DESIGN for COASTALSCAPE.

The spatial dimension of land-sea planning

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Cover image: conceptual drawing of land-sea interactions fluxes by Alberto Innocenti

Abstract

The PhD examines the phenomenon of coastal territories and their land and sea dynamics by a planning perspective. The study starts from the consideration that half of the world's population interacts daily with the sea through living in coastal cities and that these geographical areas are under constant pressure from anthropic activities and climate change threats.

This doctoral dissertation aims to understand how a well-structured framework of knowledge about land-sea interactions might enhance the resilience of coastalscapes. The research considers multiple approaches to tackle the topic from diverse points of view. The PhD path is divided into two key milestones.
The first key milestone of the research, coming along on a double literature review on land-sea interactions, attempts to detect, find gaps and build a framework of knowledge on land-sea interactions in order to make more accessible the topic to scientists and policymakers.
The second key milestone endeavours to enlarge the knowledge gained from the first key milestone; by looking at the coastal area through a different lens, it tries to interpret the land-sea interactions phenomena that shape the coastalscape. This milestone is based on multiple case studies approach through a mapping analysis. The first phase is focused on understanding the typologies of anthropic and natural environments present in the case studies through three types of mapping analysis. The second phase zooms in on edge to understand the components of the coastalscape by revealing a common mapping language.
The approach and methods used in the research - the double literature review, fluxes schemes and mapping - have contributed to the knowledge and even though applied on four specific cases can be relevant as guidance through the study of other cases.

ACKNOWLEDGEMENTS

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Introduction

1.1 Coastal challenges overview

Almost half the world's inhabitants interact on a daily basis with the sea through living in coastal cities (United Nations, 2017), so this research starts by addressing the need to comprehend the complexity of coastal areas.
I intend to do this by structuring the already existing knowledge in order to make it more accessible and applicable.

The overall aim is to develop a framework that can support the planning perspectives and processes to enable a holistic approach to coastal areas. More specifically, besides the environmental and spatial conditions prevailing in coastal areas, it is necessary to address issues relating to multiple stakeholders, climate change, different administrative levels and composite environments in a sustainable and integrated way.

The complexity of interactions, synergies and conflicts affecting coastal areas is not only often researched in academic fields, but is also a topic of interest to policymakers. However, there is often a knowledge gap between academic research and policymakers' decision-making, which results in a disconnected and non-organic way of tackling the many issues involved.
According to Mee, "science and policy rarely advance in a linear way" (Mee, 2010), which can create gaps in the planning process. To bridge these gaps, and in order to strengthen and build a common body of knowledge that can enhance and support the planning process of coastal areas, it will become increasingly necessary to merge both fields.

Moreover, there is one definition, not recognised from the academics, released in one of the report of the European Union regarding land-sea interactions (Jones et al., 2017): the fact that this definition is not recognised and per se not exhaustive can create misunderstanding among the researchers. This issue will be addressed in this research study (2.4.4).

The overall aim of this research is to understand how a well-structured framework of knowledge about coasts might enhance the resilience of coastalscapes in a planning perspective.

Since coastal areas are under constant pressure and are changing at a very fast pace, considering these areas from the point of view of resilience requires a better understanding and engagement with the territory and its dynamics.

There are a number of different definitions of resilience, most of which refer to the meaning of the Latin root, resi-lire, 'in rebound'. In fact, the original use of the word resilience was in the engineering field, where was used to describe the stability of materials and their resistance to external shocks. Only later was this concept integrated into a broader contexts, including ecology (Davoudi, 2012).

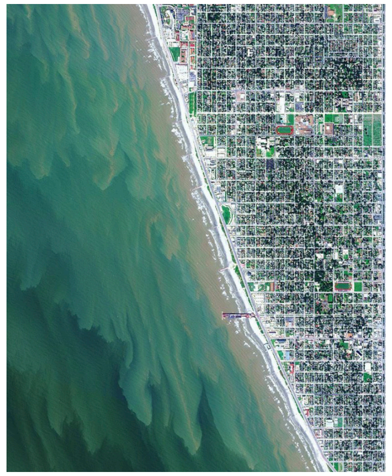
The main definitions are applied in the fields of engineering, ecology and evolution.

The definition of engineering resilience formulated by Holling refers to: "the ability of a system to return to an equilibrium or steady-state after a disturbance" (Holling, 1973, 1986). In this way, the resilience is based on the time frame of a system to return to normality.

The definition of ecology resilience according to Holling is: "the magnitude of the disturbance that can be absorbed before the system changes its structure" (Holling, 1996, p. 33).

The last definition is evolutionary resilience, which according to Carpenter: "is not conceived of as a return to normality, but rather as the ability of complex socio-ecological systems to change, adapt, and, crucially, transform in response to stresses and strains (Carpenter et al., 2005; Davoudi, 2012).

It represents a view of Naples gulf from the 15th century. Tavola Strozzi, 1472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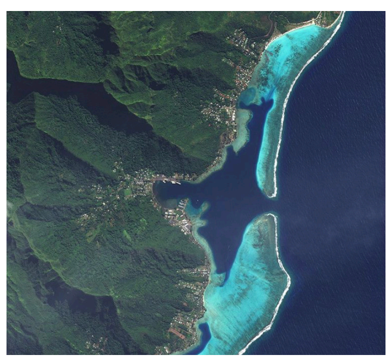
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Among this list of definitions the last one, evolutionary resilience, is the closest to how I understand the term, due to its holistic approach, which is in line with the complexity of my research topic: coastal zones, land-sea interactions and climate change.

Another of my objectives in writing the PhD is to create a structured framework of land-sea interactions to support planners in addressing the challenges that coastal cities and territories face.

Historically, coastal areas have been the most attractive places to develop settlements and communities due to the richness of the biodiversity, the extraordinary natural resources and for logistical reasons: coastal areas offer strategic advantages for trading. These are some of the reasons why the most developed cities and megacities in the world are located in coastal areas. Nearly 2.4 billion people (40% of the world's population) live within 100 kilometres of the coast (United Nations, 2017). If we only look at Europe, currently more than 206 million citizens live near coastlines, stretching from the North-East Atlantic and the Baltic to the Mediterranean and the Black Sea (European Environment Agency, 2015).

Pressure on coastal and marine environments continues to increase, putting unsustainable strain on coastal resources and biodiversity. The global population is projected to reach more than 9 billion people by 2050, with a consequential increase in pressure on marine and coastal resources (United Nations, 2017).

If we assume that 2% of the urbanized areas have been developed on coastlines that are less than 10 metres above sea level and 13% of the world's population are living in these areas (McGranahan, Balk and Anderson, 2007), we can conclude that coastal communities and settlements are among the most vulnerable to climate change.

Coastal cities are currently growing fast and are often

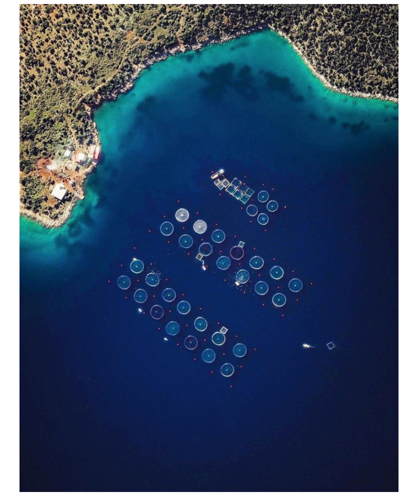
reclaiming land to expand and increase economic sectors like tourism, oil and gas, aquaculture and fishery. These processes will put an extra strain on an environment already adversely affected by human activity.

Coastal areas and coastal zones
In this text, I will refer to coastal areas using the planning-oriented term *coastal zone* since both of the terms are defined as the interface between land and sea, where the terrestrial and the marine components meet each other. Coastal areas are recognised as important sites of diverse natural systems and resources.

However, we still lack a clear definition of what constitutes a coastal zone. There are, for example, different ways of delimiting these areas by referring to natural elements, such as coastal plains, bays, estuaries, lagoons, dune fields and deltas (Ray and Hayden, 1992), but the fact that coastal environments are subject to continuous change makes it difficult to establish a precise definition.

In the ICZM protocol, the European Commission defines a coastal zone as "a strip of land and sea of varying width depending on the nature of the environment and management needs. It
seldom corresponds to existing administrative or planning units. The natural coastal systems and the
areas in which human activities involve the use of coastal resources may therefore extend well beyond the limit of territorial waters, and many kilometres inland" (EU, ICZM, January 2020).

In the field of ecology, coastal zones are also termed ecotones, defined as a transition area between two biomes (diverse ecosystems).
From an ecological perspective, a coastal zone can be defined as "the inner part of the continental shelf, the coastline and a hinterland of at least a few kilometres width. Coastal areas usually include: the surface of the land; the surface of the water; the airspace above the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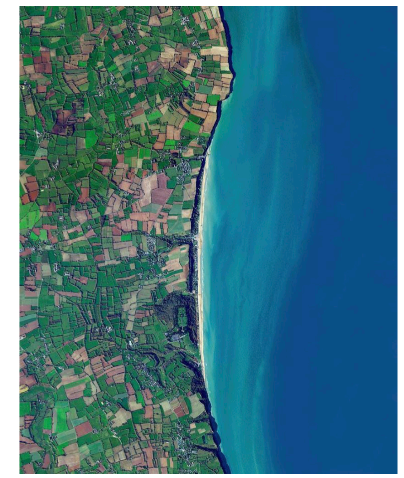
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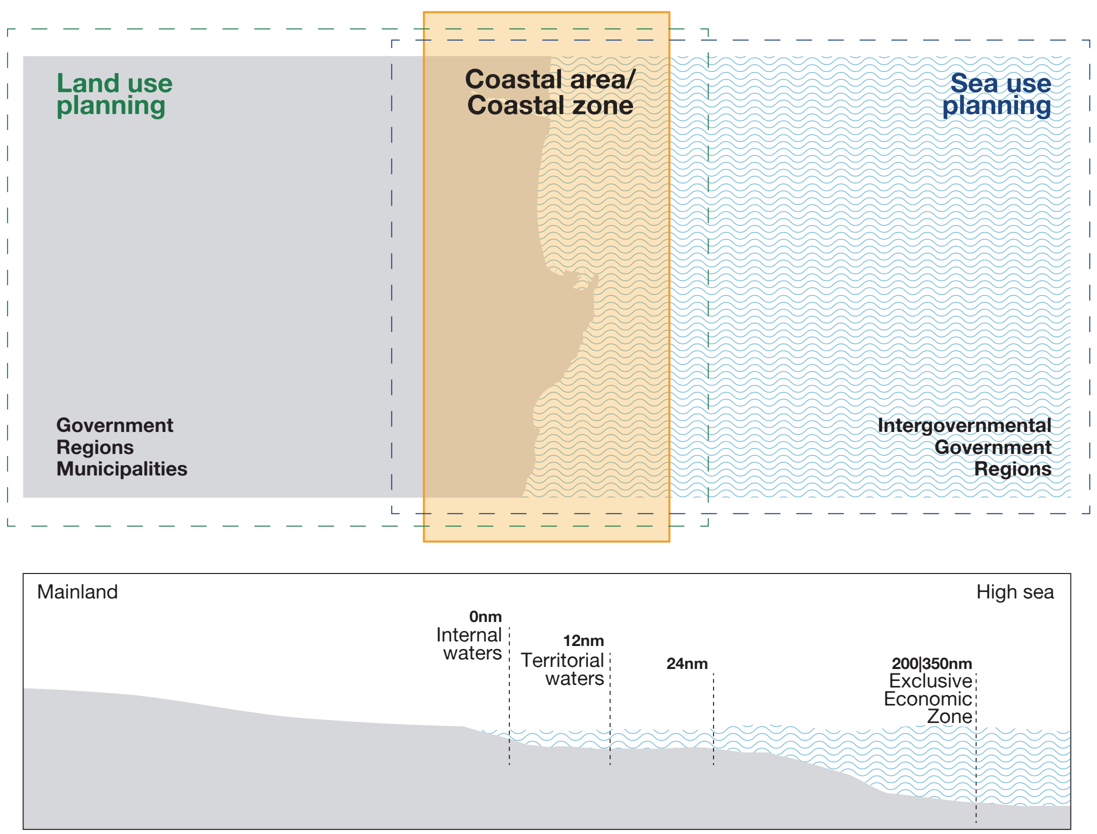
land, the airspace above the sea, the water column, the continental shelf, and the deep sea-bed” (Cullinan, 2006).

Additionally, from a planning perspective, a coastal zone is a hot-spot of interactions, not only between different ecosystems but also the result of anthropic activities.

Therefore, it is crucial to establish a clear understanding of relations and interactions between ecological and anthropic systems in order to keep the coastal environment safe, given the constant pressure from anthropic activities and threats from climate change. In the last decade, coastal areas have become increasingly vulnerable and have come under attack from natural hazards such as the 2004 tsunami in the Indian Ocean hurricane Katrina in New Orleans in 2005 and superstorm Sandy on the New York and New Jersey coasts in 2012.



Coastal area / coastal zone and UNCLOS administrative boundaries

Existing policies and climate change issues
All the issues listed here, climate change, human activities and pollution, are interesting subjects for different fields of research and for practitioners. In the last two decades, research on coastal zones and on planning processes and tools has attempted to manage the diverse human activities that have led to the deterioration of coastal environments. From a scientific perspective, different international research programmes (e.g. Future Earth) and agencies (e.g. United Nations, Unesco) have focused specifically on research into coastal zones. One example is the Future Earth Coasts Programme (from Future Earth), which is involved in a large number of research studies into coastal areas to support sustainability and to help coastal zones adapt to global change (Crossland et al., 2005; Kannen, 2008; Bricker et al., 2007; John Day et al., 2014; Kremer et al., 2013).
The main goal of these studies is to strengthen the science-policy interface and contribute to securing sustainable coastal futures in the new Anthropocene epoch, which refers to the human impact on earth’s geology and ecosystems. Together, these studies have created an enormous pool of expertise, even though it is not always shared and assimilated by policymakers. Meanwhile, there have been attempts by policymakers to manage the human impact on coastal areas, for example through the Integrated Coastal Zone Management (ICZM) tool. In 2002, Integrated Coastal Zone Management was proposed by the European Parliament and the European Council as a method for defining the principles of coastal planning and management. Unfortunately, the ICZM never became a compulsory tool for the European Union member states; indeed, there are cases of European countries that have adopted and interpreted the ICZM protocol as they pleased since the protocol never became a compulsory directive. The intention behind the ICZM was to bring the different sectors and stakeholders together to overcome conflicts and to pursue sustainable development in coastal areas (Mee, 2010).

Anthropocene
The word “Anthropocene” first appeared in IGBP literature. IGBP’s first synthesis, Global Change and the Earth System (Steffen et al, 2004), marked a pivotal shift in people’s perceptions of their relationship with the planet. The synthesis provided stark evidence that, on a planetary scale, humanity’s actions are unsustainable. Since 1987, IGBP has moved from a research strategy focusing on disciplinary science, to an Earth-system view, and now to an Earth-system view that connects to policy decisions.

Despite all these efforts, coastal areas are still facing many challenges, related to the overexploitation of this rich environment with an exponential loss of natural habitats, biodiversity and resources (Mee, 2010).

The most recent initiative regarding land-sea interaction from the European Union was through the Directive 2014/89/EU, which established a framework for Maritime Spatial Planning (MSP), by which the EU member states are committed to developing their own maritime spatial plan.
The directive puts forward a plan to carefully manage the discourse surrounding land-sea interactions. This is a key point in the Directive 2014/89/EU for different reasons: first of all, because land and maritime planning systems are not working according to a common framework and coastal dynamics are not managed in an integrated way; secondly, because land-sea interactions cannot be delimited by administrative boundaries and so there is no recognised standard spatial dimension.

The maritime spatial process works across borders and sectors to ensure that human activities at sea take place in an efficient, safe and sustainable way. A lot of attention has been devoted to blue growth, a long-term strategy to support sustainable growth in the marine sectors as a whole. A lot of activities and sectors that operate at sea are known to affect conditions on land and vice versa. For this reason, it is important to establish a clear framework on the land-sea interaction discourse, in order to support and manage the maritime spatial planning process. Such an approach will contribute to deal with the increasing pressure on both the sea and coastal areas by improving synergies and reducing conflict.

As mentioned above, the issue of climate change is inextricably linked with coastal zones and its own interactions. Moreover, climate change affects coastal areas, posing a significant threat both in the short and long-term perspectives.

From a short-term perspective, coastal areas, including their infrastructure and economy, are severely affected by inundation and flooding, storm surge, coastal erosion, shoreline relocation, and saltwater intrusion, and sometimes by even more devastating disasters (Neumann, 2015). At the same time, from a long-term perspective, coastal areas are subjected to climate change impacts like rises in sea-level, increasing water temperatures and consequently acidification of the sea.

The effect of climate change can adversely affect the dynamics of the land-sea interaction in coastal zones. Moreover, “the rising world population and the economic attractiveness (e.g. harbours, tourism) of the coastal areas to allocate new activities, the lack of space and external climate drivers (e.g. sea level rise, storm surge), are frequently posted as the main reasons to look forward and re-think these areas in an adaptive and resilient way” (Janssens and Geldof, 2014).

1.2 Research objective and questions

This PhD aims to build a framework in order to organise the comprehensive knowledge that already exists on coastal areas by drawing on facts and information from other fields of research on coastal area issues.

Building on existing literature, my PhD research will define and design a new knowledge framework for coastal area planning, by visually conceptualizing the complexity of land-sea interactions in a new way in order to enhance our comprehension of those dynamics. In order to achieve the best results, it was essential to design the research path around what I have defined as key milestones where each milestone addresses the land-sea interactions topic from a distinctly different approach and method. Each milestone has a separate set of outcomes and results, but in combination, they offer a more exhaustive overview.

Each key milestone addresses a more specific research question in order to answer the overarching research objective. The intention behind these research questions is to tackle the topic of land-sea interactions from different angles by using different methodological approaches. The aim of the overarching research objective is to take a general look at coastal areas by taking into consideration a wide perspective that ranges from the discourse surrounding land-sea interactions to the resilience of these areas.

It is crucial that a common body of knowledge on coastal areas is compiled during planning phases in order to accurately map different phenomena and human-driven changes that continually affect coasts. Furthermore, it is essential to manage resources in a sustainable way and to build adaptive and resilient coastal areas.

The first key milestone of the research addresses the first research question:

How can different fields of scientific investigation contribute to spatial planning research and practice in relation to land-sea interaction?

The first key milestone investigates land-sea interactions through a literature review in order to establish a knowledge-based state of the art. This essential starting phase aims to collect information from existing research and compile it into a coherent framework of knowledge. This will allow a better insight into the complex dynamics that affect coastal areas and define an appropriate terminology to support the land-sea interactions discourse.
As mentioned above, this knowledge is not organised in a way that is easily accessible for the different stakeholders involved; therefore, in this first key milestone the goals will be to formulate a theoretical definition of land-sea interactions and to translate all the collected knowledge visually into a pattern that is comprehensible to a wider audience.

This led to the second key milestone and the second research question:
How can coastal area surveys of spatial land-sea phenomena advance knowledge to develop a framework that can help improving coastal planning?

This second key milestone was crucial to clarify how coastal areas are dealing with the different kinds of interaction and various external drivers and how these phenomena are shaping our coastal landscapes. Moreover, with the goal of developing new knowledge on coastal areas and to inform the discourse about land-sea interaction, the second key milestone aims to explore spatial relations between uses and repeated patterns through mapping case studies. The case studies were chosen according to a set of criteria adopted so as to create as diverse and representative a sample of cases in Europe as possible; the criteria will be described in detail in chapter *3.3 Case studies and data issues*. The data used for analysing the case studies for both land and sea were mainly collected from open-source database portals such as Copernicus, Emodnet and internal university databases.

The second key milestone further explores and expands on our knowledge by mapping coastal areas. The purpose is to gather facts through looking at case studies of coastal terrains and to analyse the forces that impact land-sea interactions. More specifically, I analysed four different coastal case studies in Europe, on four seas: the North Sea, Baltic Sea, Tyrrhenian Sea and Adriatic Sea.

This act of "reading" allows information to emerge from the mappings themselves. Through actively mapping the four case studies from the research using design methodology and a selection of mapping methods (Geddes' valley section, Duany's transect, Humboldt's diagram of a cross-section and Lynch's visual form maps, outlined in chapter 3.2), the second key milestone will cross-check the knowledge acquired from the first key milestone in more detail. Applying a mixed-methods approach will enhance our ability to explore coastal areas in a more open and useful way. The method developed in this section will constitute a supportive instrument to enable us to better comprehend dynamics, to reveal new spatial features and interactions, both natural and anthropic, and to highlight complex spatial phenomena that make up coastal areas. The mixed-methods approach will enrich the mapping process by allowing consistent exploration of coastal areas and thereby lead to improved results.

1.3 Research design

First key milestone | complexity of the coastalscape
In order to broaden the perspective, unpack the complex topic and carve out a clear investigative path, the research is structured around two key milestones.

As already explained in the introduction, coastal zones are complex areas in which both natural and anthropic systems interact, resulting in both positive and negative externalities. From a planning perspective, it is crucial that we have a clear framework of knowledge about these interactions and dynamics in order to be able to deal with present and future challenges facing coastal areas. More specifically, the first research question is intended as a means to investigate land-sea interaction typologies and to identify the gaps between academic research into and policymakers' knowledge of this subject. The aim is to present an overview of the state of the art on land-sea interactions and to propose a precise definition.
Building a common framework of knowledge about land-sea interactions may be also be beneficial as, despite the enormous amount of information that already exists on coastal areas, it does not seem to be organized in any usable form. Scientists from across the globe have investigated coastal areas extensively across a range of disciplines including chemistry, physics, biology, social, political and economic sciences; however, although this has yielded an astonishing amount of knowledge, both in terms of quantity and quality, it has not been systematized in an organic way. The research fields mentioned were therefore all covered in my literature review. This list of disciplines gives just a brief overview of the complexity of coastal areas and the diversity of the different research fields involved, but highlights the importance of taking a holistic approach in order to comprehend and deal with all the aspects. Therefore, the first key milestone is aimed at systemizing information acquired from scientific articles, in order to create a clear framework of knowledge about land-sea interactions through different representations.

A double literature review was essential to fully cover this heterogeneous topic and to choose the most useful and

relevant scientific articles for the analysis. The two parallel literature reviews also made it easier for me to verify the information acquired in structuring the framework for the research.
This part of the research employed two methods to carry out a literature review: the first one uses an open-source database, and the second one is based on the bibliography from an original world-renowned scientific paper.

In order to answer the question accurately, the first key milestone took the form of a three-step process to build an extensive and inclusive framework of knowledge about land-sea interaction discourse.

The first step was to select a number of EU reports on land-sea interactions (Dworak, 2016; European Commission, 2018; Jones et al., 2017); they were used as a basis for the introduction to the topic although they are not part of the literature review itself. They were mainly used as a source for the initial groundwork.

The second step was a systematic literature review from an open-source database (Scopus) of academic research papers, guided by a set of criteria for selecting the most relevant and useful articles; the adopted methodology will be outlined in chapter 4.2.1.

The last step of the literature review was based on the bibliography from an original world-renowned article on land-sea interactions called “Land-Ocean Interactions in the Coastal Zone: Past, present & future” (Ramesh et al., 2015), which details all the work done on land-sea interactions by an internationally renowned group of researchers under the auspices of the International Geosphere-Biosphere Programme (IGBP) .

The selected papers from both literature reviews were used to lay the foundation for the research and to structure the information gathered into a framework of knowledge on land-sea interactions.

International Geosphere-Biosphere Programme (IGBP).
IGBP was launched in 1987 to coordinate international research on worldwide and regional interactions between the Earth’s biological, chemical and physical processes and their interactions with human systems. IGBP views the Earth’s systems as the Earth’s natural physical, chemical and biological cycles and processes and also considers the social and economic dimensions.
Part of IGBP’s success lies in its concept of the Earth as a complex system with human society and the environment intrinsically linked. The concept of a human dimension to the Earth’s systems is now widely acknowledged as a powerful way to analyse problems and identify longterm sustainable solutions to society’smost pressing challenges.

The final outputs from the first key milestone are the organization and systematization of the information collected, the construction of a land-sea interaction fluxes scheme and a more suitable definition of the topic.
The results from the first key milestone thus provided me with in-depth background knowledge which I used in the second part of the research during the exploration of the interactions between land and sea that was carried out by mapping the case studies.

Second key milestone | From mapping to reality
The methodological approach used for the second key milestone was research by design (Downton P., 2003), which then enabled me to structure the final phase of mapping method. The research by design approach supported the mapping process by opening up to explorational inception and stimulating the use of other methods through an iterative process. Additionally, the research by design approach was fundamental to look at the complexity of coastal areas; according to Janssens, three elements are needed when you employ the research by design approach: criticality, imagination and syncretism (Janssens, 2012).

Therefore, looking at the coastal zone with a *critical* perspective will allow the expert (researcher, practitioner and planner) to conceptualize information and develop a conceived framework of knowledge.
The second element is *imagination* as an engine to redefine thoughts and lead to an innovative design.

The last element is *syncretism* that helps to discover unexpected connections and enable contradictions to be brought to light (Janssens, 2012).
The other methods that were used as a starting point, and which were both later modified for the mapping process, were Geddes’ valley section, Duany’s transect, Humboldt’s diagram of a cross-section and Lynch’s visual form maps. These methodological tools will be explained in chapter *3.2 Theory, context and concepts for a mapping approach.*

The mapping process was divided into two phases. The first involved an analysis modified from the concept of the valley section and diagram of a cross-section and performed on a regional scale to interpret land-sea dynamics from their inception to their endpoint in order to define possible boundaries and recurring patterns. The second phase was based on the transect method and visual form maps and aimed to scale the analysis down to the coastal interface in order to investigate and highlight details pertaining to the interaction of natural elements that can play a role in building a resilient coastal landscape.

I used the methodology research by design to facilitate the merging of the other methods and approaches to create my own mapping methodology. The whole mapping process was, in fact, guided by the research by design methodology through an iterative process of feedback and review, which allowed me to choose the best method for performing the analysis on the case studies. Since the main objective of this milestone was to map land-sea interrelations by exploring the dynamics from land to sea and looking at coasts from different planning scales, the research by design method proved to be a very useful approach. The methods used in the mapping process were Geddes' valley section and Duany's transect, which were redefined and modified so as to better fit this specific analysis. The mixed-methods process allowed me to explore and gain new knowledge and to compare interrelations between similar coastal areas. It also showed how certain natural elements can be beneficial both for land-sea interactions and for coastal resilience.

The main results from the second key milestone were producing new knowledge through the mapping analysis and the creation of a coastal language glossary that will enhance our understanding of the field and enable typical coastal elements to be more accurately identified. A secondary result comes from the mapping methodology itself, which was created from the iterative process and the blending of diverse methods.

1st key milestone

Complexity of COASTALSCAPE

The general aim of this chapter is to organize and systematize the enormous quantity of information that exists on land-sea interaction.
More precisely the chapter is intended to answer the sub-research question: “How can coastal area surveys of spatial land-sea phenomena advance knowledge to enable a framework to inform the discourse surrounding land-sea interaction and so improve coastal resilience planning?”

The introductory section to this chapter, *2.1 Land-sea interaction from the academic and EU perspectives*, briefly outlines the aims, objectives and modalities that I took into consideration in developing the first key milestone “The complexity of the Coastalscape”.

The purpose of the following section, *2.2. Literature review, methodology and visualization tool*, is to go through the methodology employed to produce the two parallel literature reviews and to describe the visualization tool used.

The next section, *2.3 Gaps in the discourse on land-sea interactions*, highlights some of the structural gaps in the discourse on land-sea interaction.

The first key milestone ends with section *2.4 New knowledge on land-sea interaction*. This last section sets out the results derived from both literature review analyses (2.4.1 and 2.4.2) and the visualization of the information (2.4.3) and paves the way for a more precise definition of land-sea interaction (2.4.4).

2.1 Land-Sea Interaction from the academic and EU perspectives

As a point of departure in the research to develop this key milestone, I decided to approach the overall topic of land-sea interaction from a non-scientific viewpoint. I already had some insight into the area from participating in a conference organized by the European Union under the auspices of the MSP platform network: “Maritime Spatial Planning: Addressing Land-Sea Interactions”. I followed this up by reading some European Union reports (Dworak, 2016; European Commission, 2018; Jones et al., 2017), which gave me several new perspectives on the topic. This proved a highly useful start in developing some basic knowledge about this theme.
More specifically, this first step was crucial in providing me with the appropriate background knowledge to enable me to formulate the sub-research question more concisely. As explained in the research questions and methodology chapters, the first key milestone was developed following a parallel literature review based on a number of key scientific articles in order to fully investigate the current knowledge on land-sea interaction. To build further upon the findings from the literature reviews, my research will be supported by Sankey Matic, an open-source tool, and utilise drawings in order to better visualize and assimilate the information.

Before going into more detail on the topic, there is some other essential information that I need to introduce here in order to gain a better understanding of how the discourse surrounding land-sea interaction aligns with current dynamic between academic research and policymakers. The following paragraphs constitute an introduction to one of the most important scientific projects ever carried out on land-sea interactions and to how the European Union perceived and were involved in this project.

Scientific perspective
There has been research into coastal areas for over four decades, but from around the beginning of the nineties, one group of researchers started to work specifically on Land Ocean Interactions in the Coastal Zone also

known as LOICZ (in Europe we use the term land-sea interactions - LSI).
The LOICZ programme involved scientists from across the globe who investigated changes in the biology, chemistry and physics of coastal zones. In a second wave of research, social, political and economic sciences also became involved in order to more fully address the human dimensions of coastal zones.
All results have been published in peer-reviewed journals, books and studies series. Since 2015, LOICZ has become a core project for the new Future Earth initiative under its new name, Future Earth Coasts. The very robust and impressive work carried out by LOICZ represents a cornerstone in the research on coastal zones. This extensive body of work will therefore constitute one of my literature reviews.

The European Union involvement and perspective
During the same period, in Europe, after the Earth Summit in Rio de Janeiro in 1992, the European Commission began work on the Integrated Coastal Zone Management project (ICZM).
This is a process for the management of coasts using an integrated approach, taking into account all aspects of coastal zones, including geographical and political boundaries, in an attempt to achieve sustainability. The ICZM, or as it was later called the Integrated Coastal Management (ICM) project, was never made compulsory for European countries; therefore, even today, the planning of coastal zones is still not being carried out in an integrated way.
Over the last decade, the European Commission has tried to tackle coastal issues from a different perspective, drafting a directive on Maritime Spatial Planning (MSP), in which the 27 member states of the European Union are obliged to develop a national maritime spatial plan by 31 March 2021 at the latest.
The most interesting aspect of the 2014/89/EU directive is the emphasis put on human activities, climate change and shoreline dynamics as the most closely interrelated marine and coastal activities. As described in several

of the articles of Directive 2014/89/EU, it stresses the need to include land-sea interactions in the maritime spatial planning process. However, the directive does not describe how to deal with land-sea interactions, and it is left up to the member states themselves to decide how to interpret the directive in the ways they see most fit.
In order to clarify their intentions, the Maritime Spatial Planning directive 2014/89/EU established a framework for maritime spatial planning, committing EU member states to developing their own maritime spatial plan with the objective of supporting the sustainable development of seas and oceans in a coordinated, coherent and transparent way across all sectors and involving decisions and policies that would affect oceans, seas, island and coastal areas. Paragraphs [13] and [16] of the introduction to the Maritime Spatial Planning directive note how marine and coastal areas are under considerable pressure from human activities and climate change that can have a dramatic impact on coastal economic development and growth and lead to the deterioration and loss of biodiversity and ecosystems. They also describe how marine and coastal activities are often closely interrelated, as quoted below:

(13) "In marine waters, ecosystems and marine resources are subject to significant pressures. Human activities, but also climate change effects, natural hazards and shoreline dynamics such as erosion and accretion, can have severe impacts on coastal economic development and growth, as well as on marine ecosystems, leading to deterioration of environmental status, loss of biodiversity and degradation of ecosystem services. Due regard should be had to these various pressures in the establishment of maritime spatial plans. Moreover, healthy marine ecosystems and their multiple services, if integrated in planning decisions, can deliver substantial benefits in terms of food production, recreation and tourism, climate change mitigation and adaptation, shoreline dynamics control and disaster prevention".

(16) "Marine and coastal activities are often closely interrelated. In order to promote the sustainable use of maritime space, maritime spatial planning should take into account land-sea interactions. For this reason, maritime spatial planning can play a very useful role in determining orientations related to sustainable and integrated management of human activities at sea, preservation of the living environment, the fragility of coastal ecosystems, erosion and social

and economic factors. Maritime spatial planning should aim to integrate the maritime dimension of some coastal uses or activities and their impacts and ultimately allow an integrated and strategic vision".

The European Union directive also specifies that member states should promote a sustainable use of marine space in their maritime spatial planning that should take into account land-sea interactions. Moreover, in the articles of the directive, land-sea interaction is mentioned several times (Art.1 n.2, Art.4, Art.6 and Art.7) as an important topic to take into account during the implementation of maritime spatial planning.

Article 1 (Subject matter) n.2. "Within the Integrated Maritime Policy of the Union, that framework provides for the establishment and implementation by Member States of maritime spatial planning, with the aim of contributing to the objectives specified in Article 5, taking into account land-sea interactions and enhanced cross-border cooperation, in accordance with relevant Unclos provisions".

Article 4 (Establishment and implementation of maritime spatial planning) n.2 "In doing so, Member States shall take into account land-sea interactions".

Article 6 (Minimum requirements for maritime spatial planning) Member States shall:
(a) "take into account land-sea interactions";
(b) "take into account environmental, economic and social aspects, as well as safety aspects";
(c) "aim to promote coherence between maritime spatial planning and the resulting plan or plans and other processes, such as integrated coastal management or equivalent formal or informal practices";

Article 7 (Land-sea interactions)
1. "In order to take into account land-sea interactions in accordance with Article 4(2), should this not form part of the maritime spatial planning process as such, Member States may use other formal or informal processes, such as integrated coastal management. The outcome shall be reflected by Member States in their maritime spatial plans".
2. "Without prejudice to Article 2(3), Member States shall aim through maritime spatial planning to promote coherence of the resulting maritime spatial plan or plans with other relevant processes".

This recognition of the importance of the discourse on land-sea interactions was crucial in providing a solid base from which to start my research.

2.2. Literature review methodology and visualization tool

Carrying out a systematic literature review of the land-sea interaction discourse was fundamental for several reasons. First of all, it was important to build up a complete picture of all the academic fields that have contributed directly and indirectly to the research on this topic. Secondly, I needed to immerse myself in the subject of land-sea interaction in order to integrate new knowledge and different perspectives and so reveal the complexity and heterogeneity of coastal areas. Finally, it was crucial for me to be able to put together a general frame of references on the topic and to marshal the considerable amount of information about land-sea interactions into a clear and comprehensible form.
The following paragraphs will outline the methodology used for both literature reviews and the visualization tool used, Sankey Matic.

Both literature reviews followed Dewey, Drahota and Pittway, who highlight the importance of "following a clearly defined protocol where the criteria is clearly stated before the review is conducted. It is a comprehensive, transparent search conducted over multiple databases and grey literature that can be replicated and reproduced by other researchers" (Dewey and Drahota, 2016; Pittaway, 2008).

The systematic literature review
The systematic literature review was conducted with the aim of finding interesting new studies on land-sea interaction. The only search criterion was that all articles should be scientific in nature; therefore, I used the open-source academic database Scopus. The methodology was structured according to a four-stage review process: (a) criteria settings, (b) literature search, (c) literature refinement and (d) analysis of selected articles.

(a) Criteria settings
In this first stage, the set of criteria chosen included only English-language, peer-reviewed academic journals, while books, conference papers and dissertations were

excluded. The key search terms used were: "land-sea", "land-ocean", "interact*", "land interact*", "ocean interact*", "sea interact*", "lsi", "loicz", "coast*", and "planning".

(b) Literature search
To cover the whole spectrum of disciplines contributing to such a complex topic, the Scopus database was chosen, as it is made up of an enormous number of peer-reviewed journals all the relevant subject fields: life, social, physical and health sciences. The search was conducted using the search terms mentioned above on titles, keywords and abstracts.
The terms were used in a combination of three strings: the first one TITLE-ABS-KEY ("land-sea" OR "land-ocean" OR "interact*"), the second one TITLE-ABS-KEY ("land interact*" OR "ocean interact*" OR "sea interact*") and the third one TITLE-ABS-KEY ("land interact*" OR "ocean interact*" OR "sea interact*"). Each string resulted in a different number of articles found: 4,214,228, 12,739 and 1,574,484 respectively.
The next step was to refine the results from the three strings in this final query, TITLE-ABS-KEY ("land-sea" OR "land-ocean" OR "interact*")) AND (TITLE-ABS-KEY ("land interact*" OR "ocean interact*" OR "sea interact*")) AND (TITLE-ABS-KEY ("lsi" OR "loicz" OR "coast*" OR "planning")). The aim here was to limit the search to articles that contained at least one of each of the string terms. This resulted in 2,536 papers containing at least three terms.
The last step of this stage was an extra "cleaning" pass of the search results by limiting the articles chosen to only those with a final publication status, published between 1999 and 2019. This extra filter yielded 223 papers.

