEA, 2017; Esri, n.d.; Folmer et al., n.d.; HZG, 2014; Wadden Sea Forum & EUCC, n.d.)

Agriculture



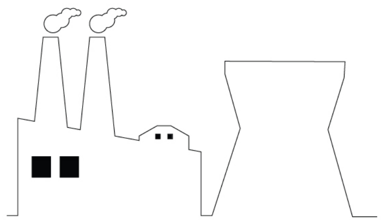
Livestock farming 2017 — 4 296 200 EUR
Goods of nutritional economy 2017 — 10 823 300 EUR
[Lower Saxony, DE]

Mussel mariculture



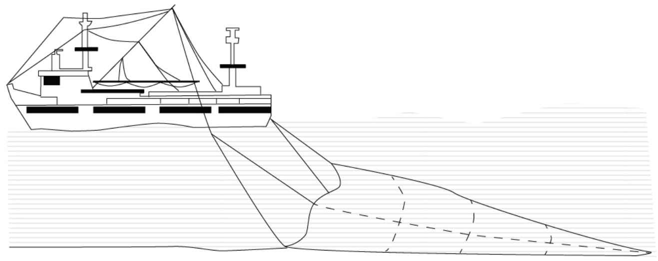
Brown shrimp landings [DE] 2015 — 15 000 tonnes
Brown shrimp landings 2015 — 43 000 tonnes
[Wadden Sea total]

Industry



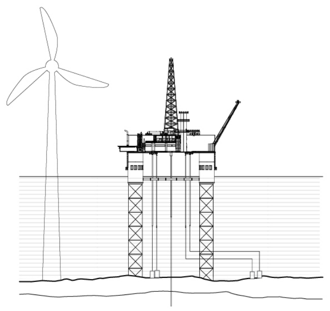
Chemical Industry 2016 — 7 344 617 EUR
Metal Industry 2016 — 6 035 805 EUR
[Lower Saxony, DE]

Bottom trawling



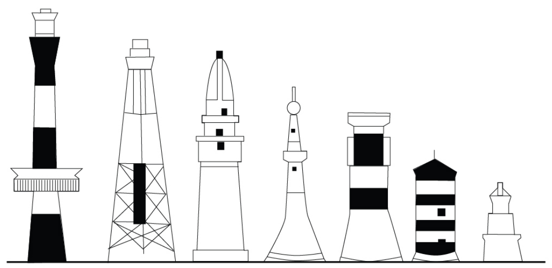
Fisheries 2017 — 362,2 Mio EUR
Goods of nutritional economy 2017 — 10.823,3 Mio. EUR
[Lower Saxony, DE]

Energy

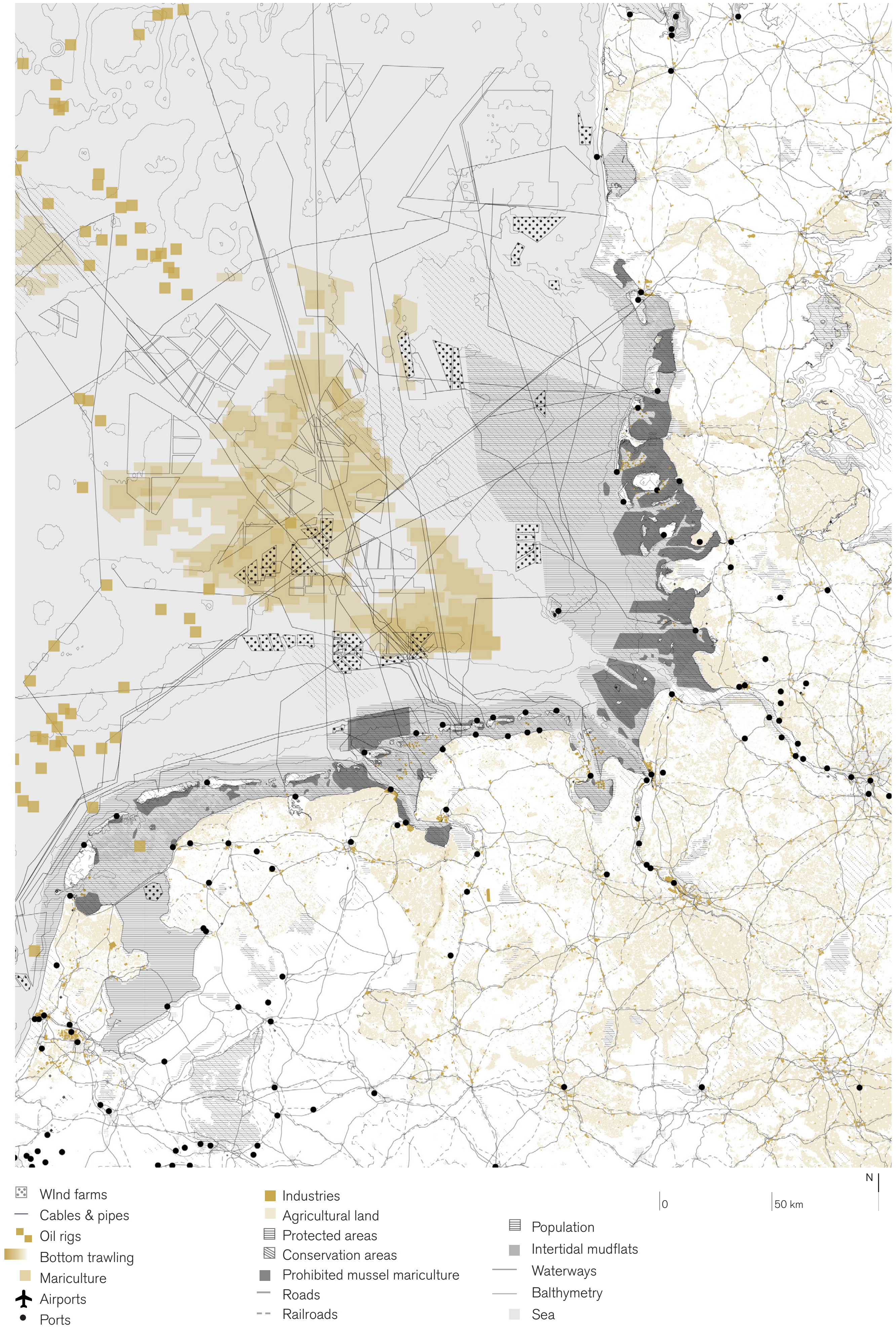


Energy from Fossil fuel 2016 — 6 244 338 MWh
Energy generation 2016 — 7 922 676 MWh
[Lower Saxony, DE]

Vessel traffic



Vessel Traffic Density 2017 — > 100 vessels per km² per day
Goods Traffic 2015 — 33 518 (1000 tonnes)
[Bremerhaven + Lower Saxony, DE]



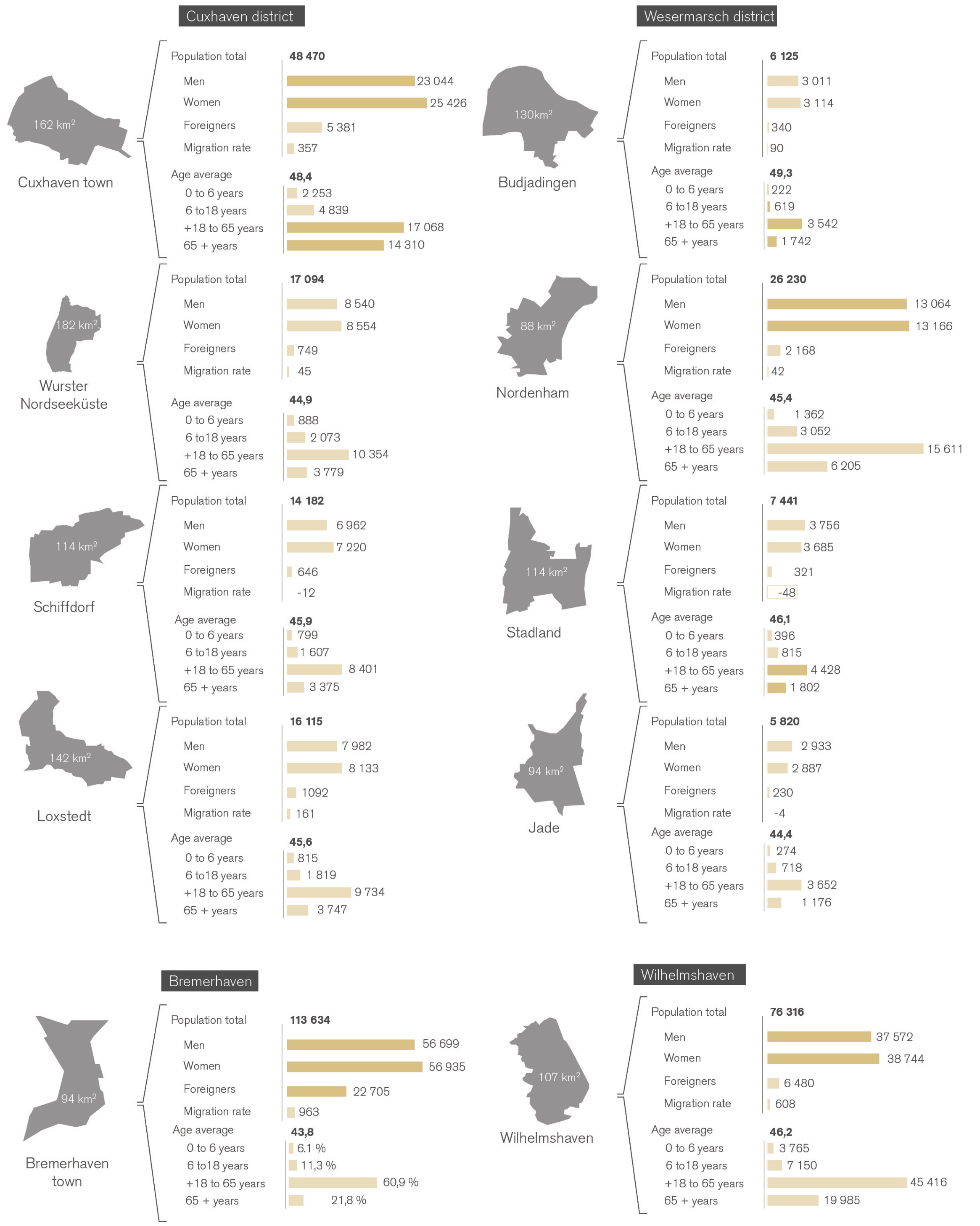


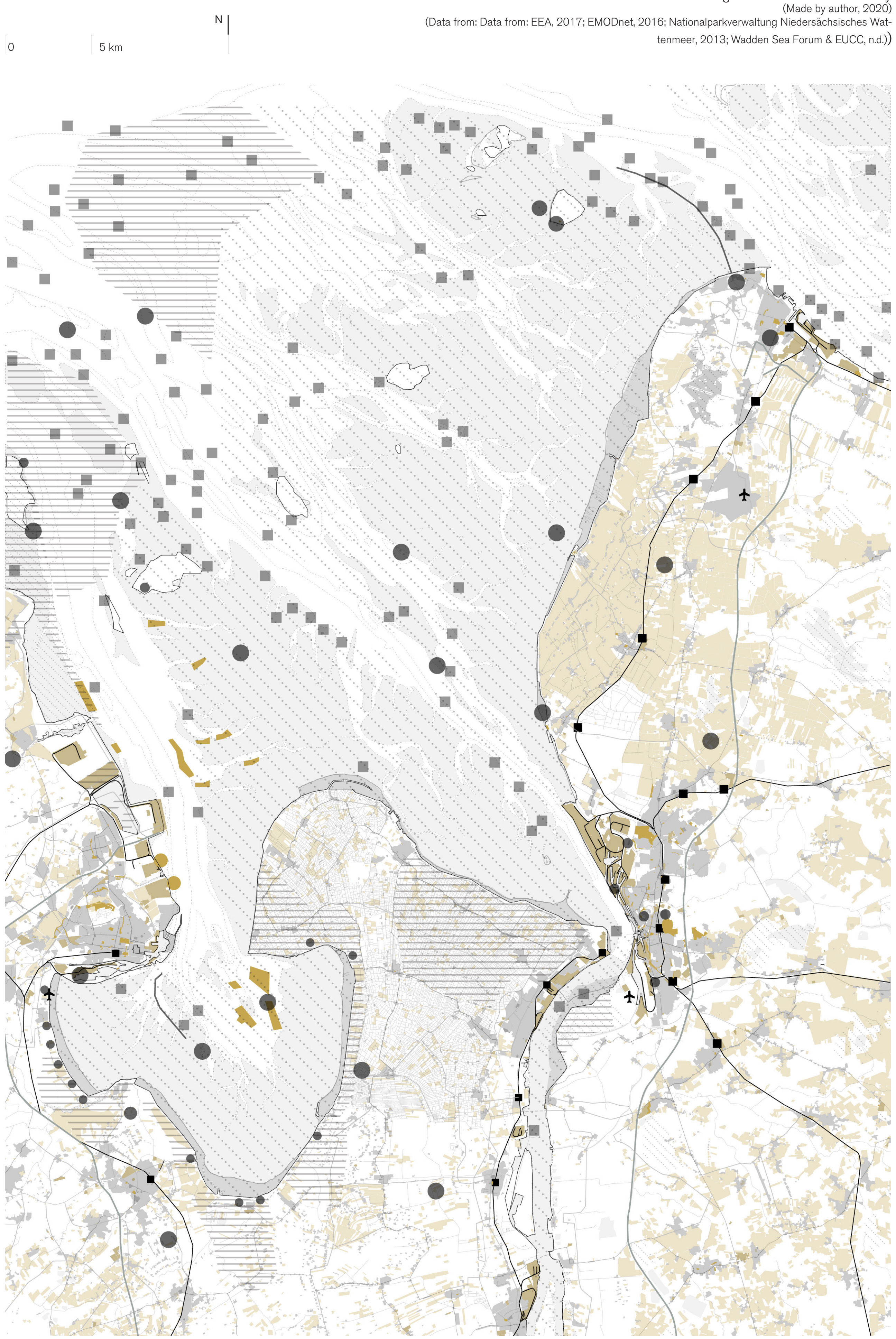
Fig. 50 Demographics of Weser Estuary.
(Made by author, 2020)
(Data from (Landesamt für StatistikNiedersachsen, 2016b; Staatisches Landesamt Bremen, 2019)

Weser Estuary - Cultural identity & activities

As visible in the diagram and map the most populated areas are Bremerhaven, Wilhelmshaven, Cuxhaven, and Nordenham. Besides the high rates of foreign inhabitants, Wesermarsch's society is shrinking more than the general trend of births not exceeding the aging population.

- WInd farms
- Cables & pipes
- Mariculture (mussels)
- Airports
- Shipwrecks
- Landmarks
- Park
- Industries
- Agricultural land
- Protected areas
- Conservation areas
- Prohibited mussel mariculture
- Roads
- Railroad & stations
- Saltmarshes
- Population
- Intertidal mudflats
- Waterways
- Balthymetry
- Sea

Fig. 51 Urban cultural identity
(Made by author, 2020)
(Data from: Data from: EEA, 2017; EMODnet, 2016; Nationalparkverwaltung Niedersächsisches Wattenmeer, 2013; Wadden Sea Forum & EUCC, n.d.))



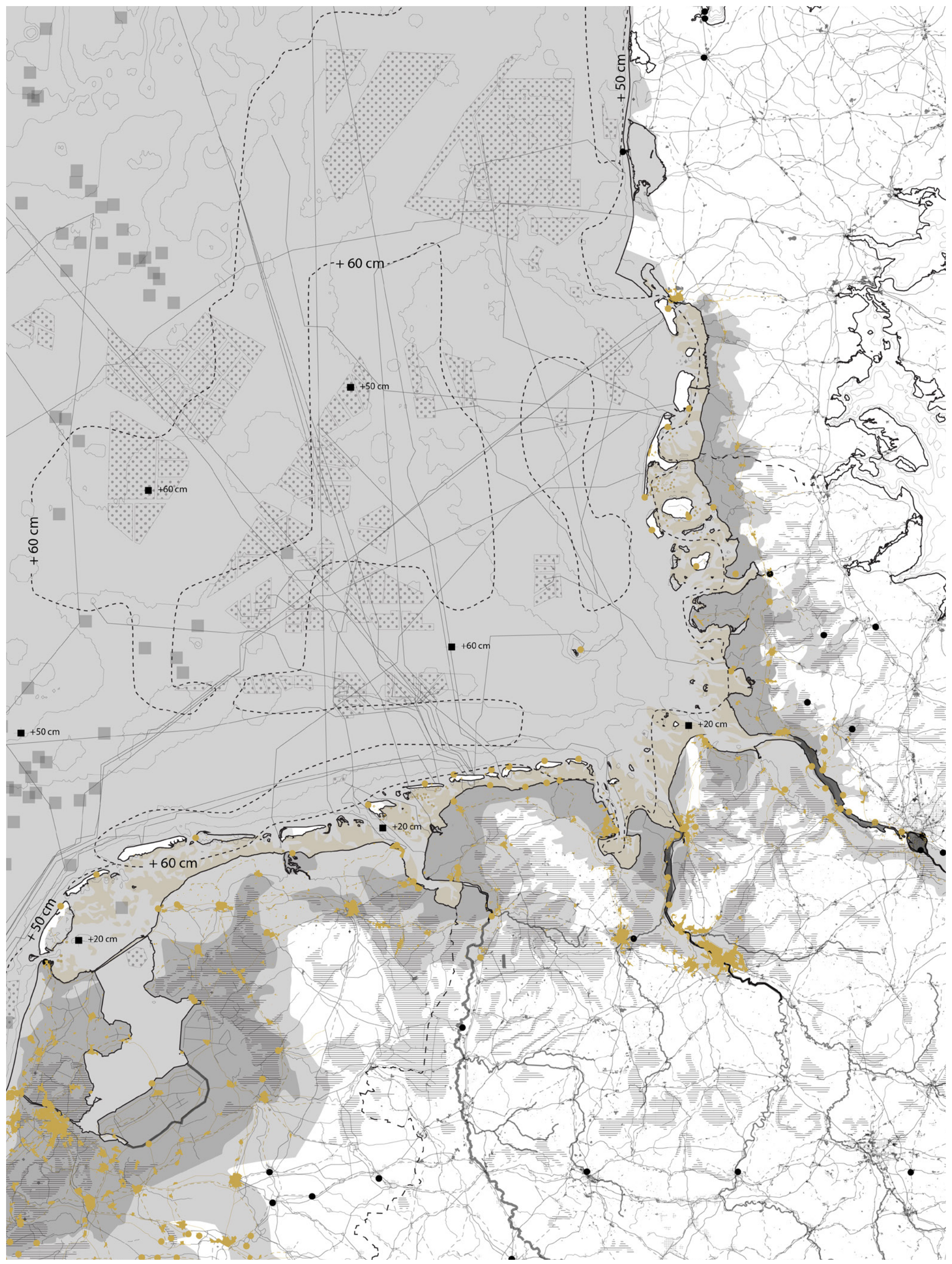
Safety

Although flood protection in the Wadden Sea is not only relying on hard infrastructure (dikes) but also soft infrastructure (saltmarshes, barrier islands), the RCP 8.5 scenario for 2100 predictions shows that most of the coast and barrier islands will be continuosly flooded. Starting from the territories in the Netherlands to Denmark, following the movement of the currents and high tidal movement. development is concentrating mostly on renewable energy (Baer & Nehls, 2017). The lack of big barrier islands and the fact that it relies on scattered thin salt marshes and dikes most of the Weser Estuary populated areas, landmarks and agricultural fields will be periodically inundated and the conserved and valuable wetlands permanently flooded (Becherer et al., 2018; Kabat et al., 2012).

Fig. 52 Regional Sea Level Rise by 2100.
(Made by author, 2020)
(Data from: Blatter & Roux, 2016; BSH, n.d.; de Groot et al., 2017; DWD, 2015; EEA, 2017; Geobasis- DE/ BKG, 2020; Transitional Territories Studio, 2018; Wadden Sea Forum & EUCC, n.d.; Zijlstra et al., 2017)

N

0 50 km



Regional Scale

- Predicted flood [RCP 8.5]
- Predicted flood [RCP 2.6]
- Added centimeters of sea level rise
- Subsidence + 20 mm per year
- Populated areas at risk
- Port & airports
- Waterways
- Wind farms
- Oil rigs
- Cables & pipes
- Mariculture
- Rail road
- Roads
- Balthymetry
- Permanently sumerged intertidal mudflats

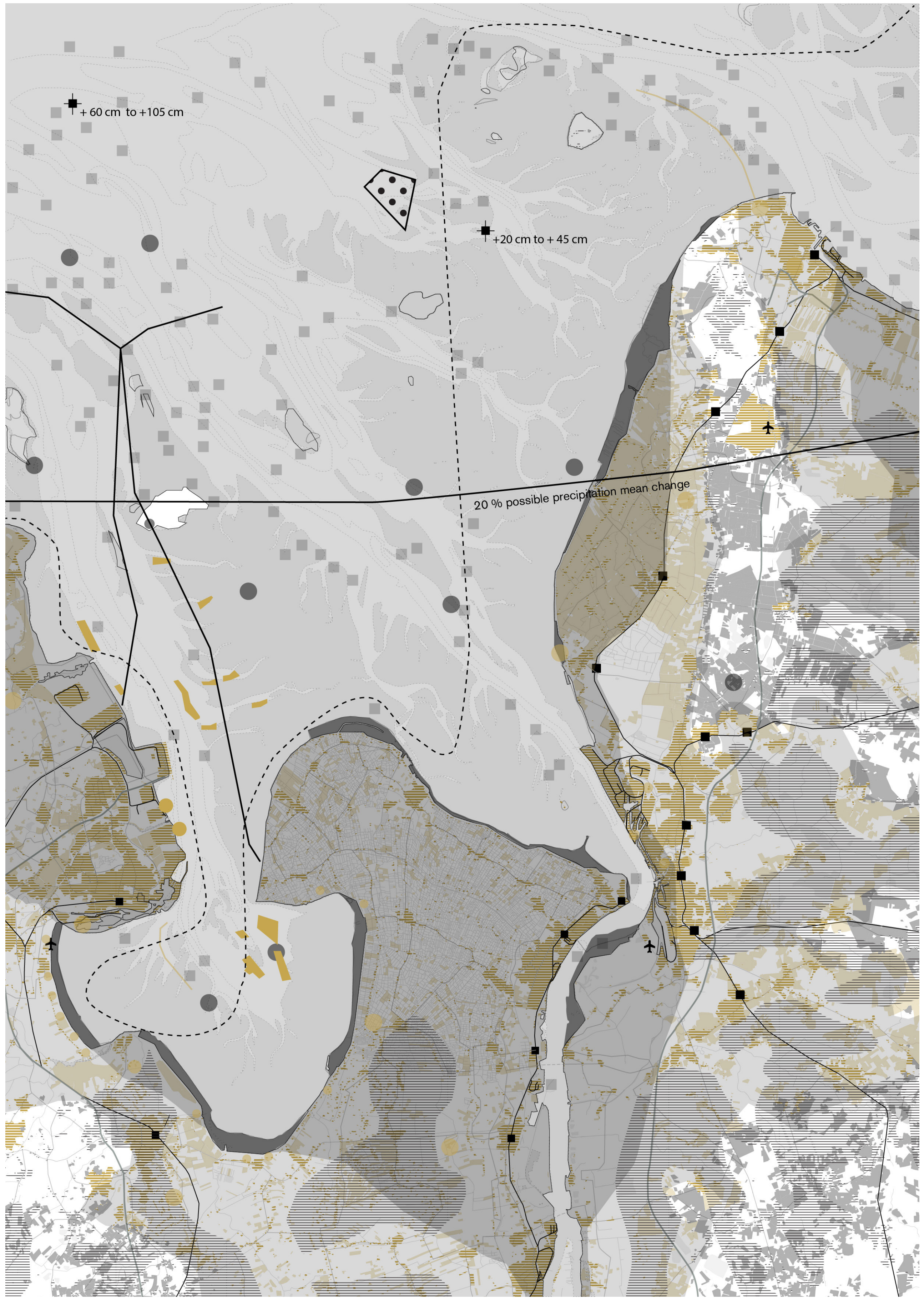
Urban Scale

- Predicted flood [RCP 8.5]
- Predicted flood [RCP 2.6]
- Added centimeters of sea level rise
- Subsidence + 20 mm per year
- Affected population
- Airports
- Waterways
- Wind farms
- Cables & pipes
- Mariculture
- Roads
- Rail road
- Balthymetry
- Permanently sumerged intertidal mudflats
- Precipitaion mean change
- Shipwracks & landmarks
- Agricultural land at risk
- Agricultural land

Fig. 53 Urban Sea Level Rise by 2100.
(Made by author, 2020)
(Data from: Blatter & Roux, 2016; BSH, n.d.; DWD, 2015; EEA, 2017; Geobasis- DE/ BKG, 2020; Wadden Sea Forum & EUCC, n.d.; Zijlstra et al., 2017))

N

0 5 km



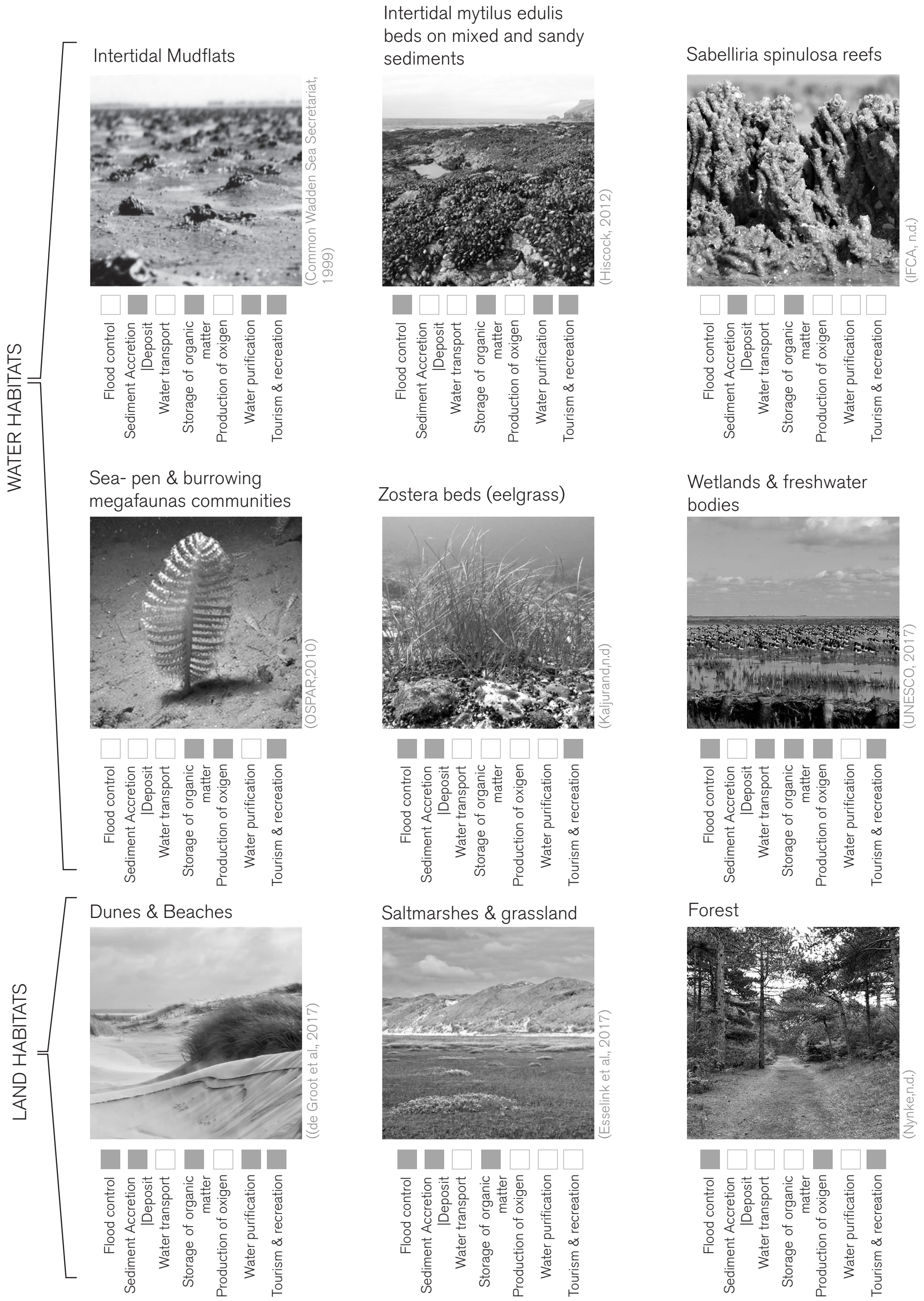
ANALYSIS

Natural Habitats & Biota

The Wadden Sea region is not only locally valued by different species, but also globally since it hosts nursing and overwintering grounds for birds migrating from East Africa to the Arctic and cold-water fish species (eels, blue tuna & salmon) from the Atlantic (Blew et al., 2017; van Roomen et al., 2017). Biodiversity flourished in this region due to the availability of different habitats created by the variation of water-related landscapes (sublittoral, eulittoral and supralittoral areas) and land vegetation (saltmarshes, dunes & beaches, forests & meadows). Due to anthropogenic activities and climatic changes (sea temperature rise), fragile habitats such as zoostera beds (eelgrass), mytilus edulis beds (oyster reefs), and sabellaria spinulosa reefs are increasingly declining (Dolch et al., 2017).

Fig. 54.East Atlantic Migration.
(Made by author, 2020)
(Data from: Nationalparkverwaltung Niedersächsisches Wattenmeer, 2013)

Fig. 55. Regional Natural Habitat.
(Made by author, 2020)
(Data from: Baptist et al., 2019; Blew et al., 2017, 2017; EEA, 2017; Folmer et al., n.d.; HZG, 2014; IUCN, 2016; Jensen et al., n.d.; Transitional Territories Studio, 2018; Wadden Sea Forum & EUCC, n.d.; Waddensleutels, 2011; WWF, n.d.)



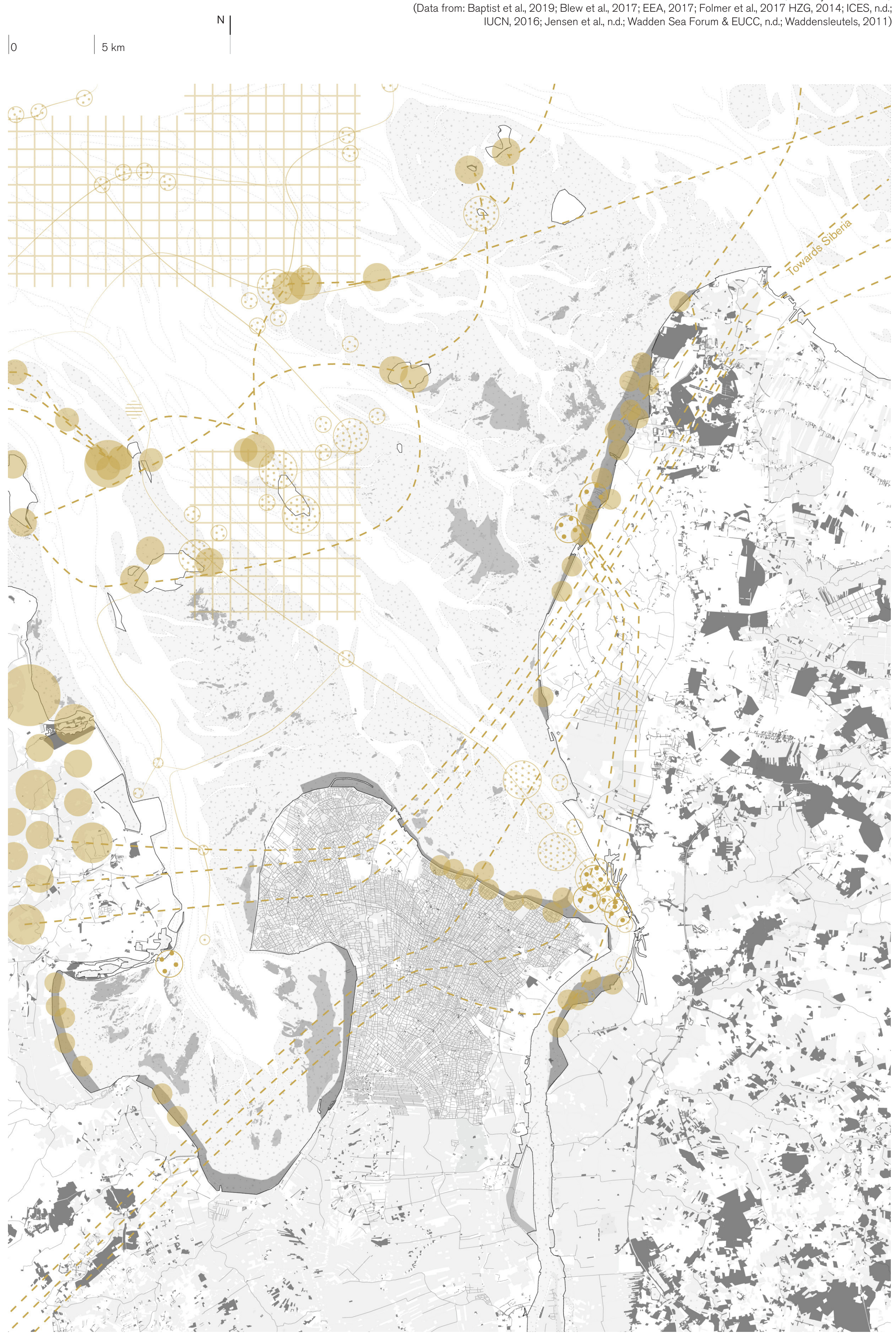
Weser Estuary - Natural Habitats & Biota

The identified habitats serve different ecosystem functions to secure life, where flood control stands out within the most common services. Although hosting a great number of marine mammals and birds, the Weser Estuary has few benthic species and flows of fish communities.

- Migratory & nesting birds
- Purpoise
- Grey seal | Harbour seal | Walrus
- Cold water fish concentration
- Zoostera beds (Eelgrass)
- Mytilus edulis beds
- Saltmarshes
- Forest
- Meadow
- Intertidal mudflats
- Waterways
- Balthymetry
- Sea

Fig. 56 Habitats of the sea.
(Made by author, 2020)
(Data from: de Groot et al., 2017; Dolch et al., 2017; Drent et al., n.d.; Esselink et al., 2017; IUCN, 2016; MEA, 2005)

Fig. 57 Urban natural habitat
(Made by author, 2020)
(Data from: Baptist et al., 2019; Blew et al., 2017; EEA, 2017; Folmer et al., 2017 HZG, 2014; ICES, n.d.; IUCN, 2016; Jensen et al., n.d.; Wadden Sea Forum & EUCC, n.d.; Waddensleutels, 2011)



ANALYSIS

Estuarine characterictics: freshwater & salinity

Due to augmenting air temperatures (highest in June- August) water temperatures are also increasing, almost leveling to the atmospheric degrees. In general, we can observe extremely dry summers (July) and cold rainy months (January) that cause the delay of vegetation bloom. In the map, we can depict the production of oxygen by benthic species, which are sensitive to sea temperature and salinity rates. Saltmarshes are valuable species that not only protect the coast from eroding but can also cope with an extension with salinity (Esselink et al., 2017). The map also depicts on the Weser river catchment that extends in the German continental grounds, allocating many ports (Bremen) and industrial areas (mining & car manufacturing).

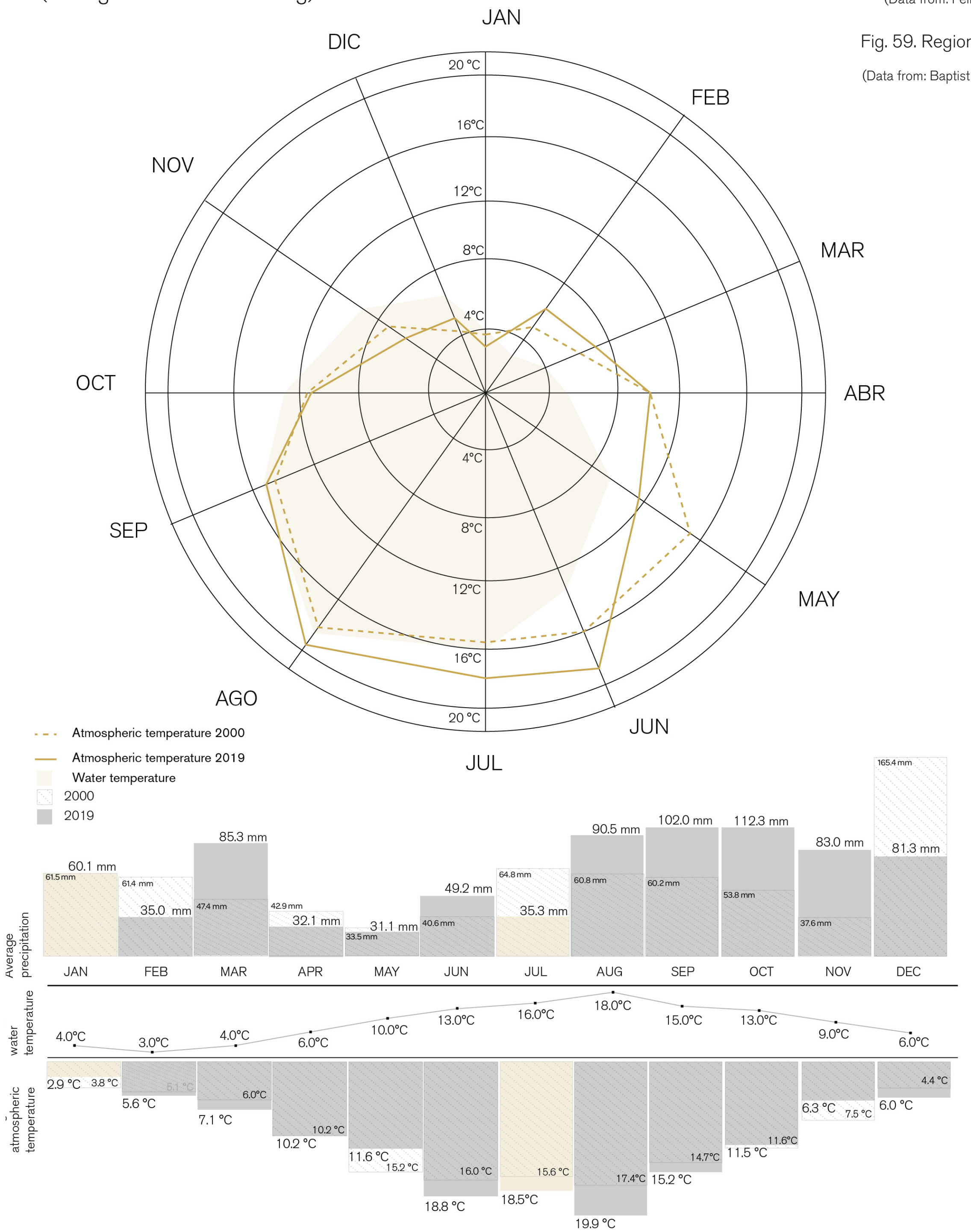
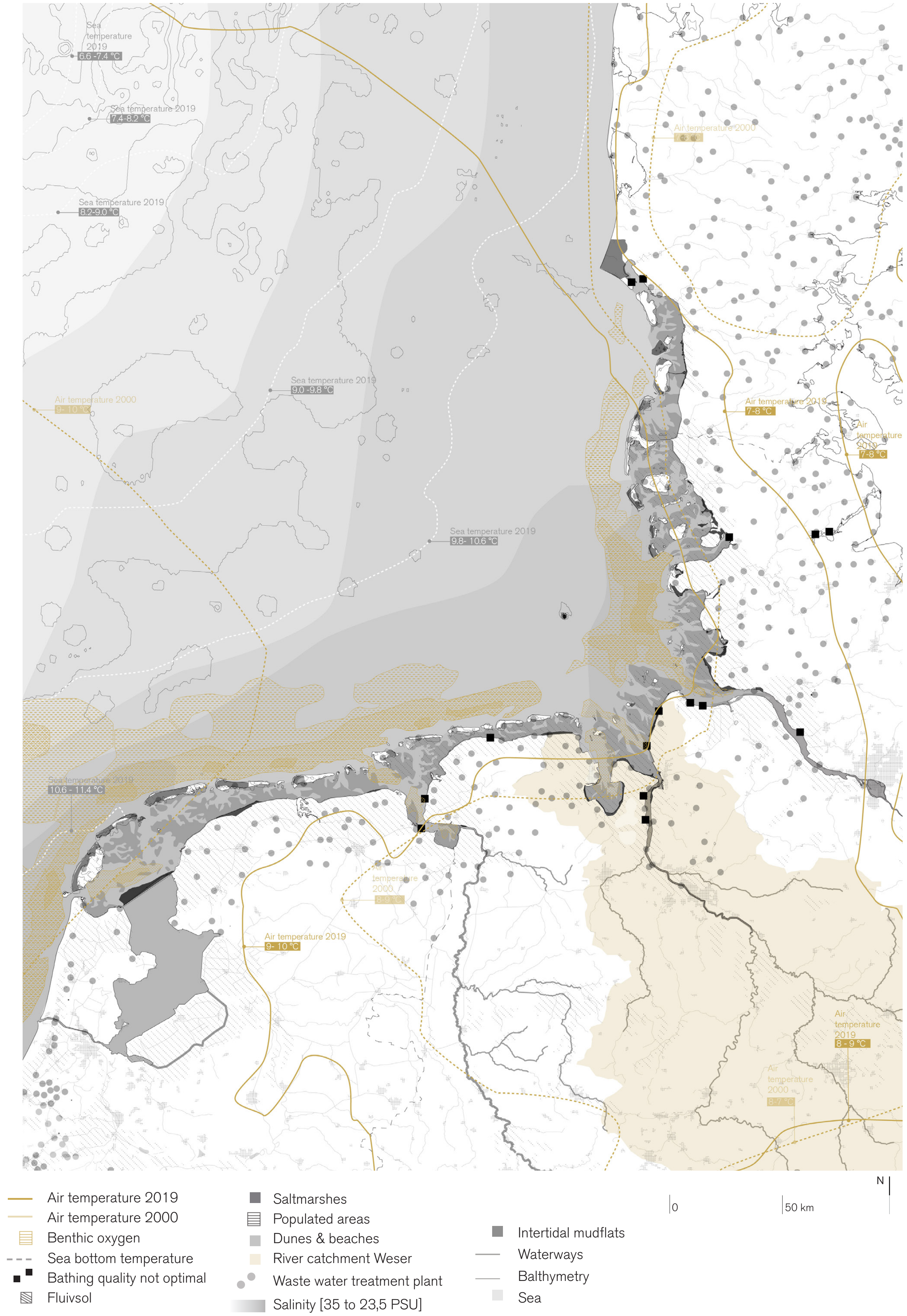


Fig. 58. Temperature
(Made by author, 2020)
(Data from: FeiReu GbR, 2019; Wetterkontor, 2019)

Fig. 59. Regional Estuarine characteristics.
(Made by author, 2020)
(Data from: Baptist et al., 2019; EEA, 2017; HZG, 2014; Transitional Territories Studio, 2018)



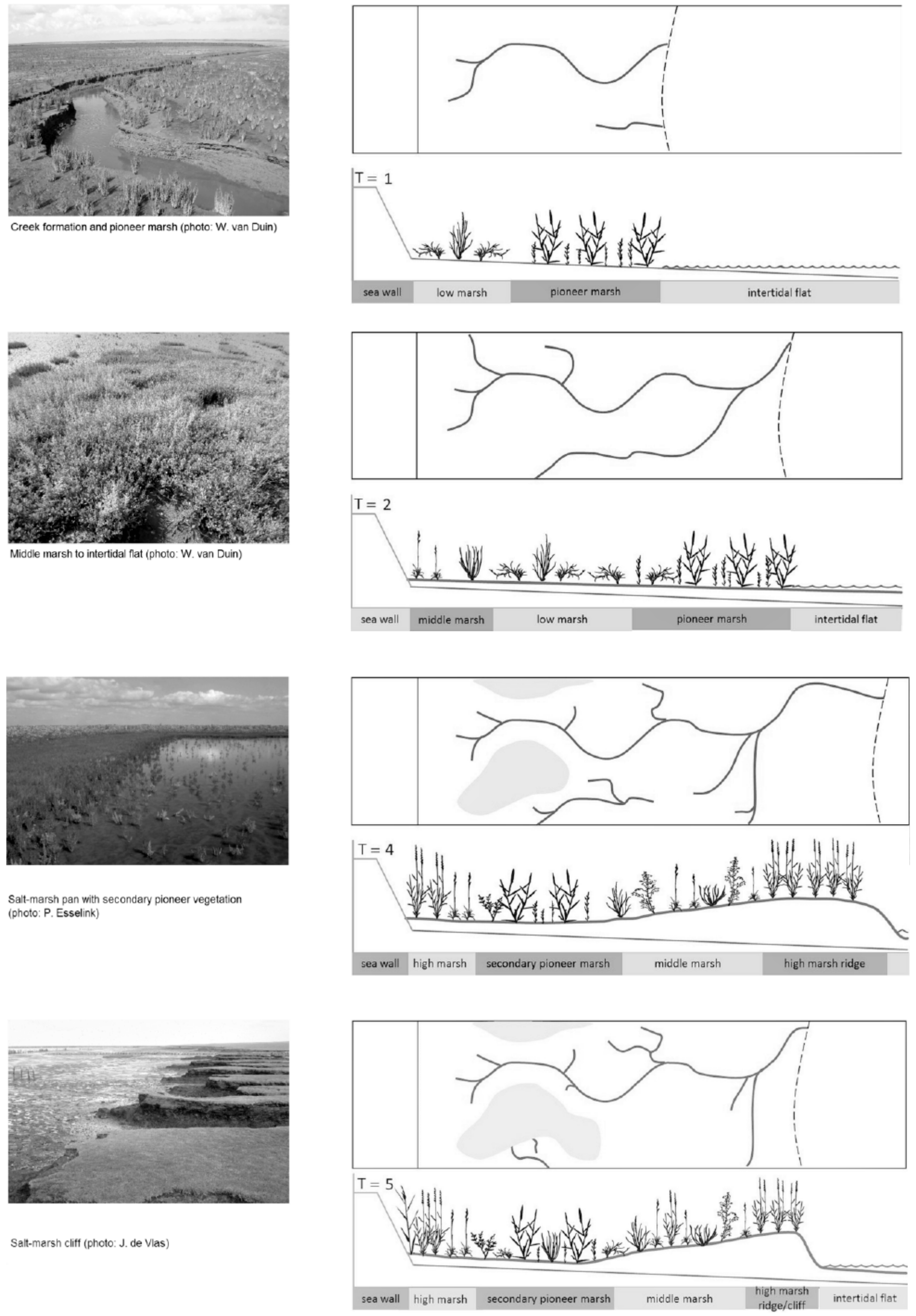


Fig. 60 Salt marsh experiments
(Modified by author, 2020)
(Taken from Esselink et al., 2017)

Weser Estuary - Freshwater & salinity

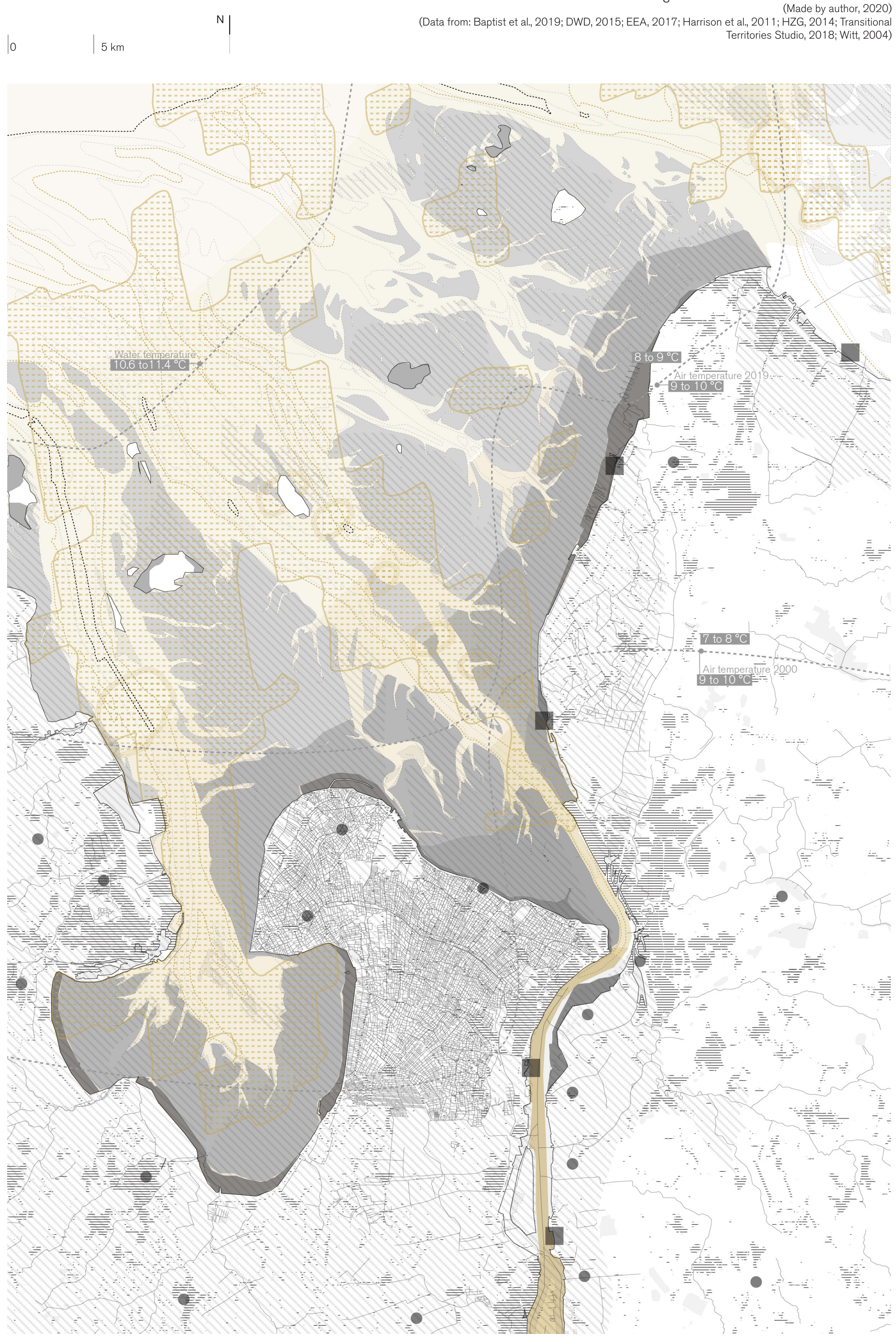
The diagram shows ', various restoration experiments (that) have been carried out during the past decades, such as filling up parts of the drainage system and removing the topsoil' to create saltmarsh landscapes. In the map, we can identify scattered salt marshes mostly from the typology of middle marshes to intertidal flat. Salinity rates are lower in the areas of the intertidal mudflats.

- Air & water temperature 2019
- Air temperature 2000
- Benthic oxygen
- Bathing quality not optimal
- Fluivsol [sodic & saline soils]
- Saltmarshes
- Dunes & beaches
- Waste water treatment plant
- Intertidal salinity [30 to 5 PSU]

Supratidal salinity
- Polyhaline [18-30 PSU]
- Mesohaline [5-18 PSU]
- Oligohaline [0.5 -5 PSU]

- Populated areas
- Intertidal mudflats
- Waterways
- Balthymetry
- Sea

Fig. 61 Urban estuarine characteristics
(Made by author, 2020)
(Data from: Baptist et al., 2019; DWD, 2015; EEA, 2017; Harrison et al., 2011; HZG, 2014; Transitional Territories Studio, 2018; Witt, 2004)



Health

Salinity rates are increasing due to more evaporation of freshwater because of the increase of water and atmospheric temperatures. This not only affects benthic species that produce oxygen, but groundwater which directly influences the salinity in soils (damage to vegetation & crops). The RCP 8.5 scenario also predicts the possible delay of vegetation bloom by one month, which would affect most land species and non- coastal birds. Not just cold water species and migratory fish might colonize northern areas, migratory birds routes might change due to less availability of food and breeding grounds (sea level rise). This also applies to species from warmer waters of the Atlantic, which speculatively will migrate to the North Sea, since temperatures are more suitable for them there. These new alien species could catalyze flourishing events, but they also might take over pools of several endemic species (Büttger et al., 2017).

0 50 km N

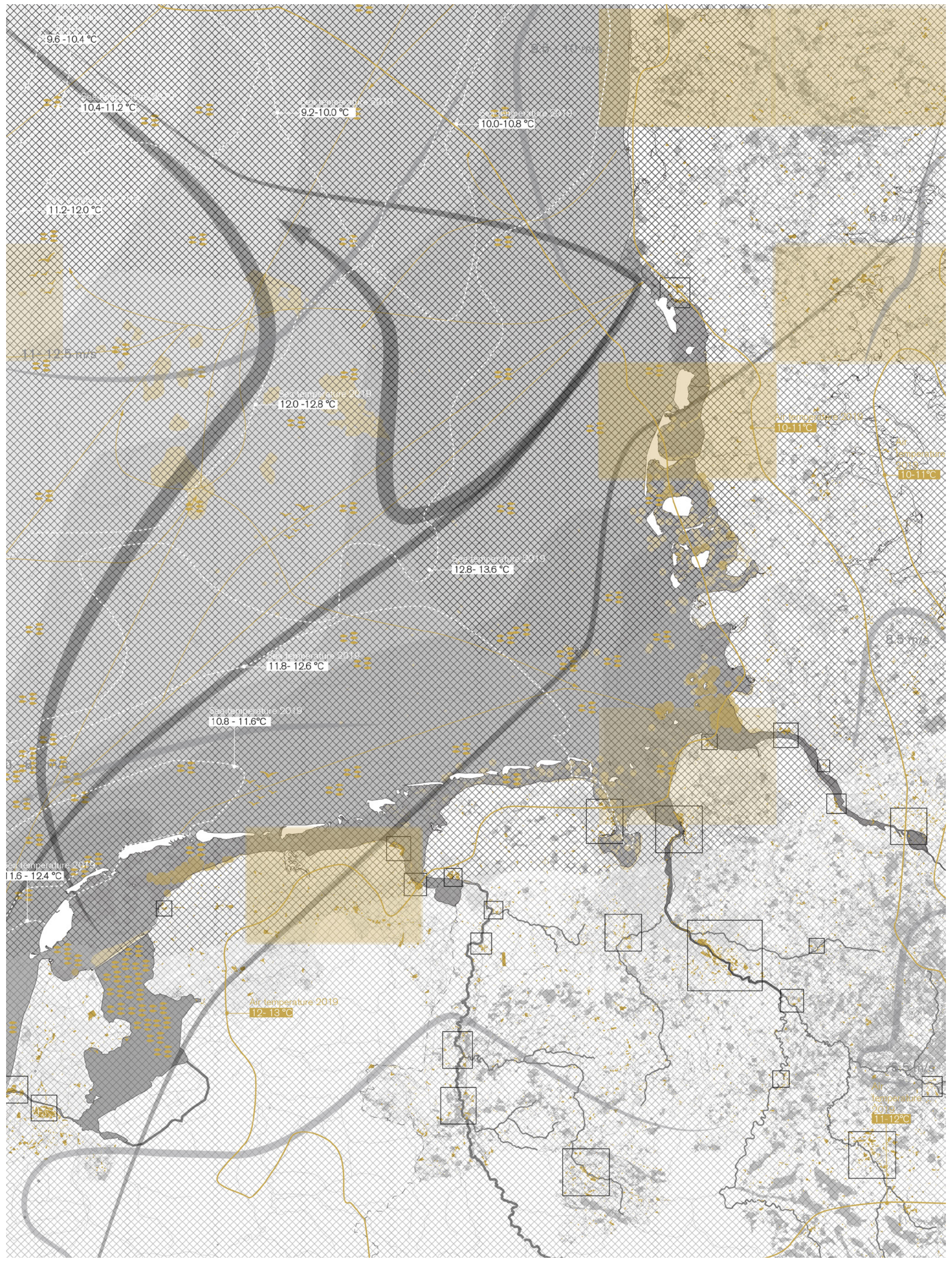


Fig. 62 Regional Sea Temperature Rise by 2100.
(Made by author, 2020)
(Data from: Baptist et al., 2019; Blew et al., 2017; Büttger et al., 2017; DWD, 2015; EEA, 2017; Folmer et al., 2017; HZG, 2014; ICES, n.d., n.d.; IUCN, 2016; Jensen et al., n.d.; Transitional Territories Studio, 2018; Wadden Sea Forum & EUCC, n.d.; Waddensleutels, 2011)

Regional Scale

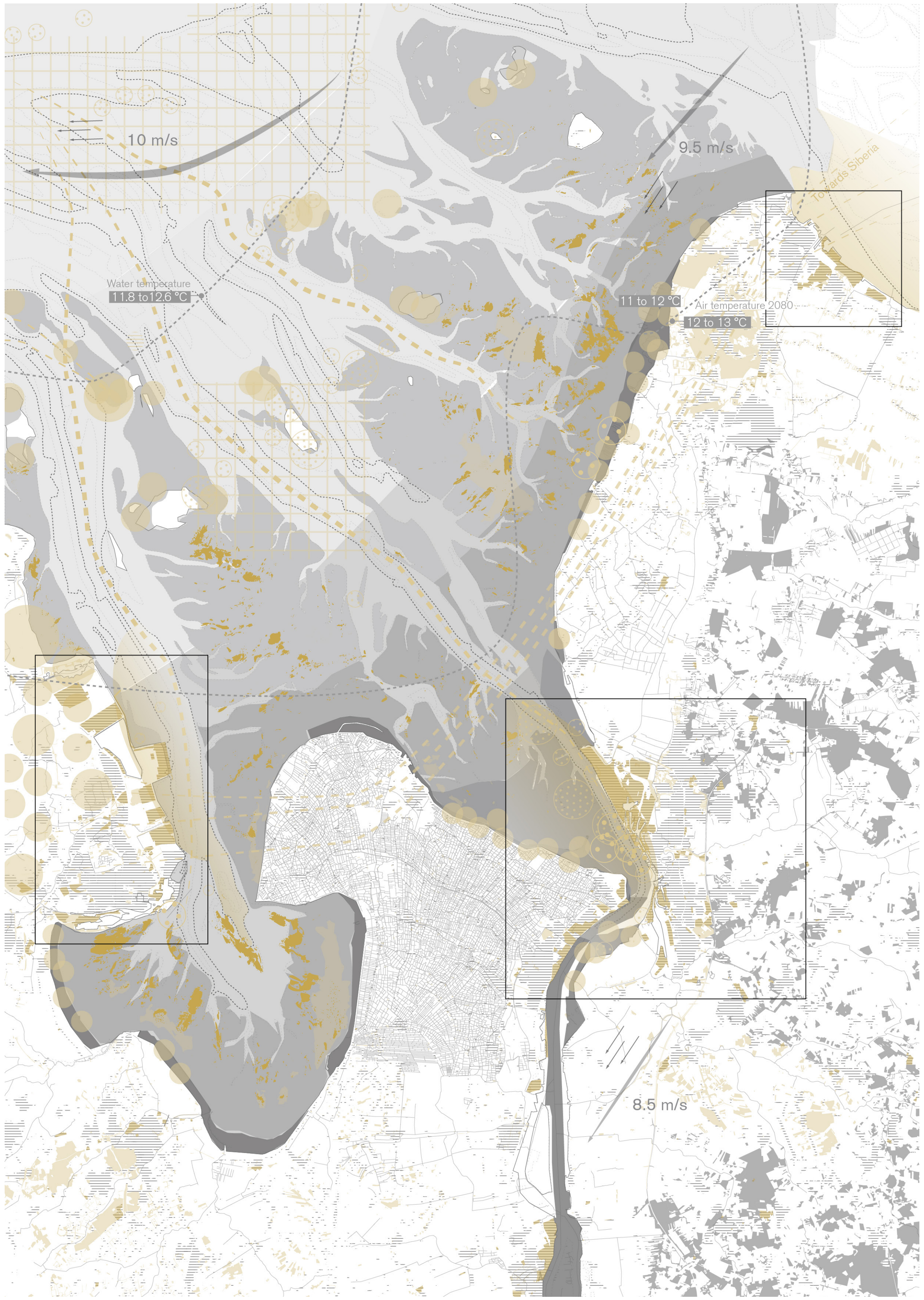
- Predicted air temperature
- Predicted sea temperature
- Predicted wind speed & direction
- Invasive alien species concentration
- Spectulative migrating birds flow
- Benthos concentration
- Cold fish migration
- Breeding birds
- Predicted precipitation pattern
- Cooling water exhaust [industry]
- Industrial growth
- Sea pen & burrowing megafauna communities
- Zoostera beds [eelsgrass]
- Mytilus edulis beds
- Sabellaria spinulosa reefs
- Salt marshes
- Forest
- Meadow
- Intertidal mudflats
- Salinity [60 to 18 PSU]
- Balthymetry
- Waterways

Urban Scale

- Predicted air& sea temperature
- Predicted wind speed & direction
- Spectulative migrating birds flow & Cold fish migration
- Cooling water exhaust [industry]
- Industrial growth
- Zoostera beds [eelsgrass]
- Mytilus edulis beds
- Salt marshes
- Forest
- Meadow
- Intertidal mudflats
- Supratidal salinity [40 to 5 PSU]
- Intratidal salinity [60 to 18 PSU]
- Balthymetry
- Waterways

Fig. 63. Urban Sea Temperature Rise by 2100.
(Made by author, 2020)
(Data from: Baptist et al., 2019; Blew et al., 2017; Büttger et al., 2017; DWD, 2015; EEA, 2017; Folmer et al., 2017; HZG, 2014; ICES, n.d.; IUCN, 2016; Jensen et al., n.d.; Transitional Territories Studio, 2018; Wadden Sea Forum & EUCC, n.d.; Witt, 2004)

0 5 km N

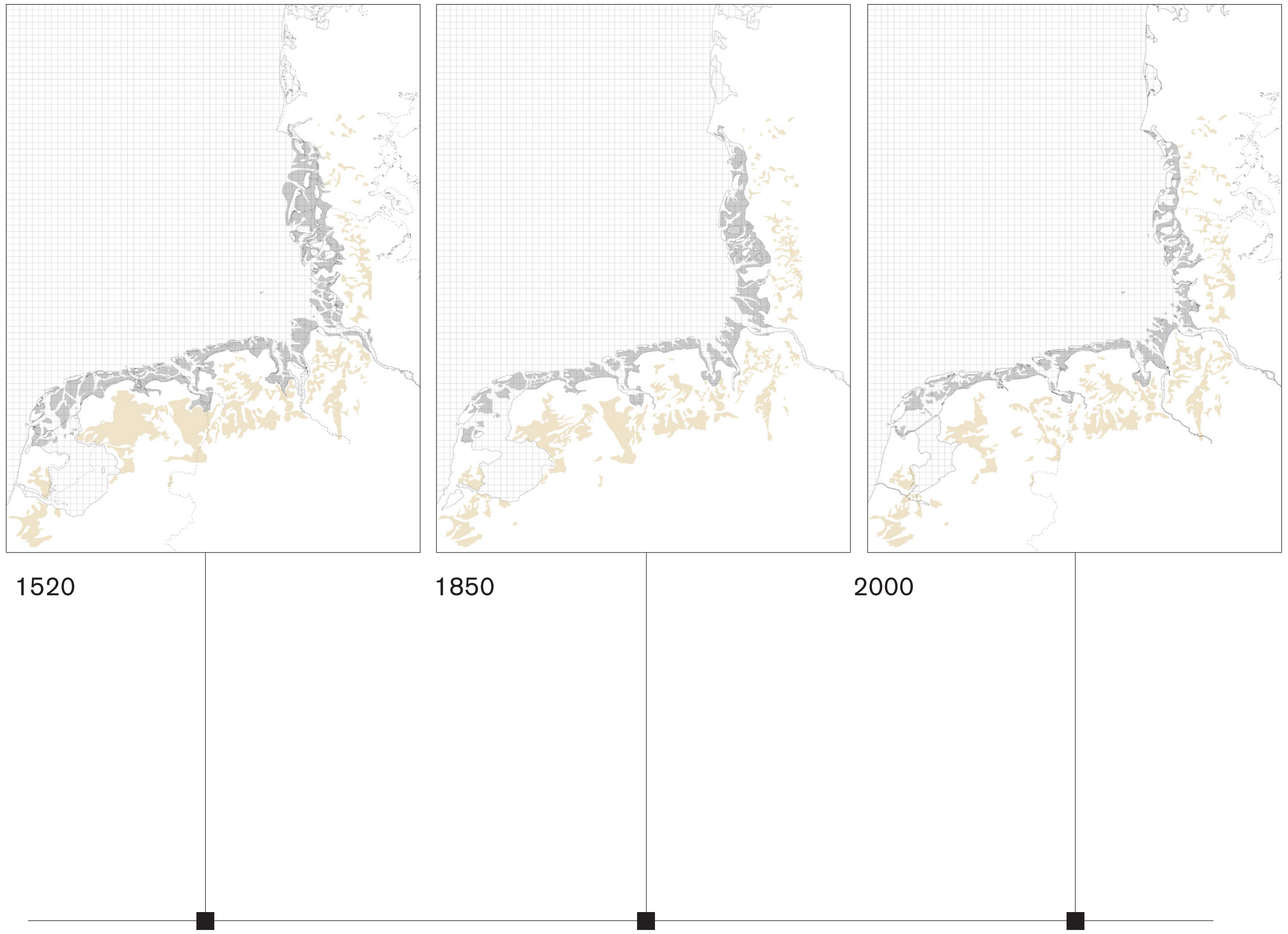


ANALYSIS
Hydrodynamics: Morphology & sediments

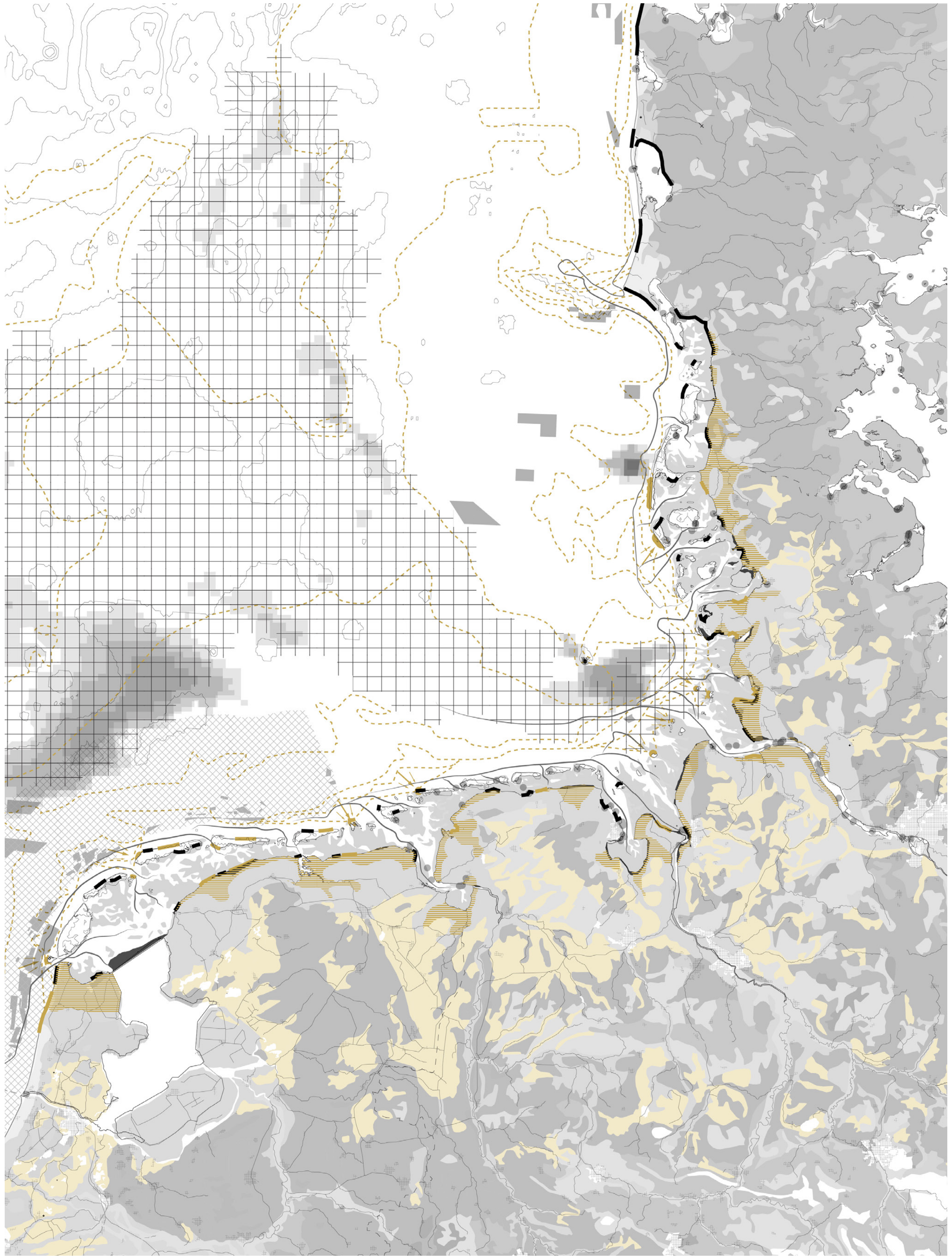
Throughout time humans and water have claimed large portions of land of the coast. Human alterations already started 1000 years ago with dike building and wetland drainage. Initiated in the Netherlands large portions of peat soil were drained or covered by sand, that allow the morphological change of the coast, the most significant changes being the creation of the Ijsselmeer, the Dollard, and in the Jade Bight. Most of the Wadden Sea region is formed by sand at the sea bottom but also in islands (mostly fine-grained) fluvisol (saline and sodic soil) Histosol (peat, moist) and scattered parts by Podzol (coniferous vegetation) so that arable crops can hardly grow on these grounds. Sand and fluvisol are easily transported by water, and therefore are prone to erosion or contribute to accretion of the coast. Sand sediment is dredged and extracted from the bottom to maintain the morphology of the coast (mostly islands because of wave shear stress) or used for construction (coarse sand for concrete) (Schultze & Nehls, 2017).