(c) Literature refinement
The aim of this stage was to further refine the search by skimming the academic articles. Even though the search method was well defined by the terms and the criteria used, there was still a margin of error from the Scopus database open source. Therefore, in this step, duplicated

articles that did not fulfil the inclusion criteria were also discarded. A further refinement was made through checking titles and key words and reading through all the abstracts of the sampled articles; more specifically, I manually checked the articles to establish if they contained any of the keywords and read the abstracts to see if they were relevant to the topic. From the original 223 articles, a final selection of 22 was made.

(d) Analysis of selected articles
In the last stage, the 22 selected articles were analysed through reading them all the in full.
This made it possible to choose the definitive 12 papers to be used for the land-sea interaction literature review.
An Excel table was set up to collate all the information gathered for the outcoming fluxes scheme.

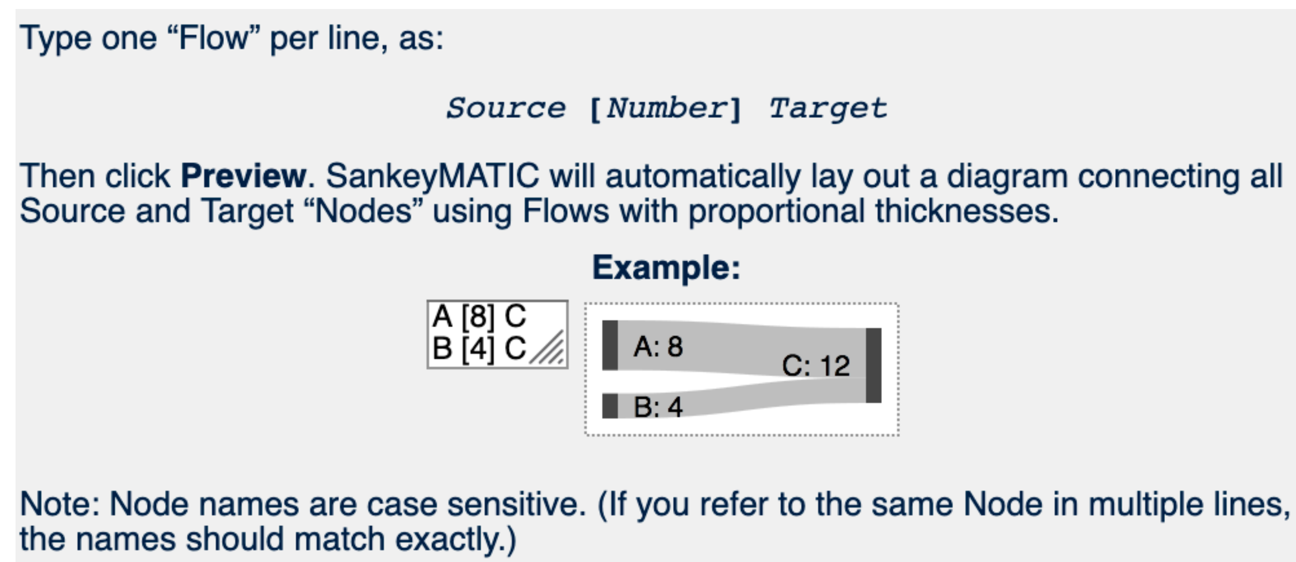
Review of LOICZ
Despite all the information acquired from the database literature review, I decided to do a further analysis on a central research paper called "Land-Ocean Interactions in the Coastal Zone: Past, present & future" (Ramesh et al. 2015) in order to enrich my research and have a solid base from which to investigate land-sea interactions. This paper gave me invaluable knowledge and understanding of the topic.
The literature review was based on the scientific articles that make up the bibliography of the "Land-Ocean Interactions in the Coastal Zone: Past, present & future" paper. The search followed a shorter three-stage review process: (a) Criteria settings, (b) Literature refinement and (c) Analysis of selected articles.

(a) Criteria settings
The bibliography of the "Land-Ocean Interactions in the Coastal Zone: Past, present & future" article is composed of 74 articles. The aim of the first stage was to discard all the papers that were not peer reviewed, since the criteria set was based only on English-language, peer-reviewed academic journals.

(b) Literature refinement
At this point, I carried out a search of all the peer reviewed articles from the bibliography using the same search terms as in the previous literature review, i.e. “land-sea”, “land-ocean”, “ interact*”, “land interact*”, “ocean interact*”, “sea interact*”, “lsi”, “loicz”, “coast*”, “planning”. This step consisted of checking all terms listed in the title, abstract and keywords of each selected article.

(c) Analysis of selected articles
After the second refinement stage, it was possible to carry out the last stage, which consisted of me reading all the 15 selected papers in full, in order to select the definitive articles which I could use for the land-sea interaction literature analysis. This last stage resulted in the final 9 papers on which the land-sea interactions literature review was based. I also set up an Excel table to collate all the information acquired from this stage.

Sankey Matic tool
In the first key milestone, the aim was to make all the information collected from the two reviews as comprehensible and clear as possible. To identify patterns in the information gathered and to present the results into a more easily readable format, I used the diagram builder Sankey Matic.
The Sankey Matic is an online open-source tool that depicts flows of information, where the width of each flow pictured is based on the amount of input. Sankey diagrams are very effective at showing particular kinds of complex information, for example, flows of energy from source to destination and flows of goods from place to place. Land-sea interaction flows in the diagram are built on strings based on a pair of nodes (A to B, from B to C and so on).
Since the tool works in pairs of nodes, all the land-sea interactions collected through the literature reviews were systematized into an Excel file.
The logic underlying the categorization process was based on the structure flow of a land-sea interaction. The sequence starts from the land and ends at the sea and is composed of the following categories: stressors, causes, drivers, consequences and receivers.
The stressors generate the interaction flow and are composed of economic sectors and activities (when they are known).
The causes are the externalities produced from the stressors.
The drivers are natural or anthropic elements that enable the interaction.
The consequences are the impact of the interaction.
The receivers are economic sectors and activities that are influenced by the interaction.
This step of the categorization process enabled me to structure and prepare the results in a more accessible way through the Sankey Matic tool.



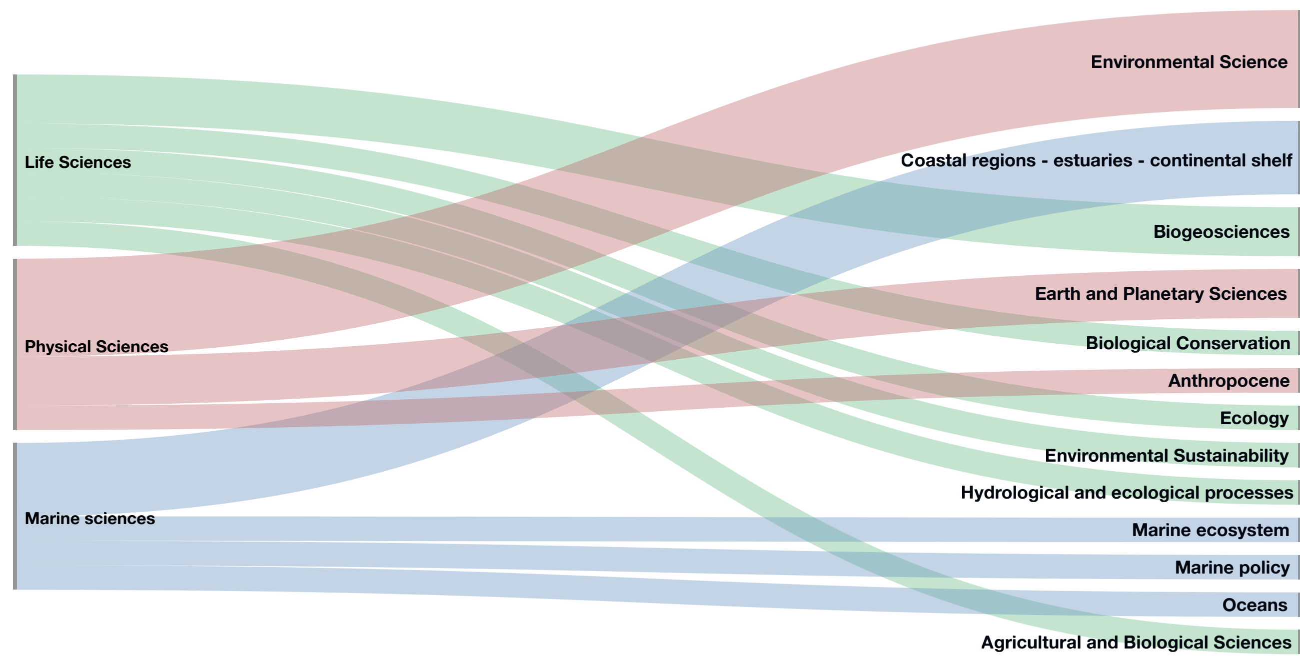
Sankey Matic diagram function | screenshot http://sankeymatic.com/

2.3 Gaps in the discourse on land-sea interactions

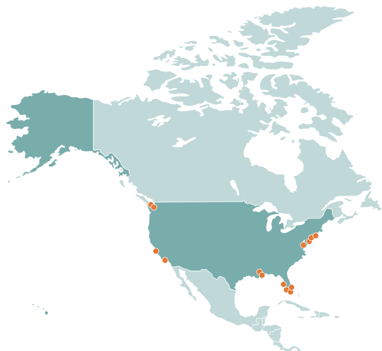
There are two main gaps in the discourse surrounding land-sea interactions, although they are closely related. The first one is the lack of communication between scientific research and decisions made by policymakers. According to Mee, “science and policy rarely advance in a linear way” (Mee, 2010).
The truth behind this statement became clear after the first overview of land-sea interactions described in some of the European Union reports and took on even more meaning after the scientific literature review in the first key milestone.
The first impression one gets is that European Union reports are not in line with current scientific thinking and lack the same level of information.
In fact, although the European Union reports, project deliverables and guidelines cannot be regarded as having the same weight as scientific papers, they still play an important role in contributing to the common pool of knowledge from which researchers, policymakers and practitioners draw their information.
In the overview of the European Commission report, “*Maritime Spatial Planning Conference: Addressing Land-Sea Interactions - Conference Report* ” can be found a number of inaccuracies about the definition of what constitute land-sea interactions and in the descriptions of the interactions themselves. These inaccuracies can create misunderstandings and lead to mistakes being made by people working in the field. This will be fully explained in the results section 2.4.4.

The second major gap in the discourse on land-sea interaction, which I discovered during my literature review, is that the enormous number of studies and amount of material about land-sea interactions are not systematized in any way.

Most of the papers analysed contained relevant information to contribute to the discourse on land sea interactions, even though these studies were not specifically oriented to the theme covered. Studies ranged from microbial ecology, through marine science, bio-coastal and planning to geochemistry which, from a non-expert perspective, could easily result in a chaotic and incoherent body information, even though all the studies did refer to coastal areas. Formulating a clear objective for investigating these different land-sea interactions may serve to widen the perspective and so help to organize all the diverse information into a more coherent whole.
Identifying the discourse gaps mentioned above allowed me to gain a clearer understanding of what is required to enhance land-sea interactions from a planning perspective.



Theme coverd from the analysed articles



Case studies of the Systemic Literature Review

Case studies of LOICZ Literature Review

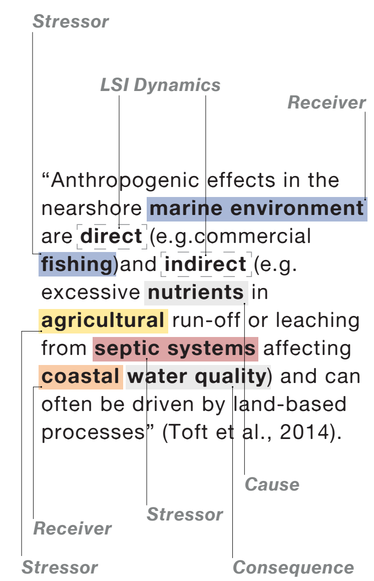
2.4 New knowledge gained on land-sea interactions

This section aims to report on the results from both literature reviews, the fluxes schemes and the new definition of land-sea interactions. In the next chapters I will reveal the literature results.

Almost all the research papers in both literature reviews are based on case studies.
All the 12 articles selected from the systemic literature review were based on case studies; in the LOICZ literature review, however, only 5 out of 9 articles were based on case studies. Of the total of 21 articles from both literature reviews, 17 were based on case studies. The articles in the database from the first literature review have case studies located in the United States on both the west and east coasts. In the second literature review, the case studies referred to in the articles that make up the bibliography of "Land-Ocean Interactions in the Coastal Zone: Past, Present & Future" are mainly located in Europe both in the north and the south, and in some sporadic cases in countries on the Indian and the Pacific oceans.
As already indicated, the papers selected from both literature reviews come from different research fields. In the first literature review, which originated from the open source database, the most common fields are bio-geosciences and marine environment.
For the LOICZ "bibliography" literature review, on the other hand, the journals tend to be about the marine environment and Estuarine, Coastal and Shelf Science, Environmental sustainability and Anthropocene.
However, due to the complexity of the theme, I was able to collect a heterogeneous selection of papers, which proved very useful to adding to the current body of knowledge about land-sea interactions. This mix of research fields aims to enrich the discourse on land-sea interactions, not only by more accurately defining the interaction between land and sea, but also by adding important insight through detailing the human activities that interact with both natural processes and other anthropic activities.

Other important findings were uncovering the positive and negative impacts of the externalities on these interactions, the way pollutants interact with the ecosystem, and the multiple benefits of specific natural elements in coastal areas that can help to counteract the effects of climate change.

Excel table and information collecting
All the information acquired from both literature reviews was collected systematically using two excel files. These files kept track of all the information gleaned from each article.
The excel files were made up of two sections, each divided into columns. One section contained the land-sea interaction information gathered from the literature review and the second section contained the details of the related article.
The composition of the columns of the first section was defined after collecting the information from the first three articles and was structured as follows: activities land, macro sector land, interaction causes, first driver, second driver, interaction consequences, macro sector sea, activities sea. These categories enabled me more clearly to identify the components of land-sea interactions and their functions; the categories are also used to explain the literature review results (2.4.1 and 2.4.2).
The second section contains information regarding each article analysed, as follows: author, article title, journal, year, field, pages (where information was collected), case study and the location.
For example, in this article's extract, "Anthropogenic effects in the nearshore marine environment are direct (e.g. commercial fishing) and indirect (e.g. excessive nutrients in agricultural run-off or leaching from septic systems affecting coastal water quality) and can often be driven by land-based processes" (Toft et al., 2014), I identified three different land-sea interactions: fishing impacting marine and coastal waters and ecosystems; agriculture affecting marine water quality; and sewage systems affecting marine water quality. The article also provides information about direct and indirect land-sea interactions. All the information collected was logged in the appropriate columns.



Land							Sea
Activities	**Macro sector**	**Interaction cause**	**First driver**	**Second driver**	**Interaction consequence**	**Macro sector**	**Activities**
	Agriculture	Pollutions (N + P)	River		Habitats loss, biodiversity loss	Marine ecosystems	
Sewage sources	Urbanization	Sewage pollution	River		Habitats loss, biodiversity loss	Marine ecosystems	
Sewage sources	Industry	Sewage pollution	River		Habitats loss, biodiversity loss	Marine ecosystems	
Dams	Infrastructures	Change hydro morphology	River		Habitats loss, biodiversity loss	Marine ecosystems	
Animal rearing	Agriculture	Pollutions (N + P)	River		Habitats loss, biodiversity loss	Marine ecosystems	
WW treatment plants	Industry	Pollutions	River	Bay	Habitats loss, biodiversity loss economic loss	Aquaculture	
	Urbanization	Pollutions	Surface runoff	Bay	Habitats loss, biodiversity loss economic loss	Sea tourism	
Refineries	Industry	Heavy chemicals Pollution	River	Bay	Habitats loss, biodiversity loss economic loss	Aquaculture	
Harbor	Maritime transport	Pollutions (Chemicals + N + P)	River	Bay	Habitats loss, biodiversity loss economic loss	Aquaculture	
	Inland tourism	Pollutions (N + P)	River	Bay	Habitats loss, biodiversity loss economic loss	Marine ecosystems	

Extract of the first section of the Excel table. The first section contains all the information collected about land-sea interactions and are divided as follows: activities land, macro sector land, interaction causes, first driver, second driver, interaction consequences, macro sector sea, activities sea.

Authors	Title article	Journal	Year	Field	Page	Case study	Coordinate
Xu, H. Et al	The fate of phosphorus in the Yangtze (Changjiang) Estuary, China, under multistressors: Hindsight and forecast	Estuarine, Coastal and Shelf Science	2015	Estuarine, Coastal and Shelf Science	1 1 3 5	Yangtze River (China)	31.735650 121.123524
Sekovski, I. Et al	Megacities in the coastal zone: Using a driver pressure-state-impact-response framework to address complex environmental problems	Estuarine, Coastal and Shelf Science	2012	Estuarine, Coastal and Shelf Science	1 2 3 4 5 6		

Extract of the second section of the Excel table. The second section contains information regarding each article analysed, as follows: author, article title, journal, year, field, pages, case study and coordinate of the case.

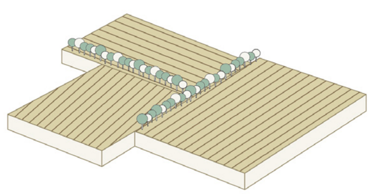
2.4.1 The database literature review

The majority of the papers analysed from the database literature review were based on case studies in the United States; from the northern part, close to the border with Canada in the state of Washington, going south along the California coast (the Santa Barbara channel, Santa Cruz, Monterey) to the east side from the New Jersey coast, bay of Chesapeake between Maryland and Virginia, the Biscayne bay, the southern part of Florida and ending in the Gulf of Mexico from Tampa bay in Florida and the Caloosahatchee river estuary to the Mississippi river. All these coastal areas are characterised as being densely urbanized and under constant pressure from anthropic activity.
In the following paragraph, I will make a summary of the different land-sea interactions according to their composition, the sectors involved, the different roles of watersheds and rivers, the implications of dense urbanization, the role of natural elements and climate change events.

Macro sectors and activities
For the sake of clarity, I chose to adopt the following classifications, as explained below.

One of the common threads that ran through all the analysed papers was the way that authors recognised macro sectors and (human) activities on both land and at sea. More specifically, the prevailing assumption seems to be that, for the majority of the cases, the interaction flows between land and sea are generated from inland human activities. How these activities are impacting coasts and marine ecosystems was also clearly described.
The macro sectors identified as inland are agriculture, industry and urbanization; the maritime macro sectors are the marine ecosystems, fishing, aquaculture and tourism. Here, I need to clarify a few things about the macro sectors: for example, with agriculture, I am referring to a specific typology of intensive agricultural practices that aim to maximize yields through the heavy use of pesticides and chemical fertilizers; with urbanization, I am referring to a vector of many human activities and distinct

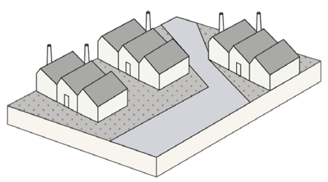
dynamics.
Clarification is also needed for the marine ecosystem, by which I mean a community of living organisms in conjunction with the non-living components of their environment, interacting as a system.
For some of these macro sectors I was able to identify precise sub activities.
For example, in agriculture, one sub activity is the branch concerned with raising animals intensively for meat, milk, eggs, and other products.
For the industry macro sector, the only activity identified in the review that produced any interactions was running wastewater treatment plants.
In the review, urbanization was referred to more generally as a macro sector. The only activity mentioned was sewage source systems.
In the maritime macro sector, marine ecosystems were mostly referred to in a general way, and only in a few studies were fish nurseries and spawning specified as distinct activities.
The fishing macro sector covers commercial fishing.
Aquaculture macro sectors include shellfish and bivalve farming.
The tourism activities are recreational fishing, boating and other water activities.



AGRICULTURE
From the literature review, it emerged that the agricultural sector is one of the most likely generators of interaction. Although agricultural activities can be located far inside a coastal area, the pollutants (nutrients and fertilizers) that are discharged can reach the sea, impacting negatively on both the marine ecosystem and human activities situated in and/or on the sea.
An example of this is the case of the Mississippi River in an article by Hurst, White and Baustian, 2016. The case describes the effects of adopting only a short term view of agricultural development, which resulted in the destruction of almost 80% of the bottomland hardwood forests on land adjoining the Mississippi River. Despite the positive effect that bottomland hardwood forests could have had on nutrient removal, the decision was made to chop them down and to convert the land into agricultural fields. This change in land use consequently increased the discharge of NO3 (nitrates) into the Gulf of Mexico (Hurst, White and Baustian, 2016).

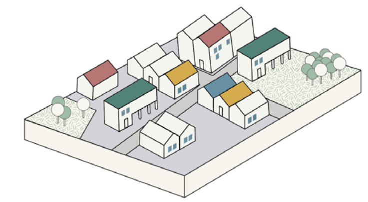
Overexploitation of agricultural fields and intensive production can lead to waterways transporting not only freshwater, but also a range of anthropogenic chemicals (Swart et al., 2013) into the sea. In another case study, located on the east side of Florida facing the Atlantic Ocean, researchers showed how agriculture and the needs of urbanization seriously affected the watershed of the St. Lucie Estuary; modifying the natural wetlands system into a series of sub-basins created changes in flow, salinity, and water quality by increasing the amount of algae blooms (Buzzelli et al., 2013; Sime, 2005).
The sub activity of raising animals in the agricultural macro sector discharges large amounts of pollution and is therefore also a generator of interactions. All too frequently, mixed pollutants from machinery, nitrogen loads, phosphorus loads and nitrates are released into local water systems.
A case illustrating this is the paper by Kinney and Valiela (from Ryther, 1954), who reported on duck farms that dumped nitrogen pollution in Moriches Bay (on the New York coast). The paper showed how high quantities of nitrogen in the bay generated eutrophication which induced an excessive growth of algae (Kinney and Valiela, 2011).
Despite this, there are also examples among the articles which show marine ecosystems functioning as cleaners of nitrogen entering the bay, as in the Feng article. This paper describes how the nitrogen disappeared as a result of natural denitrification and fishing harvests, with the residue being transported out into the open sea (Feng et al., 2015).
From these studies, it is clear how intensive agriculture and farming production generate pollutants that can contaminate the flow of watersheds, rivers, creeks, wetlands, lagoons and therefore affect marine ecosystem

cycles.
The consequences of this, apart from polluting the marine environment, have led to eutrophication, decreasing quality of water and loss of biodiversity directly affecting spawning and nursery mechanisms. At the same time, such pollution affects anthropic sectors based on the sea, such as tourism (recreational fishing), commercial fishing, and aquaculture activities, as these are based on the biodiversity and quality of water in the marine environment (Hurst, White and Baustian, 2016).



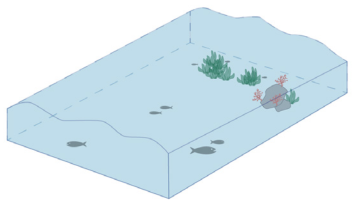
INDUSTRY
Another prominent sector that generates interactions on coastal areas in a number of ways is industry. However, industry differs from agriculture, where pollutants typically derive from across a wide area; in the industrial sector, interactions tend to have taken place in a more precise location and the source of contaminants is more easily identifiable (Samhouri and Levin, 2012). Therefore, it is easier to pinpoint more exactly where industrial pollution – direct or indirect - originates.
As many industrial areas have a high percentage of impervious surfaces, sometimes up to 75% (Kinney and Valiela, 2011), if the area is located close to a river or a coastal area, it will increase the chances of pollutants entering the water system as the result of indirect surface runoff.
Samhouri and Levin’s case study of Puget Sound, in Washington state, demonstrates the increasing level of risk associated with industrial toxic contaminant loadings, leading to the loss of several species of fish, including pacific herring and canary rockfish, as well as the dungeness crab and a number of marine mammals (Samhouri and Levin, 2012).
According to Kinney and Valiela, it has been recognised that one of the most invasive activities in the industry macro sector are the wastewater treatment plants. From their study on the Great South Bay, on the New York coast, it appears that wastewater treatment plants are directly responsible for dumping large amounts of nitrogen into watersheds and consequently into the sea

(Kinney and Valiela, 2011), leading to a significant loss of water quality.

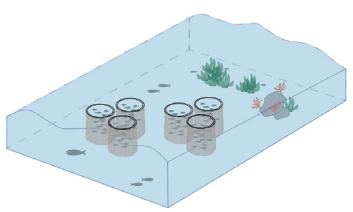


URBANIZATION
The third macro sector located on land that is described in the literature review is urbanization. As I have already indicated, it is not considered to be a ‘sector’ as such, because coastal urbanization is seen to play a number of different roles in the discourse on land-sea interactions. The continuous exponential growth of coastal cities has led to a series of problems related to land-sea interactions. Cities are expanding rapidly and the number of people who live in them is densifying, leading to an increase in the drainage of the sewage systems into river basins and consequently into the sea.
Another problem with the densification of cities is the subsequent loss of urban green spaces, which has led to an increase in the percentage of imperviousness in those areas. The expanding number of impervious surfaces increases the pollutants runoff into rivers and their catchment areas; furthermore, this type of city has a reduced ability to react quickly to the effects of climatic change, making it much less resilient (Drupp et al., 2011). The constant expansion of cities leads to an exploitation of natural resources and deforestation of adjacent areas. The main consequence is a decreased capacity for retaining the extra nitrogen produced by human activities (Valiela et al., 1997). Some of the studies in the literature review regarded sewage sources as the major pollution source (sub activity) when talking about urbanization.
In his paper, Miller outlines the close relationship between urbanization and the environmental loading of faecal sewage. According to Miller, this externality can affect the quality of coastal waters, coastal habitats and biodiversity. At the same time, he considers sewage pollution to function in a way that somehow defines the borders of these specific interactions. More precisely, the study explains how there is a lower risk of sewage pollution if sites are more than 5 km away from sea, and pollution increases dramatically if sites are less than 5 km away the sea (Miller et al., 2006).

It appears from the literature review that the role of urbanization is multi-faceted and can be regarded as a hotspot for generating interactions, because a multitude of dynamics shape urbanization, such as the expansion of some coastal regions and their boundaries, for economic, tourism or commercial or productive purposes. These dynamics increase the pressure on coastal environments resulting from human activity that affects other linked activities and priority habitats.



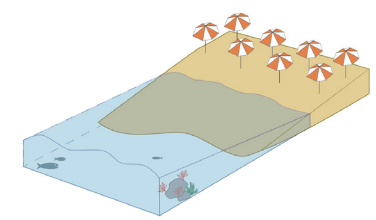
MARINE ECOSYSTEMS
The macro sector identified as marine ecosystems is clearly not an economic sector in itself, but it is under serious threat from human activities both on land and on or in the sea. In most of the cases in the articles, marine ecosystems were referred to in a general sense; only in a few of the papers were the components of the interaction marine ecosystem specified as consisting of fish nurseries and spawning.
For example, Samhouri and Levin, in their case study research on the Puget Sound on the north-west coast of the United States, discovered that some fish species that relied heavily upon the nearshore for as their nursery or spawning habitat were expected to experience serious adverse effects from coastal developments and human activities (Samhouri and Levin, 2012). Similar observations were made by Hurst, White and Baustian in their research on the Gulf of Mexico, in which over-contamination of organic matter in the Gulf of Mexico impacted on spawning and migration habitats, affecting the benthos and having repercussions for some human activities that take place on the gulf, such as recreational and commercial fishing (Hurst, White and Baustian, 2016).



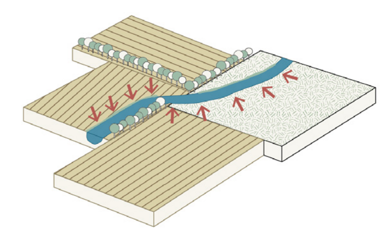
FISHING and AQUACULTURE
Other macro sectors located at sea are fishing and aquaculture.
Some activities related to these macro sectors have also been identified including commercial fishing, and shellfish and bivalve farming.
These activities are threatened by the same sources of

pollution produced inland from human activities. One of the rare cases of interaction occurring from the sea to the land described in the literature analysed comes from intensive aquaculture production, which uses antibiotics to maximize production.
These antibiotics can affect the quality of coastal waters, which contain coastal priority habitats (places where fish spawn or nurse), thereby creating a conflict situation vis-á-vis coastal tourist activities.

According to the case study analysed by Samhouri and Levin, which focused on diverse human activities on coasts (such as coastal developments, industry and residential land use), these activities could lead to adverse consequences on the ecosystem components in the case study area and on fishing activities (Samhouri and Levin, 2012). Toft's paper describes how anthropogenic pressure affects marine environments both directly (from tourism and industrial activities) and indirectly (from agriculture and industrial activities) and how such pressure usually originates inland (Toft et al., 2014).

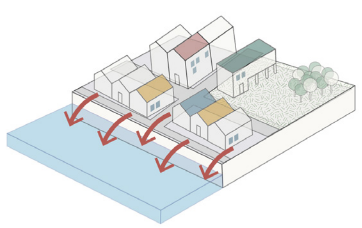


TOURISM
The activities found in the literature that make up the sea tourism sector are recreational fishing, sailing and water sports. All of these activities are in some way dependent on water quality. Therefore, similarly to the land-based anthropic activities, such as agriculture, industry and operating harbours, that interact with the marine environment, the sea tourism sector pressures on ecosystems and priority habitats (Samhouri and Levin, 2012).



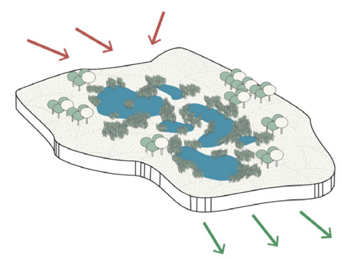
Role of WATERSHEDS and RIVERS
All the articles analysed clearly describe the crucial role that streams and bodies of water have in the land-sea interactions discourse as drivers of contaminants discharged from anthropic inland activities.
Moreover, water streams, or watersheds, constitute the land feature where water networks converge and where most human activities, such as agriculture, urbanization

and industrial areas, are located; this is why watersheds are the 'motorway' for the flow of pollutants from land to sea.
Watersheds and rivers do not, however, always cause pollutants and nutrients to flow into the sea, which does not mean that they become unimportant, but rather that the situation is more complex and dependent on a great many different factors. In a case study of the Baltic Sea carried out by Winder et al., the land-sea patterns produced by watersheds changed considerably depending on the use of the area. In the case study, the quantity of nutrients found in the northern part of the Baltic Sea was lower than that in the south, since the south is an area that is dominated by agriculture (Winder et al., 2017).
Other studies have also shown that watersheds and rivers can retain nitrogen and pollutants generated inland, but that often they are overwhelmed by excessive pressure from anthropic activities. Several papers pointed out that significant increases in nutrient and pollutant transportation from land to sea have been caused by human activities ever since pre-industrial times (Regnier et al., 2013; Ren et al., 2016).
This makes it possible to identify areas that have specific characteristics, such as very intensive agriculture or densely urbanized areas adjacent to rivers, which make them prime candidates for creating an interaction between land and sea. At the same time, we can never be 100% certain, for this reason, it is useful to utilise instruments, such as buoy systems, to monitor autonomous water quality in bays close to estuaries (Drupp et al., 2011).



Role of dense URBANIZATION
Urbanized areas and coastal cities are not only responsible for producing human activities; densely urbanized coastal cities also tend to have a higher percentage of impervious areas, which is why they have a similar role as rivers. A highly impervious area will increase surface runoff, resulting in urbanized areas functioning as drivers for moving pollutants to

rivers and/or into groundwater after rainfall events. Impervious areas in cities located on the coast can even cause a direct discharge of pollutants into the sea. For example, according to Feng's model, "Chesapeake Bay nitrogen fluxes derived from a land-estuarine ocean biogeochemical modelling system: Model description, evaluation, and nitrogen budgets", urbanized areas producing surface runoff after rainfall events increase substantially the amount of pollution transported to the sea (Feng et al., 2015). The situation resulting from these highly impervious cities and the surface runoff events that they generate is also exacerbated by the growing number of climate change events that has led to a sharp rise in interactions related to surface runoff.



Role of NATURAL ELEMENTS
One of the most interesting observations from the literature review is the crucial role played by some of the natural elements present in coastal areas. These elements, such as marshes, wetlands and lagoons, make up some of the world's most productive land-sea transitional ecosystems and are an important source of fish and aquaculture production, providing at least 40% by value of the world's ecosystem services (Winder et al., 2017).
At the same time, these natural elements have a double role in the discourse on land-sea interactions, namely retention and cleaning. From several of the papers in the literature review, it appears that these natural elements have an important role in the reduction of pollutants generated from human activities and deposited into the sea (Hurst, White and Baustian, 2016; Kinney and Valiela, 2011; Ren et al., 2016). If we take a closer look at coastal areas, we can see that, besides salt marshes and fresh and salt wetlands, bottomland hardwood forests, forests and green cover in general also function as natural basins helping to retain and clean pollutants. In addition, some of these elements can work to counteract climate change events. For example, according to Costanza: " Coastal wetlands function as valuable, self-maintaining "horizontal levees" for storm protection, and also provide a host of

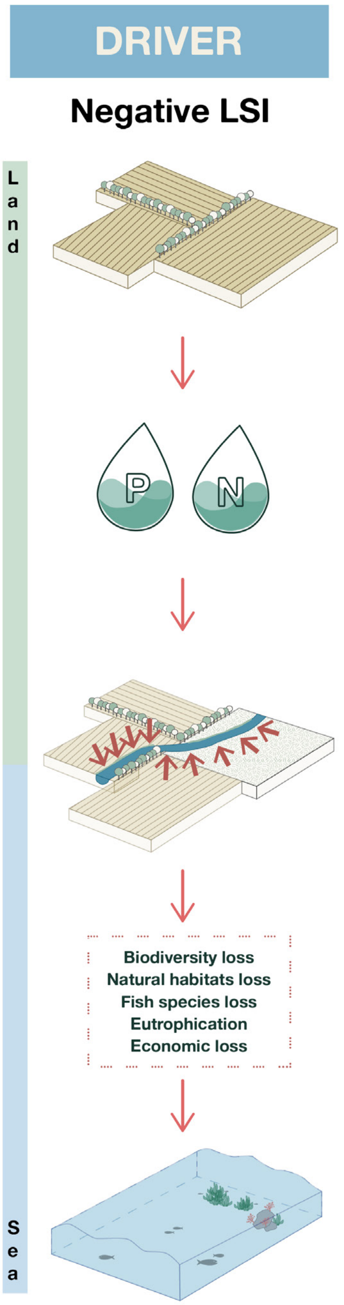
other ecosystem services that vertical levees do not" (Costanza et al. 2008).

These natural elements in the environment are part of the complex patchwork of systems which also include anthropic activities and urbanized areas. According to Hurst et al., their role in, for example, reducing nitrates (NO3), has long been recognized. This is the case with the Mississippi River, where bottomland hardwood forests located along the river and its tributaries were instrumental in reducing nitrate deposits into the Gulf of Mexico (Hurst, White and Baustian, 2016). However, even though the bottomland hardwood forests had a positive impact on nutrient removal, they were replaced by new field crops because of growing pressure from the agricultural sector. Historically, the forests on the flood plain of the Mississippi River have played a significant role in reducing nitrates during spring flooding events, since the types of soil associated with these forests tend to have higher denitrification rates than agricultural land. Nowadays, however, the water carried by the river flows directly into the Gulf of Mexico, transporting an enormous quantity of building sediment, nutrients and pollutants straight into the sea (Ullah et al., 2005; Lindau et al., 2008; Hurst, White and Baustian, 2016). These natural elements, therefore, have multiple roles and are crucial to keeping our coastal environments healthy have multiple roles and are crucial to keeping our coastal environments healthy. As the exponential growth of coastal cities continues to be at the expense of natural habitats, it is clear, as Kinney and Valiela point out, that we need to take steps to preserve the natural environment, such as forests, marshes and wetlands, in order to increase the capacity of watersheds to retain nitrogen (Kinney and Valiela, 2011) and so conserve these important areas of biodiversity. The continuous exploitation of natural coastal elements for production purposes and the transformation of coastal sites into new urban areas will have the effect of making the environment much more impervious. These changes will adversely affect the land-sea interaction dynamics by increasing the surface runoff of pollutants; at the same

time, it will become increasingly difficult to recover these areas and reduce their capacity to counteract extreme climate events.
These studies show how important it is to preserve these natural elements that are so crucial for ensuring positive land-sea interactions and addressing climate change challenges. According to Hurst's research on the Mississippi, it is vital that we not only preserve, but also restore many natural elements if we are to reduce externalities caused by human activity (Hurst, White and Baustian, 2016).