Fig.64. Geomorphological Evolution
(Made by author, 2020)
(Data from: Oost et. al, 2017)

Fig. 65. Regional Hydrodynamics.
(Made by author, 2020)
(Data from: Harrison et al., 2011; HZG, 2014; Oost, Winter, et al., 2017)



- - - Current coastline
— Coastline
Peat
Intertidal mudflats
Sea



Soil types
Arenosol [Acidic]
Cambisol [Boreal vegetation]
Fluvisol [sodic & saline soil]
Histosol [Peat]
Podzol [Coniferous vegetation]
Stagnosol [oxygen deficiency]
Technosol [landfills, pavements]

Sediment porosity
Accretion
Erosion
Anthropogenic alterations
Flows of water
Saltmarshes
Carbon in sediments

Wave shear stress
[4,25 - 0 N/m_2]
Sediment extraction (planned & in use)
Intertidal mudflats
Waterways
Balthymetry
Populated areas

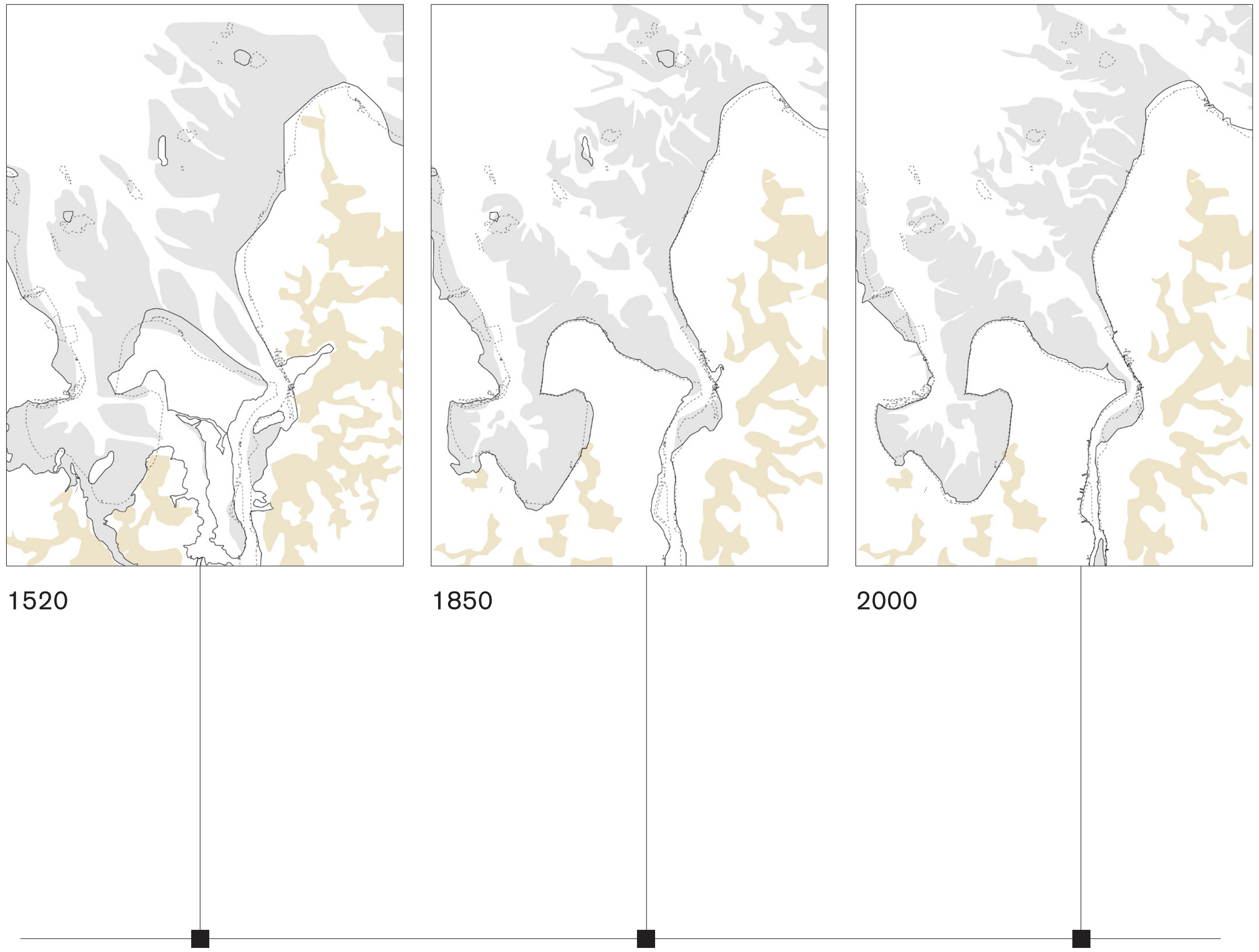


Fig. 66 Geomorphological Evolution.
(Modified by author, 2020)
(Data from: Behre, 1999; Homeier, 1974; Ulrich Lamm, 2014)

Weser Estuary - Hydrodynamics: Morphology & sediments

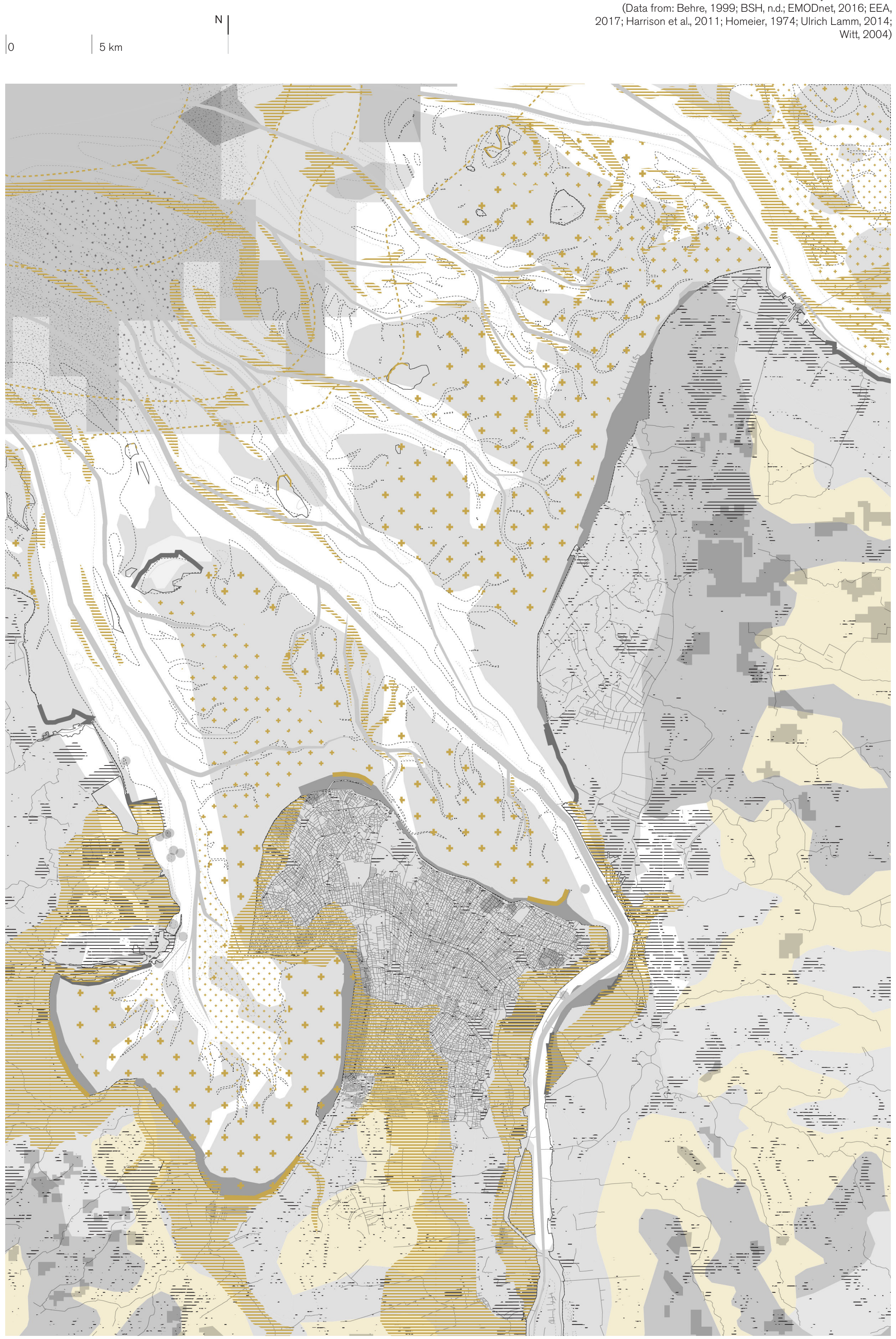
In the Weser Estuary, human alterations mostly concentrate around the Jade Bight, which formerly belonged to the estuarine structure, and today forms a separate waterbody. The intertidal mudflats are supplied by sediments from the eroding small islands and estuarine borders.

Soil types
- Arenosol [Acidic]
- Cambisol [Boreal vegetation]
- Fluvisol [sodic & saline soil]
- Histosol [Peat]
- Podzol [Coniferous vegetation]
- Stagnosol [oxygen deficiency]
- Technosol [landfills, pavements]

- Coarse sand areas
- Accretion
- Erosion
- Anthropogenic alterations
- Flows of water
- Saltmarshes
- Sediment porosity

- Wave shear stress [4,25 - 0 N/m$_2$]
- Sediment extraction (planned & in use)
- Intertidal mudflats
- Waterways
- Balthymetry
- Populated areas

Fig. 67 Urban hydrodynamics
(Made by author, 2020)
(Data from: Behre, 1999; BSH, n.d.; EMODnet, 2016; EEA, 2017; Harrison et al., 2011; Homeier, 1974; Ulrich Lamm, 2014; Witt, 2004)



ANALYSIS

Port activities: Logistics & industry

The Wadden Sea region has medium (such as Den Helder, Eemshaven, Emden and Wilhelmshaven) to small harbors (such as Emden, Cuxhaven, and Norden). Most ports allocate fisheries and small tourism or service vessels. Nevertheless, the biggest harbors of Germany such as Hamburg, Bremerhaven, and Wilhelmshaven are located around and within the region, having to deal with the restrictions of the protected UNESCO World Heritage site. Port activities have attracted many industries that handle hazardous materials (such as heavy metals and chemicals), add to emissions to generate energy (coal, waste & nuclear), and pour cooling water for machinery to rivers.

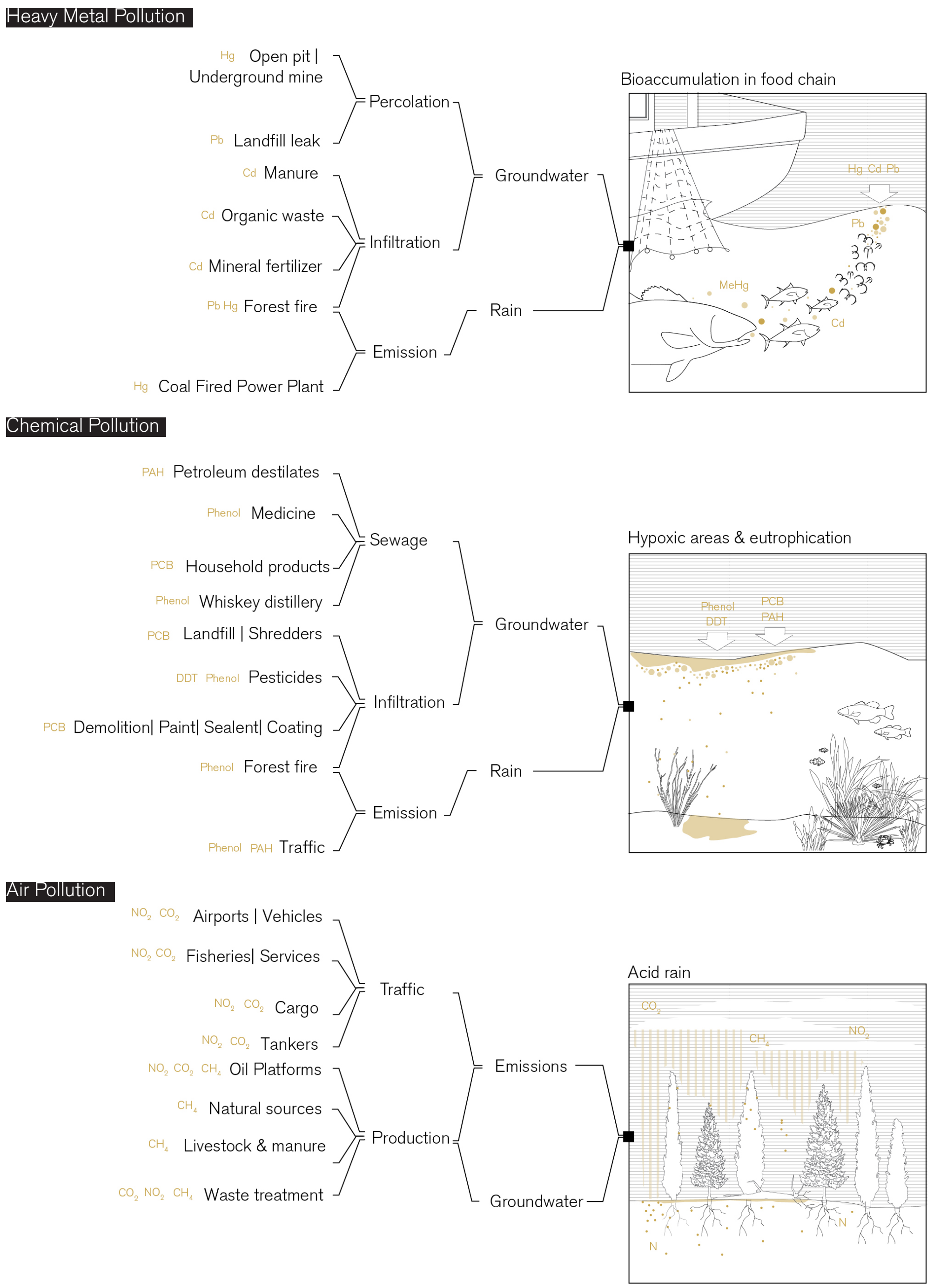
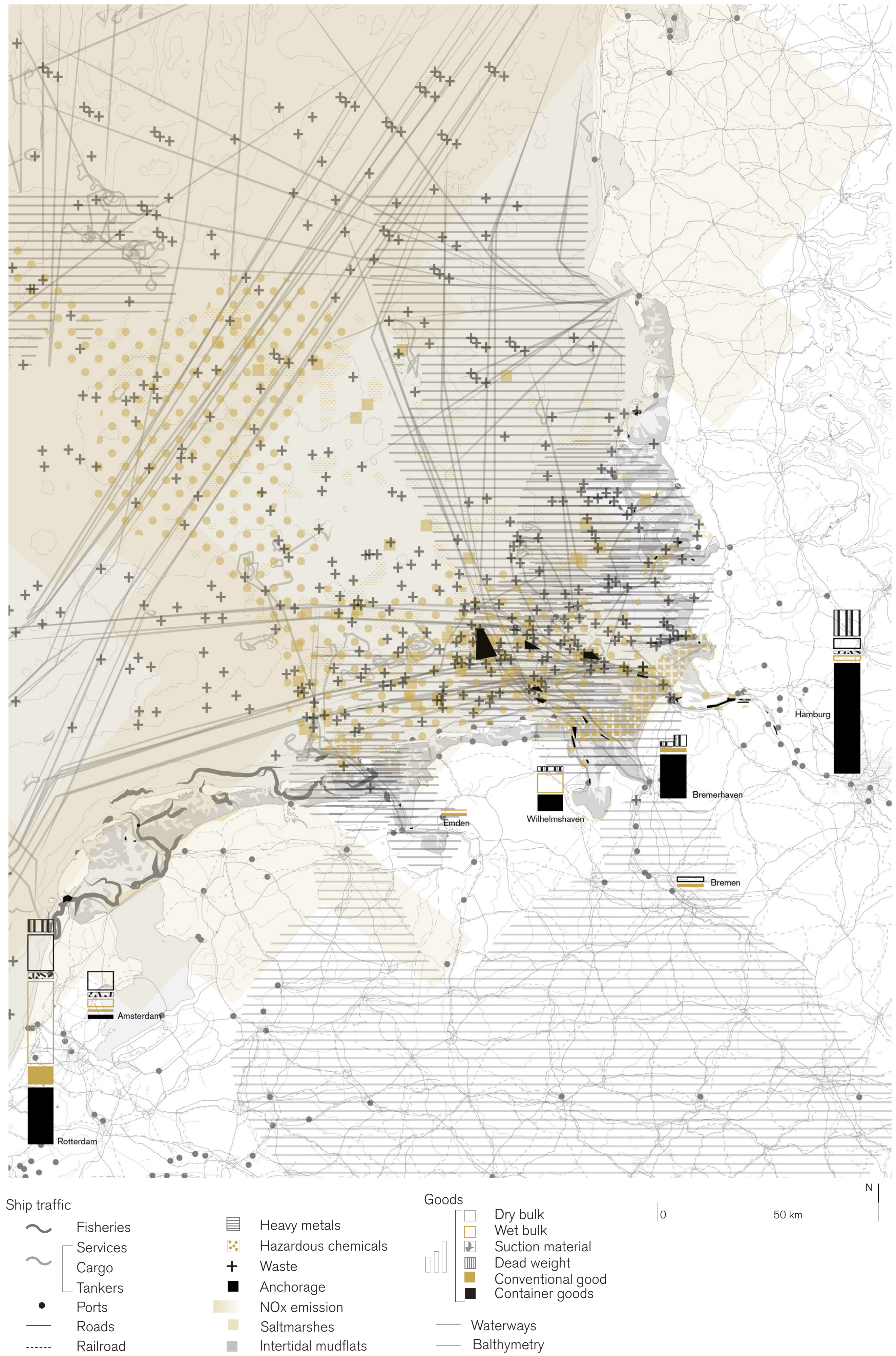


Fig. 68. Process of port & industrial externalities.
(Made by author, 2020)
(Data from: OSPAR, 2017)

Fig. 69. Regional Port activities.
(Made by author, 2020)
(Data from: Bahlke, 2017; BSH, n.d.; EMODnet, 2016; EEA, 2017; HZG, 2014; Lado et al., 2008; OSPAR, 2017)



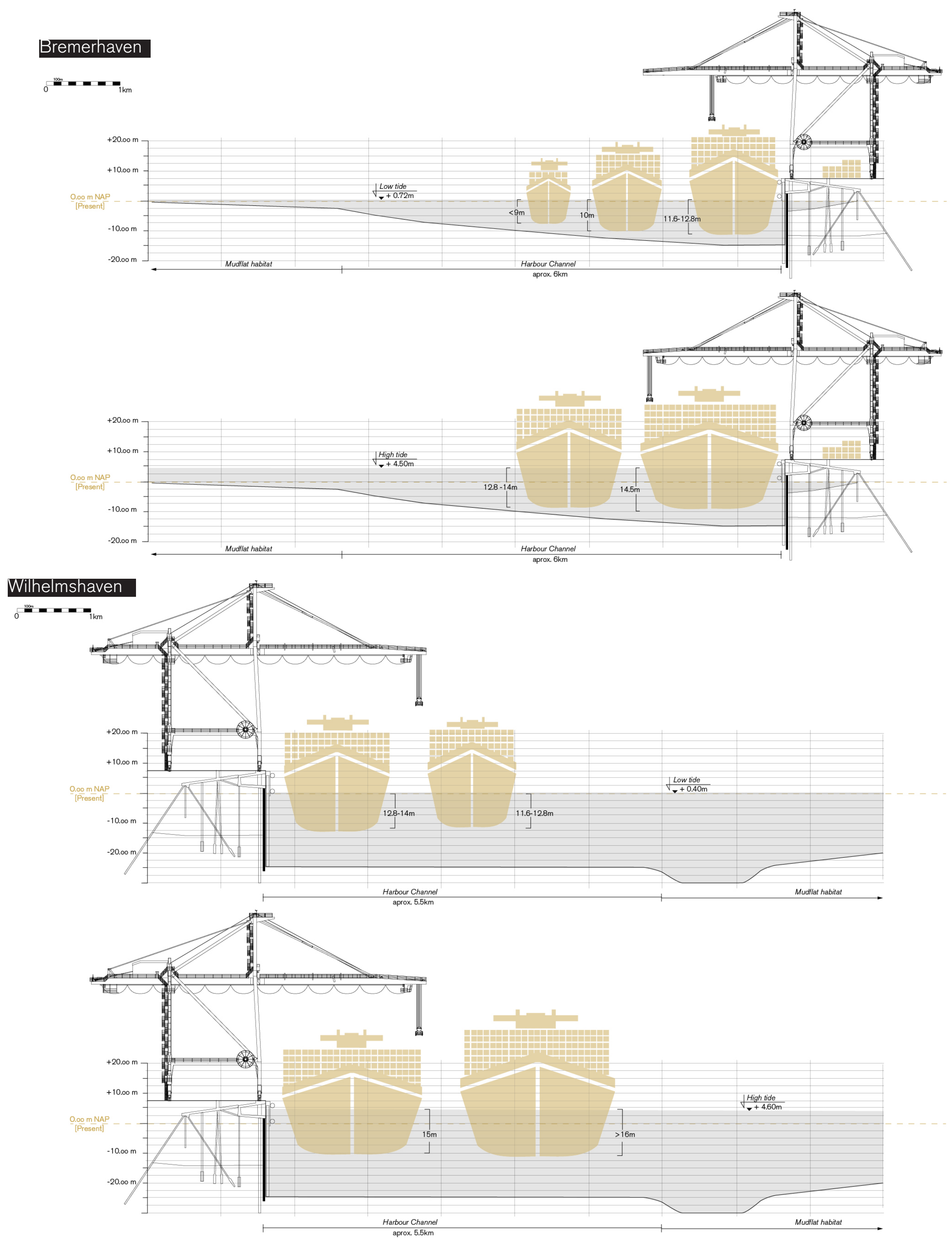


Fig. 70 Channel diameters.
(Modified by author, 2020)
(Data from: Mapbox, 2019; Vesseltracking, 2013)

Weser Estuary - Port activities: Logistics & Industry

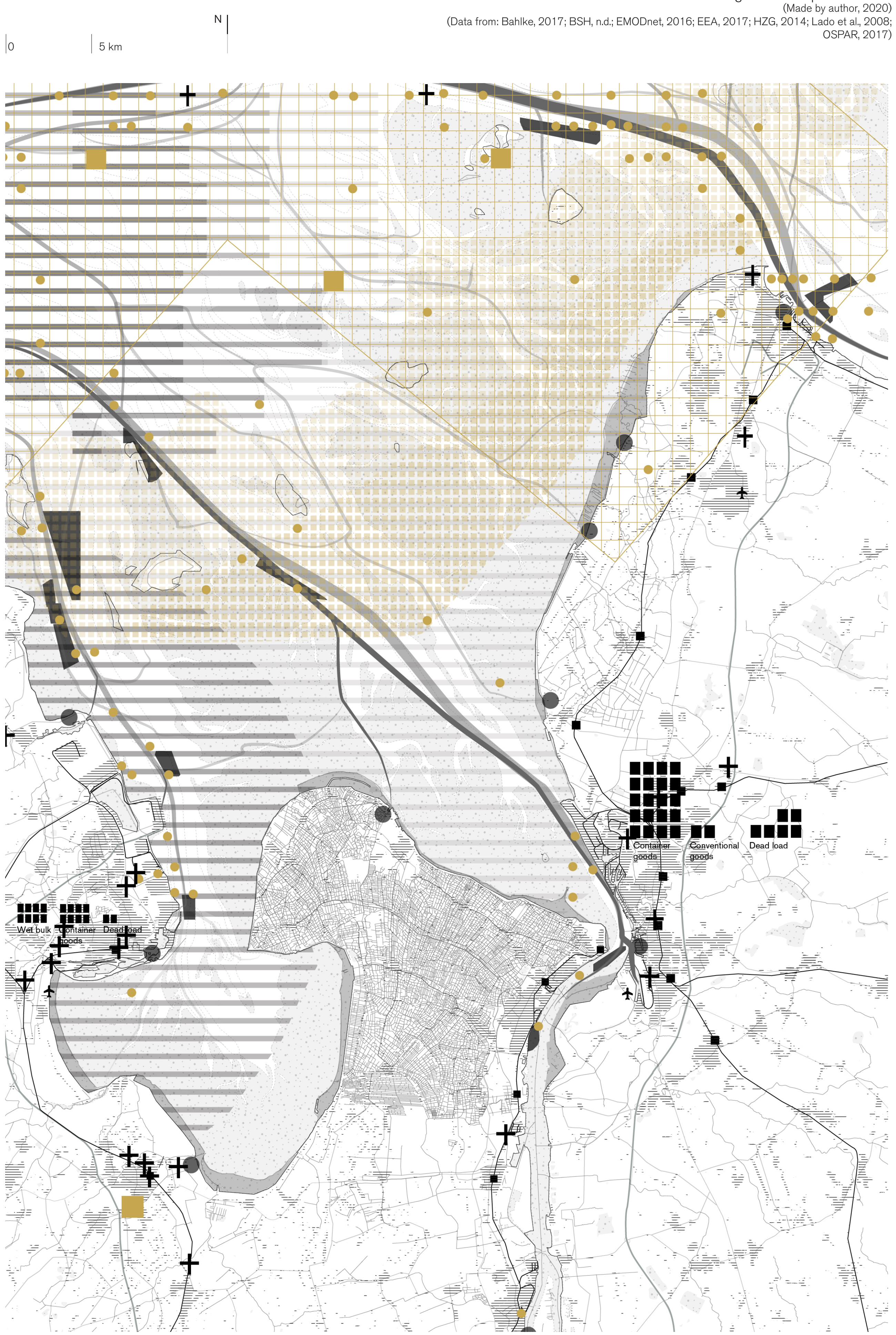
Due to economic growth harbors continued to grow, putting pressure on channel dredging because of augmenting vessel size and capacity, as well as increasing emissions, water turbidity, accidents, and spills by shipping (Bahlke, 2017).

Ship traffic
Fisheries
Services
Cargo
Tankers
Waterways
Balthymetry

Heavy metals
Hazardous chemicals
Waste
NOx emission
Saltmarshes
Intertidal mudflats

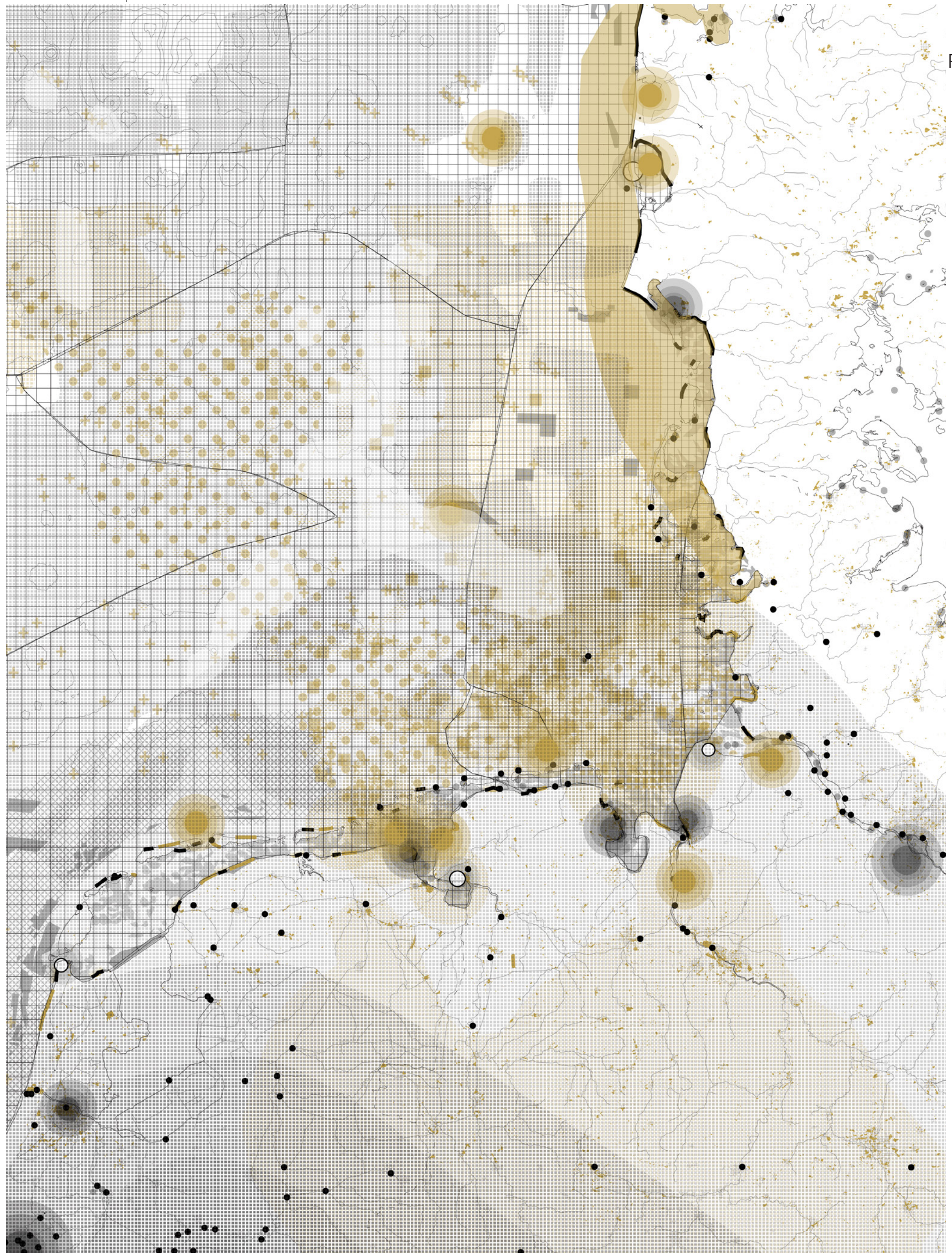
Fishery ports
Roads
Railroad
Goods [1ton]
Anchorage
Populated areas

Fig. 71 Urban port activities
(Made by author, 2020)
(Data from: Bahlke, 2017; BSH, n.d.; EMODnet, 2016; EEA, 2017; HZG, 2014; Lado et al., 2008; OSPAR, 2017)



The development of harbors based on a linear economic model will increase the number of externalities already reaching the sea bottom and surface, inhibiting its functions and overall degrading the ecosystem. Externalities such as heavy metals (cadmium, mercury, and lead as the most common) put the health of living species in jeopardy bioaccumulating, climbing the food chain that even reaches humans (Lado et al., 2008). Chemicals such as PAH, PCB, and DDT although restricted or banned, are still widely used for medicine and anti-corrosive paint. Chemicals reaching the water by spilling or exhausts add to the flourishing of algae blooms, that if spread can lead to dead zones and hypoxic water bodies (no oxygen). Air pollution caused by carbon dioxide, methane, and nitrogen emissions by shipping and industrial activities around the port can ultimately generate acid rain, which unfertilized and damages vegetation and water bodies (OSPAR, 2017).

Fig. 72 Regional Water Pollutione by 2100.
(Made by author, 2020)
(Data from: Behre, 1999; BSH, n.d.; EMODnet, 2016; EEA, 2017; Harrison et al., 2011; Homeier, 1974; Transitional Territories Studio, 2018, 2019; Ulrich Lamm, 2014; Witt, 2004)



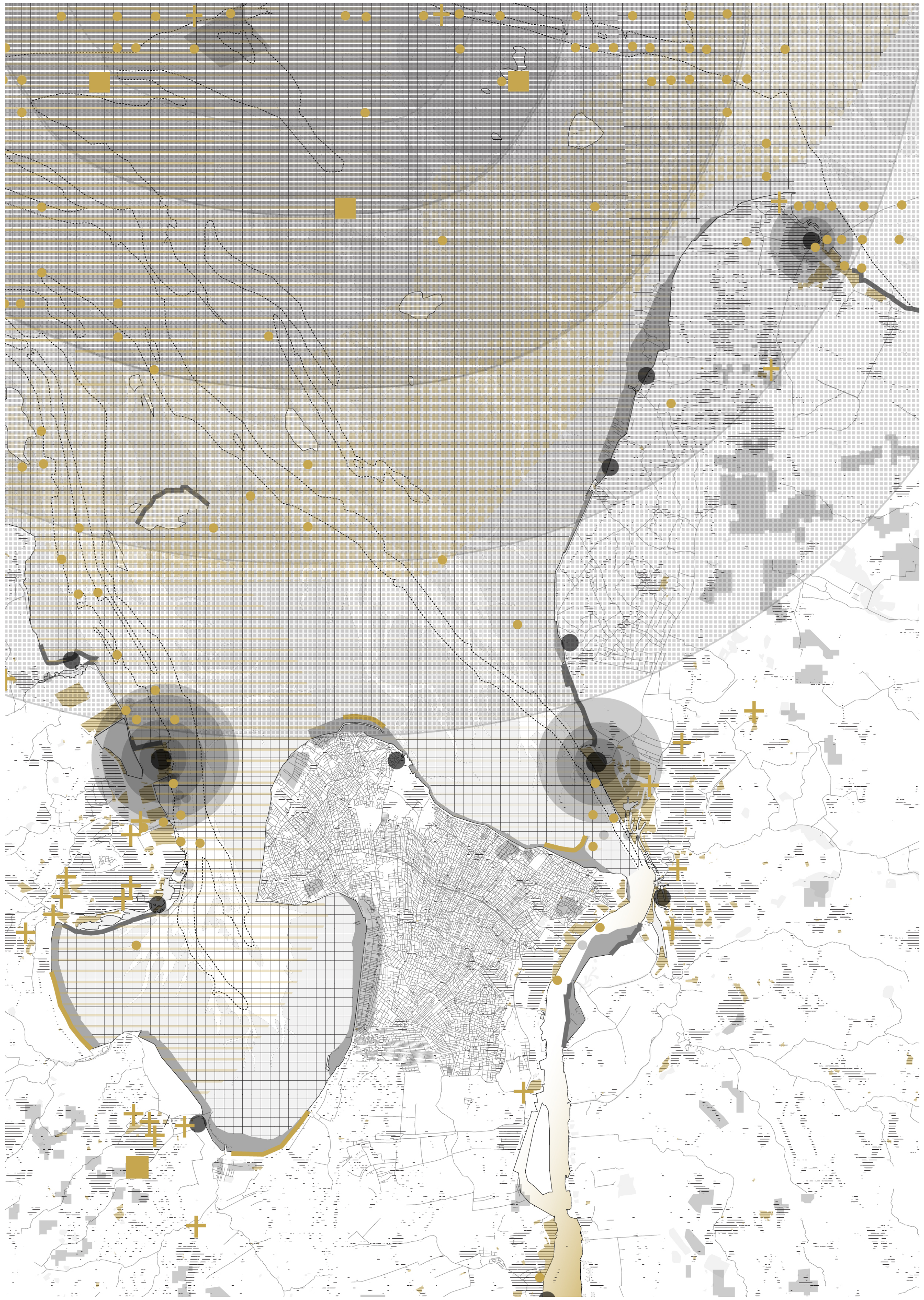
Regional Scale

- Predicted NO_x emissions [RCP8.5]
- Predicted CO_2 emissions [RCP 8.5]
- Hypoxic areas
- Predicted acidification
- Ports
- Growing ports
- Pollution concentration
- Industry
- Sediment extracion sites
- Coastal erosion
- Coastal accretion
- Balthymetry
- Saltmarshes
- Intertidal mudflats
- Populated areas
- Waterways

Urban Scale

- Predicted NO_x emissions [RCP8.5]
- Hypoxic areas
- Predicted acidification
- Fishery ports
- Growing ports
- Pollution concentration
- Industry
- Sediment extracion sites
- Coastal erosion
- Coastal accretion
- Balthymetry
- Saltmarshes
- Intertidal mudflats
- Populated areas
- Waterways

Fig. 73. Urban Water Pollution by 2100.
(Made by author, 2020)
(Behre, 1999; BSH, n.d.; EMODnet, 2016; EEA, 2017; Harrison et al., 2011; Homeier, 1974; Transitional Territories Studio, 2018, 2019; Ulrich Lamm, 2014; Witt, 2004)



Conclusions: Opportunities & Disadvantages

The presented understanding of the territory in two scales [regional & urban), three temporal frames (2000, 2020 & 2100) through three values (safety, health & connectivity) has allowed me to advance on the following opportunities and disadvantages to be taken into account when developing future measures.
In general, we can observe that the most vulnerable area affected by the listed hazards are located around the German Bight and coast. In the German Bight different social, economical and environmental interests seem to collide both in the present and the future planned development. For example, economical progress is prominently interested in expanding wind farm fields in the same areas where industrial fishing is allowed. On the other hand, these areas, although currently unprotected, also host one of the few rich sea bottom habitats left in the German Bight. Allowing a trivial construction of energy landscapes or fishing through the bottom trawling technique would degrade and potentially destroy these habitats.

The following maps synthesize the conclusions taken from the analysis considering the vulnerabilities in terms of safety, health, and connectivity.

Fig. 74. Synthesis of safety, health and connectivity urgencies of the Wadden Sea region.
(Made by author, 2020)

Fig. 75. Synthesis of urgencies of the Wadden Sea region.
(Made by author, 2020)

DISADVANTAGES

- Most of the coast and barrier islands will suffer from periodical inundation from **storm surges.**
- Declining biodiversity due to sea temperature rise that could influence migration paths of birds and fish.
- Many areas have a high demand for **sand nourishment.**

- Air temperatures will further **delay** vegetation bloom.
- Alien **invasive** species will still concentrate around port areas.
- Highly used vessel areas are prone to **accidents**.

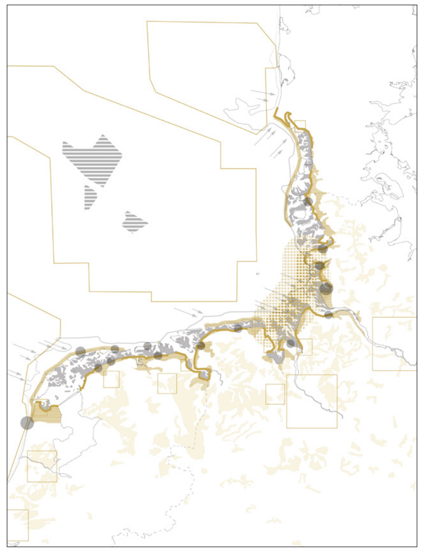
- Increasing vessel size demands more channel **dredging** to access the port.
- Industries around the port will continue to handle **hazardous material.**
- Although vulnerable the economically relevant German harbors will still be located around the Wadden Sea region.

OPPORTUNITIES

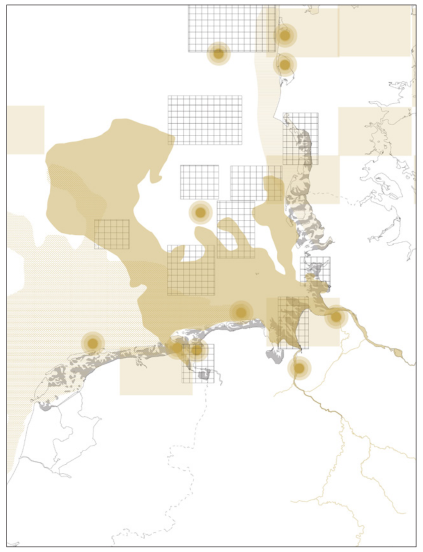
- Fishing and energy activities could **mix** and use sea space efficiently.
- **Raise** highways & railroads as further protection.
- Highly altered areas could become dynamic or **permeable** again to reduce their constant flooding problems.

-Respect or **regenerate** marine habitat with energy projects.
-Collect and **regain** externalities to use pollution from river runoff as a resource.
-Saline agriculture to **mitigate** increasing salinity rate that affects already poorly arable soil and groundwater.

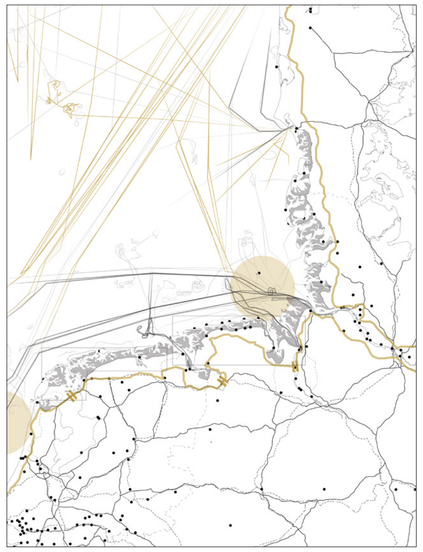
- Organize **shipping routes** so they do not collide with energy projects.
- Mudflats can **accumulate** sediments and protect from coastal erosion.
- The process of erosion of small islands that **supply** intertidal areas with sand can be supported to accelerate mudflat accretion.



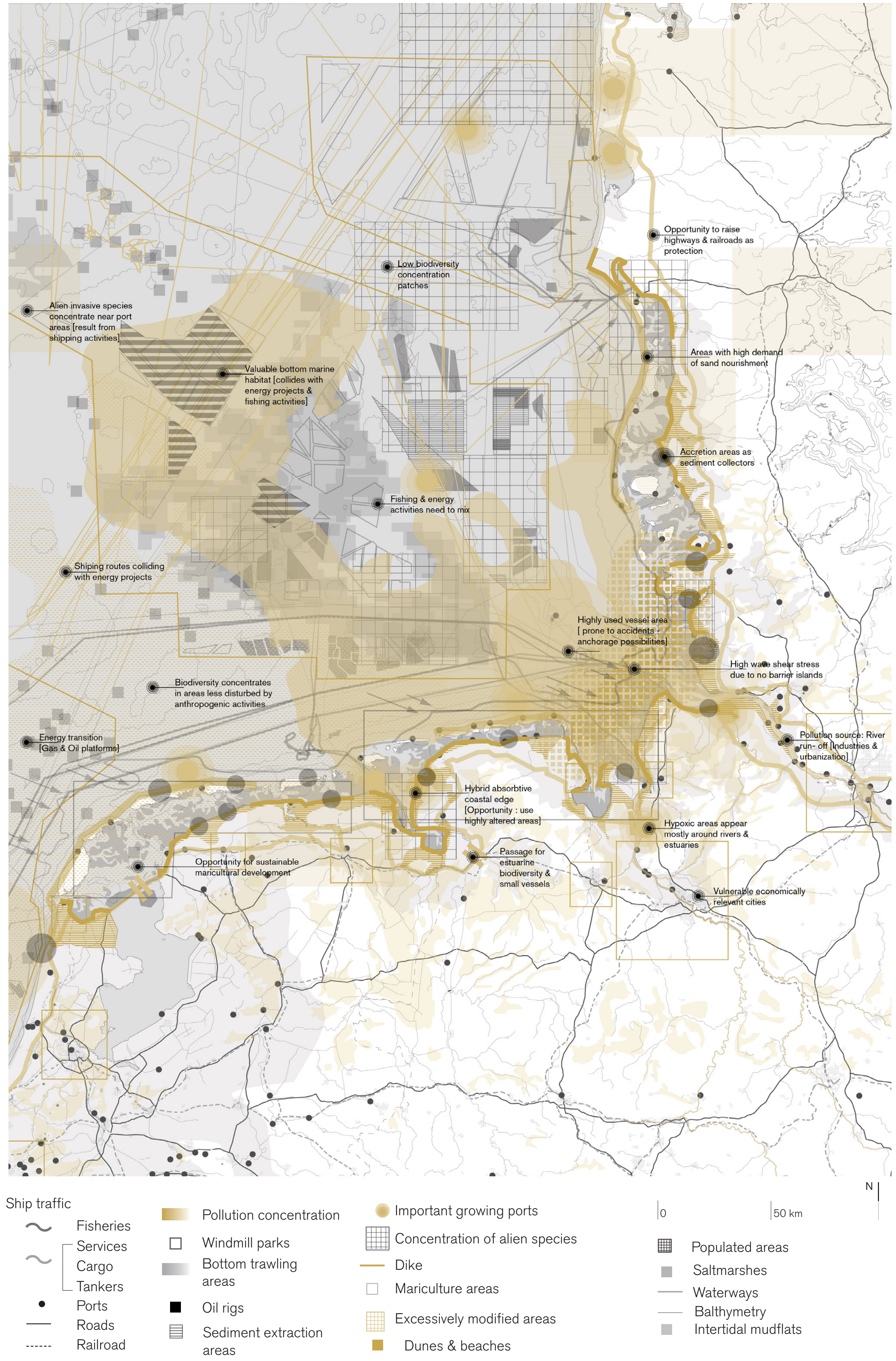
Vulnerability in terms of **safety**

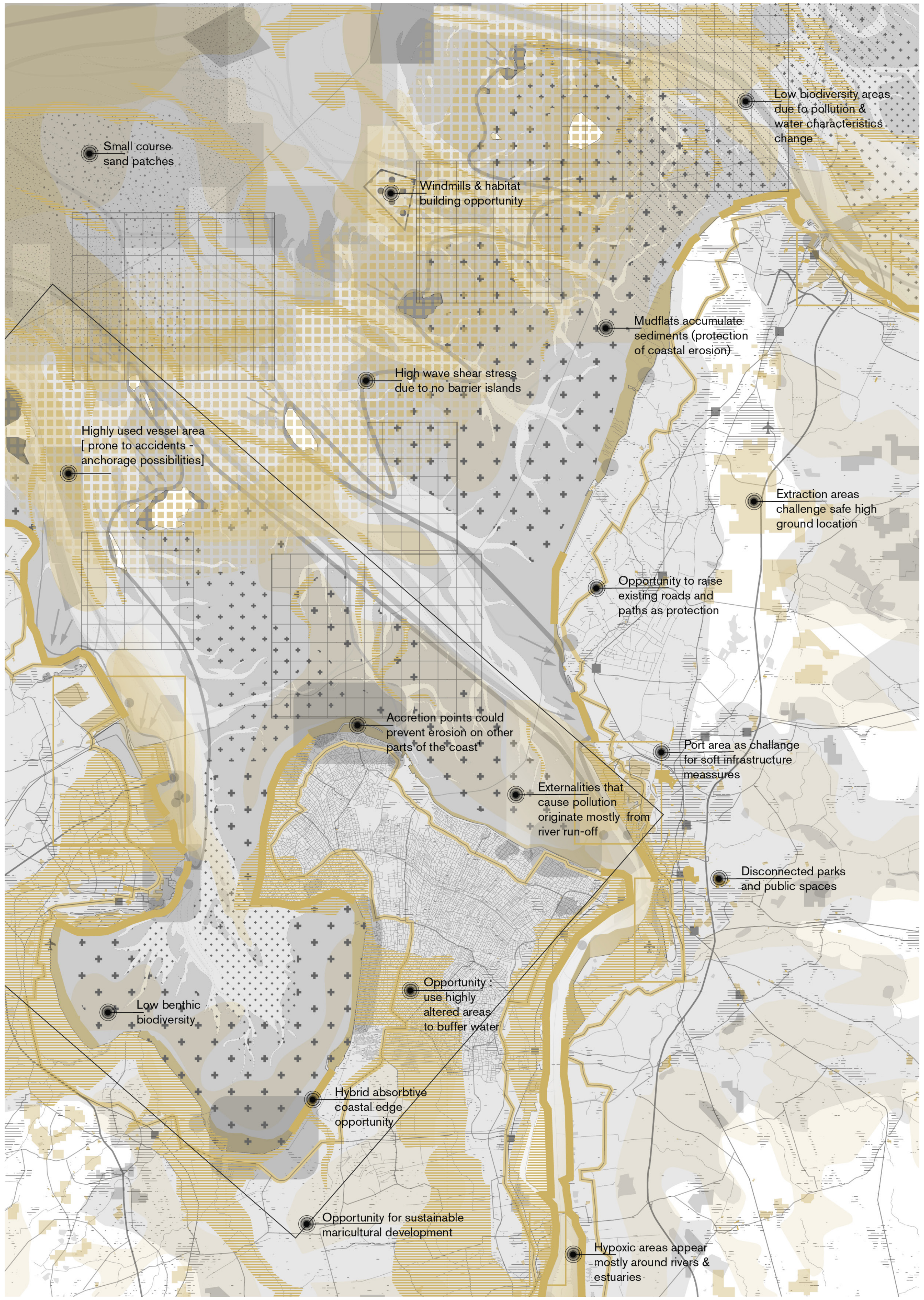


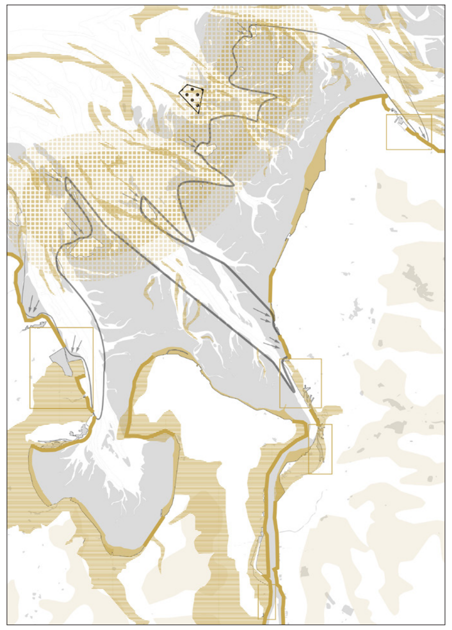
Vulnerability in terms of **health**



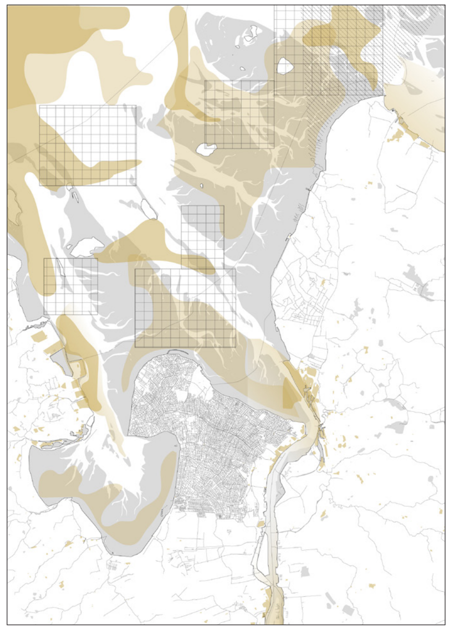
Vulnerability in terms of **connectivity**



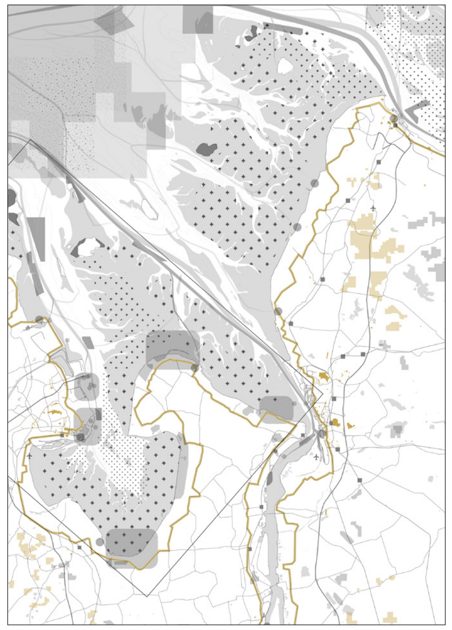




Vulnerability in terms of **safety**



Vulnerability in terms of **health**



Vulnerability in terms of **connectivity**

DISADVANTAGES

- Wave shear stress will affect the dikes, mudflats, and saltmarshes due to no barrier islands.
- Extraction areas around highlands challenge potential evacuation areas.
- Port spatial expansion and inefficient storage space defy landscape and city continuity & relation

- Low biodiversity due to high differences in sediment transport dynamism [anthropic structures & wave shear stress].
- Metal industry around Wesser add to the externalities originating from the river runoff.
- Water characteristics and dynamism change due to intensive anthropic activities and climate change are lowering the chances of survival of remaining seagrass and oyster beds (and benthic life).

- Anchorage and highly used vessel areas increase the possibility of accidents
- Increasing vessel size demands more channel dredging to access the port.
- Industries around the port will continue to handle hazardous material.

OPPORTUNITIES

- Connect existing saltmarshes to built a continuous soft protection edge
- Use the most altered areas to buffer water from rain or ground.
- Areas with high elevation can serve as emergency locations.

-Opportunity to develop sustainable mariculture due to flexible policy in Jade Bight.
-Collect and regain externalities to use pollution from river runoff as a resource.
-Saline agriculture to mitigate increasing salinity rate that affects already poorly arable soil and groundwater.

- Connect and increase the number of parks and public spaces.
- Mudflats can accumulate sediments and protect from coastal erosion.
- The process of erosion of small islands that supply intertidal areas with sand can be supported to accelerate mudflat accretion.

Weser Estuary - Synthesis of urgencies

Ship traffic
- Fisheries
- Services
- Cargo
- Tankers
- Ports
- Roads
- Railroad

- Pollution concentration
- Area prone to flood by precipitation & river runoff
- Subsidence
- Accretion areas

- Important growing ports
- Concentration of alien species
- Dike
- Mariculture areas
- Excessively modified areas
- Dunes & beaches

- Mudflat accretion
- Populated areas
- Saltmarshes
- Waterways
- Balthymetry
- Intertidal mudflats

Fig. 77. Crossing hard infrastructure
(Taken by author, 2019)

CONCLUSIONS

In this chapter, I chose to scan the territory under the judgment of three values: safety, health, and connectivity. Hereafter each undergone analysis looked over a structure and highlighted a process. This way the link between static and dynamic systems could be shown. Therefore the analysis of flood management was linked to data on climate, cultural identity to activities, natural habitats to biota, freshwater to salinity, morphology to sediments, and Industry to logistics.
Hereby I could understand how the intertidal system acts as a transitional area between the North Sea and the continental land and how anthropogenically induced climate change is constantly challenging and wearing off this function.
In terms of safety, it is challenging the function of the intertidal area to mitigate wave action, winds, sediment transport, currents, and tidal range change. Regarding health, it is affecting the ability of the mudflats to maintain water quality for different ways of life due to extreme nutrients, chemicals, and heavy metals input.
Concerning connectivity, changes are putting the cultural value of the mudflats in jeopardy, making them harder to access, creating restricted areas for the sole purpose of productivity and surrounding them with unattractive and temporary development that causes shrinkage, unemployment, and disconnection with the landscape.
The results of the analysis indicate that both the region and estuary are still not evolving towards adaptability since they rather present vulnerabilities in terms of safety health and connectivity.

Chapter

5

PROJECTION

MULTISCALAR DESIGN PROPOSAL

The chapter '*Projection*' presents the set of proposed strategies, visions, ideas and design for the region, urban area and two local points.

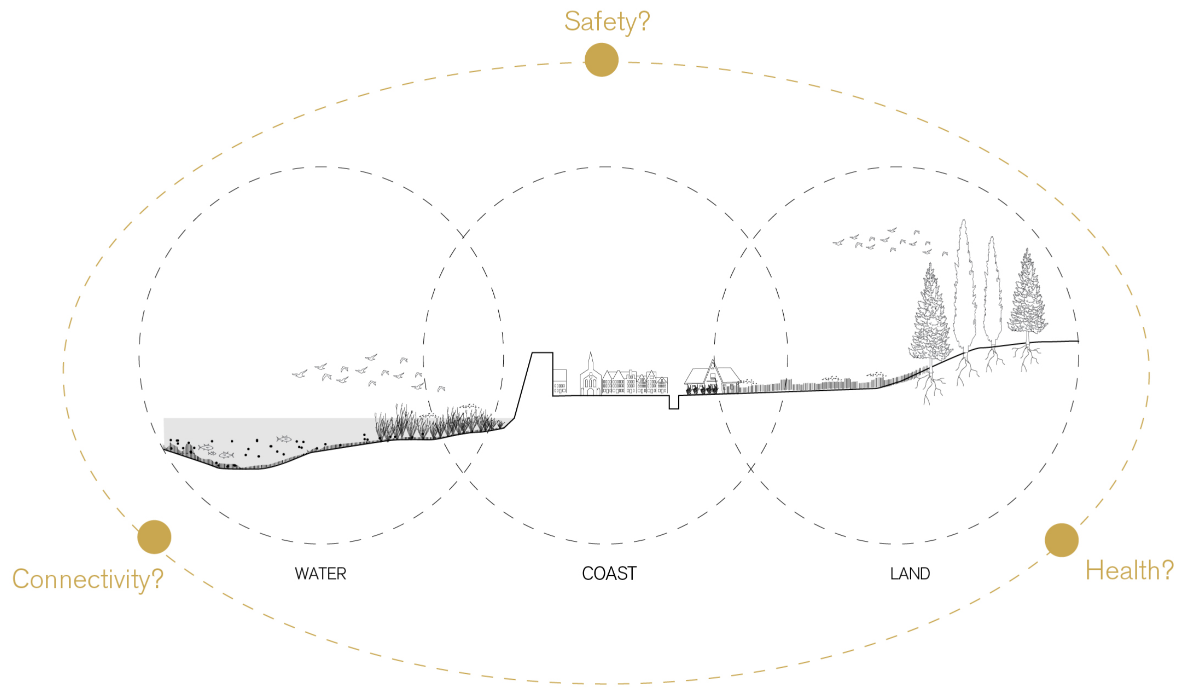
[CONTENT]

Fig. 78 Bremerhaven
(Taken by Ulrich Rehrmann, 2019) (Modified by author, 2020)

Introduction

In this chapter, I will expose the design of different systems in different scales that consider the discoveries and the identified disadvantages and opportunities of chapter 4 'Deconstruction'. The proposed projection emerges from the intersection between values and space. As previously stated these values consist of safety, health, and connectivity, and are the key goals of the following design and strategies. The analysis showed that these values are not met since some critical processes and infrastructures are not functioning as a system but as individual entities. In order to enhance a systematic design, it was necessary to include the three main ecosystem groups that compose the selected area (water, coast & land ecosystems), rather than concentrating on one to generate a transition. Hereafter water consists of the sea area, the coast of the edges of the interstitial area between the sea and the continental grounds, and the land as these continental grounds prominently hosting agricultural fields.
The proposed systems and networks envisioned (see *Subchapter 5.1*) for the region and urban territory are looking for the synchronization of humans and non- humans with the environment that would lead to an 'ecopragmatic' adaption by 2100. An '*ecopragmatic*' adaption is based on embracing risk by trusting the joined action of socio-ecological processes and infrastructure. As reviewed in literature and conceptually, this could be achieved by implementing *Infrastructural Ecologies* (Belanger, 2009; Brown, 2019) that create synergies between two different systems (in this case ecosystems). In other words, it means enhancing socio-ecological *ecotones*.
In the subchapter *5.2 Process scale*, I explore how this could be achieved by applying the notions of *ecological succession*. In order to work with the great complexity of water, coast, and land ecosystems and their interactions in different time frames, it was necessary to look at them separately. With the exception of land ecosystems, I used two pilot projects to finally built a phased urban project that creates different interactions between ecosystems from time to time in order to enhance an '*evolutionary resilience*' (Davoudi et al., 2013) through an ecosystem synchronization of the territory.

Fig. 79. The intersection of space with values (Made by author, 2020)



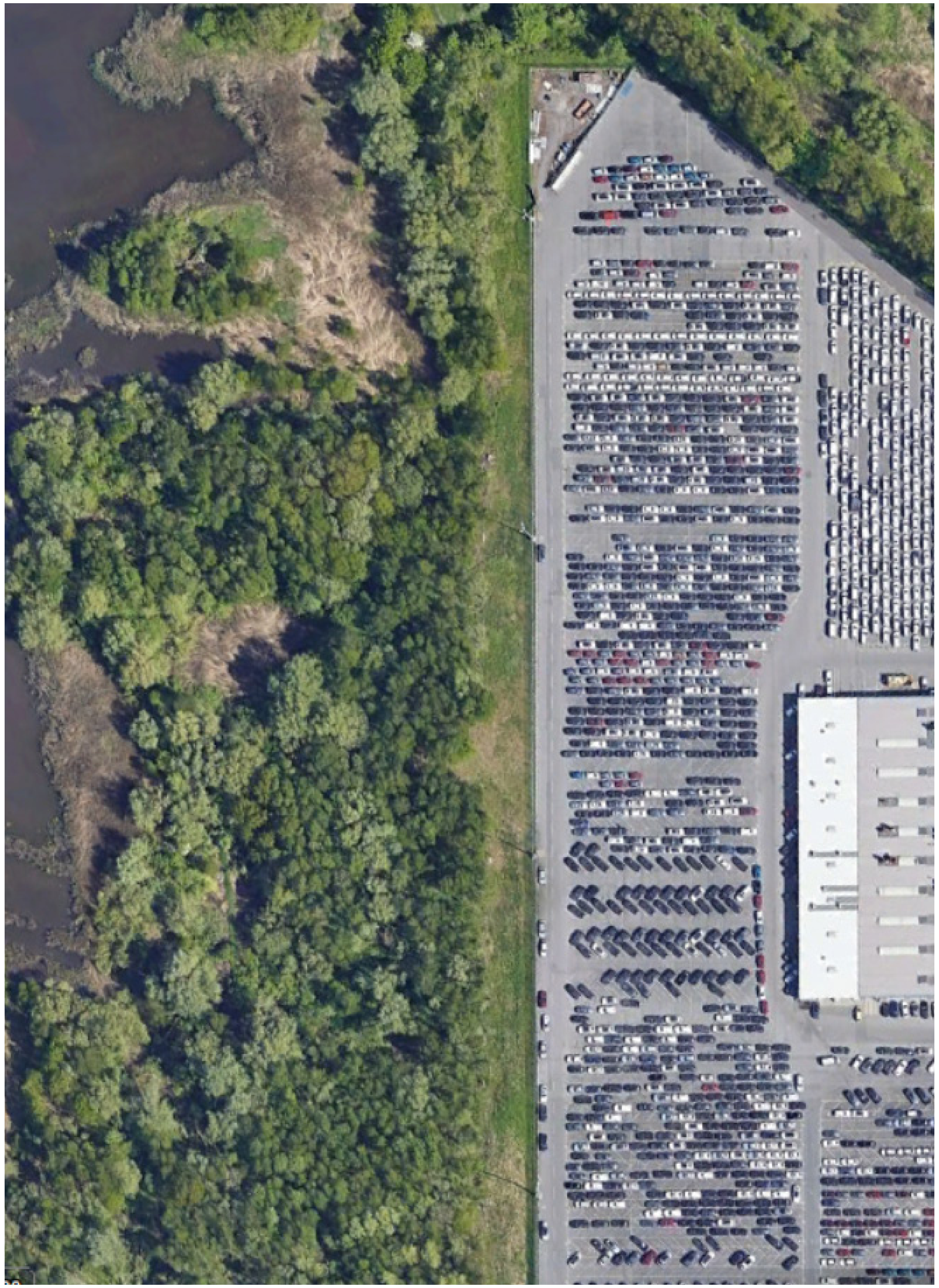
Chapter

5.1

System & network scale

SCENARIOS & VISION

Fig. 80 Bremerhaven.Vehicle logistics vs. natural park
(Taken from Google Earth, 2018) (Modified by author 2020)



PROJECTION

What happens if we do nothing by 2100?

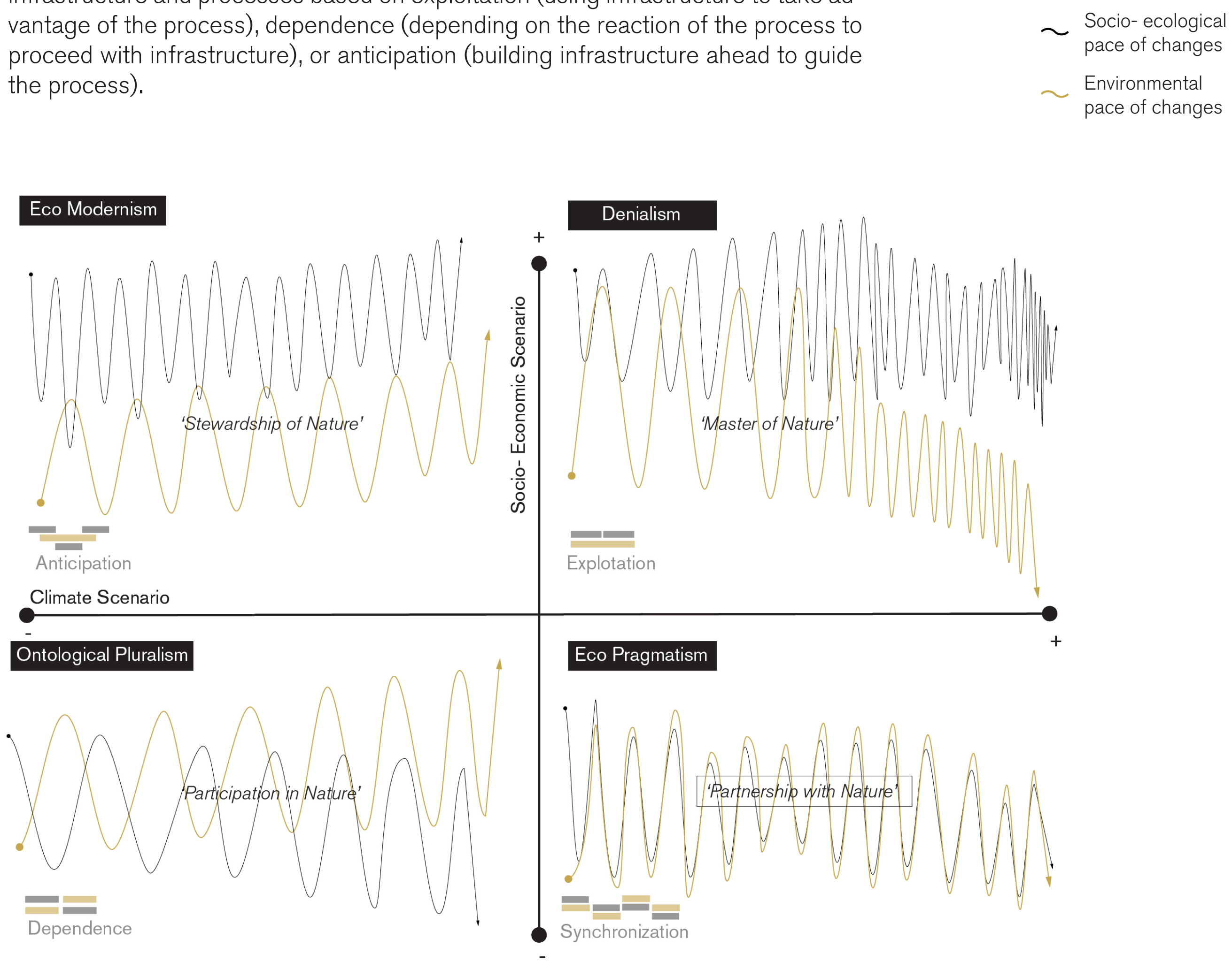
Before going into developing a possible set of actions for the region, I decided to illustrate what would happen to the region if none of the listed opportunities would be considered and the disadvantages ignored. The following image of a dystopic 'worst- case' scenario displays the Wadden Sea region after an extreme storm event. As we can observe most of the coastal cultural landscape (laying under sea- level) would be periodically inundated, the intertidal area would completely disappear, and the sea would be completely urbanized by windmills, more extraction grounds, pollution and vessel traffic.

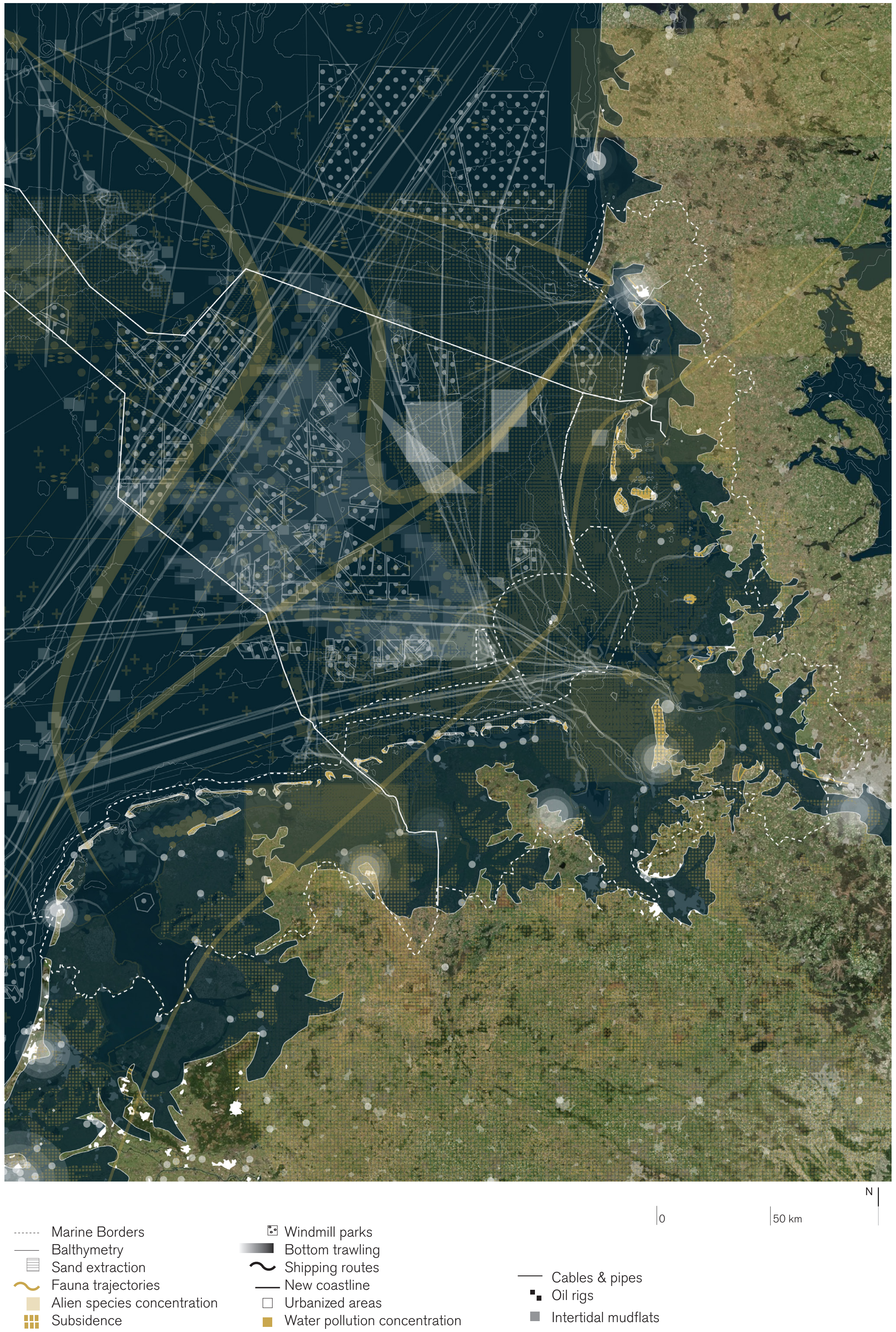
For this image to become only a dystopian warning instead of a haunting reality, I explored a set of scenarios in which a vision could expand to. The scenarios were constructed around the variables of an uncertain development of climate change and the linked socio-economical set of actions. We could say that the region has been advancing under the influence of the scenario of Denialism, so there seems to be a tendency to continue down this 'traditional' path of infrastructural growth and extractivism. To shift this path towards a more ecocentric perspective that supports the idea of 'partnership with nature' (see Chapter 4 'Theoretical framework'), I explored the possibility of the region and estuary to thrive towards an 'ecopragmatic' progress. In comparison with the other scenarios 'Ecopragmatism' looks for the synchronization of biotic and abiotic infrastructures with environmental processes in time. The other scenarios rather focus on a pace of changes and relationship of infrastructure and processes based on exploitation (using infrastructure to take advantage of the process), dependence (depending on the reaction of the process to proceed with infrastructure), or anticipation (building infrastructure ahead to guide the process).

Fig. 81.Paces of change under the scenarios for 2100.
(Made by author, 2020)

Fig. 82. . A dystopian vision of the Wadden Sea region 2100.
(Made by author, 2020)

(Data from: Baptist et al., 2019; Behre, 1999; Blatter & Roux, 2016; Blew et al., 2017; BSH, n.d.; Büttger et al., 2017; de Groot et al., 2017; DWD, 2015; EMODnet, 2016; EEA, 2017; Folmer et al., n.d.; Geobasis- DE/BKG, 2020; Harrison et al., 2011; Homeier, 1974; HZG, 2014; ICES, n.d., n.d.; IUCN, 2016; Jensen et al., n.d.; Transitional Territories Studio, 2018; Ulrich Lamm, 2014; Witt, 2004 Wadden Sea Forum & EUCC, n.d.; Waddensleutels, 2011; Zijlstra et al., 2017)





Scenarios for 2100

The design process started with the construction of strategies within four scenarios to build a vision based on the scenario that shows more alignments to the conceptual ideas presented in the theoretical framework (see Chapter 3 'Structure'). In Fig. 84 I list a set of possible actions under each scenario to explore which strategies could be developed to respond to the problems and opportunities stated in the previous chapter (Chapter 4: ' Deconstruction') by 2100 and could additionally lead to an ecocentric adaption of the region and estuary.

In this thesis, I decided to explore the '*EcoPragmatism*' scenario, which looks into the worst-case scenario of the given quadrant, since climate-induced changes are high and socio-economical development is low. This desition also considers the current situation of the cities around Weser Estuary, which seem to host important ports but has one of the highest unemployment rates in Germany (12,2 % Bremerhaven). This means that judging by the current development, it is more likely that socio-economical revenue will continue to be limited in this area. Since evolutionary resilience (Davoudi et al., 2013) is about embracing risk to adapt, it was interesting to look into the possibilities of this in the climatic scenario RCP 8.5 (IPCC, 2018).

The developed initial strategies proposed under the influence of the 'ecopragmatic' scenario differ from the ones supporting the other scenarios primordially in terms of temporality. In *Ecopragmatism*, both variables (socio-economic and climatic) are limited, and therefore demand a long- term plan, supported by careful research and testing, before it is executed. Hereby strategies are meant to last longer but need regular maintenance to deliver maximum efficiency.