Role of CLIMATE CHANGE

Several studies in the literature review describe the profound effects that climate change has had on coastal areas and land-sea interactions.
It has been recognized that "coastal habitats are affected by a changing climate from both terrestrial and marine sources" (Nicholls et al., 2007; Rosenzweig et al., 2007; Toft et al., 2014), and that this occurs in different ways depending on the climate change-related event. Coastal areas and their hinterlands are being affected by climate change events as a result of the general increase in temperature that leads to heat island events and an increasing amount and frequency of heavy precipitation. These extreme events are producing significant changes in the soil moisture, the hydrology network, the runoff from watersheds and the salinity of estuaries.
From the marine side, the major short-term threats are the increasing number of coastal storm surges, the rising effect of coastal erosion and coastal flooding. From a longer term perspective, changes in sea level, saltwater intrusion and the warming up of the sea all present potential dangers (Toft et al., 2014).
These extreme events in coastal areas can have direct and indirect effects on the interactions between land and sea, and in general, they tend to exacerbate the effects of externalities on interactions. Therefore, in the discourse on land-sea interactions, climate change is seen to play a role as an external driver that increases both the number and magnitude of such interactions. As noted



Interaction resulted from LOICZ Literature Review.
Harbor (maritime transport) > pollutions (chemicals+N+P) > lagoon > fish species loss and drcrease in catches > fishery

above, natural elements in coastal areas have a dual role in building more resilient coastal landscapes: firstly, by reducing the externalities of human activity on the environment, and secondly, by counteracting some of the extreme climate events, such as coastal flooding, erosion, storm surges and saltwater intrusion.

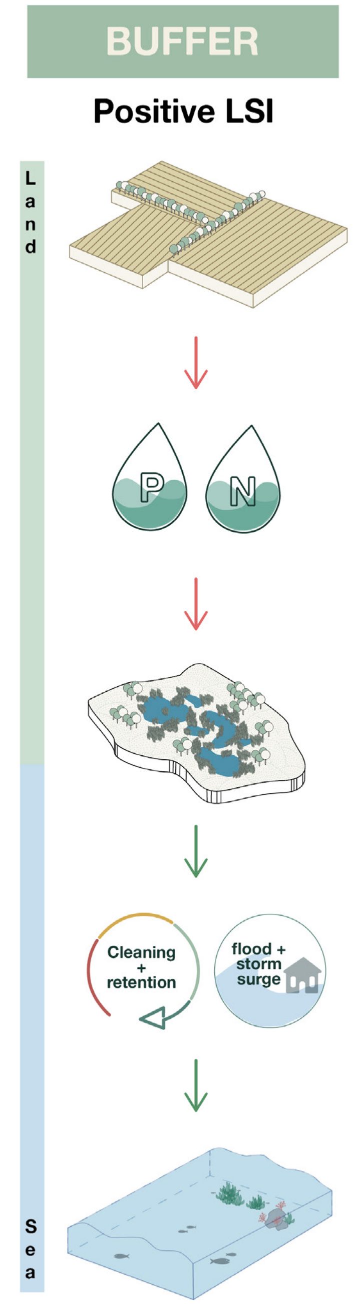
Positive/negative and direct/indirect LAND-SEA INTERACTIONS
From the literature review, it appears that the discourse on land-sea interactions has its own distinct structure and hierarchy in the spatialization of these areas.

These interactions are generated by human activity and not by natural processes; in fact, natural processes exist with or without the interference of any human activity, with human activity generating externalities that interact with natural processes.
From the literature, I could identify both the land and sea macro-economic sectors and sub activities that are the generators of these interactions.
Regarding the macro sectors and activities at sea, similarities can be noted with the uses (activities) identified in Maritime Spatial Planning (MSP). The sub activities and, more generally, the macro sector need a catalyst to activate the process of interaction between land and sea; from the literature, these catalysts can be identified in watersheds, individual rivers and creeks. The literature also describes another anthropic element that acts as a conductor: surface runoff, which is the anthropic transporter of pollutants, indirectly via the hydrographic networks or directly into the sea, as is typical of coastal cities. Surface runoff, as already described, is an externality of the densification of urbanized areas and the subsequent increased waterproofing of the soil.

Anthropic activities interact with both land and sea, impacting natural processes to an extent that then creates situations of conflict with other anthropic activities.
A classic example of this kind of conflict is the intensive production of field crops, where the excessive use

of chemicals and fertilizers often results in discharge of these substances into watersheds, groundwater and rivers. The watersheds are unable to absorb and metabolize all the released substances and therefore transport the pollutants to the sea, contaminating the marine ecosystems. This adversely affects natural processes and at the same time is in conflict with aquaculture activities or recreational water activities in that area. From these examples, we can see that the majority of the interactions have some kind of pollution component which affects the quality of the natural environment and impacts on other activities.

From the literature, it is clear that a great many natural elements play an important role in maintaining a balance between externalities produced by human activity and natural processes. These natural elements perform a number of functions in reducing the quantity of pollutants; they may therefore provide a remedy to some of the effects of climate change. Natural elements can reduce the impact of extreme events in coastal areas; at the same time, they are typically areas of high environmental value, with exceptional biodiversity and landscape significance.
Consequently, it is clear that far greater efforts are needed to preserve and protect these elements.



Positive interaction resulted from LOICZ Literature Review.
Agriculture > pollutions (N+P) > wetlands > cleaning and retention + counteract flood and storm surge > marine ecosystem

2.4.2 From the LOICZ literature review

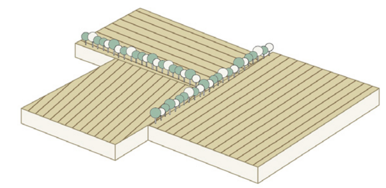
The second literature review was more oriented towards the theme of land-sea interactions, but the results generally confirmed the conclusions from the first review and served to contribute more detail for the framework of knowledge.
The literature review based on the articles selected from the bibliography of Land–Ocean Interactions in the Coastal Zone: Past, present & future paper provides a more comprehensive perspective on the theme of land-sea interactions. As such, the material analysed enhanced my knowledge on the topic in a number of ways. For example, the information collected in this review added significantly to the material on macro sectors and activities that take place around land-sea interactions. On land, in addition to agriculture, industry and urbanization, these included tourism, maritime transport and infrastructure and their activities.
Two new sectors located at sea were introduced in the second review: maritime transport and coastal ecosystems, besides the previously mentioned marine ecosystems, aquaculture, fishing and tourism. The sub activities at sea were the same as in the first review.

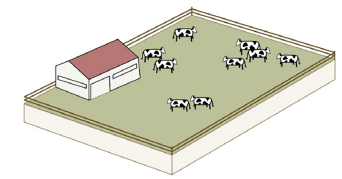
The papers analysed in this review were made up partly of studies looking at general theories on land-sea interaction and partly of land-sea interaction case studies; these case studies served to inform and enhance the more theoretical side of the discussion.
One of the papers, “An overview of ecological status, vulnerability and future perspectives of European large shallow, semi-enclosed coastal systems, lagoons and transitional waters” (Newton et al., 2014), contained an enormous amount of information and focused on the types of natural elements that I highlighted in the previous review. The article was based on 17 case studies located from northern to southern Europe and including almost all the European seas.

In the following paragraphs, I will go through what the second literature review says about the different sectors, sub activities and their interactions with the land and the sea, and about the respective roles of water streams, natural elements and climate change.

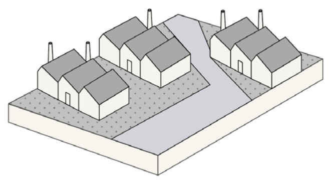
Complexity of the COASTALSCAPE
1st Key Milestone
DESIGN for COASTALSCAPE

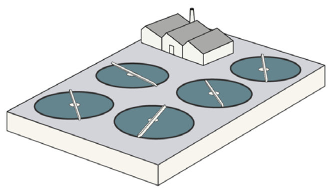
AGRICULTURE





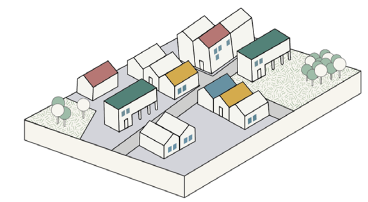
As described in the first literature review, the agricultural sector, more precisely intensive agriculture production, is one of the main generators of land-sea interactions.
As we have seen, a small amount of nutrients, primarily nitrogen and phosphorus, are vital for maintaining a healthy marine ecosystem, but an oversupply of nutrients can cause eutrophication in estuaries and bays (Xu et al., 2015), because marine ecosystems are also under considerable pressure from many other anthropic activities.
Similar case studies such as that of the Mississippi river (shown in the previous literature review) can also be found in Europe; many productive European coastal areas have changed their boundaries to expand agricultural fields, taking over wetlands and other natural habitats that have important roles for balancing the adverse effects of anthropic activity in these coastal areas.
According to Newton et al, the agricultural sector is putting enormous pressure on European semi-enclosed coastal systems, including lagoons and transitional waters (Newton et al., 2014).
It is clear that intensive animal production, for example pig and poultry farming, also results in increased quantities of nutrients and chemicals being deposited in river basins and coastal waters (Newton et al., 2014).
In the United States and in European seas, one of the common problems caused by intensive agriculture and animal production is the eutrophication syndrome, i.e. the processing of organic matter and sewage (Newton, Carruthers and Icely, 2012).
What is apparent from the review is that marine ecosystems are closely interconnected through biogeochemical cycles. These ecosystems can be affected directly from anthropic activities that are located on the coast or away from it, but in both cases, the result is loss of habitat and biodiversity (Patterson and Glavovic, 2013).

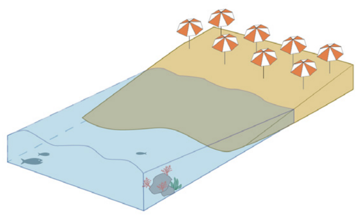




INDUSTRY
A number of other sub activities were identified in the review as being associated with the industrial sector. Broadly speaking, the industrial sector has a number of negative externalities caused by wastewater, chemicals, metal and organic pollution that impact on coastal and marine environments. There are several studies that have analysed coastal megacities all over the world that lack minimal infrastructure, such as wastewater treatment plants, with the consequence that faeces and pollutants are discharged directly into the sea (Newton, Carruthers and Icely, 2012).
The activities identified through this second review are industrial processes such as food, paper, chemical industries, power generation and refineries.
For example, food and paper production can direct result in eutrophication from the discharge of nutrient and organic matter into watersheds or directly into the sea (Newton et al., 2014).
Newton's case studies show that many lagoon and wetlands are threatened by human activity, for example, by industries in Porto Maghera, near Venice, the industrial complexes near Marismas de Odiel in Spain and the industries centred on Aveiro in Portugal. In most cases, it is the factories that generate interactions with other ecosystems and activities.
Newton's case study in Etang de Berre, on the Mediterranean coast of France, also describes the power plant activity that produces direct externalities by altering the temperature of sea, also called thermal pollution, changing the salinity and resulting in loss of fish species and fishing activities (Newton et al., 2014). Last but not least, according to Sekovski, Newton and Dennison's article, some land-based industrial activities (such as refineries and municipal waste processing plants) have a negative effect on coastal and marine habitats through accidental discharges (Sekovski, Newton and Dennison, 2012).

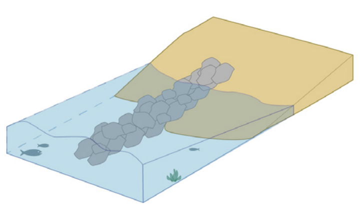
URBANIZATION
Coastal urbanization also plays a significant role in land-sea interaction. Coastal cities around the world are growing and expanding and therefore continually need new land into which to expand their borders. Rivers, deltas, forest clearings, wetlands, salt marshes, mangroves and seagrass meadows are all threatened by this exponential growth, which is often implicated in the destruction of important coastal habitats (Sekovski, Newton and Dennison, 2012).
The expansion of cities is directly proportional to the loss of habitat and biodiversity around these cities, and the degradation of water quality on their coasts (Sekovski, Newton and Dennison, 2012). This type of city is densely urbanized and highly populated; consequently the increase in pavements and asphalt areas produces a more impervious environment that is unable to retain and slow down the runoff of pollutants, exacerbates the effects of flood events and fails to maintain the balance and capacity of watersheds (Sekovski, Newton and Dennison, 2012). Furthermore, in these critical events, this reduced drainage capacity increases the likelihood of overwhelming sewage systems, leading to potential catastrophe and more pollutants being deposited into the sea.
In poorer overpopulated coastal regions, such as in India and Bangladesh, many priority habitats such as mangroves are exploited for charcoal, fuel wood and salt production, threatening the estuarine environment, which is also a resource for other anthropic activities such as fishing and tourism (Kiwango, Njau and Wolanski, 2015).
Apart from very poor coastal regions, the coast remains one of the most attractive areas for economic growth.
In general, developing resorts and marinas for tourism purposes results in an overexploitation of coastlines; this not only endangers inland priority habitats, such as wetlands, marshes and lagoons, but also affects marine habitats like seagrass meadows, which are essential for the spawning and nursery activities of many types of fish, with a consequent loss of biodiversity and possible adverse repercussions for the fishing industry (Newton et al., 2014).





TOURISM

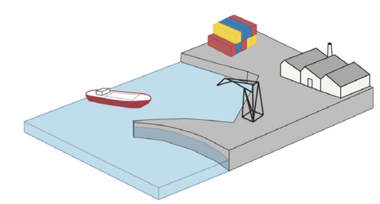
The tourism sector is closely interconnected with natural resources and with the inherent attractiveness of natural landscapes. However, if the massive growth in tourism in coastal cities and areas is not well managed, it will inevitably lead to a deterioration of resources, habitats and coastal landscapes.
Tourism has a direct and indirect impact on the environment, affecting, for example, priority habitats and leading to a loss in biodiversity, primarily due to land reclamation in coastal zones used to build tourist resorts, marinas, beaches and even airports (Sekovski, Newton and Dennison, 2012; Newton et al., 2014).
Another aspect of the tourism sector that adversely impacts on the environment is the seasonal peak in population size that leads to an increased production of waste, overburdening urban wastewater treatment plants and leading to increased stress on sewage disposal systems that can cause severe problems in coastal areas (Newton et al., 2014).
Tourism puts direct pressure on a city's infrastructure and on natural systems. The coastal and sea tourism sectors include a wide range of different activities like recreational fishing, sailing, water sports and ecotourism that, if not well regulated, can directly increase the pressure on marine ecosystems. The growth of boat transportation and water recreational activities also increases levels of pollution, contributing to the destruction of numerous habitats (Newton et al., 2014).



INFRASTRUCTURE

From this second literature review, a new sector connected with urbanization was identified: infrastructure. When cities and territories growing and expand their boundaries, they exploit areas all along the coast; to protect these new urbanized areas, it is often necessary to build dams and dykes. These types of constructions are typically made with hard surfaces, which have a profound impact on the hydro-morphology, leading to a number of changes in the sedimentation process, an increase in the amount of pollutants deposited in rivers,

changes in water flux that increase coastal erosion, and impacting on natural processes such as the migration of eels, salmon and trout for spawning (Newton et al., 2014).
Generally, human activity requires the constant construction of infrastructures such as irrigation channels in agricultural fields, and dykes, dams, road networks, highways, airports and harbours. These infrastructures change the landscape dramatically, albeit with the aim of improving conditions for the city's population, but at the same time, by disrupting ecological corridors, natural streams and sediment flows in coastal areas, they cause a lot of environmental problems (Sekovski, Newton and Dennison, 2012).
Other types of infrastructure, such as dams, breakwaters and seawalls, are located in coastal zones, and according to Xu, since they are built specifically on the shore or in the sea, they contribute significantly to changing sea-currents by altering marine natural processes (Xu et al., 2015).



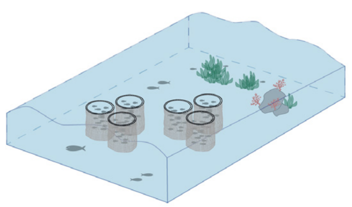
MARITIME TRANSPORT

Another new sector identified from the second review is maritime transport.
This is a strategic economic sector worth billions, but at the same time one that has an enormous impact on the environment and natural ecosystems.
The main area of activity for maritime transport is harbours, mainly because of their key roles in the network between land and sea and their strategic locations on coasts. For these reasons, the harbour can be identified as a potential hotspot of interaction.
Many inland industrial activities are closely linked to collateral harbour activities such as refineries, chemical production etc. Similarly, maritime activities as energy plants and hydrocarbon platforms are also linked with harbours. All these activities create a network because of all goods moving from land to sea and vice versa through the harbour.
From the literature review analysis, it is clear that harbours put an enormous amount of pressure on the environment, from pollutant discharges, oil spills and the introduction of

alien species through ballast water discharges that cause the proliferation of algal blooms and subsequent loss of habitats (Wolanski, 2006). Oil spills are mainly caused by accidental discharges from ships inside the harbour or outside in the landing zones (Sekovski, Newton and Dennison, 2012).

In European coastal areas, there is a high risk of producing externalities when estuaries are turned into harbours, by constructing navigational channels or straightening, widening and dredging existing ones to provide passage for big ships. These developments result in hydrological and sediment changes and fluxes that impact on different migrational fish species. One example is the lagoon in Venice, where more and more channels are being built, putting ever more pressure on the lagoon's ecosystem.

A very interesting interaction generated by one of the activities in the maritime transport sector is that from ballast water. This is a regular procedure for large cruise ships, tankers and bulk container ships which involves them loading a large amount of water from the place of departure to increase stability and manoeuvrability during transit. This ballast water is then unloaded at the next harbour, and typically contains a variety of biological organisms, including plants, marine species and bacteria. These organisms often include non-native and exotic species that can cause extensive ecological and economic damage to marine ecosystems (Tamburri et al., 2002; Sekovski, Newton and Dennison, 2012).



AQUACULTURE

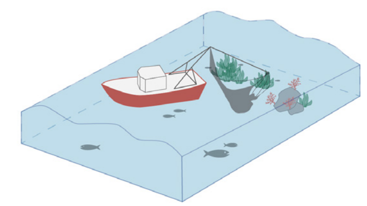
Aquaculture is one of the fastest-growing economic sectors based on anthropic activity located at sea. The sector can be divided into two main sub activities: molluscs and fish farming. The production of aquaculture in the sea is open with water flowing freely through the cages; this openness makes the system vulnerable to external influences. For fish farming to be profitable requires intensive production, with a higher quantity of fish kept in the same cages that need to be fed and given antibiotics. As mentioned above, intensive production

can lead to problems, and the increase in intensive fish farming has been identified as having a negative environmental effect, contributing to, for example, mangrove and wetlands loss.

Intensive production can lead to the introduction and transfer of invasive species, to the spread of parasites and diseases, and to the release of chemicals, nutrients and waste in general (Sekovski, Newton and Dennison, 2012). It produces its own externalities and, together with pressure from other anthropic activity, can result in the loss of coastal and marine habitats such as seagrass meadows, and have direct consequences for lower primary production, reduced sediment stabilization and nutrient traps, and the loss of fish and shellfish nurseries (Orth et al., 2006; Sekovski, Newton and Dennison, 2012).

Several studies from the literature review also highlight the fact that very often pollutants discharged inland can have a detrimental impact on the aquaculture sector, especially fish aquaculture, and lead to economic losses.

With regards to mollusc farming, and more specifically bivalves, several studies have demonstrated that they have an important role in protecting marine ecosystems from pollutants. Furthermore, shellfish farming (molluscs) is considered as a possible way to compensate nutrient loading, which effectively removes nitrogen from the system, thus providing a valuable ecosystem service (Newton et al., 2014).



COASTAL ECOSYSTEMS and FISHERY

In the discourse on land-sea interactions, the fishing sector is indirectly impacted by many inland anthropic activities such as tourism, industry, urbanization and agriculture. The pollution produced from these activities directly affects marine ecosystems by decreasing the environmental quality of the sea with the consequential loss of natural coastal and marine habitats that are the spawning and nursery sites for many species of fish (Newton et al., 2014).

Another consequence of the discharge of chemicals, fertilizers and nutrients is the increasing eutrophication in estuaries. If pollutants spread to coastal waters, this can lead to a loss of desirable fish species and a reduction in harvestable fish and shellfish and can result in significant economic losses (Newton et al., 2014).

Role of WATERSHEDS and RIVERS and NATURAL ELEMENTS

Analysis of the second literature review reveals how the crucial role of watersheds and rivers are closely connected with certain natural elements.
It is widely accepted that watersheds and rivers function as carriers of nutrients, sediments and pollutants generated inland from many different anthropic activities. Problems arise when the water networks reach natural elements located primarily in coastal areas such as marshes, wetlands, lagoons, estuaries, deltas and mangroves. These natural elements shape coastal zones and are recognised as forming an interface between land and sea with a high concentration of bio-diverse and valuable ecological areas providing a variety of ecosystems and avian habitats that are economically important for tourism, agriculture, aquaculture and fishing (Newton et al., 2014; Ramesh et al., 2015).
Glavovic refers to this land-sea interface as the margin, and it is typically composed of wetlands, estuaries and lagoons. The margin also interacts with a huge number of human stressors that have dire consequences, such as the loss of natural resources, overfishing, pollution, eutrophication and hypoxia (Glavovic et al., 2015).
According to the literature, most of these natural elements function as recyclers and retainers in fixing nitrogen and other nutrients discharged into rivers and groundwater (Glavovic et al., 2015); some studies highlight the capacity that these coastal margins have in protecting the coast by counteracting storms and flooding (Ramesh et al., 2015).

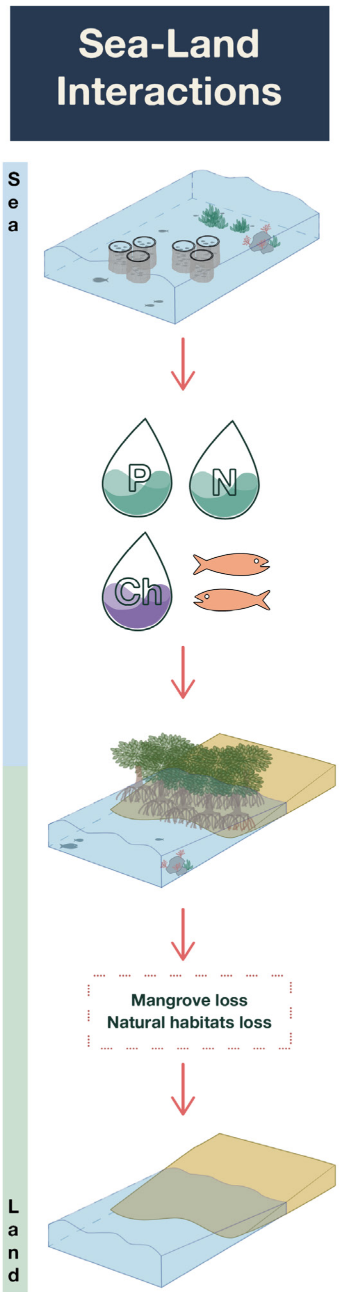
Role of CLIMATE CHANGE

One relevant issue that emerged from the literature review in regard to climate change is the concern that all land-sea interactions and natural processes currently located in coastal area will be exacerbated by climate change (external driver) events. Specific types of coastal areas

such as lagoons, rivers and estuaries are particularly vulnerable to these extreme events. According to Newton: “coastal regions are hotspots of global change and vulnerable to environmental, economic and social pressures, especially when they are associated with river-mouth systems” (Newton et al., 2012).
The increase in sea temperatures can greatly affect the marine environment and its biodiversity, and have a knock-on effect for fishing, aquaculture and tourism activities.
The frequency and increased power of coastal storm surges and flooding will directly affect tourism activities, through the damage they cause to coastal cities’ shorelines. Furthermore, the increase in sea level will present new challenges to many megacities and cities which have been developed below sea level. The myriad ways that the environment has been exploited in order to develop human activities has significantly affected the functionality of coastal ecosystems, and thus made them more vulnerable (Newton et al., 2014) to climate change impact.

What was learnt?

The second literature review has added greatly to the state of the art regarding land-sea interaction by increasing the number and types of interactions both from land and sea.
It is worth noting here that almost all the interactions are generated on land and end up in the sea; only a small percentage are created at sea which then have an effect on the land. In fact, in my research, I found only one sea-land interaction, namely fish farming, which discharged antibiotics and chemicals to stop the spread of parasites and diseases, but which then affected the marine and coastal ecosystems, resulting in significant losses of mangroves (Sekovski, Newton and Dennison, 2012).
These data have allowed me to go into more detail about some interactions and to better understand the dynamics and effects of these areas. More specifically, the research has broadened my knowledge of the range of the types of human activities that interact with coastal areas and their



SEA-LAND Interaction resulted from LOICZ Literature Review. *Fish farming (aquaculture) > pollutions (chemicals+N+P+ invasive species) > mangroves > mangrove and natural habitats losses > coastal and marine ecosystems*

natural processes, and directly or indirectly with other human activities both on land and at sea (Patterson and Glavovic, 2013).
In this review, I have examined important maritime transport activities (e.g. harbour and shipping) whose actions take place on the exact interface between land and sea. At the same time, harbours can be said to involve significant logistical and production components both on land and at sea, creating a land-sea continuum.
As was anticipated, a great deal of information from the articles analysed looked at the role of water basins, rivers and canals as conductors of interactions.
The articles stressed the close relationship between drivers (streams and rivers) and specific natural elements that play a fundamental role in maintaining the balance of nutrients released into nature by human activities.
The natural coastal elements already highlighted in the previous literature review, such as lagoons, estuaries, deltas, marshes and wetlands, are not only recognised for their high environmental value and as biodiversity boosters: these elements also play an essential role in maintaining a balance between nutrients released in nature and pollutants produced from human activities (Patterson and Glavovic, 2013; Newton et al., 2014).
No less important is how these natural elements can contribute to counteracting some types of climatic events affecting coastal areas. Unfortunately, the pressures caused by anthropic activities are proving challenging for these natural environments, which have often been reclaimed in order to widen urban boundaries in coastal areas.
The final point I'd like to mention from this review regards hard infrastructures, such as dams and coastal defence systems, that interact with the environment by altering natural processes in coastal areas (Newton et al., 2014).
With the increased frequency of extreme climatic events, the externalities generated from infrastructures, cities and other anthropic activities can exacerbate land-sea interactions.

2.4.3 A systematic framework of flows

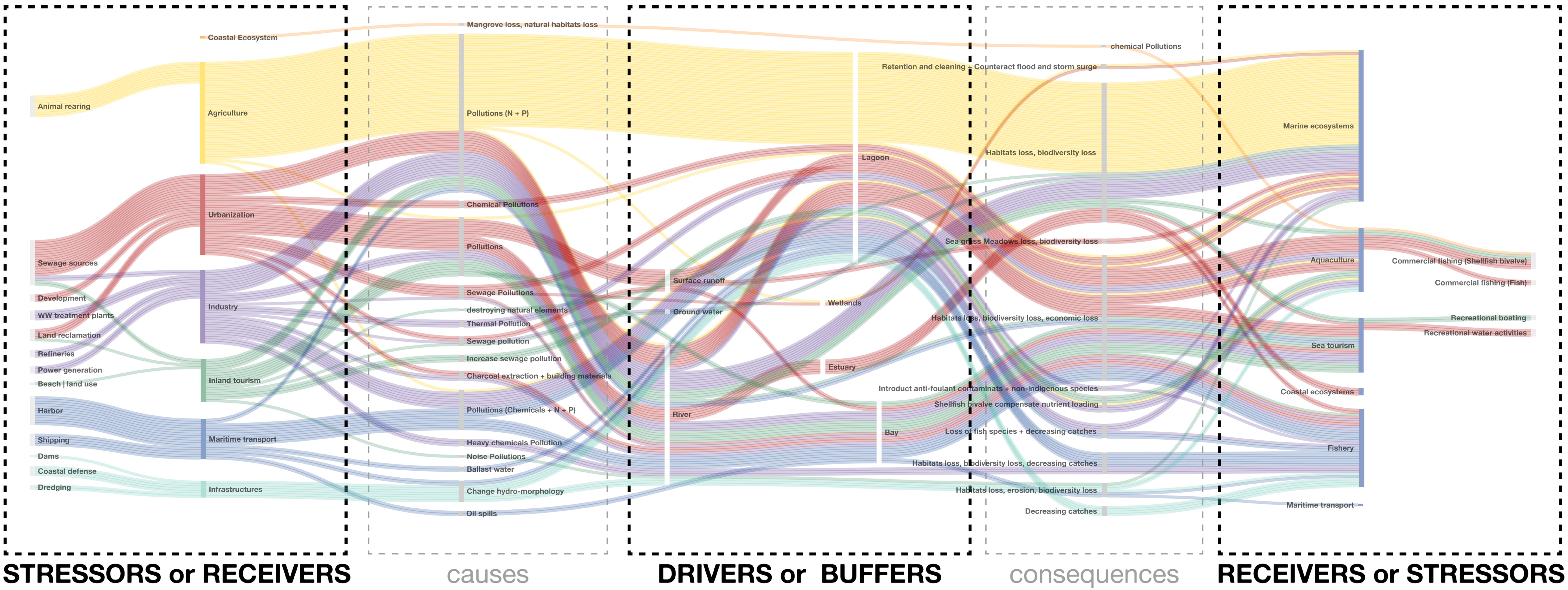
In general, as outlined in chapter *2.3 Gaps in the discourse on land-sea interactions*, there exists a gap between the knowledge generated by research and the application of that knowledge.
For the subject of land-sea interactions, the situation is even more intricate since the theme itself incorporates an enormous number of diverse fields of research, covering marine biology, bio-geosciences, marine ecosystems, microbial ecology, environmental monitoring, aquatic geochemistry, bio-coastal and planning, soil science, marine science, biogeochemical cycles and applied geochemistry.
To be able to understand these diversified fields, the reader needs to have at least a minimal knowledge and understanding of the theme, otherwise it is very difficult to comprehend.
The results and conclusions from academic study appear to be rather inaccessible to practitioners; there seem to be two main reasons for this. First of all, the individual research disciplines involved are very specialized, making it difficult for laypeople who don't have the necessary expert knowledge to access them. Secondly, the information obtained and results generated from these studies have not generally been presented in a clear and visual way. This latter reason is key.
By choosing the right tool - depending on the type of research and the results - the information can be made more visual, and so ease the dissemination of the research.
It will increase accessibility to the research for policymakers and practitioners and will expand outreach to a broader range of audience, depending on the relevance of the topic researched. The visualization of the results thus gives added value to the outcome of the research.
Based on the double literature review, I was able to make a description of the current state of the art of land-sea interaction. Although in the previous two chapters, *2.4.1 From database literature review* and *2.4.2 From LOICZ literature review*, I tried to present the results in as simple

a form as possible, a certain level of complexity for non-specialists remains.

It was therefore crucial that I translate this technical knowledge into a more accessible form. This step is also important so as to be able to systematize all the information acquired and to facilitate the application of this information for the second key milestone.

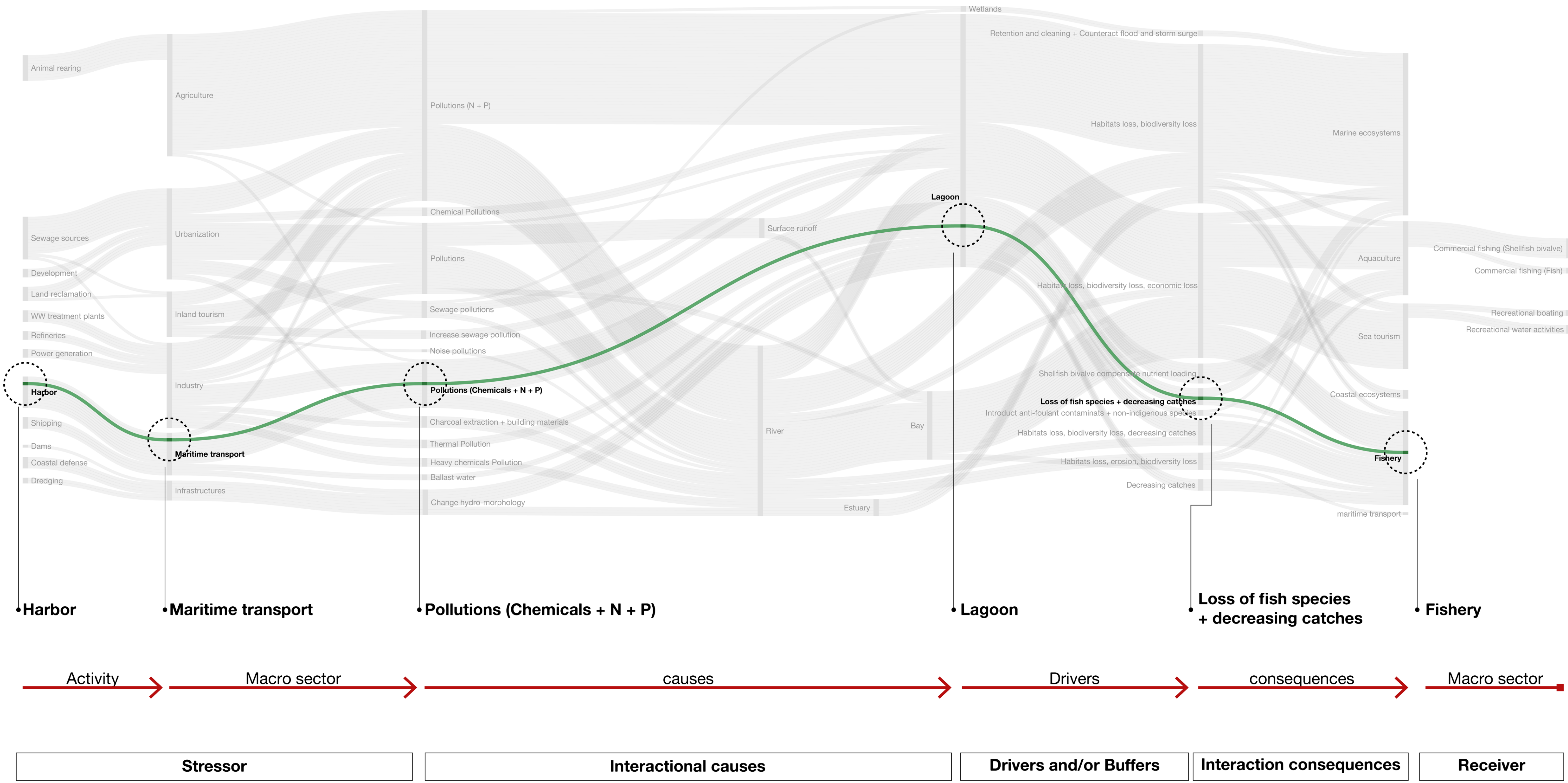
My aim was to add value to the work that had been done, to enable results from land-sea interaction research to be understood by a wider audience. In order to make the knowledge gained more understandable and clear, this step is based on a framework to visualize this knowledge as much as possible.
The main point gleaned from the research is that interactions are like fluxes that can move either from land to sea or vice versa. Based on this simple key piece of information, the initial idea was to convert interactions into a schematic diagram.
However, I needed some kind of tool to help me do this. The idea of disseminating knowledge through visualization already existed before I started my literature review. One of the tools available was the Sankey Matic, which creates a flow diagram used to depict a flow from one set of values to another. The items being connected are called nodes and the connections are called links. Therefore, as I read and analysed the literature review papers, I built a double Excel grid to collect all the information in a systematic and logical form.
For my research, visualization is achieved through several sets of values.
This means that a single land-sea interaction is actually composed of a minimum of four to six or eight sets of values, depending on the complexity of the interaction.
This type of diagram helps to conceptualize the interactions, its structure visually constructing the coastal area with one end of the diagram representing the land and the other end the sea.
The representation made by the Sankey Matic tool has three main purposes: one, to present each single interaction in a simple and intelligible form; two, to interpret in a unequivocal way the composition of and the externalities provoked from an interaction; and third, to be able to comprehend the complexity of coastal zones through a clear straightforward diagram that shares the knowledge acquired in an easy-to-understand way.
In most cases, the diagrams should be read from left to right, from land to sea. In a few cases, however - collected from the Land-Ocean Interactions Coastal Zone (LOICZ) - some interactions have been generated in the opposite direction from sea to land, so the diagram is read from right to left.
These sea-land interactions were generated by fish farming activities (aquaculture sector) that badly polluted coastal seas (affecting water quality and priority habitats), consequently affecting tourism activities.
Building the diagram also enabled me to fully comprehend land-sea interactions and allowed me to categorise the components involved in the interactions by using particular terminology in the explanation to offer more clarity .
This categorization can be seen in the diagrams since they divide the fluxes into five components: *stressors, interactional causes, drivers* and/or *buffers, interaction consequences* and *receivers*.
The *stressors* are all the economic macro sectors and their activities that generate an interaction. The *interactional causes* are the externalities produced from the stressors. The *drivers* are both natural (watersheds, rivers) and anthropic (impervious surfaces) components, where externalities converge and result in the interaction. The *buffers* are natural elements (wetlands, forested wetlands, marshes and mangroves) which have a key role as cleaners and retainers. The *interaction consequences* show the effects of the externality. Finally, the *receivers* are the environment, all economic sectors and sub activities that have direct or indirect interaction with the *stressors*.

FLUXES SCHEME EXPLAINATORY



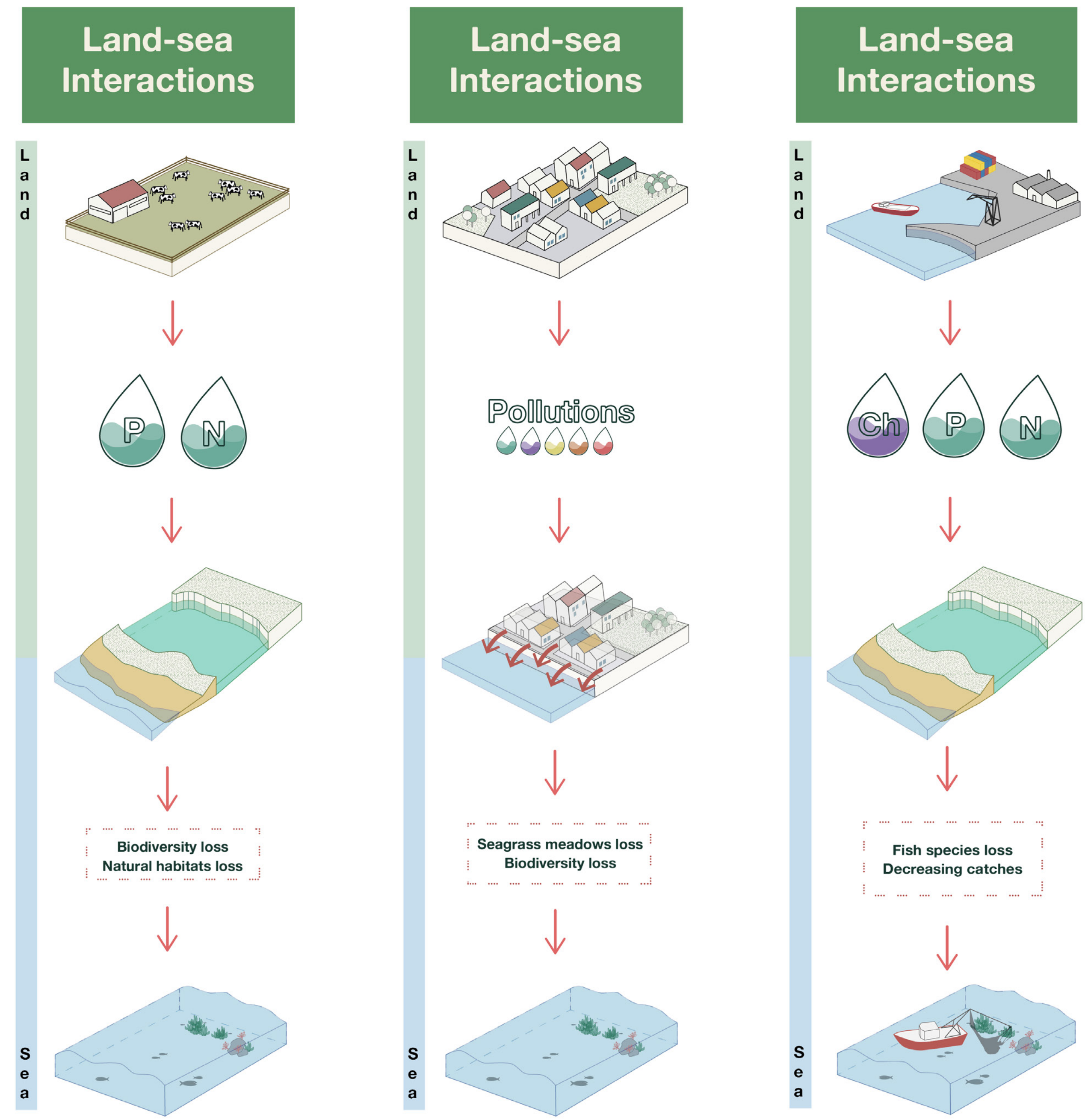
This caption explains the structure of land-sea interactions as follows: from left to right, the stressors or receivers (depending if is a land-sea or a sea land interaction) are macro sectors and activities that can generate an interaction. The causes are the externalities produced from the stressors. The drivers are the elements where externalities converge and result in the interaction. The buffers have a key role as cleaners and retainers. The interaction consequences show the effects of the externality.

HOW TO READ A LAND-SEA INTERACTION IN A FLUXES SCHEME



From inception to endpoint, land-sea interactions are composed of *STRESSORS*, which are the generators of interactions; *DRIVERS*, which can be both natural (rivers) or anthropic (surface runoff), and which function as conductors of the interaction; *RECEIVERS*, which are affected by the consequences of the interactions. Natural elements can function as *BUFFERS*, which retain and clean, decreasing the damage caused by the interactions. *BUFFERS* also function as natural solutions to counteract extreme climate events.

The fluxes diagram made with Sankey Matic, and this kind of information design in general, has great potential as a way of communicating studies and research findings or as a platform for data manipulation and exploration. The design and presentation of information is a very relevant topic regarding for the academic community, as visualizations of information are critically important to understanding themes that encompass several fields, to coupling large amounts of data to existing knowledge, and finally to amplifying the cognition of research (Meirelles, 2013).
In some specific sections in the fluxes diagrams, some particular interactions that are relevant for all the land-sea interaction discourse are not highlighted and otherwise may not so easily be noticed. Through the drawing of icons-schemes and illustrations, I tried to explain these not highlighted interactions in detail.

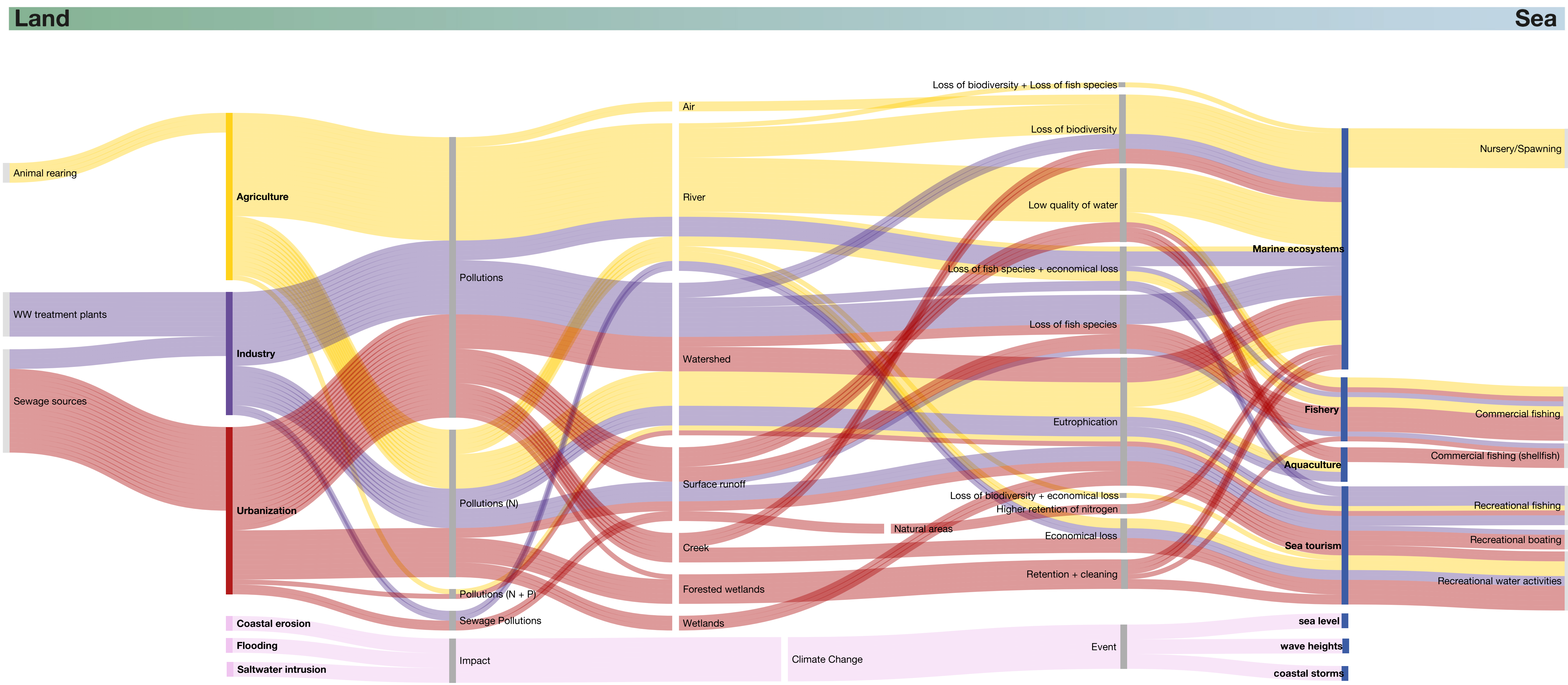


Interaction resulted from LOICZ Literature Review.
Animal rearing (agriculture) > pollution (N+P) > lagoon > biodiversity and natural habitat losses > marine ecosystem

Interaction resulted from LOICZ Literature Review.
Urbanization > pollution > surface runoff > seagrass meadows and biodiversity losses > marine ecosystem

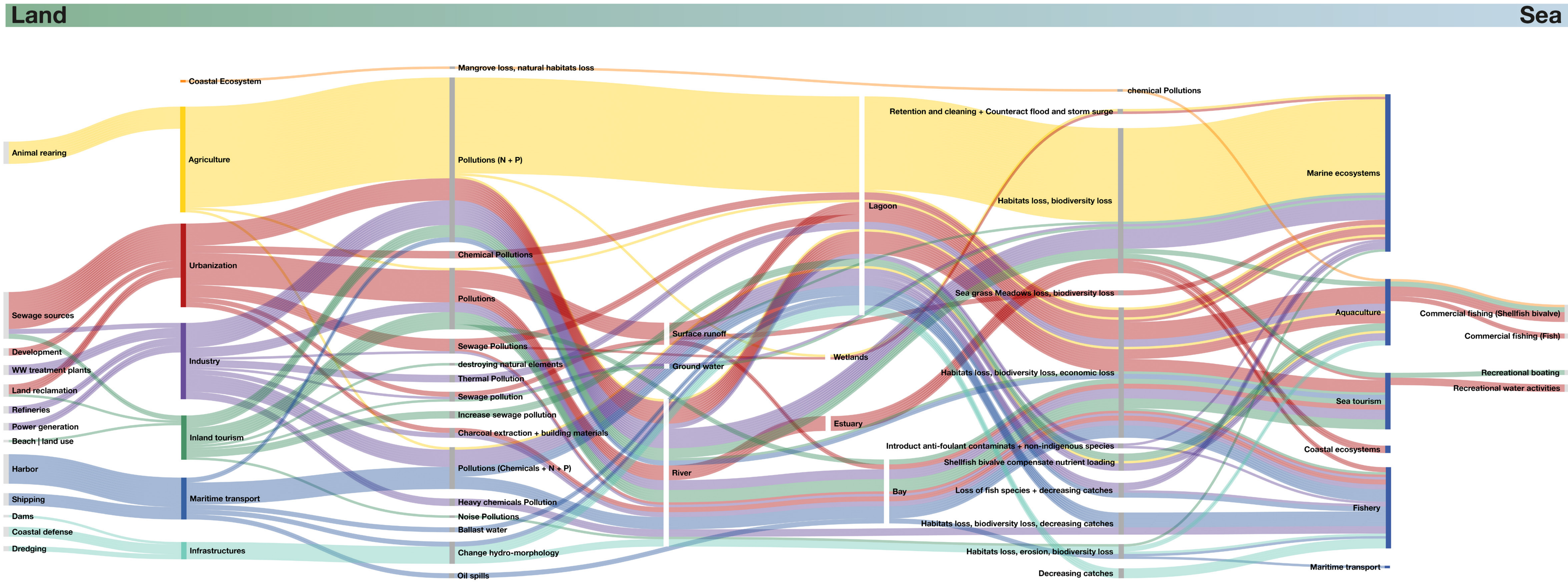
Interaction resulted from LOICZ Literature Review.
Harbour (maritime transport) > pollutions (chemicals+N+P) > lagoon > fish species loss and drcrease in catches > fishery

SYSTEMIC Literature Review FLUXES SCHEME



This caption shows all the land-sea interactions found during the systemic literature review analysis.

LOICZ Literature Review FLUXES SCHEME



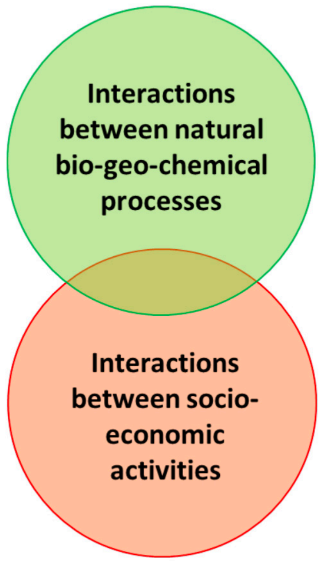
This caption shows all the land-sea interactions found during the LOICZ literature review analysis.

2.4.4 A new definition and scheme for LSI in planning

After completing the double literature review and building the results into an accessible and clear framework describing land-sea interactions, the last step was to find a means of addressing this complexity so that it could applied to supplement the already existing definition of land-sea interaction.

As mentioned in chapter 2.3, *Gaps in land-sea interactions*, the biggest challenge is the lack of a clear definition for land-sea interactions recognised by the scientific community as a whole; at the moment, we have to make do with the incomplete definition provided by the European Union reports.

The definition outlined in the European Union report "*Addressing Land-Sea Interaction A briefing paper*" describes land-sea interactions as "a complex phenomenon that involves both natural processes across the land-sea interface, as well as the impact of socio-economic human activities that take place in the coastal zone". As briefly explained in the report, there is some confusion regarding the meaning of interactions, since they are recognised as dynamics of land-sea both "between natural bio-geo-chemical processes" and "between socio-economic activities" (Jones et al., 2017). This second part of the definition can create ambiguity about what is and what is not a land-sea interaction.



Dynamics of land-sea intercation, a general framework on land-sea interaction, European Union report "Addressing Land-Sea Interaction A briefing paper"

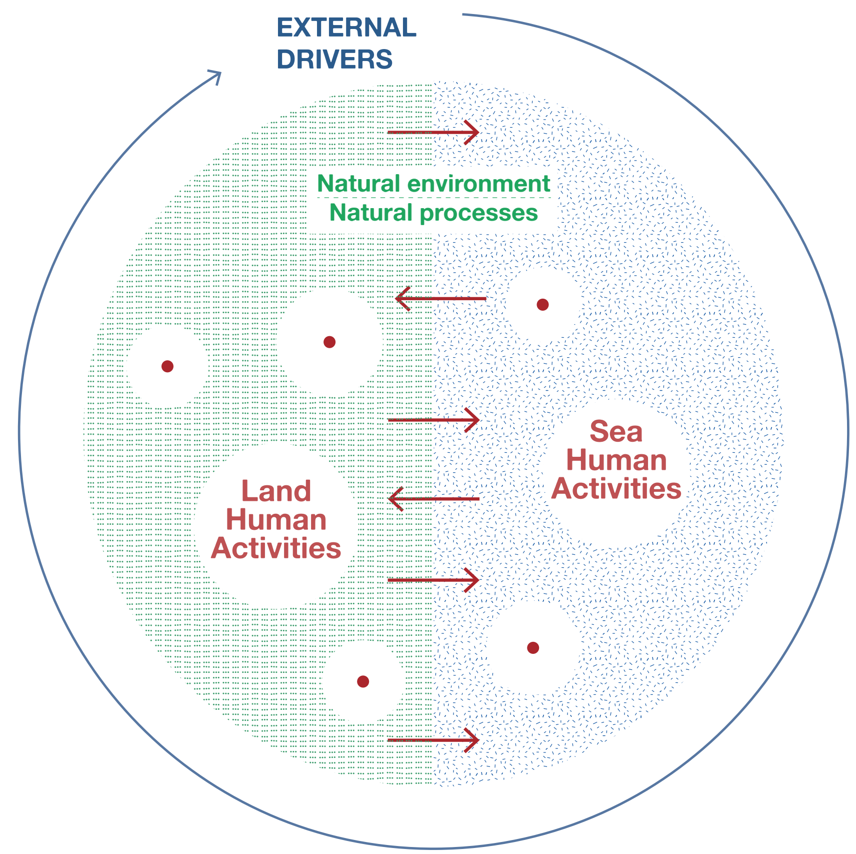
From my work for the first key milestone about land-sea interactions, I can agree with the first part of the definition outlined by the European Union that "land-sea interaction is a complex phenomenon" (Jones et al., 2017), because it involves anthropic activities, natural processes and external drivers (e.g. climate change and other factors). The remaining part of the definition, however, needs clarification. In the European Union definition, two types of interaction are identified, the less clear one being "interactions between natural bio-geo-chemical processes", which is explained using the examples of: "agricultural run-off resulting in eutrophication of coastal waters, or land based pollution associated with industrial / agricultural activities affecting coastal waters"(Jones et al., 2017).

Impact from climate change. Superstorm Sandy devastated New Jersey, New York and East Coast of the United States

Development of the commercial harbour of Singapore

However it should be clarified that natural biogeochemical processes exist in nature, i.e. not generated from human activities, for example biogeochemical processes such as energy flows, nutrient cycles, water cycles, plant/animal interactions and so on. These are natural processes that have shaped and are shaping our environment with or without human pressures.
Therefore, human activities both on land and at sea generate interactions with the externalities they produce. These externalities interact with or put pressuring on the natural environment and its own natural processes, leading to dramatic changes and biodiversity losses. Most of the interactions generated from human activities impact the environment and sometimes also human activities located in the area under investigation.
For these reasons, I believe that only by monitoring and managing externalities generated from human activities is it possible to decrease potential interactions with natural processes and other human activity.
As it is a very complex phenomenon, it is also necessary to take into account uncertainty in the discourse about land-sea interactions. From the literature review, it appears that climate change (or natural and human catastrophes) is an important external driver.
These drivers should be taken in consideration in a land-sea interaction analysis because they can exacerbate the interactions or severely impact on the area.

To conclude as a last result of the first key milestone is my elaboration of a definition of land-sea interaction as “a complex set of dynamics, across the land-sea interface involving the impact of anthropic activities on and at sea affecting the natural environment and its processes. External drivers, such as climate change or human disasters should be incorporated since they can exacerbate the already existing dynamics on the coastal zone”.



Output scheme of the land-sea interaction definition.
The scheme shows the natural environment composed both from land, sea and their natural processes.
Human activites placed both on land and sea are generating interactions between land and sea and viceversa. The crowne, external drivers, resembles phenomena that can exacerbate the already existing human interactions.

2nd key milestone

From cartography to reality

The general aim of the second key milestone, From cartography to reality, in my research is to add to the knowledge we have about land-sea interactions through mapping cases. This will be achieved by answering the second research question: “How can coastal area surveys of spatial land-sea phenomena advance knowledge to develop a framework that can help improving coastal planning?”

The introductory chapter, *3.1 Mappings of land-sea relations in coastal areas*, briefly describes the aims, objectives and modalities that I took into consideration for the second key milestone “From cartography to reality”.
The purpose of the following chapter, *3.2 Theory, context and concepts for a mapping approach*, is to present the main methodologies and approaches used and the reasons for adopting a mixed methods approach.
Chapter *3.3 Case studies and data issues* addresses the issues of data availability, the collection of data and the criteria chosen for the case studies.
The next chapter, *3.4 The mapping methods used*, expands on the output from chapter 3.2 and is intended to delineate the final approach adopted and used in the mapping analysis of the second key milestone “From cartography to reality”.
The second key milestone concludes with chapter *3.5 The DNA of the coastalscape* and *3.6 Coastal transect for a coastal glossary*, which describe the new knowledge acquired through this process and the new insight it yielded on land-sea interactions.

3.1 Mappings of land-sea relations in coastal areas

The second key milestone takes as its point of departure the findings on land-sea interactions from the literature review outlined in the first key milestone, *The complexity of coastalscapes*.
In fact, the main output from the first key milestone was understanding the complexities of coastalscapes through the systematization of the information gathered about land-sea interactions from the literature review.
The systematization enabled me to translate the expert information into accessible knowledge through the use of a schematization of fluxes.
Prima facie, the land-sea interactions “fluxes schemes” may merely seem to offer a visual presentation of interactions, but it is clear that the schemes contain a lot of valuable information about coastal relations, nature and anthropic environments.
For example, by having a clear list of elements that contributed to the discourse on land-sea interaction has facilitated linking the knowledge acquired in the first key milestone to this second key milestone.

Coastal landscapes are complex patchworks of human activities interacting with each other and with the environment, both in positive and negative ways.
From the results yielded by the first key milestone, it is possible to conclude that some of the natural elements that compose the environment have different functions and relations depending on their location in the area concerned and the proximity to other anthropic elements.
In order to answer the second research question, the investigation is divided into two mapping phases developed to form a common approach, the intention of which is to support the mapping process in shaping the methodology I will finally adopt to explore and analyse coastal territories.
This common approach is structured using diverse methods, in order to build a step-by-step mapping analysis to address the study of coasts from diversified perspectives and different territorial scales.

The aim of the first mapping phase is to reveal territorial patterns and systemic relations in coastal areas.
The purpose of the second mapping phase is to identify the interface between land and sea interactions and to propose a common language for describing coastal components.
Through displaying and spatializing systematic patterns on maps, I hope to gain a better understanding of the territories covered in the case studies analysed. Once the structures and elements typical of coastal areas have been categorised, it will be easier to investigate specific natural elements in further detail.
This will be useful for learning how these natural elements - which are multifunctional and which make a significant contribution to adapting to climate change - are shaping our coastal territories and how they can be utilised further when planning coastal developments.

The heterogeneity of the coastal territory cannot be analysed using regular methods and tools; this is the main reason for adopting a mixed-methods approach, which is necessary if we wish to cover the multiplicity and continuously changing dynamics of coastal areas. Coastal zones are by no means affected by uniform administrative systems between regions and countries in terms of spatially effective urban planning, allocation of functionalities, and integrated resource management.

Despite all these issues, this part of the research attempts to examine coastal territories through a wide lens, by initiating an explorative and speculative mapping process (in both phases). The research will investigate the relations between natural and anthropic elements that comprise our coastal landscape - or as I prefer to call it coastalscape.

In the next section, *3.2 Theory, context and concepts for a mapping approach*, I will address in more detail the overall methodological approach and the methods that inspired the mapping process and the construction of the final methodology.

3.2 Theory, context and concepts for a mapping approach

As mentioned in the sections above, one of the peculiarities of the coastalscape is its natural environment; it is an important repository for biodiversity and ecosystems that can contribute significantly to counteracting climate events. At the same time, the heterogeneity of coastal landscapes means that there is a multitude of different patterns and shapes in the territories under investigation. This is the main reason for adopting a mixed-methods approach for the second key milestone, *From cartography to reality*.

Coastal zones suffer greatly from continuous human-driven pressures, since the natural resources they contain are crucial to societal and economic growth. As a result, coastal areas often constitute major production centres for sectors such as agriculture and fishing; they are also logistical hot-spots for transportation and industrial manufacturing and for the ongoing development of maritime tourism. The rapid development involved with these activities causes huge changes to take place in these coastal territories, thereby modifying their own boundaries and upsetting the natural balance.

In order to accurately assess these complexities, it will be beneficial to devise a method that will be able to analyse and explore the coastal areas.
The process of mapping has been applied to the case studies to make it possible to tackle the different types and patterns of actual territories and thereby add new knowledge to what is currently known about coastal zones.

The importance of cartography and mapping in advancing knowledge
In the first key milestone, the complexity of coastal territories was addressed through a literature review; in the second key milestone, From cartography to reality, as the title suggests, there has been a shift in the approach adopted in the research study. Cartography has a long history in extending scientific knowledge by

helping to understand and illustrate geographically and environmentally different areas of the world.
The central idea of cartography is that spatial distribution and relation can reveal the interdependence between the natural environment and the anthropic one. According to Humboldt, maps and graphic visualizations not only display information regarding spatial distribution, but they also help to formulate them (Humboldt, 1820).
Two examples showing how maps can aid scientific thinking are the map of vegetation distribution on the Peak of Tenerife in the Canary Islands and the diagram of a cross-section of the earth's crust. These two examples of cross-sections demonstrate a new way to show the relationship between elevation and the distribution of plant life and geologic, geomorphological aspects of the earth's crust. In both cartographies, Humboldt attempted to break down and synthesize a significant amount of information into a visual form to represent change over time and diversity across the environment.
Nowadays, mapping is used by planners to illustrate and analyse cities and territorial dynamics in order to develop plans for re-designing and regenerating parts of the cities and other areas. It is an essential tool in helping planners respond to the many challenges that cities are constantly subjected to.

Common approach - RbD
The mapping process used in the second key milestone required an unconventional approach that enhanced and developed alternative ways to analysis coastal areas. Therefore, I decided to adopt the research by design approach.
This approach allowed flexibility, through a number of explorative and speculative graphic operations. The research by design approach was used as a working instrument to support the development of the final method by merging and adapting different mapping methods. The approach was useful in allowing me to alternate between the different mapping phases, supported by an iterative three-step procedure for developing the methods: mapping drawing, feedback and drawing review.
The purpose behind adopting this iterative process was to increase the amount of revision of the mapping already completed and to explore better ways of merging different tools with a constant cycle of feedback and review.

Research by design is a complex but flexible research approach, as it involves disciplinary-specific practices where design is utilized as a research practice, constituting both the means and outcome (Downton P., 2003). The practice can also be defined more generally as "a way of inquiring, a way of producing knowing and knowledge" (Downton P., 2003). Furthermore, according to Zaman: "most research by design is done to explore, specialise and visualise new concepts, to make new transitions in urban planning matters understandable" (Zaman, Geldof and Geens, 2014). This "flexibility" was crucial to the study, not only in shaping the different mapping tools, but also in developing the subsequent steps of the mapping process and representations, so as to enhance the exploration of all possible coastal territorial patterns, recurring types, systems, and their relations to each other. In other words both the mapping techniques and the representations themselves were developed using this approach; in addition, a lot of spatial information about coastalscapes was obtained by applying this approach to those areas.

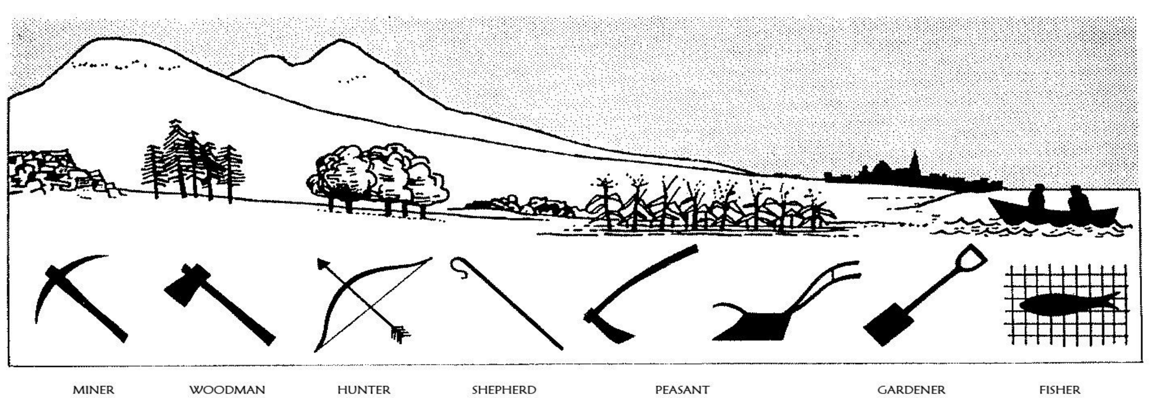
Theory, context and concepts
In order to approach the mapping phase in the best way, I studied the approaches and tools already available that would enable me to analyse and show the relations between the anthropic and the natural environments.
I reviewed tools used in geography, regional planning and landscape architecture, mainly focusing on sections and transect models. These tools have been used in the past for mapping unknown territories around the world.

The intention behind doing this was to draw inspiration from well-known tools in order to further develop and tailor my own mapping methodology tool.

From cartography to reality
2nd Key Milestone
DESIGN for COASTALSCAPE

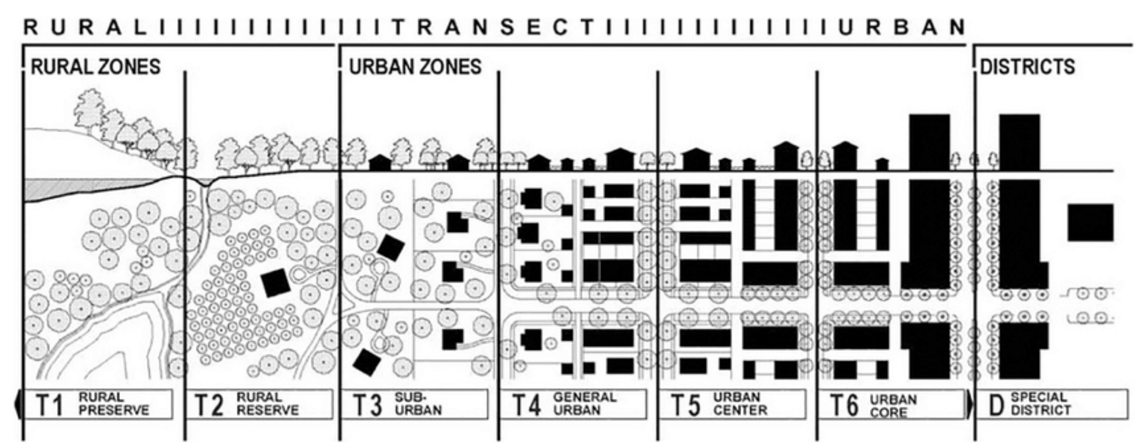
I mainly focused on four analytical mapping approaches: Geddes' valley section, Duany Plater-Zyberk's transect approach , Alexander von Humboldt's diagram of a cross-section of the earth's crust of and the elements forming the cities from Lynch's most famous work, The Image of the City.
In the past, **Geddes' valley section** was adopted as a way of discovering the rhythms of the landscape (Geddes, 1915). From Geddes' studies, the valley section depicts an ideal regional-urban condition that does not comprise a single valley, but a number of valleys (Welter, 2001). This was a way to depict an ideal type of territory which could be found time and again throughout mankind's evolution (Welter, 2001).

According to Thompson: "the valley section is a complex model, which combines physical conditions - geology and geomorphology and their biological associations - with so-called natural or basic occupations such as miner, hunter, shepherd or fisher, and with the human settlements that arise from them" (Thompson, 2004). Geddes' valley section was based on an investigation of Edinburgh and the area surrounding it. The valley shows all the anthropic activities taking place in that area, from the pastoral hills to the agricultural plains with their diffuse settlements to the city of Edinburgh right up to the fishing village closest to the sea.

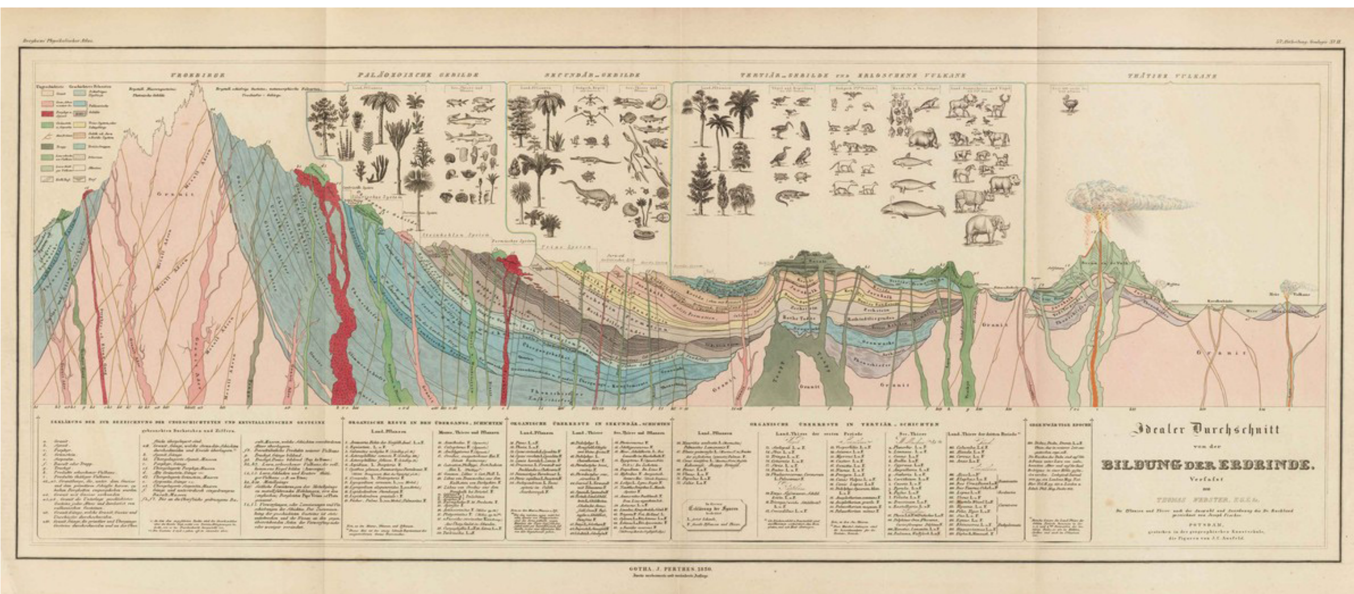


The main aim of the valley section was not just to illustrate the landscape around Edinburgh, but to explain the relations and patterns of the human landscape (Thompson, 2004).

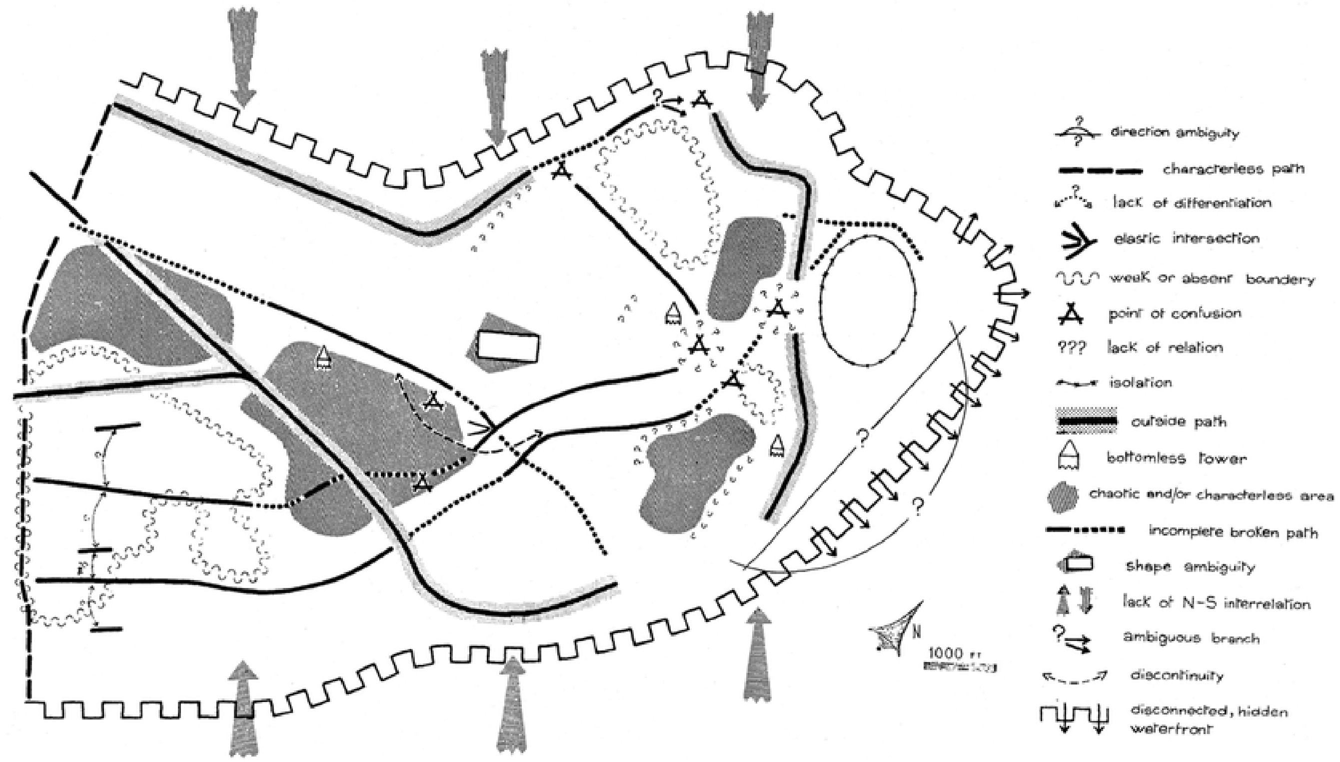
Duany Plater-Zyberk's transect approach was also basically used to find an appropriate spatial allocation of the elements that make up human habitats (Duany and Talen, 2002) and to trace repeated patterns, features and territorial systems.
The transect - or as Duany refers to it the transect approach- contains a set of codified zoning models called SmartCode that divide the transect into six different ecozones: rural preserve, rural reserve, suburban, general urban, urban centre and urban core (Duany and Talen, 2002). The transect approach and the SmartCode division enable us to see the sequence of environments composed of anthropic territories, to identify a set of natural habitats with diverse urbanization levels and intensity (from rural to urban). Furthermore, the transect approach outlines the organizational structure of the components making up a built environment, such as buildings, lots, land use, streets, and other physical elements (Duany and Talen, 2002).
The results from studies utilising these analytical tools have proven that they are highly useful instruments for generating new knowledge through producing drawings using different scales and types of visual representation.