Fig. 83. Scenarios.
(Inspired by: "Mobilis in Mobile" lecture (February 2019) by Dirk Sijmons.)
(Taken from: Garcia Vogt et. al, 2019)

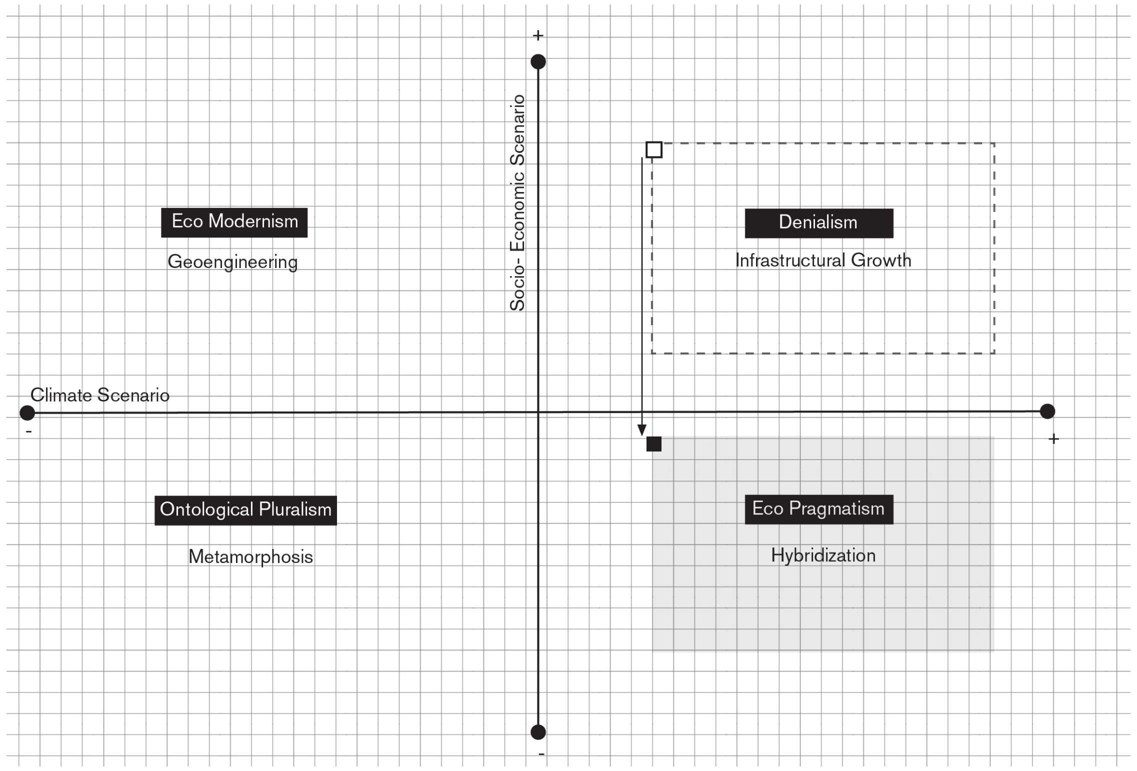
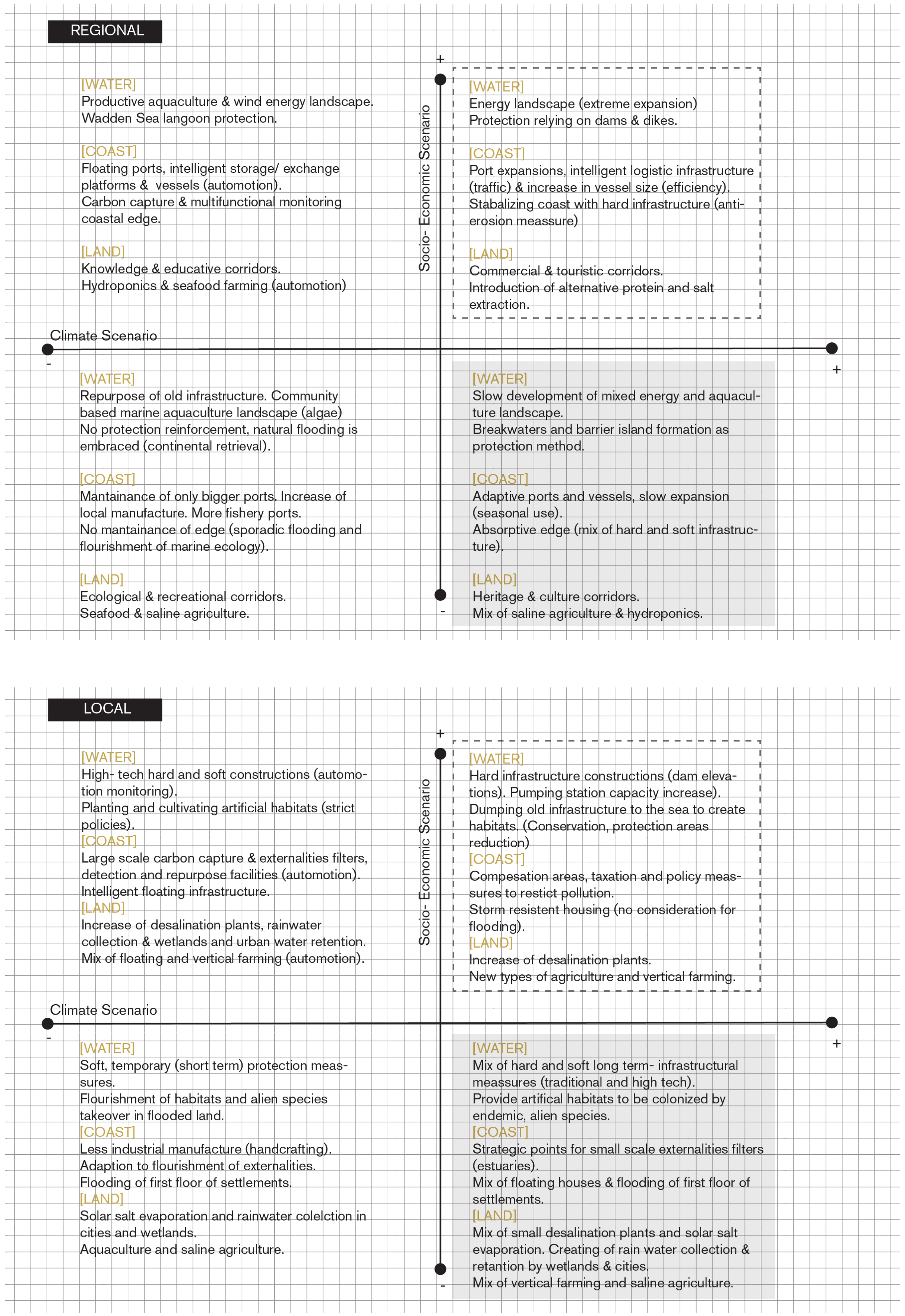


Fig. 84 Strategies under scenarios 2100
(Made by author, 2020)



Imagining Wadden Sea 2100

As an initial dive into an ‘ecopragmatic’ scenario, I decided to set the scene generating three images with the help of a taxonomy and a manifesto. In a way, the taxonomy is inspired by the deconstruction of the conceptual framework (see page 50, *Chapter 3: ‘Structure’: Conceptual framework*).

The taxonomy comprises around the three mentioned territories (water, coast & land) categorizing which hard and soft infrastructure is available and what biotic/ abiotic and cultural elements are attached to them. The combination of these would create a process that in the case of this project aims for safety, health, and connectivity. Therefore the resulting images present initial impressions of the three territories combined with the targeted functions and aims of the project.

Fig 85. Taxonomy .
(Made by author, 2020)

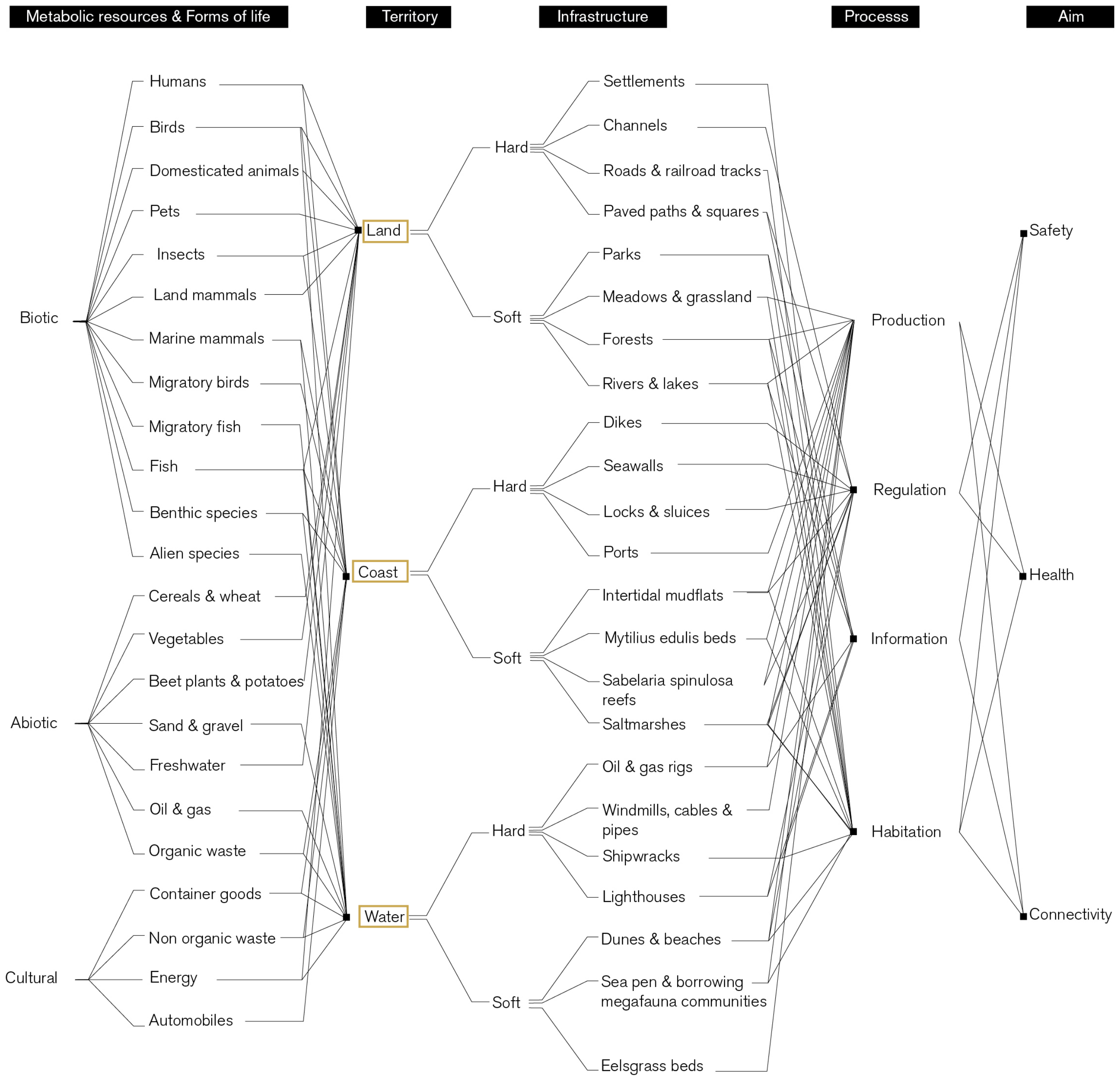
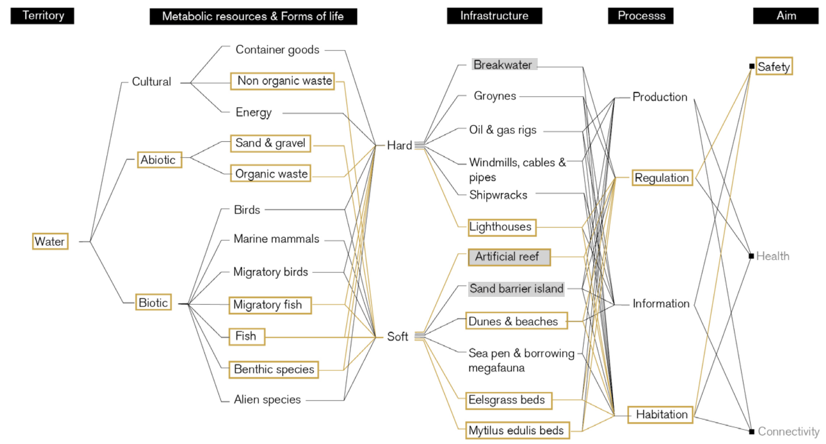


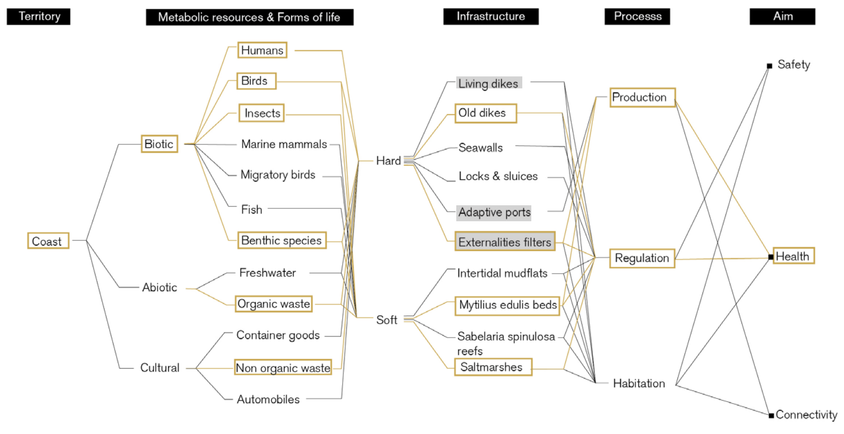
Fig. 86 Manifesto: Water vision & taxonomy
(Made by author, 2020)



ECOPRAGMATIC MANIFESTO

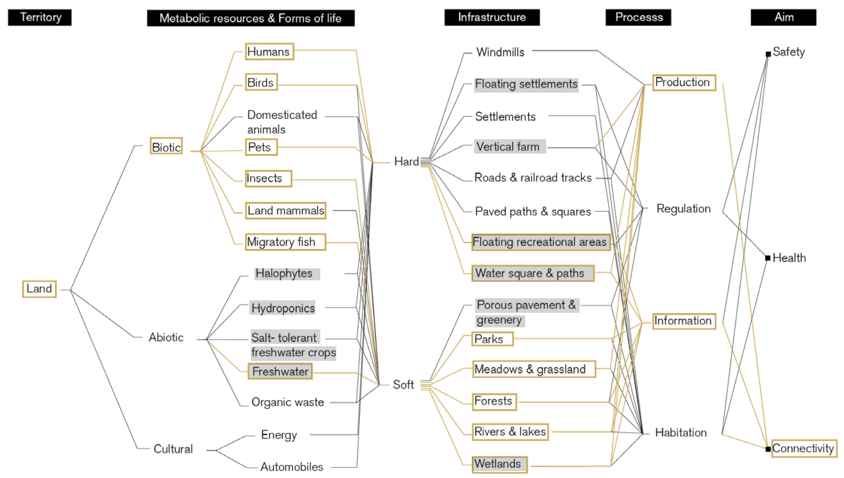
1.
Changes are slow but in time they will be in tune with ecological rhythms and the dynamics of our habitat. A *choreography* between biotic and abiotic induced transformations will work with the intelligence of environmental processes to help us- all living beings- embrace the coming risks.
As part of our cultural landmarks, we will build our benthic friends a habitat to thrive alongside other species. In exchange they will guard us against dangerous pollutants and trap sediments to the ground, restoring our sea bottom.

Fig. 87 Manifesto: Coast vision & taxonomy
(Made by author, 2020)



2.
Although the sea will remain the extraction ground of most species, the human economy will profit from filtering pollutants out of the water. This way externalities regain their original value and a chance to rebuilt absorptive landscapes becomes as attractive for investors as for human and non- human life. To maintain and cultivate these 'Infrastructural ecologies' we need to trust the experienced hand of nature and its processes. The creation of hybrids, especially in our most anthropologically dominant spaces, will introduce transformation, effectiveness, and attract innovation to avoid obsolescence.

Fig. 88 Manifesto: Land vision & taxonomy
(Made by author, 2020)
(inspired by EFFEKT, 2018)



3.
Our cities will welcome the risk of transformation since it will let us enjoy and connect with the forces of nature we were missing. Hereafter we see a chance in every hazard: flooding by precipitation as an opportunity to store fresh water, salt intrusion as a farming heritage activator, flooding from river runoff as irrigation and enhancement of recreational spaces, waves as dune builders and storms as landscape sculpture artists and energy providers. With short term actions based on long term goals, we will motivate our present communities to inspire and teach future ones to adapt to constant changes.

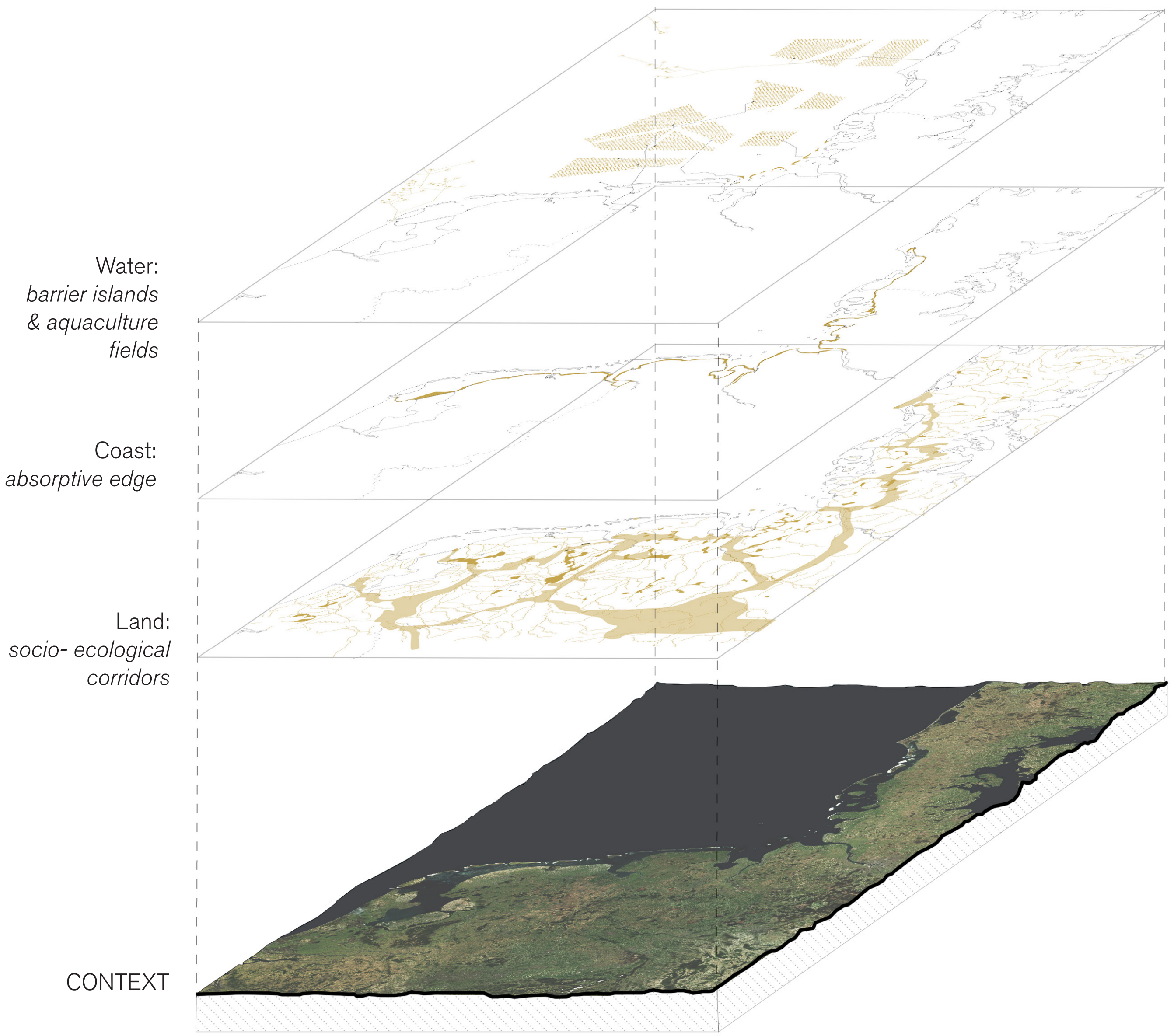
PROJECTION

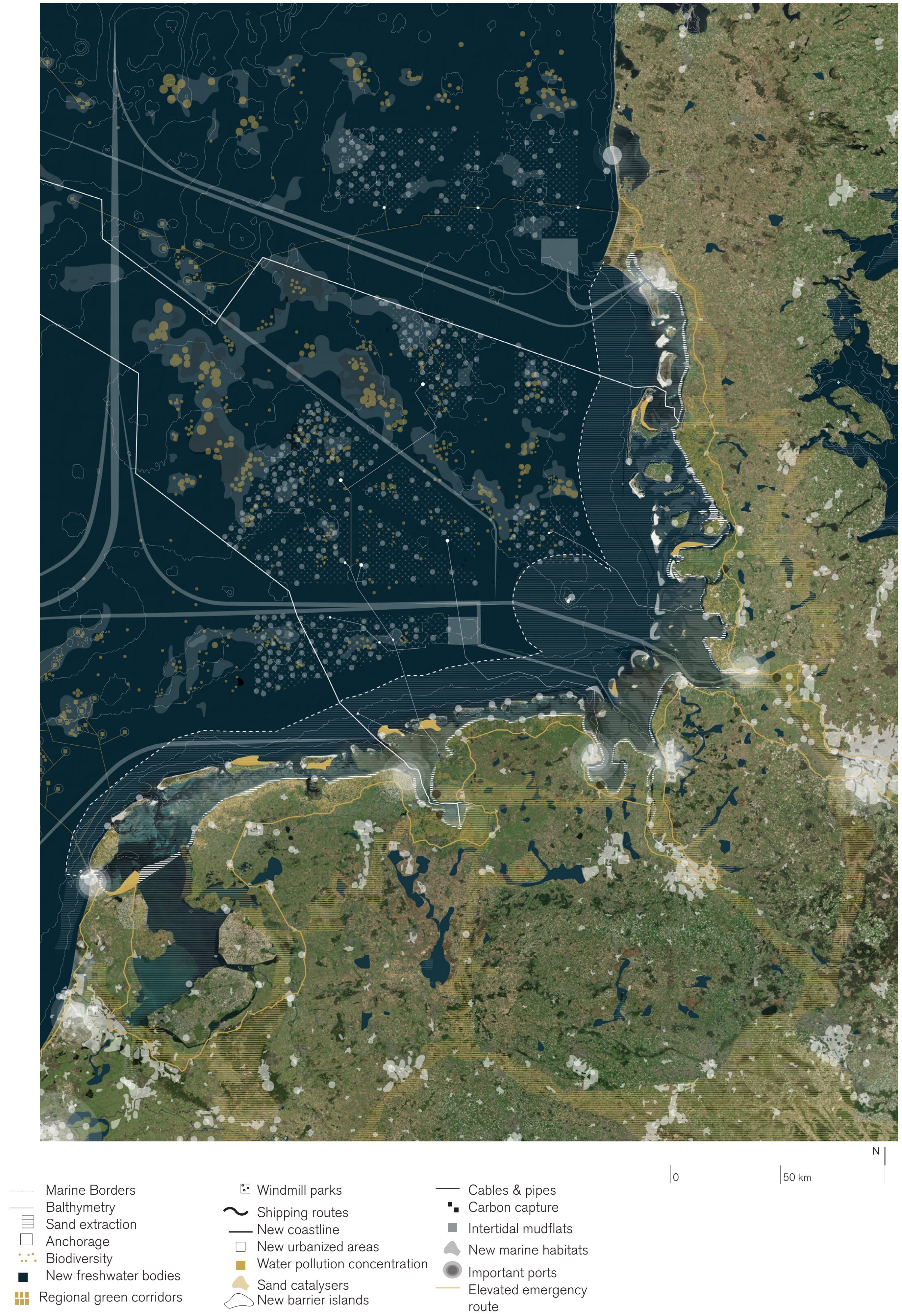
‘Ecopragmatic’ vision of Wadden Sea region

To reach an ‘ ecopragmatic’ condition in the region three critical strategies are implemented. Together they create a system that connects three territories: water, coast, and land. Given their current protection effectiveness, the first regional strategy promotes the formation of barrier islands in areas of the intertidal area that are stressed by waves shear stress (mostly around the German Coast). Linked to this strategy is the conception of aquacultural fields which would impulse the organization of vessel traffic to avoid accidents. Hereby space efficiency, as well as economical revenue and environmental gain could be catalyzed. As a second measure to mitigate further hazards is enhancing an absorptive edge. This strategy is set to provide mixed (soft, hard) and compact solutions in order to protect and form a smoother transition between land and mudflats or sea. And at last, a strategy positioned to create a network of socio-ecological corridors to enjoy the cultural landscape of the Wadden Sea region, would make room for more freshwater storage and meandering waterways to flush and recharge the nutrient-rich groundwater, or allow saline water into agricultural fields to grow new crops. These socio-ecological corridors follow subsiding areas, that are not prone to be inhabited by humans, and could proportion an exhaust for animal and plant life.

Fig .89 Axonometry of three strategies for the region
(Made by author, 2020)

Fig. 90. Ecopragmatic vision for the Wadden Sea Region
(Made by author, 2020)





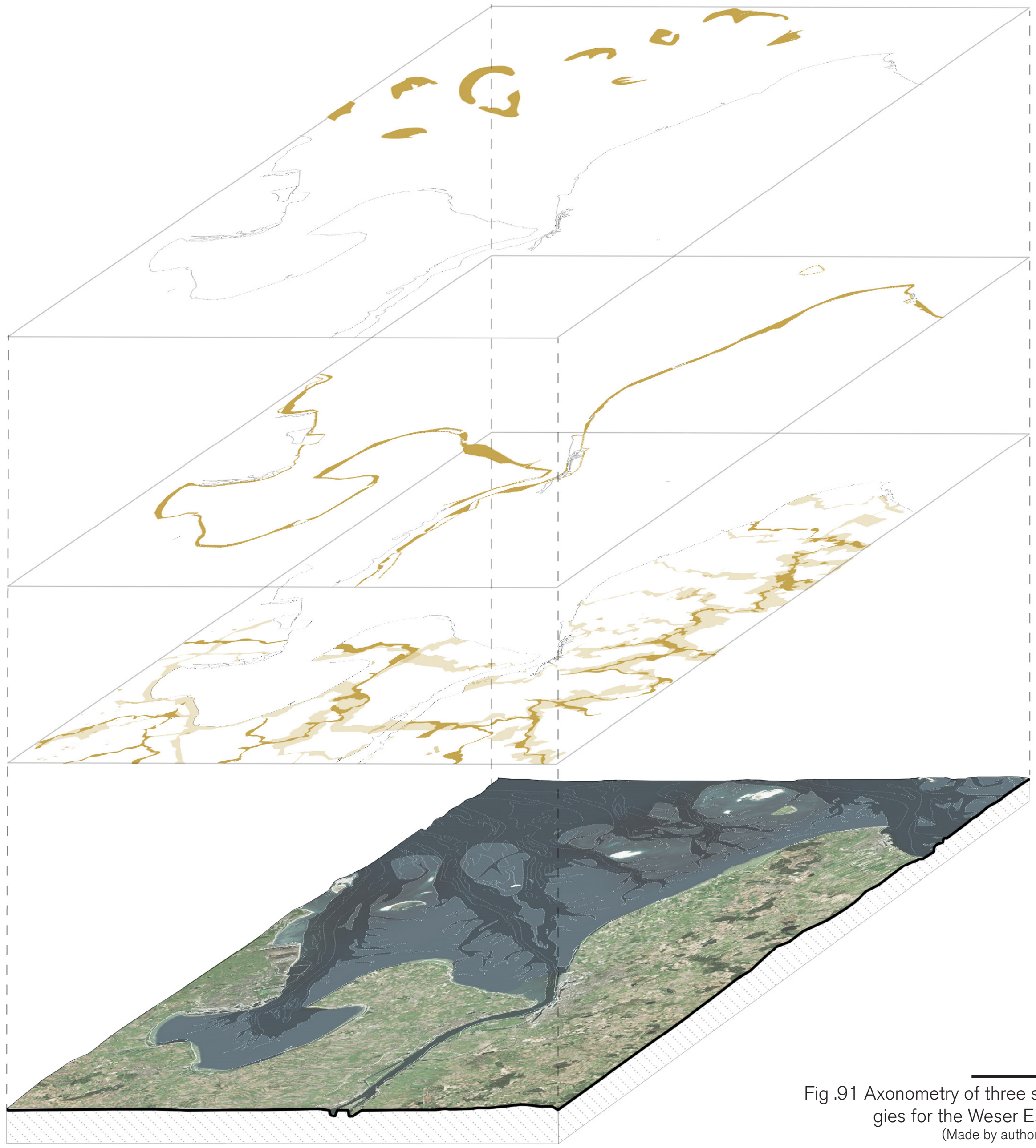


Fig .91 Axonometry of three strategies for the Weser Estuary
(Made by author, 2020)

'Ecopragmatic' vision for Weser Estuary 2100

When zooming in the region to the Weser Estuary, we can recognize the same logic system design consisting of a three-layered adaption strategy.

- Marine Borders
- Balthymetry
- Biodiversity
- New freshwater bodies
- Green corridors
- Heavy metal filters
- Shipwrecks
- Lighthouses & landmarks
- Artificial reefs
- Windmills
- Shipping routes
- Elevated paths
- New urbanized areas
- Industrial areas
- Barrier islands
- Mix farms(saline | none) & Vertical farms
- Intertidal mudflats
- New & old marine habitats
- Dredged sand dumping
- Sand Catalyser
- Dikes
- Existing forests
- Absorptive edge

Fig .92 Ecopragmatic vision forthe Weser Estuary
(Made by author, 2020)

Design Principles

Since hazards are affecting different parts of the territory with different intensities (see Fig. 93), it was necessary to create a layered set of actions on space to intensify safety, health, and connectivity on a regional and urban scale. These layered sets of actions are designed to build the three systems that construct regional and urban vision.
The principles of the design consist of the intersection between the values and the territory and respond to the most urgent risks that the system has to adapt to in time. In terms of safety we are talking about wave action, erosion, and subsidence; as for health it is temperature rise, water pollution, and salinity increase, and for connectivity, it is flooding, tidal range change and the loss of marine identity (cultural distance towards the seascape).
Hereby it is also revealed that the proposed infrastructure comprises an interplay of soft and hard, dynamic, and static, durable, and temporary, existing and yet to be invented hybrid interventions. The idea is to insert a sufficiently flexible infrastructure in space that can follow the logic of territorial dynamics and this way counteract them, in a moment in time, with the help of the habitat it formed alongside its adaption process.

Fig .93 Hazard intensities and strategies location
(Made by author, 2020)

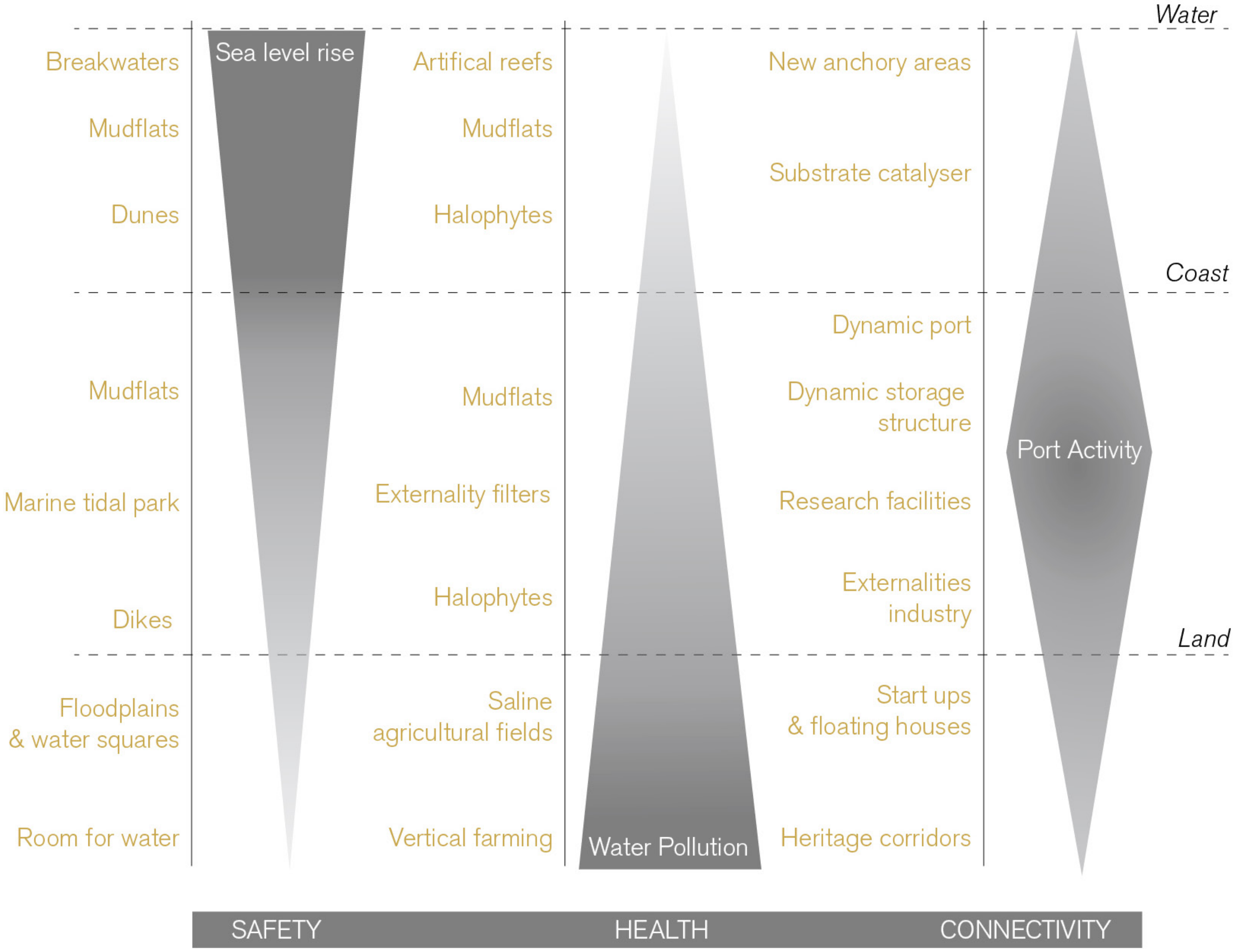
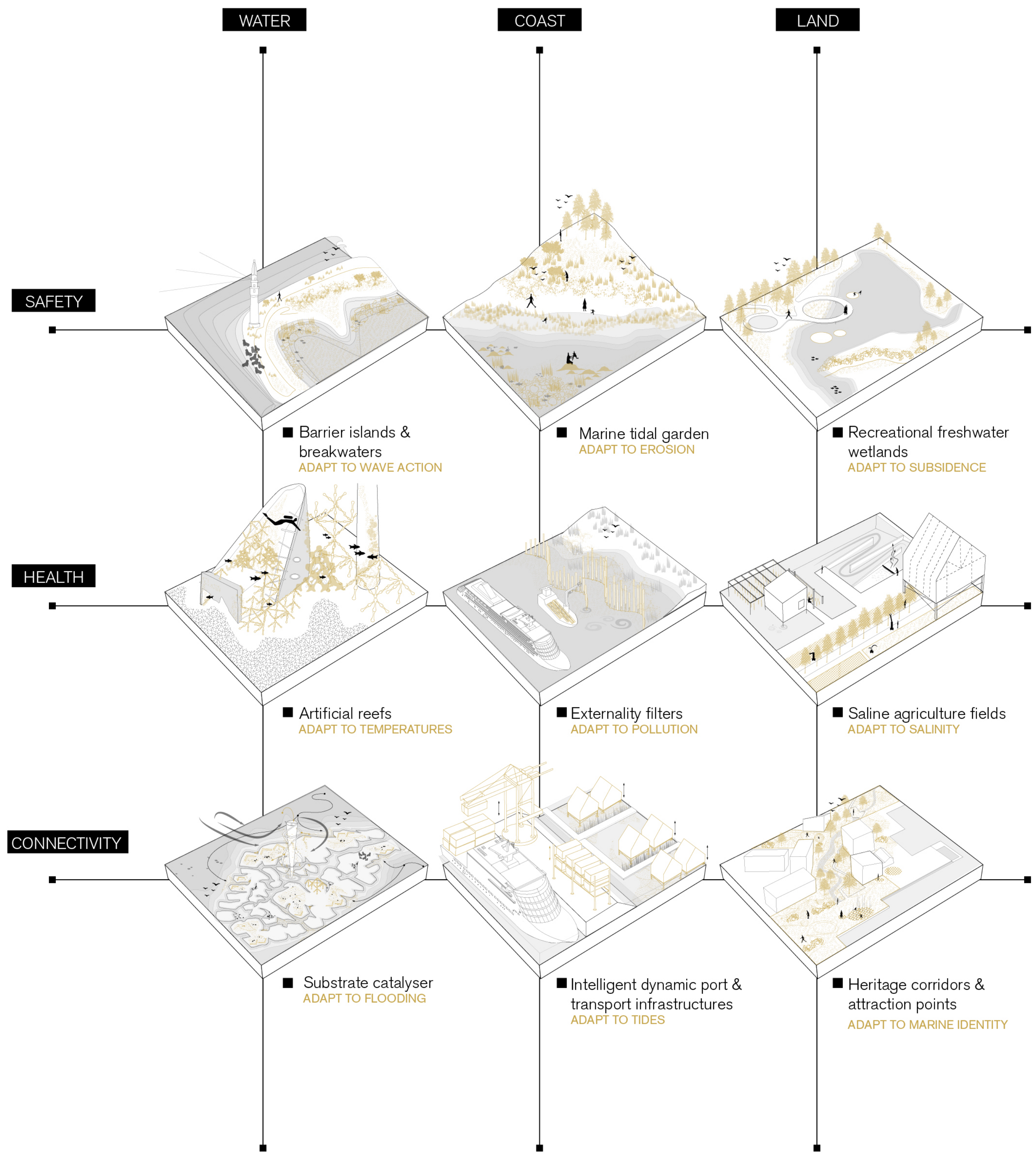


Fig .94 Design principles
(Made by author, 2020)



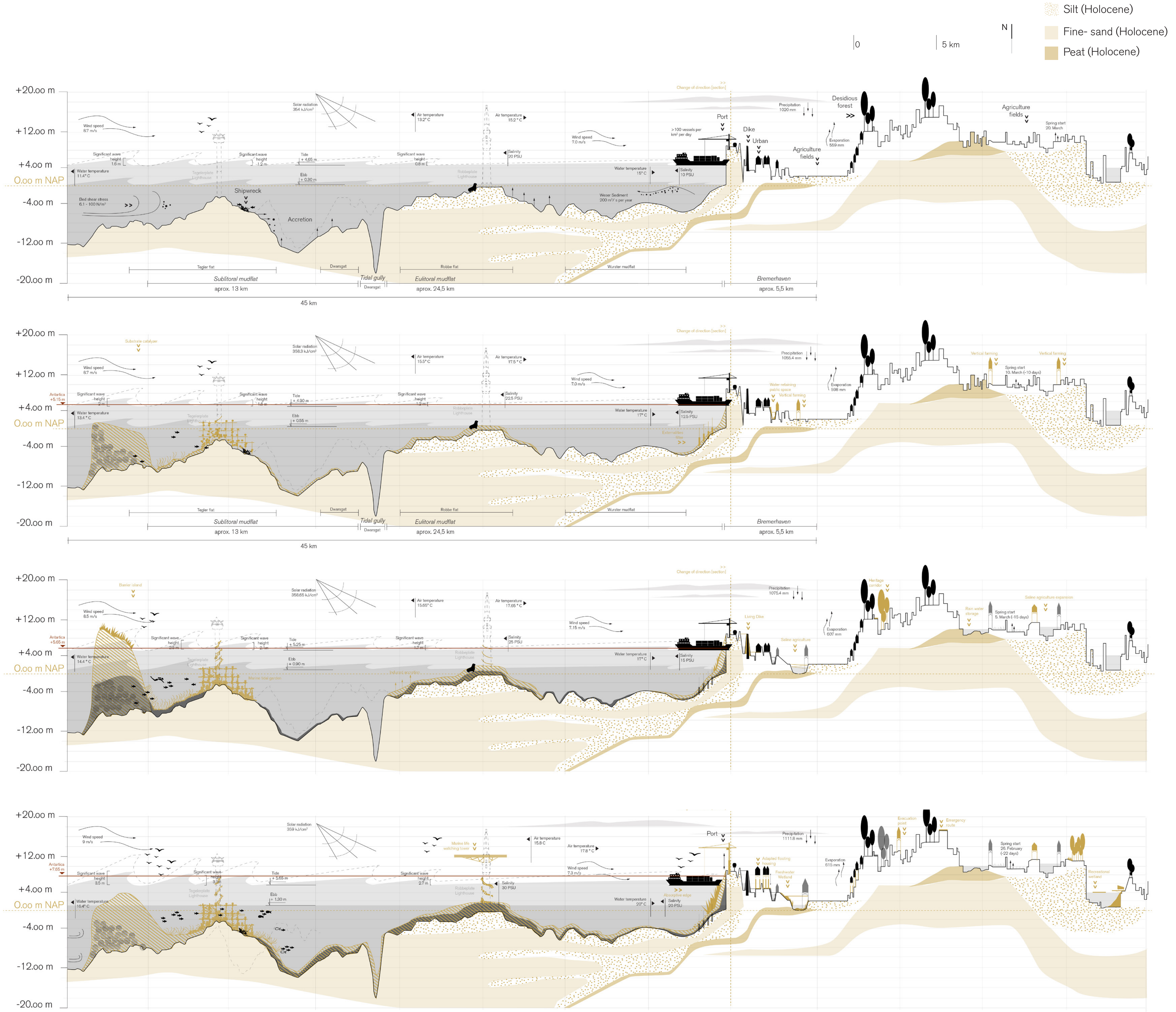


Fig .95 Evolution of strategy in the Weser Estuary.
(Made by author, 2020)
(Data from: BGR,2019; BSH,n.d.; DWD,2015; FeiReu GbR, 2019; Gehzeiten Fisch, 2019; HZG,2014; Niederschlag in Deutschland, 2019; Wetterkontor,2019 ; Windfinder,2019; Witt, 2004)

2020 AD

The following sections illustrate how the described design principles would act in the Weser Estuary to adapt the water, coast, and land ecosystem in different moments in time considering the RCP scenario 8.5 (IPCC, 2018). The first section of 2020 already shows in a topographic exaggerated view that the harbor of Bremerhaven stands out creating an abrupt elevation of the coast to protect the lower hinterland from flooding by tidal action. We can also identify higher grounds with vegetation and some isolated water bodies.

2050 AD

Most measures considered at first instance for 2020 to 2050 should have a regenerative function to start pilots to test different ideas on site. For example, It is advisable to start building the structure for the proposed barrier island which would function at first instance as a breakwater to mitigate wave action. This would enable the creation of subtidal habitats to behind it to regenerate the area from a low level of benthic life. This would also catalyze creation for the absorptive edge at the coast.

2070 AD

In 2070 measures are designed to mitigate the coming more extreme conditions. The barrier islands would need to reach a height of approximately 10 m, the absorptive edge would reach its maximum extension, and the coast and heritage corridors are planned to act as evacuation routes.

2100 AD

By 2100 the system would have adapted to the required conditions of the area and is, therefore, able to begin a phase of enhancement of habitats that support the activity of living beings. The system can cope with risk since it has adapted to dynamics such as waves through the combination of a barrier island and its soil hardening biota, erosion through saltmarsh creation, and floods and tides through dynamic infrastructures.

PROJECTION
Wadden Sea region: Ecosystems

Throughout the project, I refer to the values, structures and functions for biotic life of ecosystems, to understand their innate ability to adapt and apply this knowledge in the context of the Weser estuary and Wadden Sea region. Hereafter it was logical as a next step towards detailing the design to identify which ecosystems are located in the Weser Estuary area. As shown in the following diagram I was able to differentiate between 10 distinct ecosystems present in the Weser Estuary. Within the water ecosystem group, I recognized 3 ecosystems mainly according to their height characteristics, which has enable them to host a variety of distinct species. Coming from the littoral ocean bottom (not considered as part of the Wadden Sea area in this case) we can recognize *sublittoral mudbanks*, since they are not intertidal, *eulittoral mudflats* (intertidal) and *dunes & beaches* comprising small islands. Their function according to the adapted classification of ecosystem functions under *production, regulation, habitation, and information* (MEA, 2005) indicate that most of the water ecosystems momentarily are providing regulation services.

The coast ecosystem group comprises 4 different types of ecosystems, including urban ecosystems (Alberti, 2008). I was able to distinguish between *harbor, urban coast, salt marshes, and river & estuary* ecosystems. Although encompassing a great variety of very dissimilar elements, these ecosystems function mainly as productive and regulative areas. We can distinguish natural ecosystems as more multifunctional but less 'productive' and anthropic ecosystems as more productive for its target species but of monofunctional essence. As for land ecosystems, we can find *deciduous forests, meadows & grasslands, and urbanized lan* (discerns from an urbanized coast in terms of human settlement density). These higher areas of the territory are as well mostly productive land, but less regulatory than water rich-ecosystems.

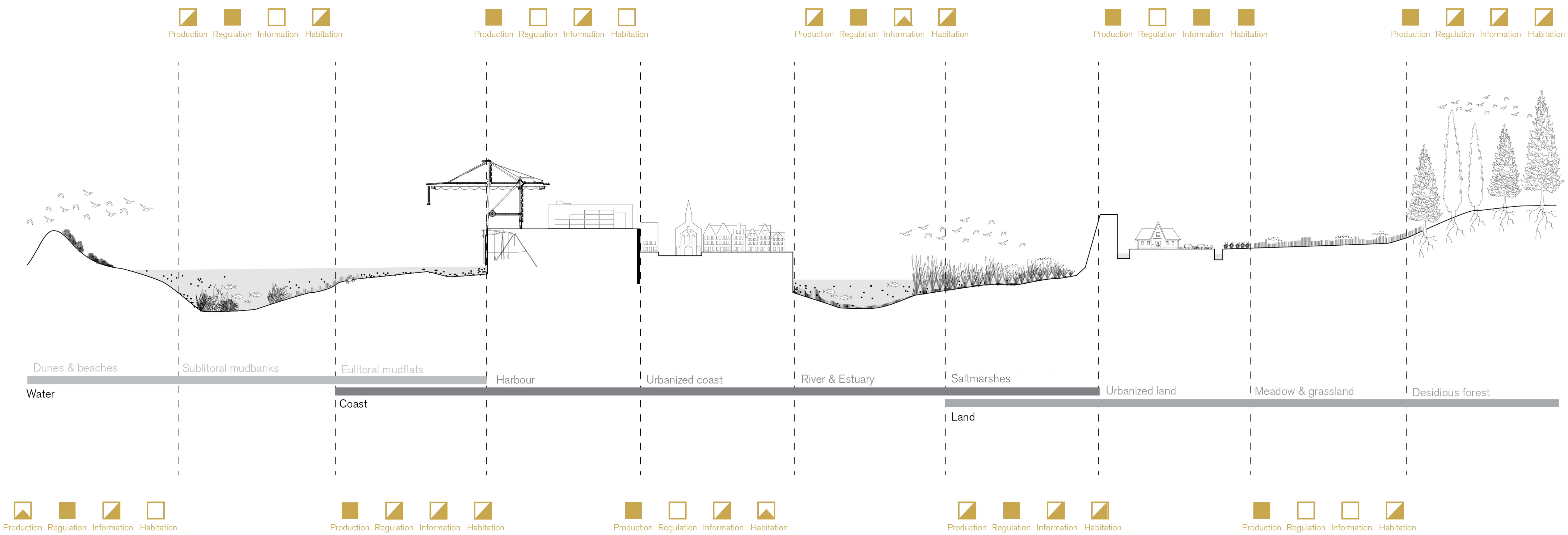
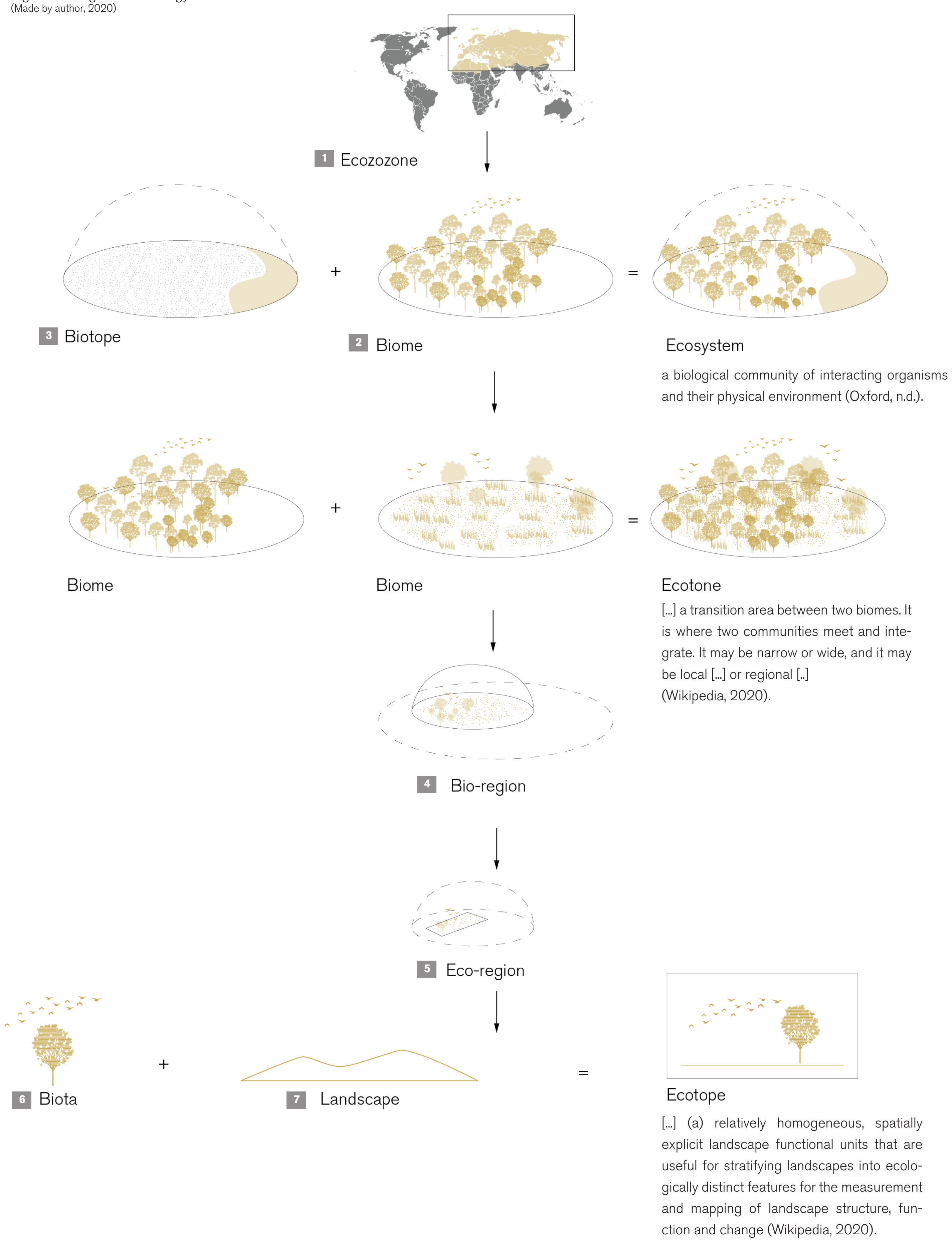


Fig .96 Ecosystem classification & functions.
(Made by author, 2020)
(Data from: Baptist et. al, 2019; EMODnet, 2016; ICES, 2018; MEA,2005)

Fig .97 Ecological terminology.
(Made by author, 2020)



PROJECTION

Ecotones: An opportunity to adapt

The framing of ecosystems in the territory led me to a deeper understanding of the biological terminology used in the project. In biological research, ecosystems are conformed by *biotopes* (abiotic) and *biomes* (biotic).
Biomes are comprised of living systems that, when crossed with another biome, create relationships with the other species to survive : a transformation is triggered for them to adapt and survive the change. Through the encounter of biomes in space, ecosystems start evolving, so that future generations of a species (*ecological succession)* are not troubled by the disturbance. In other words, with the creation of *ecotones* a system of living beings might be able to embrace changes in time.

This presents itself as an opportunity to catalyze an adaptive cycle by setting the seeds to create *ecotones*. *Ecotones* might be the key to more resiliency, since they aditionally work through the intelligent structure of a system: not all elements would be affected by a disturbance (just partially) and these affected areas could regenerate through the support of the other elements encompassing the transition area (*ecotone*), making the network less vulnerable.

Moreover, *ecotones* enhance that ecosystems get accustomed to change because they consists of spaces of transition that deal with more processes, and therefore more dynamic interactions than others. Although more complex, *ecotones* would manage to provide the desired multi- equilibrium between different systems (hybrids).

1 *Ecozone:*
An ecozone is the broadest biogeographic division of the Earth's land surface, based on distributional patterns of terrestrial organisms [Definitions, n.d.).

2 *Biome:*
a large naturally occurring community of flora and fauna occupying a major habitat [...] (Oxford, n.d.).

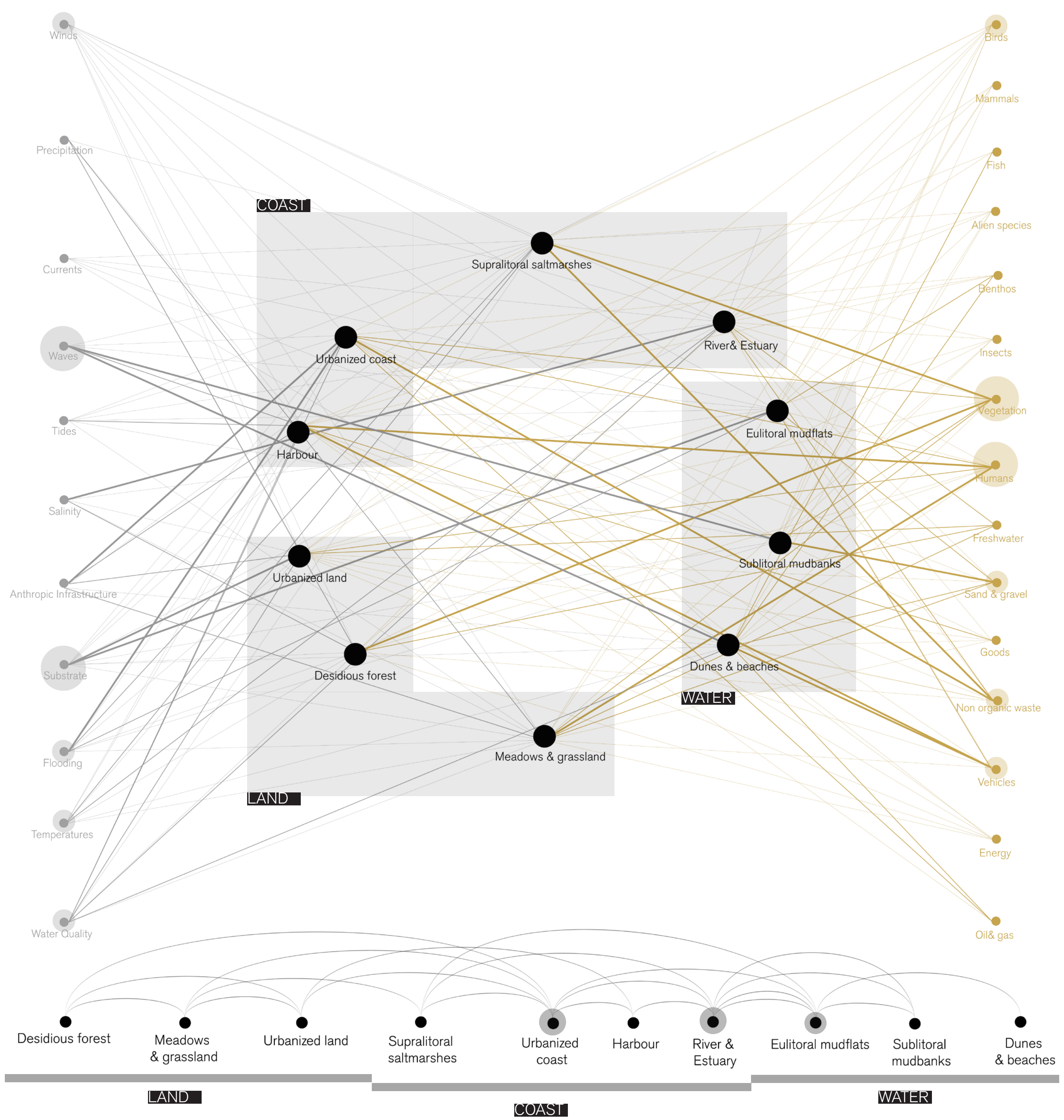
3 *Biotope:*
the region of a habitat associated with a particular ecological community (Oxford, n.d.).

4 *Bio- region:*
A bioregion is an ecologically and geographically defined area that is smaller than a biogeographical realm, but larger than an ecoregion or an ecosystem, in the World Wildlife Fund classification scheme (Wikipedia, 2020).

5 *Eco- region:*
Ecoregions cover relatively large areas of land or water, and contain characteristic, geographically distinct assemblages of natural communities and species. (Wikipedia, 2020).

6 *Biota:*
Biota is a common term in biology. It means all the living things at a particular time or place (Wikipedia, 2020).

7 *Landscape:*
A landscape is the visible features of an area of land, its landforms, and how they integrate with natural or man-made features (Wikipedia, 2020).



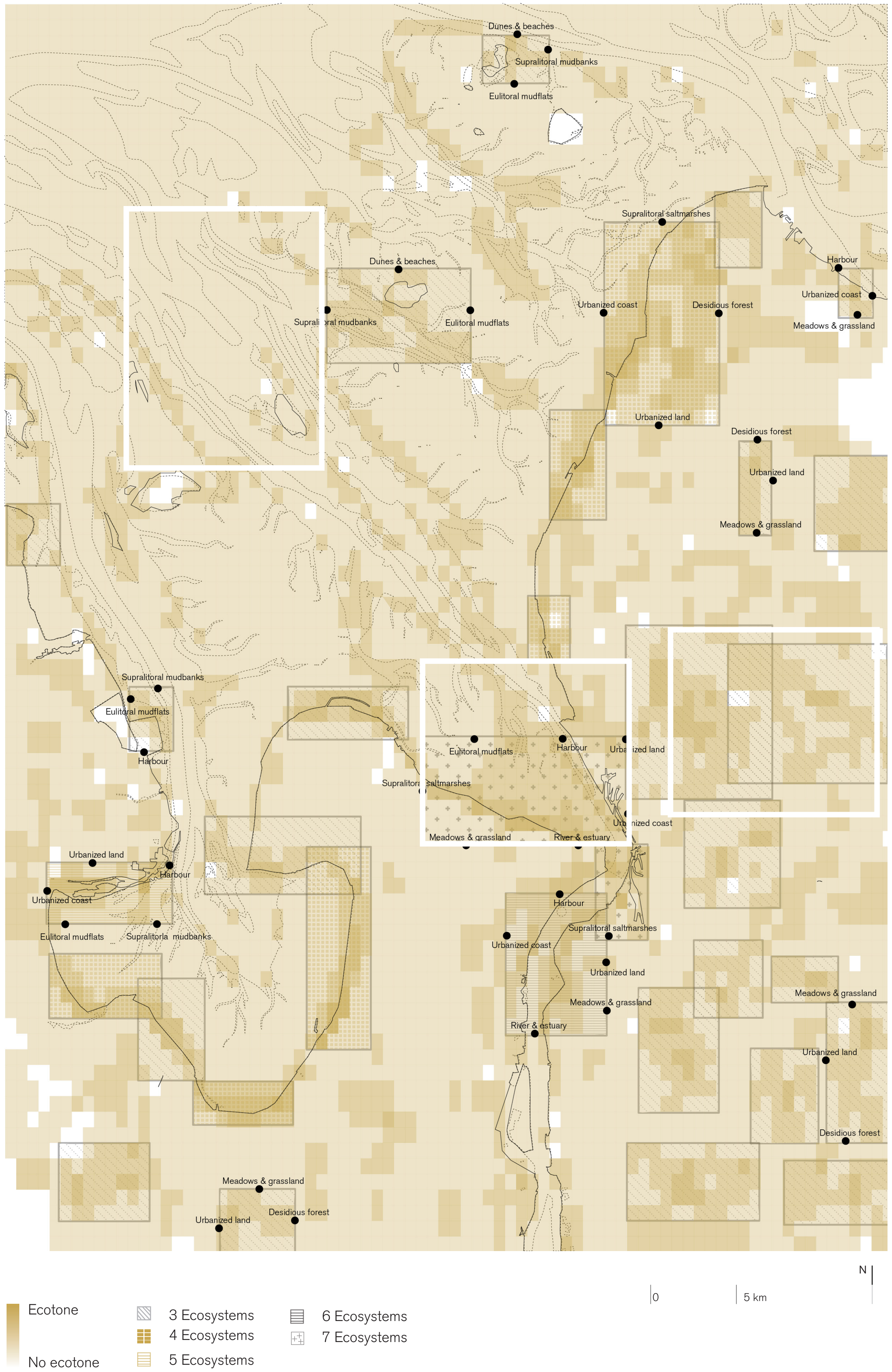
Weser Estuary - Ecotones

In the following map, it is possible to recognize the location of different ecosystems, according to the previously shown classification (see page 135, 'Wadden Sea region: Ecosystems') of water, coast ,and land ecosystems. We can notice areas where the presence of ecosystems is intensive or reduced. Most ecosystem accumulate near the coast, whereas less seem to collide in the water (land ecosystems seem to be 'balanced'). To test ecotone enhancement in the Weser Estuary, I decided to advance on the two extremes: a sample area in the water (least ecosystem presence) and a sample area at the coast (most ecosystem presence).

A synergies analysis showed that most ecosystems are either affected or pushed by waves, sediment transport (substrate) and mostly interact with biotic elements like vegetation and humans, which might suggest that water ecosystems have become more isolated since they are being stressed by a bigger intensity of these factors then coastal ecosystems. An analysis of the quality and quantity of these synergies will be presented in the next subchapter.

Fig .98 Ecosystem synergies assessment
(Made by author, 2020)

Fig .99 Ecosystem location in Weser Estuary
(Made by author, 2020)



Synchronizing habitat: Risk management by co- evolution of environment and society

Chapter

5.2

Process scale

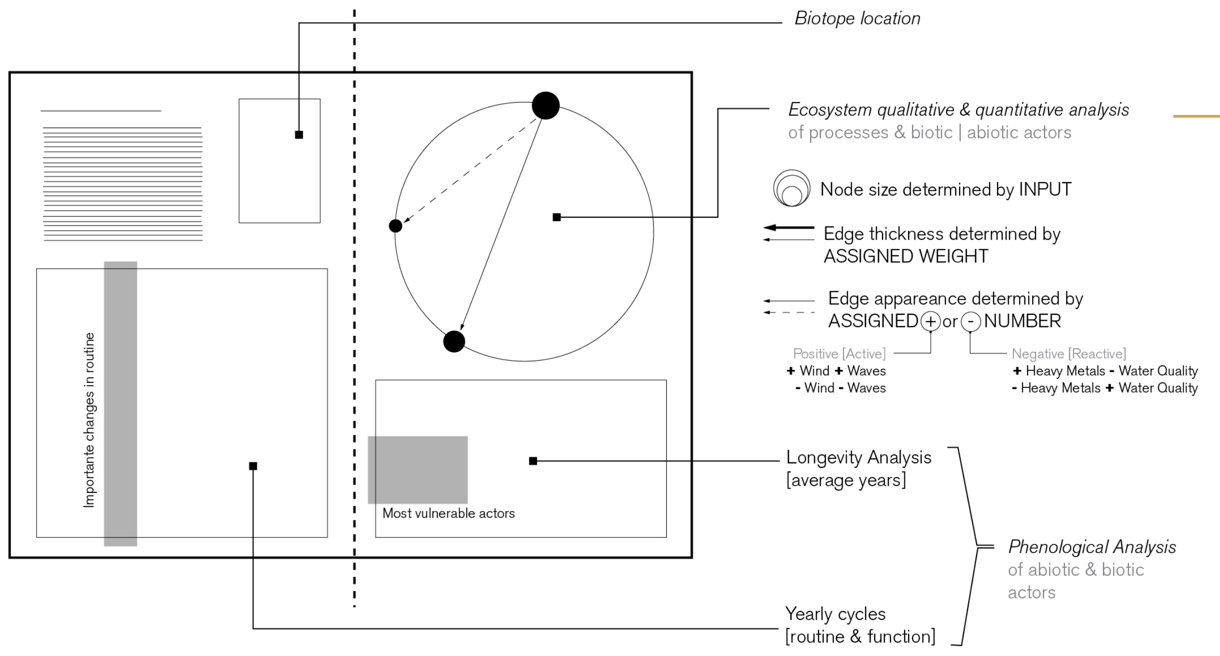
DESIGN PROJECT

Fig .100 Colonization of concrete structure by benthic life at Wadden Sea
(Taken by author, 2019)

Ecosystem assessment: Methodology

Since a framework to asses ecosystem synergies not solely based on their functionality to human life was available, the following method was created. The idea behind this framework is to asses which actors or elements present in the ecosystem are the most vulnerable and which are the influences that are affecting it the most. Since ecosystems are complex systems, a model was required to represent this in a readable way. The model required the assignment of values for each connection (edge) to give the actors or elements a size (node) that represented their vulnerability within the system. The appointed values were determined by careful research on all elements, with special attention on the results of the latest Wadden Sea Quality Reports by the common Wadden Sea Secretariat in 2017.
Since *ecological succession* required the understanding of cycles and routines to have a notion of time and evolution, I decided to include a phenological analysis for each ecosystem. Hereby I determined the average longevity of each biotic and abiotic element that could approximately give me an idea of the lifespan of the ecosystem as a whole. Additionally, the analysis of the yearly cycles shows at what moments in time certain elements perform certain actions and fulfill a function required by the next actor/ element. It was also interesting to include the repercussions of climate change over these cycles, which mostly constitute of monthly shifts, that affect its own or a dependable actor's ecological succession.

Fig .101Ecosystem Assessment . Page content
(Made by author, 2020)



Step 1: Make table *(Microsoft Excel)* with source target & assign a weight [from -1 to 4] determiend by research.

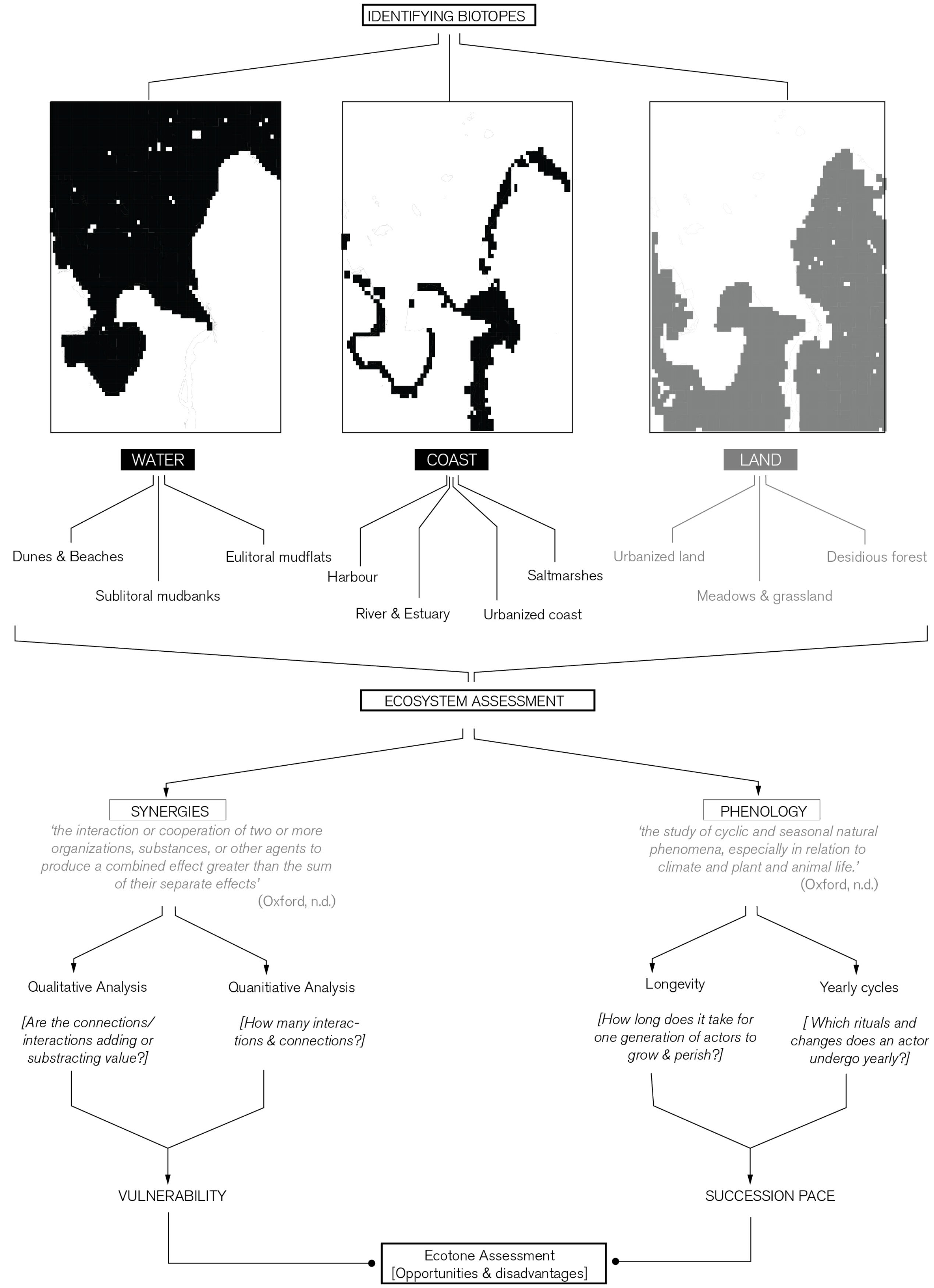
Step 2: Introduce table in *Gephi* + run 'Average Weighted Degree'.

Step 3: Set node appearence to organize by 'Input- Weighted Degree'. Set edge appearence to show 'Weight' [assign colours].

Step 4: Data table in *Gephi* shows 1) most vulnerable actor [most negative input degree] 2) Less vulnerable actor [more possitive input degree].

Step 5: Graphic shows which nodes send the most negative outputs [most substractive actors].

Fig .102 Ecosystem Assessment . Step by step
(Made by author, 2020)



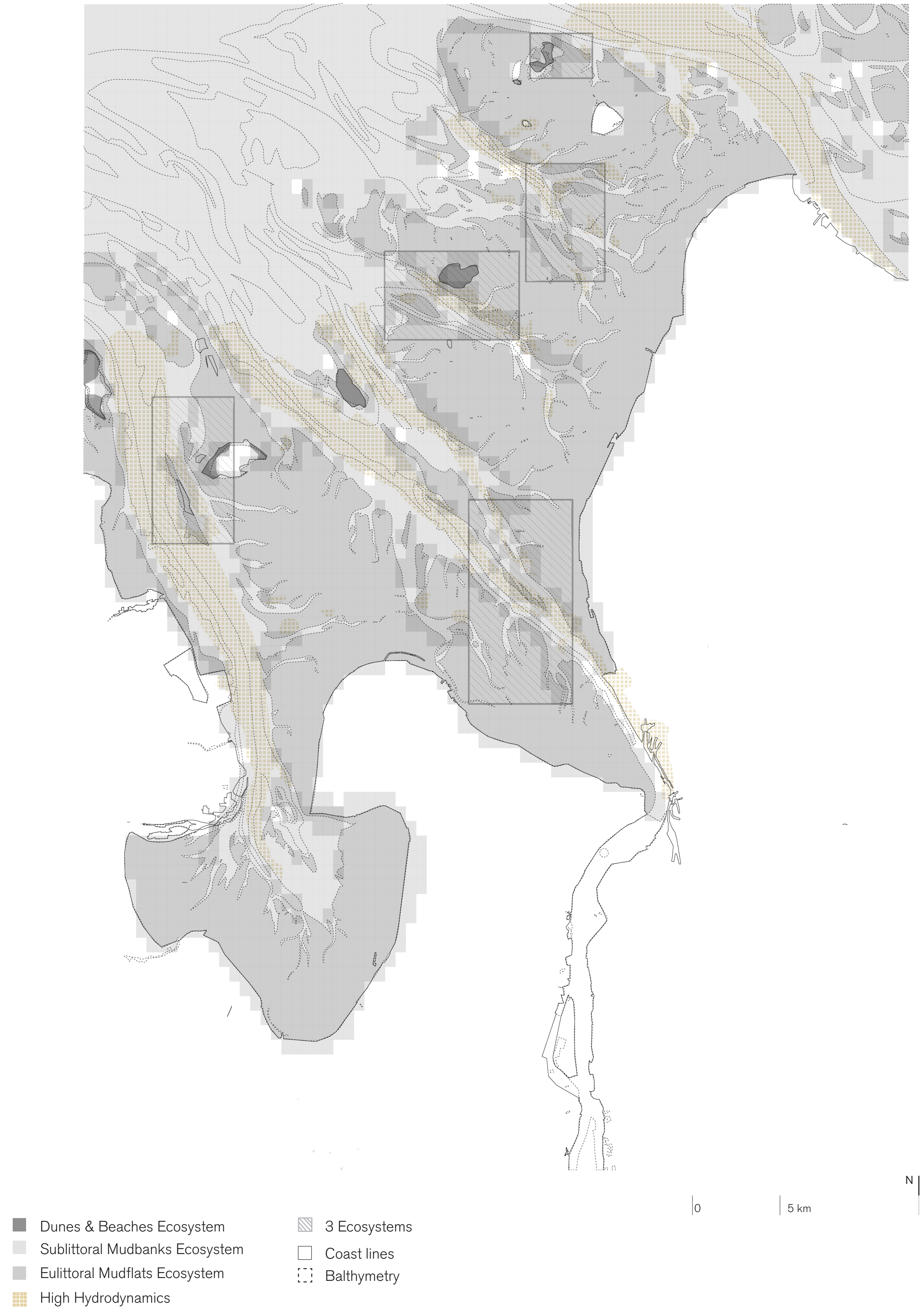
Chapter

5.2.1

Barrier Island

WATER ECOSYSTEM ASSESMENT & DESIGN

Fig .103 Water Ecosystems location
(Made by author, 2020)
(Data from: Baptist et. al., 2019)



ANALYSIS

Assesment of Ecosystem: Dunes & Beaches

Even though dunes and beaches only concentrate scarcely around the Weser Estuary area it is one of the most valuable areas for marine fauna, birds, and humans alike. These ecosystems are also the most elevated above the ground, but the most influenced by oceanic dynamics. The assessment shows that most processes have a great influence over the system allowing only a small amount of life to inhabit them. We can see that the most vulnerable actor is dune vegetation, probably because of the low elevation of the Weser estuary dunes (some are even classified as sandbanks).

The longevity analysis revealed that most biotic elements could suffer from life-span shortage due to underdevelopment as a consequence of climatic changes and unavailable habitats to grow properly without a disturbance. The phenological analysis supports this by showing how migratory species that come to this area for breeding are forced to leave later or earlier, which leads to the abandonment of their youngling or to skip the period completely due to lack of food and shelter (de Groot et al., 2017; Jensen et al., n.d.; Koffijberg et al., n.d.).

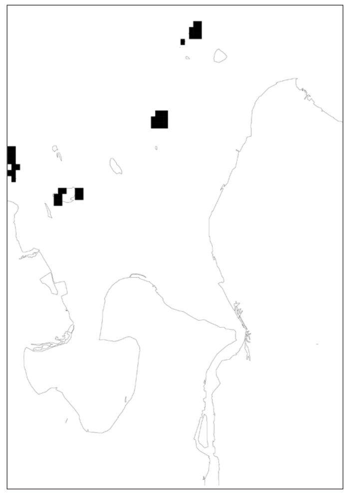
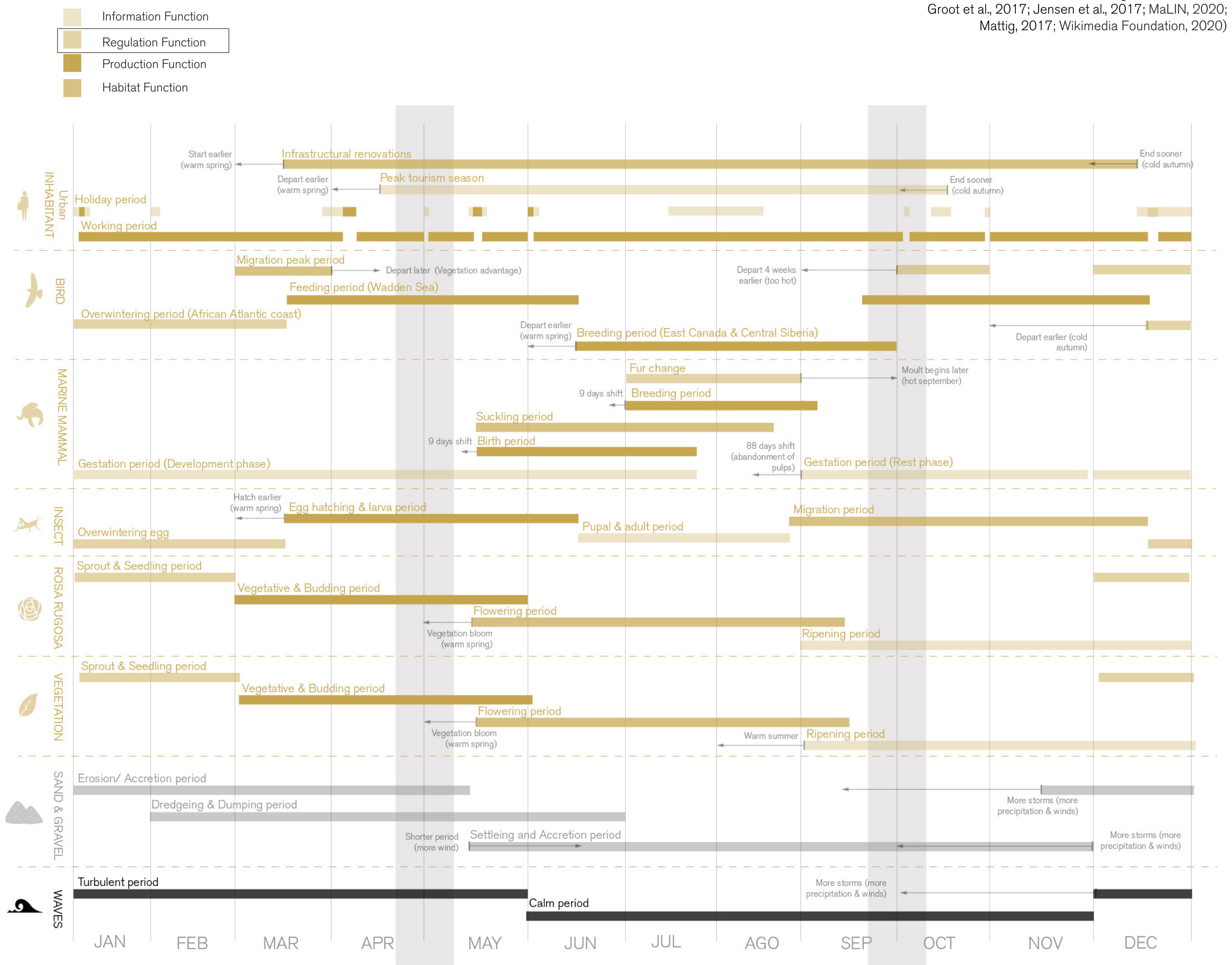
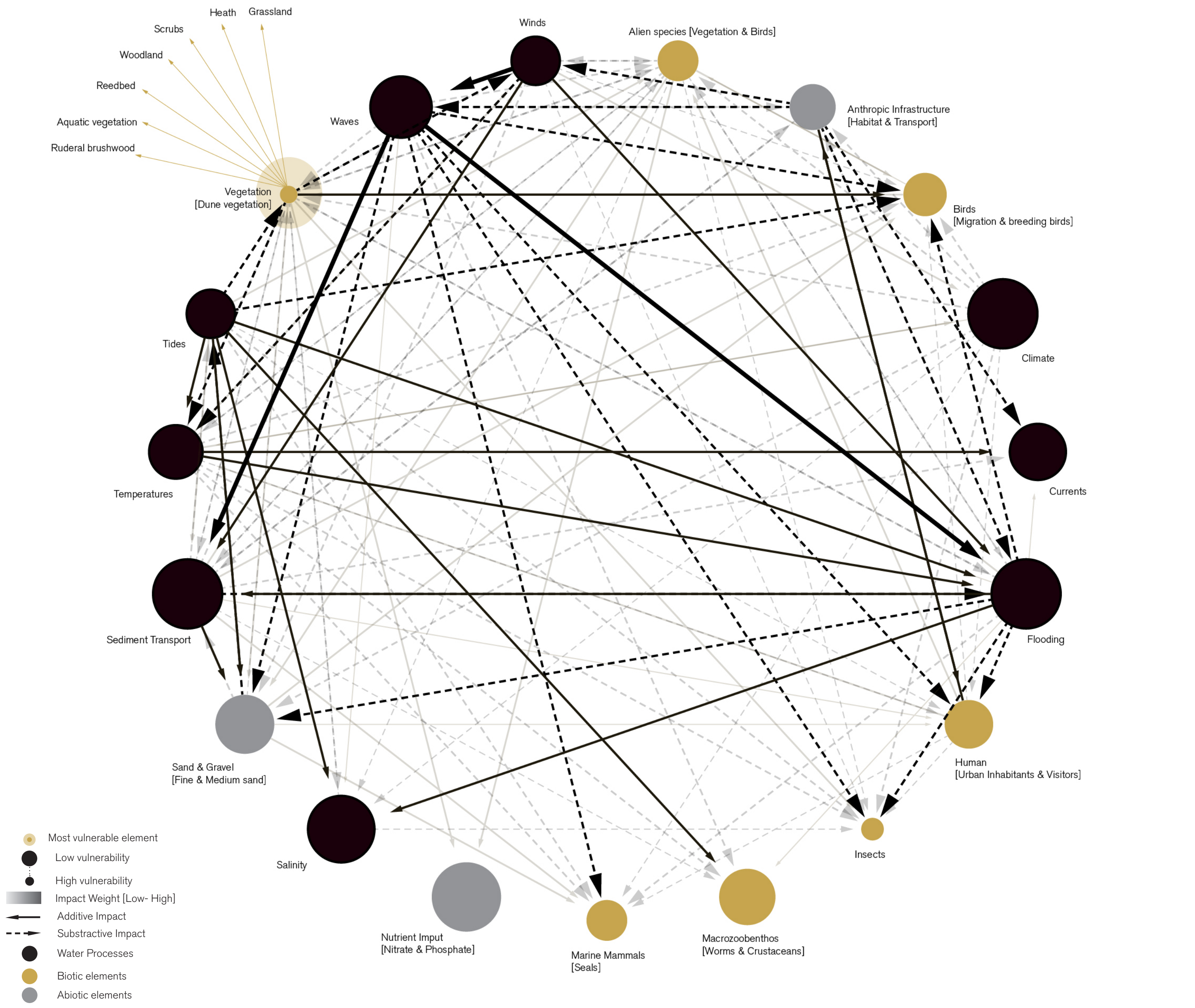
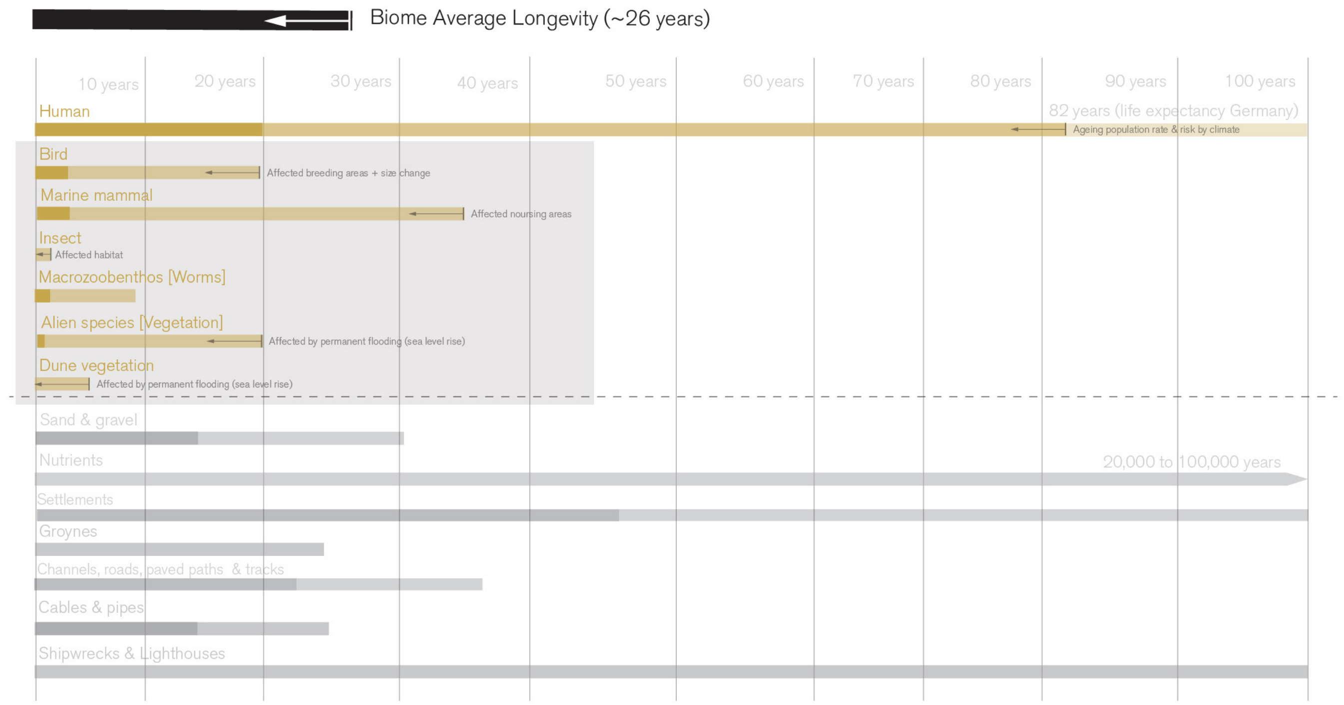


Fig. 104 Location & Longevity Analysis of Dunes & Beaches
(Made by author, 2020))
(Data from: Blew et al., 2017; Büttger et al., 2017; de Groot et. Al., 2017; Donnelly, 2015; Jensen et al., 2017; MaLIN, 2020; Mattig, 2017; Mendick, 2012; SubOptic, 2016; Iannotti, 2019 ; Tietz & Stuart,2017; Wikimedia Foundation, 2020; WorldBank, 2017)

Fig. 105 Dunes & beaches synergies & yearly cycles analysis.
(Made by author, 2020)
(Data from: Blew et al., 2017; Büttger et al., 2017; de Groot et al., 2017; Jensen et al., 2017; MaLIN, 2020; Mattig, 2017; Wikimedia Foundation, 2020)





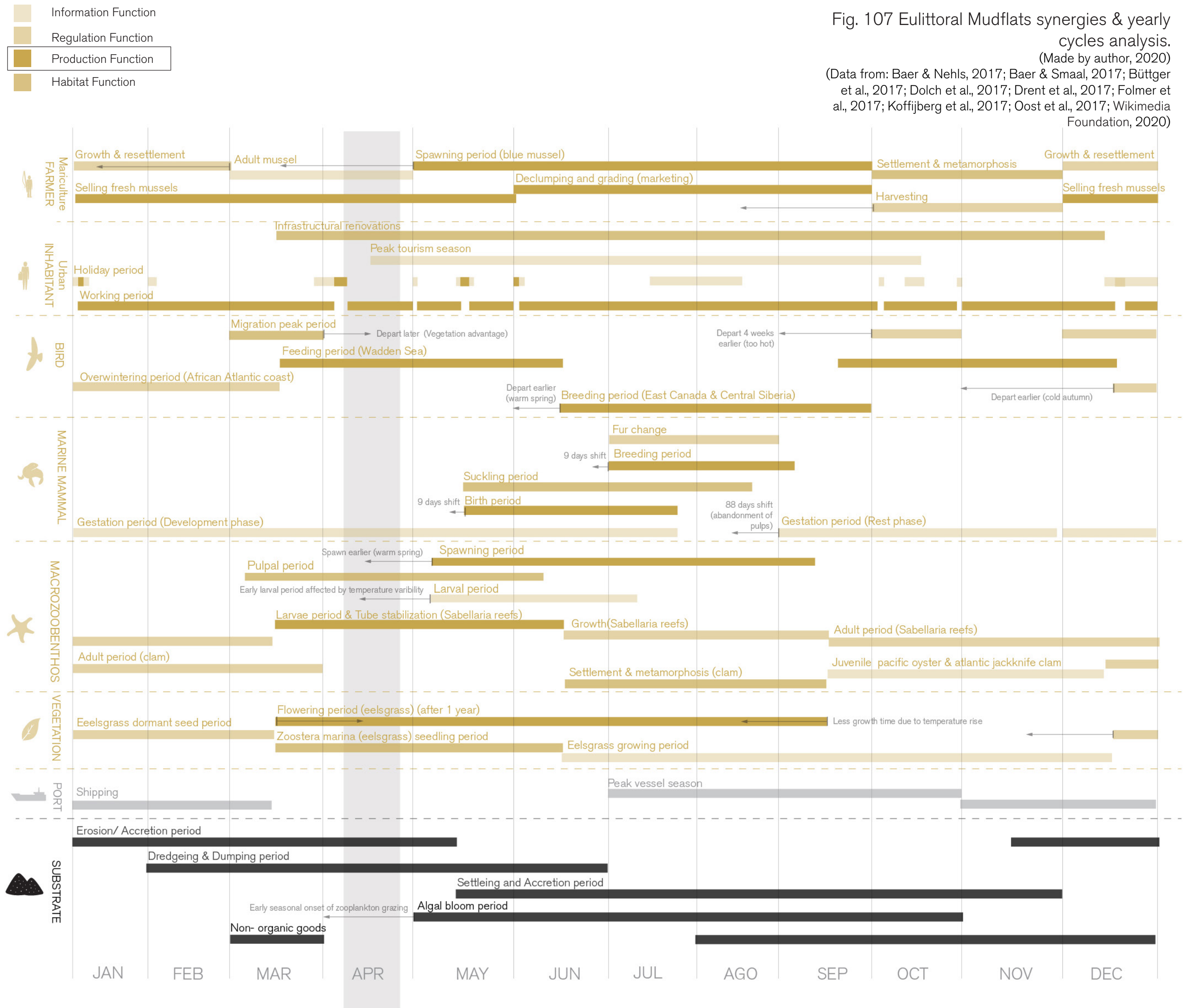


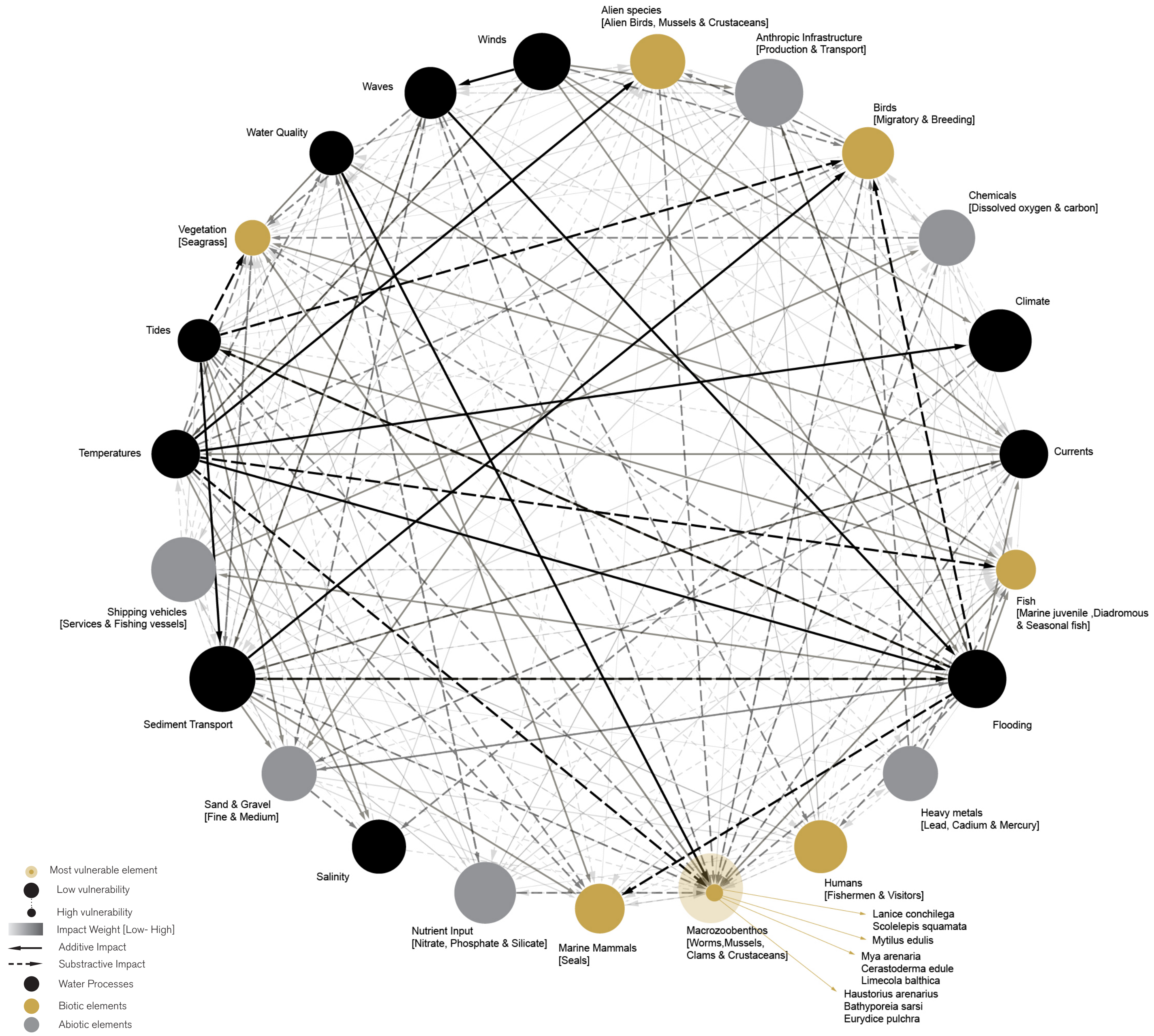
Assesment of Ecosystem: Eulittoral Mudflats

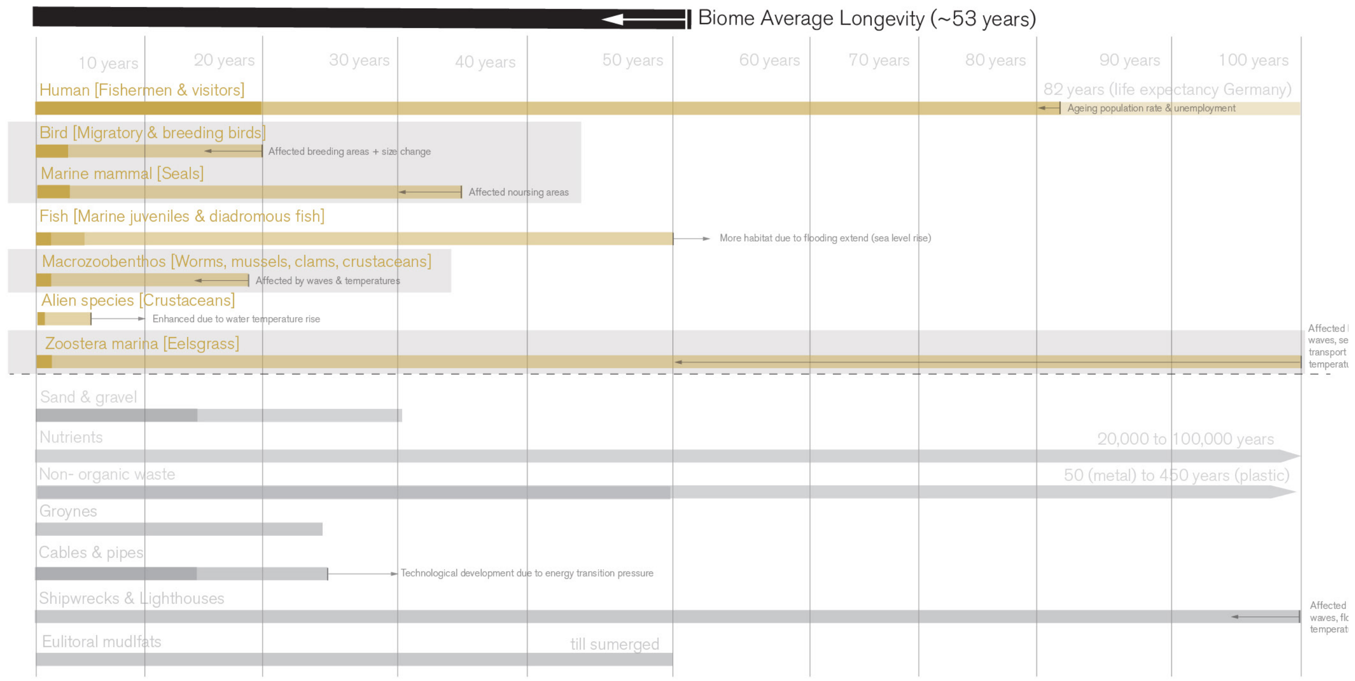
Eulittoral mudflats make out the valuable intertidal area that protects the coast and are the reason why the Wadden Sea became a UNESCO Heritage Site. They have greater importance in the Weser Estuary since a system of barrier islands is unavailable. They have to carry the load and stress of waves, sediment transport, anthropic activities, currents, and tides alone. This is also shown in the synergies circle where processes like sediment transport, flooding and waves are continuously increasing in strength, so that biotic and abiotic thresholds are overtopped and either increasing its succession rate to survive or completely disappearing from the area. This is the case of most of the macrobenthic species still left in the Weser Estuary. Its longevity is decreasing alongside other biotic species like birds and fish that depend on their availability to colonize these areas.
Their decrease in the area affects the cycles of other species, including human mariculture farmers that are beginning to implement alien invasive species as an alternative, which conditions the system to change even more. The loss of macrozoobenthos also allows sediments to move even more freely so that vegetation species can hardly attach to the ground to form habitats for fish and food for birds. The month of April will probably show significant activity compared to previous times (Drent et al., 2017).

Fig. 106 Location & Longevity Analysis of Eulittoral Mudflats
(Made by author, 2020)
(Data from: Baer & Nehls, 2017; Baer & Smaal, 2017; Büttger et al., 2017; Climate- ADAPT, 2015; Dolch et al., 2017; Drent et al., 2017; Folmer et al., 2017; HAGR, 2020; IUCN, 2019 ; Koffijberg et al., 2017; MaLIN, 2020; Mendick, 2012; Oost et al., 2017; SeaLifeBase, 2019; SubOptic, 2016; University of Michigan, 2020; Wikimedia Foundation, 2020; World-Bank,2017; World Life Expectancy, n.d.)

Fig. 107 Eulittoral Mudflats synergies & yearly cycles analysis.
(Made by author, 2020)
(Data from: Baer & Nehls, 2017; Baer & Smaal, 2017; Büttger et al., 2017; Dolch et al., 2017; Drent et al., 2017; Folmer et al., 2017; Koffijberg et al., 2017; Oost et al., 2017; Wikimedia Foundation, 2020)







Assesment of Ecosystem: Sublittoral Mudbanks

The sublittoral mudbanks are the ecosystem that stands between the deep sea and the intertidal mudflats. Its extension has been morphologically modified by humans by building channels to allow huge vessels to enter the shallow water of the Weser Estuary and reach several container ports. Surprisingly they still host small habitats for marine communities, but most of the species found in this ecosystem are not residents (migrating). This is also visible in the synergies analysis were most marine fauna takes advantage of the traffic of different migratory species to hunt. Therefore the only sedentary species is the most vulnerable: macrozoobenthos. The dynamics of the sea enhanced by its greater depth (in comparison to the rest of the ecosystems) added to the anthropic turbidity and externality input by anthropic traffic and anchorage areas, makes this area hard to inhabit and prone to low water quality characteristics.

Even though most species are passing by, biotic lifespan is threatened by these changes and water quality issues, which lower the biomes longevity that creates routine changes, again mostly around April / March. Due to tidal range change and sedimentation increase, vessel channels might need to be dredged more often, disrupting vessel traffic continuity and increasing the frequency of ecological succession rates that cannot keep up with constant rapid morphological change by dredging (Bahlke, 2017; Drent et al., n.d.; Schultze & Nehls, 2017).

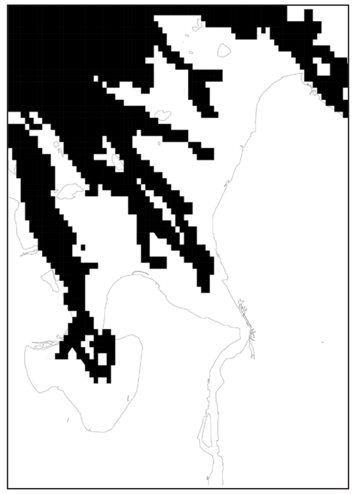
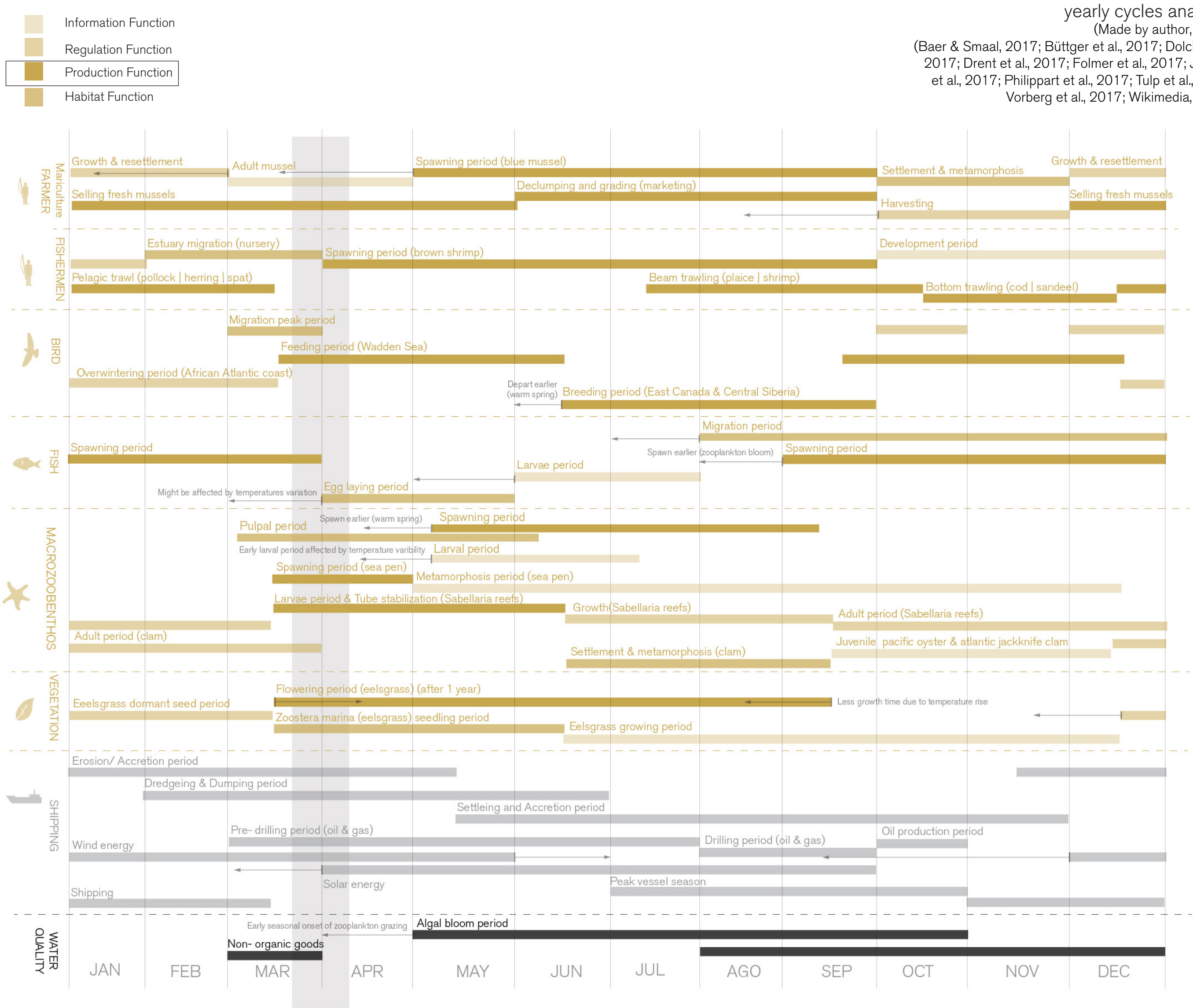
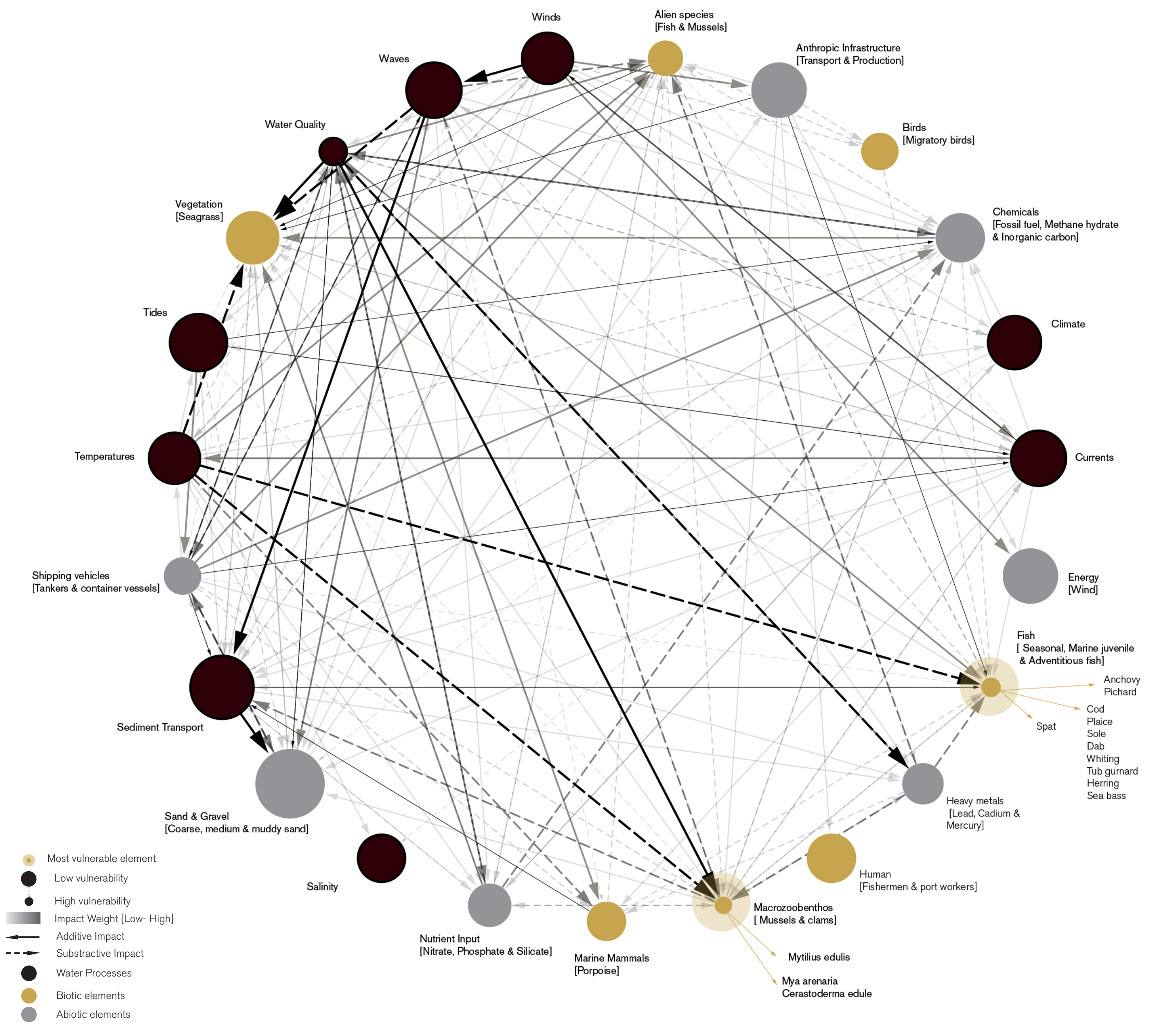
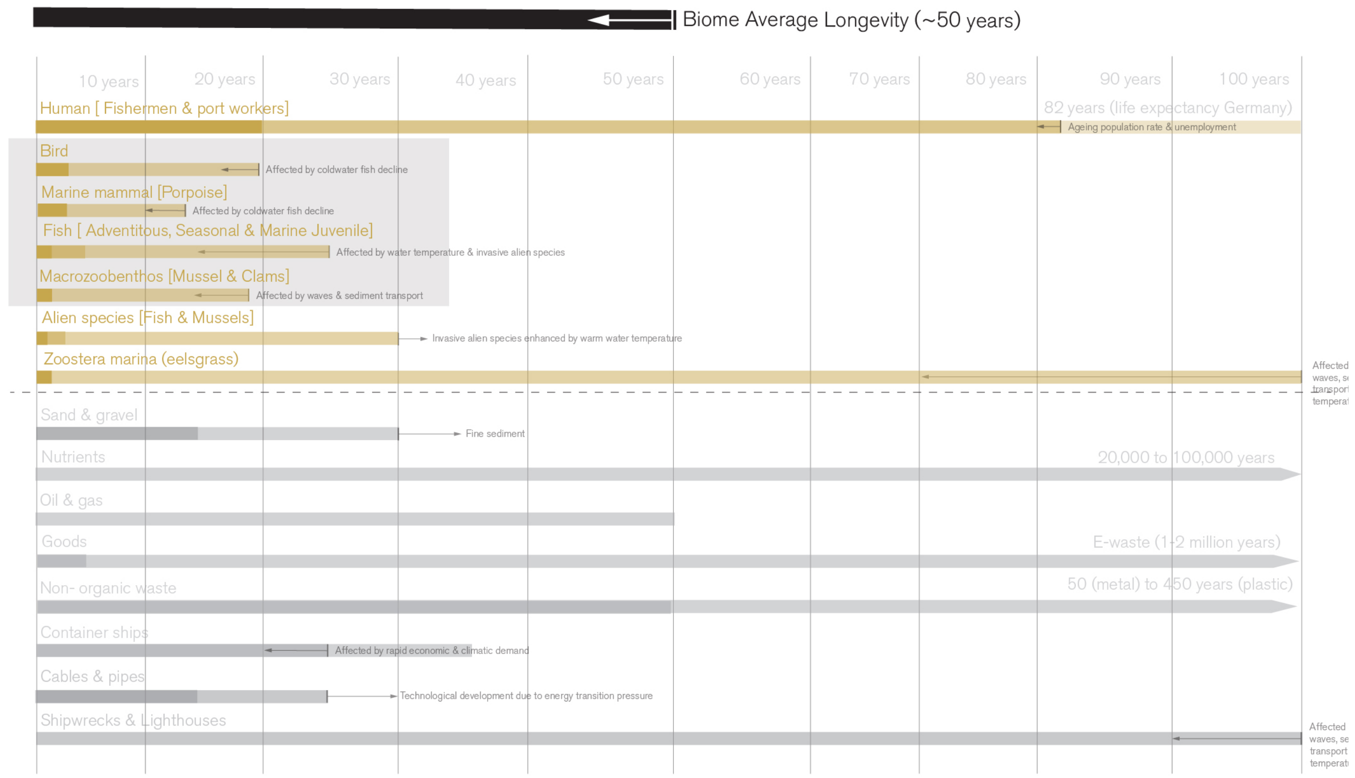


Fig. 108 Location & Longevity Analysis of Sublittoral Mudbanks
(Baer & Smaal, 2017; Büttger et al., 2017; Climate-ADAPT, 2015; Dolch et al., 2017; Drent et al., 2017; Folmer et al., 2017; HAGR, 2020; IUCN, 2019 ; Jensen et al., 2017; MaLIN, 2020; Mendick, 2012 ; Philippart et al., 2017; SeaLifeBase, 2019; SubOptic, 2016; Tulp et al., 2017; University of Michigan, 2020; Vorberg et al., 2017;Wikimedia, 2020; WorldBank,2017; World Life Expectancy, n.d.)

Fig. 109 Sublittoral Mudbanks synergies & yearly cycles analysis.
(Made by author, 2020)
(Baer & Smaal, 2017; Büttger et al., 2017; Dolch et al., 2017; Drent et al., 2017; Folmer et al., 2017; Jensen et al., 2017; Philippart et al., 2017; Tulp et al., 2017; Vorberg et al., 2017; Wikimedia, 2020)





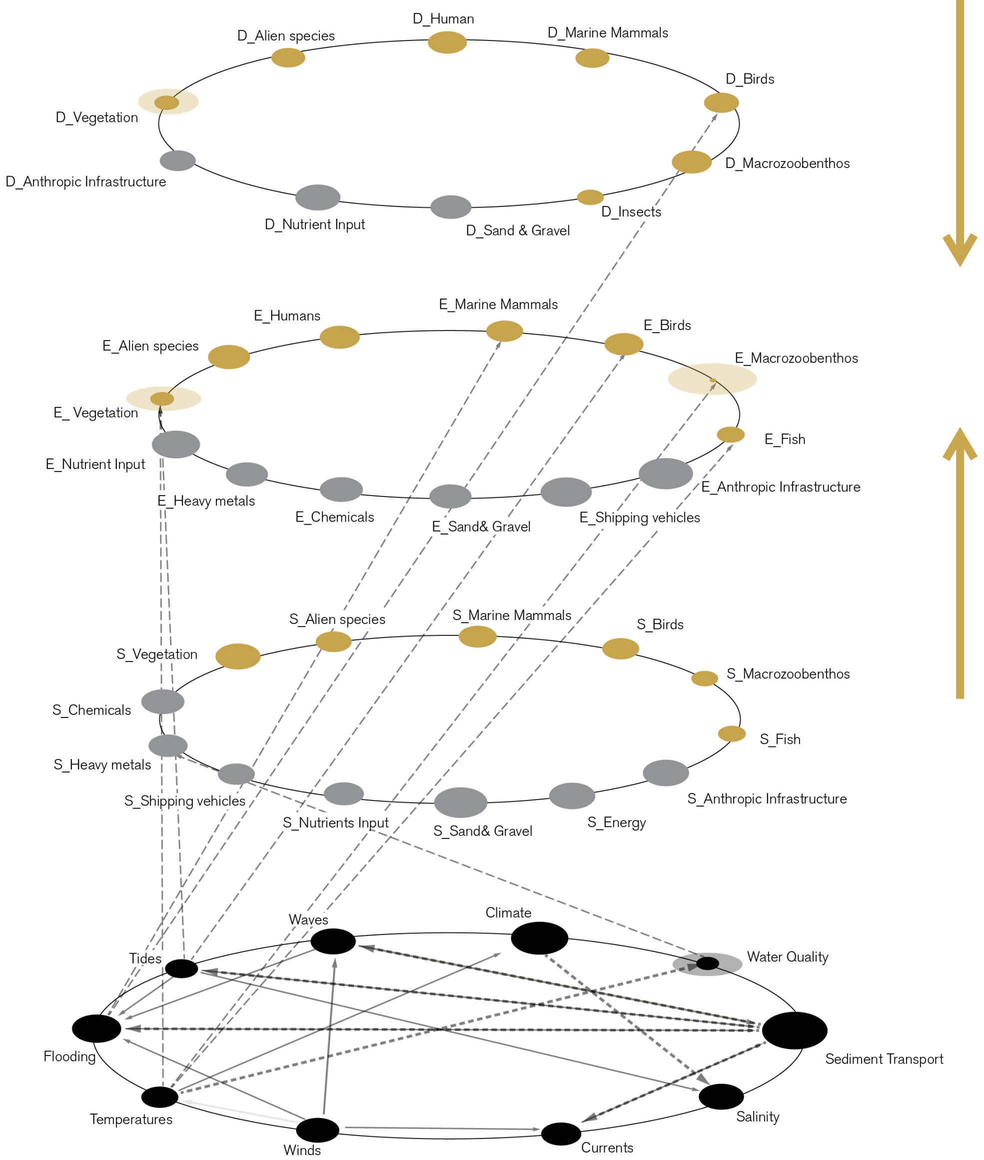


Assesment of Ecotones & Ecosystems: Results

As a final step of the assessment, it was important to see how the three water ecosystems interact with each other. This way I could see if they are already building ecotones by judging the quality and quantity of interactions.
As we can observe in the graphic below most ecosystems do not have a strong interaction between each other, meaning ecotones are scares or missing in the area. We can also depict the most vulnerable elements/ actors within this group of ecosystems, the less vulnerable and processes that stress the system with more intensity than others. All of these results were used as information to be considered in the design to catalyze ecotones in the area.

Fig. 110 . Results of synergies between water ecosystems
(Made by author, 2020)

Fig. 111 Results of synergies of each water ecosystem.
(Made by author, 2020)



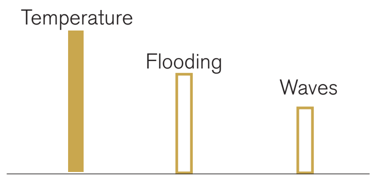
Most vulnerable elements

1. Eulittoral mudflat macrozoobenthos
2. Water quality
3. Eulittoral mudflat vegetation
4. Dune vegetation

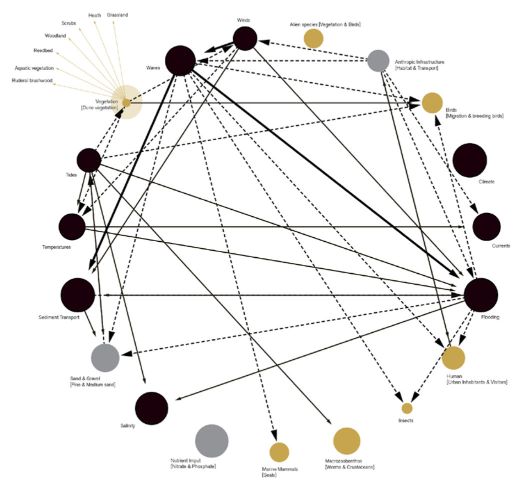
Less vulnerable elements

1. Sediment transport
2. Climate
3. Eulittoral mudflats anthropic infrastructure
4. Sublittoral mudbanks sand & gravel

Most substractive outputs on ecosystems



Dunes & Beaches



Most vulnerable elements

Dune Vegetation > Tides

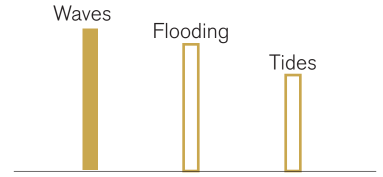
Insects > Waves & Flooding

Less vulnerable elements

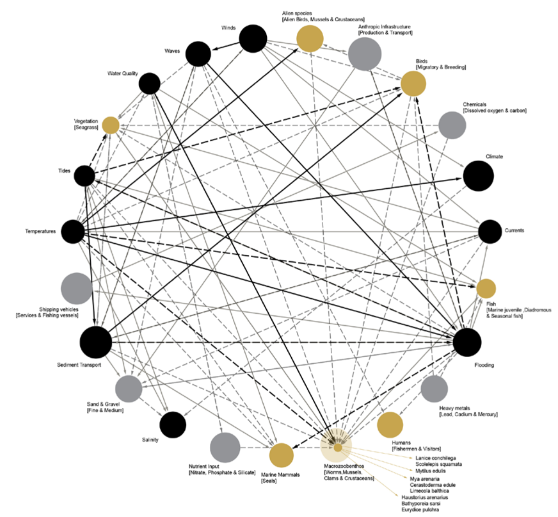
Climate

Flooding

Most substractive output on ecosystem



Eulittoral Mudflats



Most vulnerable elements

Macrozoobenthos > Temperatures

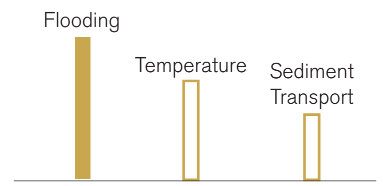
Vegetation> Tides

Less vulnerable elements

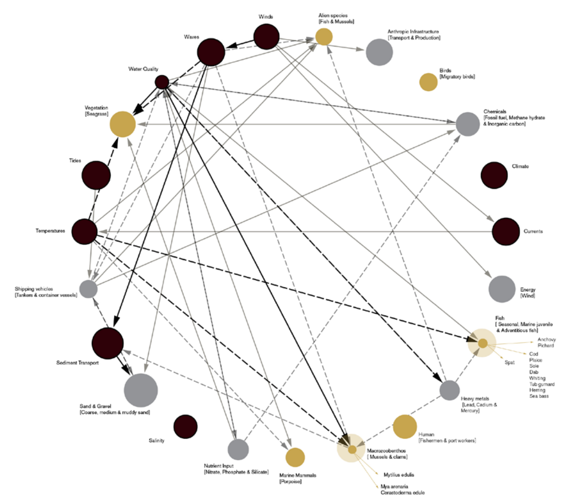
Anthropic Infrastructure

Sediment Transport

Most substractive output on ecosystem



Sublittoral Mudbanks



Most vulnerable elements

Macrozoobenthos > Temperatures & Heavy Metals

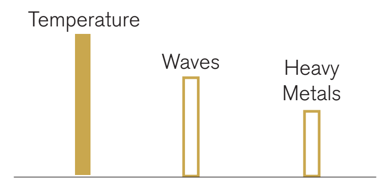
Fish > Temperatures

Less vulnerable elements

Sand & Gravel

Sediment Transport

Most substractive output on ecosystem



RESULTS

Most vulnerable elements

Macrozoobenthos > Change in Temperatures

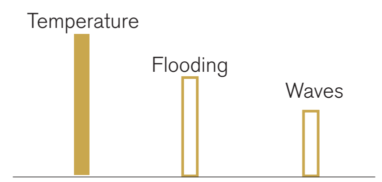
Vegetation > Change in Tidal range

Less vulnerable elements

Sediment Transport

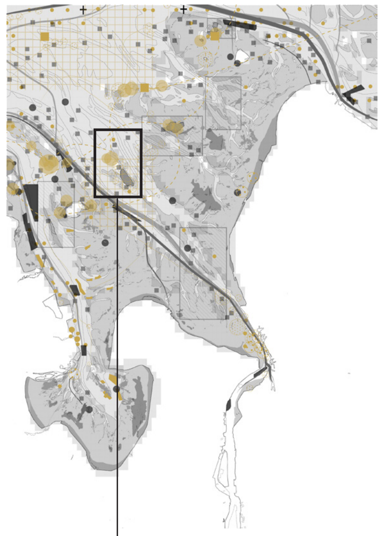
Climate

Most substractive output on ecosystems



Water Ecosystems: Local Scale [Present]

To respond to the presented vulnerable elements of water ecosystems in the Weser Estuary, I decided to test the previously explained design principles in a site on water (see page 129: *Design Principles*). This specific location was determined because it marks the entrance of several ports (fishing and container ports), it hosts a variety of anthropic infrastructure in comparison to other parts of the area such as a windmill park, lighthouses, and shipwrecks, and it also includes small sand formations (dunes) and small extensions of eulittoral mudflats and sublittoral mudbank zones. However only limited and small patches of biotic life concentrate around the area, including seals and birds. Nevertheless, each of these ecosystems seems to be functioning individually, missing the chance of exchange (ecotone formation). If we decompose the area into layers we can only recognize small and isolated interactions between and within the '-*spheres*'.



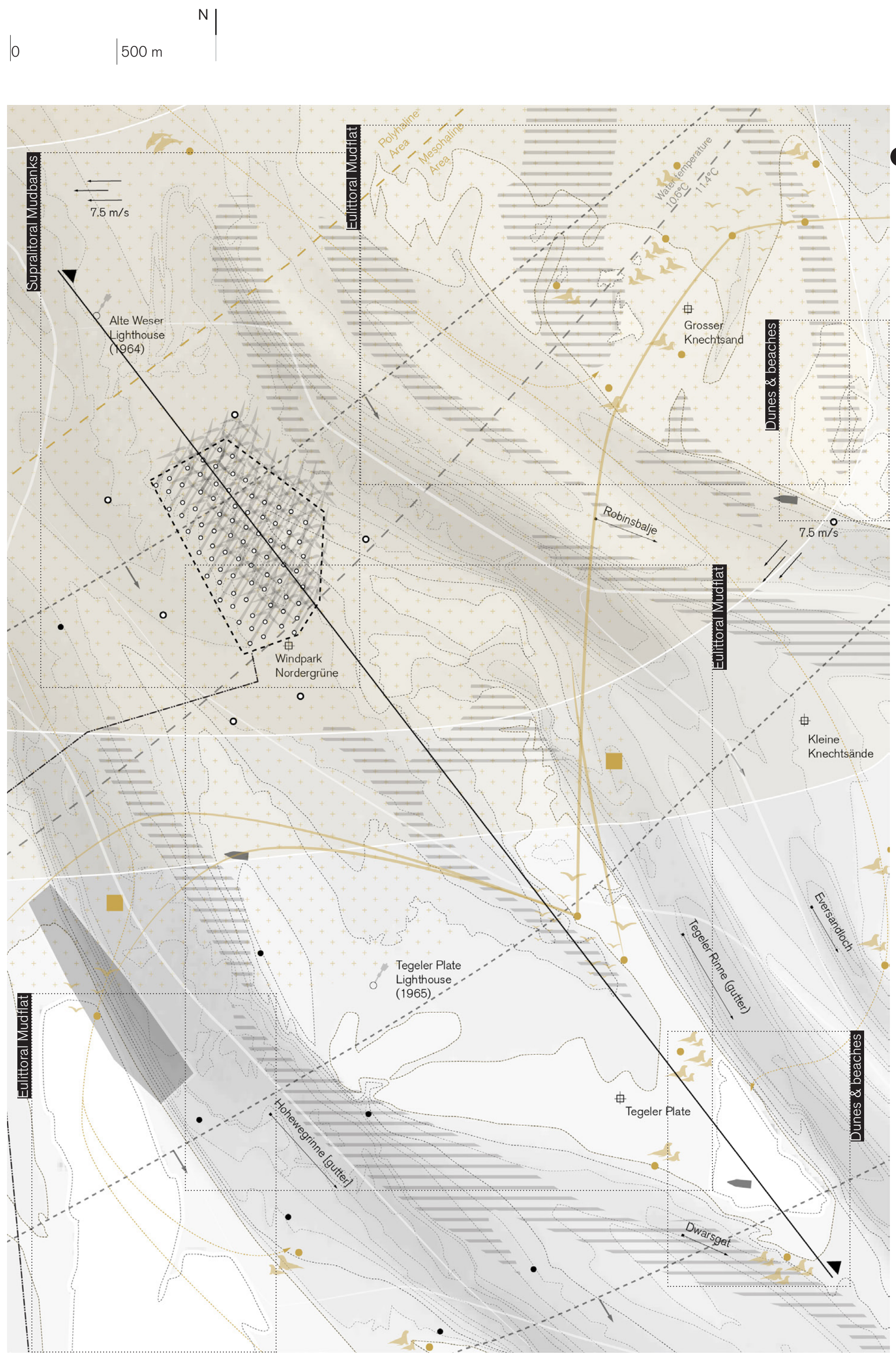


Fig. 112 . Map of conditions 2020 of water ecosystem - Tegler platte [Local scale]
(Made by author, 2020)
(Data from: Geofabrik, 2020; BSH, 2020; Google Earth Pro, 2020; Wattenmeer Besucherzentrum, n.d.)

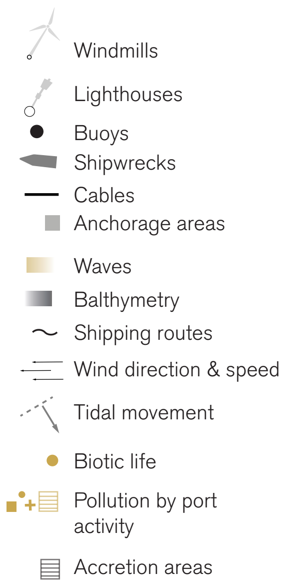


Fig. 113 . Axonometry of present conditions [Local scale]
(Made by author, 2020)

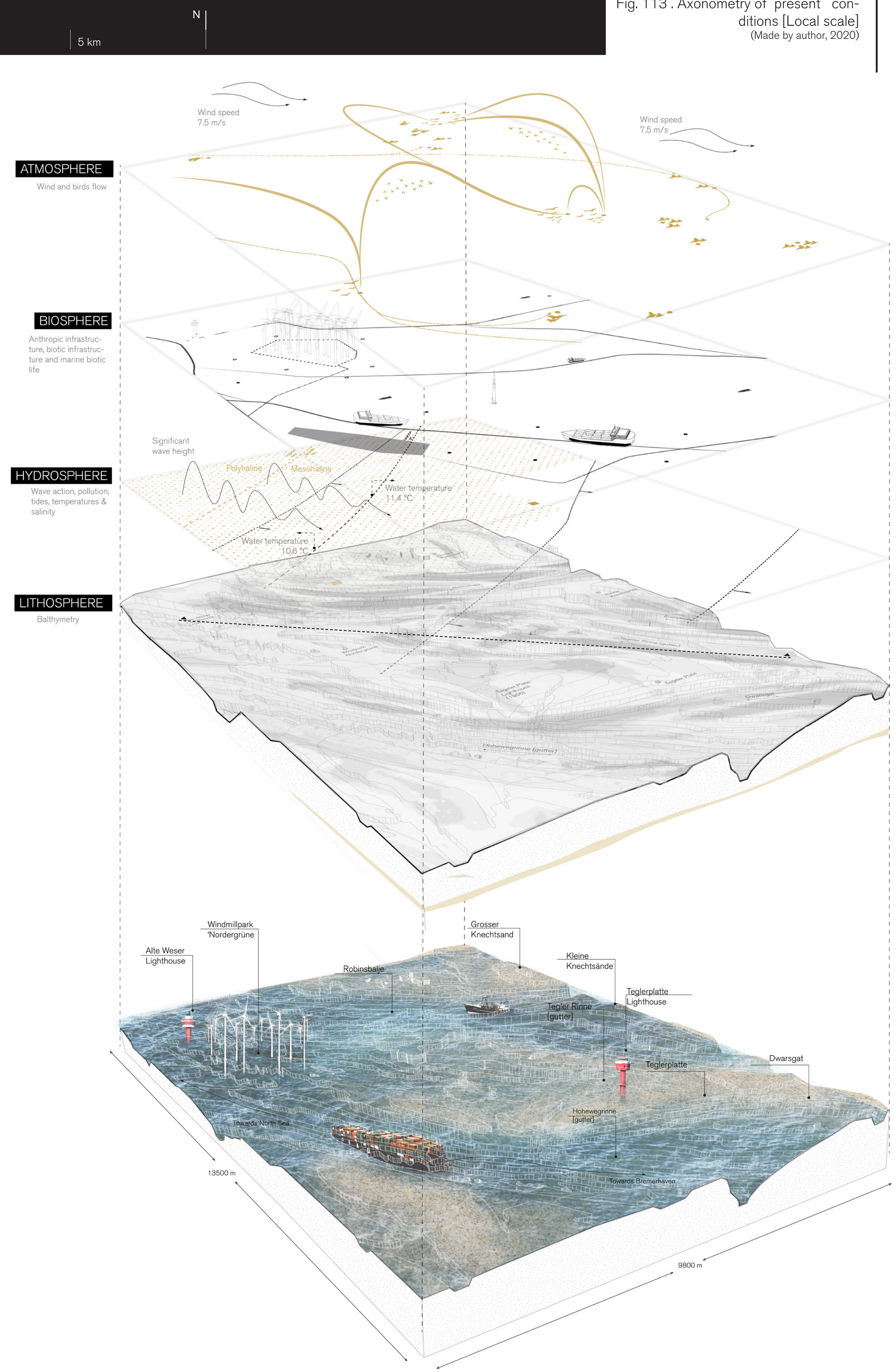


Fig. 114 . Section of current conditions of water ecosystem [Local scale]
(Made by author, 2020) (Data from: BGR,2019; Geofabrik, 2020; GeoSeaPortal, 2020; Google Earth Pro, 2020; Seehkarte Südliche Nordsee, n.d.)

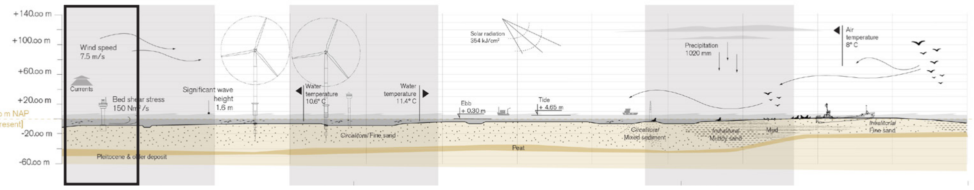
ANALYSIS

Sample of water ecosystems [Present]

A section through the current context reveals the extension of occupation of each element occupying the area. Through this method, we can easily identify gaps where few and unrelated actors wander around. These gaps highlighted in grey can serve as areas to test 3 different projects that could enhance three different ecotones. The first could serve as a transition between the litoral and sublittoral ecosystem, the second as a transition between the sublittoral and the eulittoral ecosystem, and the third between the eulittoral and the dune ecosystem.

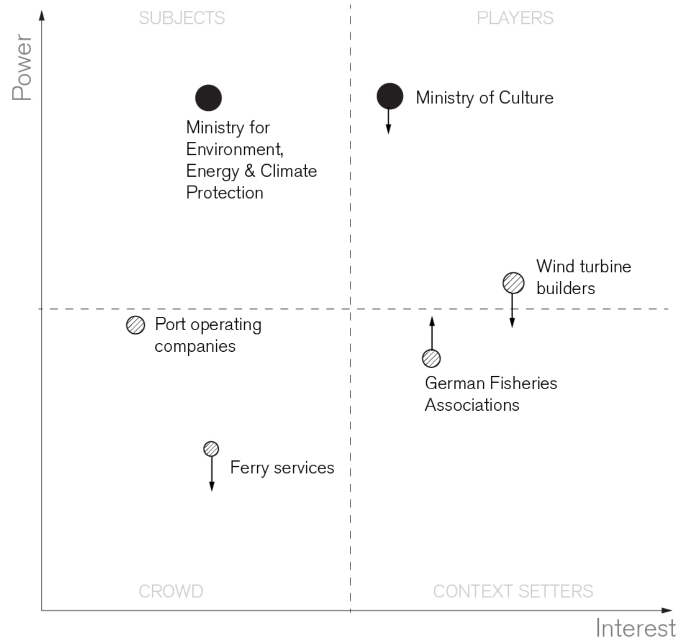
PROJECTS

Pilot 1: Subtidal Breakwaters



The function of the proposed first pilot project is building a subtidal breakwater that takes advantage of the processes available and integrates naturally with anthropic constructions. Anthropic actions are not executed at once but are spread over 60 years and still can respond to the predicted hazardous events. Hereby the project allows the hand of nature to accommodate the intervention first before the next phase begins. This also gives time for technology and research organizations to come up with new innovative and better performing materials for the construction underwater. The proposal shown in the sections below uses a mix of existing and experimental ideas to build a permeable breakwater over time.

Fig. 115 . Evolving section of barrier island project pilot 1[Detail]
(Made by author, 2020)
(inspired by Goad, 2019 ; SCAPE, 2014)



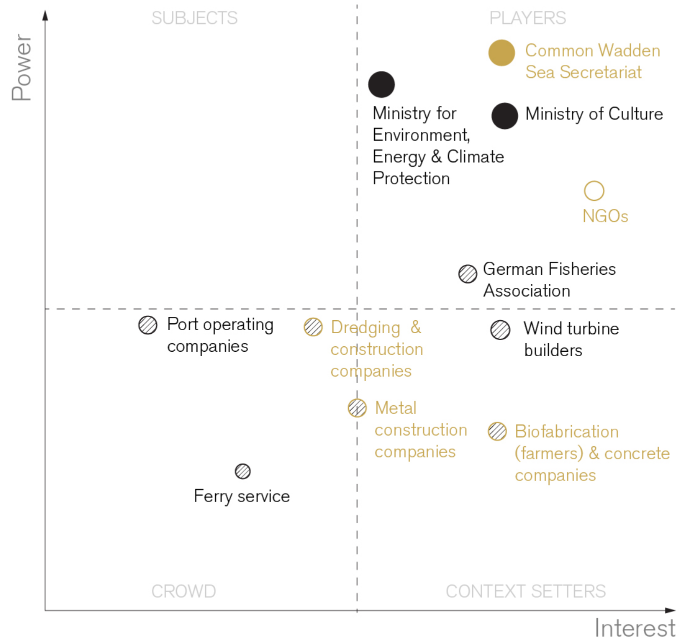
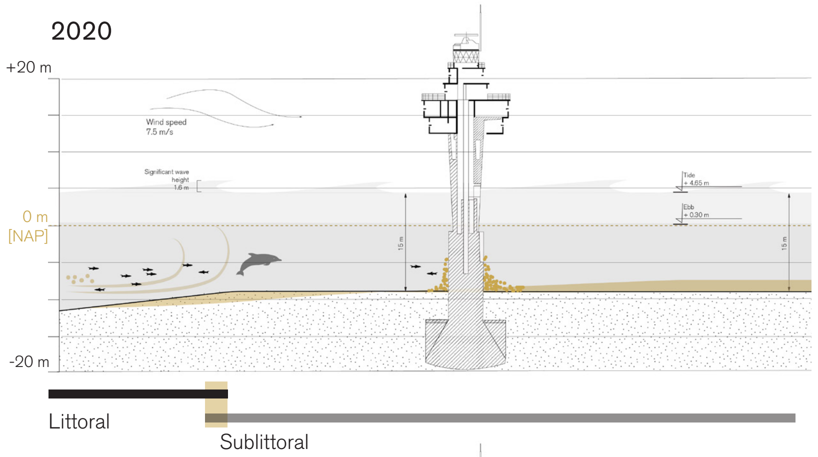
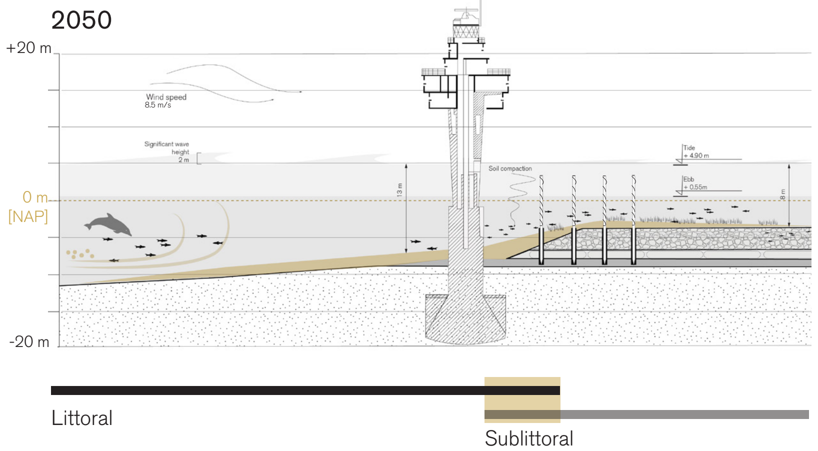
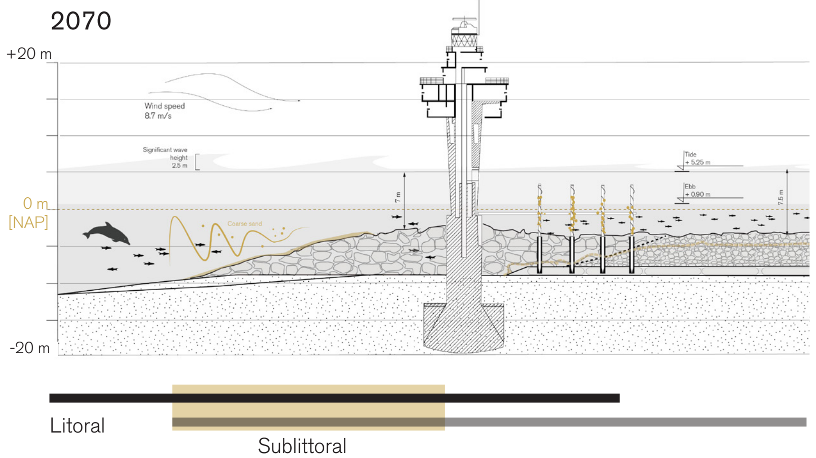
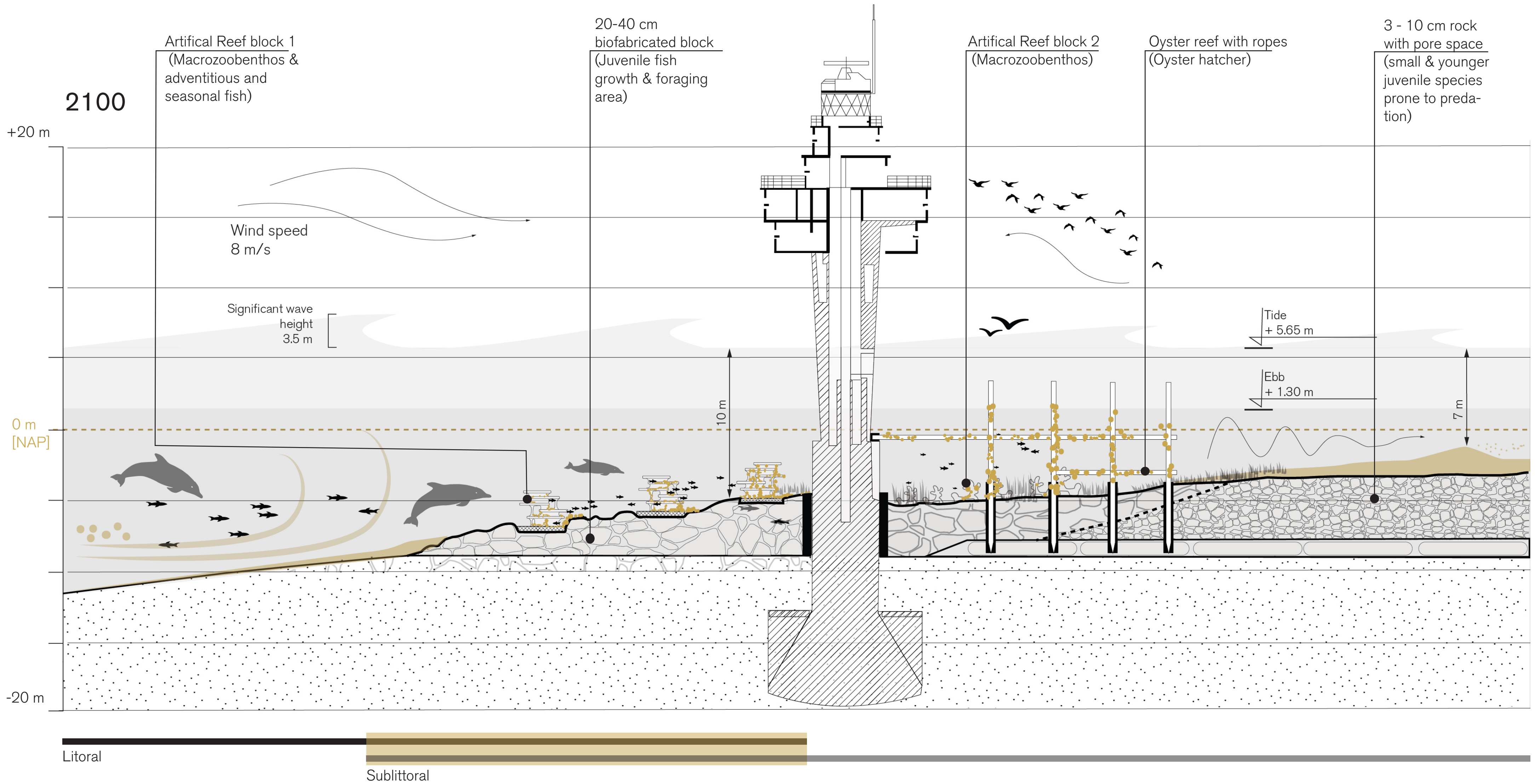


Fig. 116 . Stakeholders analysis - Breakwaters
(Made by author, 2020)



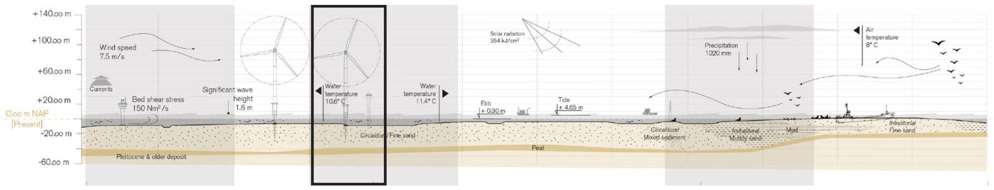






PROJECTS

Pilot 2: Productive mudflat



A second project to enhance an ecotone between eulittoral and supralittoral biomes is a productive mudflat. At first instance, the anthropic project concentrates on sediment accretion strategies with biodegradable poles. The action of waves and currents will allow the ground to grow upwards while trapped between the poles and vegetation that hopefully decided to colonize these areas of low turbidity. As the poles are biodegradable, a second batch could be tested with oyster larvae (Mytilus edulis preferably) These could serve as heavy metal filters (bioaccumulation). Fishermen could extract the fully grown mussel and sell it to construction & cosmetics industry (calcium carbonate). When the water quality is restored the area could be periodically used as an aquaculture cultivation site. However, the most shallow areas of the site should remain uncultivated so that the marine fauna can spread and colonize the area with the additional help of artificial reefs (ECOncrete, n.d.; Goad, 2019).