Alexander von Humboldt's diagrams of cross-sections and his use of maps as tools for scientific exploration put him at the cutting edge of the revolution in cartography in the19th century. For example, his cross-sections of the earth's crust and of the Peak of Tenerife in the Canary Islands interpret the landscape in order to try and reveal not only the ecological elements of the earth, but also the ethical and aesthetic dimensions and their relationship to the natural world. Humboldt also synthesized a significant amount of data into visual forms to represent change over time and diversity across space (Humboldt, 1820). His mapping was an important tool in representing how a particular territory could be understood. Most of Humboldt's illustrations provided information not only on the spatial extent of various botanical species, but also on the interconnectedness of terrestrial phenomena. These illustrations also contained a lot of other relevant detailed information.



The **elements forming the visual form maps designed by Kevin A. Lynch** from his book "The Image of the City" depict the different components that shape cities.
Lynch got people to analyse cities and to set up a mental map composed of five elements: paths, edges, districts, nodes, and landmarks.
According to Sundilson: "one of Lynch's innovations was the concept of place legibility, which is essentially the ease with which people understand the layout of a place" (Sundilson, 2002). The concept of place legibility and, as an extension, lynch maps showing different physical components gave me further insight into coastal edge components.



In the literature, section and transect are often regarded as being the same tool; in fact, Duany calls them both: "a method that involves taking a linear cut across a landscape, usually horizontal (although vertical is also used), along which a diversity of systems and habitats are sampled, measured, and analysed".
This definition indicates that there are two types of cross-section, but does not specify the outputs generated by each type.
Therefore, depending on the information being sought, the researcher should choose the appropriate cut-sector. In my research, I used both cross-cut lines in the case studies in order to generate a larger quantity of information and to be gain further understanding of coastal territories.
Geddes' valley sections, which are particularly useful to understanding human interactions and their relations with the environment, turned out to be the right approach for the case studies analysis.
The idea of a transect is a useful tool to reveal both the anthropic and natural elements that contribute to the construction of coastal territories and showing the hierarchies of the elements. The transect approach thus provided the inspiration for creating my transect edge analysis map.
Both Humboldt's and Lynch's approaches were useful in helping me address the mapping work and producing the results in illustrative form.
Each approach provided inspiration for different parts of the mapping process and helped me greatly to develop the methodology; but this will be further explained in chapter 3.4, *The mapping methods used*.

3.3 Case studies and data issues

As introduced in chapter *3.2 Theory, context and concepts for a mapping approach*, the second key milestone is based on case studies studying costalscapes at four European sites.

Multiple cases provided greater context to investigate, thereby generating more information from the mapping analysis phase. The case study method is used in many fields of research, including spatial planning, where it is one of the most common instruments used for analysing geographical territories. The case study method explores territorial phenomena with a holistic approach, mainly when boundaries are not evident as in the context of land-sea interactions (Yin, 2009). The case study method was chosen because it allows the researcher to identify the characteristics of real-life relations between different anthropic elements in the environment, their organisation in the areas under investigation and their behavioural characteristics. For my research, I attempted to select the four case studies which would be the most representative cases for answering my research questions.

Therefore, the four cases were chosen according to four relevant criteria: geographical position and a variety of types of seas, environmental peculiarity, types of urban systems and data availability.

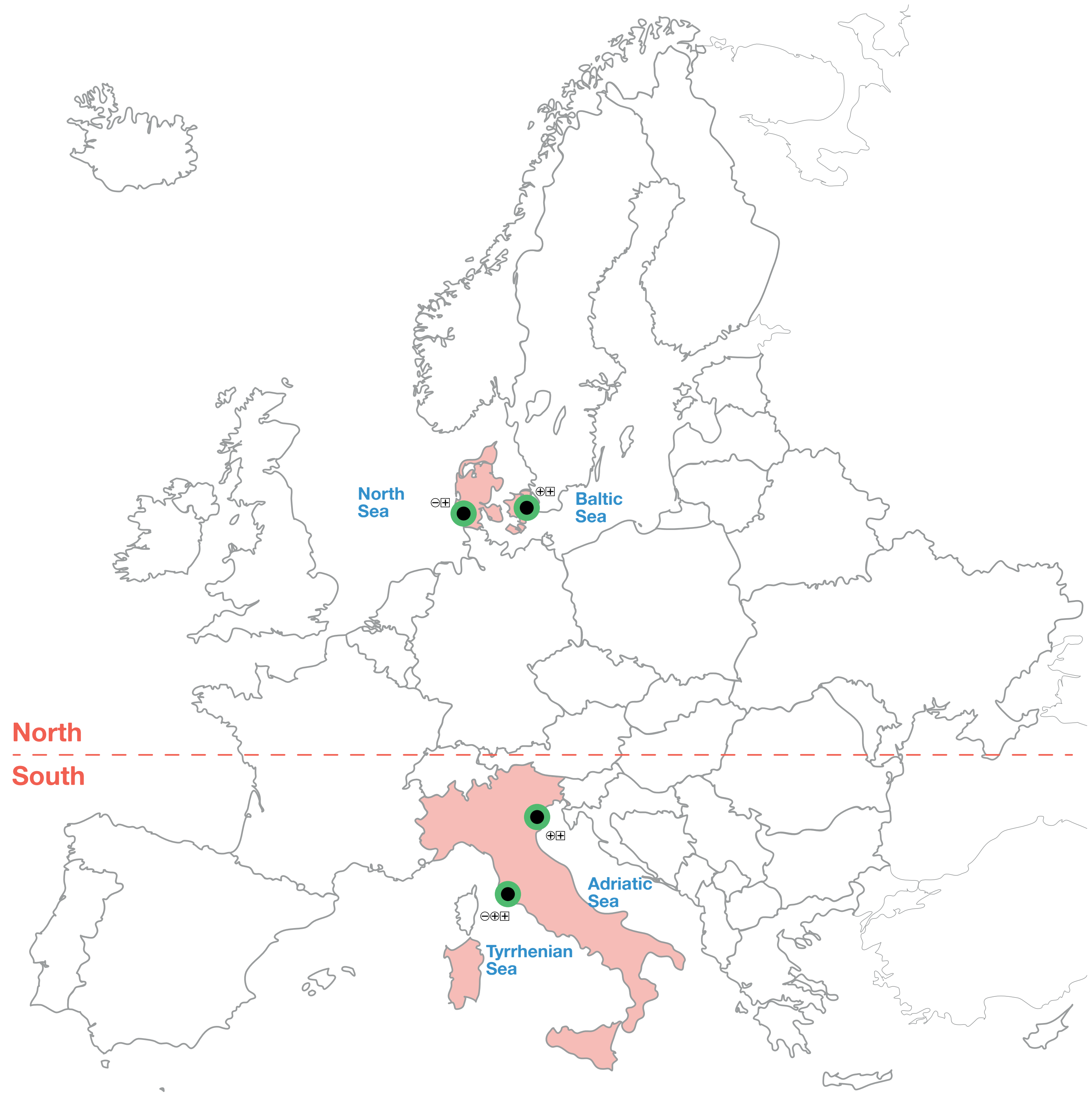
In order to have as wide a range of examples as possible for the first criterion, I chose cases both from the north and south coasts of Europe and from different types of seas.

The second criterion, environmental peculiarity, is based on the knowledge acquired from the first key milestone. The double literature reviews highlighted specific types of coastal environment that are rich in biodiversity but also vulnerable to human pressure and climate change events. These typically also constitute interaction hot-spots. Examples of peculiar environments are deltas, lagoons, wetlands, salt marshes and bays.

The third criterion, typologies of urban system and strategic infrastructure, is mainly based on urban density and different features of urban systems in order to have a variety of different types of cases to draw on to enable me to carry out a comprehensive mapping analysis of land-sea interactions. The typologies of urban systems adopted here describe densely populated coastal cities, low density populated coastal cities, spread conurbations along the coast and urban sprawl in coastal areas. The strategic infrastructure feature is needed in order to accurately describe specific territories, such as ports, that constitute an important economic driver to the development of the territory.

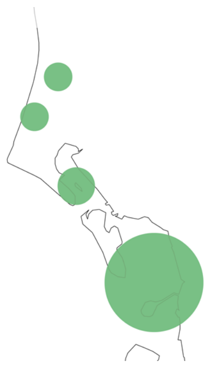
The last criterion is data availability. This is of particular relevance to my research, and one of the reasons for this is that I am looking at two diverse systems: land and sea, each of which are visualized differently and are subject to different methods to gather data.

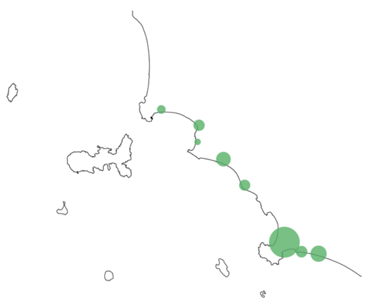
Moreover, for the landside, each region and country have their own data portal, and at the European level there is also a common data portal. For these reasons, data was gathered mainly by using the European data portal, Copernicus, so as to have comparable data between the case studies. In some instances, this was supplemented with extra data from regional data portals.
For gathering data about the marine space, I used the common European data portal Emodnet, since not all countries have their own data portal, and at the European level the process of building a common exhaustive data portal for all member states is still ongoing. The mapping analysis also included extra data from the open-source databases of countries that had developed such databases.

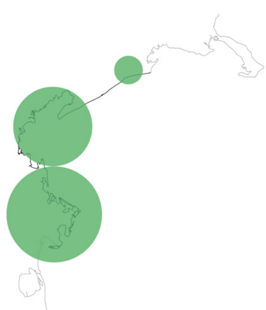


Cases choosen from the criteria set. From the geographical variety Nord-South Europe on different seas, North Sea, Baltic Sea, Tyrrhenian Sea and the Adriatic Sea. The black dots are the location of the central city of the case and urban systems. The green dots show that all cases have at least a peculiar environment (delta, lagoon, intertidal area, wetland). The small square (land data) and round (marine data) shapes containing the symbols + or - show the data availability per case.


Zealand | Copenhagen


Jutland | Esbjerg


Tuscany | Piombino-Orbetello


Veneto | Venice

Based on these criteria and on the fact that my PhD was through Copenhagen University and IUAV University, it made sense to choose cases located in these two countries. The choice of countries is also in line with the last criterion, data availability, since I had access to both universities' databases. Therefore, the case studies chosen were: Esbjerg (Jutland region, DK), Copenhagen (Zealand region, DK), Piombino-Orbetello (Tuscany region, IT) and Venice (Veneto region, IT).

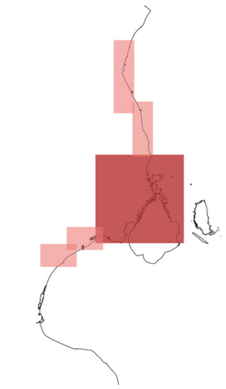
Starting from the geographical criteria, the four chosen cases are divided between the north and south of Europe, and even though each pair of cases are in the same country, all four cases are located strategically on different seas, namely: the North Sea, the Baltic Sea, the Tyrrhenian Sea and the Adriatic Sea.

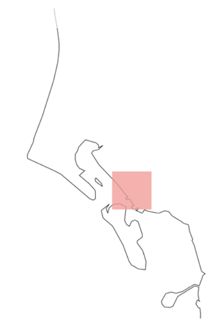
At the same time, each case has its own peculiar environment (second criteria): Esbjerg is located in the northern part of the Wadden Sea, which is an intertidal zone in the south-eastern part of the North Sea. This type of environment is formed by a shallow body of water with tidal flats and wetlands. It has rich biological diversity and is an important area for fish breeding and migratory birds. The other Danish case, Copenhagen and its coast, is a mixture of a highly urbanized coastal area, lying partly at sea level, with a number of important natural areas nearby urbanized areas. Moving to the south of Europe, Italy, the Tuscany case has a mix of different peculiar environments such as bays, wetlands and a small lagoon along the coast between the cities of Piombino and Orbetello. The Veneto region case has one of Europe's most significant delta rivers and lagoon systems along the coast of the region. At the same time, this morphology has resulted in parts of the coastline being below sea level.

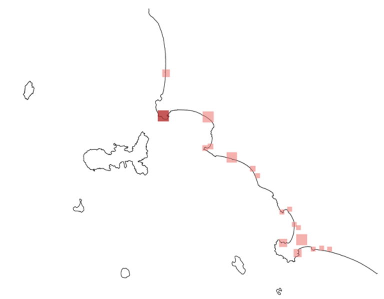
Looking at the third criteria, typologies of urban systems, the Danish cases feature two different types of urbanizations.
The area around Esbjerg has a compact, low-density urban system with a robust port infrastructure (it is the

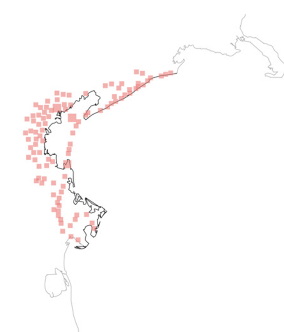
second largest port in Denmark). It is also an important centre for agricultural exports, and it has recently become a centre for shipping offshore wind turbines to wind farms in the North Sea.
The city of Copenhagen is a compact and highly densely urbanized area whose boundaries stretch all along the coastal area. It is the capital of Denmark and has the first cruise ship port of Denmark. In the Tuscany case, the type of urban system is interesting because of its spread conurbation of medium and small compact towns along the coast.
The Veneto region case is a well-known case of urban sprawl, not only inland but also in the coastal area.

The last criterion, data availability, was essential to carrying out the mapping analysis as I needed data sources which would allow me to investigate both the sea and the land territories. It was important to be able to compare the information from the four case studies, so it was crucial that I identify the right data portals for collecting the data.
The landside data was based on a European open-source data portal called Copernicus. For the sea areas, although a common European portal called Emodnet does exist, it does not cover all the European seas. For the Zealand - Copenhagen case study, therefore, I also used data from the Helcom data portal, which draws on the results from a large number of European-funded projects. The Esbjerg case only had the data from the Emodnet portal. For the Veneto - Venezia and Tuscany - Piombino and Orbetello cases, extra data were collected from the European projects Adriplan, Supreme and Simwestmed, which I was also involved in.
Thus, I tried to collect as much comparable data as possible from the same data portal , but in some specific cases, I also added other information from other portals where relevant.


Zealand | Copenhagen


Jutland | Esbjerg


Tuscany | Piombino-Orbetello


Veneto | Venice

3.4 The mapping methodology used

The methodology used for the mapping process, mentioned in chapter 3.2 Theory, context and concepts for a mapping approach, was developed from the iterative circular flow of mappings, feedbacks and reviews. The iterative flow allowed me to critically explore different existing methods, such as Geddes' valley section, Duany's transect, Humboldt's cross-sections and the visual form maps drawn by Lynch, in order to identify the parts I would use later for the final mapping methodology. The final mapping methodology was tailored to perform the research analysis on the coastal areas and to obtain new insights into land-sea interactions.

The methodological process
The mapping methodology comprises two phases: the first one examines the coastal territories on a regional scale; the second one zooms in on the coastal edges. The first phase of the mapping process was inspired by the theories and concepts from Geddes' valley section and Humboldt's cross-sectional diagrams. It is organized into three types of maps. The first map is the thematic section, the second is a coloured section and the third is a DNA sequence map.
Each map investigates specific features ranging from an extended general overview of each case study to the fragmentation of the coastal territories from excessive anthropization to comparisons of European coastal territories in an attempt to find similar behaviours relating to land-sea interactions.
It is important to stress that in a lot of the considered cases, human activities in a particular territory have interactions with other activities and with natural elements: the boundaries of these interactions are not always evident, depending on the types of elements involved in the interaction.
The second phase of the mapping process was inspired by concepts and theories from Duany's transect and Lynch's visual form maps; the cases were analysed in a two-step process, firstly using a transect edge, after which the data collected were organized into components that make up the visual form of the coastal area and construct a coastal elements glossary. In this second phase, the analysis goes into more detail by downscaling into the coastal edge to reveal components and shapes in the coastal area. The glossary constitutes a way of building a common language in order to facilitate understanding and mapping the coastalscape.

First phase of the mapping methodology
The first phase is divided into three mapping steps: the thematic section, the coloured section and DNA sequence. The aim of this phase is to describe the rhythms of the coastal territory. For the first two steps of the mapping analysis, I considered using Geddes' valley section as a theoretical point of departure; however, the complexity of the four case studies required me to significantly revise Geddes' method.

The thematic section mapping step focuses on a single theme, such as the agricultural sector, the industrial sector etc., of a territory's land and sea elements, both human and natural, and cross-cut by landscape sections. This mapping step was intended to unfold the complexity of the particular coastal territory by highlighting single themes to ease the understanding of the elements that were predominantly responsible for shaping the territories in the respective case studies.
This first step is important in highlighting how all the elements outlined in the mapping come from the fluxed scheme of the first key milestone.
At the same time, the mapping provides extra morphological information from the landscape sections shown for each thematic section.
The morphology is hugely relevant for land-sea interaction discourse because, as we know, the orography and the hydrography play a crucial role; merging all the information into one map makes this easier to read. After the overview of the case studies was streamlined into single thematic section maps to facilitate understanding, the next coloured section re-composes the themes from the landscape section of the previous step. The first two

steps paved the way for the last step: DNA sequence.
For the last map in the first phase, the coloured sections were transformed into a DNA sequence map showing the inner structure of the coastal territories.
DNA sequence obviously resembles a DNA structure; in my case, the DNA carries information about the development, functionality and relations of the coastalscape. Therefore, the aim of producing DNA mapping is to visualize more clearly the coastal structures and functionalities in order to then compare them with the DNA from the case studies to highlight similar patterns and interactions. This makes it possible to discover if diverse coastal areas, with different levels of urbanization, could be compared in terms of their interactions.

Second phase of mapping methodology

The second phase of the mapping involved zooming in on/downscaling to the coastal edge in order to more closely examine the interface between land and sea and obtain new insight into the composite elements.
The main mapping tool used in the second phase was the transect edge, inspired by Duany's transect approach and drawing on components from the book "The Image of the City" by Kevin Lynch (namely paths, edges, districts, nodes, and landmarks).

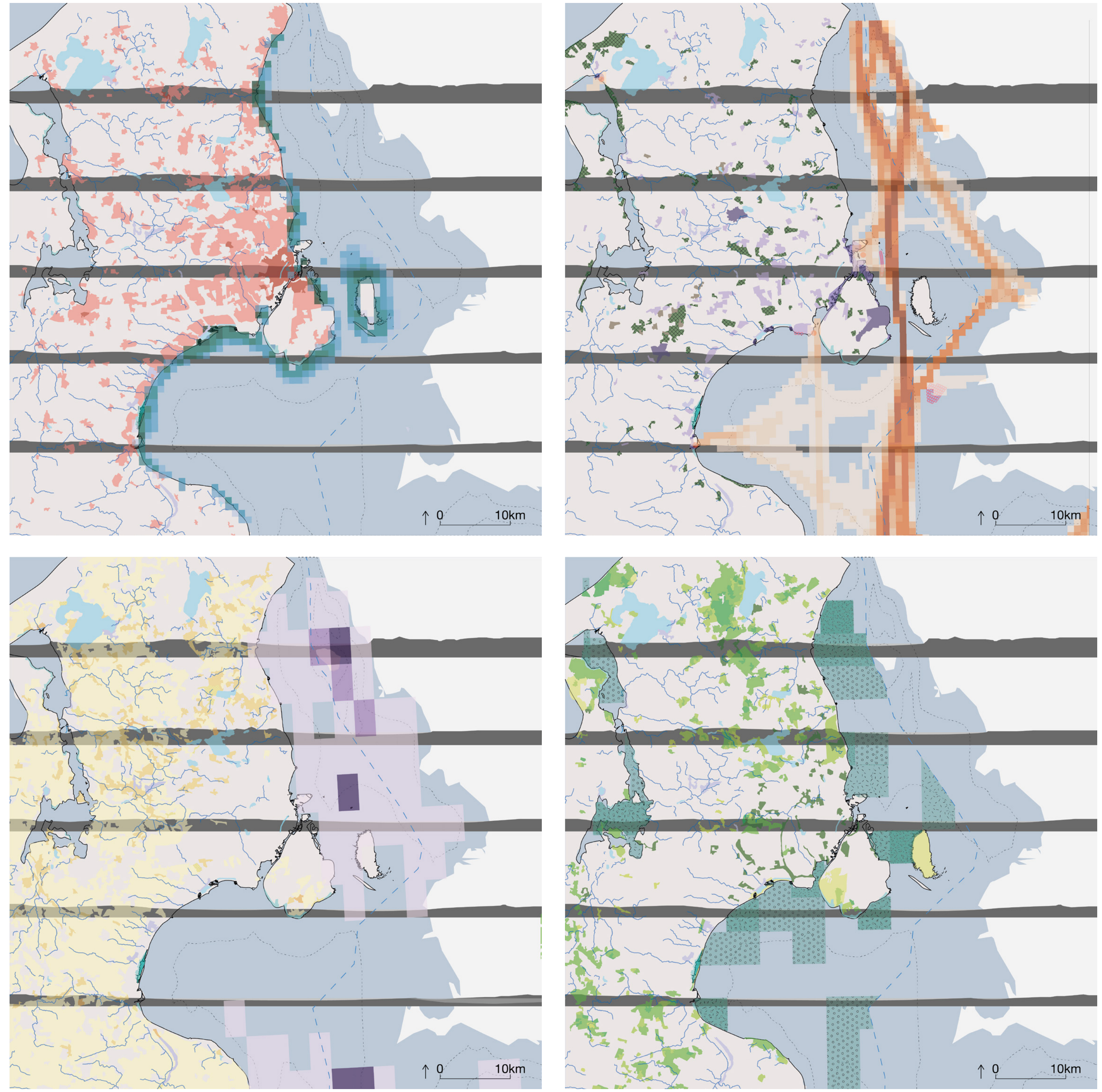
The transect edge analysis was performed on four key components of land-sea interactions: buffers, drivers, edges and limits.
Buffers and drivers make up part of the terminology that emerged from the first key milestone. Buffers are natural elements that can ameliorate the externalities of an interaction.
Drivers are also referred to in the first key milestone terminology, defined as a natural or anthropic element of the territory carrying pollutants from land to sea.
From the literature, the natural drivers are water catchments, rivers, creeks and estuaries. Anthropic drivers occur in densely populated cities that as a consequence have a higher percentage of impervious surfaces. This imperviousness can drive increased surface runoff and carry pollutants created on land into the sea.
Limits are boundaries in the territory such as rail and road infrastructures, built-up areas and artificial surfaces. They also include the infrastructure of port areas that interrupt the continuity of the landscape or of ecological corridors.
Edge reveal the different ways the land reaches the sea and vice versa, and include such features as coastal plains, beach dunes, beach barriers, sea cliffs and artificial edges. Analysing these components using the transect edge aimed to enhance our knowledge about how elements found on coastal edges are shaped.
This will link to the last step of phase two, which is the codification of the information acquired through a simplified set of symbols and using the common set of terms which emerged from the case studies.
The aim of producing this glossary is to introduce a common set of terms to describe coastalscape dynamics in relation to land-sea interactions and climate change.

3.5 The DNA of the coastalscape

This chapter will illustrate the results from the first phase of the mapping analysis, divided into three maps: thematic sections, coloured sections and DNA sequence.

The cases analysed were Copenhagen in the Zealand region and and Esbjerg in the Jutland region in Denmark; Piombino and Orbetello in the Tuscany region and Venice in the Veneto region in Italy.
The results from each case studied is illustrated through each one of these types of maps.
The following paragraph will start with the first mapping analysis, thematic sections, which show the predominant land use components shaping the territories and the probable linked land-sea interactions in the case studies.
The Coloured sections give a linear representation, looking at the complete territorial sections with all the themes represented in one section.
The last mapping study of the first phase, DNA sequence, is a step further in the analysis because it conceptualizes the identity of the coastal territories studied. The analysis passes the data through a sort of DNA sequence which carries information about the development, functioning and relations of the coastalscapes in each case study.

The thematic sections are divided into four types: Urbanization, Industries & Infrastructures, Agricultures, Fishing & Aquaculture and the Environment.



These maps show the four types of thematic sections of the first analysis.
From up to down and from left to right, Urbanization map, Industries & Infrastructures, Agricultures map, Fishing & Aquaculture map and Environment map.

URBANIZATION MAPS
The Urbanization maps contain information collected from the Copernicus data portal relating to the density of urbanization, more specifically:

1.1.1 Continuous urban fabric.
The continuous urban fabric class is assigned when urban structures and transport networks are dominating the surface area. >80% of the land surface is covered by impermeable features like buildings, roads and artificially surfaced areas. Non-linear areas of vegetation and bare soil are exceptional.

1.1.2 Discontinuous urban fabric.
The discontinuous urban fabric class is assigned when urban structures and transport networks associated with vegetated areas and bare surfaces are present and occupy significant surfaces in a discontinuous spatial pattern. The impermeable features like buildings, roads and artificially surfaced areas range from 30 to 80% land coverage.

It should be noted that extra data was used in two of the case studies: For Zealand, information was collected from the database of the University of Copenhagen regarding the extent of recreational boating near the coastline. In the Tuscany case, additional information was collected regarding tourist marinas from the SIMWESTMED EU project.

INDUSTRIES & INFRASTRUCTURES MAPS
The Industries & Infrastructures maps contain data collected from the Copernicus and Emodent data portals, relating to industry, infrastructures and maritime traffic, more specifically:

1.2.1 Industrial or commercial units and public facilities.
Buildings, other built-up structures and artificial surfaces (with concrete, asphalt, tarmacadam, or stabilised like e.g. beaten earth) occupy most of the area. It can also contain vegetation (most likely grass) or other non-sealed surfaces. This class is assigned for land units that are under industrial or commercial use or serve for public service facilities, such us all kinds of industrial and production complexes, utilities (wastewater treatment plants) and roads and railways on industrial sites.

1.2.3 Port areas.
Infrastructure of port areas (land and water surface), including quays, dockyards and marinas.

1.2.4 Airports.
Airports installations: runways, buildings and associated land. This class is assigned for any kind of ground facilities that serve airborne transportation.

1.3.1 Mineral extraction sites.
Open-pit extraction sites of construction materials (sandpits, quarries) or other minerals (open-cast mines). Includes flooded mining pits.

1.4.2 Sport and leisure facilities.
This class is assigned for areas used for sports, leisure and recreation purposes. Camping grounds, sports grounds, leisure parks, golf courses, racecourses etc. belong to this class, as well as formal parks not surrounded by urban areas.

Shipping intensity.
Shows the distribution of ships (i.e., of maritime traffic), based on the instantaneous number of vessels per unit area, such as a square kilometre or a square degree.

AGRICULTURES, FISHERIES & AQUACULTURE
Agricultures, fishery & aquaculture maps contain data collected from the Copernicus and Helcom, Simwestmed and Supreme EU project data portals, more specifically:

2.1.1 Non-irrigated arable land
Cultivated land parcels under rainfed agricultural use for annually harvested non-permanent crops, normally under a crop rotation system, including fallow lands within such crop rotation. Fields with sporadic sprinkler-irrigation with non-permanent devices to support dominant rainfed cultivation are included.

2.1.2 Permanently irrigated arable land.
Cultivated land parcels under agricultural use for arable crops that are permanently or periodically irrigated, using a permanent infrastructure (irrigation channels, drainage network and additional irrigation facilities). Most of these crops cannot be cultivated without artificial water supply. Does not include sporadically irrigated land.

2.1.3 Rice fields
Cultivated land parcels prepared for rice production, consisting of periodically flooded flat surfaces with irrigation channels.

2.2.1 Vineyards
Areas planted with vines, vineyard parcels covering >50% and determining the land use of the area.

2.2.2 Fruit tree and berry plantations
Cultivated parcels planted with fruit trees and shrubs, intended for fruit production, including nuts. The planting pattern can be by single or mixed fruit species, both in association with permanently grassy surfaces.

2.2.3 Olive groves
Cultivated areas planted with olive trees.

2.3.1 Pastures
Permanent grassland characterized by agricultural use or strong human disturbance. Floral composition dominated by graminacea and influenced by human activity. Typically used for grazing-pastures, or mechanical harvesting of grass–meadows.

2.4.1 Annual crops associated with permanent crops
Cultivated land parcels with non-permanent crops (mostly arable land) associated with permanent crops (fruit trees or olive trees or vines) on the same parcel.

2.4.2 Complex cultivation patterns
Mosaic of small cultivated land parcels with different cultivation types -annual crops, pasture and/ or permanent crops-, eventually with scattered houses or gardens.

2.4.3 Land principally occupied by agriculture, with significant areas of natural vegetation
Areas principally occupied by agriculture, interspersed with significant natural or semi-natural areas (including forests, shrubs, wetlands, water bodies, mineral outcrops) in a mosaic pattern.

Fisheries data
The fishing data for the Zealand case study were collected from the Helcom data portal (EU funded project), which covers the Baltic Sea. For Tuscany and Veneto, data from the SIMWESTMED and SUPREME EU funded projects were used.
In all the case studies, the data about fisheries relates to fishing intensity in the respective areas.

Aquaculture data
For aquaculture, I was only able to collect data from two case studies: Tuscany and Veneto.
The data came from the SIMWESTMED and SUPREME EU funded projects.
The aquaculture data show the areas of concession for aquaculture farming.

ENVIRONMENTAL MAPS
Environment maps contain data collected from the Copernicus, Helcom, Simwestmed and Supreme EU project data portals, more specifically:

1.4.1 Green urban areas
Areas with vegetation within or partly embraced by urban fabric. This class is assigned for urban greenery, which usually has recreational or ornamental character and is usually accessible for the public.

3.1.1 Broad-leaved forest
Vegetation formation composed principally of trees, including shrub and bush understorey, where broad-leaved species predominate.

3.1.2 Coniferous forest
Vegetation formation composed principally of trees, including shrub and bush understorey, where coniferous species predominate.

3.1.3 Mixed forest
Vegetation formation composed principally of trees, including shrub and bush understorey, where neither broad-leaved nor coniferous species predominate.

3.2.1 Natural grassland
Grasslands under no or moderate human influence. Low productivity grasslands. Often situated in areas of rough, uneven ground, steep slopes; frequently including rocky areas or patches of other (semi-) natural vegetation.

3.2.2 Moors and heathland
Vegetation with low and closed cover, dominated by bushes, shrubs, dwarf shrubs (heather, briars, broom, gorse, laburnum etc.) and herbaceous plants, forming a climax stage of development.

3.2.4 Transitional woodland/shrub
Transitional bushy and herbaceous vegetation with occasional scattered trees. Can represent woodland degradation, forest regeneration / recolonization or natural succession.

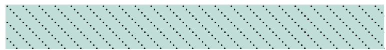
Depending on the type of sea, there were different priority habitats necessary for spawning, fish nurseries and for counteracting the power of the waves.
In the Zealand case, the data collected for priority habitats were Zostera marina, Fucus and Furcellaria. For the southern Europe cases, they were Cymodocea nodosa, Posidonia oceanica and Coralligenous.

Zostera marina is a species of seagrass native to marine environments on the coastlines of mostly northern sections of North America and Eurasia.
Zostera grows in muddy and sandy shores only at and below spring tides. This plant is an important member of the coastal ecosystem because it plays a crucial role for many other species; for example, it provides a sheltered spawning ground for the Pacific herring and Juvenile Atlantic cod.

Fucus is agenus of brown algae found in the intertidal zones of rocky seashores throughout most of the world. Several seaweed species from Fucus are harvested for use in industrial processes such as soap-manufacture glassmaking and other industries.

Furcellaria is a genus of red algae. It is an important habitat-forming seaweed, which creates underwater "belts". These belts provide spawning habitats for many species of fish, and for this reason some governments have put regulations on the harvesting of this seaweed. Furcellaria lumbricalis has commercial importance as a raw material for carrageenan production (in the food industry). It is mainly harvested from the waters of Denmark.

Cymodocea nodosa is a species of seagrass in the family Cymodoceaceae. As a seagrass, it is restricted to growing underwater and is found in shallow parts of the Mediterranean Sea.
It is adversely affected by mechanical disturbances such as trawling and by pollution. At the same time, it is an important breeding ground for juvenile fish and invertebrates.



Posidonia oceanica is a seagrass species that is endemic to the Mediterranean Sea. It forms large underwater meadows that are an important part of the ecosystem. Posidonia grows best in clean waters, and its presence is a marker for a lack of pollution.

Coralline algae or ***Coralligenous*** is red algae in the order Corallinales. They are characterized by a calcareous deposits. The colours of these algae are most typically pink, or some other shade of red. Coralligenous plays an important role in the ecology of coral reefs. In the temperate Mediterranean Sea, coralline algae are the main builders of a typical algal reef, the Coralligène ("coralligenous").

All the data collected and listed here were used to create the mappings for the case studies in the first phase of the mapping process, covering the thematic sections, coloured sections and DNA sequence.

Finally, all thematic sections and coloured sections maps have some common information such as the hydrography and bodies of water (lakes, marshes, wetlands and lagoons) displayed on the maps.
The thematic sections maps have five landscape sections of the territory that show the relation between the orography of the landscape and the human and natural elements in the territory. With regard to the sea areas, in the thematic maps and coloured sections, bathymetry and territorial sea borders are also illustrated.

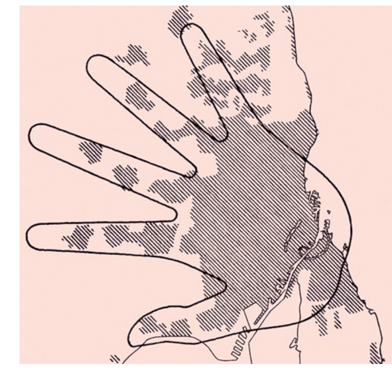
Zealand and Copenhagen

The case study of Zealand & Copenhagen reveals compact and organized urbanization due to the so-called Finger Plan, that has successfully avoided urban sprawl through comprehensive public planning (Torfing, 2019). The Finger Plan was also an ambitious initiative for the future urbanization of the metropolitan city of Copenhagen since it structured the regional traffic axes for trains and cars running outwards from the city centre along the five fingers that created compact residential areas separated by green areas (Torfing, 2019).

From the first thematic section, urbanization, it became evident that the urban typology of the Copenhagen case study features continuous and dense urbanization in the inner part of the city, which leads to a high probability of soil imperviousness, especially in the historic city centre. This conformation has some adverse consequences for land-sea interactions discourse, such as increased surface runoff during intense rainfall events. Outside the city centre, the type of urbanization changes to a discontinuous type which nevertheless remains compact, albeit with a small decrease in the imperviousness of the surfaces.

This discontinuous urbanization, which follows the finger plan, has resulted in an urbanized coastal landscape that often stretches directly to the sea without a buffer zone (see the photo of the coastal house) to help balance the pollutants discharged from the ground and flowing out to the sea. For the Copenhagen case study, I was able to retrieve data on the intensity of recreational boating activities along the entire coast of the metropolitan city of Copenhagen from previous studies. These data are relevant as they help us understand which anthropogenic activities are pressuring the coastal area and to what extent. The boating activities data is distributed over the entire coastal area with greater intensity in the areas adjacent to marinas and in the city of Copenhagen, Køge and Nivå (see the map showing cities) where there is also greater population density.

The **Finger Plan** is an urban plan from 1947 which provides a strategy for the development of the Copenhagen metropolitan area, Denmark. According to the plan, Copenhagen is to develop along five 'fingers', centred on commuter rail lines, which extend from the 'palm', which is the dense urban fabric of central Copenhagen. In between the fingers, green "wedges" are intended to provide land for agricultural and recreational purposes.



The Industries & Infrastructures map investigates the highly productive, and consequently potentially harmful, human activities, such as industry, public facilities, port areas, airports, mineral extraction sites and sports and leisure facilities.
As we saw in the literature review, these types of activities not only have direct externalities, but in many cases - like industrial areas and public facilities - they also have a high percentage of impervious surfaces (Kinney and Valiela, 2011) that will increase the surface runoff of pollutants into rivers and seas.
The area of Copenhagen has a number of industries, ports and airport areas in the adjacent inner part of the city. The most important human activity is the port, because Copenhagen is an important tourist port. The channel dividing the city is also a hugely popular for recreational boating.
At the same time, on the island of Amager (in the south-east of the city), part of the sixth finger of Copenhagen is located at the international airport, which has a high percentage of impervious surfaces and is on the border to the sea.
In the inner city of Copenhagen and along the coast, there are a large number of sports and leisure facilities, which can produce negative externalities (e.g. golf facilities with an excessive use of fertilizers and chemicals can increase pollution into the sea).
The thematic section map for the sea area clearly shows the high volume of shipping traffic; this is due to the fact that the sea that Copenhagen is located on provides the only access route to the Baltic Sea and the Gulf of Bothnia. There are also strong commercial relations between the ports of Copenhagen and Malmö.