Fig. 117 . Evolving section of barrier island project pilot 2 [Detail]
(Made by author, 2020)
(inspired by Kotenko & Kakali, 2014; Ta et. al, 2018)

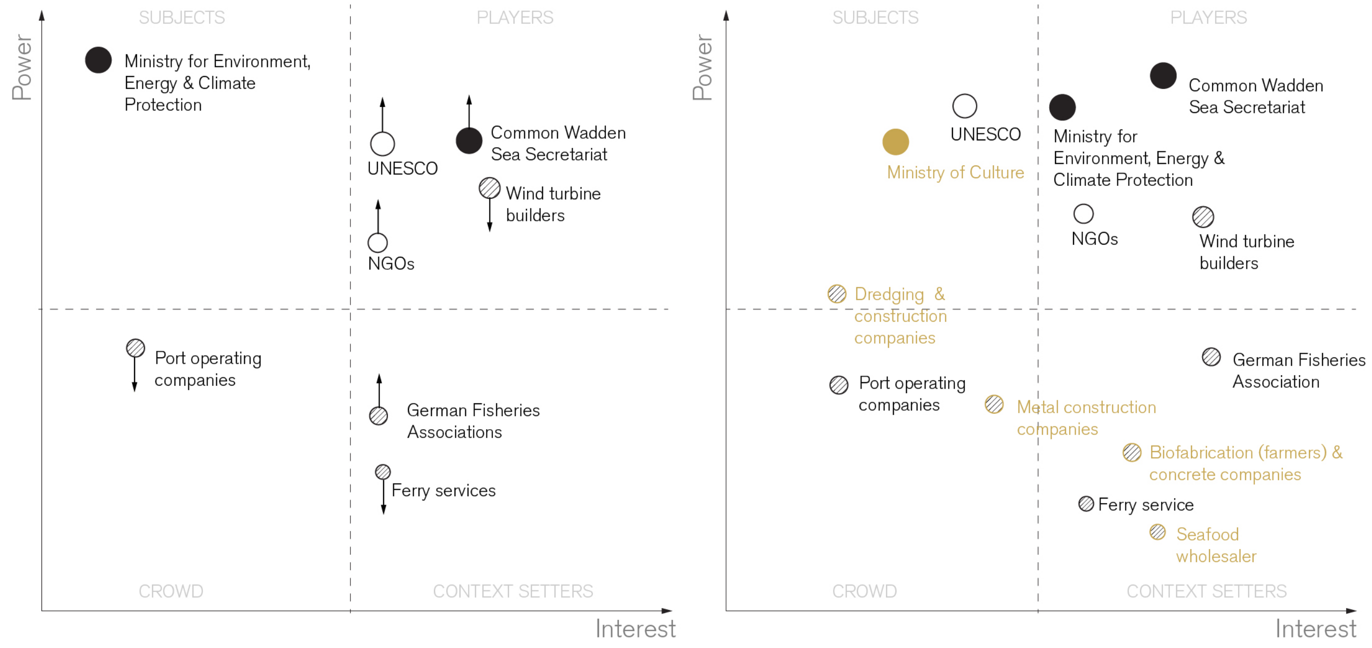
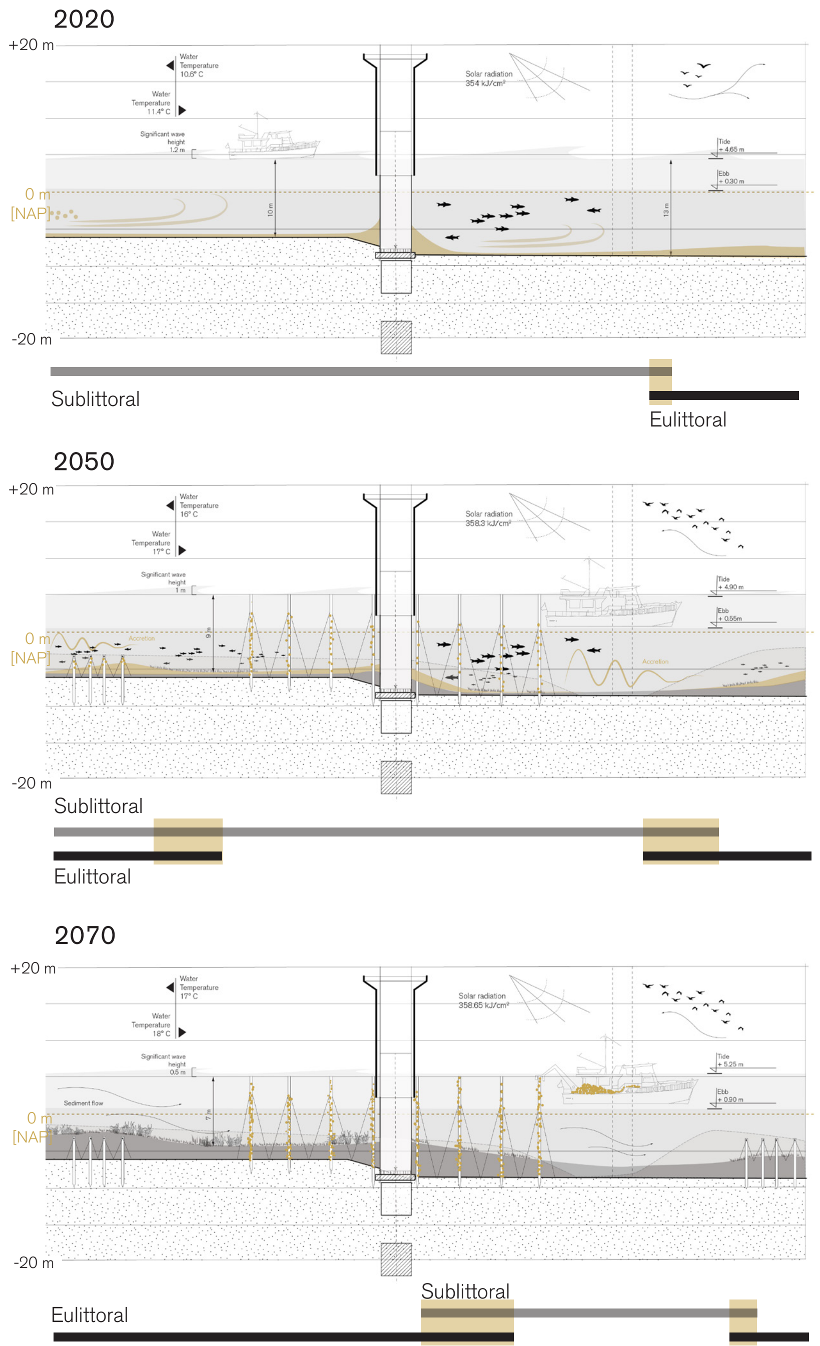
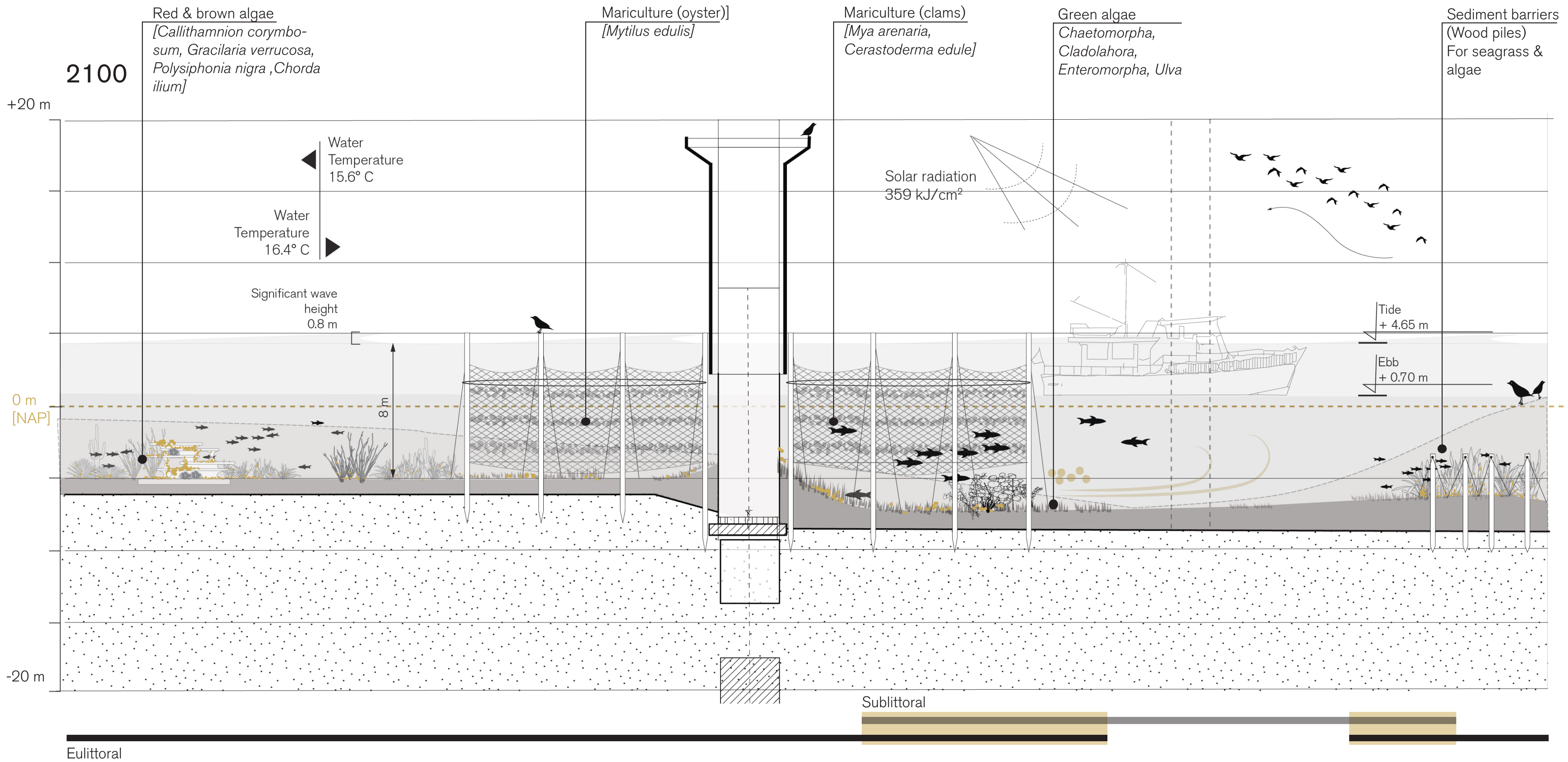


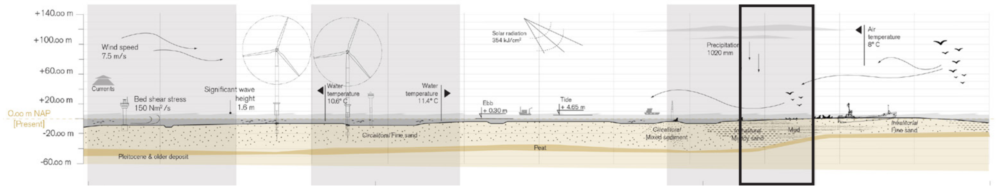
Fig. 118. Stakeholders analysis - Productive mudlftats
(Made by author, 2020)





PROJECTS

Project 3: Barrier Island



The final project for this area consists of the formation of a barrier island. Around the small existing sandbanks, it is possible to place a set of permeable geotubes (Tencate, n.d.) that would form an obstacle or breakwater for waves, currents, and winds. Thorugh time the geotubes will be buried under sediment pushed by these processes forming elevated dunes and beaches. As a way to engage society in the project, education programs and research organizations could place monitoring stations as well as plant and set the seeds for vegetation to bloom around areas of the island. This way a marine tidal garden might evolve, which could trap sediment, as well as nature enthusiasts and visitors so that the island could also offer paths, platforms, and other small recreational/ educational installations.

Fig. 119 . Evolving section of barrier island project pilot 3 [Detail]
(Made by author, 2020)
(inspired by Deng et. al., 2016)

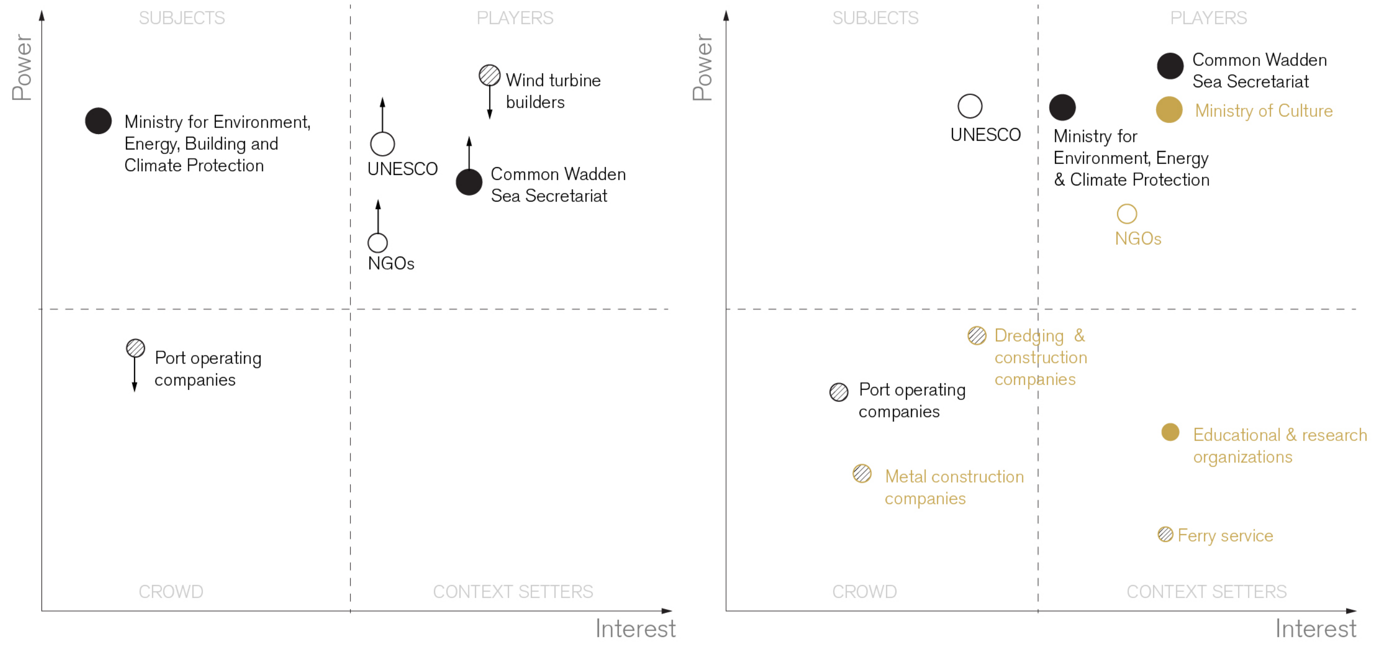
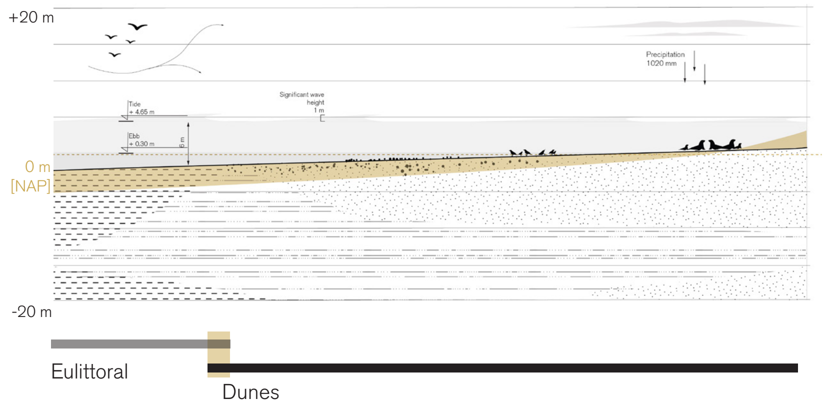
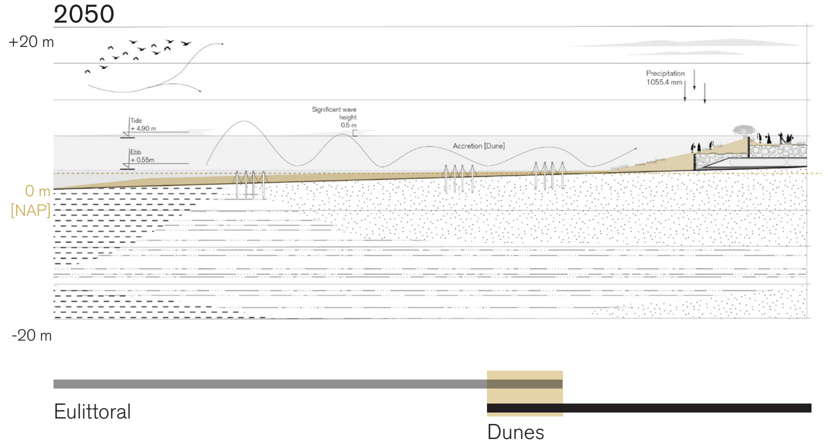


Fig. 120. Stakeholders analysis - Barrier Island
(Made by author, 2020)

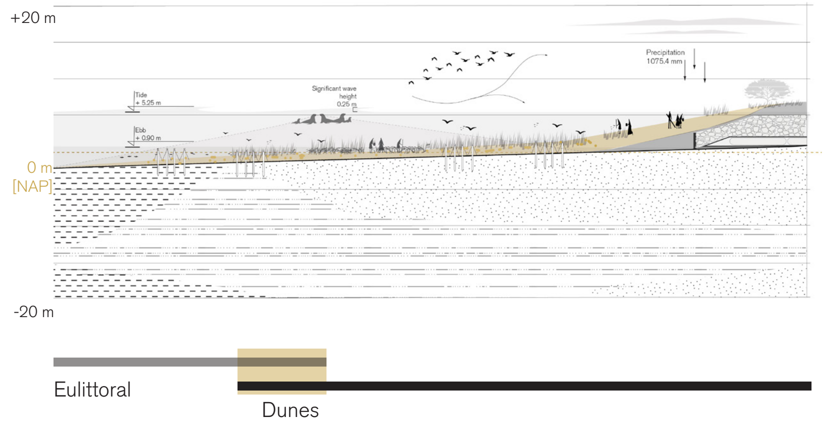
2020



2050



2070



2100

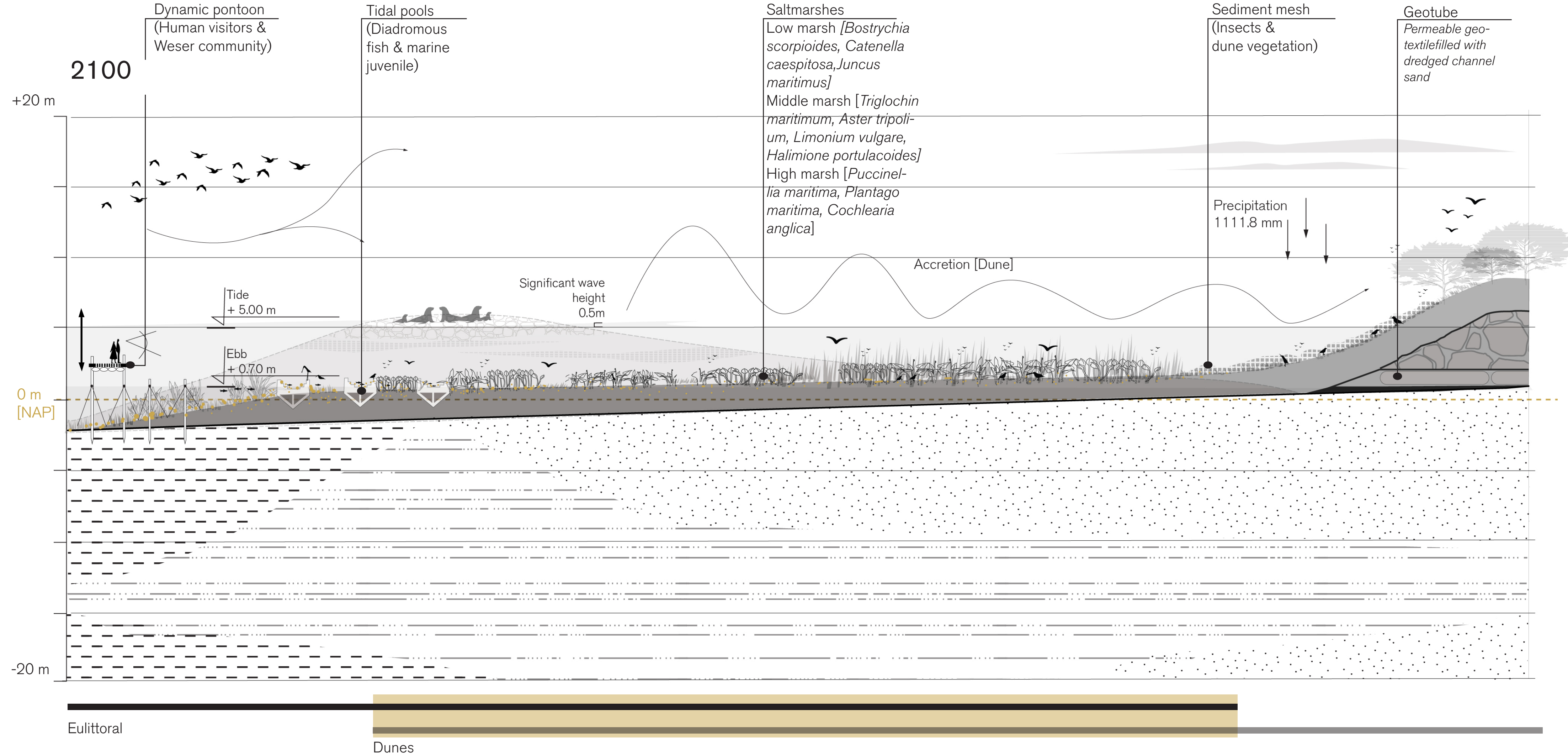
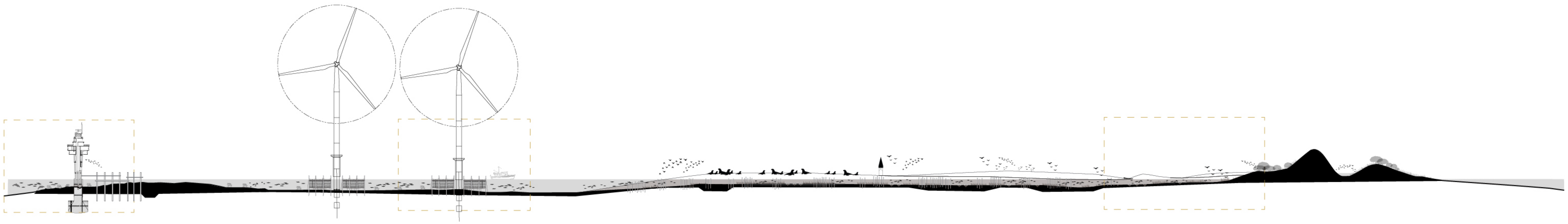


Fig. 121. Overview of the barrier island project and pilots
(Made by author, 2020)

Pilot 1: Breakwaters

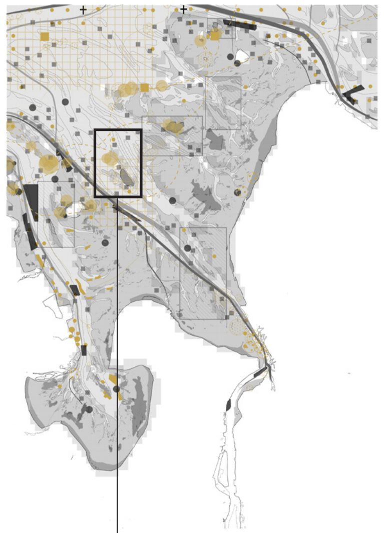
Pilot 2: Productive mudflats

Pilot 3: Barrier Island



Water Ecosystem: Local Scale [Proposed Future]

The combined development of the presented ecotones would suggestively take up the form represented in the following map. We can notice that the subtidal breakwaters smoothly transitions into a eulittoral mudflats area (with one navigable tidal creek) which is contained within the arms of the barrier island. We can assume that the design will enhance more interactions between and within each layer. In the atmospheric layer, we can see more birds making use of the newly created breeding areas. In the biospheric layer, we notice more presence of human and non- human life, with a great biodiversity extension in the contained eulittoral areas. In the hydrospheric layer, we notice that most processes are mitigated or redirected to contribute to the island's livelihood without eradicating its dynamism. The lithosphere layer shows the resulting landscape topographic variety which supports the needs of diverse forms of life.



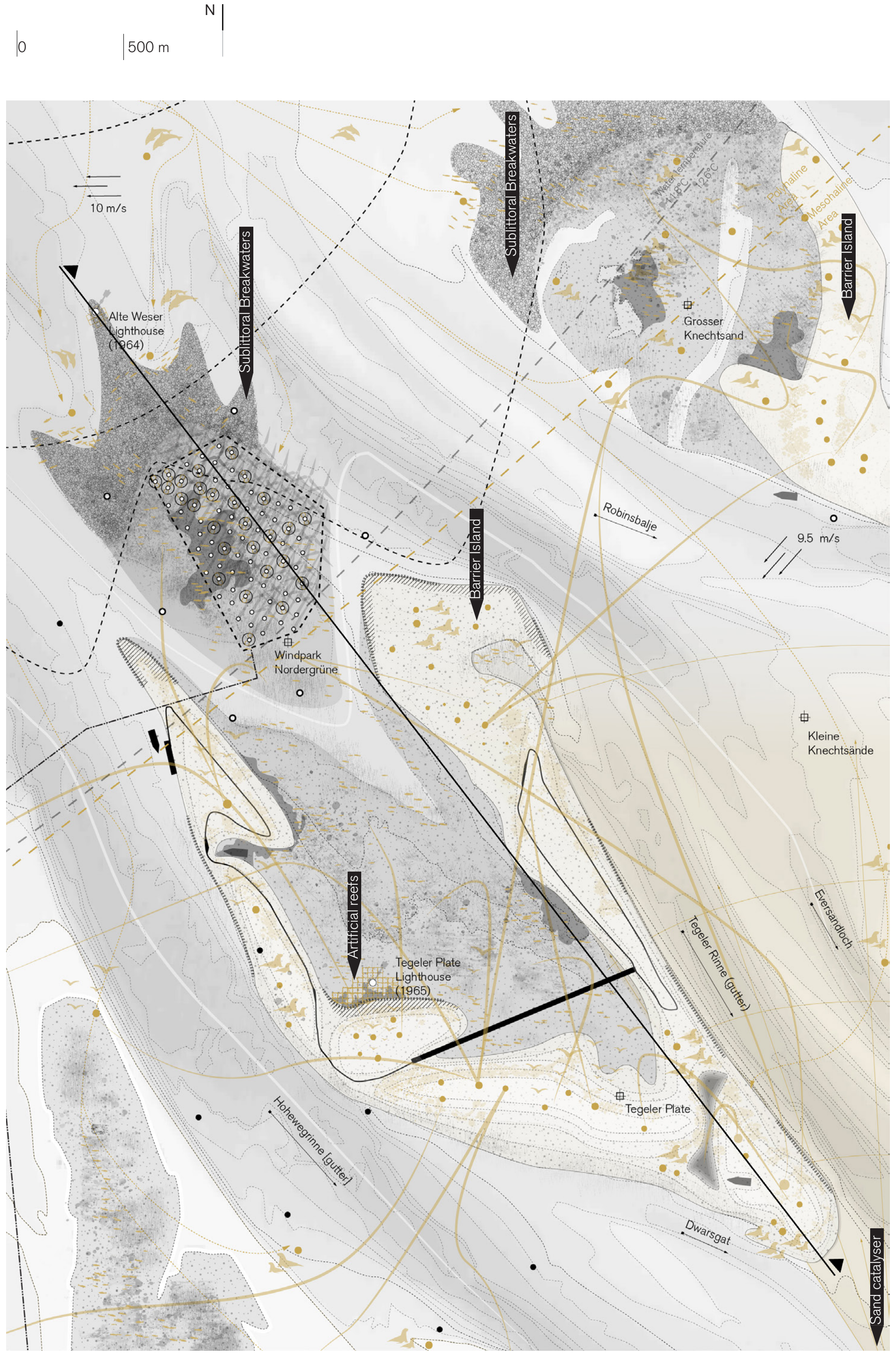
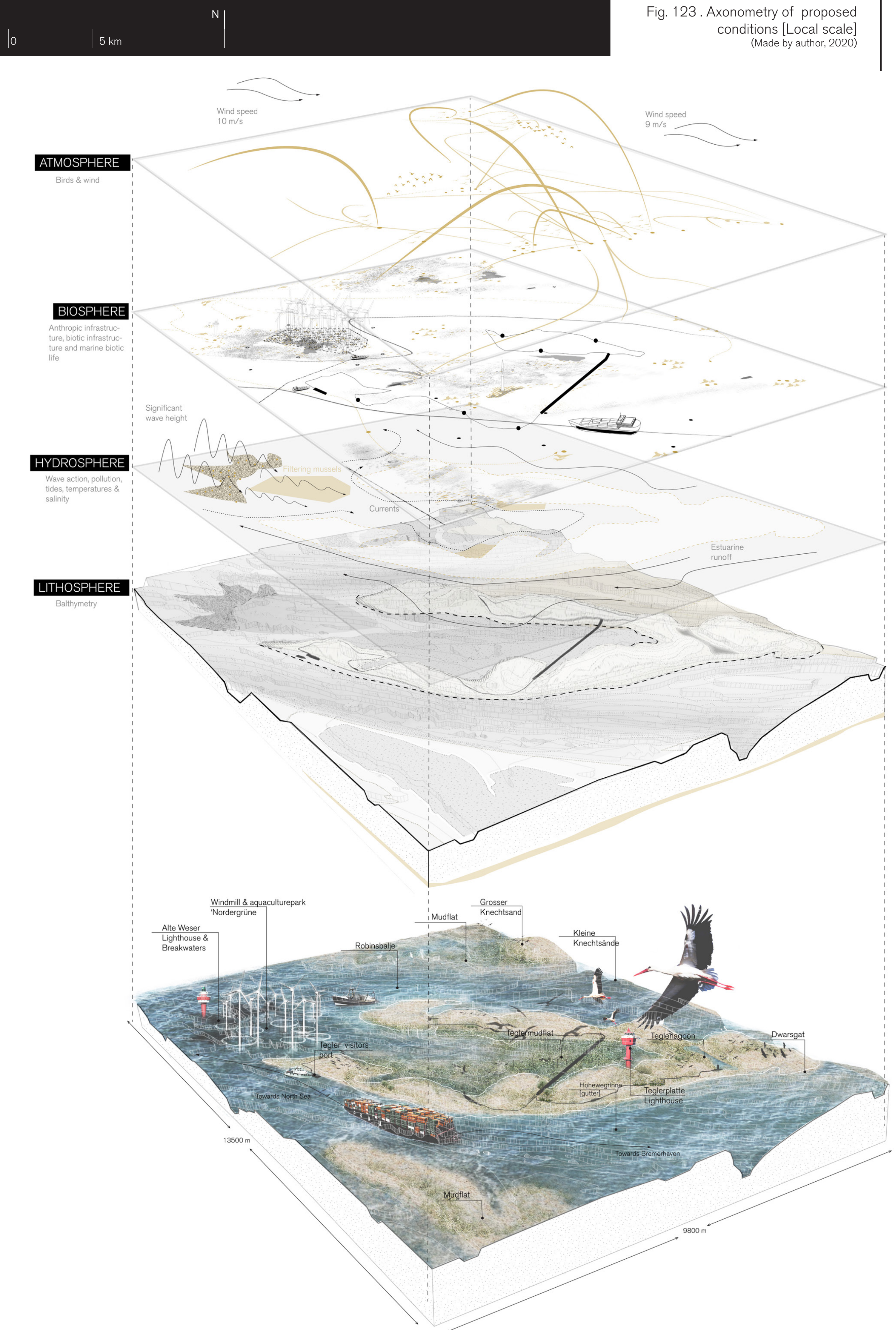


Fig. 122 . Map of proposed conditions 2100 of water ecosystem [Local scale]
(Made by author, 2020)

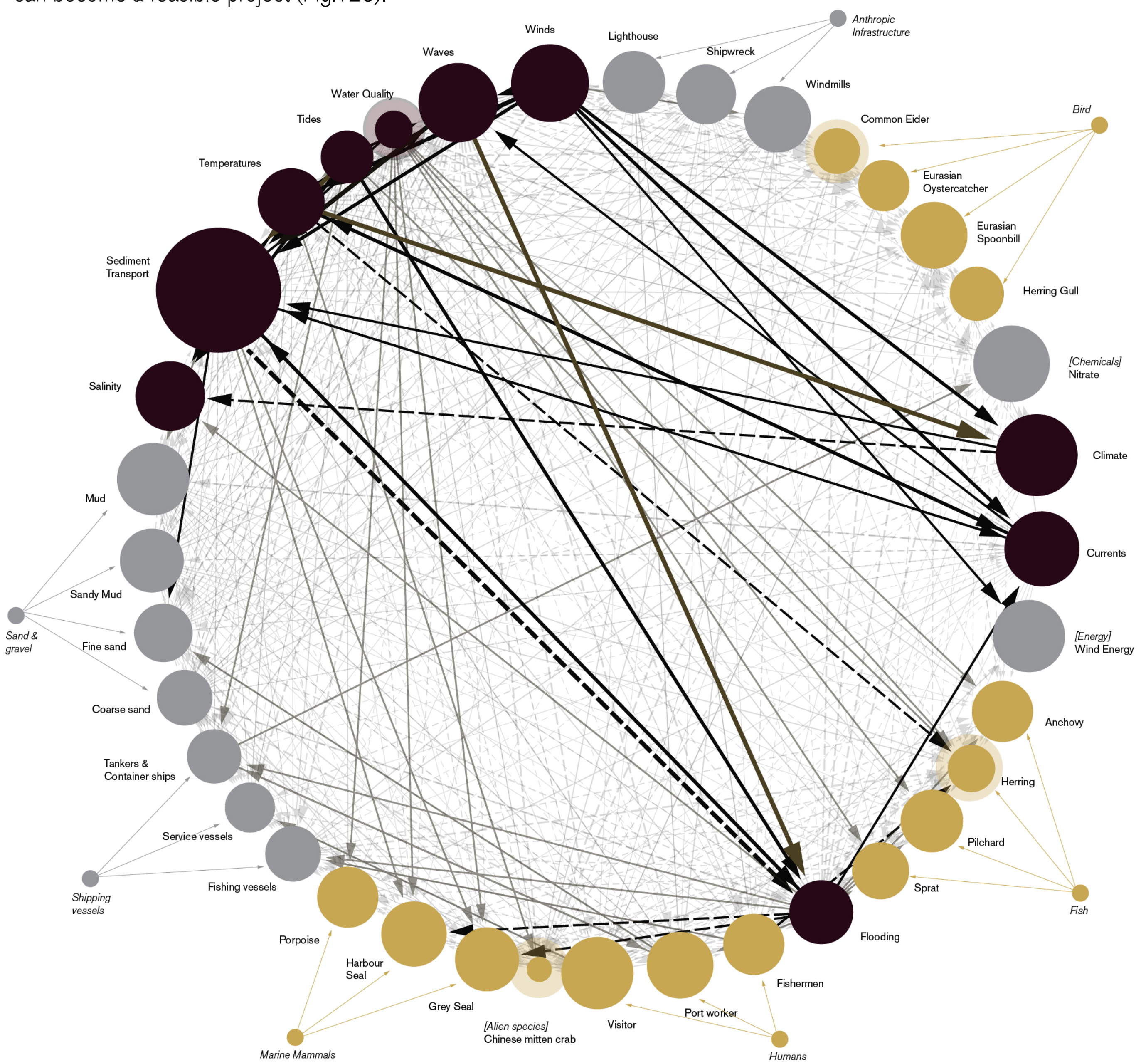
- Biotic life
- Subtidal breakwaters
- Dune vegetation
- Barrier Island
- Oyster reefs
- Marine vegetation, benthic species & artifical reefs
- Anthropic Infrastructure
- Windmills
- Lighthouses
- Buoys
- Shipwrecks
- Cables
- Mudflats
- Sand & Gravelspread by Sand catalyser
- Balthymetry
- Shipping routes
- Wind direction & speed

Fig. 123 . Axonometry of proposed conditions [Local scale]
(Made by author, 2020)



The barrier island system was designed taking into consideration the results of a specific local ecosystem assessment. The reason to implement strategies such as macrozoobenthos to filter externalities and so improve water quality as well as providing more birds breeding habitat areas and artificial habitats for juvenile fish were intentions to respond to the most vulnerable species indicated by the analysis (Fig.124). Furthermore, we can see that the main functions of the island are aligned to the three desired values of the project. The idea is to achieve them through mitigation, recovering, and embracing strategies shown in the diagram (Fig.125). As a final step of the design pilot, it was necessary to show how all steps, actors, and necessary policy actions would unfold in time so that the pilot can become a feasible project (Fig.126).

Fig. 124 . Local Ecosystem Assessment [Water]]
(Made by author, 2020)



Most vulnerable elements

1. Chinese Mitten Crab [Alien species]
2. Water Quality [Process]
3. Common Eider [Bird]
4. Herring [Fish]

Less vulnerable elements

1. Sediment Transport
2. Climate
3. Waves
4. Winds

Most substractive output on ecosystems

Fig. 125. Main functions of the barrier island design
(Made by author, 2020)

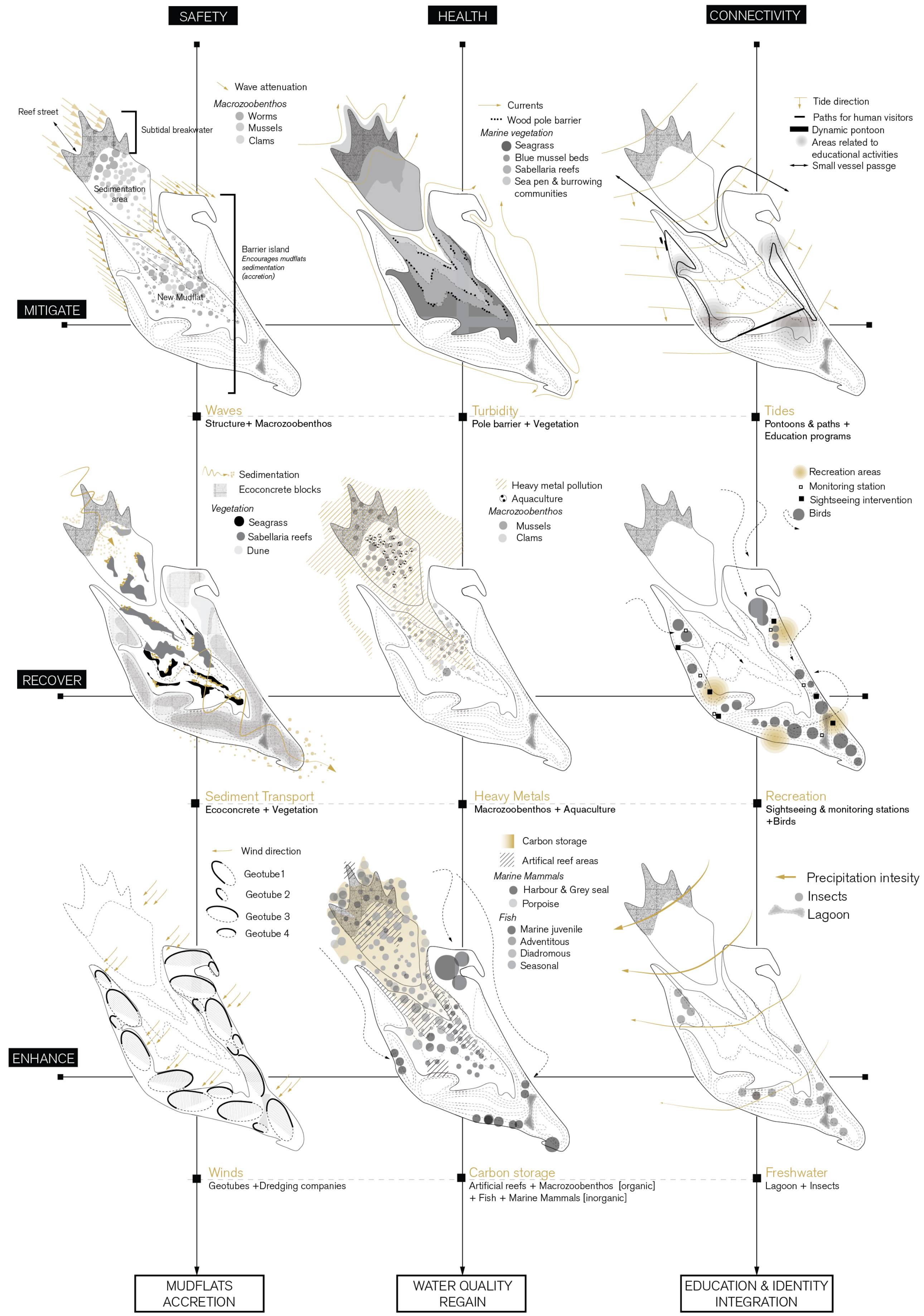
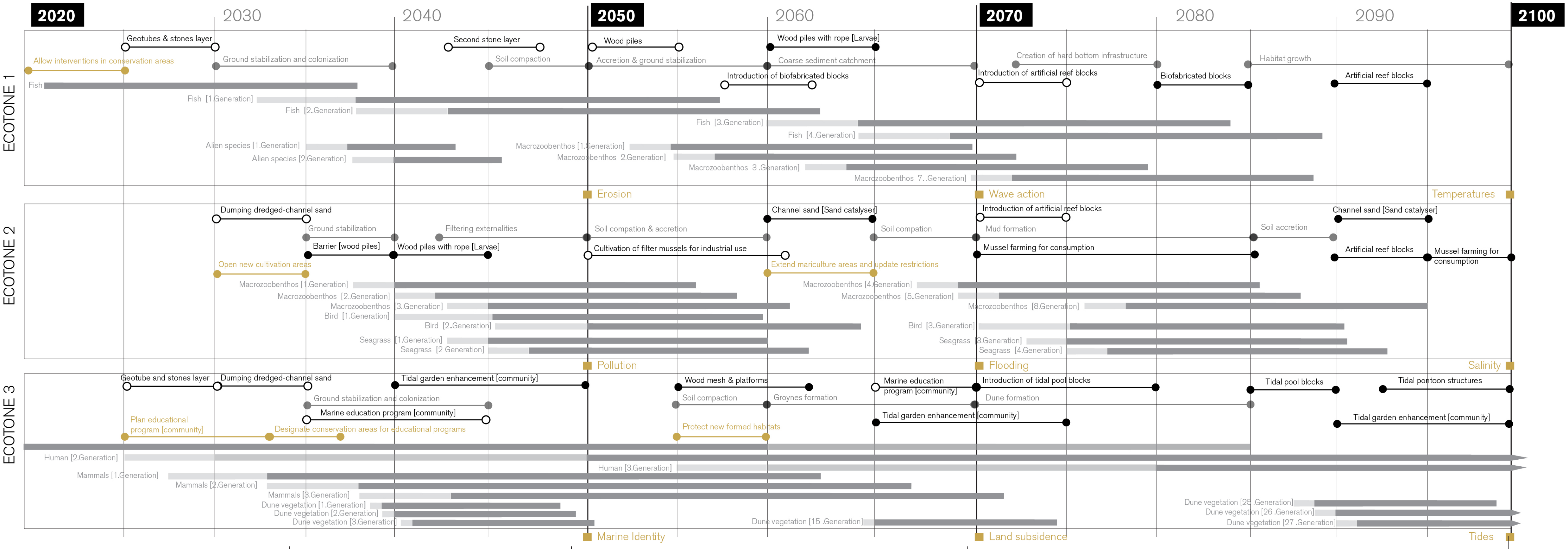
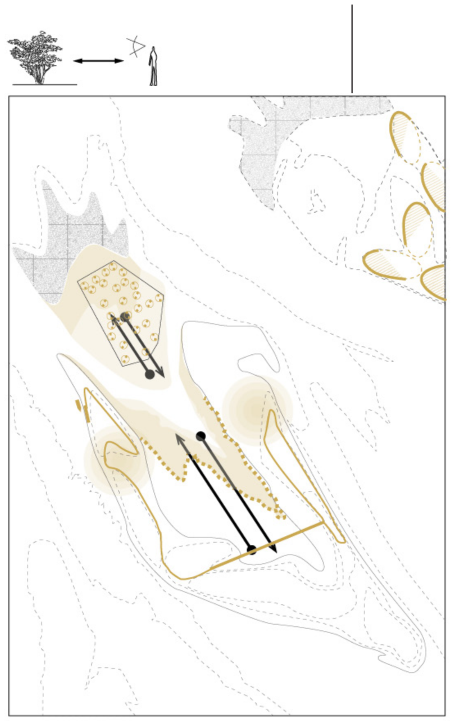


Fig. 126. Phasing of design stages for barrier island
(Made by author, 2020)

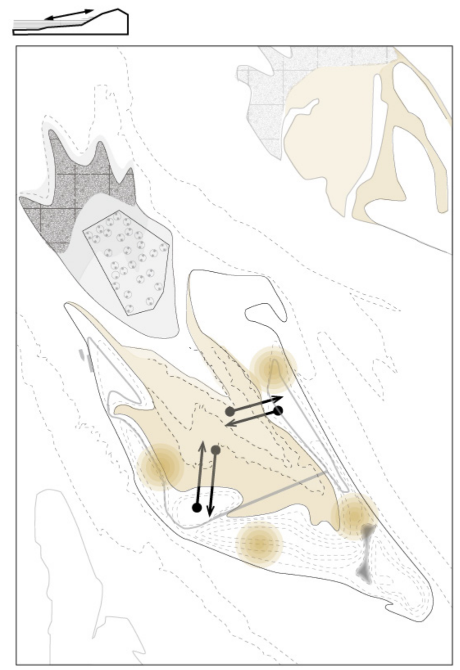


2020-2040
Relation between littoral & sublittoral areas



2040-2050
Relation between landscape & culture

2050-2070
Relation between sublittoral & eulittoral areas



2070-2100
Relation between eulittoral & supralittoral areas

Synchronizing habitat: Risk adaption by co- evolution of environment and society

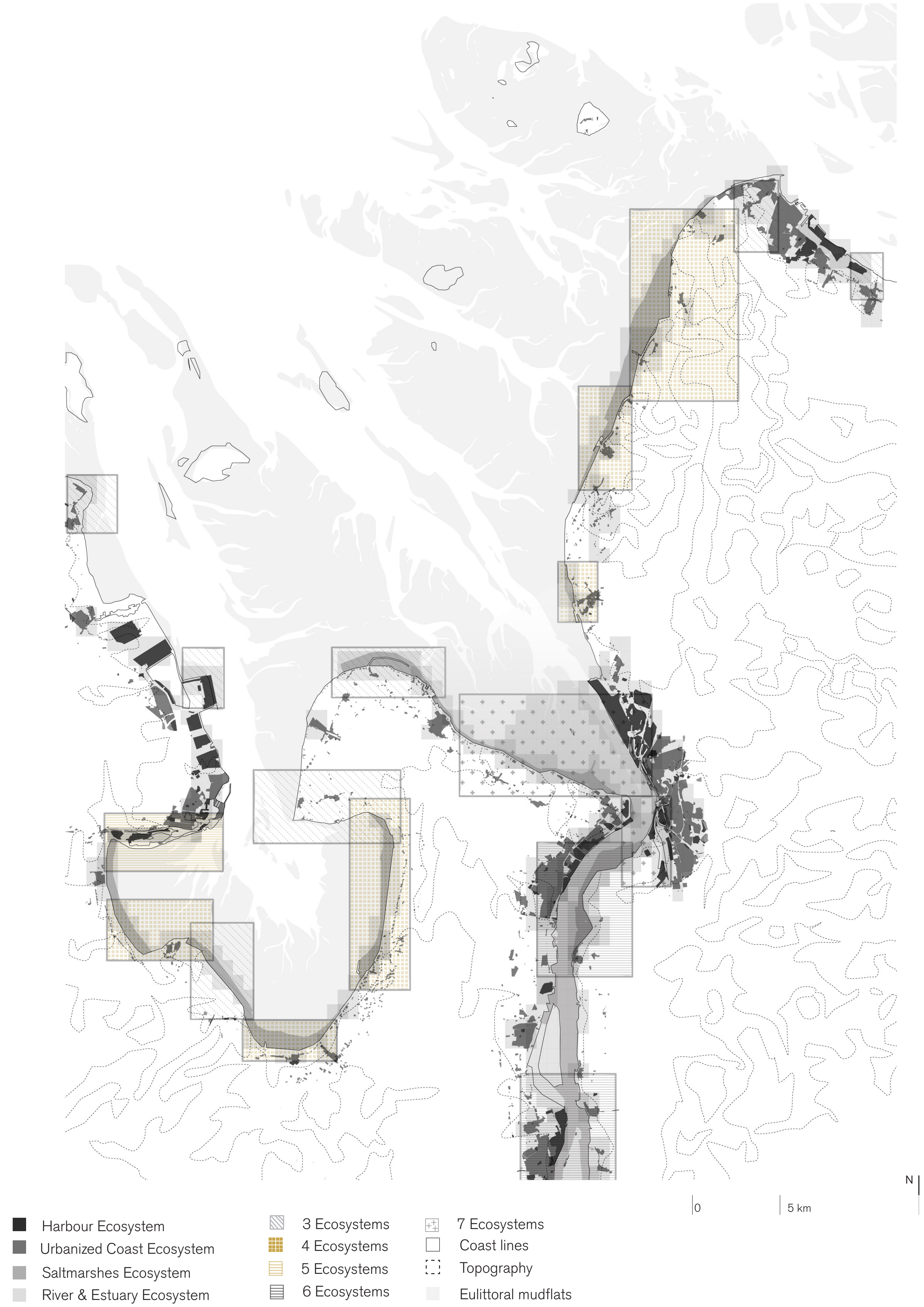
Chapter

5.2

Absorptive Edge

COASTAL ECOSYSTEM ASSESMENT & DESIGN

Fig .127 Coastal Ecosystems location
(Made by author, 2020)
(Data from: Baptist et. al., 2019)



Assesment of Ecosystem: Harbor

Harbors can be depicted as separate ecosystems in the Weser Estuary since they host very distinct flows, that do not normally cope with the ones of the city. Hereafter they tend to be very isolated ecosystems, that hardly merge and rather imposes itselves over existing structures.
Nevertheless, the qualitative analysis shows that several of their elements are vulnerable to the continuous changes in the environment. This can be explained by the fast obsolescence that anthropic developments experience when putting in contact with the sea dynamics. It is no surprise that the most vulnerable element than are shipping vessels, since the systems they support and are supported by are not able to cope with abrupt changes or hazards and are rather designed to withstand them. This static characteristic of the port as a storage platform and intermodal point requires a fast succession rate of its structures (expensive). The low diversity of forms of life it hosts can be also explained by this aspect and the fact that only undesired species (invasive species mostly) come in contact with this area besides human port workers. In the phenological analysis, we can again notice that unavoidable changes in the environment are challenging the conservative port structures and logic (Bahlke, 2017).

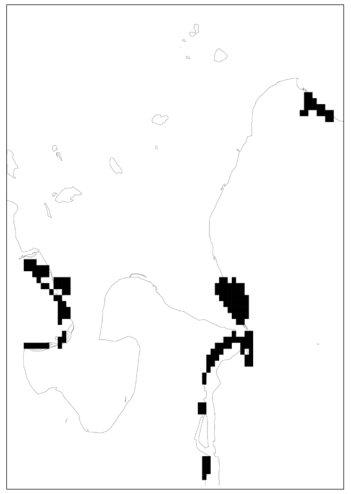
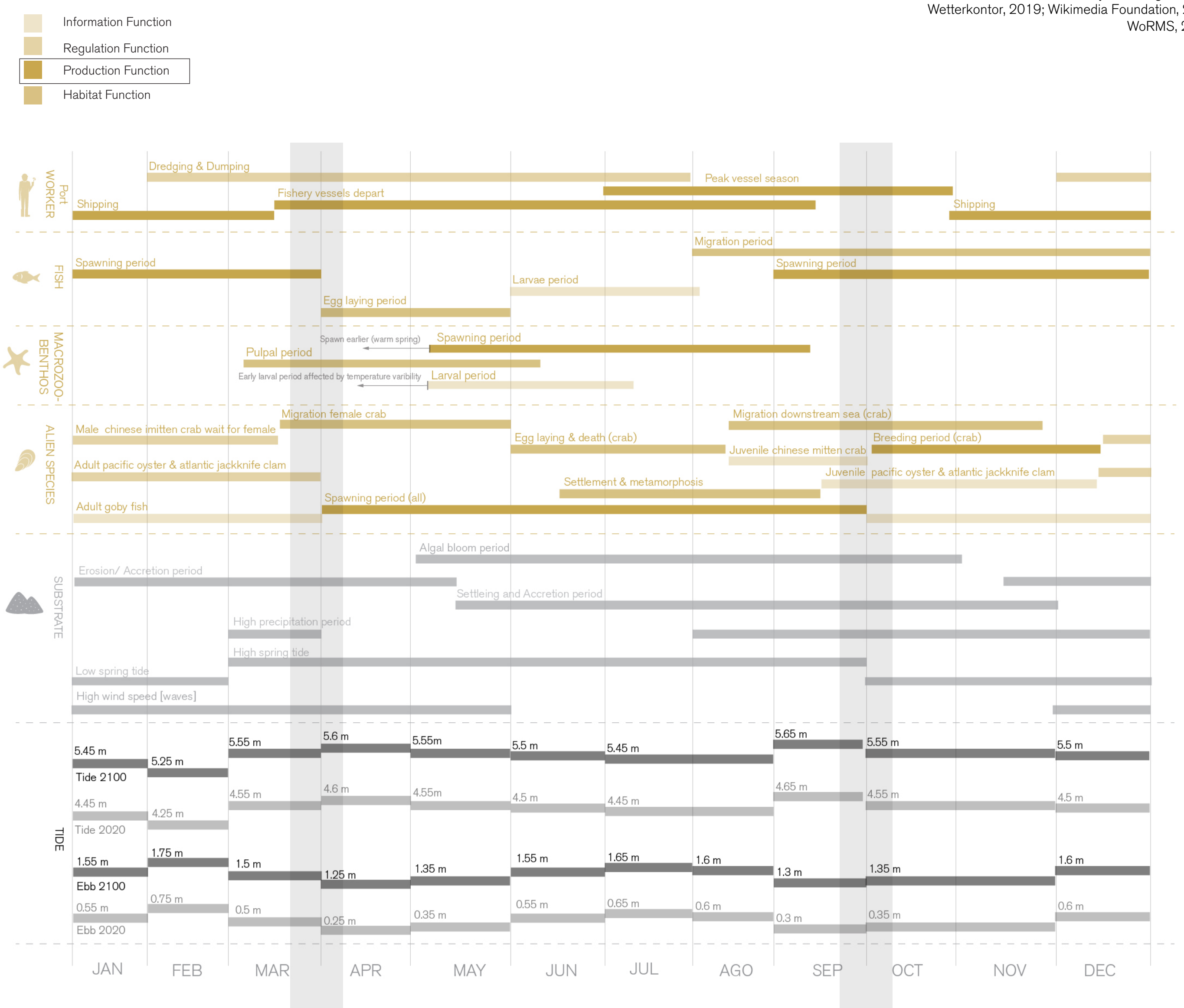
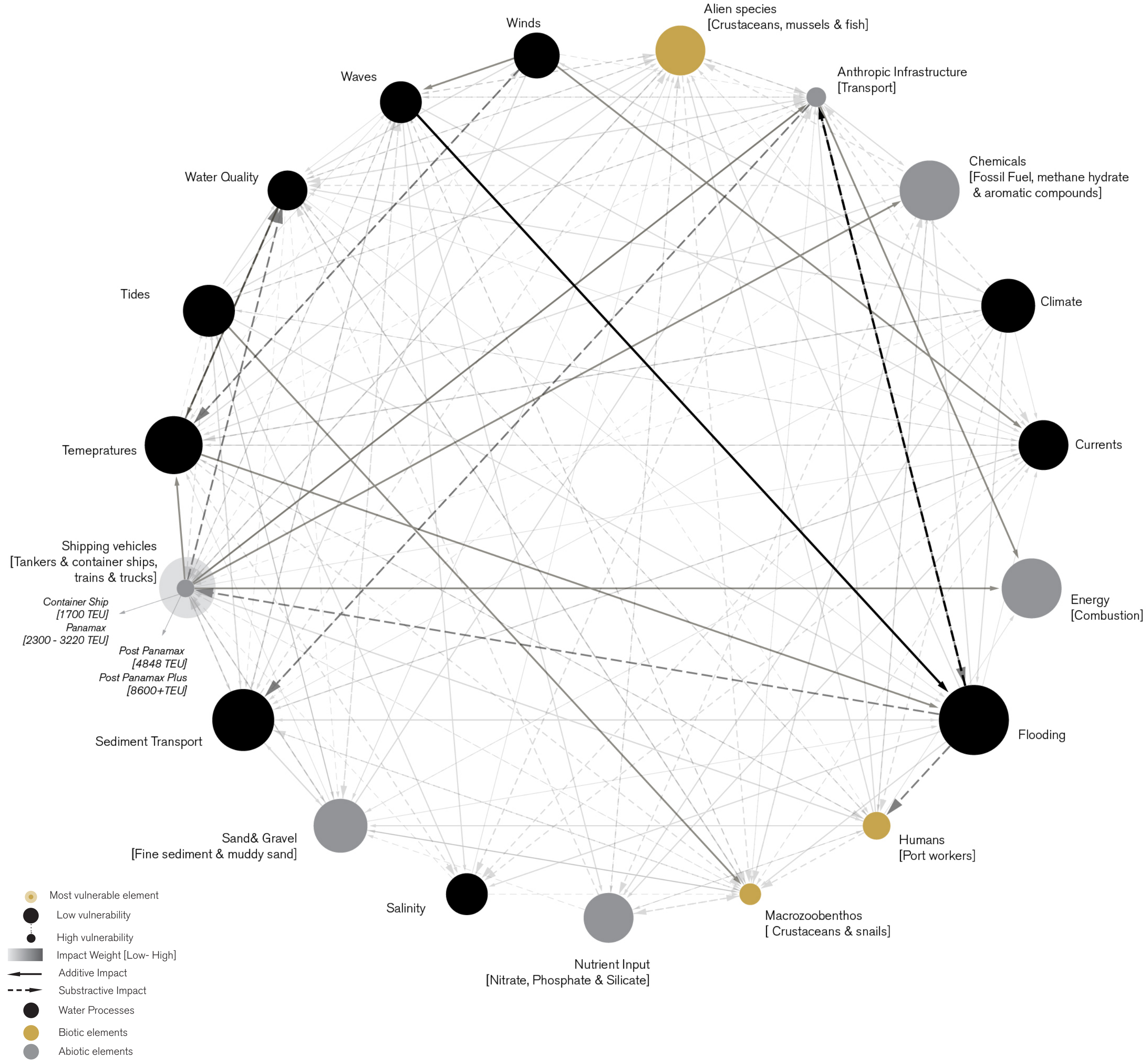


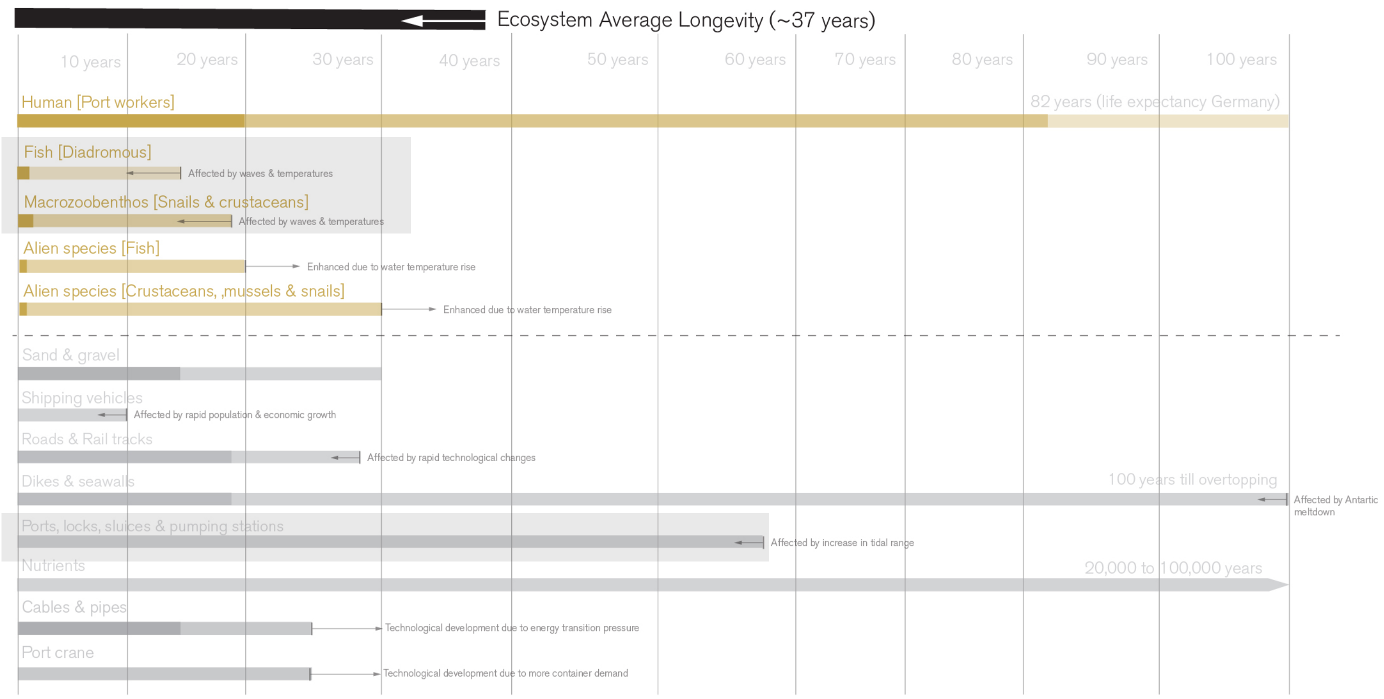
Fig. 128 Location & Longevity Analysis of Harbor
(Made by author, 2020)

Fig. 129 Harbor synergies & yearly cycles analysis.
(Made by author, 2020)

(Data from: Bahlke, 2017; BSH, n.d.; EMODnet, 2016; Gezeiten Fisch, 2019; MaLIN, 2020; OSPAR, 2017; SeaLifeBase, 2019; University of Michigan, 2020; Wetterkontor, 2019; Wikimedia Foundation, 2020; WoRMS, 2020)







Assesment of Ecosystem: Urbanized Coast

As urbanized coast, we can classify all settlement organizations with a high-density rate, which mostly consist of cities and bigger town that are in contact with a large water body such as the sea and the estuary. Hereafter we can identify several important urban concentrations around the Weser Estuary, with Bremerhaven at the very end of the river mouth. Although it is a human dominant habitat, the urbanized coast ecosystem partly welcomes other species from land, freshwater, and saltwater origin. Environmental processes stress these actors less than at sea since they are mostly located at spaces sheltered of marine fluctuations. However, they are stressed by the exhaustion processes of the land towards the sea, like river runoff dynamics and groundwater recharge.
The qualitative/ quantitative analysis indicates that the scarce macrozoobenthos community living in the urbanized coast ecosystem is the most vulnerable to these maximized stresses. Special attention has to be put on reducing the quantity of nutrient input in this ecosystem, which is probably the main cause of macrozoobenthos decrease (Drent et al., n.d.). Another rising concern is the loss of insect life since these are species with a higher probability to go extinct and already present high succession frequency rates (short longevity). Insects are mostly dependent on shrubs, which are available in isolated patches around the city but do not form a system (Esselink et al., 2017). Interestingly the analysis of the yearly cycle shows important shifts towards June and July related to animal life becoming dependent on urbanized environments as a source of food and shelter.

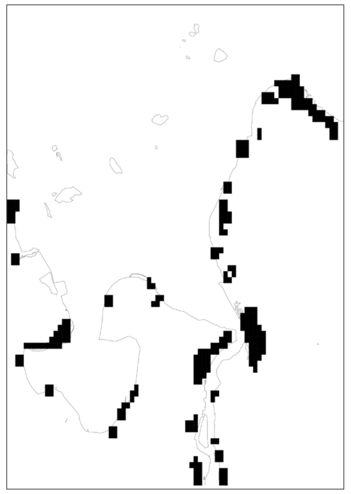
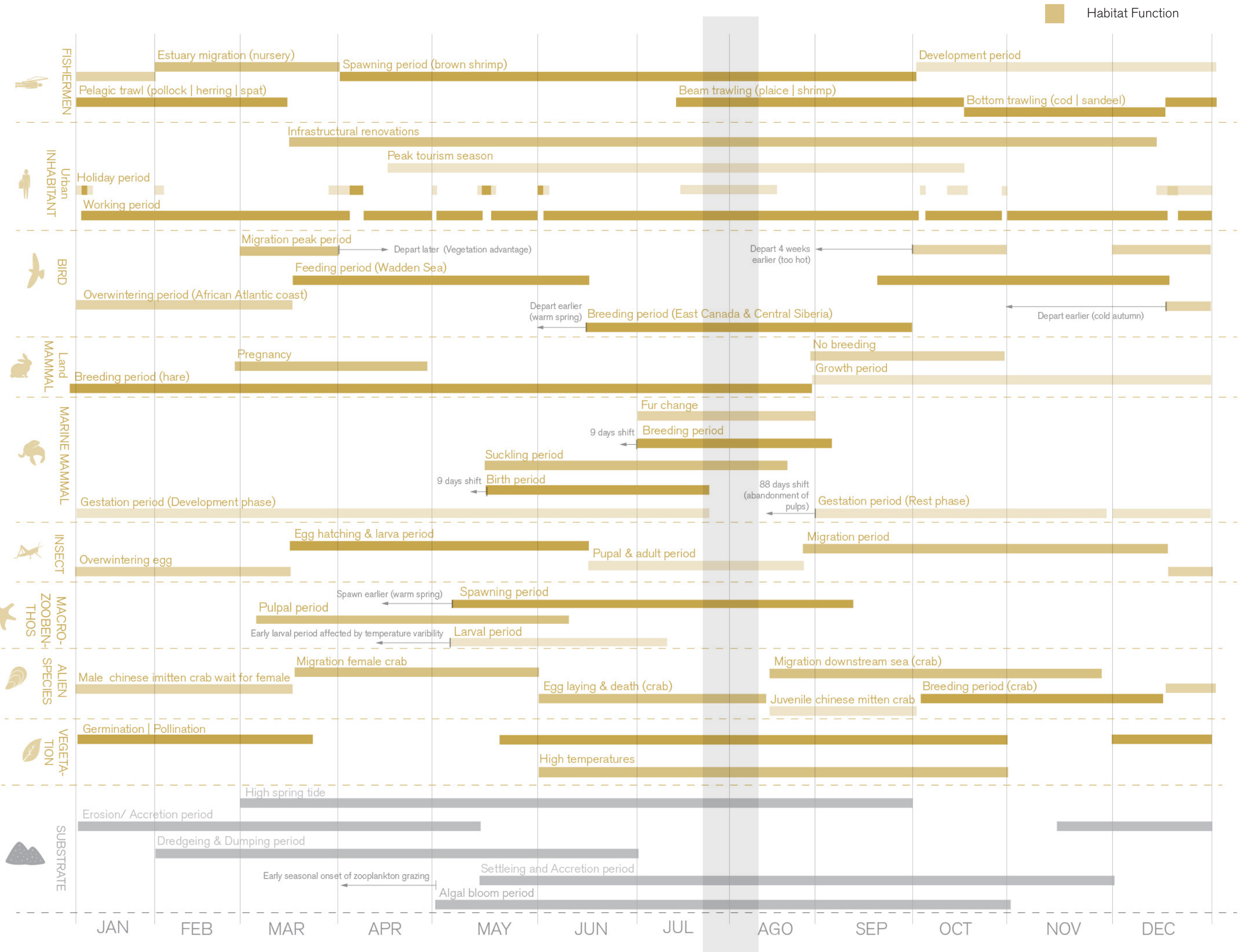


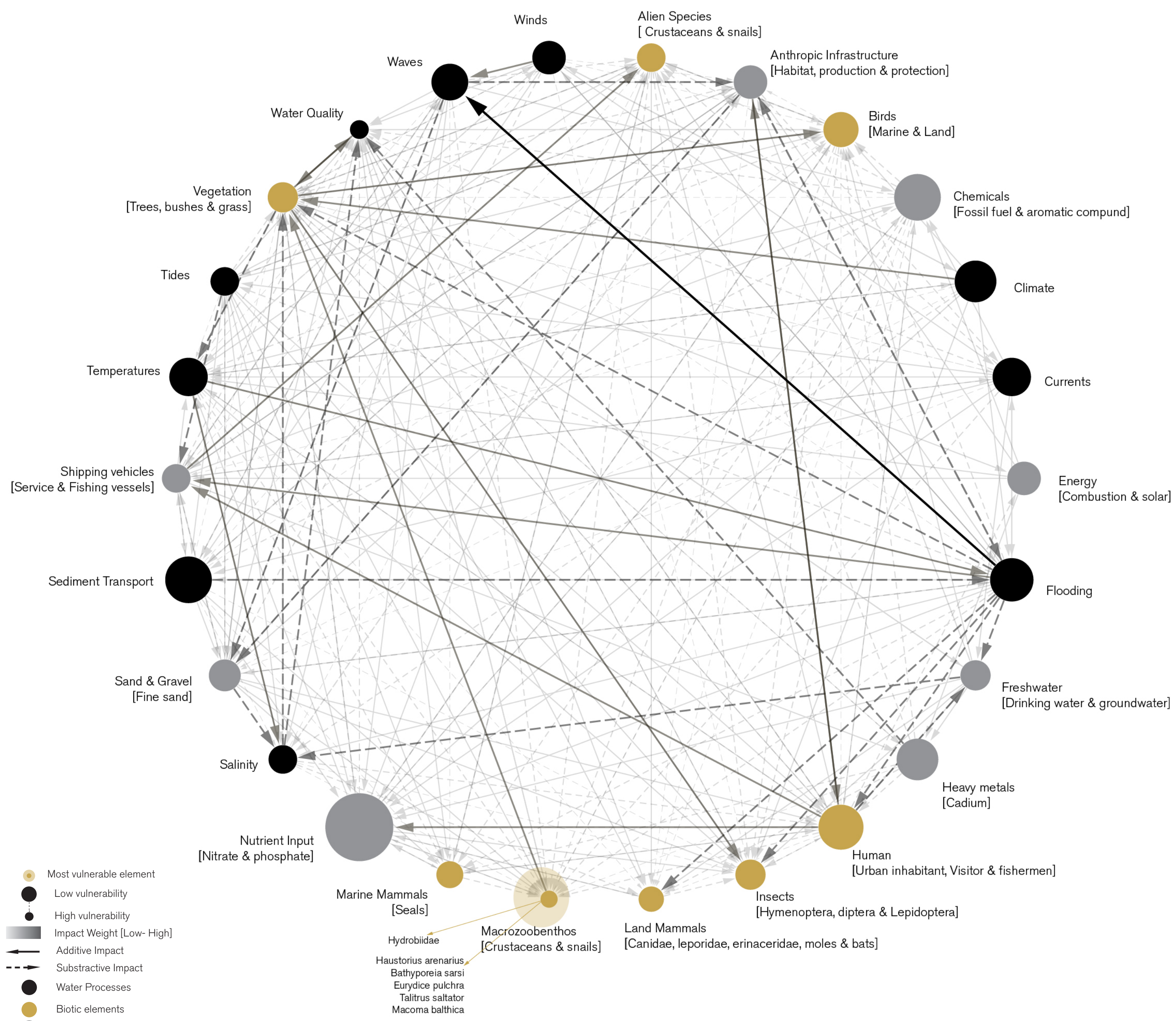
Fig. 130 Location & Longevity Analysis of Urbanized Coast
(Made by author, 2020)

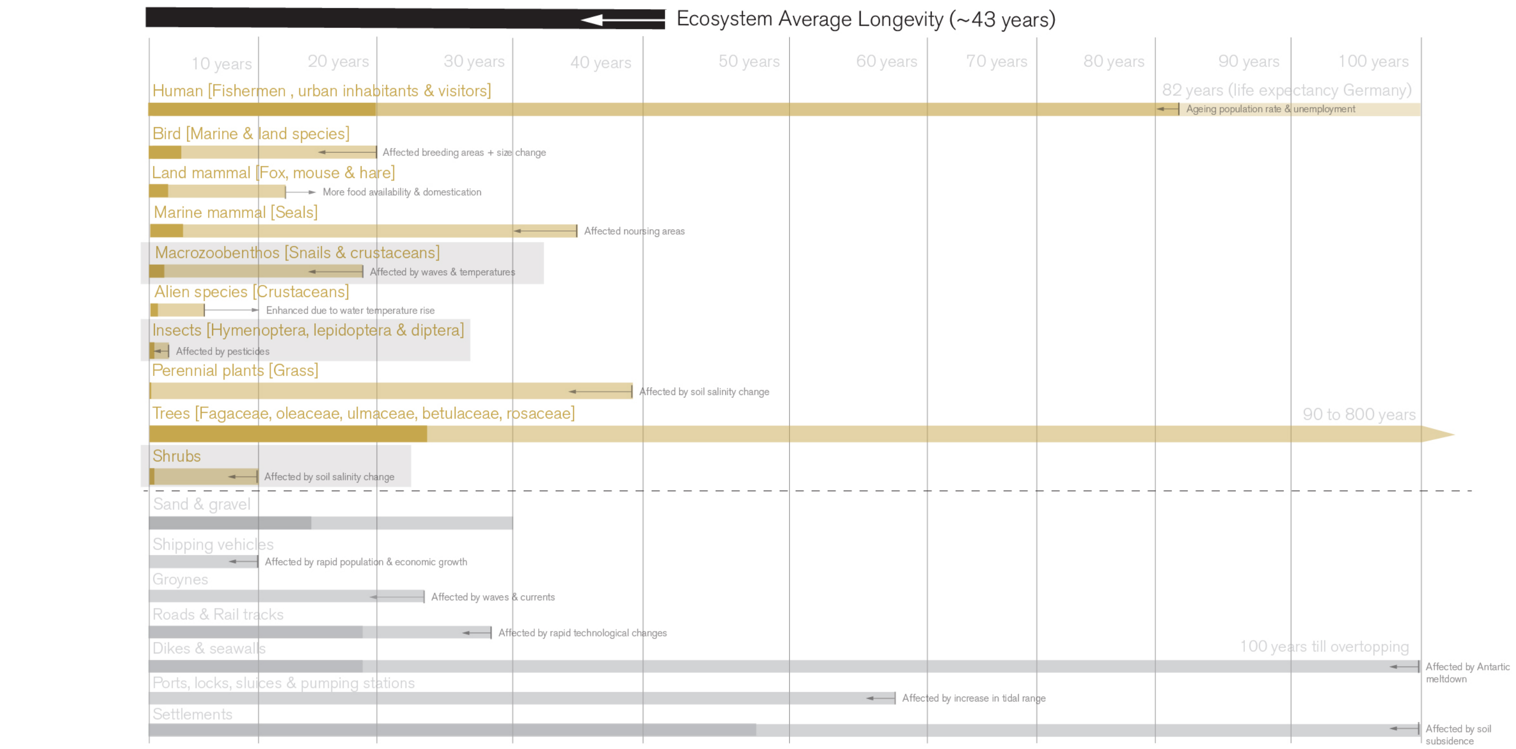
Fig. 131 Urbanized Coast synergies & yearly cycles analysis.
(Made by author, 2020)

(Data from: Baer & Smaal, 2017; BSH,n.d.; DWD, 2015; EMODnet,2016; Gezeiten Fisch, 2019; HAGR, 2020; IUCN, 2019 ; MaLIN, 2020; Schulferien, 2020; SeaLifeBase, 2019;Tulp et al., 2017; Wetterkontor,2019; Wikimedia Foundation, 2020; World Life Expectancy, n.d.)