The Agricultures, Fisheries & Aquaculture map examines human activities that can have an influence on the land-sea interactions in the case study.
For this case study I analysed agriculture on land and fishing at sea; in this area, however, there are no aquaculture activities.
According to the literature, the human activity that generates most of the land-sea interactions is agricultural production, so it is important to take a closer look at it.
The area of the metropolitan city of Copenhagen is well planned, and the urbanization is compact, well organized and distributed along the rail network (which follows the finger plan structure); following the Finger Plan, the agricultural fields are mainly located between the fingers.
Both in the northern part (where the finger plan ends) and in the southern part (which is not part of the finger plan), the agricultural fields are located not only a long way inland but also close to the coastline.
This distribution of agricultural fields creates a complete different landscape outside the compact urbanized areas.
The fishing activity is distributed in the northern part of the case study and almost completely absent in the southern part.

The Environmental map explores the natural environment in all its forms and shapes; the map shows all the bodies of water, like marshes, lagoons and wetlands, that function as buffers in retaining and cleaning the pollution discharged from human activities. The land areas the map shows are the urban green areas, forests and transitional woodland from the case study. In the sea area, the most important priority habitats are highlighted, such as Zostera, Fucus and Furcellaria algee; these habitats have the double functions of being spawning grounds and fish nurseries; they also counteract the otherwise strong sea currents.
The distribution of forest, mixed forest and coniferous forest is higher outside the city of Copenhagen, even though there are some important natural spots in the adjacent city centres like on Amager (south-eastern neighbourhood of the city of Copenhagen). The natural areas are mostly located a long way inland, with only a small percentage near the shoreline.
The low density of green or forested area along the coastline is due to the type of urbanization - highlighted in the previous map analysis - which has compact low-density urbanization stretching in many cases to the shoreline.

Amager Strandpark
(Amager Beach Park) is a seaside public park that includes an artificial island and has a total of 4.6 km of beaches. The island is separated from the original beach by a lagoon which is traversed by three bridges. The beach has two sections. The northern section has a natural beach environment with winding paths, broad sandy beaches and sand dunes. The southern section offers a city beach with a broad promenade which also functions as a seawall.

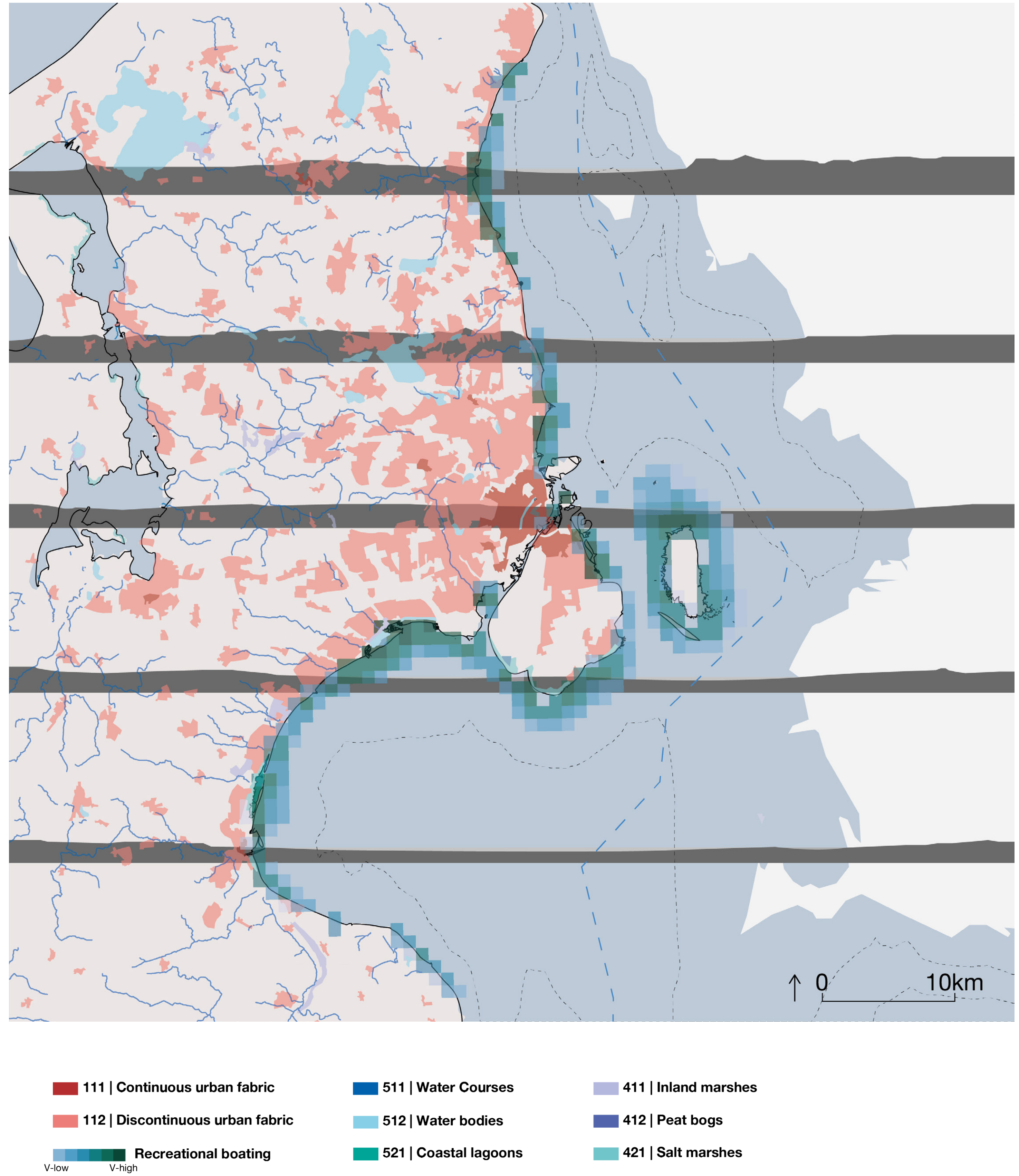
Green infrastructure
is a strategically planned network of natural and semi-natural areas with other environmental features designed and managed to deliver a wide range of ecosystem services such as water purification, higher air quality, space for recreation and climate mitigation and adaptation (EU).

Grey infrastructure
usually refers to the traditional methods of managing water, using man-made, constructed assets, most often water tight and designed to avoid any type of ecosystem growing on it. Modern grey infrastructures such as permeable pavements and some roof water retention systems mimic the natural water retention capacity of the landscape and help to restore more natural patterns of runoff and infiltration.

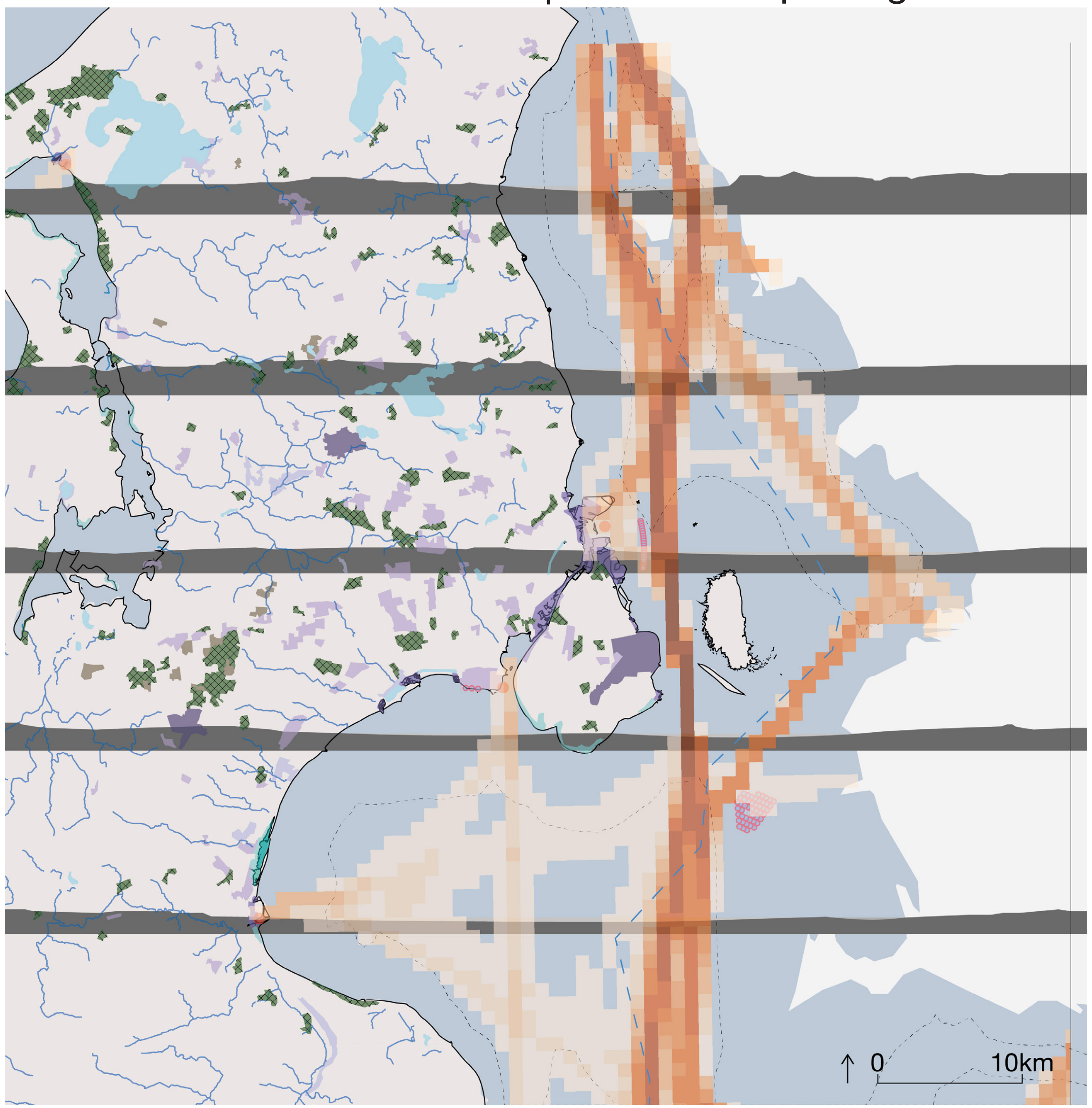
The sea area has all the three listed types of priority habitats, mainly distributed where the urbanization and human activities have less impact or are farther from the coastline. We can see that these priority habitats are non-existent close to the ports of Copenhagen and Køge, due to dredging and the high volume of traffic. Similarly these priority habitats are not found in the sea facing the airport, probably due to the shallowness of the water, the fact that it is an important corridor for shipping traffic, and the surface runoff from the impervious airport area.

In the thematic sections mapping analysis, the Zealand & Copenhagen case study has highlighted three types of elements that are predominant in the territory: agricultural fields, urbanization and natural elements. These elements have clear borders as a result of the Finger Plan. Amidst natural elements, there are some man-made components, such as Amager Strandpark on Amager, which is a mix of green and grey infrastructures, creating a mixed natural environment that enhances nature and counteracts coastal climate events such as flooding and storm surges. Similar kinds of man-made islands are also located south of Copenhagen, at Brøndby Strandpark, Ishøj Strand and Køge Bugt Strandpark: green infrastructures shaping a natural environment with internal semi-enclosed lagoons.

Urbanization map | Zealand · Copenhagen

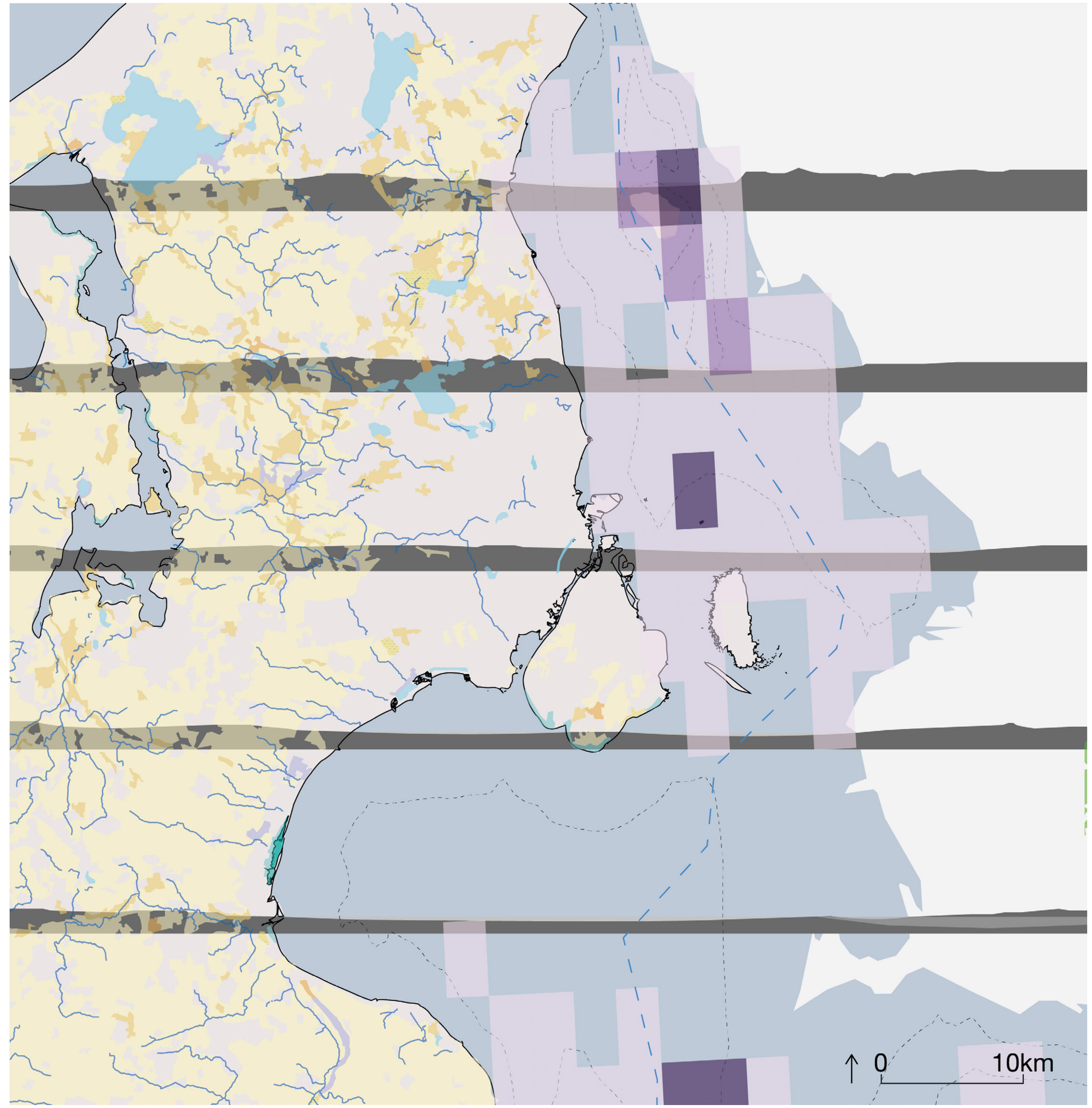


Industries & Infrastructures | Zealand · Copenhagen



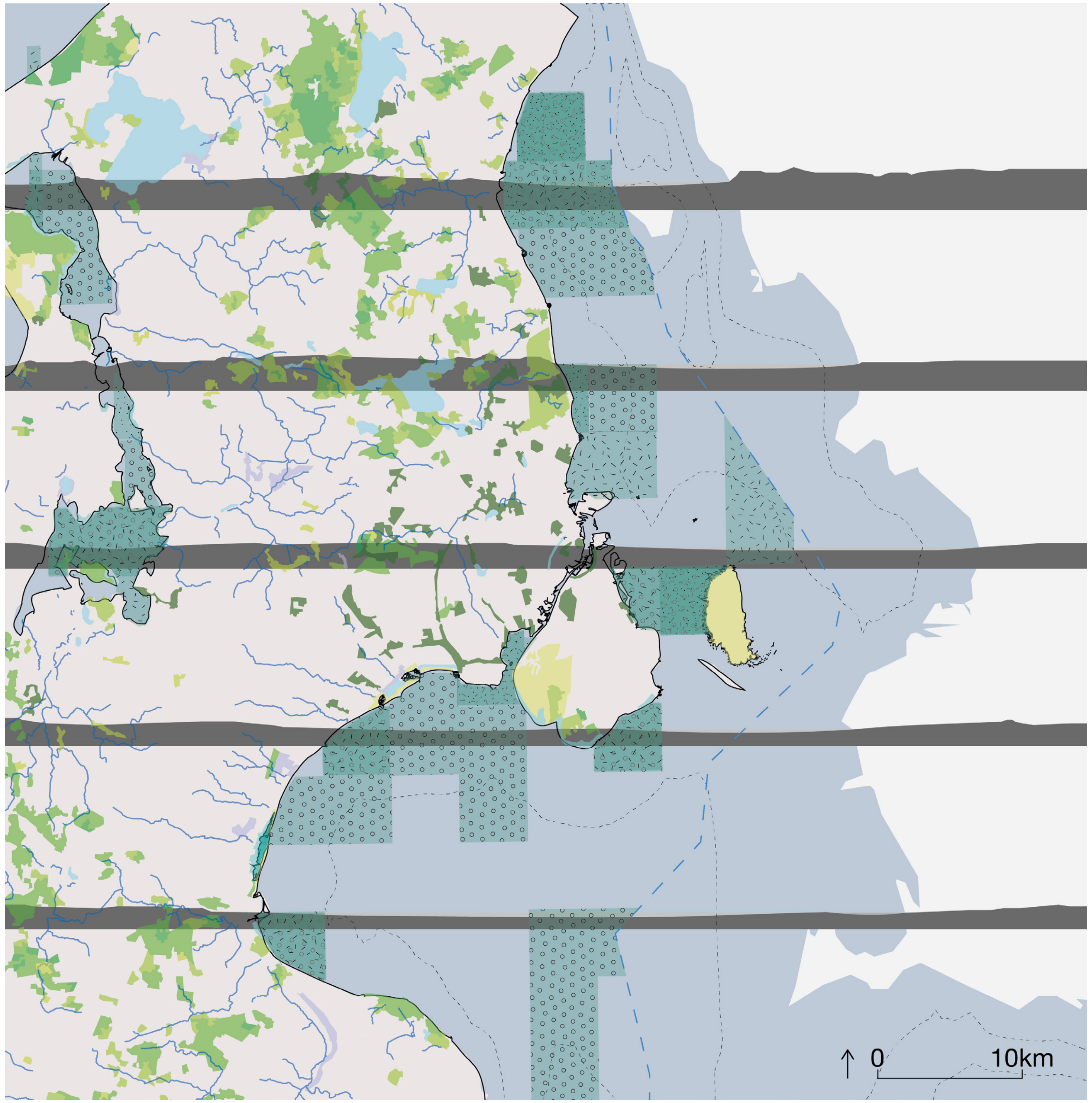
121 | Industrial or commercial units
123 | Port areas
124 | Airports
131 | Mineral extraction sites
142 | Sport and leisure facilities
Shipping intensity
V-low
V-high
Wind farm
511 | Water Courses
512 | Water bodies
521 | Coastal lagoons
411 | Inland marshes
412 | Peat bogs
421 | Salt marshes

Agricultures, Fishing & Aquaculture | Zealand · Copenhagen



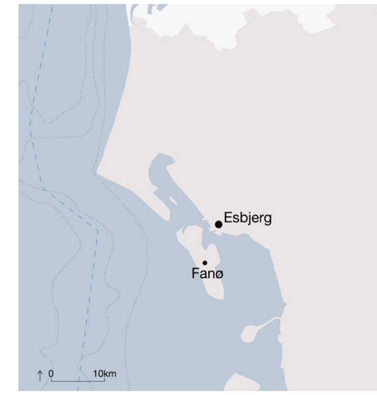
242 | Complex cultivation patterns
243 | Land principally occupied by agriculture
211 | Non-irrigated arable land
241 | Annual crop with permanent crops
231 | Pastures
Fishery effort
Low
High
511 | Water Courses
512 | Water bodies
521 | Coastal lagoons
411 | Inland marshes
412 | Peat bogs
421 | Salt marshes

Environment | Zealand · Copenhagen



- 141 | Green urban areas
- 311 | Broad-leaved forest
- 312 | Coniferous forest
- 313 | Mixed forest
- 321 | Natural grasslands
- 323 | Sclerophyllous vegetation
- 324 | Transitional woodland-shrub
- Zostera marina distribution
- Fucus distribution
- Furcellaria distribution
- 511 | Water Courses
- 512 | Water bodies
- 521 | Coastal lagoons
- 411 | Inland marshes
- 412 | Peat bogs
- 421 | Salt marshes

Jutland and Esbjerg



The case study looking at Jutland & Esbjerg is the only one for which there were not many data for the sea area, besides data on shipping intensity.

The first thematic sections map reveals a typical flat territory of low urban density, with a constellation of small compact town organized around the main city of Esbjerg located on the intertidal zone forming a semi-enclosed lagoon on the northern part of the Wadden sea.

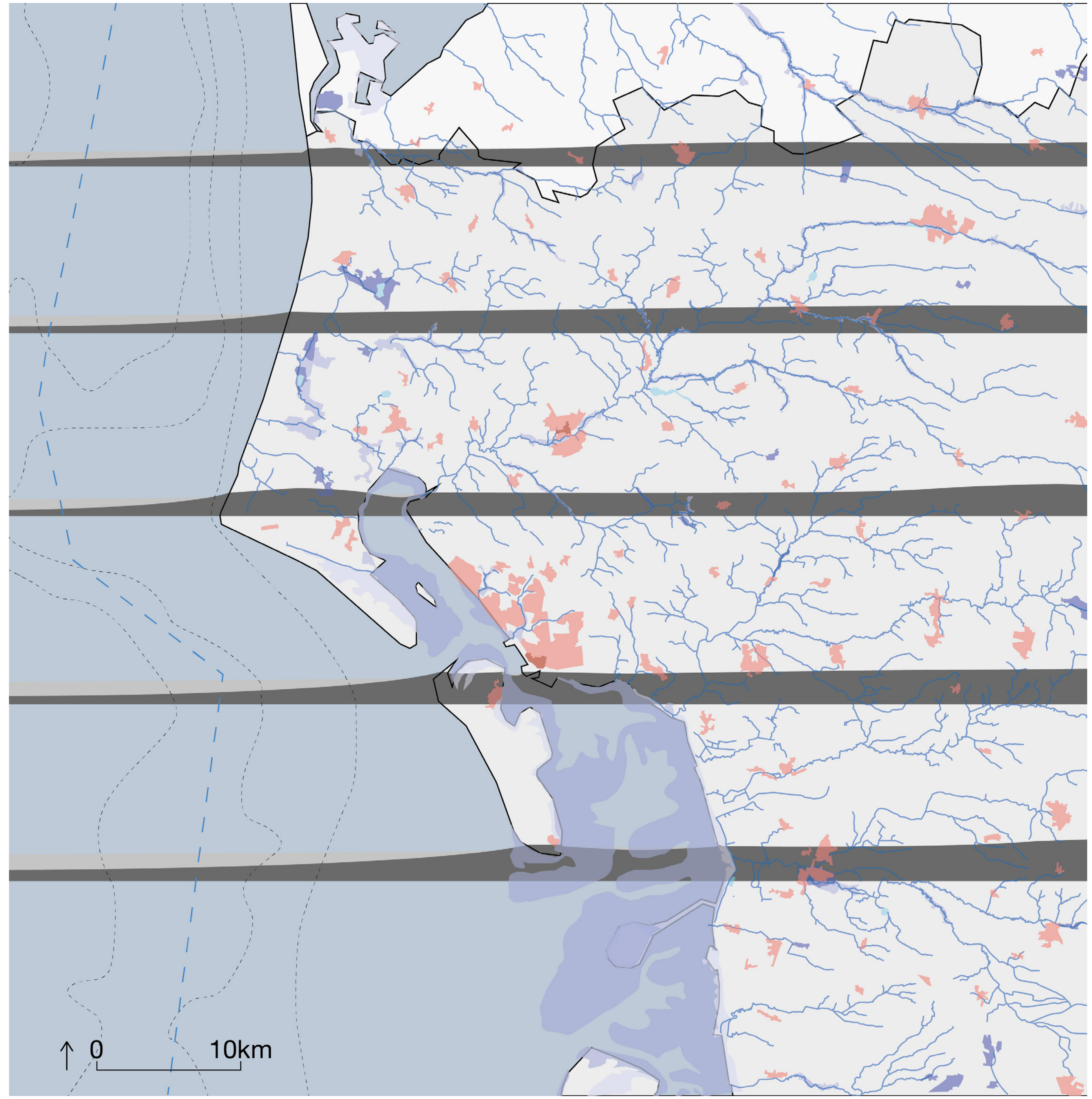
The Industries & Infrastructures map shows the main port infrastructure bordering the city of Esbjerg. From the layer of maritime traffic intensity, it is easy to see Esbjerg's role as the second cargo and utilities port in Denmark and the high pressure generated in the internal lagoon. The intensity of maritime traffic is fairly even all along the coastline. The coast around Esbjerg and on the island forming the lagoon has a few sports and leisure facilities, such as golf courses. Esbjerg itself is also organized as a tourist town.

The Agricultures, Fisheries & Aquaculture map unfortunately only shows agricultural components since it was not possible to collect the other data in this case study.
From the map it is clear that there is a lot of highly intensive agricultural production, with the port of Esbjerg port having an important role in the export of agricultural products.
The area feature three main types of agricultural fields: cultivated land parcels of non-permanent crops, land occupied by agriculture in a mosaic pattern composed from semi-natural areas, and mosaics of small cultivated land parcels with different types of cultivation, such as annual crops and permanent crops. Part of the agricultural land has been assigned to animal rearing (pastures), which are usually characterized as having a strong human impact on the environment.

The Environmental map explores the natural elements in the case study. As explained above, the case of Esbjerg was chosen also from its characteristic intertidal area, which forms a shallow body of water with tidal flats and wetlands. From the thematic section, it is clear that the natural elements, such as forest, mixed forest and grassland are located mainly in the northern part of the area under study, further inland, where there is little agriculture and urbanization.
The vegetation on the coast is predominantly moors and heathland that are characterised by having low-growing vegetation, but also include low-lying wetlands.

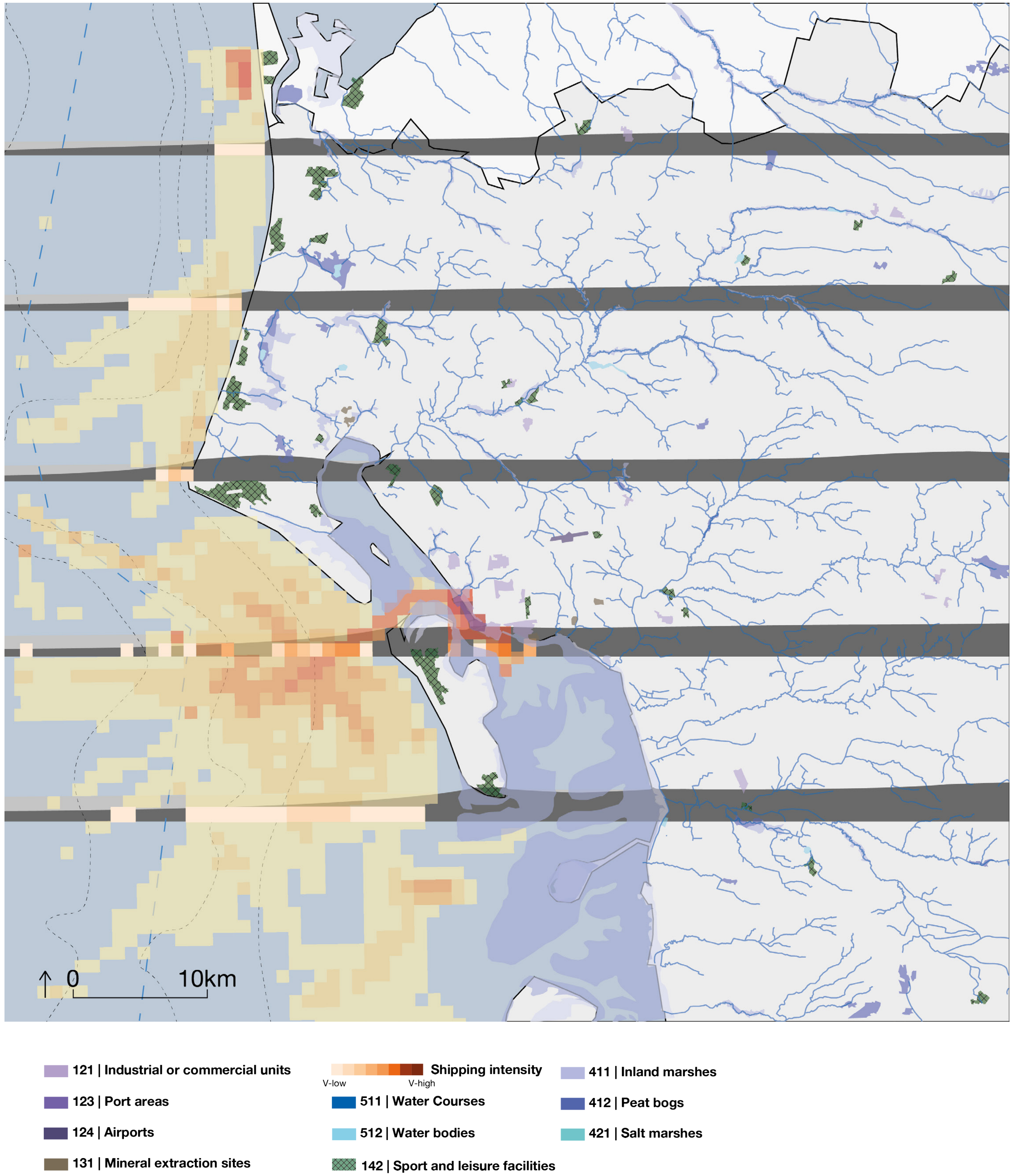
The thematic sections mapping analysis for the Jutland region & Esbjerg case study shows a territory that has a high percentage of land dedicated to agricultural fields and animal rearing. Unfortunately, it was not possible to obtain any data regarding the semi-enclosed lagoon in the sea area.
The mapping analysis reveals the buffer role that the natural moors, heathlands and wetlands on the northern coast have in retaining and cleaning any pollutants from the adjacent intensive agricultural production.

Urbanization | Jutland · Esbjerg

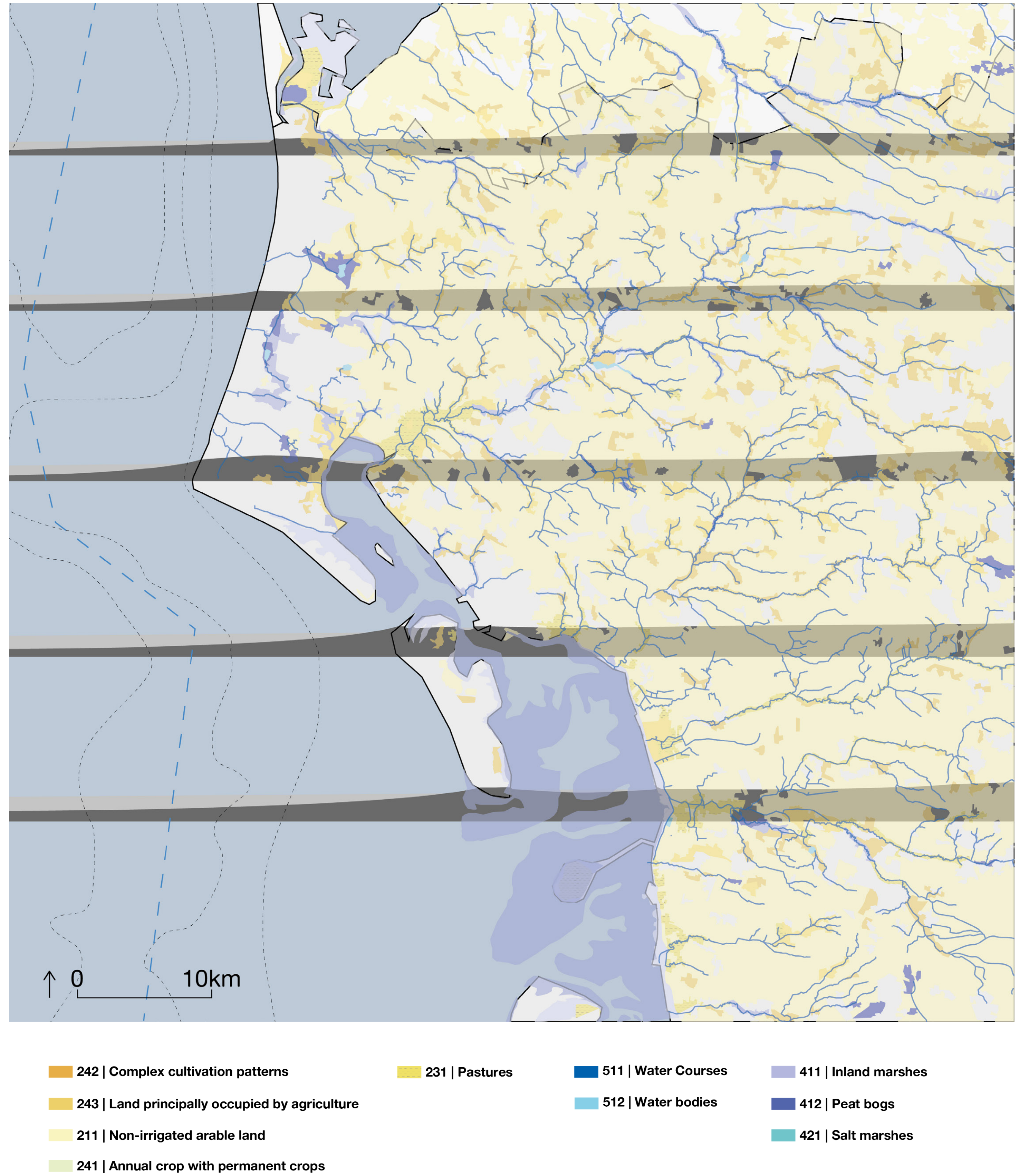


111 | Continuous urban fabric
112 | Discontinuous urban fabric
511 | Water Courses
512 | Water bodies
411 | Inland marshes
412 | Peat bogs
421 | Salt marshes

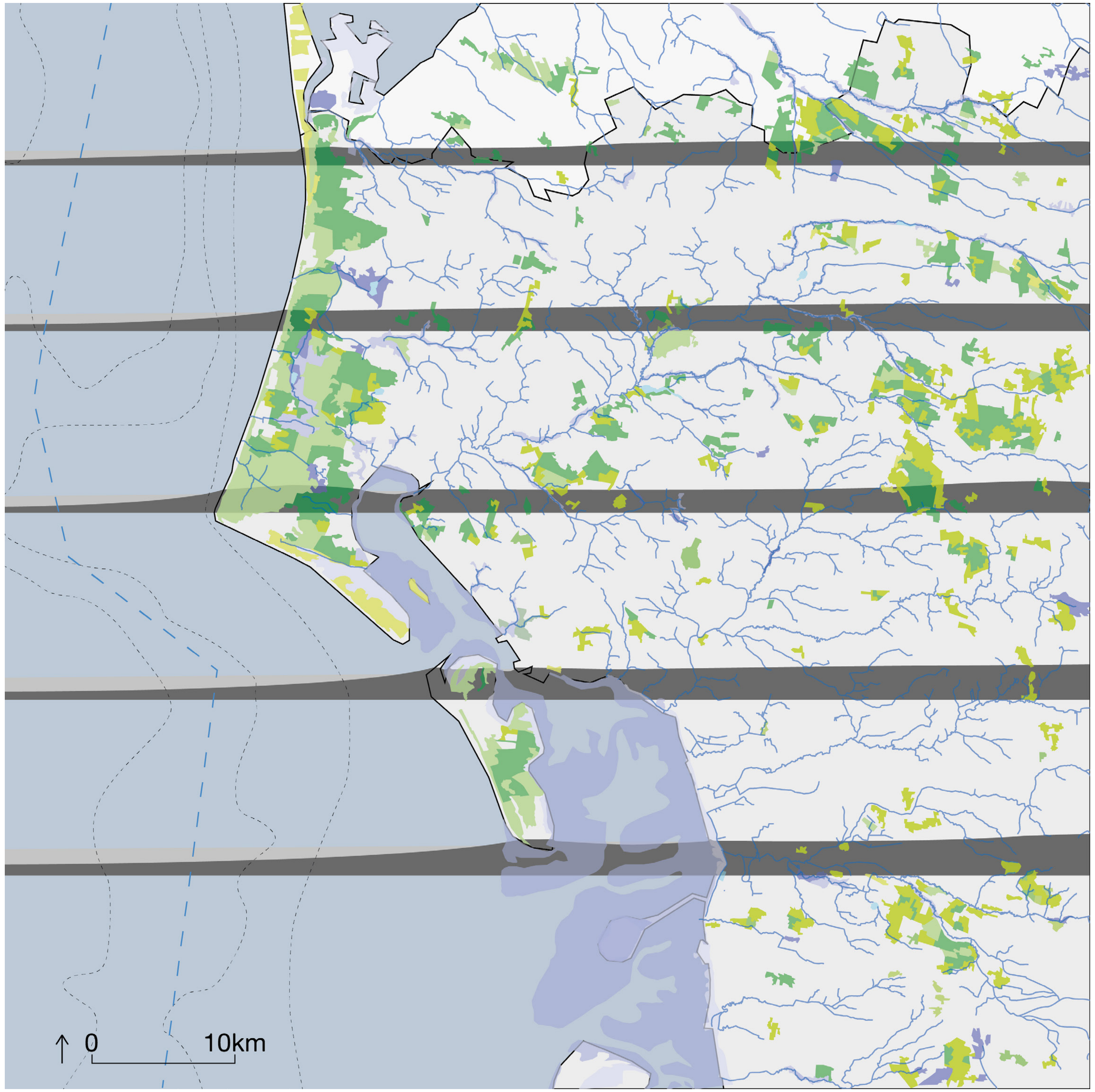
Industries & Infrastructures | Jutland · Esbjerg



Agricultures, Fishing & Aquaculture | Jutland · Esbjerg



Environment | Jutland · Esbjerg



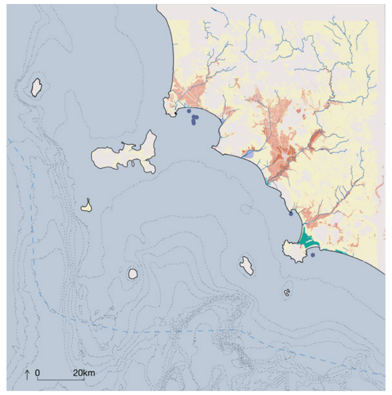
141 | Green urban areas
311 | Broad-leaved forest
312 | Coniferous forest
313 | Mixed forest
323 | Sclerophyllous vegetation
324 | Transitional woodland-shrub
321 | Natural grasslands
511 | Water Courses
512 | Water bodies
521 | Coastal lagoons
411 | Inland marshes
412 | Peat bogs
421 | Salt marshes

Tuscany and Piombino-Orbetello

The Tuscany region with Piombino and Orbetello is an example of a very diverse coastal territory ranging from a completely natural environment to an area under significant pressure from human activities (Piombino is industrial and Orbetello has a lot of tourism).