Information Function
Regulation Function
Production Function
Habitat Function







Assesment of Ecosystem: River & Estuary

Although the Weser Estuary is connected to a network of smaller rivers and channels, on an urban scale I decided to only highlight the Weser as a large ecosystem. As we have seen in Chapter 4 '*Deconstruction*' (see page 89) the river catchment extends broadly in the German continental grounds, connecting several important cities like Bremen and Hannover. In the qualitative/ quantitative analysis, we can notice that abiotic elements play a bigger role in the synergies of the river than biotic life. The most influential process is, of course, sediment transport, since the confined water space of the Weser river generates currents that drag fine sediment like sand and clay towards the sea. Since most industrial sites use the river as freshwater resource or exhaust for cooling water, added to the flush of nutrient-rich groundwater coming from agricultural and animal husbandry fields, the river has become a collector of different types of hazardous externalities (heavy metals, chemicals, and nutrients). Externalities usually gather at the bottom of the estuary and end at the mouth of the river, affecting the specimens living in these areas (fish and especially macrozoobenthos). The patched vegetation concentration in the estuary contributes to the low diversity and quantity of these specimens in the Weser (Schuchardt & Scholle, n.d.). An opportunity arises when looking at the longevity analysis which shows that most vegetation connected to the river can live for a long time if properly managed. Nevertheless, this has to be carefully considered with the help of the analysis of yearly cycles, since vegetation bloom is one of the main processes that will continue to undergo a shift due to climate change, especially sensible are the months of April/ May and Agust/ September.

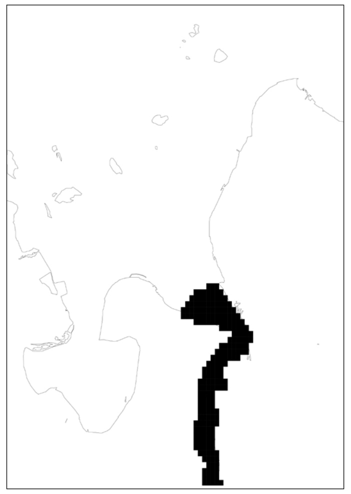
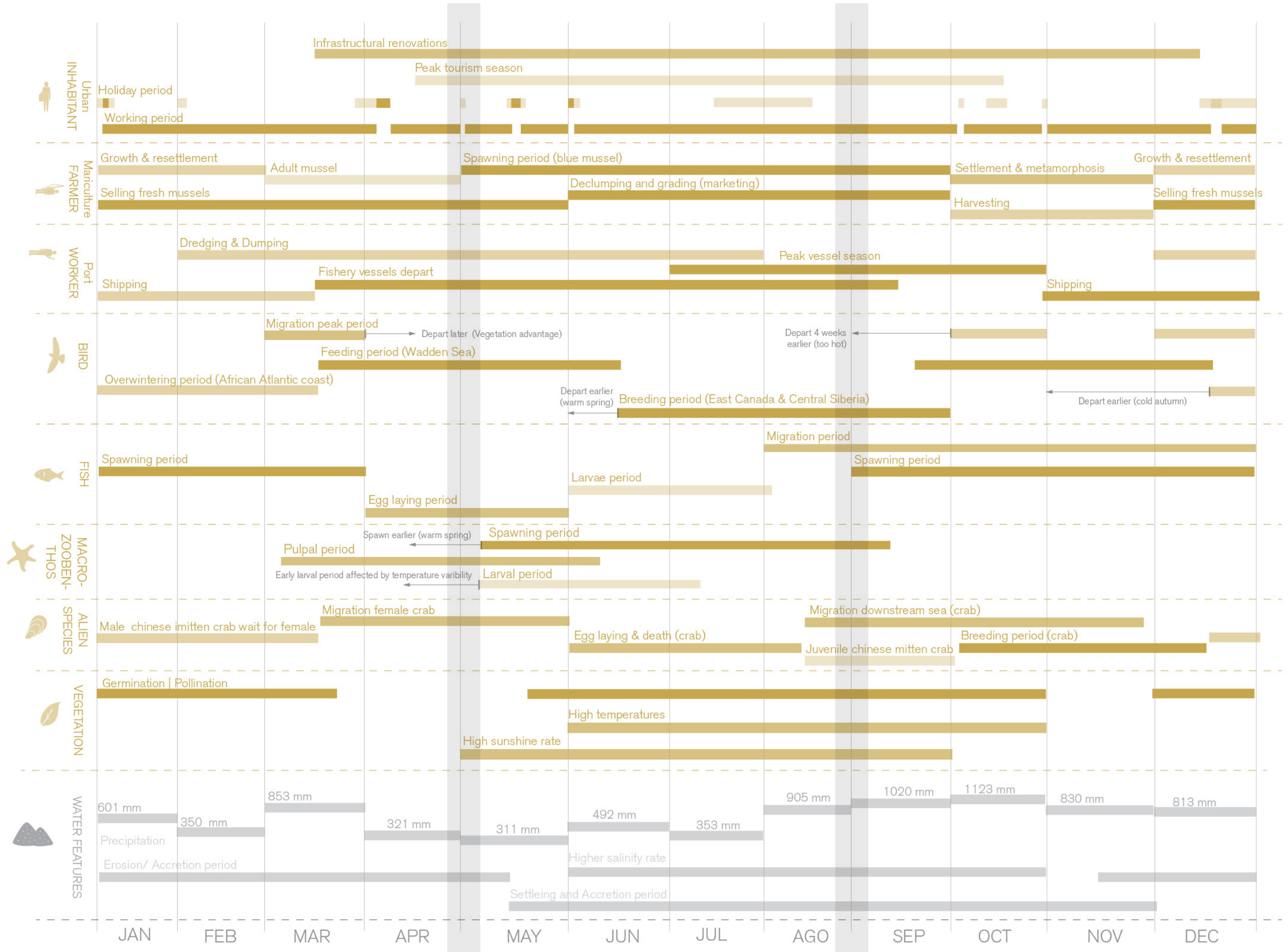


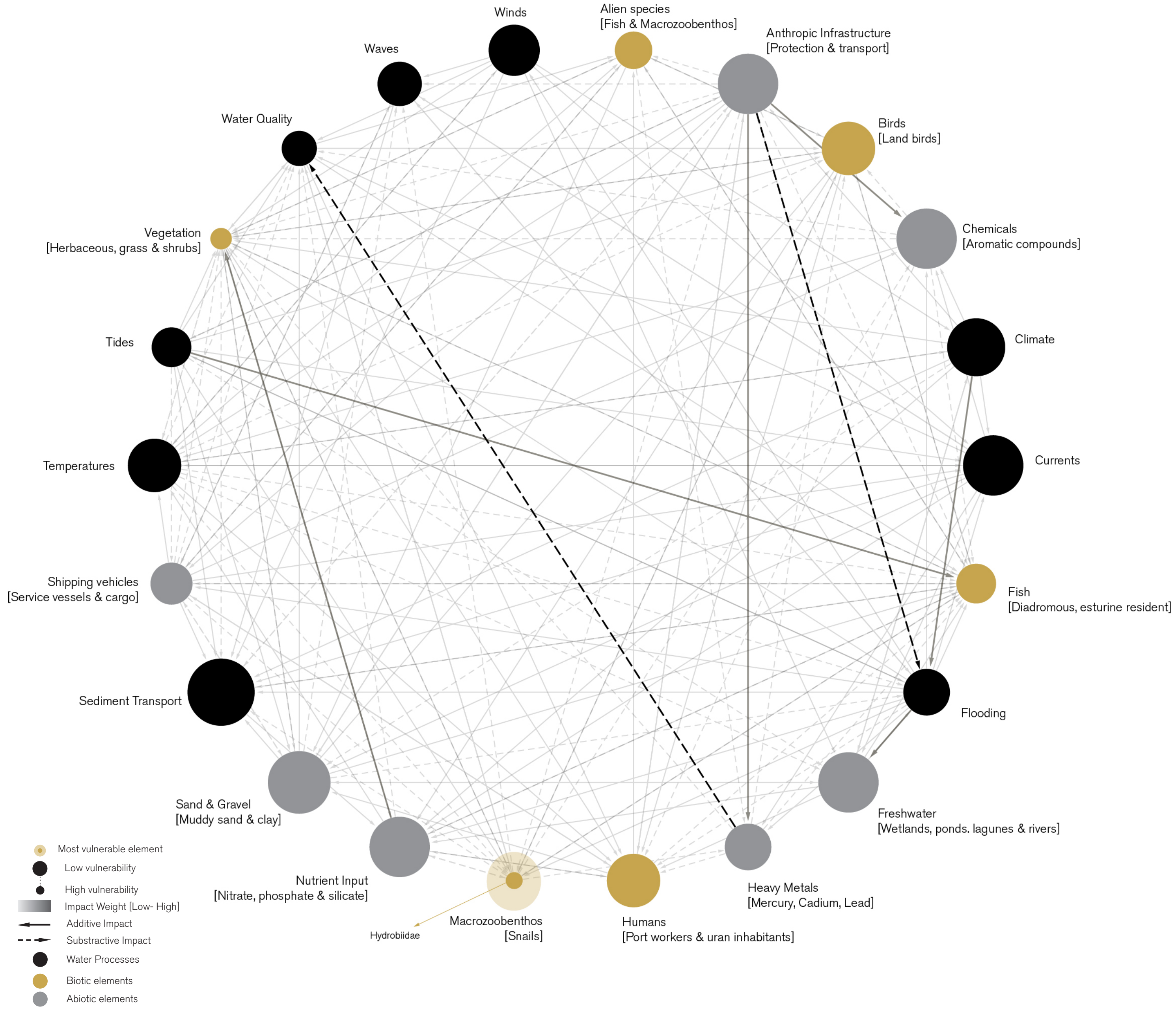
Fig. 132 Location & Longevity Analysis of River & Estuary
(Made by author, 2020)

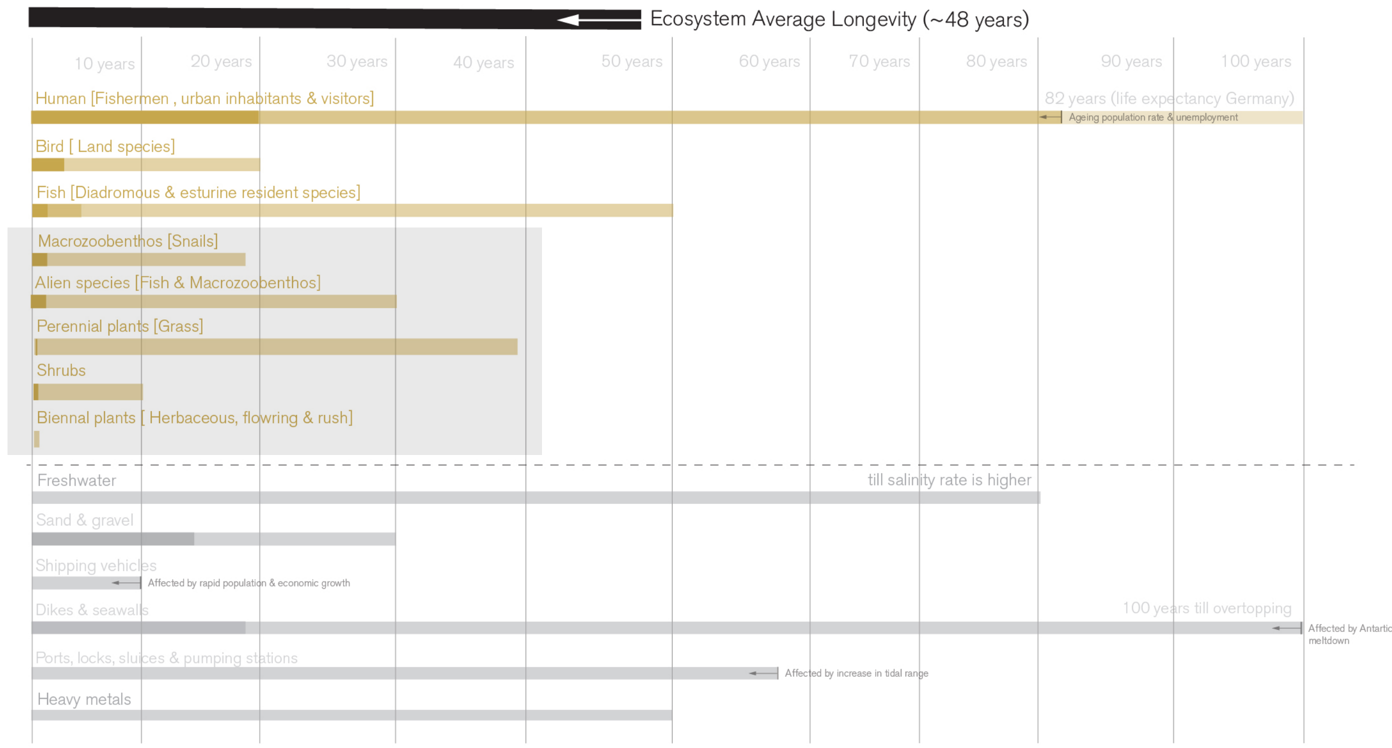
Fig. 133River & Estuary synergies & yearly cycles analysis.
(Made by author, 2020)

(Data from: Bahlke, 2017; IUCN, 2019 ; MaLIN, 2020; OSPAR, 2017; Schulferien, 2020; Schuchardt & Scholle, 2017 ;Wikimedia Foundation 2020;World Life Expectancy, n.d.)

Information Function
Regulation Function
Production Function
Habitat Function







Assesment of Ecosystem: Saltmarshes

The salt marshes around the Weser Estuary area can be found around the big extensions of intertidal mudflats. Just exceptional and experimental pilots like *Luneplate* are not linked to the eulittoral area but also work as a transition between water and land ecosystems. Salt marshes are in a way already enhancing ecotones, the problem is that the areas they occupy do not form a continuous line along the coast, which does not allow them to work as a protection system for most of the coast, and only protect low and shrinking inhabited areas.
Moreover, the quality and quantity analysis showed that the most vulnerable actor was vegetation, which is one of the key elements of salt marsh ecosystems. This means that although synergies in saltmarshes seem to be balanced, vegetation needs to be supported by other actors in the ecosystem to increase their resiliency. Although few, alien species could be avoided by encouraging a more rapid ecological succession to remove them from the system, so that endemic vegetation and species can flourish. As part of the ongoing experimentations to create a typology of different salt marsh fields so that they can be adopted in different parts of the coast, the analysis on yearly cycles shows that this could be further enhanced through the support of endemic species growing in the new germination months of March/ April till September/October (Esselink et al., 2017).

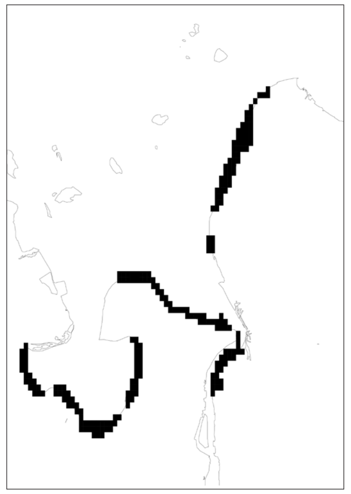
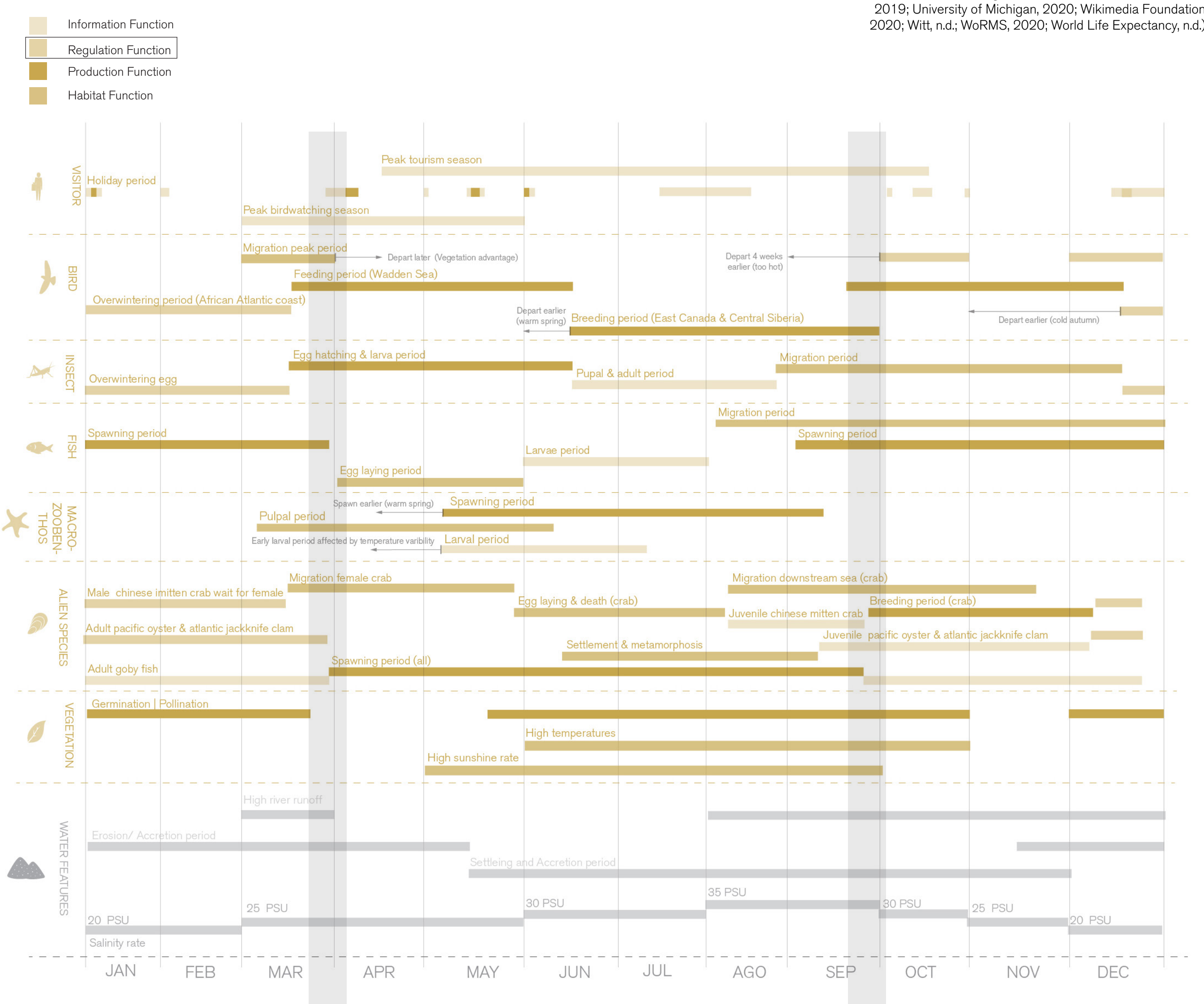
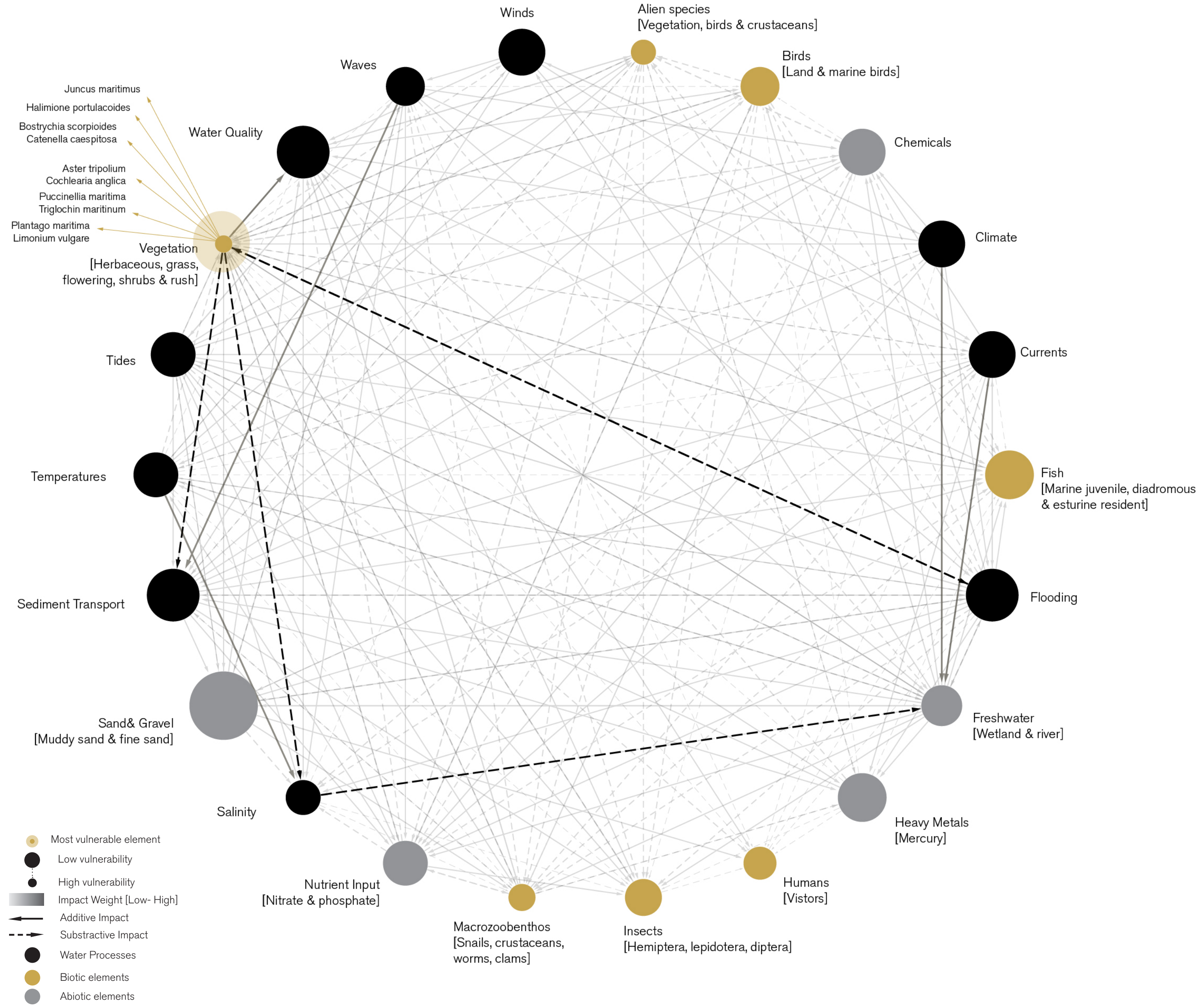


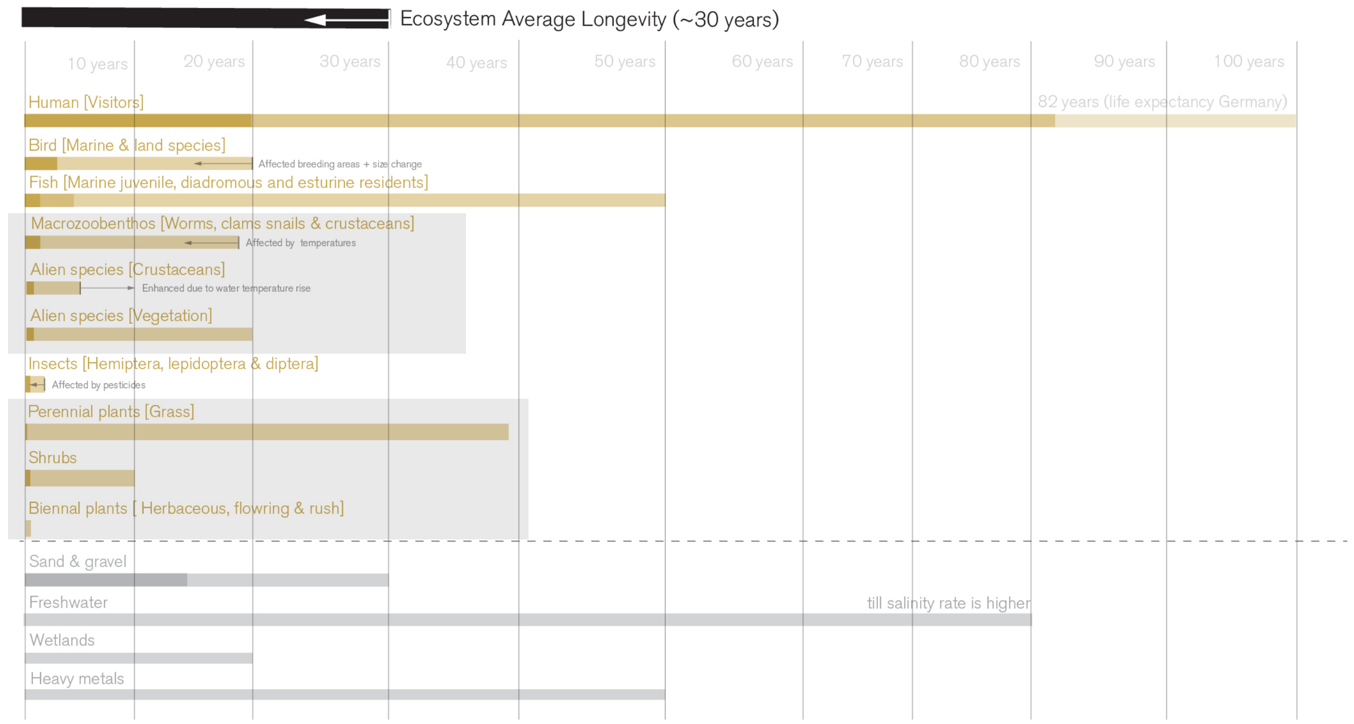
Fig. 134 Location & Longevity Analysis of Saltmarshes
(Made by author, 2020)

Fig. 135.Saltmarshes synergies & yearly cycles analysis.
(Made by author, 2020)

(Data from: DWD, 2015; Esselink et al., 2017; HZG,2014; IUCN, 2019 ; MaLIN, 2020; Nationalpark Wattenmeer, 2010; Niederschlag in Deutschland, 2019; SeaLifeBase, 2019; University of Michigan, 2020; Wikimedia Foundation 2020; Witt, n.d.; WoRMS, 2020; World Life Expectancy, n.d.)





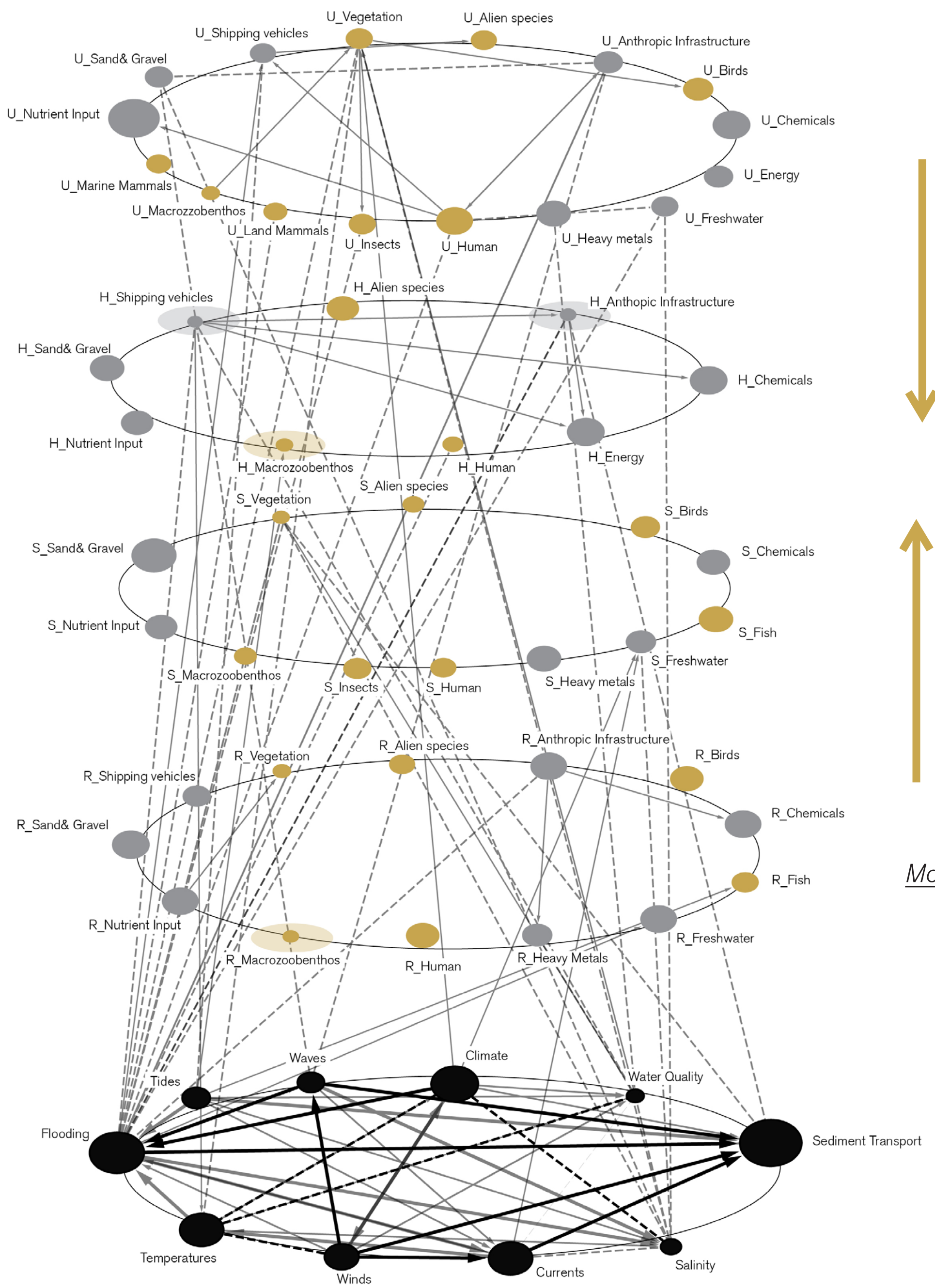


Assesment of Ecotones & Ecosystems: Results

Finally, an assessment of the interrelations between the four coastal ecosystems revealed that some important synergies between ecosystems exist, but are substractive, rather than adding value to other ecosystems. The next step needs to assure that more additive relations are set into motion. Probably most transformations have to concentrate on the harbor ecosystem synergies with the others since most vulnerable elements are located within its biome. Measures to multi- balance sediment transport processes could become a way to catalyze more biotic life in all ecosystems. These socio-ecological ecosystems seem to be moving from extreme dynamism to extreme statism, so a combination (hybrids) is advisable to break the barriers that maximize its vulnerabilities.

Fig. 136 . Results of synergies between coastal ecosystems
(Made by author, 2020)

Fig. 137 Results of synergies of each coastal ecosystem.
(Made by author, 2020)



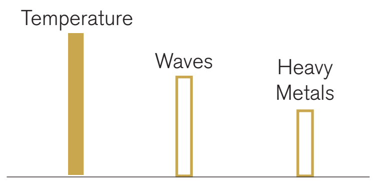
Most vulnerable elements

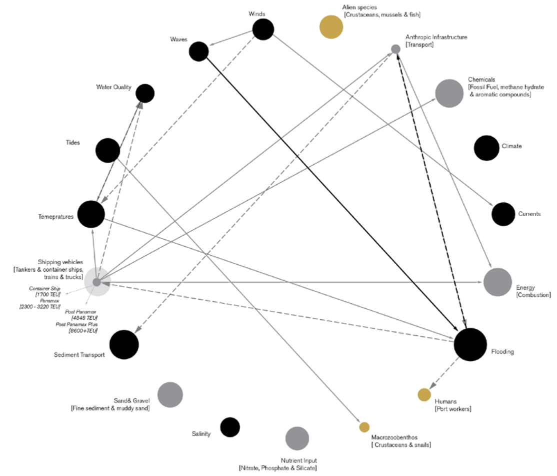
1. Harbour shipping vehicles
2. Harbour Anthropic Infrastructure
3. River Macrozoobenthos
4. Harbour Macrozoobenthos

Less vulnerable elements

1. Sediment Transport
2. Flooding
3. Urban Coast Nutrient Input
4. Climate

Most substractive output on ecosystem





Harbour

Most vulnerable elements

Shipping vehicles > Flooding

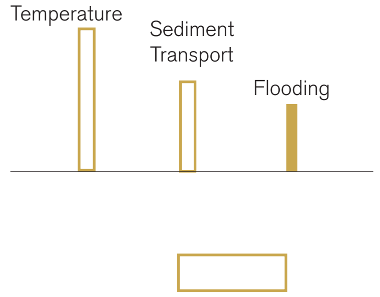
Anthropic Infrastructure > Flooding

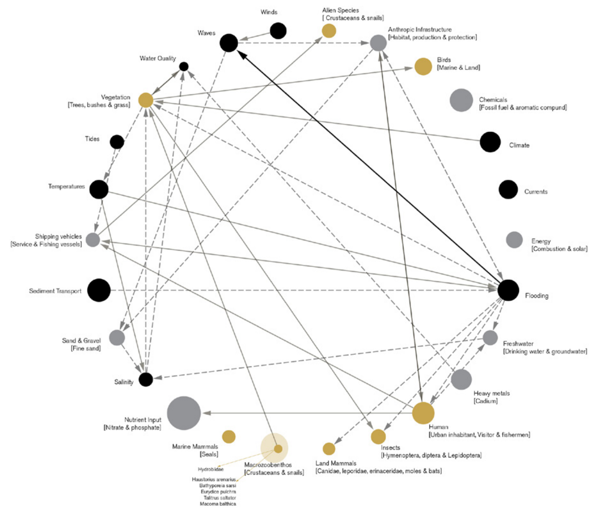
Less vulnerable elements

Flooding

Sediment Transport

Most substractive output on ecosystem





Urrbanized Coast

Most vulnerable elements

Macrozoobenthos > Temperatures

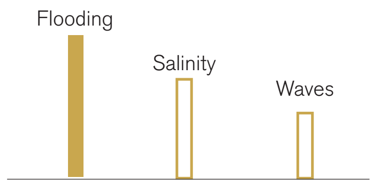
Water Quality >Heavy Metals

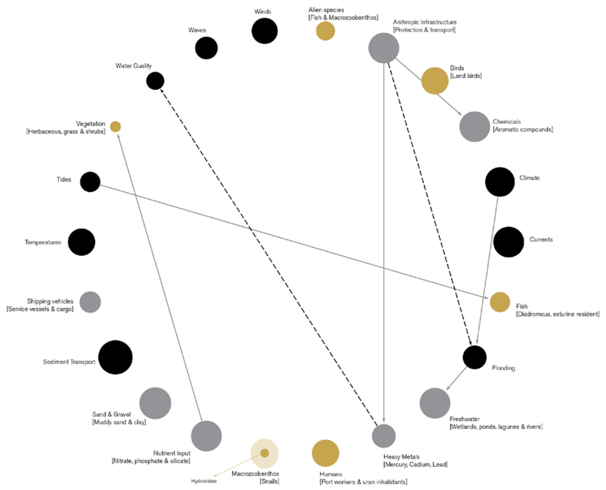
Less vulnerable elements

Nutrient Input

Chemicals

Most substractive output on ecosystem





River & Estuary

Most vulnerable elements

Macrozoobenthos > Sediment Transport

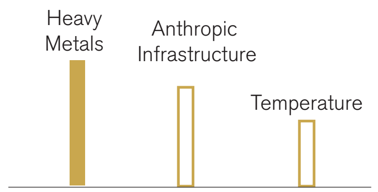
Vegetation > Sediment Transport

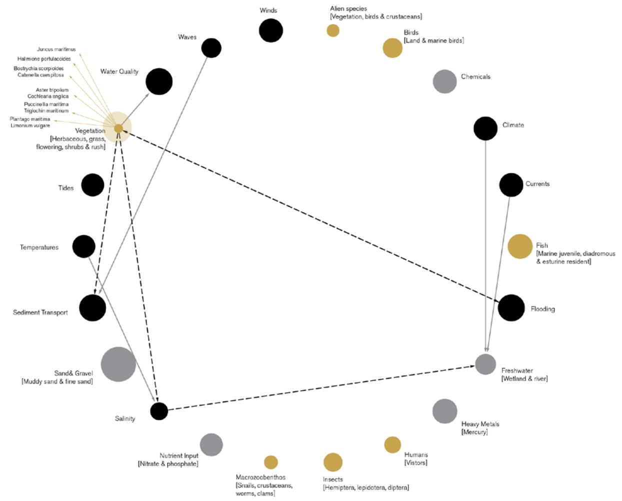
Less vulnerable elements

Sediment Transport

Sand & Gravel

Most substractive output on ecosystem





Saltmarshes

Most vulnerable elements

Vegetation >Flooding

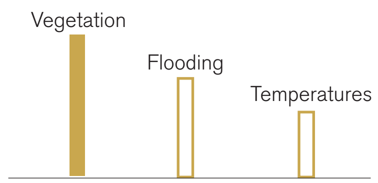
Alien species >Nutrient Input

Less vulnerable elements

Sand & Gravel

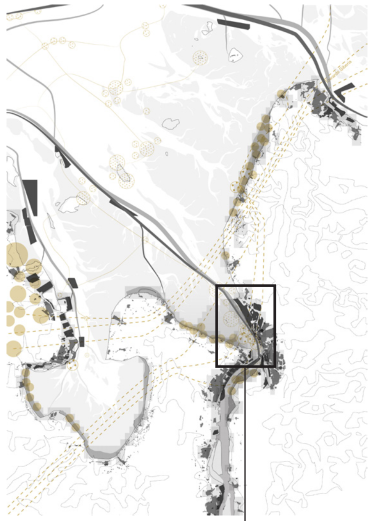
Water Quality

Most substractive output on ecosystem



Coast Ecosystem: Local Scale [Present]

Bremerhaven was decided as the location to test the design principles linked to the coast (see page 129 'Design Principles') since it presented the most vulnerabilities in socio-cultural, economic, and environmental aspects. The chosen site of the city itself comprises the container and vehicle logistic harbor, and part of the renovated city center and countryside. This also coincides with the location of the Weser Estuary mouth. We can immediately recognize that the port has a different character than the urban fabric. This becomes more obvious when looking at the site's structure in the form of layers. The lithospheric layer completely modified to suit the necessities of the port, which sticks out for its lack of internal water bodies (hydrosphere), extensive paved storage areas (technosphere), and limited biotic life (mostly human life).



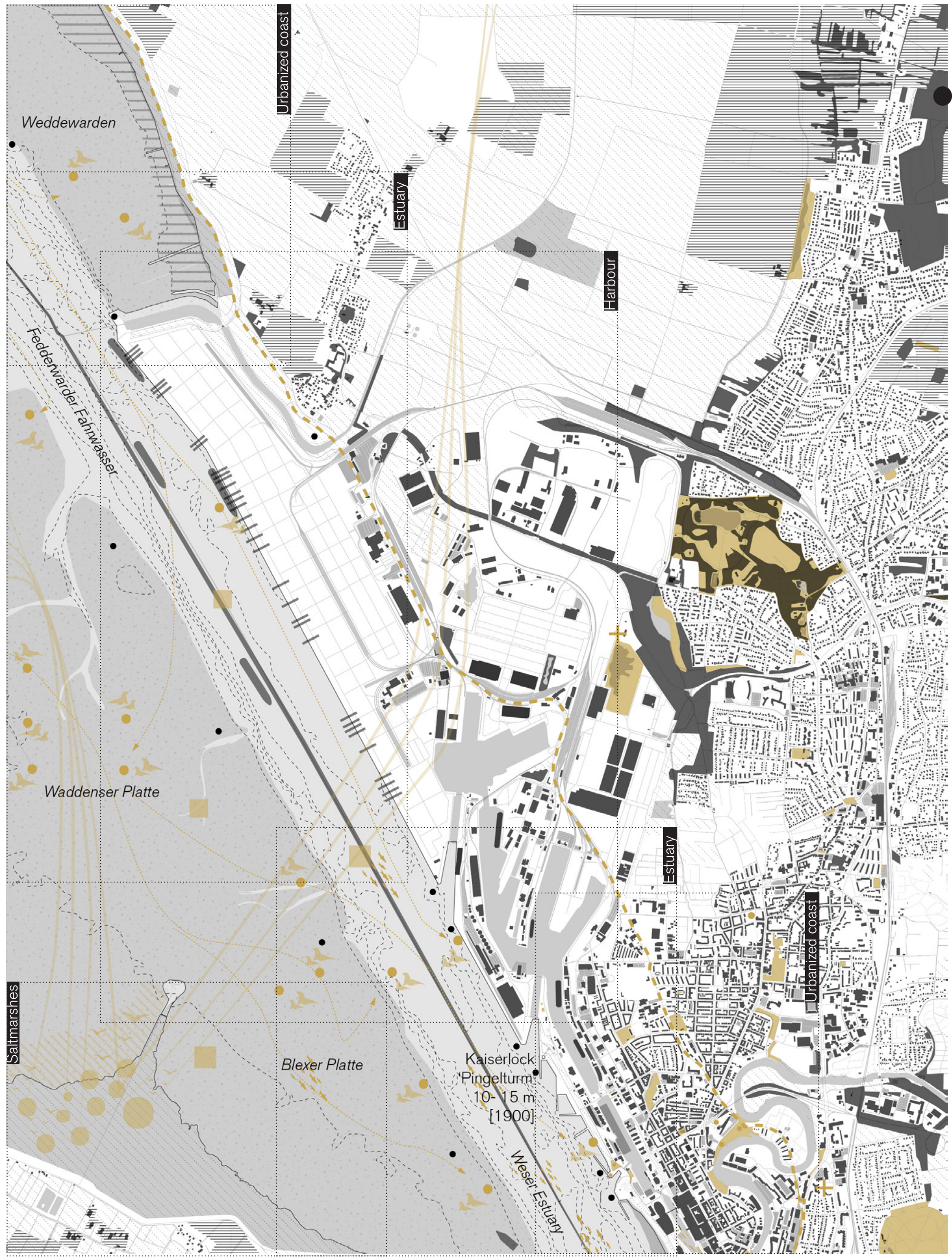
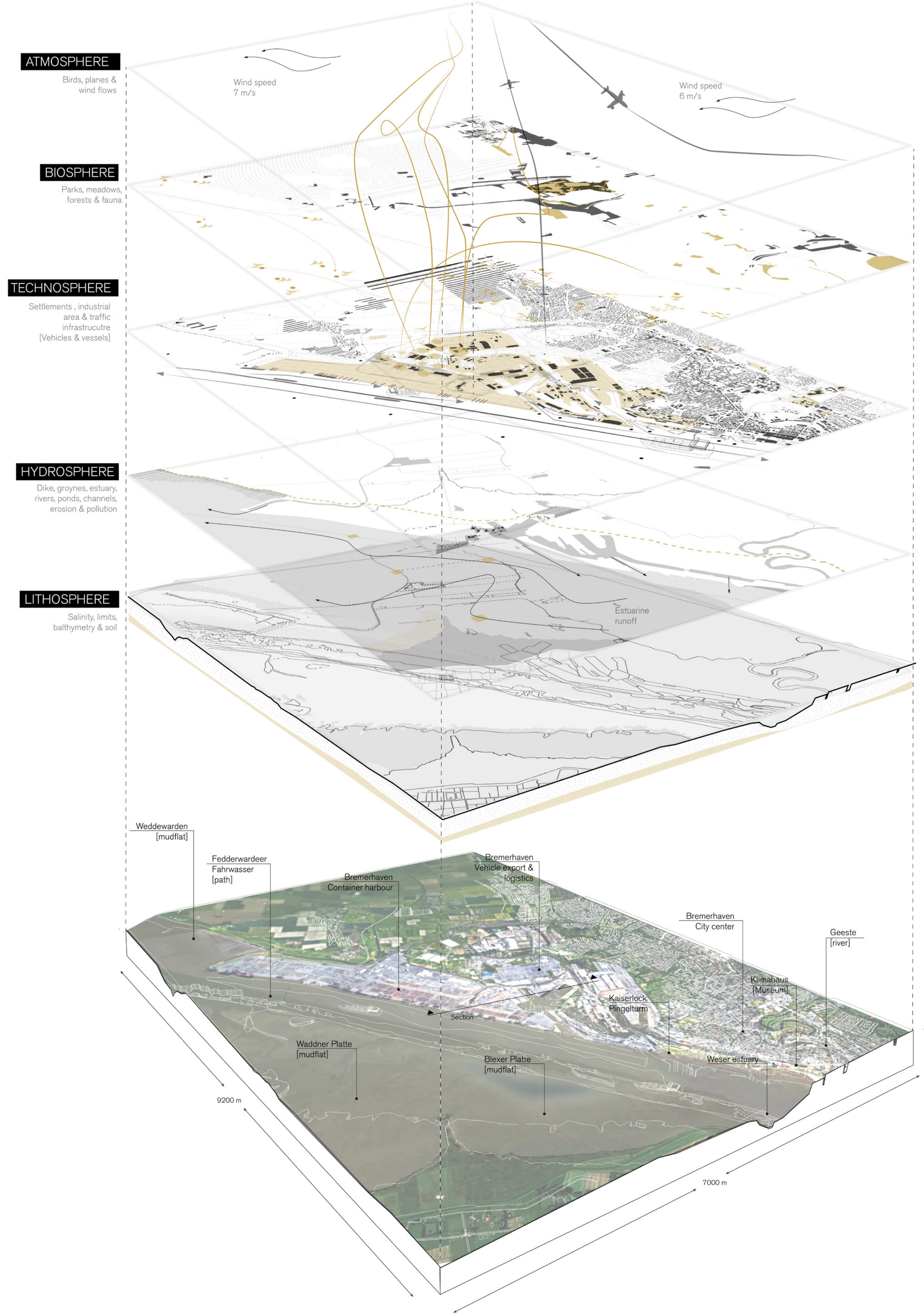


Fig. 138 . Map of conditions 2020 of coast ecosystem - Bremerhaven [Local scale]
(Made by author, 2020)
(Data from: Geofabrik, 2020; GeoSea-Portal, 2020; Google Earth Pro, 2020; Seehkarte Südliche Nordsee, n.d.)

- Dike
- Erosion area
- Accretion area
- Fauna concentration & flows
- Pollution concentration
- Vessel traffic
- Port cranes
- Buoys
- Buoys
- Shipwrecks
- Landmarks
- Balthymetry
- Buildings
- Forests
- Farms
- Waterways
- Traffic
- Parks
- Tidal flats
- Meadows & grassland

Fig. 139 . Axonometry of present conditions [Local scale]
(Made by author, 2020)



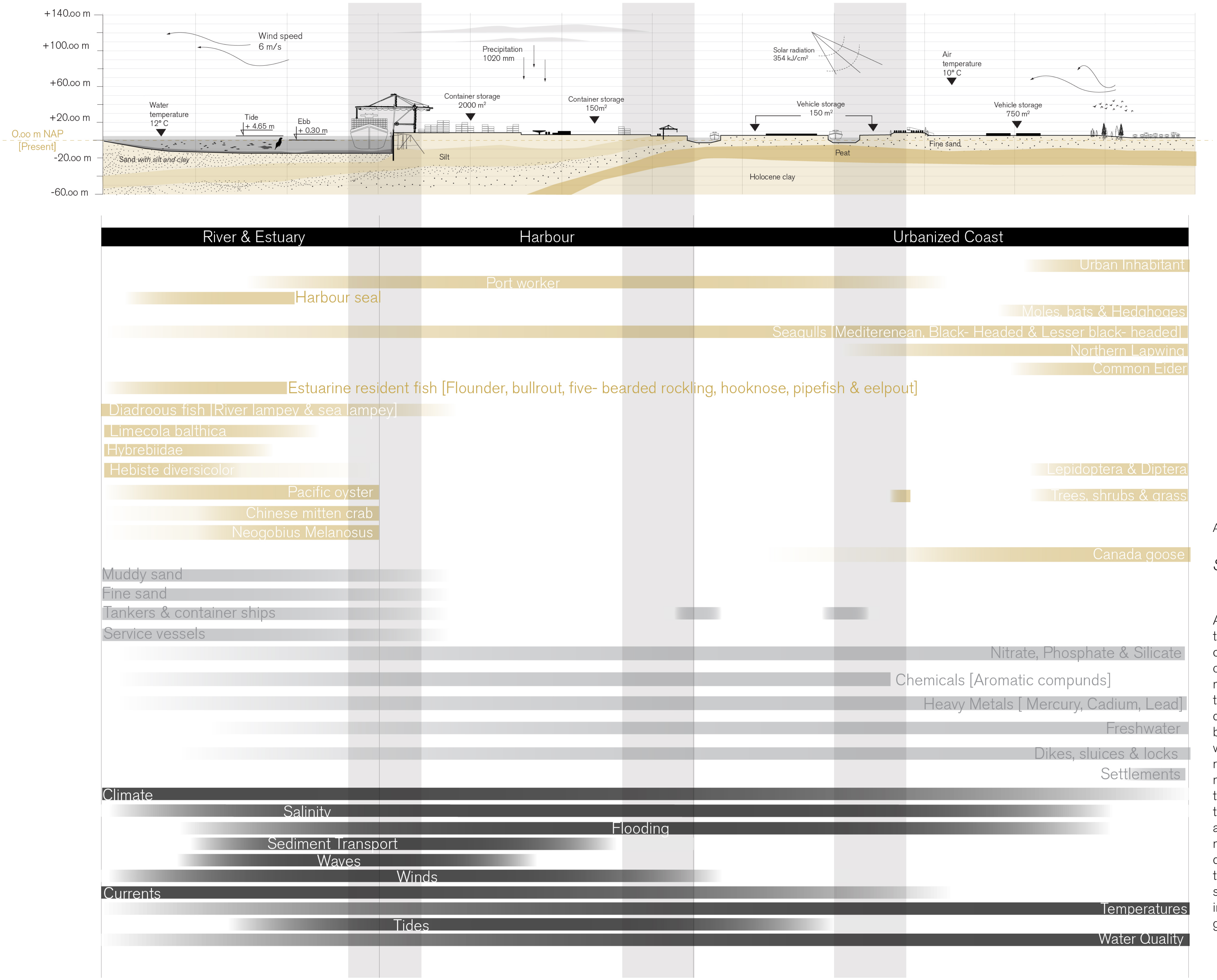


Fig. 140 . Section of current conditions of coastal ecosystem [Local scale]
(Made by author, 2020)
(Data from: BGR,2019; Geofabrik, 2020; GeoSeaPortal, 2020; Google Earth Pro, 2020; Seehkarte Südliche Nordsee, n.d.)

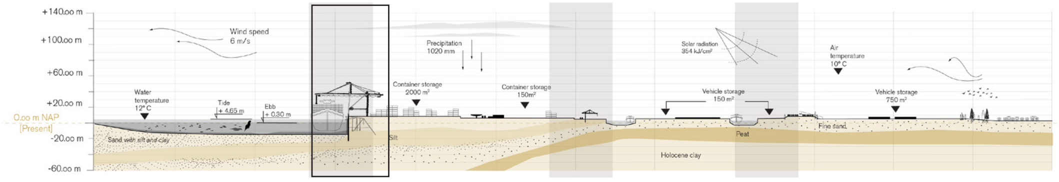
ANALYSIS

Sample of coastal ecosystems [Present]

A section that cuts through all ecosystems territorial extension reveals that most biotic life concentrates in the most 'natural' landscapes only touching the borders od the anthropic dominated ecosystems. For biodiversity to enter these territories it is necessary to introduce dynamism to the systems. This inclusion of biodiversity into static systems is not only a way to improve the aesthetics of the area, but rather to help the system overcome their vulnerability and deal with the developing fluctuations of climate change uncertainty. Of course, this will require the sacrifice of areas of pure anthropic use for transformations induced by natural systems, which will force anthropic development to look for more efficient ways to use the available space. A set of possible socio-ecological transformations will be shown in the form of three projects in the grey highlighted most urgent areas of the section.

PROJECT

Pilot 1: Dynamic Port

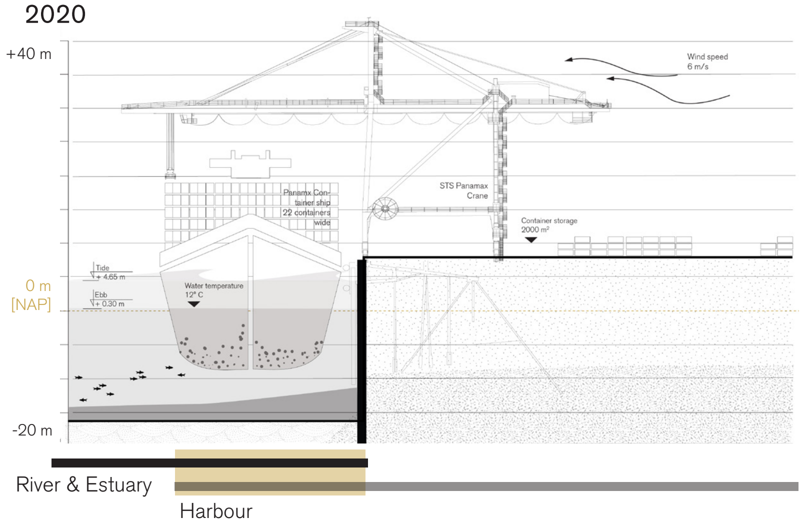


Several transformations are in order to create an ecotone between the static port and the dynamic river biomes. The idea is to make insitions in the port and reuse the material to built a soft front over time. The slow development of a soft outer edge gives time for nature to colonize the groins and humans to relocate port logistics to an inner channel system.

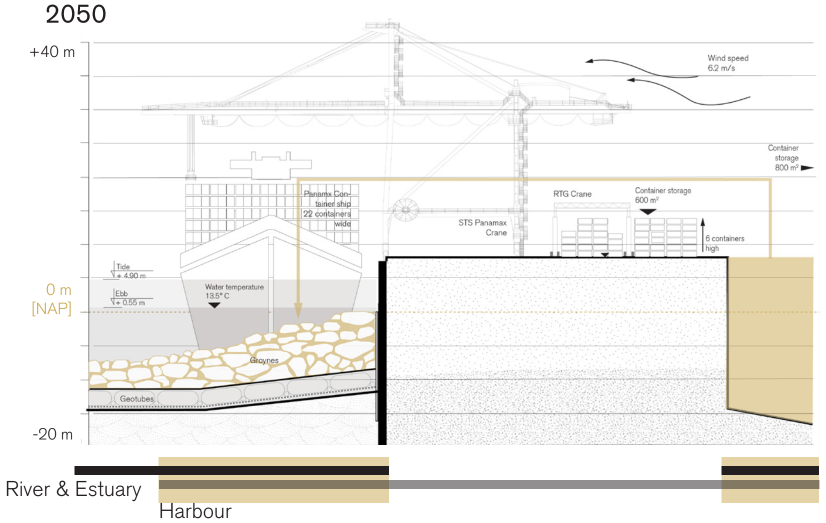
Fig. 141 . Evolving section of absorptive edge project pilot1 [Detail]
(Made by author, 2020)
(Inspired by Sinthuphan,C., 2011)

Fig. 142. Stakeholders analysis - Dynamic Port
(Made by author, 2020)

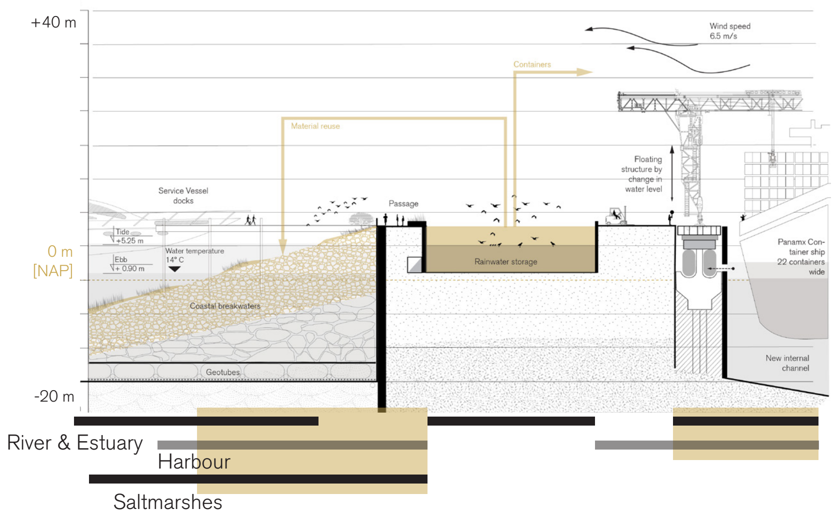
2020



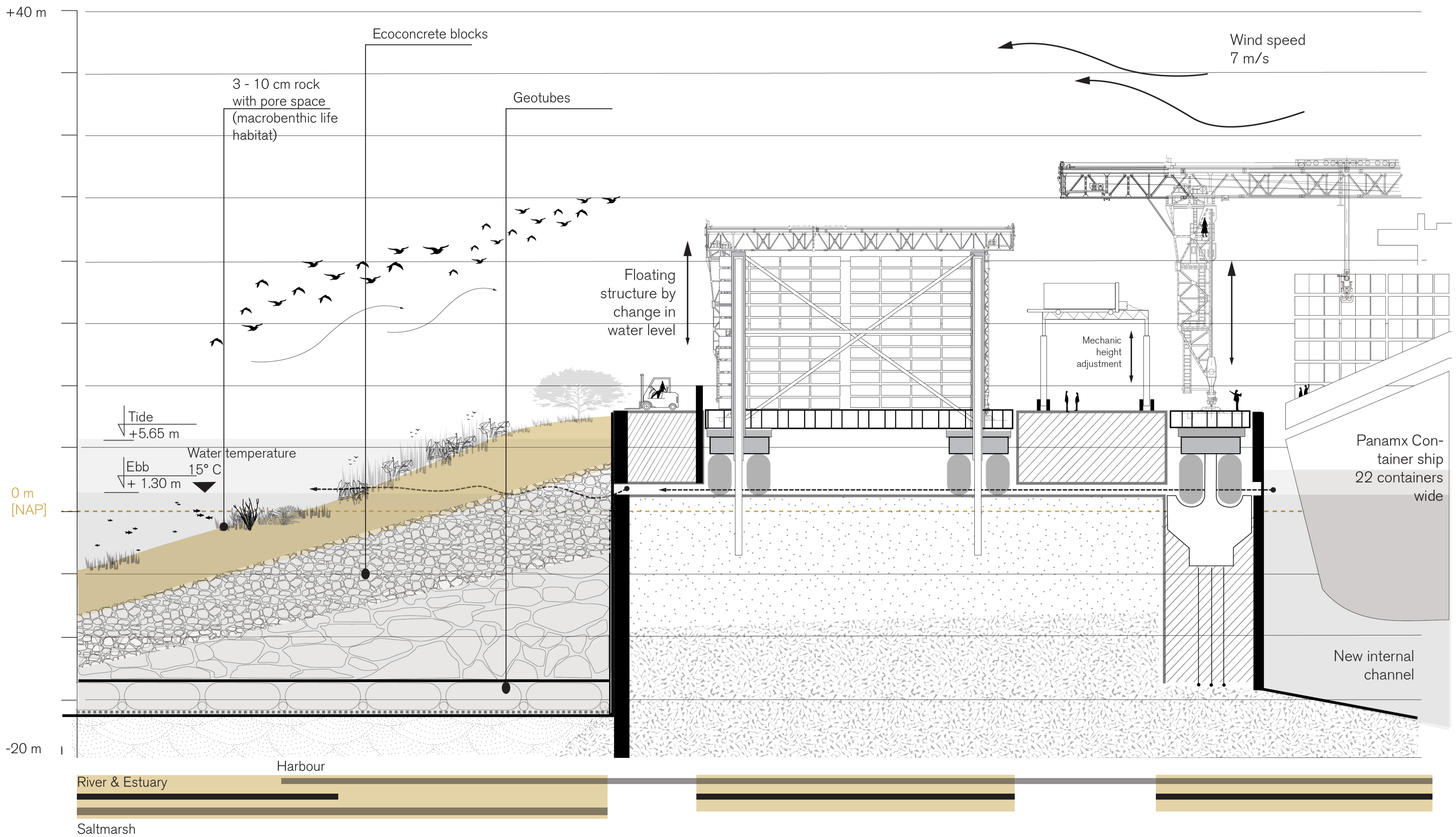
2050



2070

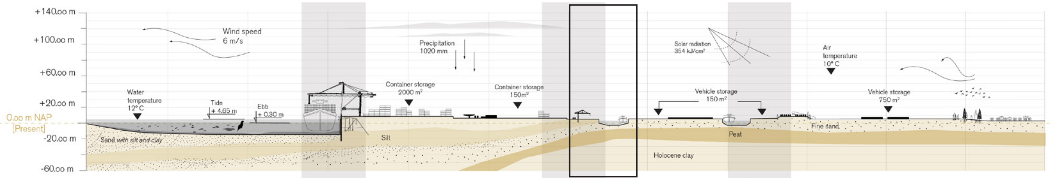


2100



ANALYSIS

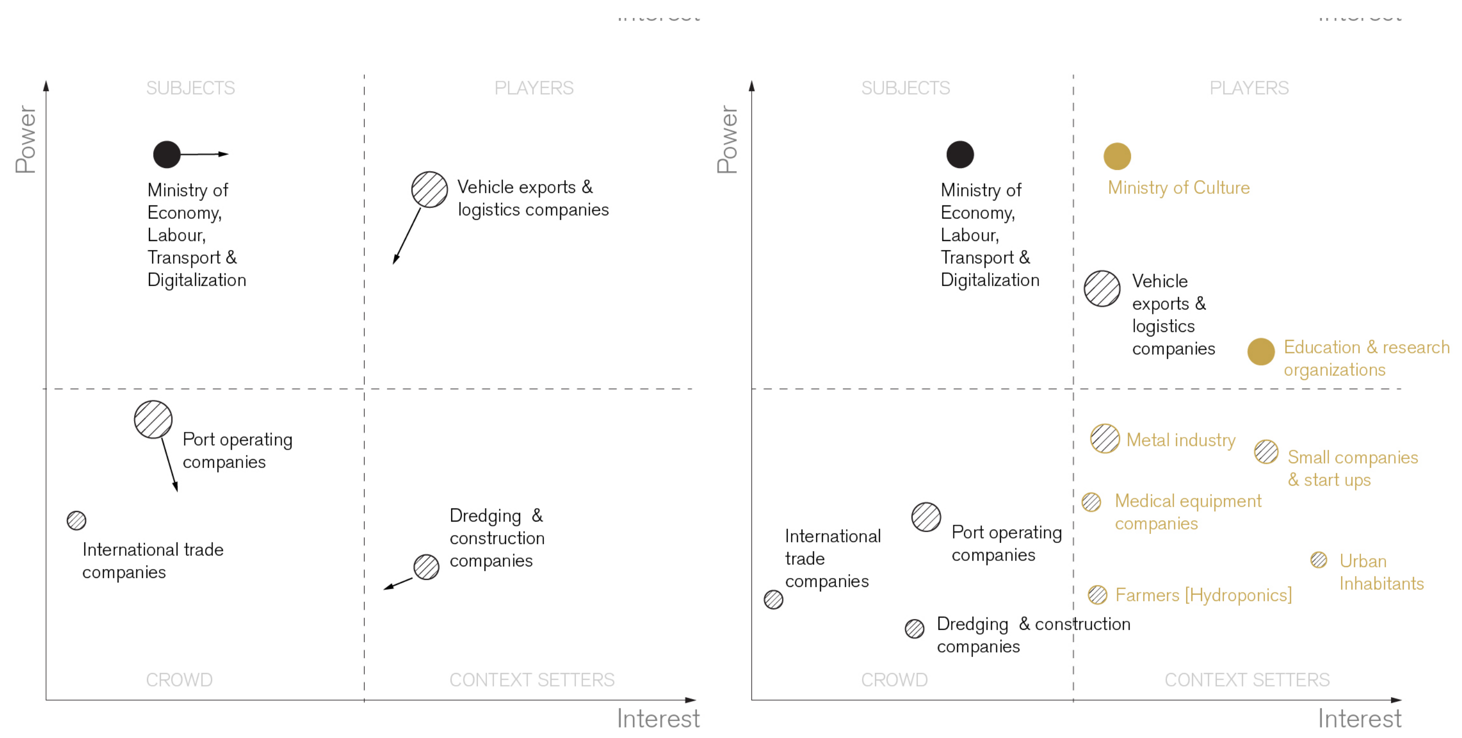
Pilot 2: Innovation hub



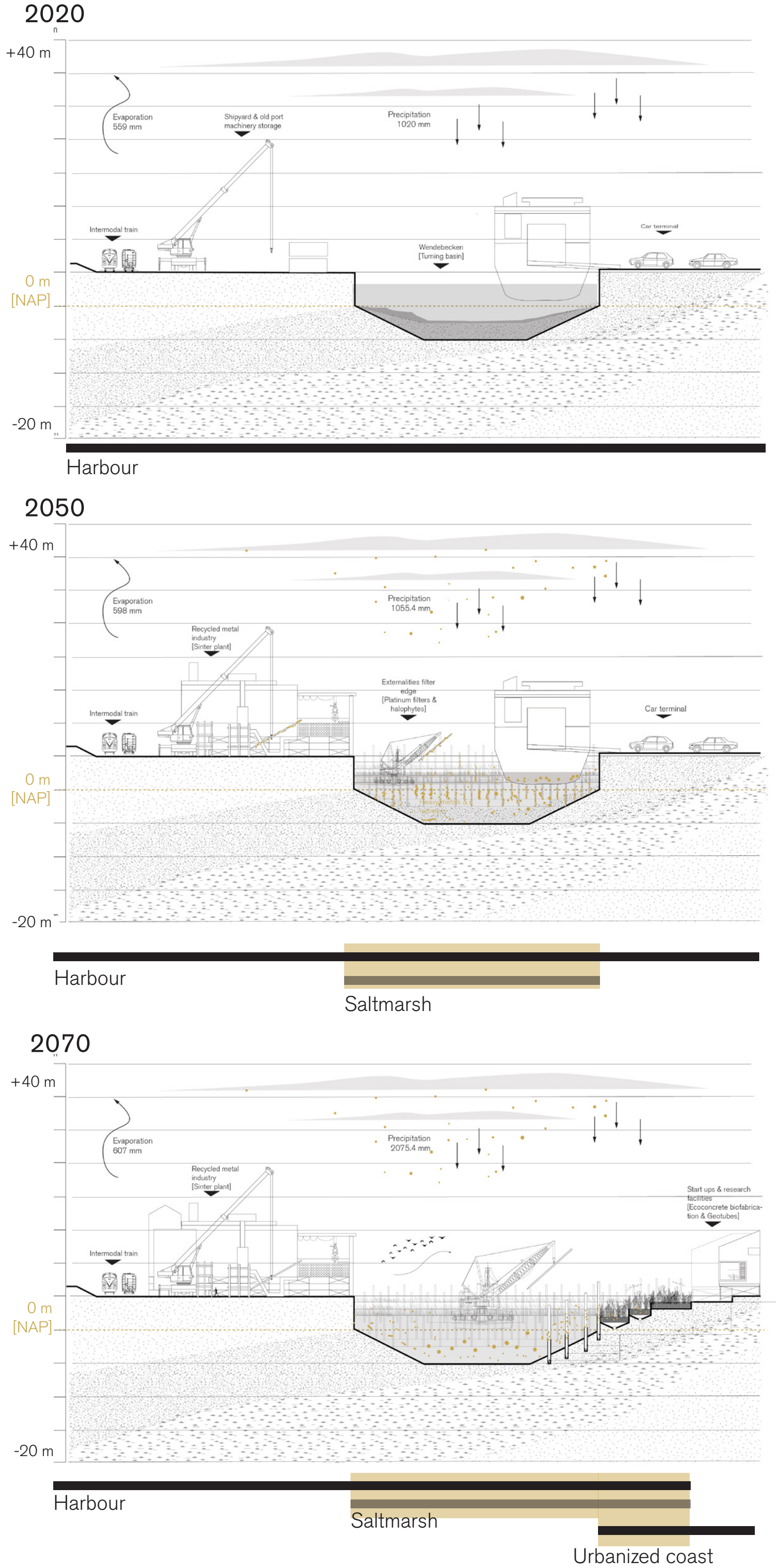
The idea behind this second project is to optimize the monotone space used as logistics and storage areas that lay between the container harbor and the vehicle port and make them more permeable and attractive. This area could become an innovation hub, where startups and research organizations could settle and develop solutions or monitor date useful for the port authorities to deal with the required dynamics.

Fig. 143 . Evolving section of absorptive edge project pilot 2 [Detail]
(Made by author, 2020)
(Inspired by EFFEKT, 2018)

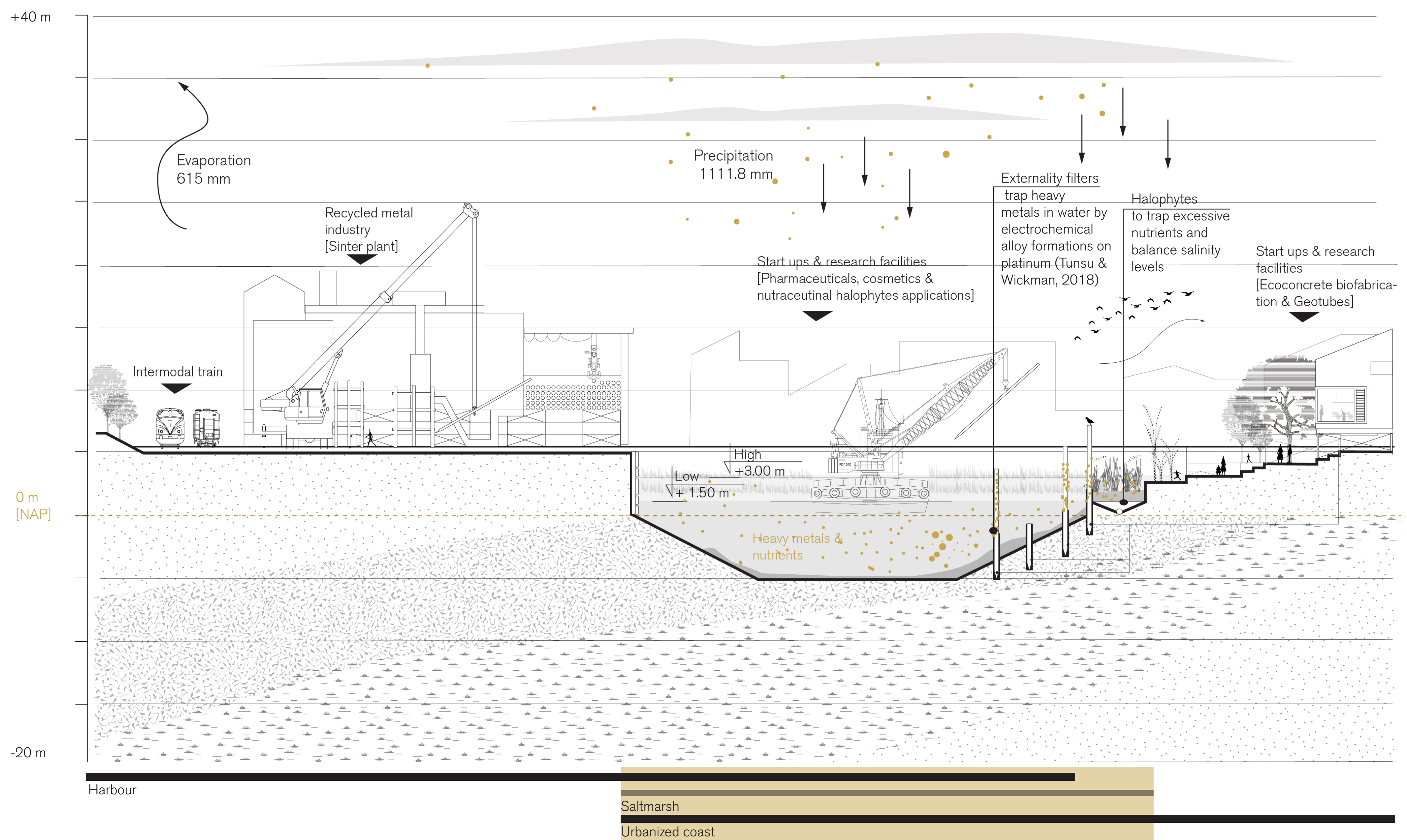
Fig. 144. Stakeholders analysis -Innovation hub
(Made by author, 2020)



2020

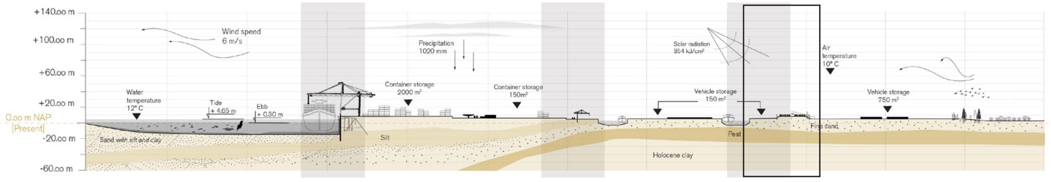


2100



ANALYSIS

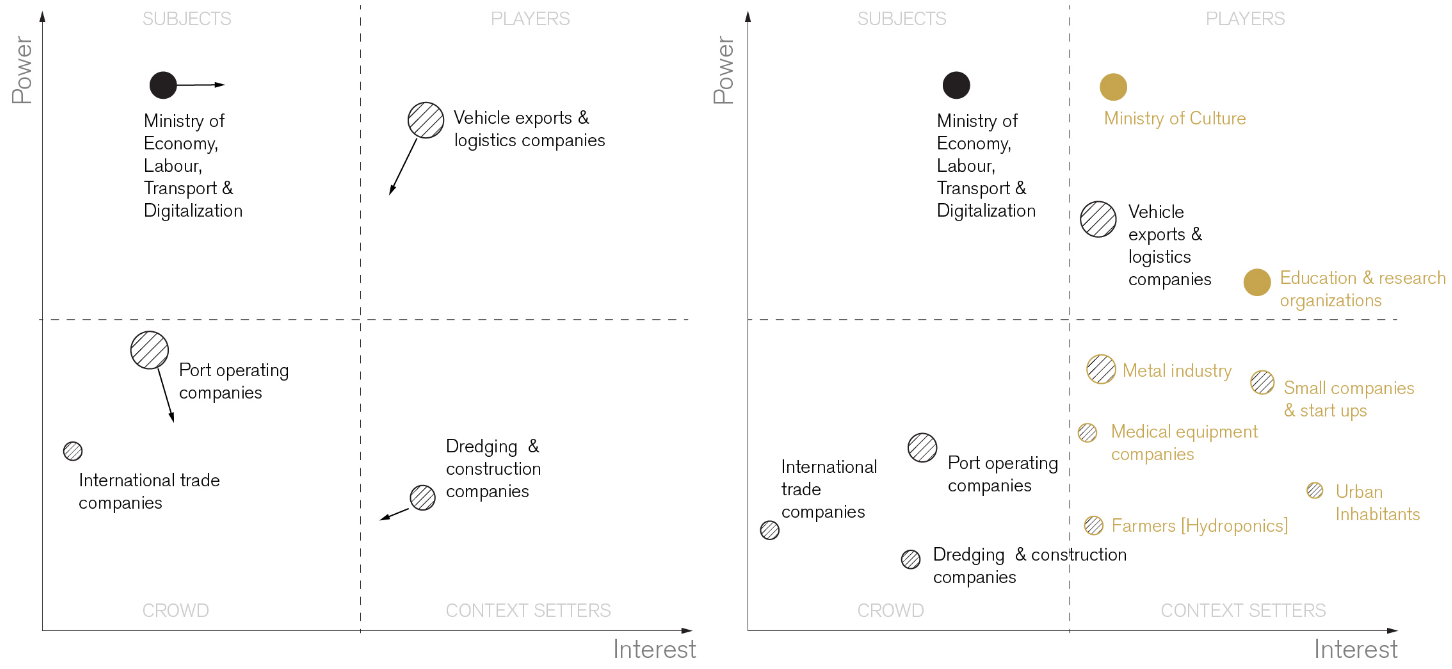
Pilot 3: Efficient habitat

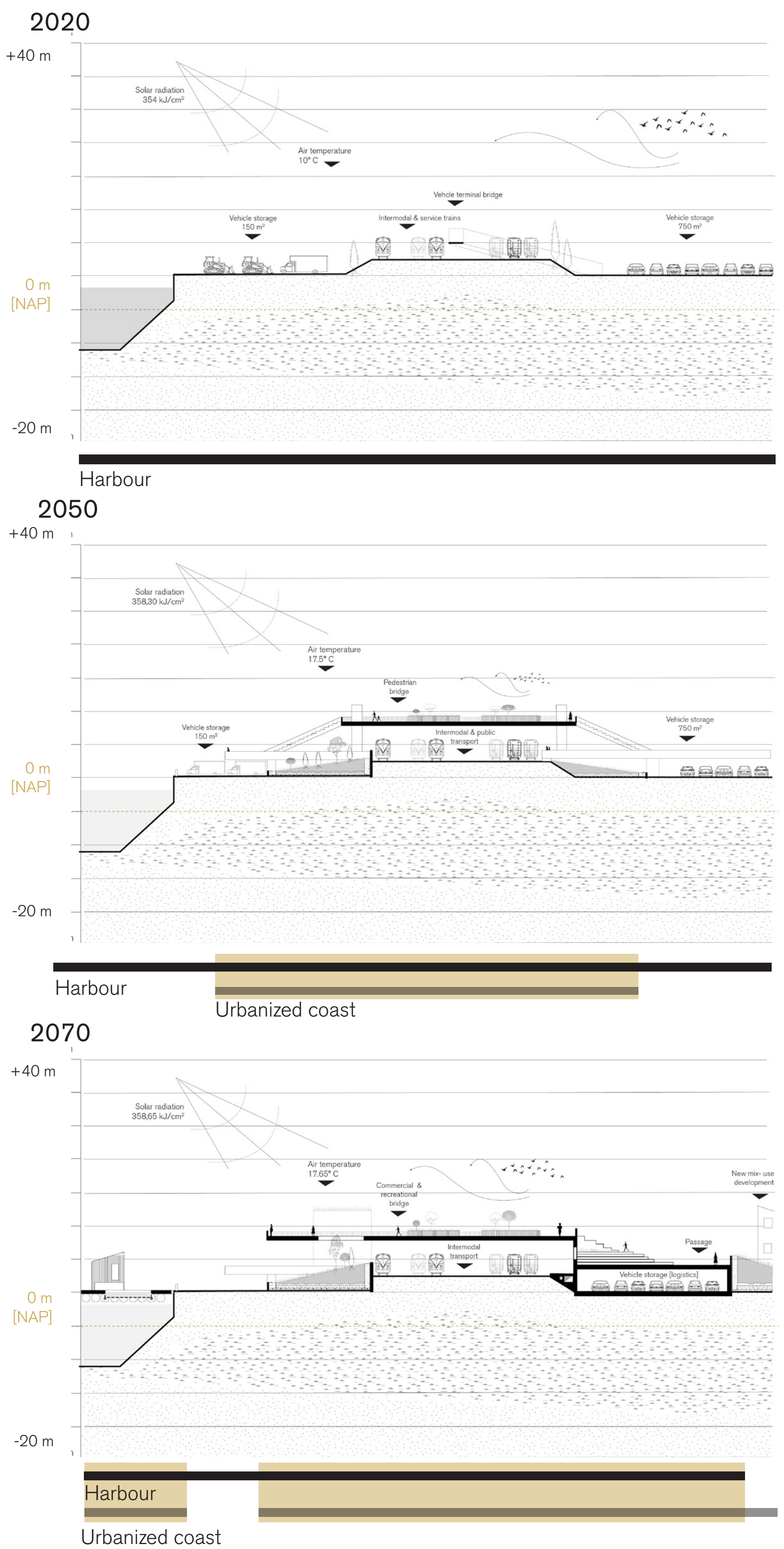


The last pilot project looks for the relation between the port and the city. Thereafter extensive vehicle storage areas are optimized into towers or underground garages, opening up space for recreational activities and bridge connections towards the inner channels. Vehicle logistics companies would not only profit from efficient space but could manage their externalities by algae farms, solve flooding by precipitation problems through rainwater storage, and resell their extensive areas for the development of alternative housing.

Fig. 145 . Evolving section of absorptive edge project pilot 3 [Detail]
(Made by author, 2020)

Fig. 146. Stakeholders analysis -Efficient habitat
(Made by author, 2020)





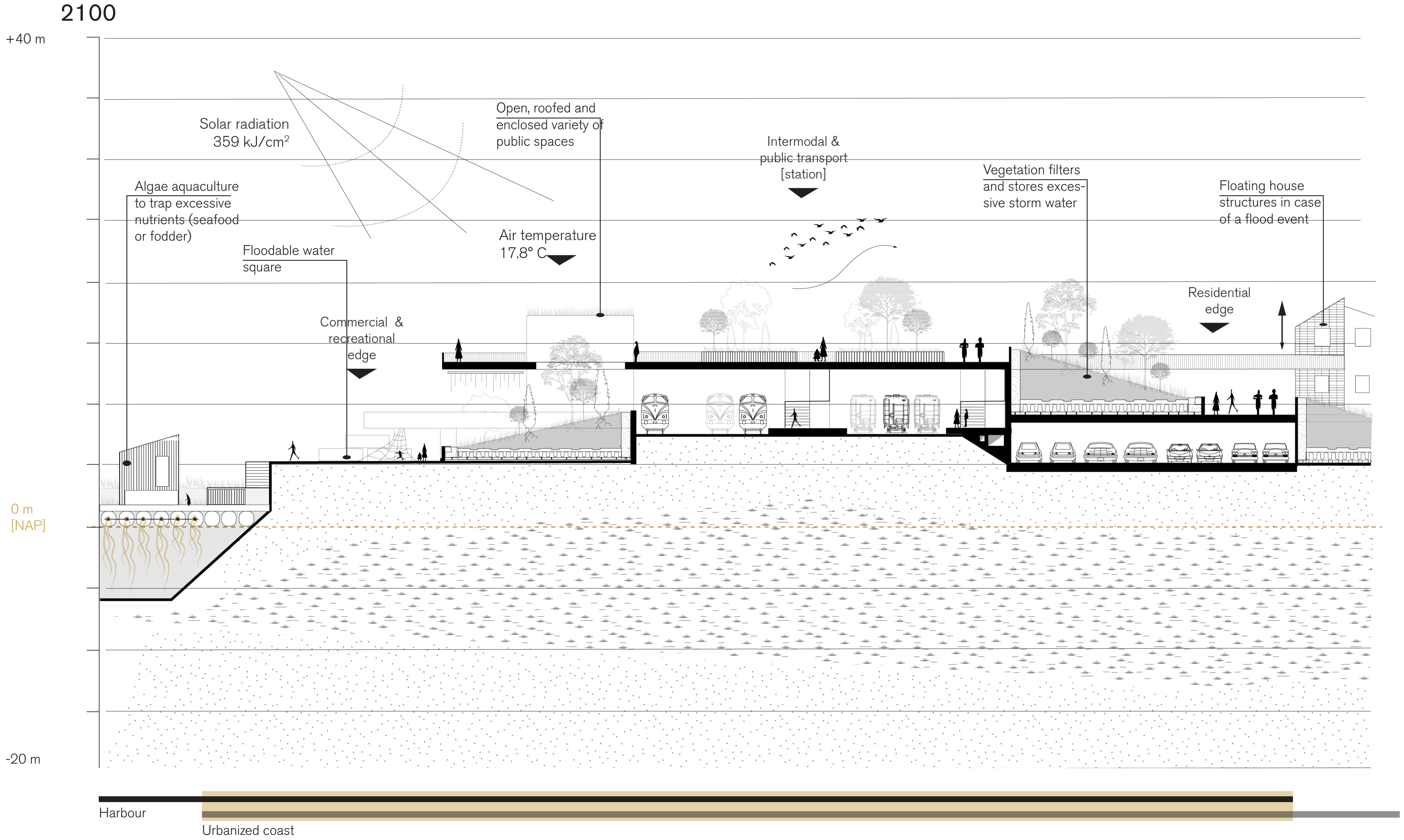
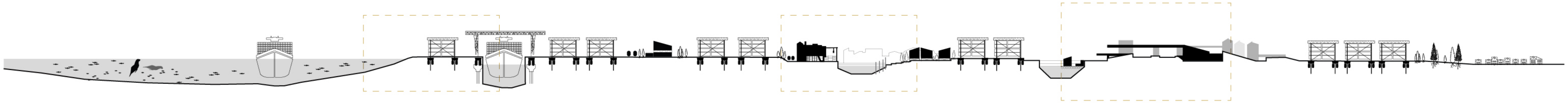


Fig. 147. Overview of the absortive edge project and pilots
(Made by author, 2020)

Pilot 1: Dynamic port

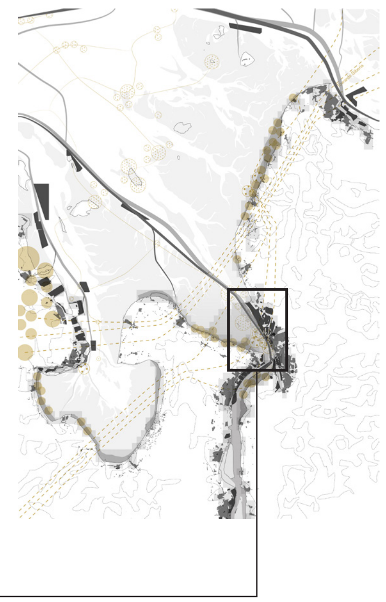
Pilot 2: Innovation hub

Pilot 3: Efficient habitat



Coastal Ecosystems: Local Scale [Projected Future]

Each of the shown pilot projects is part of structural systems that relate the whole area to one another and create the so-called 'absorptive edge'. The first project is attached to a longitudinal system of saltmarshes and the second system of internal water channels. The second pilot project is connected to the same channel system and another longitudinal recreational system that combines the existing dike with educative and recreational uses. The third project makes a bridge between the green dike corridor and a heritage corridor which consists of a series of parks, forests, evacuation routes, floodplains, and recreation areas. We can depict different networks in the layered view of the proposal: a system of new channels and space for the rivers in the hydrosphere, new development areas & saline farms in the technosphere, and green corridors for biotic life to flourish and colonize.



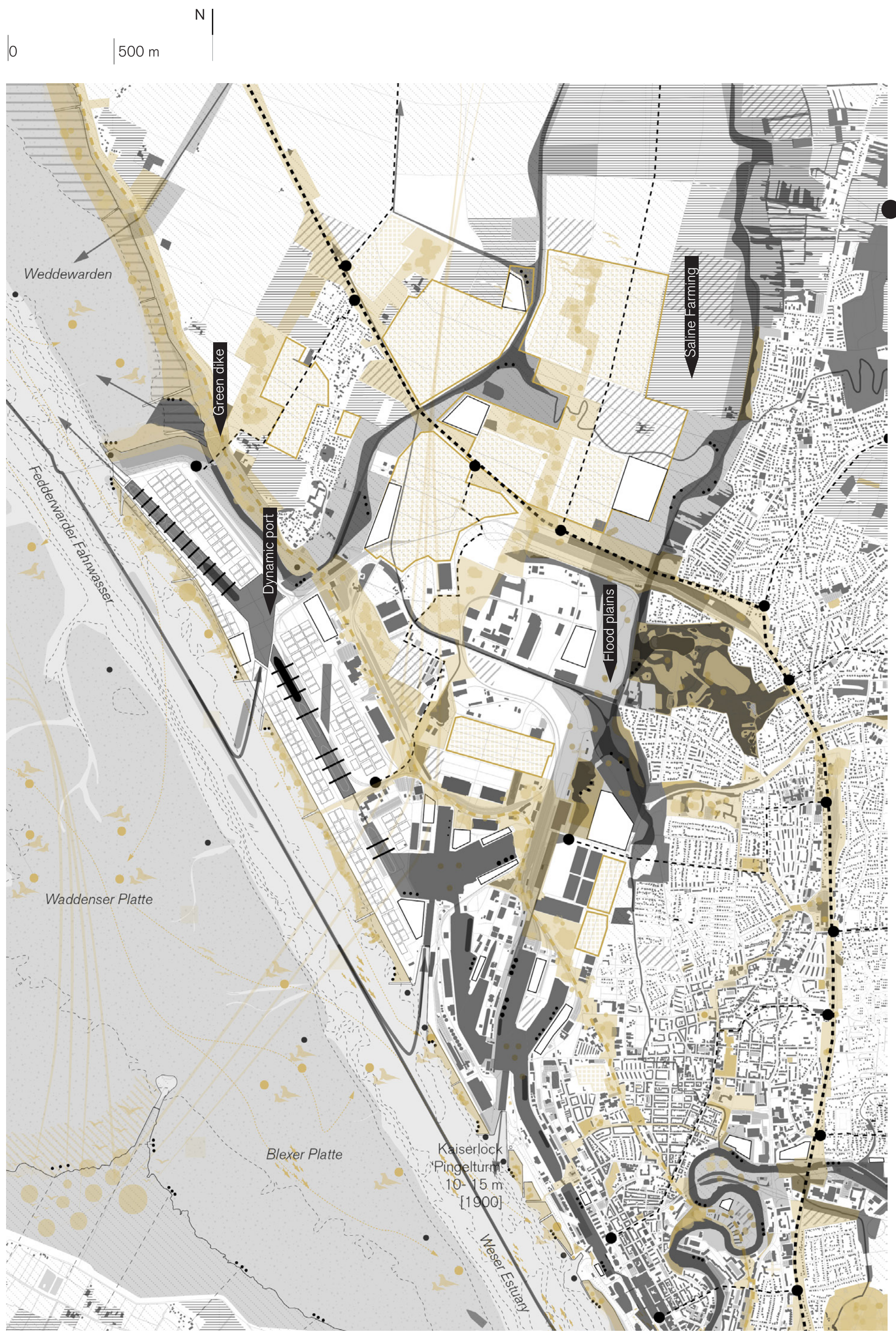
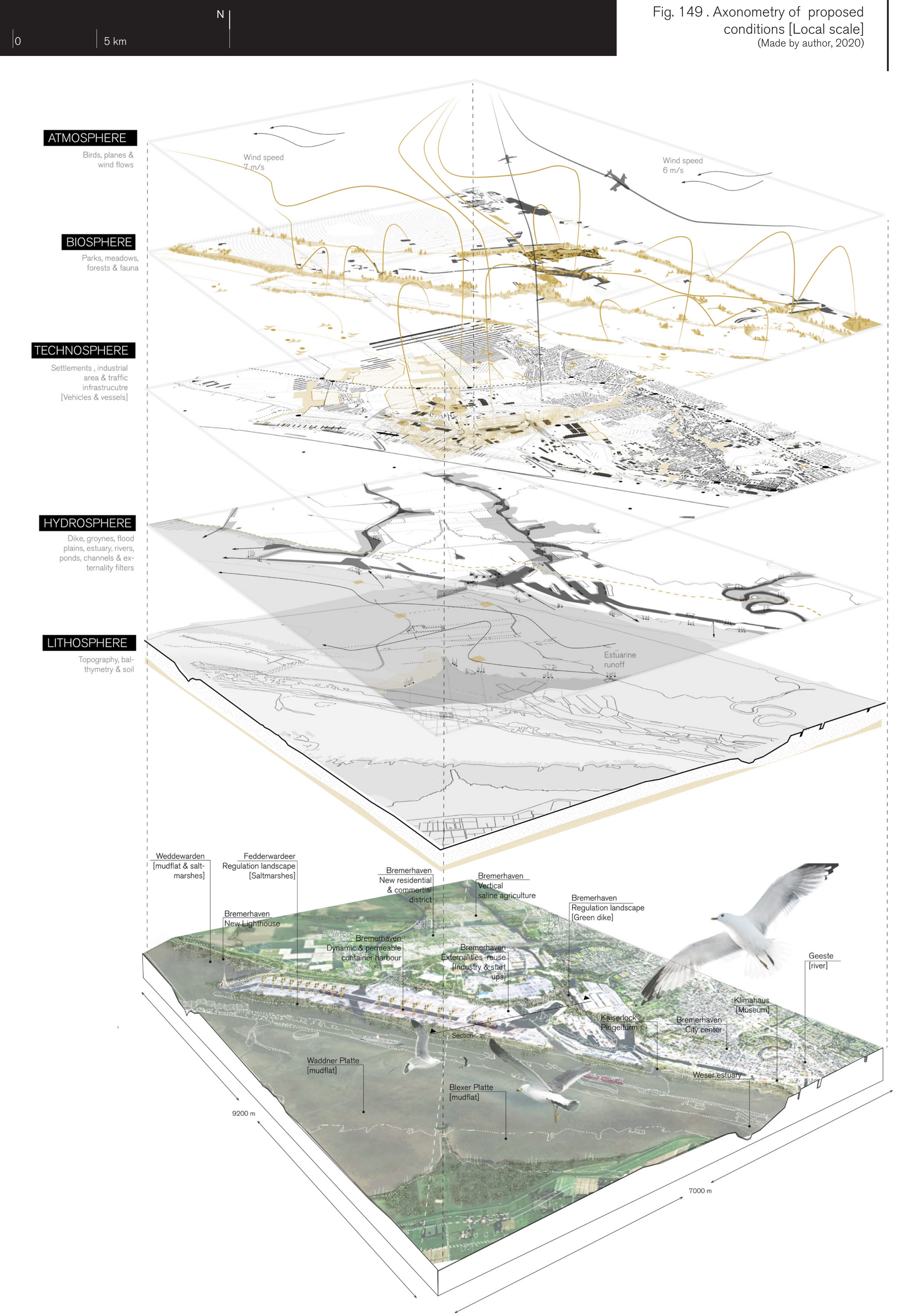


Fig. 148 . Map of proposed conditions 2100 of coastal ecosystem [Local scale]
(Made by author, 2020)

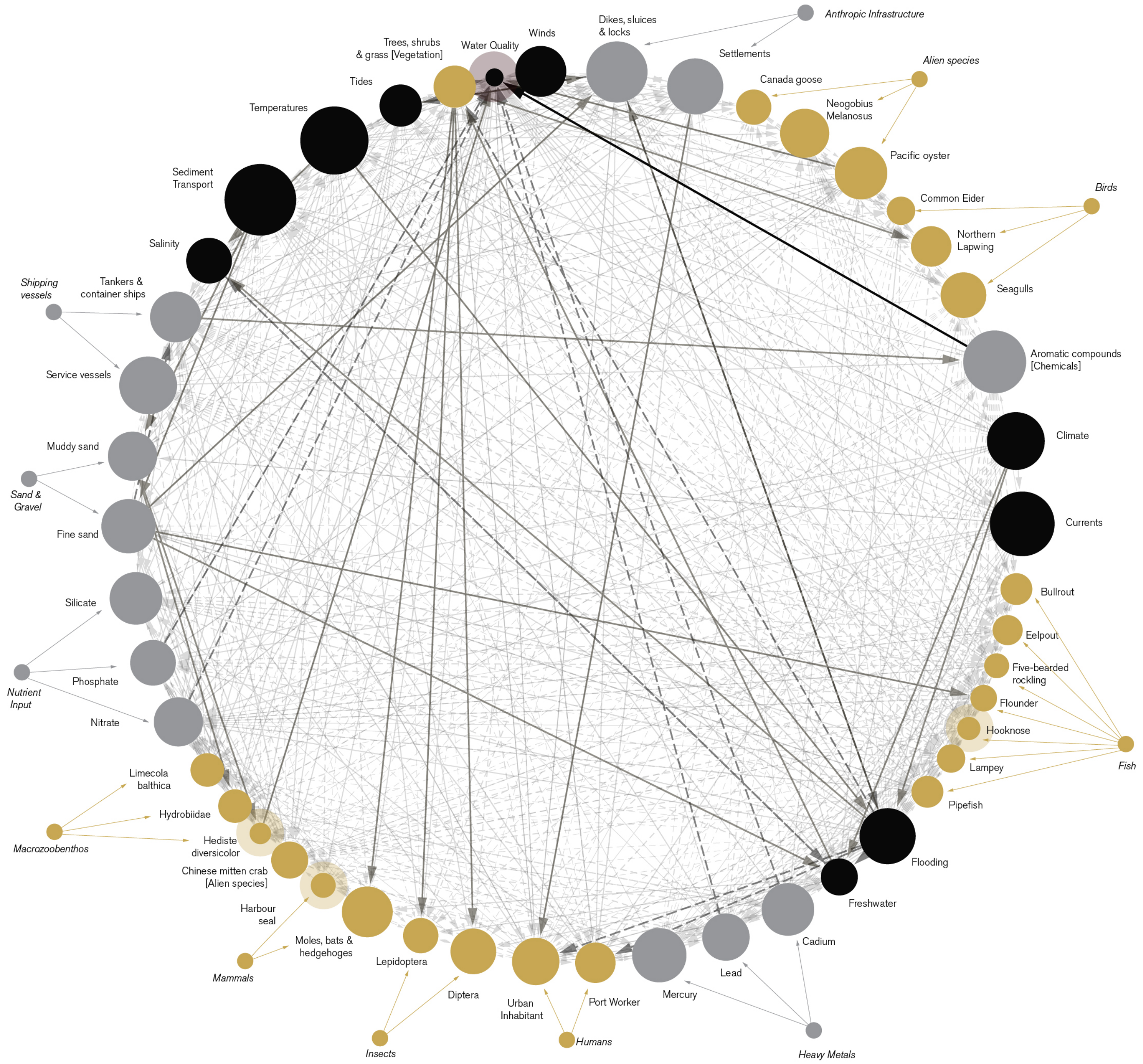
- Vertical saline farming
- New development areas
- Green dikes
- New industrial areas
- Dynamic port storage structures
- Flood plains & water recreation areas
- Fauna concentration & flows
- Vessel traffic
- Dynamic Port cranes
- Buoys
- Buoys
- Shipwrecks
- Landmarks
- Balthymetry
- Buildings
- Forests
- Farms
- Waterways
- Traffic
- Parks & vegetation
- Tidal flats
- Meadows & grassland

Fig. 149 . Axonometry of proposed conditions [Local scale]
(Made by author, 2020)



The design of the networks that will hybridize the ecosystems of Bremerhaven was considered after the careful study of the following elements synergies and vulnerable points (such as water quality). The desitions made in the design are described in Fig. 151, showing the mix of an anthropic intervention, then the natural colonization, and lastly the catalyzing process of transformation. How each project can be installed concerning time and ecological succession rates is shown in the next pages (Fig.152).

Fig. 150 . Local Ecosystem Assessment [Coast]
(Made by author, 2020)



Most vulnerable elements

1. Water Quality [Process]
2. Hediste Diversicolor [Macrozoobenthos]
3. Hooknose [Fish]
4. Harbour seal [Marine Mammal]

Less vulnerable elements

1. Sediment Transport
2. Temperatures
3. Currents
4. Aromatic compounds

Most substractive output on ecosystems

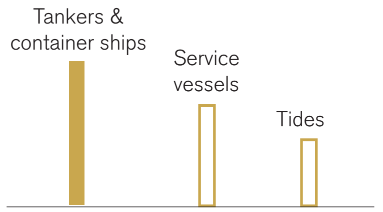


Fig. 151. Main functions of the absortive edge design
(Made by author, 2020)

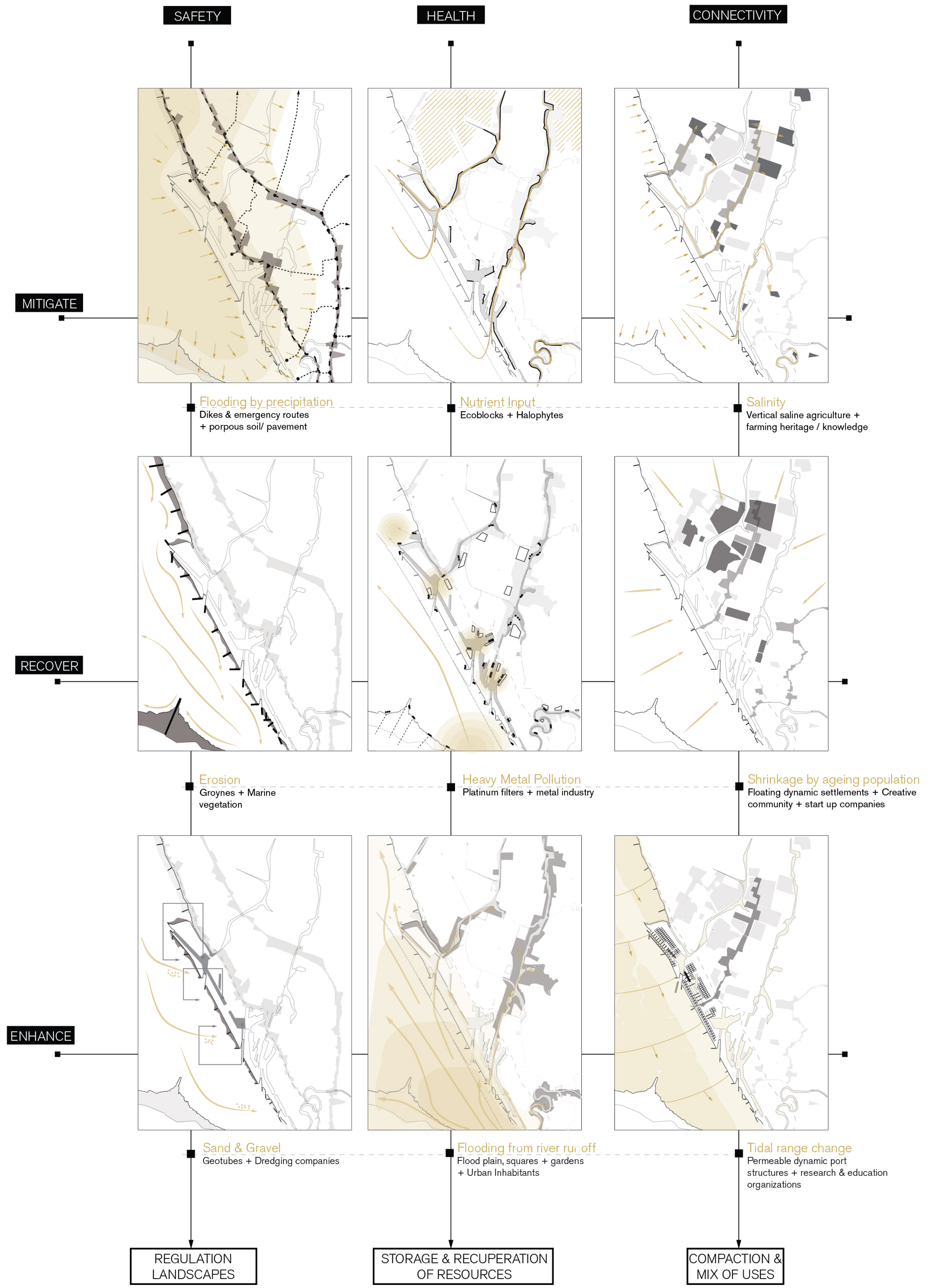
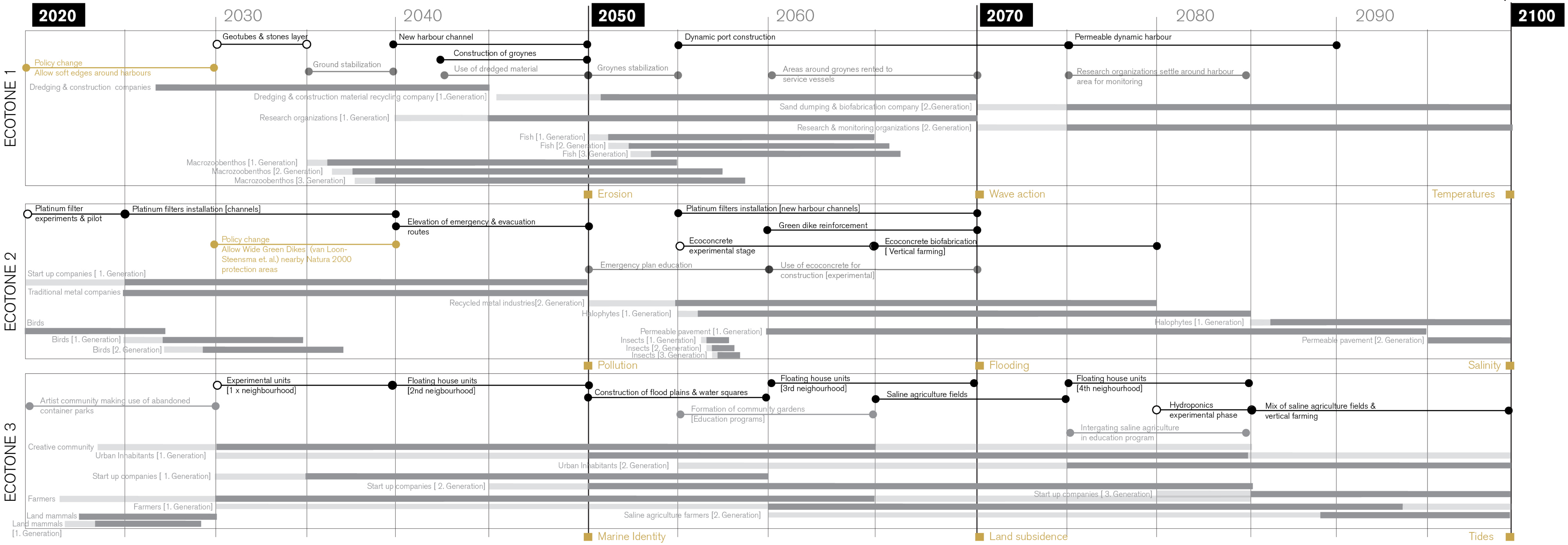
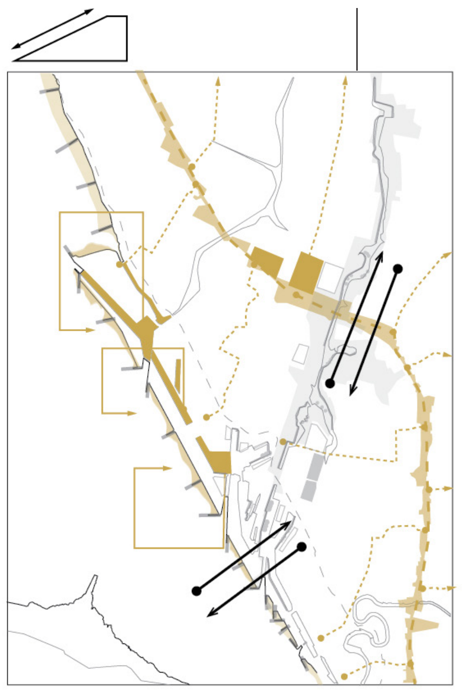


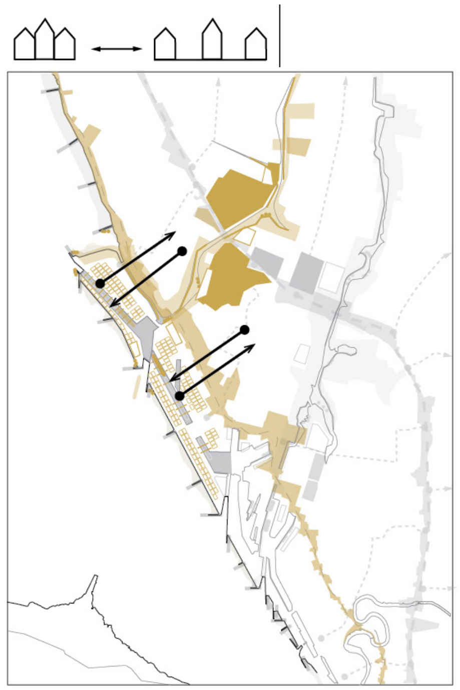
Fig. 152. Phasing of design stages for absorptive edge
(Made by author, 2020)



2020-2040
Relation between city and port



2040-2050
Relationbetween highlands & lowlands



2050-2070
Relation between less dense & more dense urbanized landscape

2070-2100
Relation between new neighbourhoods

Conclusions: Process scale design

The intention of the *'Process scale' subchapter* was to display a way of applying the design principles proposed in form of a vision, to test its applicability, possible shape, and relation in specific sites of the Weser Estuary. This was tested on two different scales: *local scale* and *sample scale* to get a grasp of the capabilities and overall look of the proposed strategies. Hereby the main functions and sequence of transformation to achieve two of the three main strategies (barrier islands, absorptive edge, and socio-ecological corridors) with an ecological succession thinking were exposed.

To realize a **barrier island strategy** it was necessary to design for mudflat accretion, water quality regains and education & identity integration.

- *Mudflat accretion* was proposed to be achieved by mitigating wave action, recovering sediment transport, and embracing winds through tunnels to spread sand on the mudflats periodically.

- To *regain water quality* I proposed to mitigate turbidity so that externalities are trapped by biofilters, recovering from heavy metals through bioaccumulation, and embracing carbon by storing through reef-building.

- *Education and identity integration* could be achieved through the mitigation of tidal stress by installing floating structures, recovering recreational areas with educational programs, and embracing storms and precipitation through water bodies.

On the other hand, the proposed **absorptive edge strategy** entailed the following goals to be aligned with the rhythms of the environment:

- Create *regulation landscapes* by mitigating floods by precipitation, recovering from erosion, and embracing recycled sand and gravel products.

- *Store and recuperate resources* through the mitigation of nutrient input by saltmarshes, recovering from heavy metal pollution with platinum filters and embracing floods by river runoff through recreation corridors.

- *Generate compact and mixed-usage of space* through the mitigation of salt intrusion by saline agriculture, the recovery of demographic shrinkage by welcoming innovation, and embracing tidal range changes through floating structures.

Fig. 153. Multiscalar Design Proposal
(Made by author, 2020)

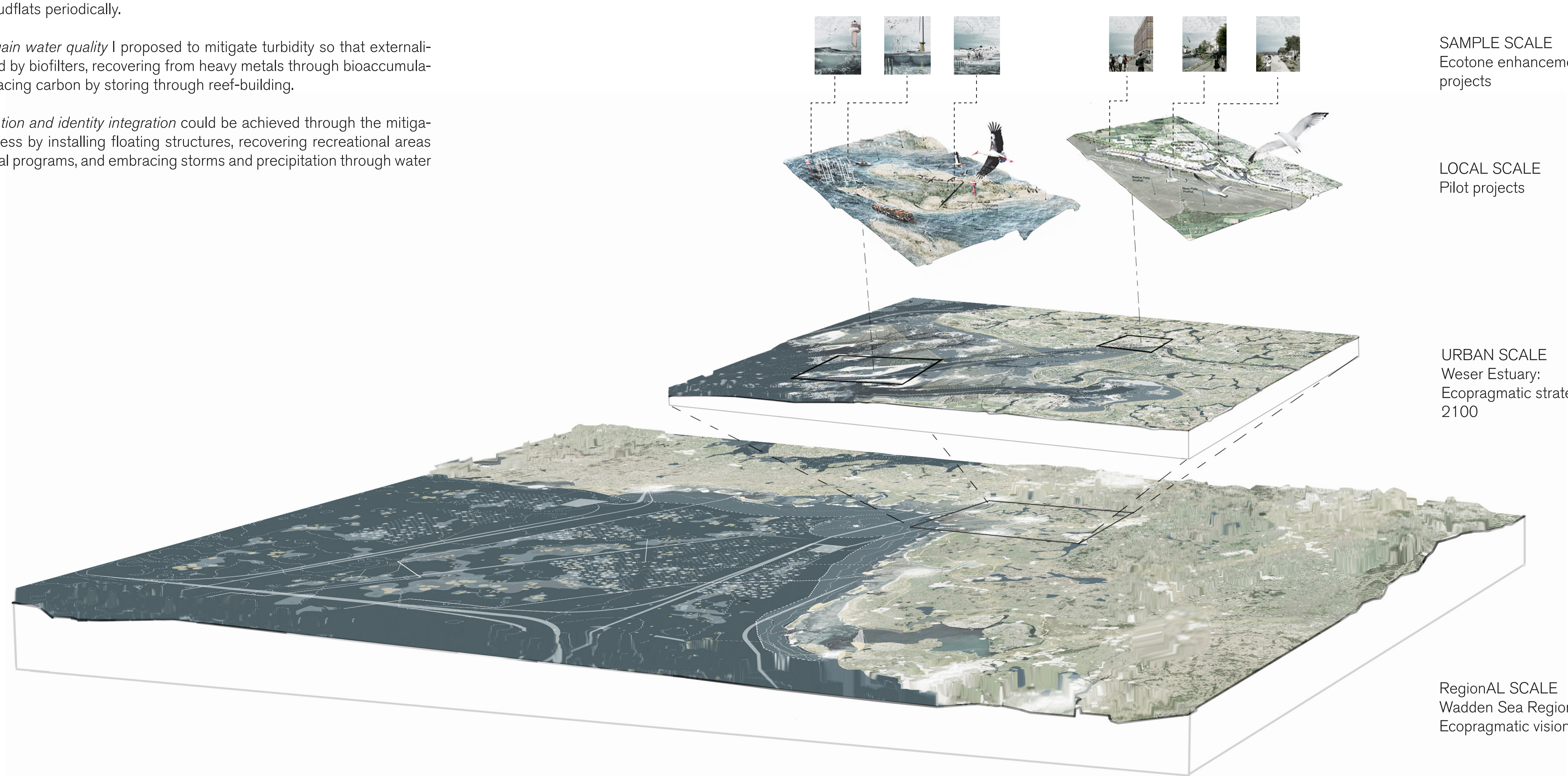
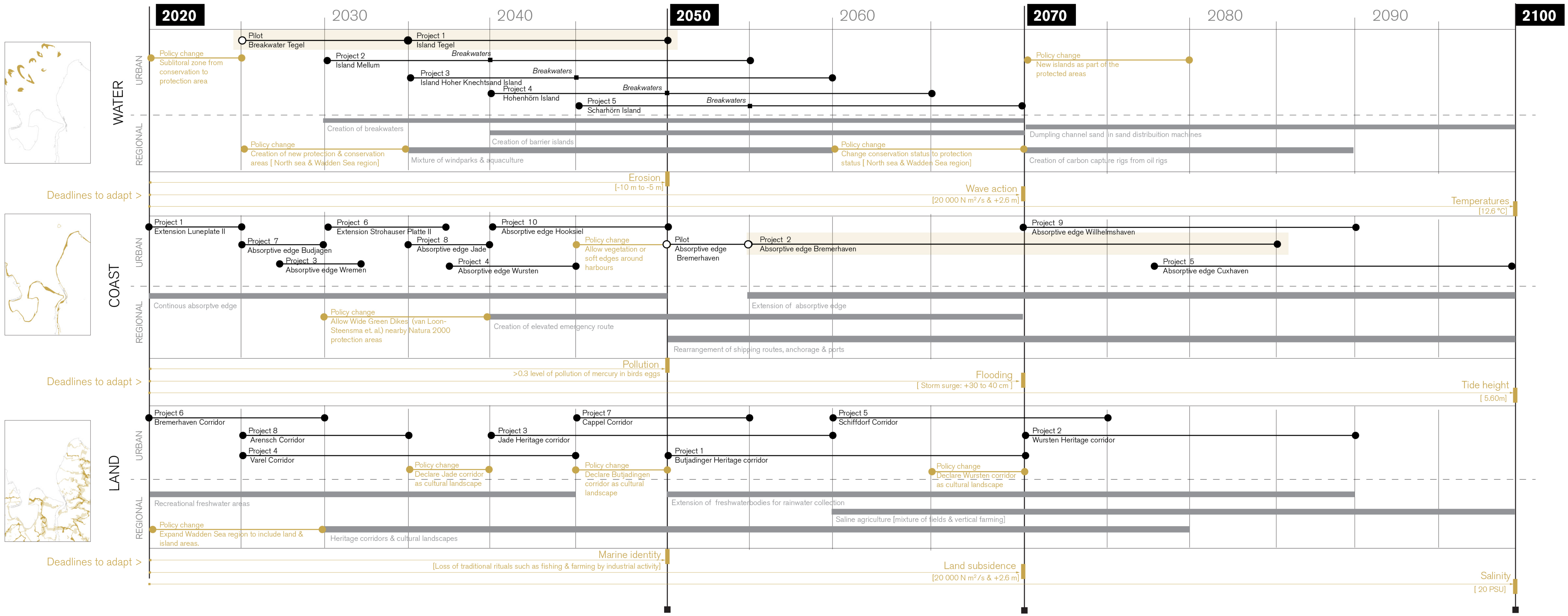


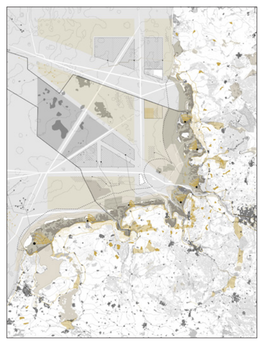
Fig. 154. Phasing of urban strategies
(Made by author, 2020)



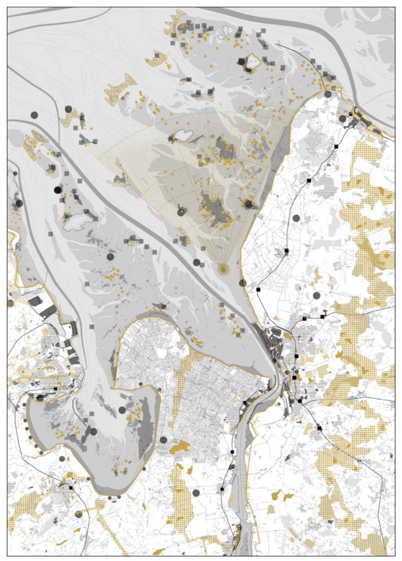
PROJECTION

Strategies phasing

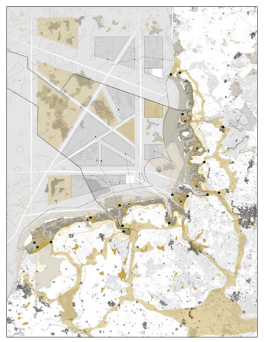
As a final step, we can zoom out again, and understand how the entire Weser Estuary and Wadden Sea region would transform alongside its ecological rhythms and the required policy changes till 2100, as a way to make the vision materialize into long term reality.



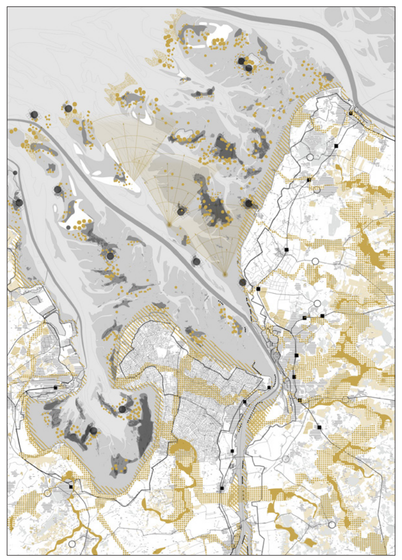
Wadden Sea region



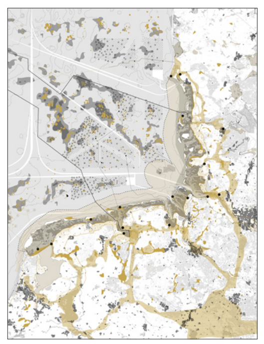
Weser Estuary



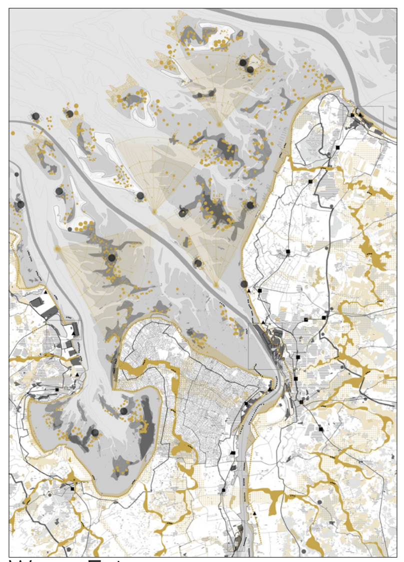
Wadden Sea region



Weser Estuary



Wadden Sea region



Weser Estuary

Fig. 155. Mellum Island
(Taken from Google Earth, 2019)

CONCLUSIONS

The purpose of Chapter 5 '*Projection*' was to materialize the design ideas and possible strategies for the Wadden Sea region and the Weser Estuary area. The first glance into possible scenarios for the region and urban area revealed that under an 'ecopragmatic' scenario an opportunity rises to align human and natural rhythms with the dynamics of changing habitats. *Ecopragmatism* as a path was worthwhile seeking due to the following, social, economical, and environmental benefits:

- *[Economical]* In a low economic development scenario, although costly, measures that will look into efficiency (compaction of different programs) will impulse innovation as well as minimize great losses.
- *[Social]* The necessary engagement of mixed stakeholder in projects will implicitly boost integrity and a common identity, that could even outgrow possible conflicts with 'traditional' thinking.
- *[Environmental]* The act of embracing risk as an opportunity which amplifies the resiliency of the system, will require welcoming the experienced hand of nature and its elements into new infrastructural developments.

The development of an 'ecopramatic' vision for the region and urban area for 2100 resulted in the design of *three* main strategies: a barrier island system involving water ecosystems, an absorptive edge system concerning coastal ecosystems, and a socio-ecological corridors system with the use of land ecosystems. These strategies were linked to a set of design principles to unfold and guide the expansion of the values of *safety, health, and connectivity*. Hereafter two samples of the site were chosen to test the applicability of two of the mentioned strategies (barrier island and absorptive edge system). An ecosystem assessment of water, coast, and land territories revealed the vulnerabilities, lifespan, and changes in routines that the design had to respond to. Both the design of a barrier island and the absorptive edge combined human and nature actions to boost synergies between social and ecological systems. Nevertheless more ecologically dominating interactions (*ecotones*) were enhanced in the barrier islands, whereas more socio-ecological synergies (*ecotones*) were encouraged in the absorptive edge design.
All in all, it was revealed that the design of hybrids which link human and non – human interactions with the processes that will intrinsically change over time, will transform climatic related risk into opportunities to evolve if ecotones are successfully created in the process. The key was to construct enough chances and support for these synergies to happen naturally across time.

Chapter

6

EVALUATION

CONCLUSIONS

In this chapter I reflect upon three subjects to answer the posed research question as well as judge what aspects of the project goals were reached by the proposed methodology.

[CONTENT]

EVALUATION

Introduction

The following chapter is meant to answer the posed research questions through the evaluation of three points of discussion.

The first discussion looks into the flexibility of the proposal in other scenarios, to answer the question: *to what extent can we multi- balance socio-ecological & environmental interests in the Wadden Sea Region considering the future pressures of climate change?* A revision of the proposal strategies under the influence of each scenario will test the possibility of their implementation under initially unplanned social, environmental, and economical circumstances. This will reveal if a certain extend of socio-ecological and environmental interest is found to be multi-balanced through these strategies no matter the scenario or if there are some constraints to the flexibility of the proposed measures.

A second point to discuss is the viability of the ecosystem succession approach, which intends to respond to the question of *which strategies would enhance the necessary links and elements of the Weser Estuary ecosystem so its ecological succession has a chance to result in an evolving adaption?* Hereafter an analysis of the speculative frequency of proposed changes inspired by the stages of the adaptive cycle (Holling & Gunderson, 2002) will be presented to test if synchronization was indeed 'achieved' in the project.

To conclude will I reflect on the feasibility of the design proposal linked to the question: *which hybrid infrastructures would allow the necessary flexibility to adapt to flooding, temperatures rise, and water pollution by port activities in the Weser Estuary over time?* I will quickly go through some of the design intentions to asses their possible implementation and autoregulation capabilities.

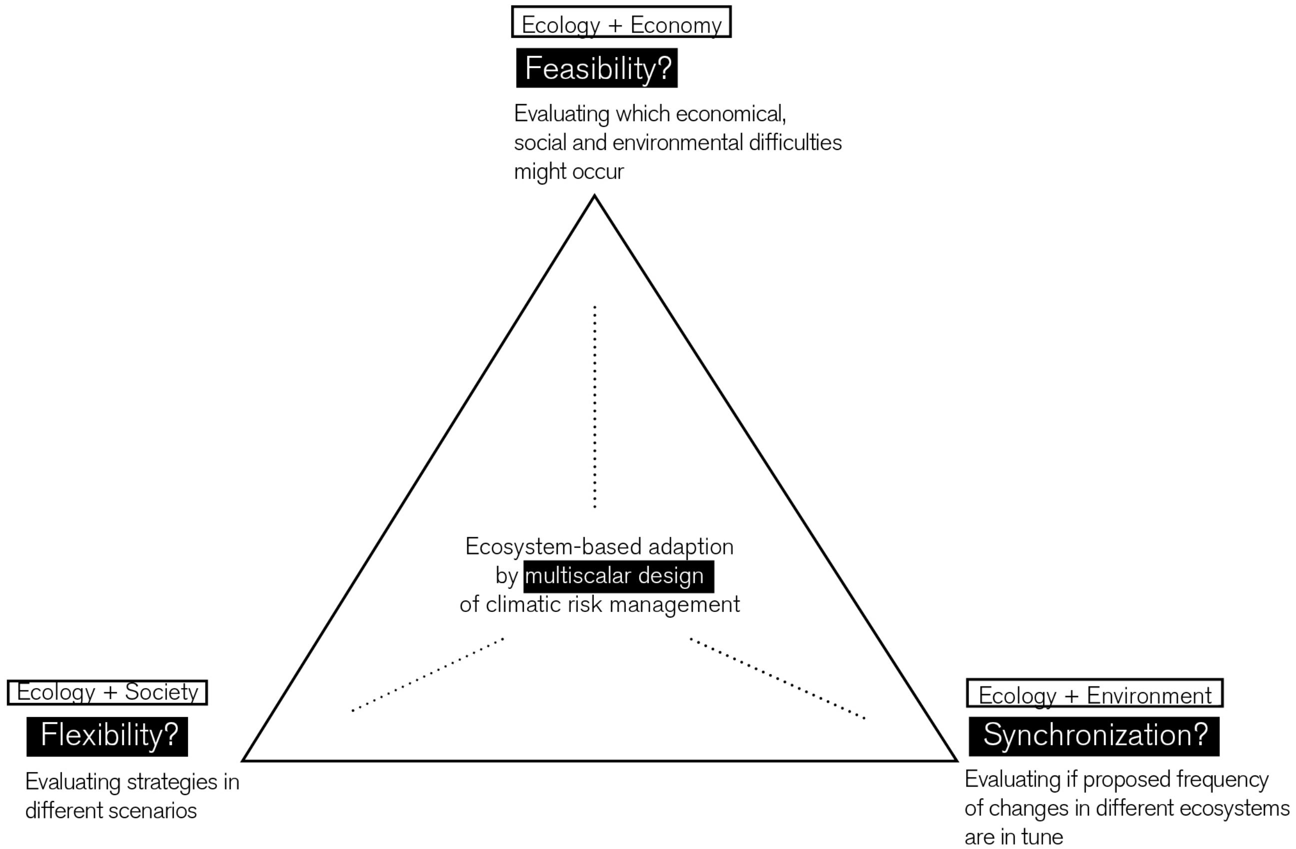


Fig. 156. Points to Evaluate.
(Made by author, 2020)

Fig. 157 Bremerhaven, Climate House.
(taken by Ulrich Rehrmann, 2019)
(Modified by author)

Discussion 1: Flexibility of proposal in other scenarios

An initial critique of the way the Wadden Sea region is currently managed was its lack of flexibility concerning the implementation of climate risk adaption measures. This inspired the thought of testing the flexibility of the proposal in the other unexplored scenarios. I decided to use the different measures implemented for the design of the barrier islands and absorptive edge which represent the socio-ecological and economic interests of the whole system. The chance of a measure to be implemented is shown with the quantity of "+' '-' each measure receives under each scenario. Although these results are merely based on speculations, scenario building is about uncertainty, so measurable methods would not be possible, or less effective. We can notice that under an '*Ecomodernism*' scenario almost all measures would be realized, nevertheless in a reformed way, where they do not rely on so many uncertain events, limiting the trust in nature and rather trust in technology. In the '*Ontological Pluralism'* scenario, these measures would be partly executed. The excluded measures would be considered too anthropogenically invasive, and in contrast to the '*ecomodern*' scenario, would prefer to leave things to chance and retreat if necessary rather than incessantly confront it and change. The last evaluated scenario would implement lesser measures than others, nevertheless, actions that would bring economical and social profit would be applied either in an excessive way or in reduced amounts.
Hereby, we can state that measures are partly flexible since most of the key projects would be even excessively implemented then planned. That all measures would respond evenly under each scenario would have indicated a failure in addressing an *'ecopragmatic'* perspective. Overall we can say that the extent to multi- balance socio-ecological & environmental interests in the Wadden Sea Region depend on the scenario reality that it will unfold in, where higher chances gather around '*Ecopragmatism* ' and lower chances lay under a *'Denialism*' scenario.

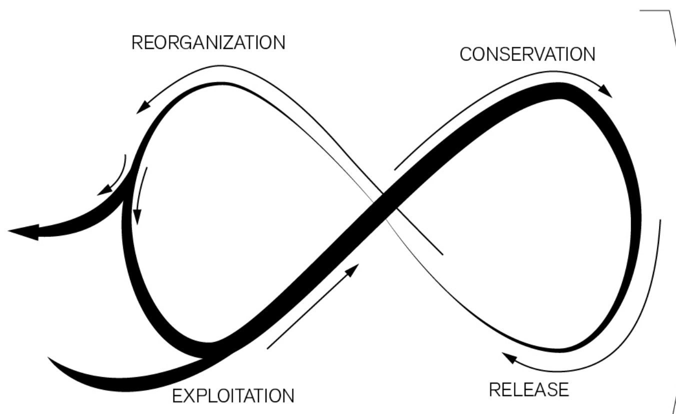
Fig. 158. Scenarios
(Made by author, 2020)

Fig. 159 Discussion 1
(made by author)

Scenarios

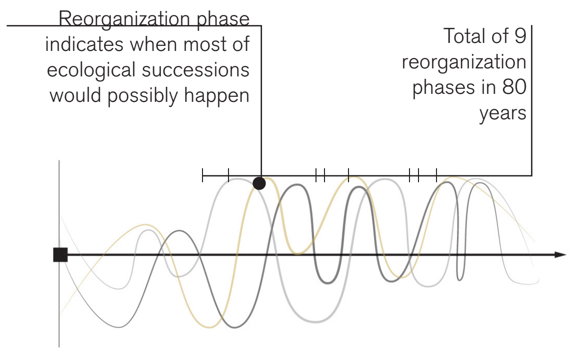
HAZARD	INTERVENTIONS	1 Ecopragmatism	2 Denialism	3 Eco Modernism	4 Ontological Pluralism
Strategy 1: Barrier Islands					
Wave height & shear stress	Breakwaters & sand islands	++	+++	++	- -
High water turbidity	Pole barriers to tap sediments	++	- -	+++	++
Tidal range change	Dynamic pontoons & permeable paths	++	+	+++	++
Sediment transport extreme variability	Permeable ecoconcrete blocks	++	+	+++	- -
Heavy metals water input increase	Aquaculture infrastrucucture around windparks	++	+	+++	- - -
Abandonment & visitor/ inhabitant shrinkage	Sightseeing & monitoring stations	++	- -	++	++
Wind speed increase and storm surge	Geotubes to elevate subtidal or intratidal grounds	++	+++	++	- -
Carbon emissions & temperature increase	Artificial reefs to motivate carbon storage by biota	++	- -	+++	++
Extreme precipitation events	Artificial lagoons to store freshwater	++	- -	- -	+++
			Low chance of implementation	*High chance of implementation*	*Probable chance of implementation*
Strategy 2: Absorptive Edge					
Flooding by extreme precipitation	Dike maintainance & evacuation routes	++	++++	++	+
High input of nutrients in water	Ecoconcrete blocks to form saltmarshes	++	- -	+	++
Salinity increase	Vertical saline farms	++	- -	++++	+
Erosion of the coast	Groynes to form saltmarshes	++	+++	+	- -
Heavy metals water input increase	Platinum filters installation	++	- -	++++	- -
Shrinkage by aging population	Attractive and safe neighbourhoods [floating dynamic settlements]	++	+	++++	- -
Sand & gravel accumulation in vessel channels	Geotubes to create soft port border [saltmarshes]	++	- - -	+	+++
Flooding by river runoff	Flood plains & water squares & community gardens	++	- -	++	++++
Tidal range change	Permeable dynamic port structures	++	- -	+++	- -
			Low chance of implementation	*High chance of implementation*	*Probable chance of implementation*

Fig. 160 Discussion 2
(made by author)

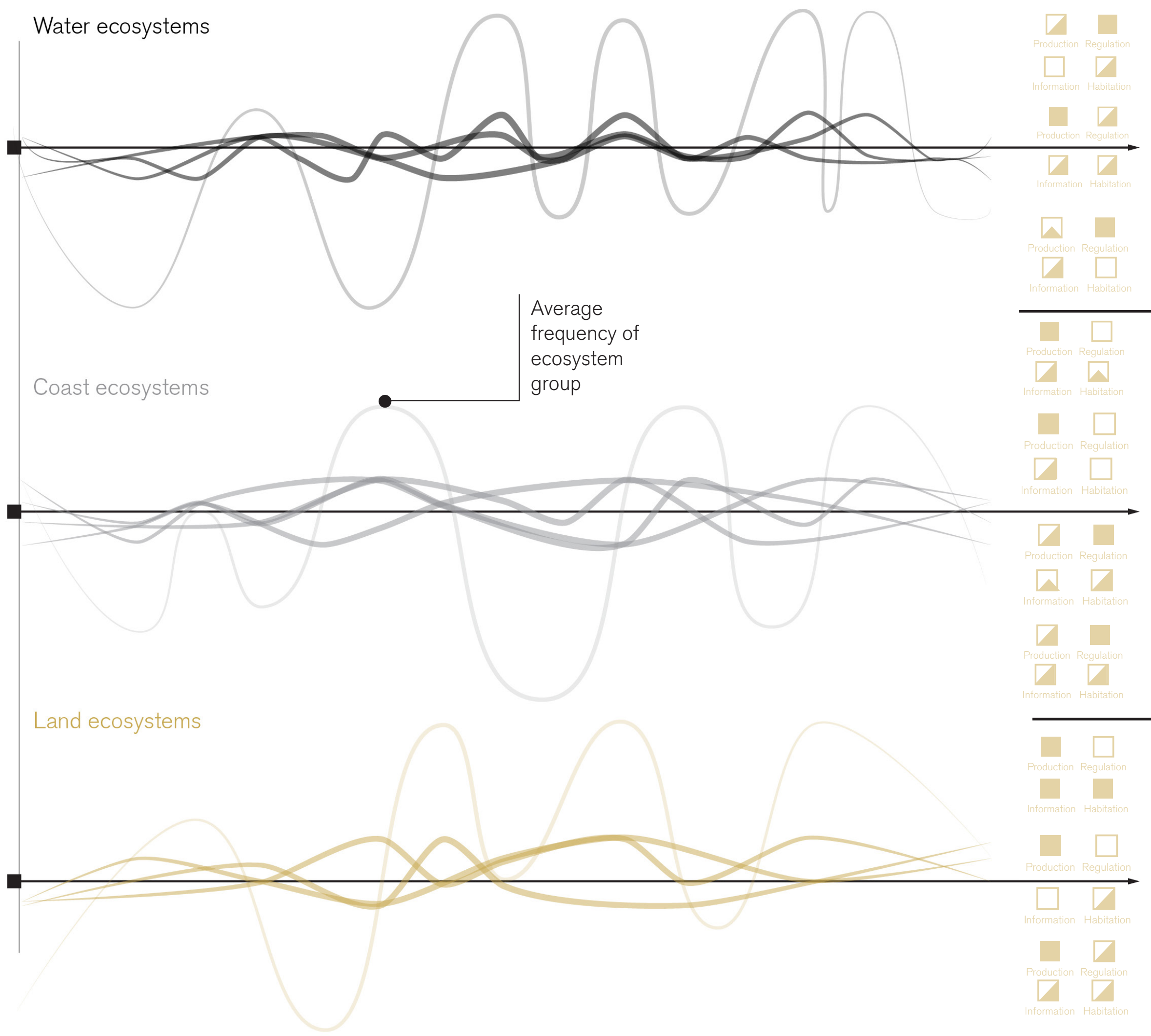


The adaptive cycle (Holling and Gunderson , 2002).

Reinterpretation of adaptive cycle in shape of a frequency curve



Synchronization of ecosystems cycles of changes

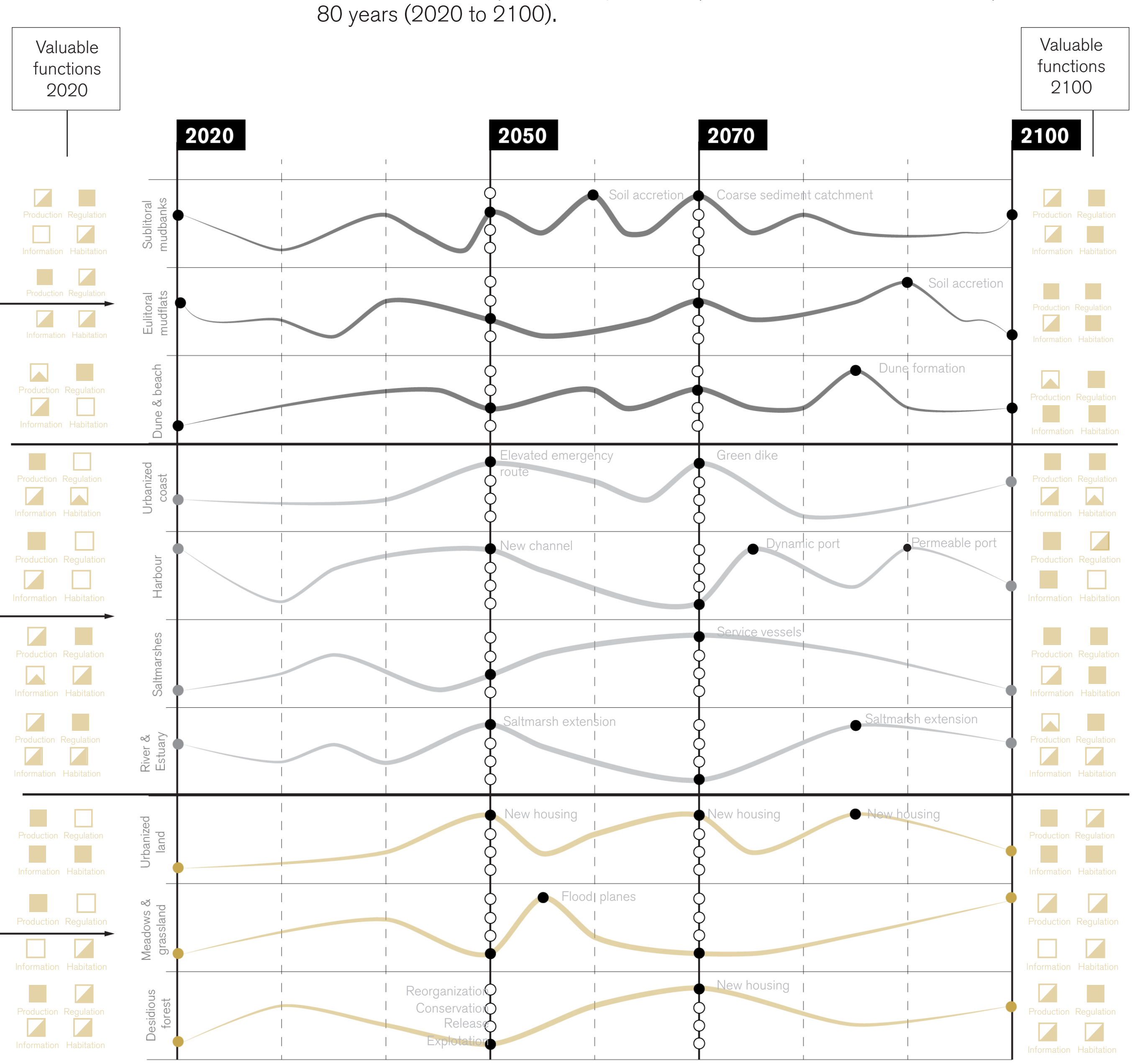


Frequency of each ecosystem group

EVALUATION

Discussion 2: Viability of Ecosystem succession approach

According to Holling & Gunderson (Holling & Gunderson, 2002), ecological systems undergo stages of exploitation, conservation, release, and reorganization to adapt. As explained in the theoretical framework (see p. 40) this concept was further expanded by the 'evolutionary resilience theory', which claims that socio-ecological systems gain the ability to adapt once they go through a transformation. In the following diagram, the notions that guided the research and supported desitions in the design are extrapolated to the project phases. Since each project stage has repercussions on the ecosystems which activate a certain behavior or reaction of the network, we can speculatively assign an adaptive cycle phase to it. Although based on assumptions on what stage ecosystems are currently in, we can see in what frequency ecosystems experience transformations to adapt, over 80 years (2020 to 2100).



Frequency of changes of ecosystems present in Weser Estuary based on project proposal phasing

Even though the classification of ecosystems treated social and ecologically dominated biomes equally, the design proposal revealed that natural systems should have a greater influence on changes in the water ecosystem. On the other hand, a mix of social systems is required to impulse a transformation in coastal systems. We can assume that the transformation in land ecosystems have to be predominantly booted by social systems. Hence if water (ecological), coast (mixed), and land (social) transformation frequencies are synchronized, an alignment of changes can be achieved in different levels and between different territorial compositions through the implementation of the strategies proposed in Chapter 5 *'Projection'* (p.110). This supports the answer to the inquiry that questions if *these strategies would enhance the necessary links and elements of the Weser Estuary ecosystem so its ecological succession has a chance to result in an evolving adaptation* (research sub-question 2).
The proposed changes also looked for the maintenance and if possible, the addition of valuable ecosystem functions till 2100. As we can see both requirements were successfully met. Maybe a further improvement of the synchronization of water and coast/ land ecosystems could be explored to achieve the perfect alignment of frequency curves. This, of course, might be an impossible task, since it could force too many rapid changes that would unchain an uncontrolled series of ecological successions. Nevertheless, the threshold of these ecological succession rates is unclear.