From the urbanization map, we can see that the urbanized territory is organised into a conurbation of small cities and towns along the coastline, with no significant urban sprawl inland.
There are three main cities in the area: Piombino, Grosseto and Orbetello.
Piombino is known for its port linking Tuscany to the island of Elba and for its iron and steel production.
Grosseto is the capital of the Tuscan province of Grosseto.
Orbetello lies in the middle of the eponymous lagoon and is connected to Monte Argentario, which is a highly pressured area as summer tourist attraction.
This type of conurbation features a coastline that is directly open to the sea. On the map, we can also see some small marinas that are important for the tourist industry all along the coast.

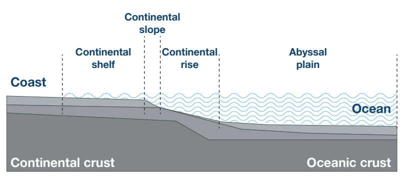
The Industries & Infrastructures map shows that the case study has principally two areas of heavy industrial production.
The main port in the area is located in Piombino; it is partly a passenger port, since it is the only link to the island of Elba, and partly a commercial port, mainly to serve the iron and steel industry, which is based on the presence of iron deposits on Elba. As a result, the port of Piombino, in relation to the discourse on land-sea interactions discourse, is a huge generator of pollution.
The map also shows that many of the industrial areas in the case study are either located on the seashore or next to a wetland.
This relation is even clearer if we look at the maritime traffic around and between Piombino and Elba.



The Agriculture, Fisheries & Aquaculture map shows a territory partially given over to different types of crop cultivation. The fields often do not extend very far since the morphology of the territory is composed of hills and small mountains and only has flat areas close to the coast. The cultivated land parcels are mixed between regular fields of permanent crops, parcel areas planted and vines and olive trees. Certain types of agricultural production also critically affect land-sea interactions since there is widespread use of fertilizers. One of the spatial plans (PIT) of the Tuscany Region shows all the cultivated fields that could potentially discharge a significant number of pollutants, leading to a negative land-sea interaction. At the same time, there are concessions for fish farming along the coastline, located adjacent to river estuaries, which could also possibly create negative interactions. There is also a lot of intensive fishing production in the sea area of the case study.

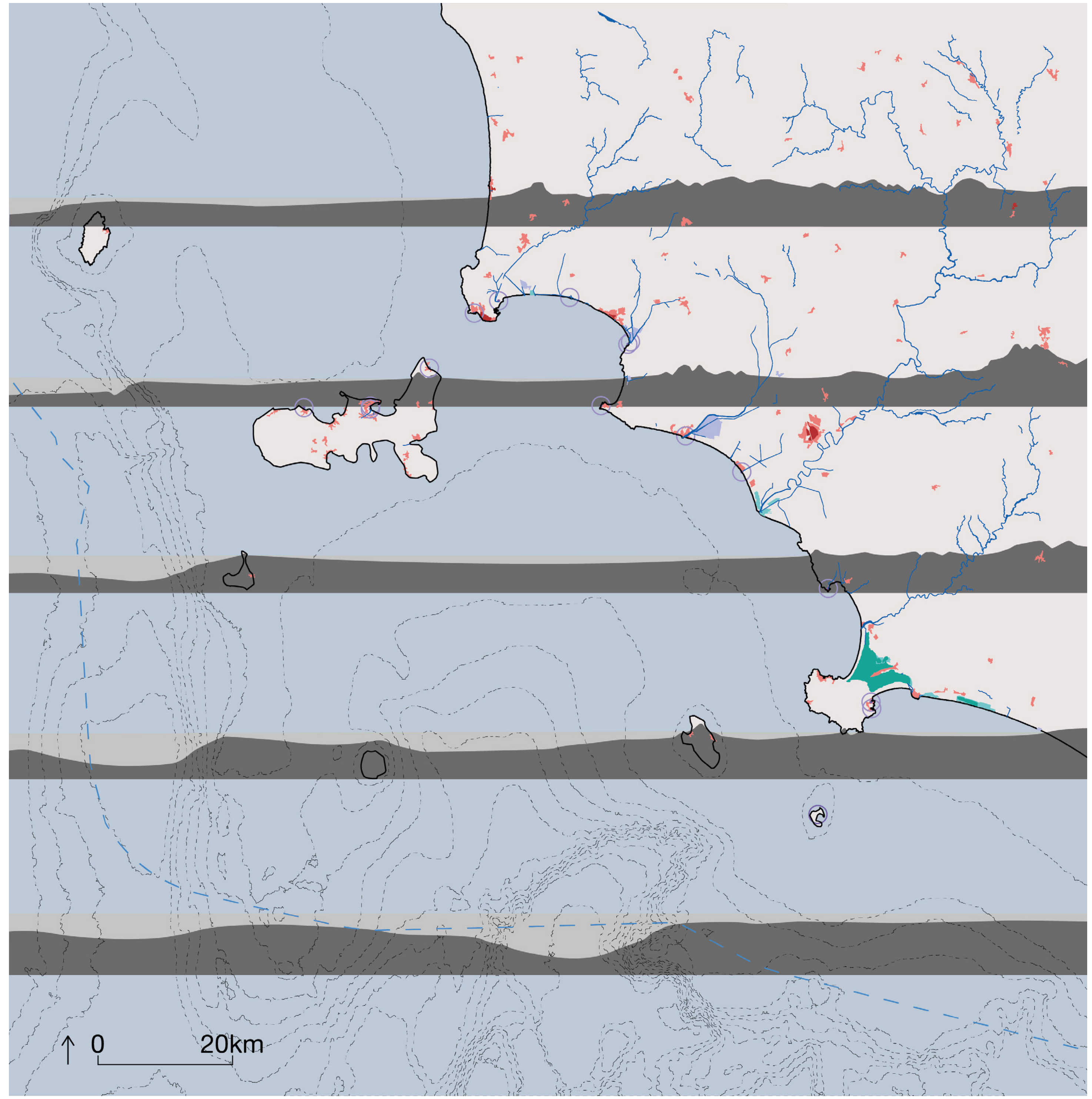
The Environmental map shows that the distributed natural areas in the Tuscany case study are composed mainly of mixed forest, broad-leaved forest and transitional woodland-shrub. In some areas, the natural elements seem to form a land to sea continuum, even though it is likely that by zooming in on these areas, we would see that the continuum may be broken by man-made infrastructures. All along the continental shelf there are seagrasses of the species Posidonia oceanica and Cymodocea nodosa, which are the perfect habitat for fish for spawning and nurseries.

The thematic sections mapping analysis of the Tuscany case study shows a territory consisting predominantly of very diverse agricultural patterns, preserving a natural environment. Agricultural crops like vines and olive trees also enhance the valuable and productive landscape.



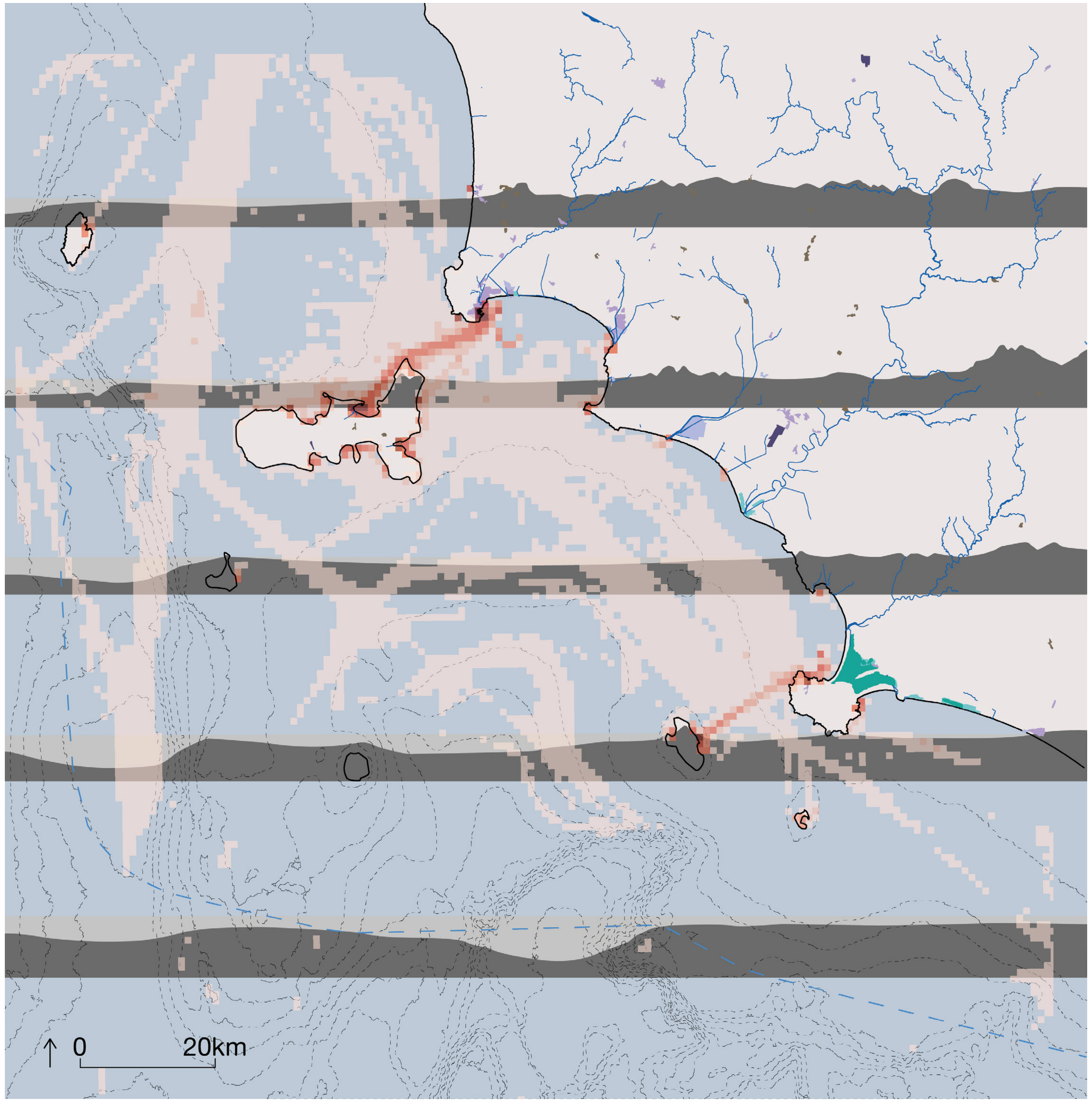
A **continental shelf** is a portion of a continent that is submerged under an area of relatively shallow water known as a shelf sea.

Urbanization | Tuscany · Piombino-Orbetello



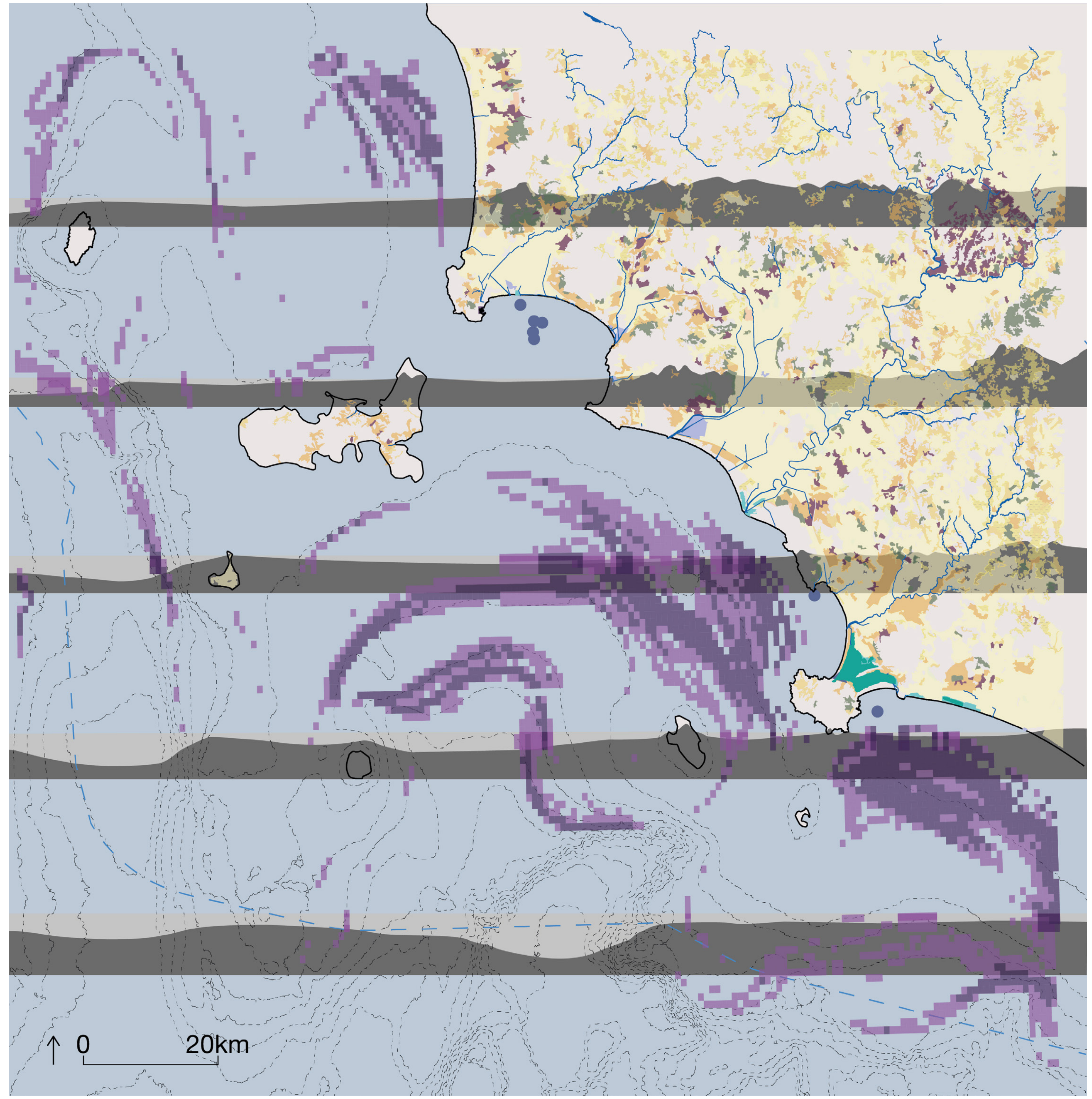
111 | Continuous urban fabric
112 | Discontinuous urban fabric
Marinas
511 | Water Courses
512 | Water bodies
521 | Coastal lagoons
411 | Inland marshes
412 | Peat bogs
421 | Salt marshes

Industries & Infrastructures | Tuscany · Piombino-Orbetello



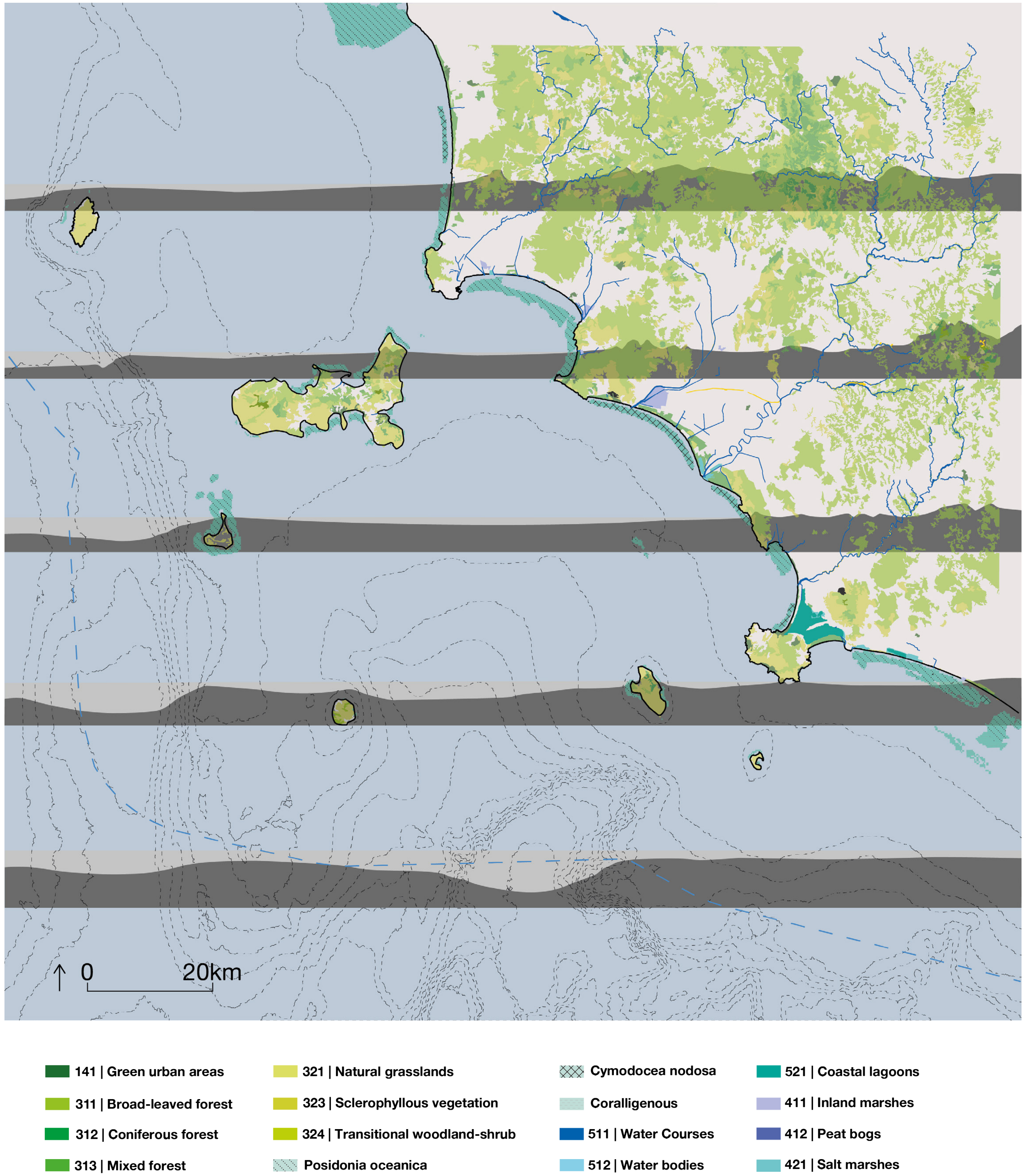
121 | Industrial or commercial units
123 | Port areas
124 | Airports
131 | Mineral extraction sites
142 | Sport and leisure facilities
Shipping intensity (V-low – V-high)
511 | Water Courses
512 | Water bodies
521 | Coastal lagoons
411 | Inland marshes
412 | Peat bogs
421 | Salt marshes

Agricultures, Fishing & Aquaculture | Tuscany · Piombino-Orbetello

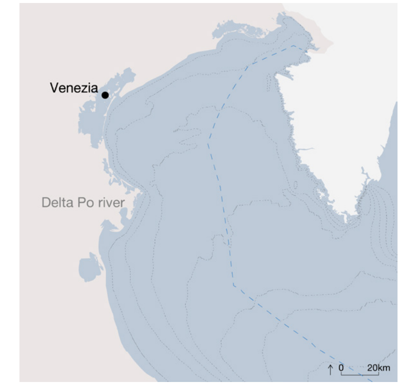


242 | Complex cultivation patterns
243 | Land principally occupied by agriculture
211 | Non-irrigated arable land
241 | Annual crop with permanent crops
231 | Pastures
221 | Vineyards
223 | Olive groves
Fishery effort (Low – High)
511 | Water Courses
512 | Water bodies
521 | Coastal lagoons
411 | Inland marshes
412 | Peat bogs
421 | Salt marshes

Environment | Tuscany · Piombino-Orbetello



Veneto and Venice



The Veneto region and Venice, which was the fourth case study, is located in the eastern part of the largest flat area in Italy, and is densely populated, with a lot of intensive agriculture and industry. Because of its strategic position, the sea around the area comes under a lot of pressure from human activity.

The urbanization map shows the best example of urban sprawl (the Italian terms being città diffusa) (Indovina, 2009) among all the case studies. It is possible to see from the first mapping analysis that there is a continuum of low density discontinued urbanization in this case study. The whole of the northern part of the coastline from the Delta Po river is densely urbanized and is a very popular tourist destination. Unfortunately, it was not possible to obtain adequate data about the pressures from tourism as compared to, for example, the Copenhagen case study with its coastal recreational boating.

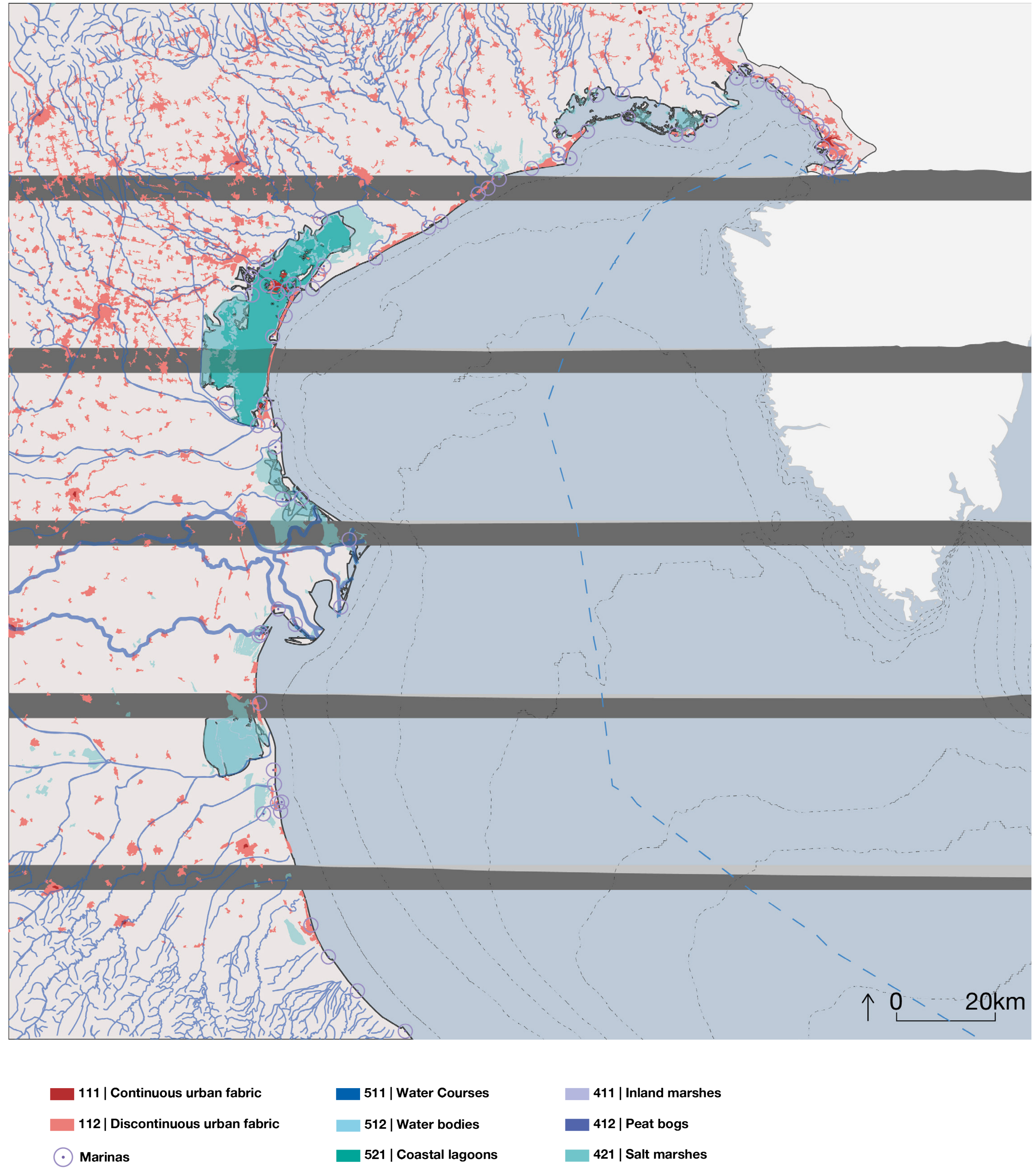
The Industries & Infrastructures map shows the widespread industrial production in the region. The only concentrated industrial area is Marghera, a municipality in the metropolitan city of Venice, which is located west of Venice and on the border of the lagoon. A heavy concentration of industries bordering the lagoon generates negative interactions due to the surface runoff from the area and because of the high probability of pollutant discharge into the lagoon. As a result of the industrial production, the mapping analysis also shows the high level of maritime traffic and the effects that this can have on the marine and coastal environments.

The Agricultures, Fisheries & Aquaculture map shows the eastern part of the Po valley, also called Padan Plain, limited in the west and north by the Alps and in the south by the Appennini chain. The mapping analysis describes a territory with a lot of agriculture and intensive animal farming and production. In fact, the Po Valley is one of the most important industrial and agricultural areas in Europe, and the Po river is extensively used for irrigation for the region's agriculture. On the northern part of the Po valley in the Veneto region at the foot of the pre-Alps, some of the agricultural fields are used for wine production. For the sea area, there is a lot of intensive fishing and fish farming all along the coast and in the lagoons.
Taken together, these activities put enormous pressure on the environment and generate land-sea interactions between other anthropic activities.

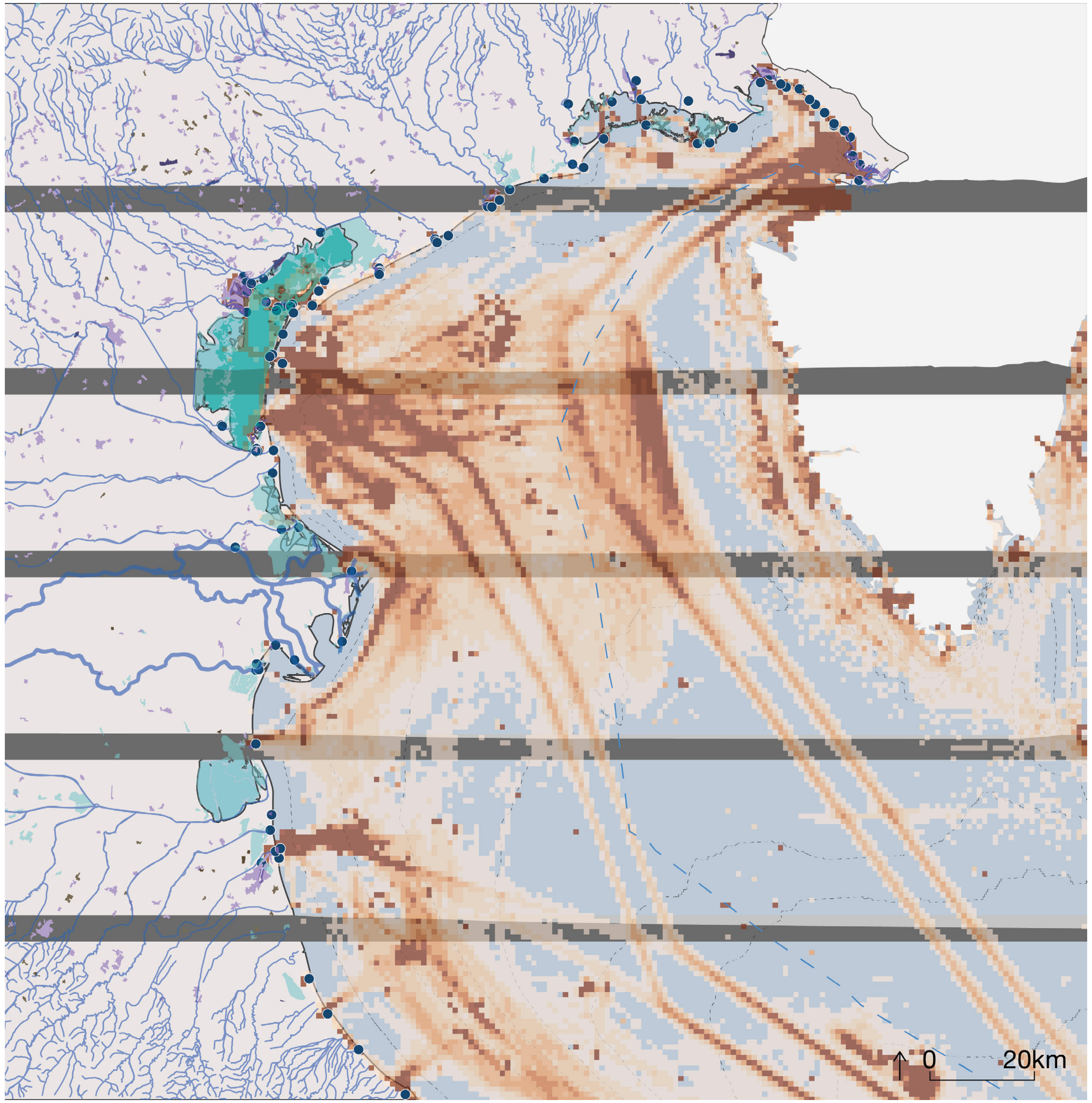
The Environmental map reveals the fact that a highly intensive agricultural and industrial territory will not also allow major natural elements to flourish. The green areas that do exist are distributed between the fields, but this morphology does not allow the growth of proper forested areas. This case study provides an excellent example of a coastal zone composed of a richly biodiverse landscape of lagoon, wetland and the biggest delta river in Europe, juxtaposed with high-production agricultural land.

The thematic sections mapping analysis of the Veneto region and Venice shows an area strongly dominated by an agricultural and, in part, industrial landscape, but which also has important natural features such as lagoons and wetlands.
These two characteristics do not always work well together in land-sea interactions.

Urbanization | Veneto · Venice

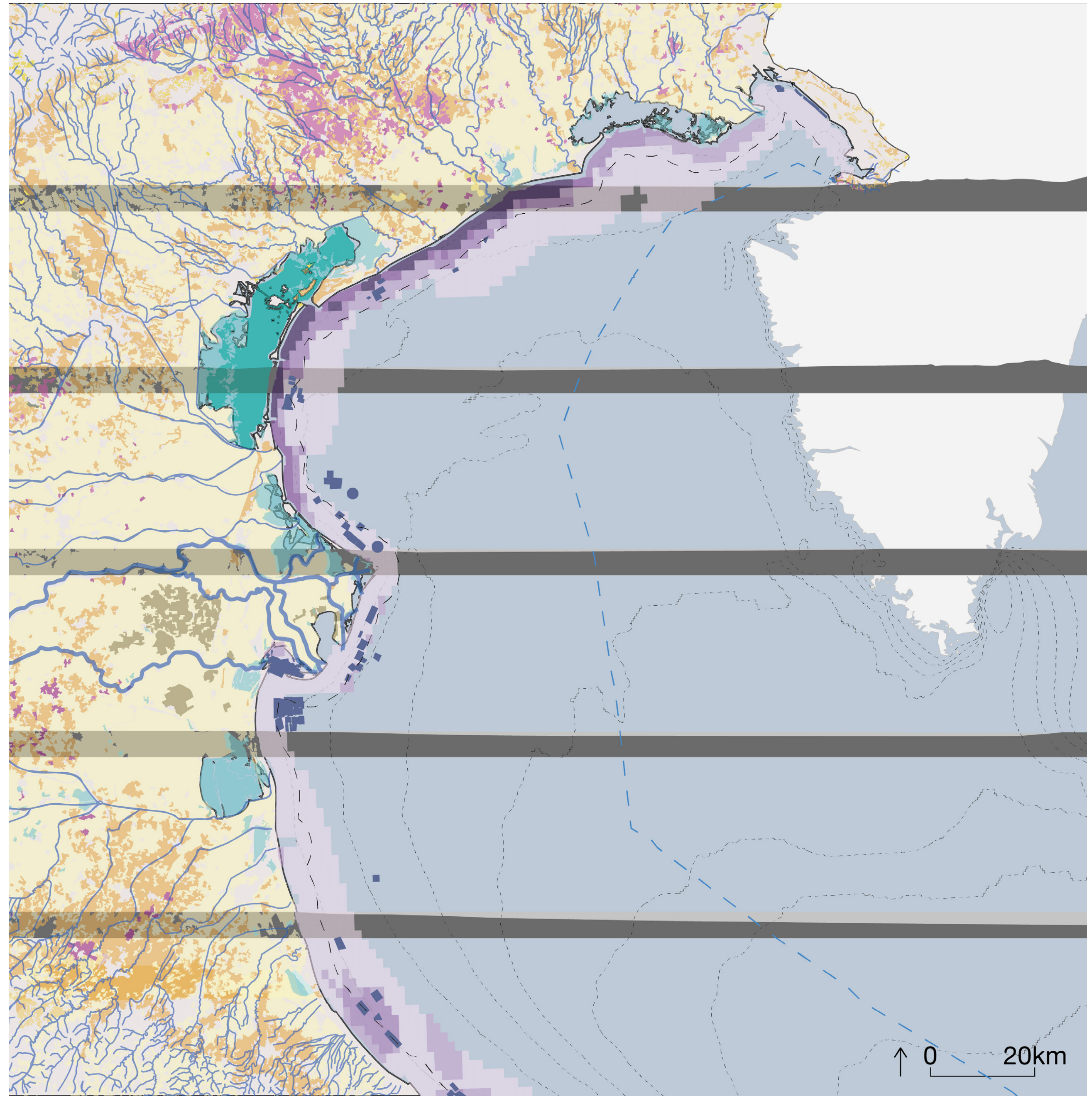


Industries & Infrastructures | Veneto · Venice



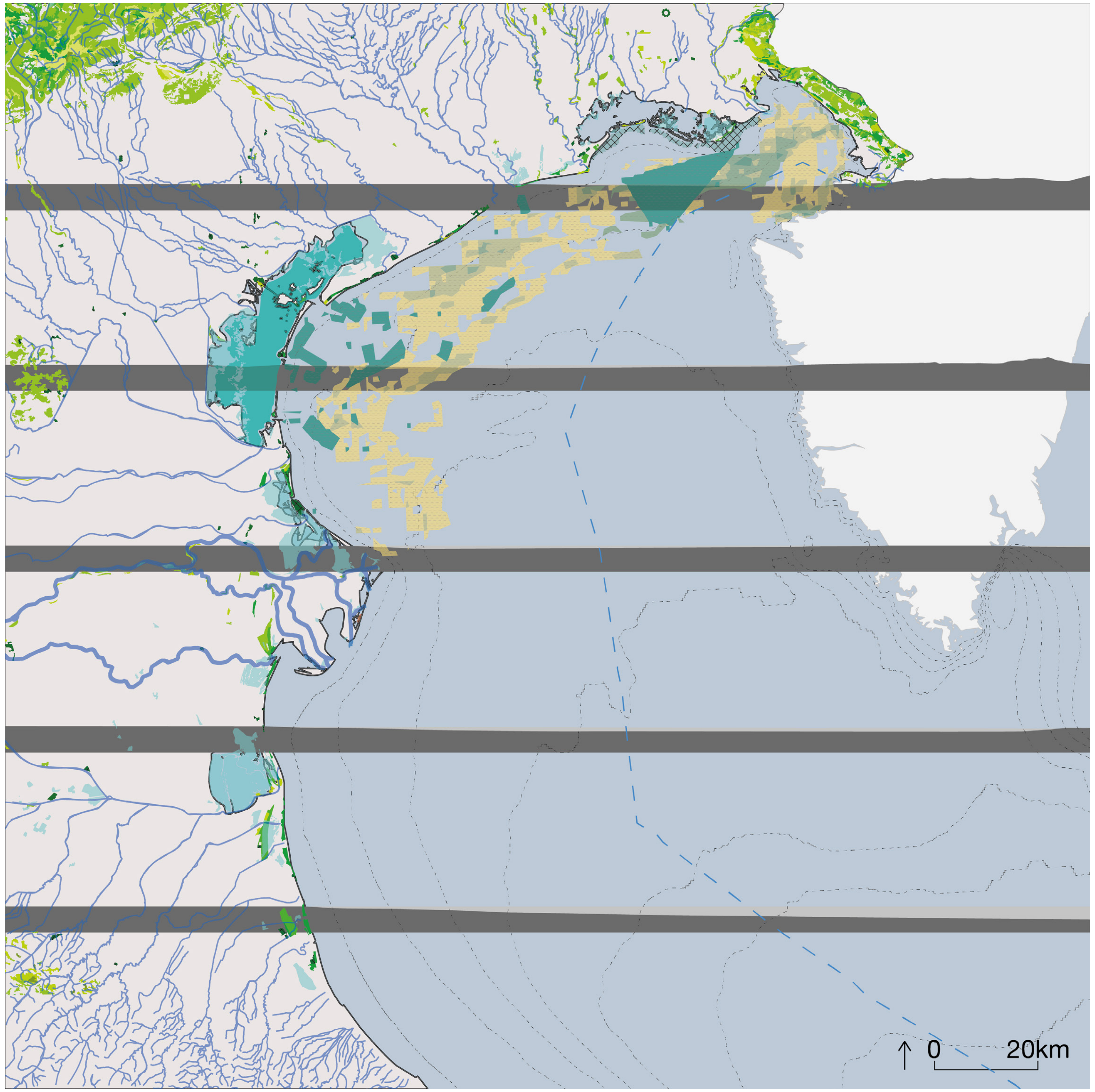
121 | Industrial or commercial units
123 | Port areas
124 | Airports
131 | Mineral extraction sites
Shipping intensity (V-low – V-high)
511 | Water Courses
512 | Water bodies
521 | Coastal lagoons
411 | Inland marshes
412 | Peat bogs
421 | Salt marshes

Agricultures, Fishing & Aquaculture | Veneto · Venice



242 | Complex cultivation patterns
243 | Land principally occupied by agriculture
211 | Non-irrigated arable land
241 | Annual crop with permanent crops
231 | Pastures
221 | Vineyards
223 | Olive groves
511 | Water Courses
512 | Water bodies
Fishery effort (Low – High)
521 | Coastal lagoons
411 | Inland marshes
412 | Peat bogs
421 | Salt marshes

Environment | Veneto · Venice



COLOURED SECTIONS

The coloured sections contain all the information highlighted in the four thematic sections: Urbanization, Industries & Infrastructures, Agricultures, Fishing & Aquaculture and the Environment.