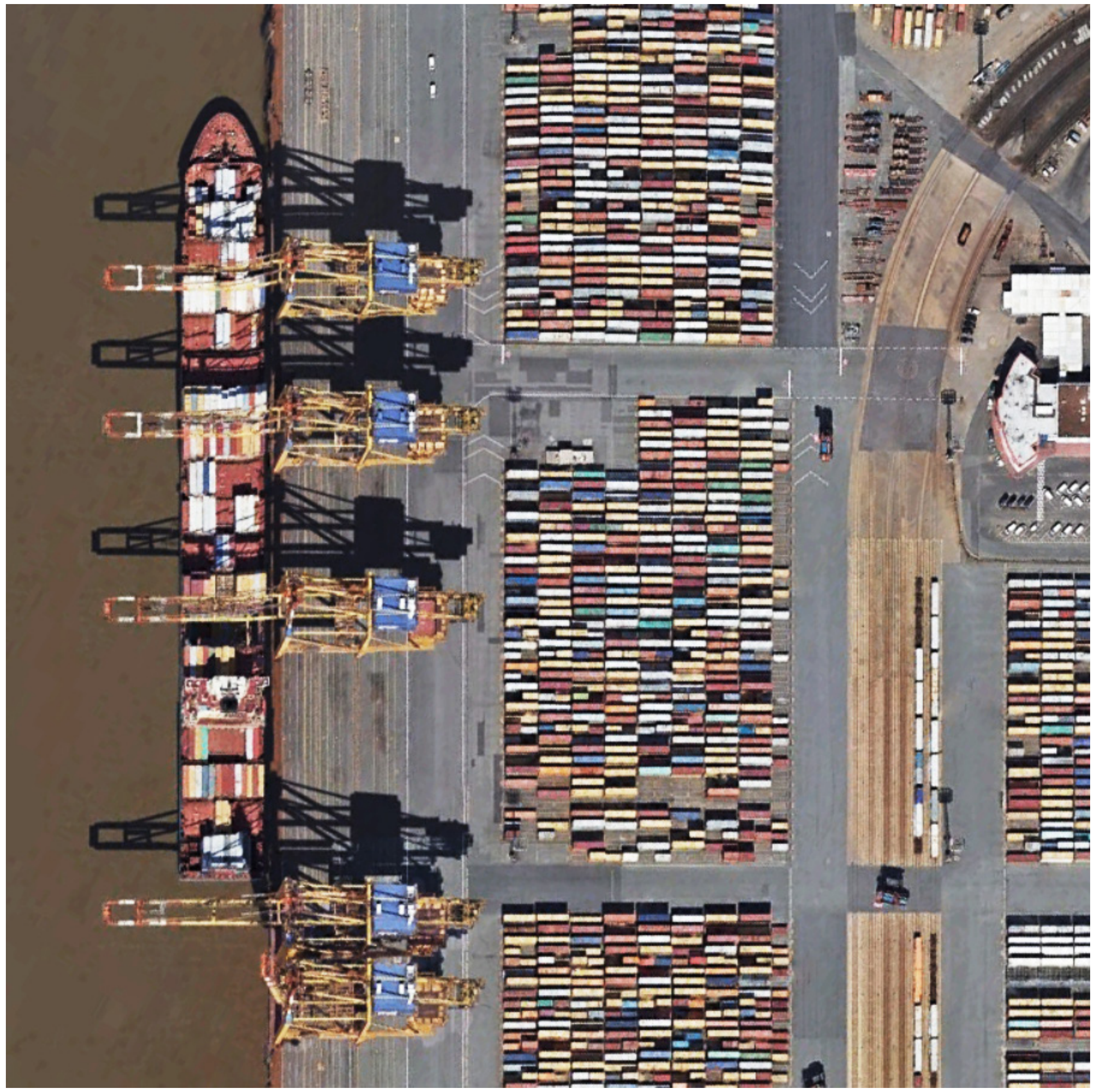
Discussion 3:

Environmental feasibility
The project places its trust in social and ecological reactions to anthropic soft and hard interventions. These, of course, could not even show a reaction or unfold in another way as planned (highly unpredictable), which is why pilot projects are vital to reduce uncertainties that could hinder the strategies implementation. Nonetheless, the idea of implementing a series of 'unsolved projects' will surely unravel the surprises and intelligence nature has to offer, that no matter the outcome, will teach us a lesson and set our joined evolution in motion.

Economical feasibility
The proposed strategies for the Weser Estuary are part of a long term project, that can only succeed if cooperation between different stakeholders is enhanced. For example a partenership between the states of Lower Saxony, Bremen, and Hamburg is needed for the endorsement and funding of costly infrastructural changes around the coast and at sea. However investment scan also come from other type of collaborations such as Public-Private Partnerships (PPP) which allowing interested research organizations and private companies to temporarily operate some areas.

Social feasibility
Change is uncomfortable and might upset many private and public stakeholders as well as civil society. However, change is necessary to evolve, as well as to survive incoming hazards. The design presents a pace of changes that are mostly aligned to slow natural changes, hereafter systems are given the chance to, reassemble, send feedback from time to time, innovate, and recuperate from potential lows. It is expected that acceptance will come when benefits attached to the values of safety, health, and connectivity will be visible and experienceable (see *Conclusions* of Chapter 5, p.204). Furthermore since the project is to be developed in a participatory manner, consensus meant to be reached by the gain and exchange of knowledge, and involvement in the process of every interested party. After all the project is based on cooperation in different levels: co-habitation (partnership with environmental dynamics), co-evolution (partnership between humans and other living species) and co-ordination (partnership between different socio-cultural actors).

Fig. 161 Discussion 3- Socio- ecological dynamics
(Picture taken from Google Earth, 2015) (Diagram made by author)



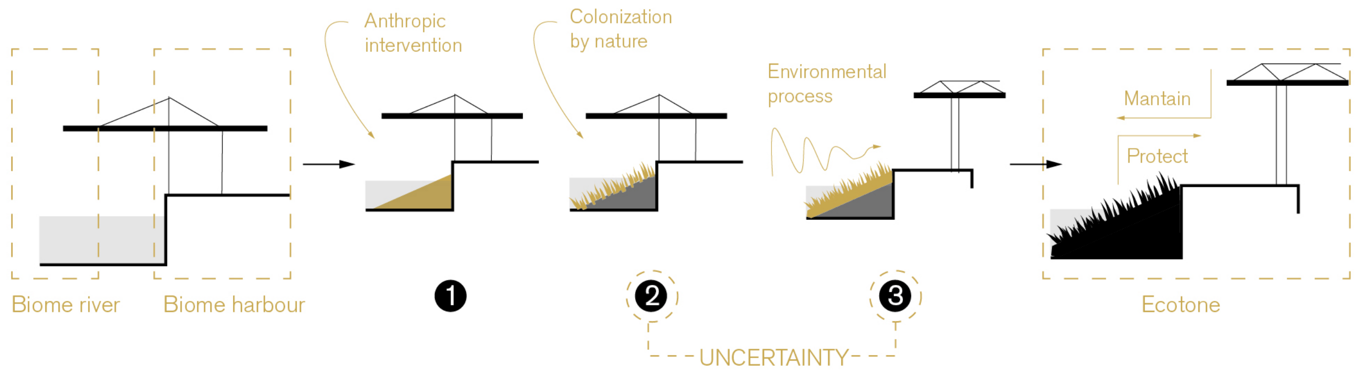
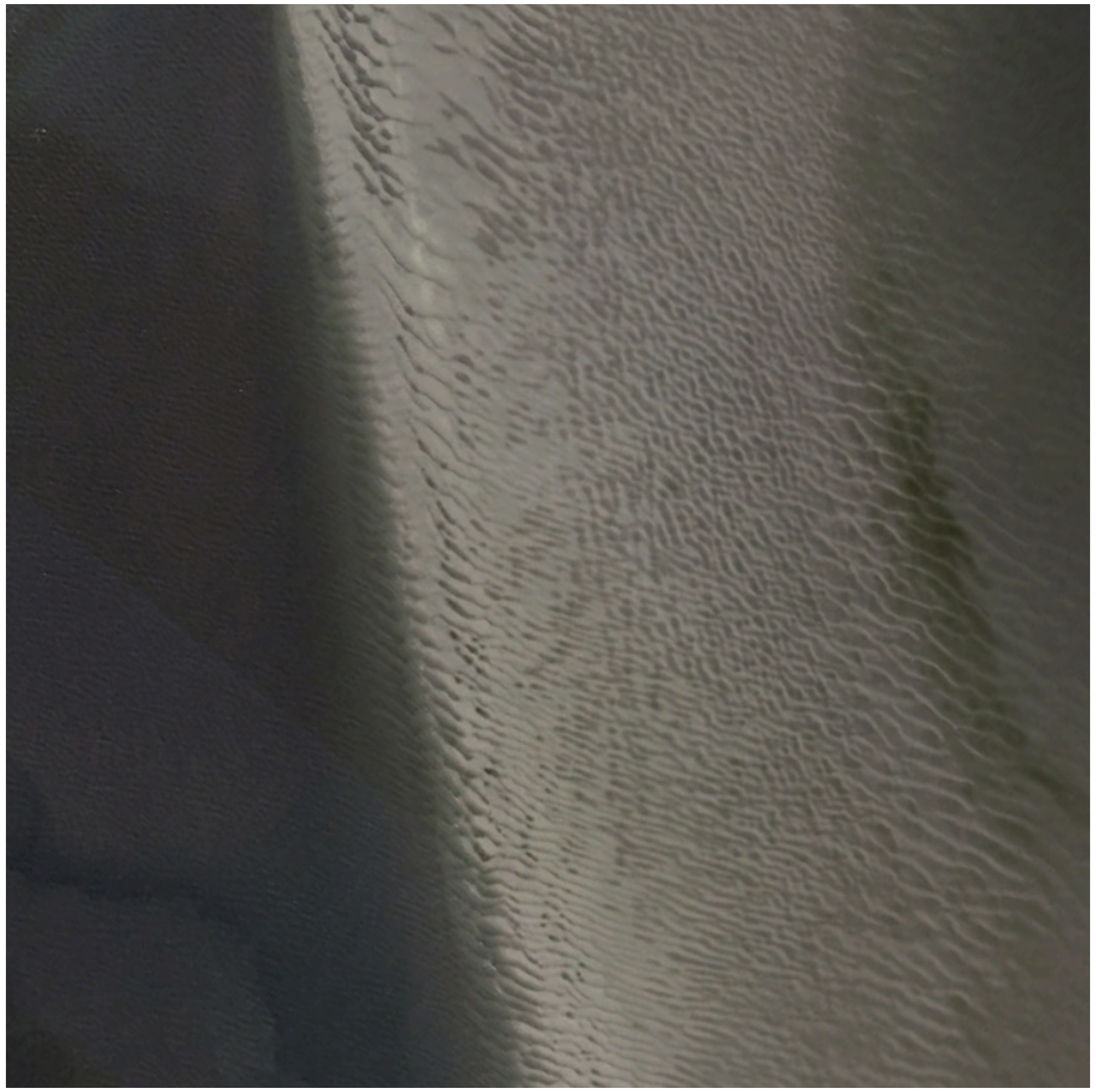


Fig. 162 Discussion 3- Ecological dynamics
(Picture taken from Google Earth, 2016)
(Diagram made by author)



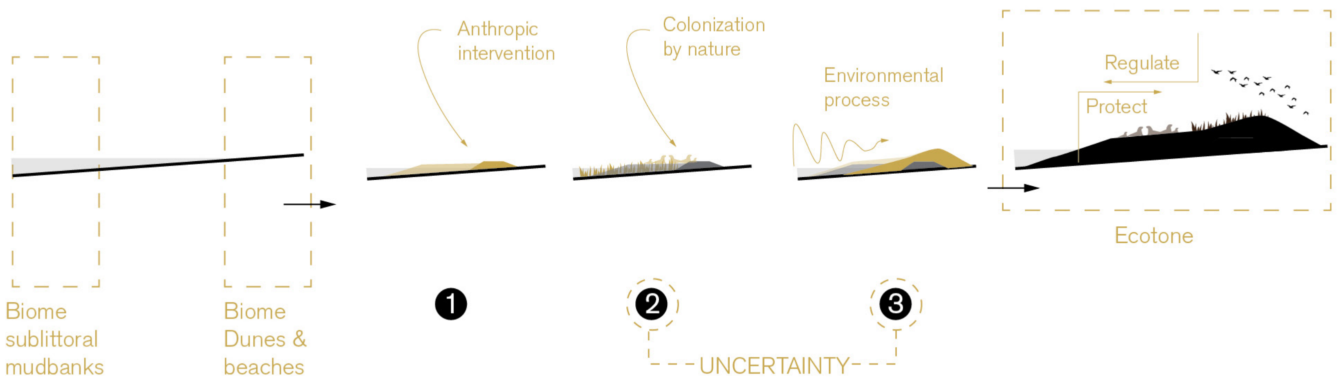
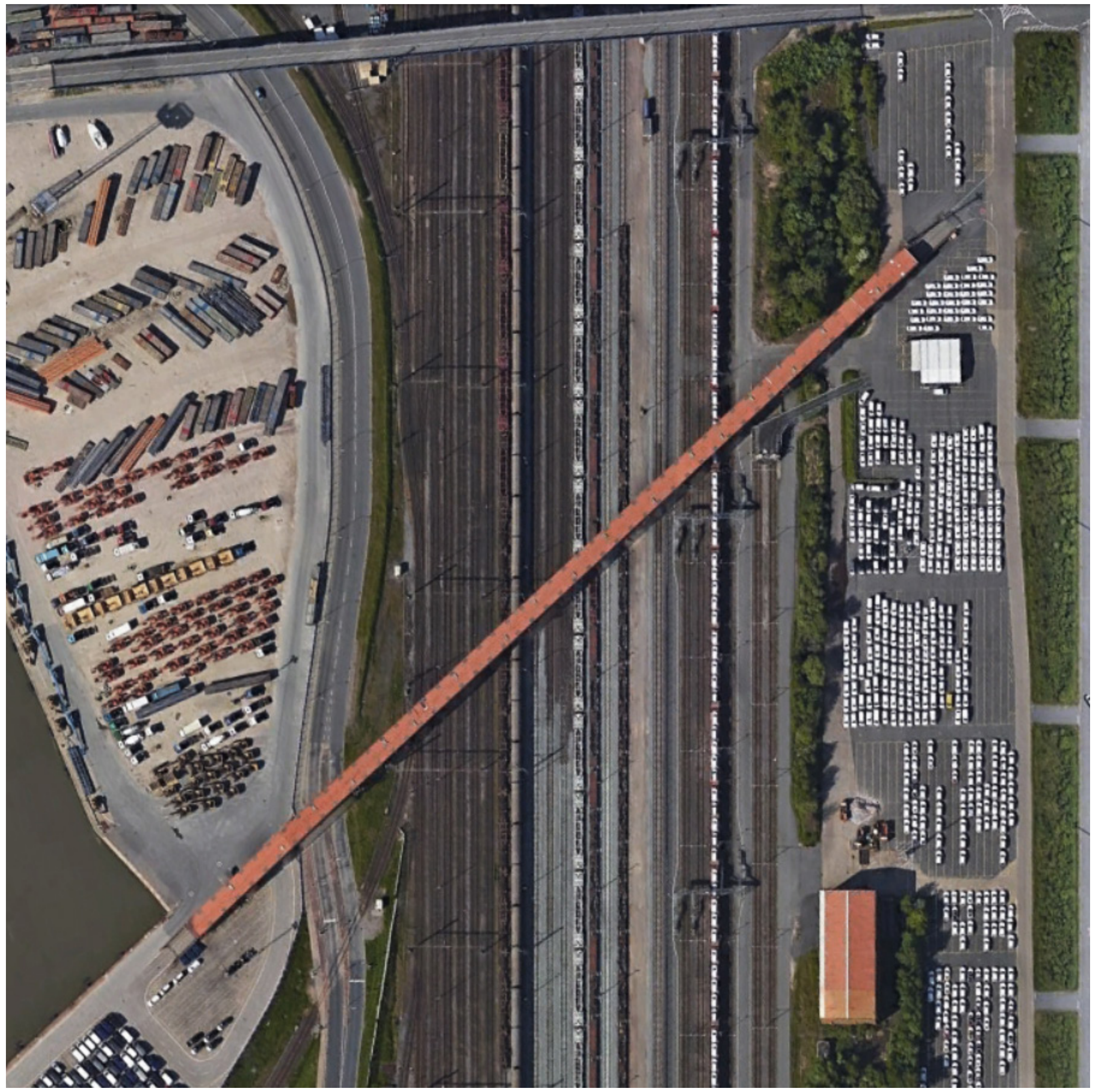


Fig. 163 Discussion 3- Social dynamics
(Picture taken from Google Earth, 2018)
(Diagram made by author)



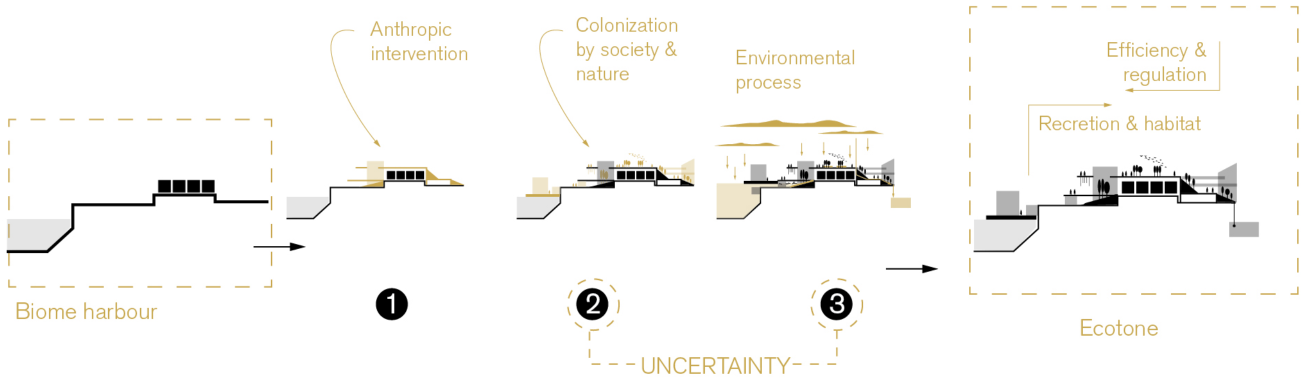
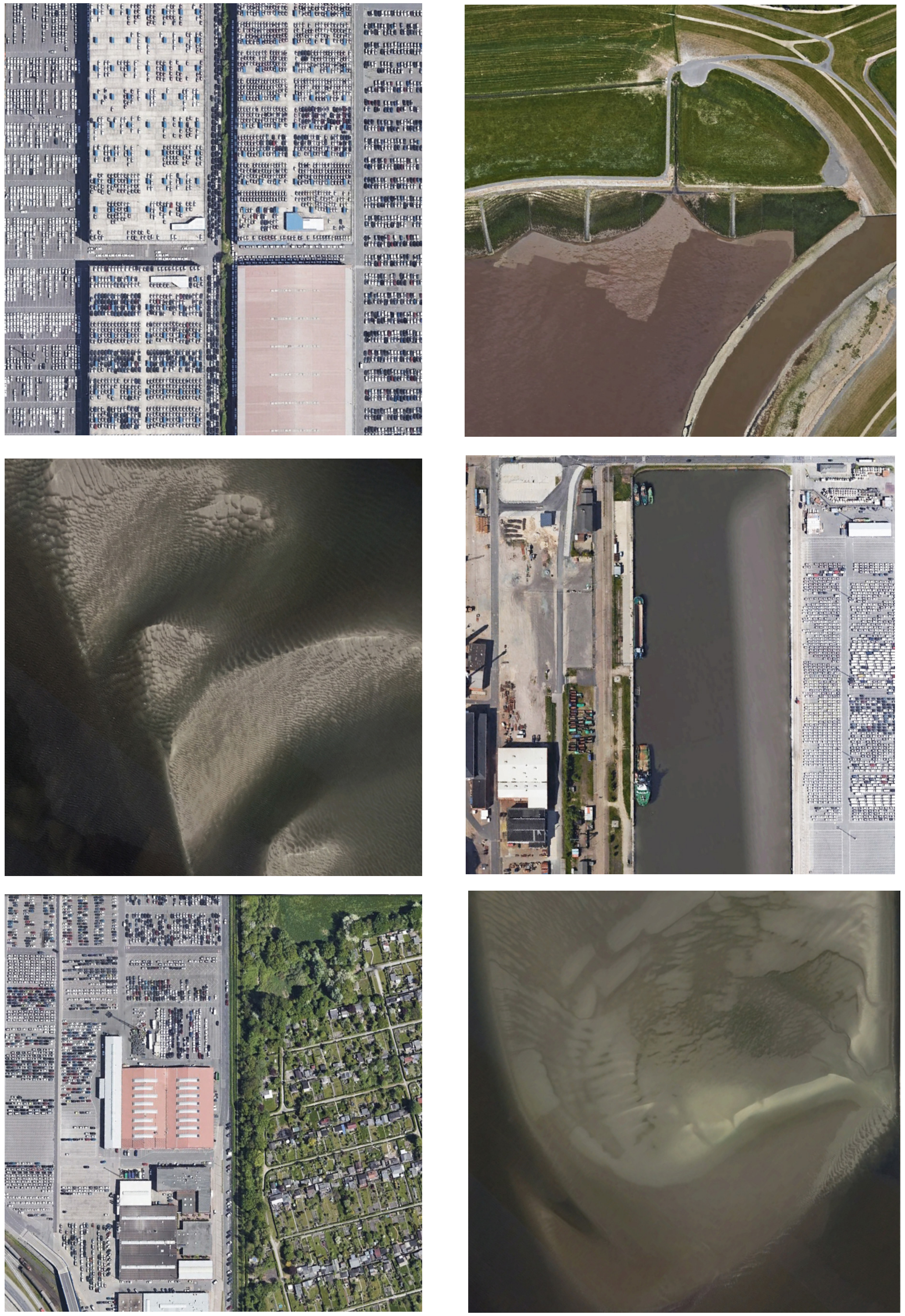


Fig. 164 Discussion 3
(Pictures taken from Google Earth, 2018)



CONCLUSIONS

This chapter intended to explore three points concerning the development of the project that are linked to the initially posed research questions.

- *The extend we can multi- balance the implementation of socio-economic and environmental interest in the Wadden Sea region* depends on the intensity of future pressures of climate change. Throughout this thesis I explored the possibility to achieve this under the scenario with the most disadvantages (Ecopragmatism), demonstrating that these interests could reach a multi-equilibria through the synchronization of human-nature systems. In this chapter, I discussed the possibility to set synchronization strategies into motion even if the Wadden Sea region would follow a different scenario path. The proposed strategies can be carried out in all of the climatic scenarios with grades of variability showing mostly in the 'Ontological Pluralism' and 'Denialism' scenarios.

- The three proposed strategies (barrier island, absorptive edges, and socio-ecological corridor systems) boost the creation of ecotones in the Weser Estuary. These are the key *to enhance the necessary links and elements of the ecosystem so its ecological succession has a chance to result in an evolving adaption*. In this chapter, I showed that the ecological succession method encouraged the desired synchronization of ecosystems by understanding the frequency and comparing the pace of the proposed transformations.

- Finally, a reflection on feasibility revealed further advantages of applying an 'ecopragmatic' development in the area such as the creation of mixed partnerships between stakeholders. These emerge due to the involvement of *hybrid infrastructures* such as breakwaters, halophyte/ platinum filter- landscapes, innovation hubs, and dynamic ports in the project, that *allow the necessary flexibility to adapt to flooding, temperature rise, and water pollution by port activities in the Weser Estuary over time.*

As argued by these three points and throughout the thesis, an 'ecopragmatic' shift of the current development of the Wadden Sea region would be a chance to generate a multi-equilibrium between nature and progress. In this thesis, this was explored by the creation of encounters between ecosystems (ecotones) and leaving the final stage to nature. Hereafter the project carefully studied nature to considered the implementation of the design in phases that encouraged a choreography between infrastructural insitions to create habitat, and ecological succession dynamics of human-nature systems. Thus, this *ecosystem succession approach* would indeed trigger *the cohabitation of human- nature systems of the Wadden Sea region to develop an evolutionary adaptation.*

Synchronizing habitat: Risk adaption by co- evolution of environment and society

Chapter

7

REFLECTION

METHODOLOGY & RELEVANCE

In this chapter is meant to recap all steps take in the project, to evaluate their overall effectiveness, applicability and limitations. I also expose my personal opinion of the journey as well as give an insight on the purpose of the developed project.

[CONTENT]

REFLECTION

Research & Design

Process & Alignments

I started this thesis choosing a site out of my comfort zone, a place I have never been before my field trip, and that I expected nothing about, and knew very little of. As in many moments of this project, I followed my gut. To my surprise, I found a truly fascinating region that allowed me to deepen knowledge and interests gained throughout my master's degree (especially on methodologies and research tools), but also allowed me to improvise, experiment, and test complex theories mostly related to the fields of ecology and landscape architecture.

My journey began by choosing Transitional Territories as a studio due to my motivation to work with maritime dynamics and the urgent need for a spatial revision of coastal ecosystems due to the dichotomy of climatic change and economic development. Transitional territories claims the sea not only as a landscape but also as a complex urbanized area. It is a studio determined to depict the relations between biotic life (society, fauna & flora), culture, and water bodies (deltas). Since changing dynamics are more visible and fast in seascapes, the era of the Anthropocene is drastically accelerating climate variability, extreme events, and the decline of resource availability in marine landscapes. Although the magnitude and rate of these extremes are relatively uncertain through time, this studio explores and encourages to find solutions based on the power of combined ecological and infrastructural systems. I find this exploration and the practice of integrating terms (especially from the discipline of geology and ecology) into spatial planning and design (urbanism) an effective and resilient way to adapt to risks by climate change and was eager to implement it in a project.

Henceforth my thesis aimed for a co-evolution of nature and culture inspired by ecosystems' functionality and adaptation capabilities. Recalibrating the Wadden Sea regionmeant enhancing the exhausted ecology of the North Sea to embrace climatic risk, store externalities, and set an example for the management of other conservation areas at risk. Hereafter the project claimed to regenerate the multi- equilibria state of coastal ecosystems and develop an evolutionary adaptation through an ecosystem succession approach (Chang & Turner, 2019).

An often asked question along the process of this thesis was if this can still be considered an urbanism project? To this day my answer is yes, since I believe urbanism can no longer be confined as the design and planning of cities and countryside spaces. It might be that the task of landscape architects and urbanists is becoming more and more similar. I trust the reason it is merging to one field of study is that it is impossible to ignore the fact that urban fabrics are ecosystems (human habitat) and therefore are intrinsically connected to other ecosystems (Alberti, 2008). Especially in the era of the Anthropocene where we humans have modified Earth's surfaces and its related systems to serve our purpose over all other functions, it is absurd to distinguish the design for natural from human systems. Hereafter enhancing habitats in the seafloor (non- human inhabitation) is a part of an urbanists task as it is proposing a new housing development (human inhabitation) since both are concerned with the design and planning of space for biotic life.

Fig. 165 Bremerhaven
(taken by author, 2019)

Methods & Approach

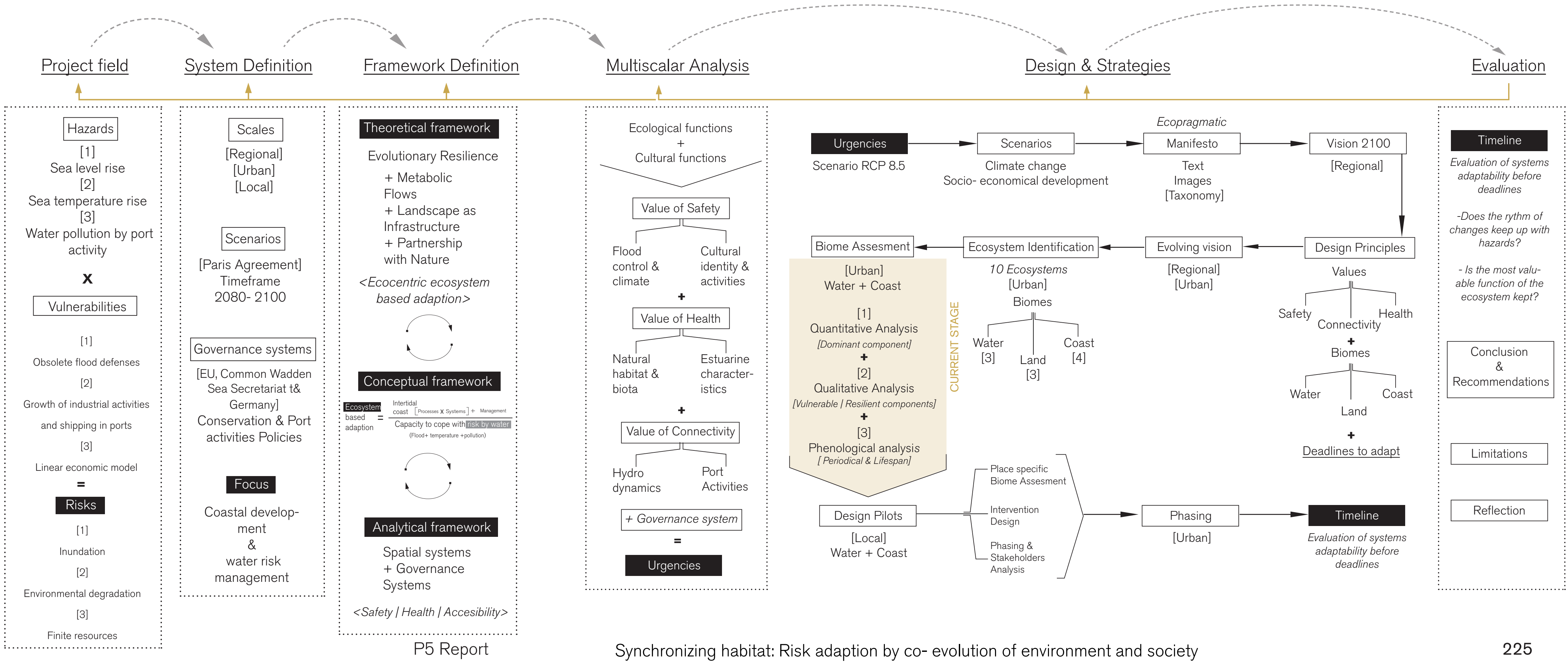
About the research method

The initial research method implemented in the thesis was inspired by the collective phase of the Transitional Territories studio. This entailed the collection of data and mapping on the North Sea, to get to know the territorial context of all our proposals. The cartographic exercise of portraying actors flows and elements helped me frame the problem statement and choosing a site due to its vulnerability to the problems of inundation, temperature rise, and water pollution by port activities. It also helped me organize the analysis in the individual phase considering the same variables of mapping flows, infrastructures, and actors/elements. The collective discovery of the meaning of risk, reflecting on climate change urgencies and scenarios gave me ideas on how to approach my graduation project. Moreover, several methods required for the making of the Collective Studio Atlas (Transitional Territories, 2019) , such as a spatio-temporal analysis and building a vision through scenarios, were also applied in the process of the individual project.
In the individual phase, I used the method of r*esearch by design* practiced and learned throughout the semesters of the Urbanism master track. This involved the collection of data with a preconception of a project. In my case, it consisted of goals impulsed by three values (safety, health, and connectivity). Hereby I hardly collected unnecessary data or did a superfluous analysis that was not useful or unrelated to my design proposal. In fact, the *research by design* method allowed me to map in a detailed manner since the intention of the analysis was clear from the start. The efficiency of this method allowed me to concentrate on the development of strategies and design at an early stage, which was an advantage given the number of scales I intentionally went through (from regional to sample scale). In the development of the project, I encountered limitations to the methods concerned with ecosystem assessment, since most concentrated only on their function to human life (MEA, 2005) and left out the information I wanted to asses to determine their vulnerabilities like the quality and quantity of their synergies, longevity, and changes in yearly cycles. Hereafter I decided to design an assessment myself with the use of the program *Gephi*, which helped me visualize the complexity of synergies of an ecosystem. This process of the creation of an ecosystem assessment framework that could give me useful results related to ecological succession required an extensive generation of data and understanding of research on biotic and abiotic elements and environmental processes. The effort of reinventing an ecosystem assessment framework was worthwhile when I could corroborate that the vulnerabilities it was indicating coincided with the urgencies described in the latest *Wadden Sea Quality reports* (2017).

About the design approach

As stated before the design approach was imported from the collective studio phase into the individual phase of the graduation year. In the following diagram, we can identify the steps taken after the multiscalar analysis. It was especially useful to revise which urgencies are linked to which values that I am addressing in several stages of the design. It allowed me to built consistency and coherence as I got into different scales and encountered new problems. A second method I used to always have an overview as the multiscalar design gained complexity was categorizing the territory by groups that shared similarities. In the case of my thesis, it made sense to interpret the territory in three ecosystem groups (water, coast, and land).

Fig. 166 Steps taken in the graduation project (Made by author, 2020)



REFLECTION

Significance & Innovation

Scientific & societal relevance

This project contributes to the current efforts worldwide to adapt coastal areas to climatic changes, especially concerning delta cities and valuable intertidal wetlands which are of one of the most vulnerable ecosystems worldwide (MEA, 2005). The thesis addresses this topic in an effort to demonstrate that 'evolutionary adaption' (Davoudi et al., 2013; Holling & Gunderson, 2002) can be triggered through the inclusion of ecosystemic thinking in spatial design. It atempts to be innovative by cotradicting the current trend of 'shepparding' nature by looking for a 'partnership'. Therefore the projects integrates a time perspective in the design, looks for adaptability through values brought by environmental processes and demonstrates how to work towards hybrid infrastructural interventions that allow flexibility by embracing the risk and working with nature (instead of trying to withstand uncertain rates and magnitudes of natural forces). This way the project is also maintaining and possibly remediating lost cultural connections to the coastal landscape. The North Sea especially shares stories and narratives linked to fear and danger, rather than 'an experience of infinity and freedom (that) […] enable us to distance ourselves from everyday life' (Sijmons et al., 2014). For these coastal communities that share a long history with the sea, it is important to keep contact with the elements of nature, since they form part of their identity. However these areas need to evolve to cope with the continuous slow and rapid changes, this dynamic landscape imposes. In the project, I propose this evolution to be synchronized with the marine ecosystem so that safety, health, and connectivity is ensured for all forms of life inhabiting the region.

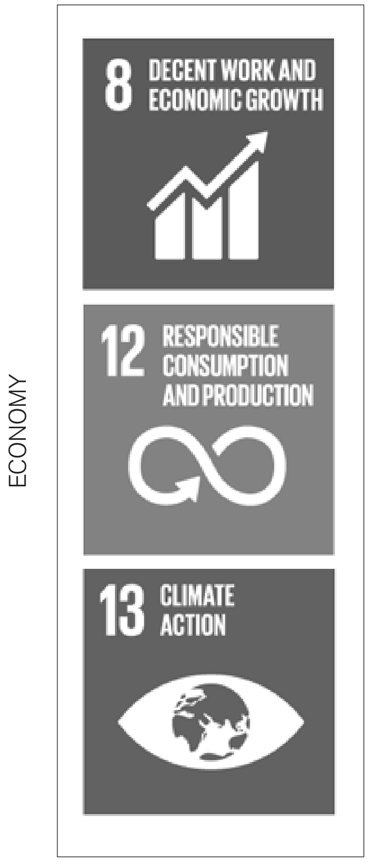
Ethical considerations & transferability

In this project, I challenge the current mindset of dominating every aspect and system of this planet. Instead, I propose to realize that our survival does not depend on supremacy but participation or collaboration in the dynamics of ecosystems. Hereby I am implying to appreciate that we are part of nature as well as equally important, which does not point towards selflessness, but rather to consciousness; one of the aspects that makes our species unique. The power of consciousness or mindfulness could distance ourselves from the extreme and bring us closer to moral concerns such as the ones described by the United Nations as Sustainable Development Goals. The following project goals are connected to the portrayed SDGs to address the values of safety, health, and connectivity.

- Safety by water risk management through hybrid infrastructure with ecological responsiveness *[Climate action + Responsible consumption and production + decent work and economic growth]*

- Health by the creation of habitats which enhance ecosystem services [Good health & well- being Life on land + Life below water+ clean water & sanation]

- Connectivity by flexible recreation and educative spaces that see risk as an opportunity [Quality education + industry, innovation, and infrastructure + sustainable cities and communities + partnerships for the goals]



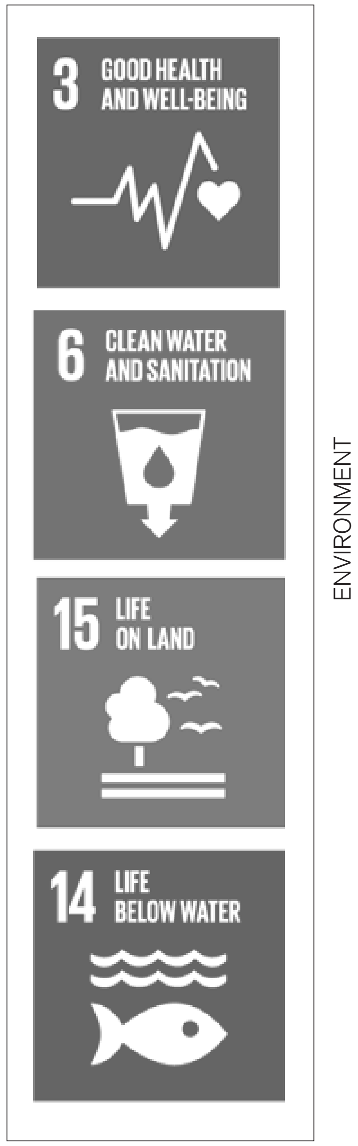


Fig.167 SDGs.
(taken from United Nations, 2019)
(Modified by author, 2020)

REFLECTION

Evaluation

Feedback & Response

I chose Luisa as my first mentor due to her expertise in urban design based on narratives, stories, and the collective imagination of space, as well as her enthusiasm and creativity when it comes to the power of representation. Her assessment has always been on point especially when it comes to narrative, pushing me to be consequent and to think on the structure and the cohesion of my thesis (Research question- Project goal – Project Purpose). I am glad Daniele, my second mentor, joined my graduation team since he is an expert in landscape urbanism and has a sensibility for ecology. From the beginning, he has been on track knowing how to translate ecological theories into practice and has enriched my research with new concepts, methods, and tools (Ecosystem succession, ecotones, Gephi, and Trello).
Although I sometimes felt I did not express myself well in words or got lost in details when the subject is complex, I was pleasantly surprised to see that both my mentors are in tune with what I was saying and manage to give me helpful suggestions. The synergy between both mentors has motivated my work from the start. Our joined (virtual and non- virtual) meetings were very constructive resulting in varied options to deal with the next steps to take. Since this thesis was developed during the corona pandemic quarantine, virtual encounters with my mentors gained a new meaning. I guess the fact that we were exposed and sharing our private habitat enhanced our emotional side, which led to fruitful theoretical discussions that enriched the design in many ways.

Limitations, lessons and recommendations

Framing of the problem field
Climate change influences the Wadden Sea region in many ways ranging from heat waves to salinity rates (Bazelmans et al., 2012; Kabat et al., 2012; Kuipers & van Noort, 2008). In this project, it was decided to focus on sea-level rise, precipitation, and sea temperature rise, as the hazards are more prone to cause mayor biophysical damage. Human activities affecting the marine ecosystem and water bodies are also varied (eutrophication, air emissions, oil, and gas extraction grounds), however, I have limited my research scope to water pollution by port activities considering their potential growth in the coming decades.

Framing of 'Ecosystem- based adaption' perspective
As I stated beforehand and extensively in the academic paper (see page 42), 'ecosystem-based adaption' can take many directions, especially when it is associated to human- nature relationship perspectives (anthropo-centric or ecocentric) (de Groot & Drenthen, 2011). I believe an ecocentric view is better linked to the idea of 'evolutionary resilience' (Davoudi, Brooks, & Mehmood, 2013) since it advocates for preparedness in form of cultural valuation, persistence, and transformation as hybridization and flexibility in form of cooperation.

Framing of critical details
I also deliberately chose to develop two of three samples of each ecosystem group in detail, mainly due to the limited time left for the graduation project development. I intentionally chose to develop the water and coast intervention since an analysis of the area showed that land territory had a more balanced amount of ecosystems concentrated in one area. These, of course, could be also working as

ecosystem clusters instead of building ecotones. However, water and coastal territories showcased two extremes: low amounts and high amounts of ecosystem concentrations, and thus were more interesting to look into in detail. Nevertheless, this led to some unavoidable assumptions in the timeline and phasing of the final stages of the project (Fig. 154, p. 202). Hereafter an opportunity arises to further apply the presented notions to this site and see if the made assumptions were on the right track.

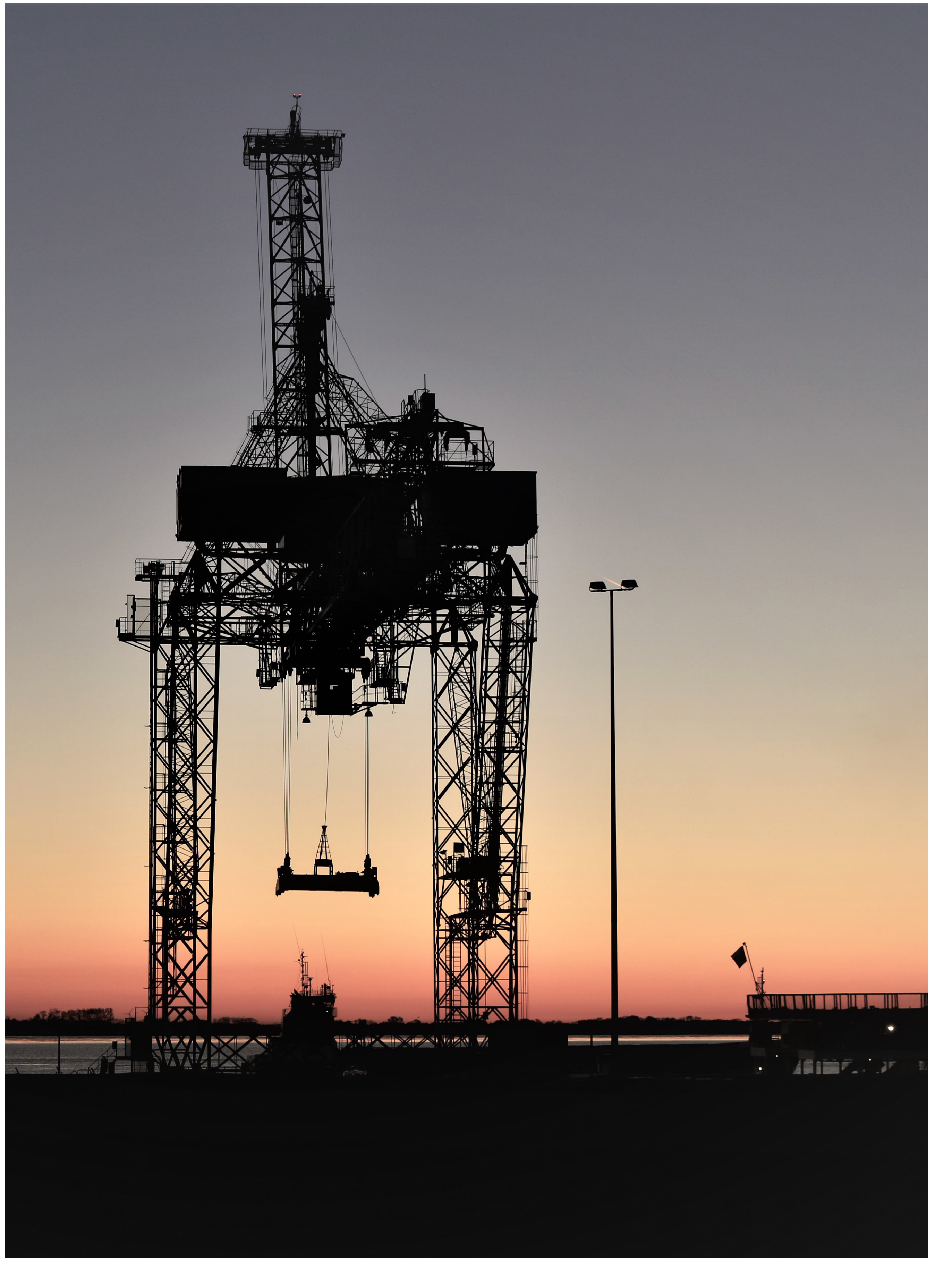
Framing the ecosystem assessment

Although I have made great efforts to understand how several elements and processes work through the consultation of knowledge from different fields, it is impossible to manage the proposed project without a great team of experts. I have been lucky to have at my disposal the analysis of several ecosystem dynamics in the Wadden Sea region (especially through the Wadden Sea Quality Status Reports of the Common Wadden Sea Secretariat) and an extensive list of research done in this area since it was declared World Heritage Site. Although based on papers and research, this graduation project just scratches the surface when it comes to the needed data and expertise on different subjects of Marine Biology, Ocean dynamics, Geology, Ecology, Chemistry, Programming, and Mathematics.

The helping hand of these experts could improve and bring precision to the presented ecosystem framework invention. In the process of this thesis, I tried out the idea of using this assessment framework not only as a way to see which vulnerabilities, longevity and changes in the yearly routine each ecosystem presents, but was also looking for a way for the model to show me results after I insert my project and its respective synergies with the ecosystems biotic and abiotic elements, and processes, but stumble upon many errors and decided to keep it out of the process of the thesis (see Appendix, page 245). I managed to include my project and its synergies with the system, and even though it appears to prove that the project is enhancing and mitigating the desired nodes, it is not. The main errors are related to the limitations of the model, the capabilities of Gephi, and my knowledge of complex systems models. Since it might be interesting to further develop this as an accurate assessment model I will conclude with the following list that states the limitations of the current model, that translates to the invalidity of the results of the second pilot model:

- The number assigned to value the range of influence of a node towards another node could be wrong since variables are hardly comparable. The problem also lies on the very assignation of a real number to these connections, because the model assumes that Node A plus two times Node B is equal to the added influence of Node C and Node D over Node E, which mathematically makes sense but does not represent reality.
- It would have been better to name all process nodes with an unbiased connotation such as 'Water characteristics change' instead of naming the node 'Water Quality', the analysis would be more consistent.
- Gephi is a great tool to visualize node and edge connections, nevertheless, it might be a limiting platform if we want to make the model more accurate. Gephi only shows the reaction of the node over another node, and not the chain reaction of nodes to nodes. So the influence of node A transforming node B works, but The influence of node A to node B reduces node B which also reduces C is a step Gephi overlooks.
- The model is not considering the threshold each node has in reality in order to change from a positive output to a negative output. For example, halophytes are resilient to high salinity levels (so salinity sends positive output to halophytes), but if salinity levels overtop the threshold these halophytes can endure the plant will die (salinity sends negative output to halophytes).

Fig. 168 Bremerhaven, Germany, Wadden Sea region.
(taken by author, 2019)



Synchronizing habitat: Risk Adaption by co- evolution of environment and society

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APPENDIX

Transitional Territories - Symposium sculpture
(Taken by Isabel Recubenis, 2019)

THE ADAPTED GLASS

...

In our group research for the line of inquiry '*The dual nature of externalities'* we highlighted that the extreme character of our linear economic model is maximizing the vulnerability of many areas around the North Sea to cope with future risks of climate change. The constant input of externalities at sea is stressing the health and function of coastal ecosystems.
In my project I am addressing how to reduce vulnerability and cope with risk through adaption (more specifically *ecosystem-based adaption*).

The object I present today is a symbol of all ecosystems ability to adapt.
One of the essential functions of the glass is to hold water (*ecosystem function*), but it can also hold other liquids and materials which enhances other functions of the glass. The design of the glass is *flexible.* If this were not the case, the glass would fall under a specific stress preformed by a hand. This motion caused by the hand stands for the impacts of anthropogenically- boosted climate change.

When filled with water (*resources)* to the top, the chance of spilling increases, therefore the vulnerability of affecting the environment outside of the glass (hand and table) rises and more resources become externalities (water spilled) But when the amount of water is balanced with what glass can cope with, we have a '*multi equilibrium*' state, so it is also not generating externalities although it is continuously stressed.
In my individual work I am aiming for a project inspired on this ability of this glass that can hold water (so fulfilling its functions) even under stress.

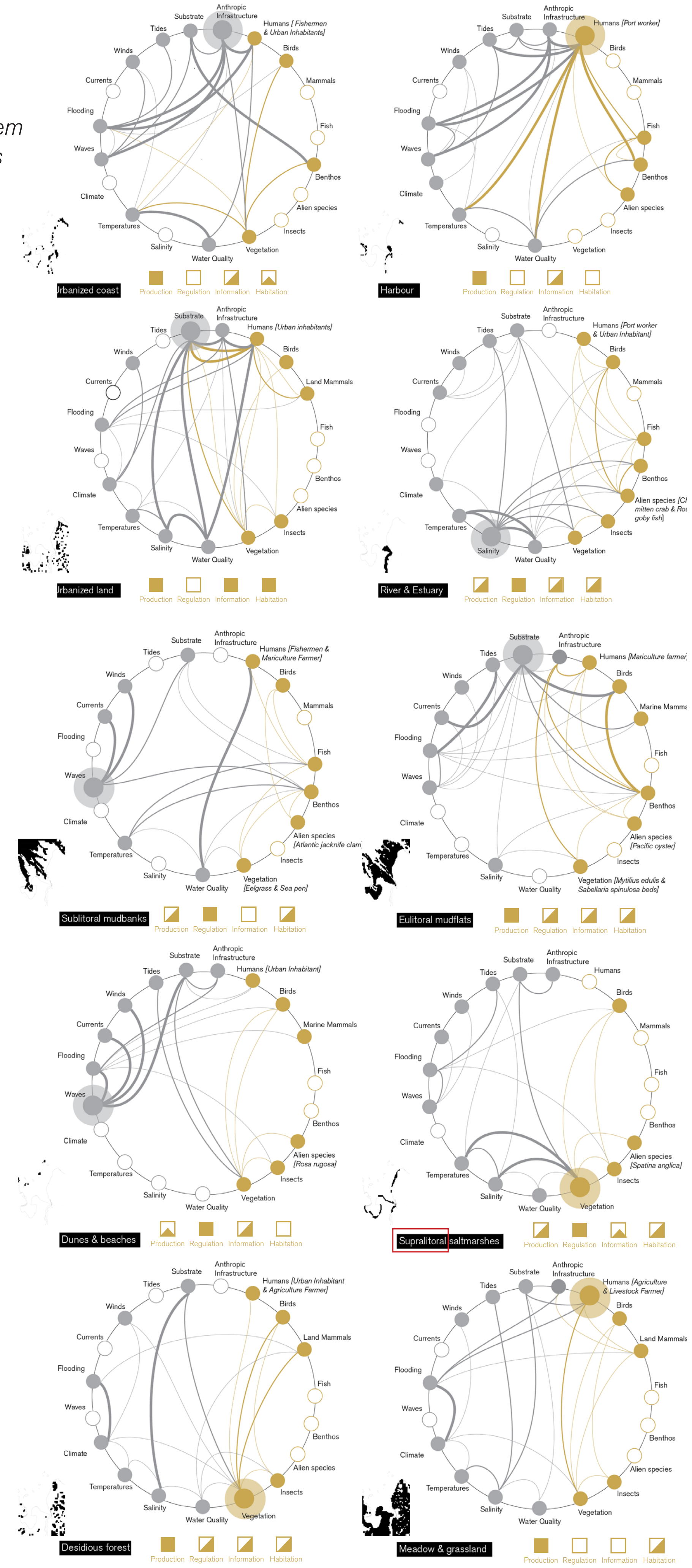
The only problem with this object representing my personal opinion is that glasses only serve the interests of human beings, and neglects the fact that water is needed by all living beings.

APPENDIX

Dependencies of ecosystem processes & biotic elements

Water Processes

Biotic Elements

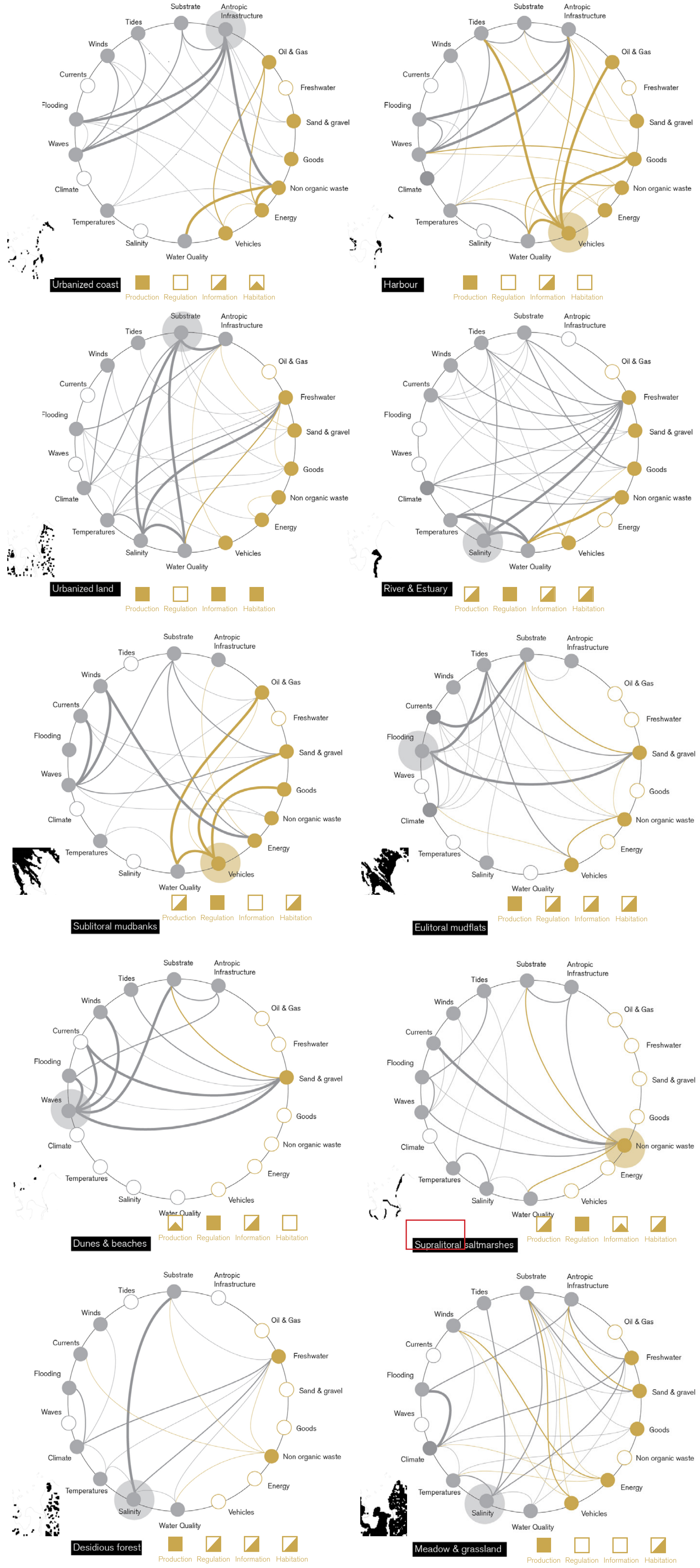


APPENDIX

Dependencies of ecosystem processes & abiotic elements

Water Processes

Abiotic Elements



APPENDIX

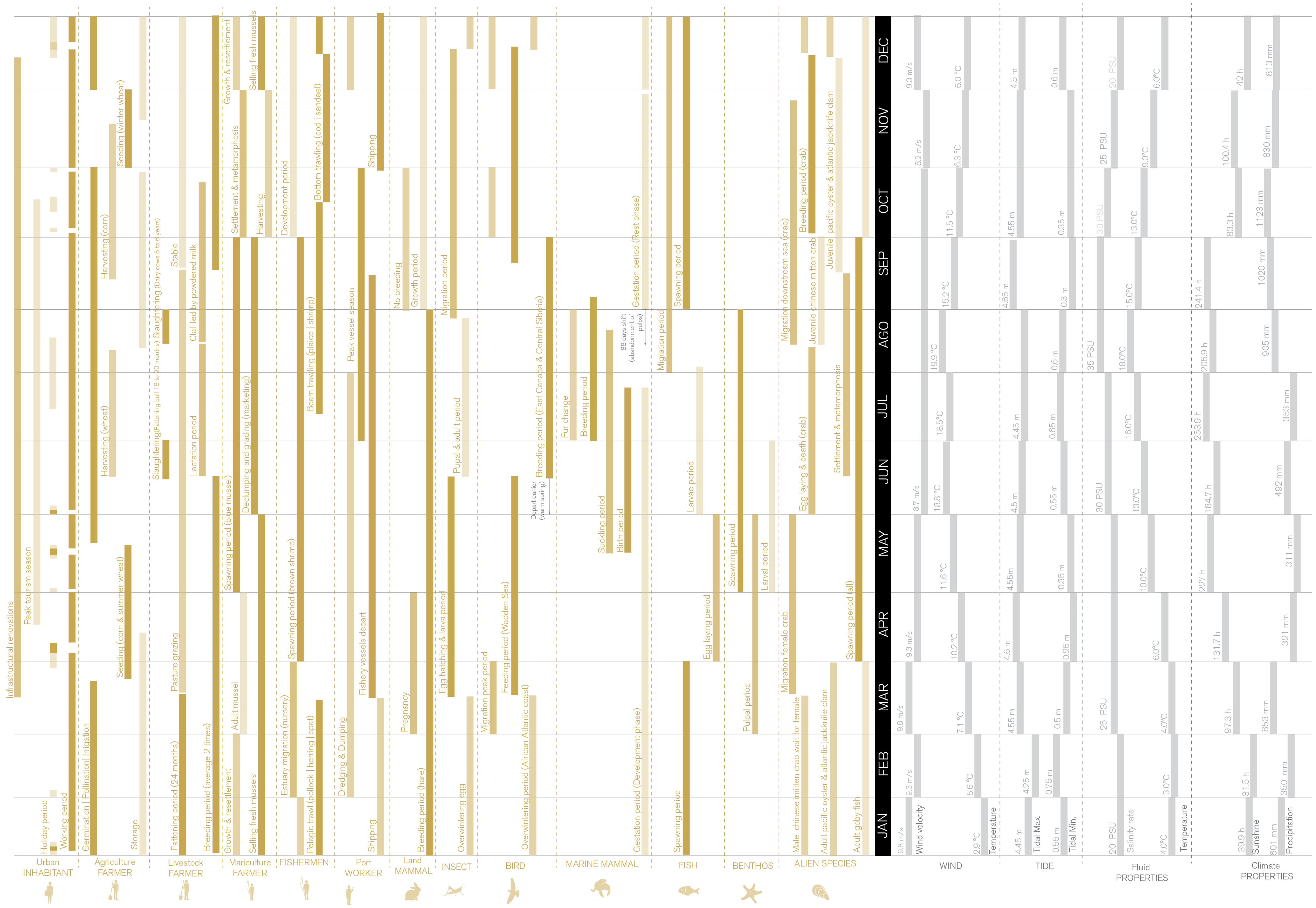
Temporality of processes of ecosystem elements

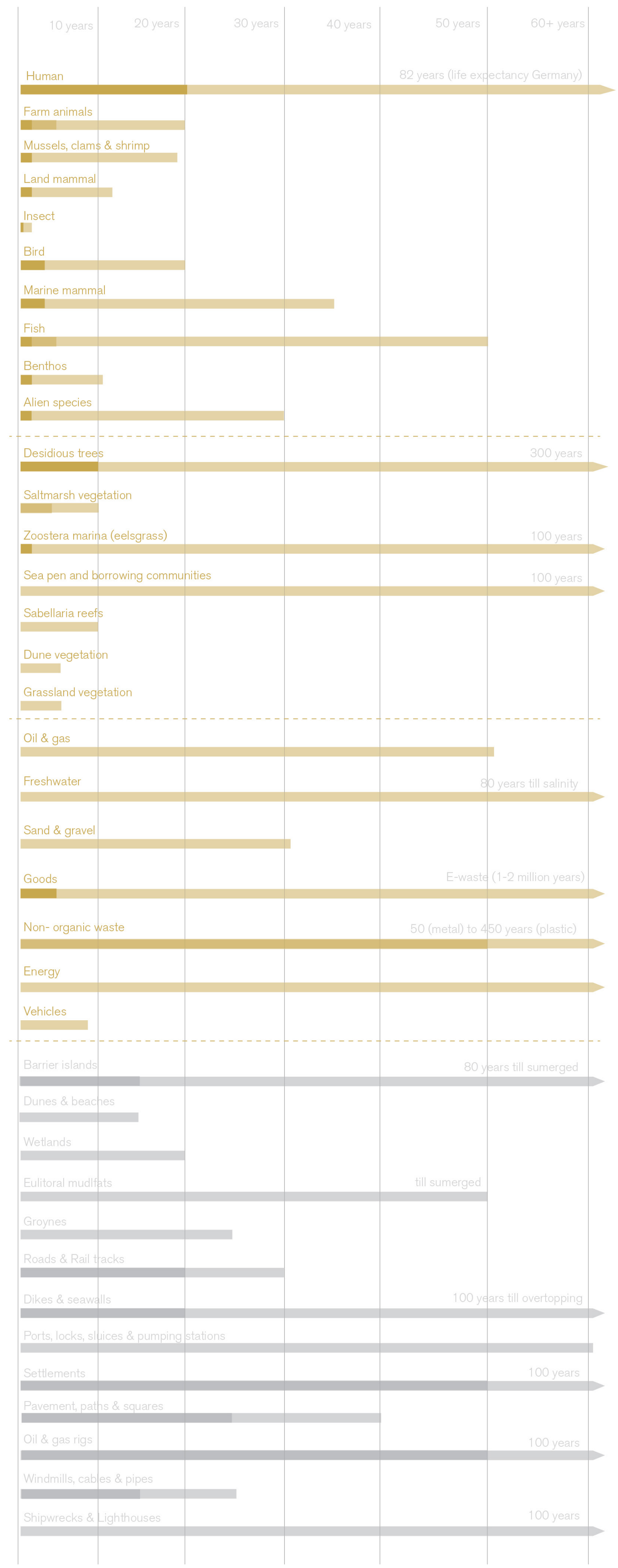
Information Function

Regulation Function

Production Function

Habitat Function





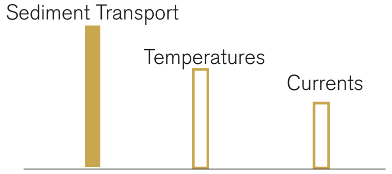
Example of data generated for ecosystem assessment- River & Estuary

Source	Target	Weight
R_Alien species	R_Shipping vehicles	-2
R_Alien species	R_Heavy Metals	-2
R_Alien species	R_Vegetation	-2
R_Alien species	R_Anthropic Infrastructurestrı	-1
R_Alien species	Waves	-1
R_Alien species	R_Macrozoobenthos	-1
R_Alien species	Water Quality	-1
R_Alien species	Sediment Transport	-1
R_Alien species	R_Nutrient Input	-1
R_Alien species	Currents	-1
R_Alien species	R_Chemicals	-1
R_Alien species	R_Sand & Gravel	1
R_Alien species	R_Birds	2
R_Alien species	R_Fish	2
R_Anthropic Infrastructurestructure	Flooding	-3
R_Anthropic Infrastructurestructure	Waves	-2
R_Anthropic Infrastructurestructure	R_Alien species	-2
R_Anthropic Infrastructurestructure	R_Macrozoobenthos	-2
R_Anthropic Infrastructurestructure	Sediment Transport	-2
R_Anthropic Infrastructurestructure	R_Vegetation	-2
R_Anthropic Infrastructurestructure	Tides	-2
R_Anthropic Infrastructurestructure	R_Fish	-2
R_Anthropic Infrastructurestructure	Temperatures	1
R_Anthropic Infrastructurestructure	R_Shipping vehicles	1
R_Anthropic Infrastructurestructure	R_Sand & Gravel	2
R_Anthropic Infrastructurestructure	R_Human	2
R_Anthropic Infrastructurestructure	R_Heavy Metals	3
R_Anthropic Infrastructurestructure	R_Chemicals	3
R_Birds	R_Alien species	-2
R_Birds	R_Macrozoobenthos	-2
R_Birds	R_Vegetation	-2
R_Birds	R_Fish	-2
R_Birds	R_Nutrient Input	1
R_Birds	R_Human	2
R_Chemicals	R_Birds	-2
R_Chemicals	Water Quality	-2
R_Chemicals	R_Vegetation	-2
R_Chemicals	R_Fish	-2
R_Chemicals	R_Human	-2
R_Chemicals	R_Alien species	-1
R_Chemicals	R_Macrozoobenthos	-1
R_Chemicals	Temperatures	2
Climate	Temperatures	-2
Climate	R_Sand & Gravel	-2
Climate	R_Birds	-1
Climate	R_Human	-1
Climate	Currents	1
Climate	R_Anthropic Infrastructurestrı	2
Climate	Sediment Transport	2

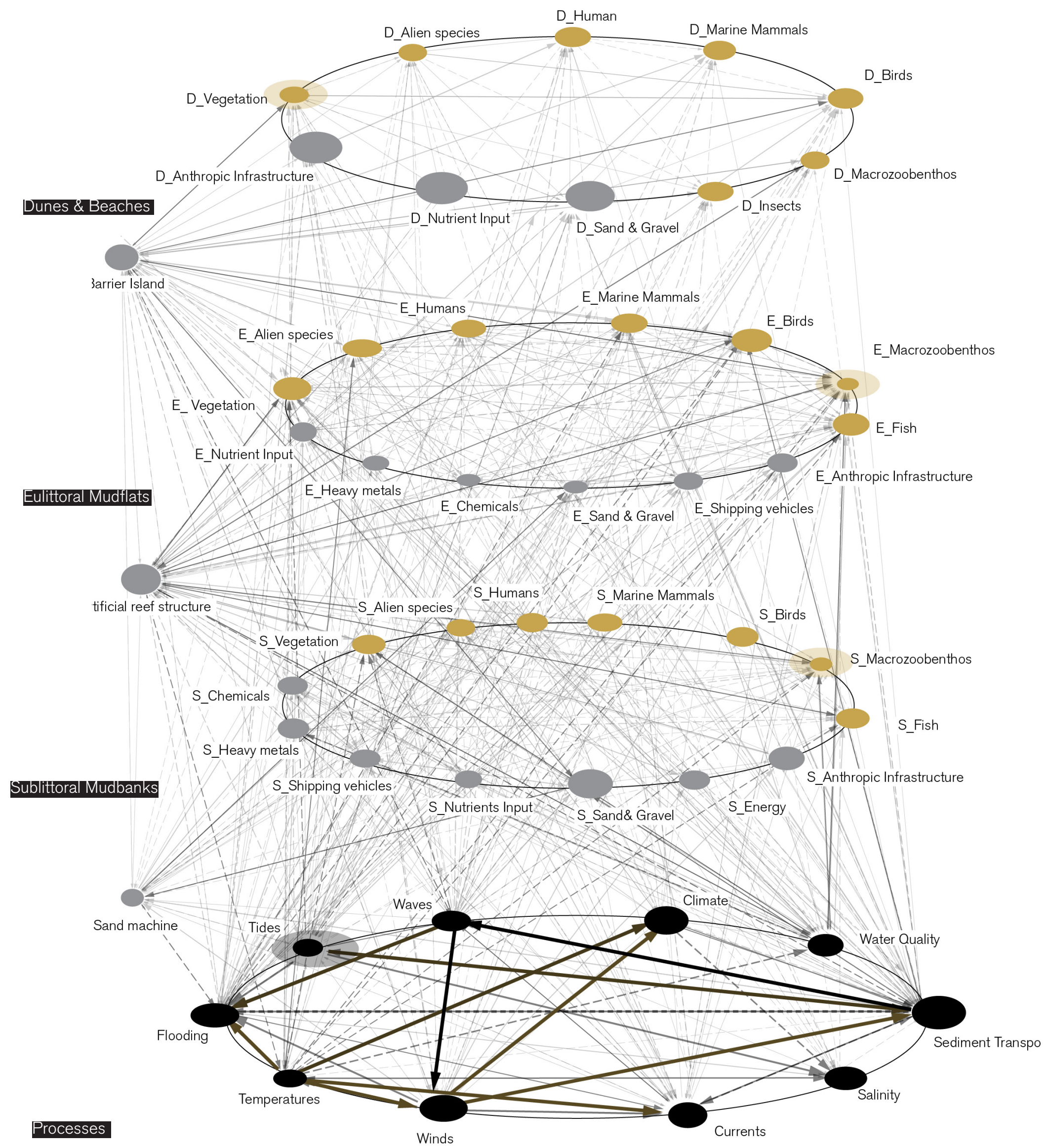
Source	Target	Weight
Climate	R_Freshwater	2
Climate	R_Vegetation	2
Climate	R_Nutrient Input	2
Climate	R_Chemicals	2
Climate	Flooding	3
Currents	R_Alien species	-1
Currents	R_Macrozoobenthos	-1
Currents	R_Vegetation	-1
Currents	R_Fish	-1
Currents	Waves	1
Currents	R_Sand & Gravel	1
Currents	Water Quality	1
Currents	R_Heavy Metals	1
Currents	R_Nutrient Input	1
Currents	R_Chemicals	1
Currents	Temperatures	2
Currents	Sediment Transport	2
Currents	R_Freshwater	2
R_Fish	R_Alien species	-2
R_Fish	R_Macrozoobenthos	-2
R_Fish	R_Vegetation	-2
R_Fish	R_Heavy Metals	-1
R_Fish	R_Chemicals	-1
R_Fish	Sediment Transport	1
R_Fish	R_Shipping vehicles	1
R_Fish	R_Nutrient Input	1
R_Fish	R_Birds	2
Flooding	R_Human	-2
Flooding	Waves	1
Flooding	R_Macrozoobenthos	1
Flooding	Currents	1
Flooding	Tides	1
Flooding	Winds	1
Flooding	R_Anthropic Infrastructurestrı	2
Flooding	Sediment Transport	2
Flooding	R_Shipping vehicles	2
Flooding	R_Heavy Metals	2
Flooding	R_Vegetation	2
Flooding	R_Nutrient Input	2
Flooding	R_Chemicals	2
Flooding	R_Fish	2
Flooding	R_Freshwater	3
R_Freshwater	R_Nutrient Input	1
R_Freshwater	R_Sand & Gravel	2
R_Freshwater	Flooding	2
R_Freshwater	R_Fish	2
R_Freshwater	R_Human	2
R_Freshwater	Climate	2
R_Heavy Metals	Water Quality	-3
R_Heavy Metals	R_Birds	-2

Source	Target	Weight
R_Heavy Metals	R_Vegetation	-2
R_Heavy Metals	R_Fish	-2
R_Heavy Metals	R_Human	-2
R_Heavy Metals	R_Alien species	-1
R_Heavy Metals	R_Macrozoobenthos	-1
R_Human	R_Fish	-2
R_Human	R_Birds	-1
R_Human	R_Macrozoobenthos	-1
R_Human	Water Quality	-1
R_Human	R_Anthropic Infrastructurestrı	2
R_Human	R_Alien species	2
R_Human	R_Sand & Gravel	2
R_Human	R_Shipping vehicles	2
R_Human	R_Nutrient Input	2
R_Macrozoobenthos	Waves	-2
R_Macrozoobenthos	Sediment Transport	-2
R_Macrozoobenthos	R_Heavy Metals	-2
R_Macrozoobenthos	R_Vegetation	-2
R_Macrozoobenthos	R_Nutrient Input	-2
R_Macrozoobenthos	R_Chemicals	-2
R_Macrozoobenthos	Currents	-1
R_Macrozoobenthos	R_Birds	2
R_Macrozoobenthos	Water Quality	2
R_Macrozoobenthos	R_Fish	2
R_Nutrient Input	R_Macrozoobenthos	-2
R_Nutrient Input	Water Quality	-2
R_Nutrient Input	R_Fish	-2
R_Nutrient Input	R_Human	-2
R_Nutrient Input	R_Alien species	-1
R_Nutrient Input	R_Birds	-1
R_Nutrient Input	Temperatures	2
R_Nutrient Input	R_Vegetation	3
R_Sand & Gravel	Waves	-2
R_Sand & Gravel	R_Shipping vehicles	-2
R_Sand & Gravel	R_Vegetation	-2
R_Sand & Gravel	Flooding	-2
R_Sand & Gravel	R_Alien species	-1
R_Sand & Gravel	R_Macrozoobenthos	-1
R_Sand & Gravel	R_Nutrient Input	-1
R_Sand & Gravel	Currents	-1
R_Sand & Gravel	Tides	-1
R_Sand & Gravel	R_Birds	1
R_Sand & Gravel	R_Anthropic Infrastructurestrı	2
R_Sand & Gravel	Water Quality	2
R_Sand & Gravel	Sediment Transport	2
R_Sand & Gravel	R_Freshwater	2
R_Sand & Gravel	R_Fish	2
Sediment Transport	R_Anthropic Infrastructurestrı	-2
Sediment Transport	R_Fish	-2
Sediment Transport	R_Alien species	-1

Most negative output on ecosystems



Ecosystem enhancement model tryout



Most vulnerable elements

1. Eulittoral Mudflat Macrozoobenthos (from -34 to -27)
2. Tides (from -8 to -14)
3. Supratidal Mudbanks Macrozoobenthos (from -14 to -13)
4. Dune Vegetation (from -16 to -12)

Less vulnerable elements

1. Sediment Transport
2. Climate
3. Supralitoral Mudbanks Sand & Gravel
4. Barrier island

Graduation Studio
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