The concept behind utilising the coloured sections was to organize all the land and sea information within one landscape cross-section and to visualize a typical section of the case study.

Looking at the Zealand & Copenhagen case study, the compactness of the urbanization both in the inner part of Copenhagen, but also in the northern and southern parts, show how it creates a very well-defined landscape. The first two coloured sections show a more urbanized territory made up partly of the cities along the coast and partly of inland areas close to Roskilde Fjord. The section of Copenhagen (3) has a very urbanized landscape on the coast, with a high density of human activities also undertaken in the sea area facing the city of Copenhagen, which is typical of densely urbanized coastal cities. Moving south to coloured sections 4 and 5, we can see how the landscape is more clearly defined with urbanized coastal areas and a predominantly agricultural landscape bordering the coastal settlements.

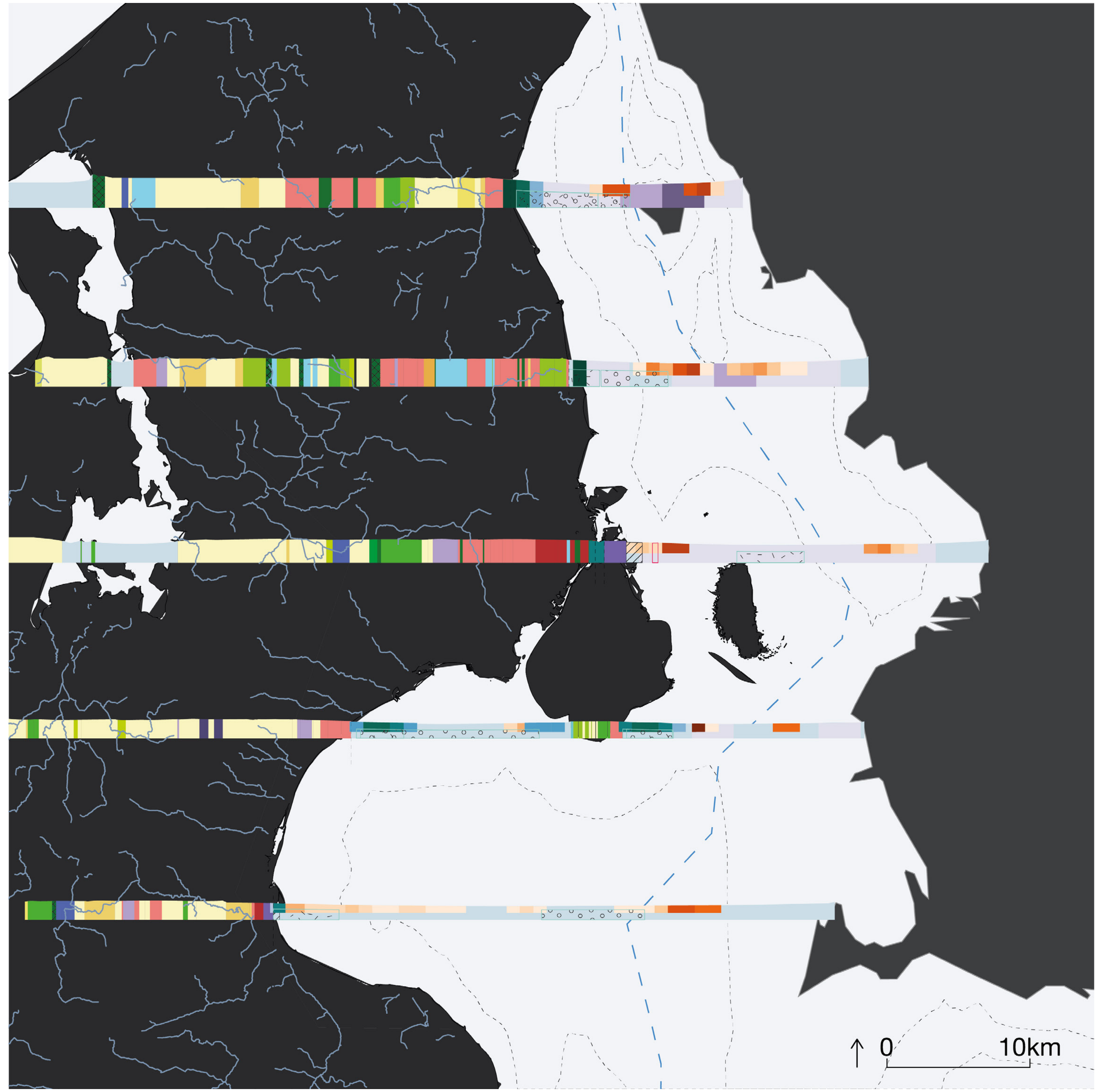
The coloured section map of the Jutland region & Esbjerg shows a completely different landscape to the Zealand region.
The predominant landscape, in all the coloured sections, is agricultural, sometimes interrupted by some small urban areas.
The first three coloured sections show that the landscape close to the coastal area is more natural, which is beneficial for the land-sea interactions discourse because of the positive effects of retaining and cleaning, which these types of elements can do. Sections 4 (Esbjerg) and 5 are much more agriculturally productive, mainly due to the proximity of the city of Esbjerg. In fact, the sea area in front of the last two sections is also very much affected by

shipping traffic (Esbjerg port).

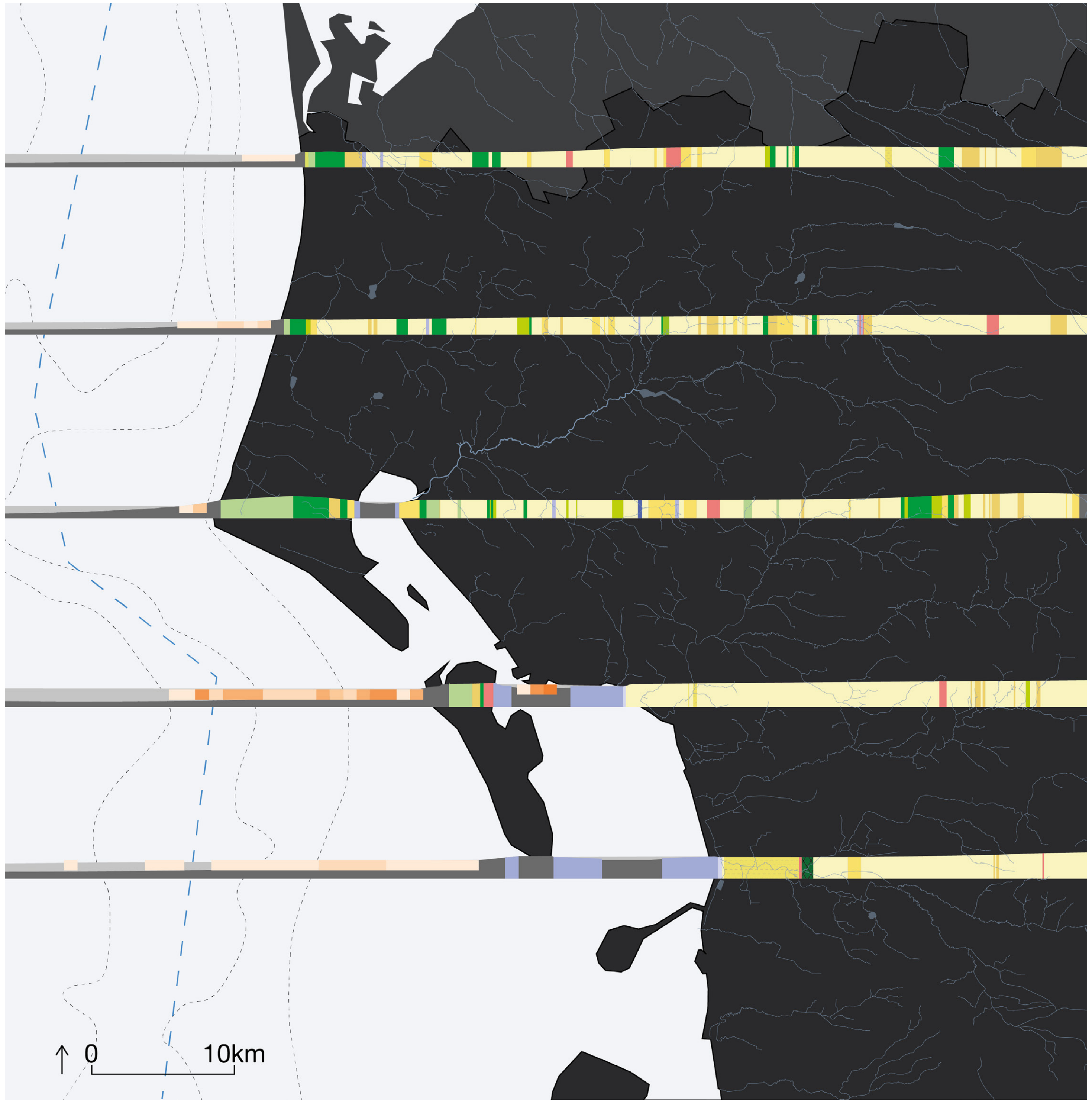
The coloured section map of the Tuscany region with Piombino & Orbetello shows a very mixed landscape made up of different types of agricultural and natural areas.
The first coloured section is a very dense patchwork of colours since the morphology of the territory is predominantly hills and small mountains. The section is covered mainly with mixed forests, forests and green areas, sometimes interrupted by small vineyards, olive groves and crop fields. In the second section, the morphology is that of a valley between two forested mountains where there are more areas of intensive agricultural production. The third coloured section of Tuscany shows a very fragmented agricultural landscape of vineyards, olive groves and small crop fields.

The coloured section map of the Veneto region with Venice shows a very fragmented territory due to the urban sprawl. Looking at the first, second and fifth coloured sections, we can clearly see the heterogeneous cadence of a sequence of different land uses, such as low density urbanized areas, intensive agricultural fields, vineyards, industry and animal rearing. The third and fourth coloured sections are predominantly agriculturally driven, due to the morphology arising from the area being located in the Po river valley. The consequences of this have been described extensively in different articles in both literature reviews; one area in a different part of the world that very much resembles this case study is that around the Mississippi River.

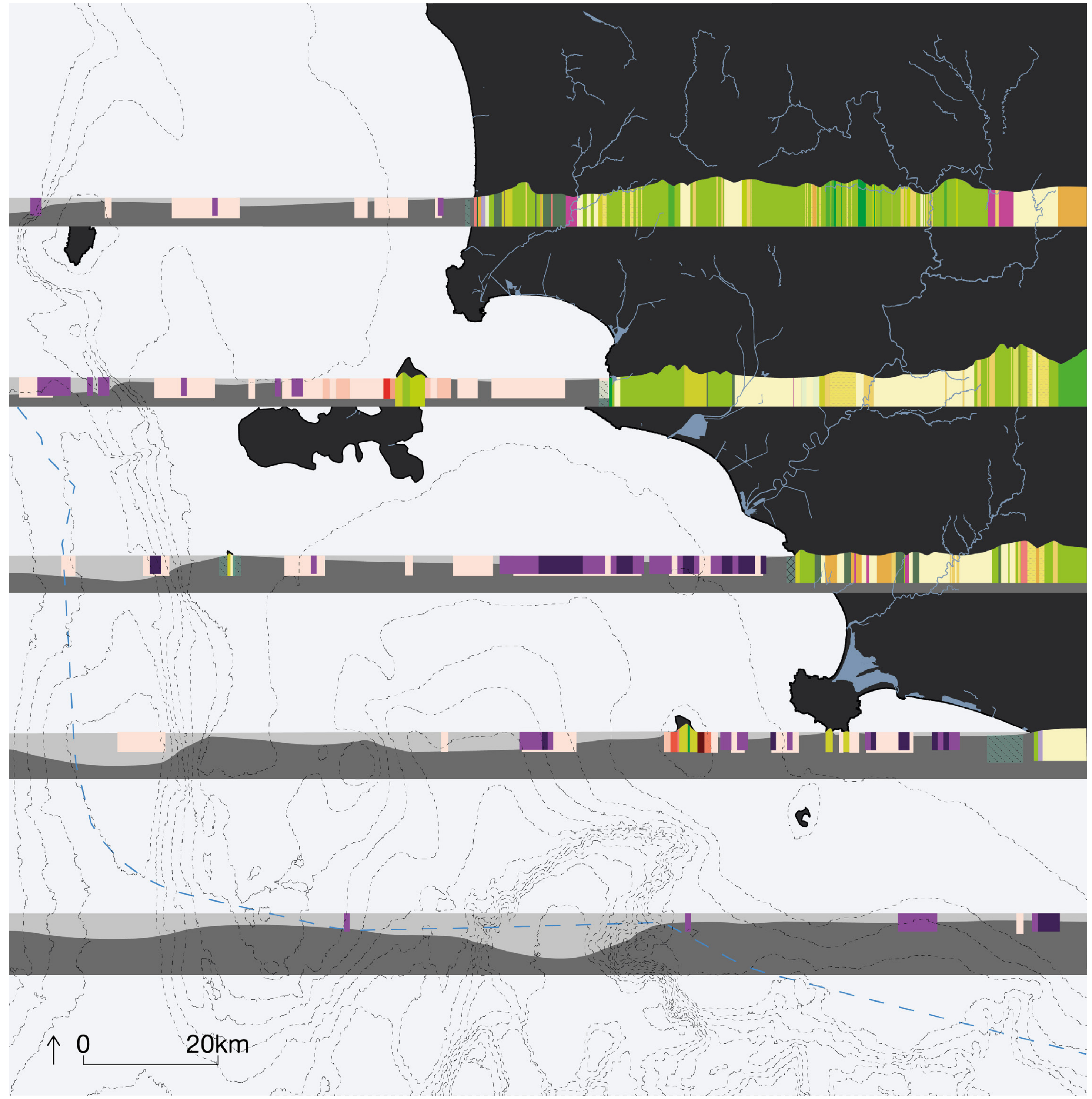
Coloured section Zealand region



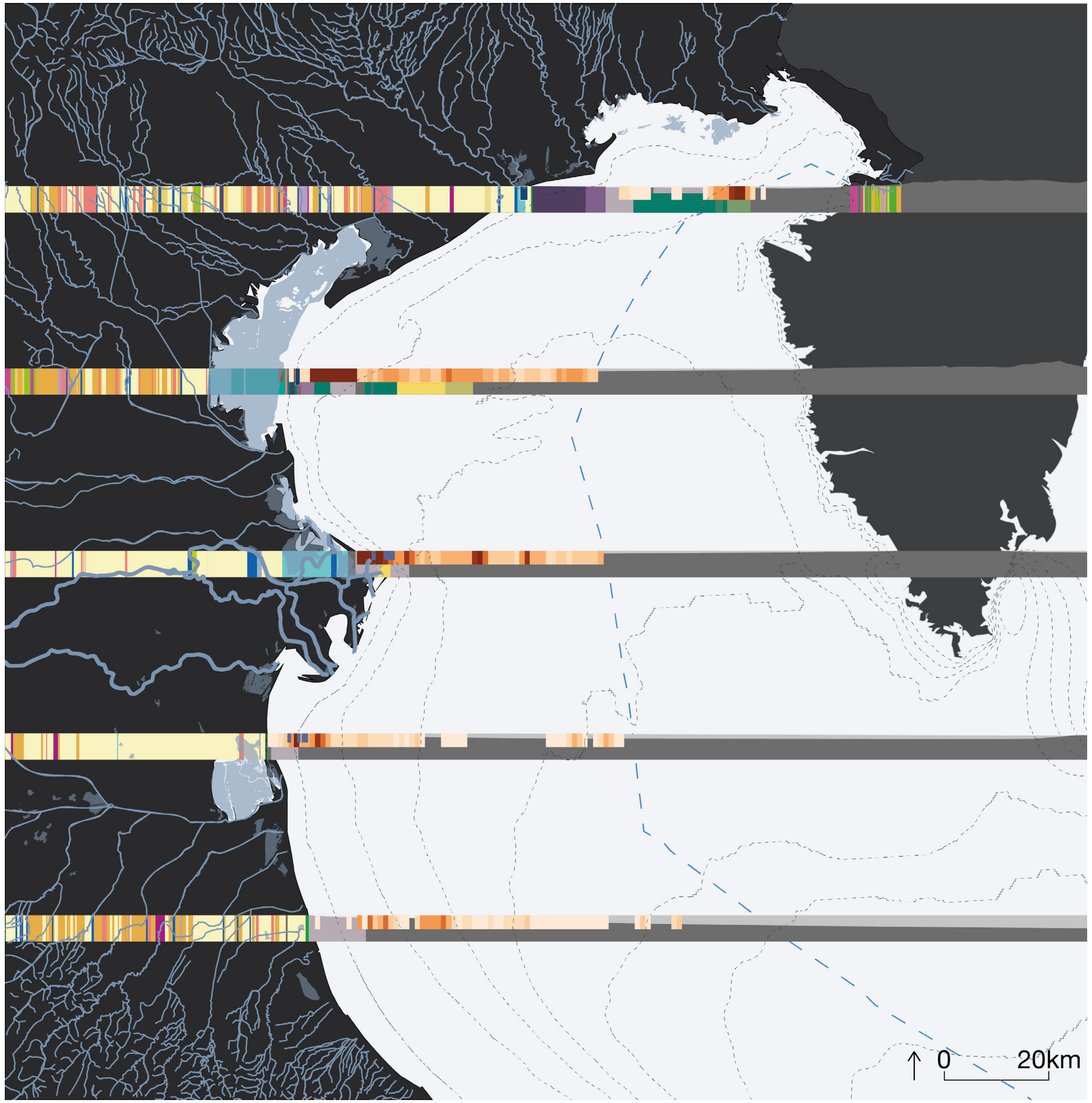
Coloured section Jutland region



Coloured section Tuscany region



Coloured section Veneto region



DNA SEQUENCES

The last mapping analysis of the first phase, the DNA sequence, provides further clues about land-sea interactions and different coastal areas in Europe through conceptualizing the areas as strips of DNA. As seen in chapter 3.3 Case studies and data issues, to the aim of using case studies was to offer a real context to facilitate the investigation.

The DNA sequence mapping analysis provides a representation of the coastal environments showing sequences of anthropic and natural elements, activities and dynamics through a “DNA strip” in order to draw clearer comparisons between different coasts, so via their different DNAs.
This method of conceptualizing landscapes creates the opportunity to think outside the box, in order to more easily find similarities and differences between coastal areas.

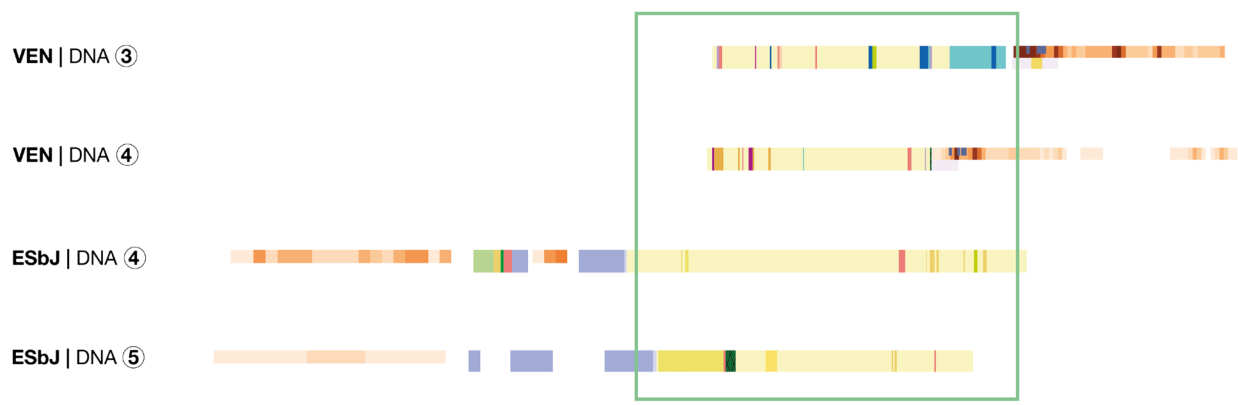
There are three main conclusions to be drawn from comparing the DNA strips in this last mapping analysis of coastal areas related to land-sea interactions.

The first comparison, which was between two DNA strips, one of the Veneto region & Venice and the other of the Jutland region & Esbjerg, shows that a certain type of environment, rich in natural resources and biodiversity, such as deltas and intertidal zones (tidal flats and wetlands), may allow for the development of agricultural areas.

Even with different urban morphologies, the Veneto region featuring urban sprawl and the Jutland region with its compact low-density urbanization, the two DNAs show some similarities, as seen in the types of agricultural fields, all of which need wide expanses of open flat land.

This kind of territory, as we know from the literature review, can have a negative impact on the coastal and marine environments. The two agricultural areas in this study are in the Po Delta and in the Wadden intertidal zone, constituting two rich but vulnerable natural areas. If not well managed, the agricultural sector of an area can seriously upset the balance of these natural systems and thereby create negative land-sea interactions.

First comparison

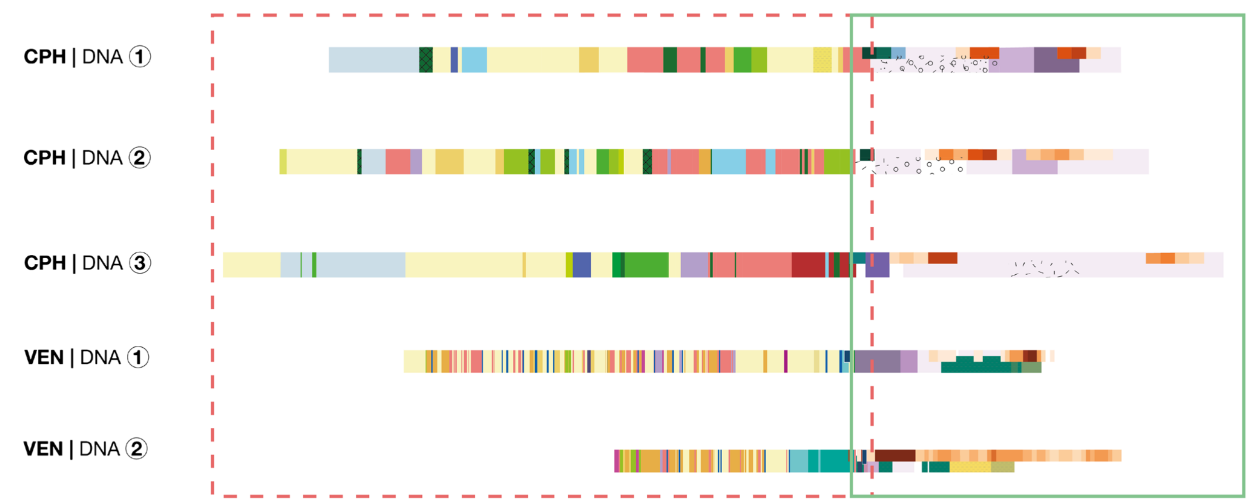


The second comparison is between three strips of Zealand data and two from the Veneto case study. While these two cases are both fragmented, Zealand & Copenhagen have clear cadence as a result of the well-planned territory so the different components take their own space in the territory. This contrasts sharply with the Veneto case study, which has an intermittent cadence that makes it difficult to clearly make out the territorial dynamics.

The most interesting insight from the comparison is that, even though the DNAs have different sequences, in both cases they contain similar distribution of anthropic and natural elements. The large number of activities on land and their high density are directly proportional to the activities at sea. In both cases, the sea areas are densely anthropized as a result of human activities.

We can therefore conclude that highly developed regions and their coastal cities generate a lot of land-sea dynamics. These areas can be seen as hotspots of land-sea interactions, so it is difficult to pinpoint one specific interaction. We therefore need to take into account all the land activities identified and follow the fluxes scheme in order to identify any possible interactions.

Second comparison



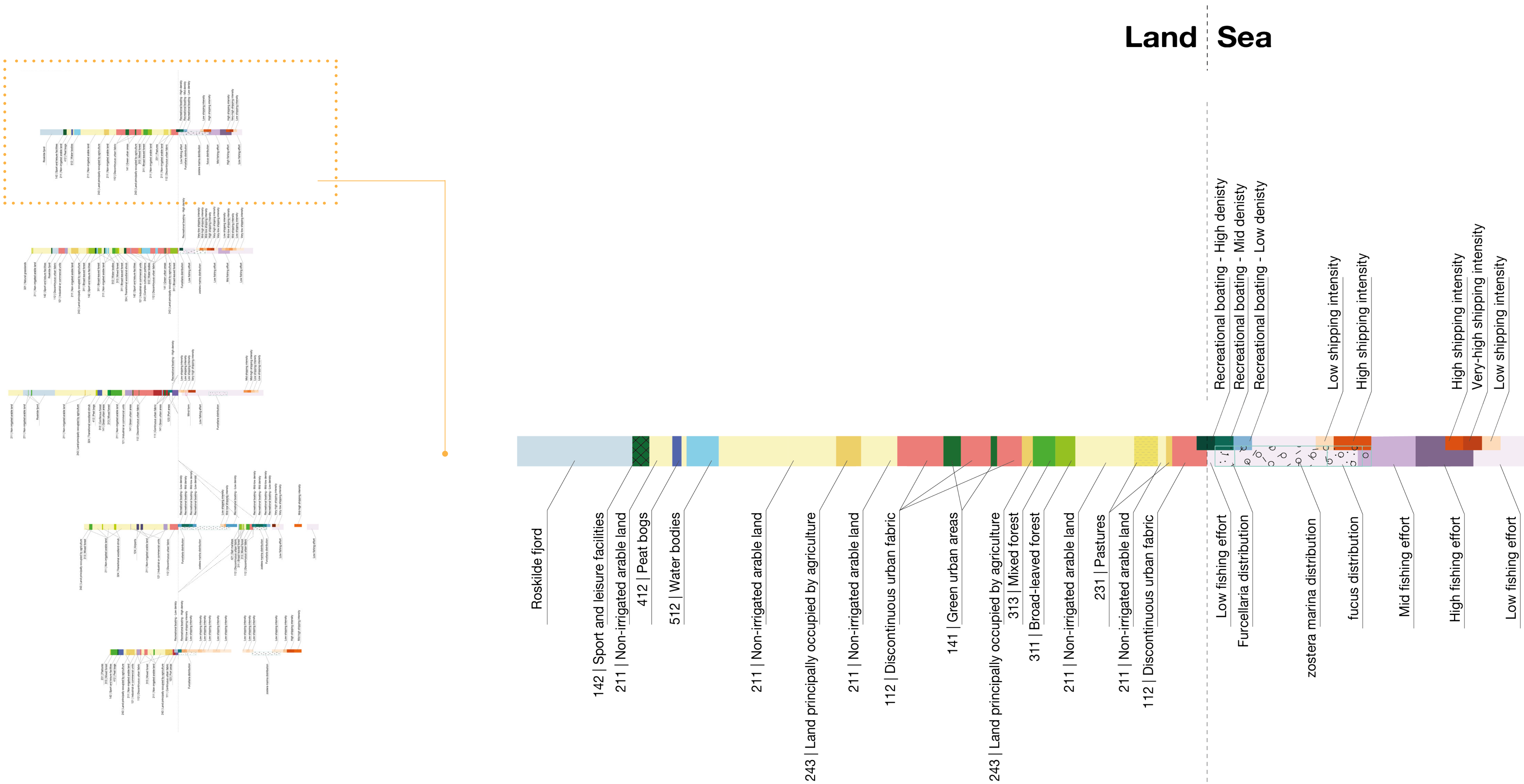
The last comparison is between some DNA strips of data from the Jutland region and from the Tuscany region. From the five strips, we can see a similar tendency in the repeated coloured patterns in both DNA strips, indicating alternating forests, natural areas and agricultural fields.
The main difference between the two regions is that in the Jutland case these patterns are spread along flat land, while in the Tuscany case the orography of the territory restricts the coastal area where both natural and human activities are concentrated.
Another main difference is the different level of intensity of the activities taking place at sea . Unfortunately, for the case study of the Jutland region & Esbjerg, I was not able to gather any other data than the levels of shipping intensity.

Third comparison

The first phase of the mapping analysis highlighted in different ways the importance of using case studies in spatial planning research.
The different types of mapping analyses have made it possible for us to more clearly visualize the spatial information about land-sea interactions and issues affecting coastal areas. The first phase of the mapping analysis enabled me to cross-check the information that was collected from the first key milestone, The complexity of the coastalscape, and apply it to real case studies.

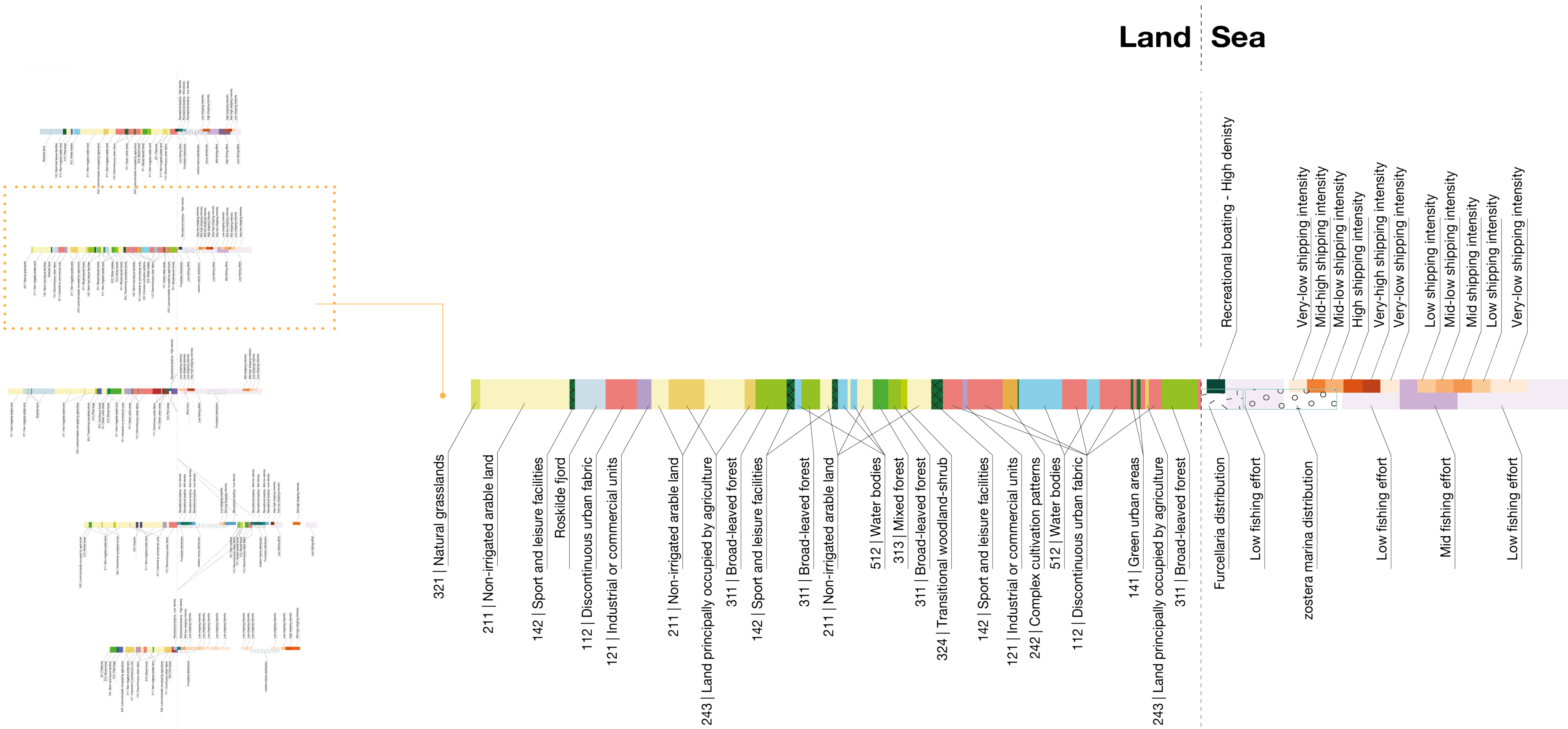
This approach enhanced the knowledge already gained, since I could analyse real-life case studies.
In the first mapping analysis, thematic sections, I analysed each case study using a single theme in order to be able to read both the anthropic and the natural elements in the territory and establish a sort of hierarchy of predominant dynamics.
A proper territorial mapping can allow to further spatialized information and have a better insight on how the coastal territories are shaped.
In the second mapping analysis, the coloured sections, I could see all the anthropic and natural elements follow each other from land to sea; in areas where the urbanization was well-managed, it appears that the elements in the territory were arranged in a more organized way; when the area is less well-managed, the section looks more complex and fractionated. The two most representative examples of organized and fractionated coastal territories are the case studies of the Zealand region & Copenhagen's finger plan and the Veneto region & Venice with its urban sprawl, respectively.
The third mapping analysis, the DNA sequences, was an exploratory way of analysing the coastal territories by conceptualising both the human and natural elements in the territories. This conceptualisation, using a sequence of colours, enabled me to shed new light on the data from the case studies.
I compared the DNA sequences from the different case studies in order to highlight any similarities between them, as with the first and third comparison, in which I discovered that similar distributions of natural elements can result in similar types of anthropic territories.
In the second comparison, the most revealing insight was that while the urban sprawl of the Veneto territory contrasted sharply with the compact and densely populated, but well-organized urbanization of the Zealand-Copenhagen territory, both cases generate a great deal of anthropic pressure on coastal areas and on the sea.
This highlights how a very mixed production coastal territory can itself become a hotspot of interactions.

COPENHAGEN case
DNA sequence



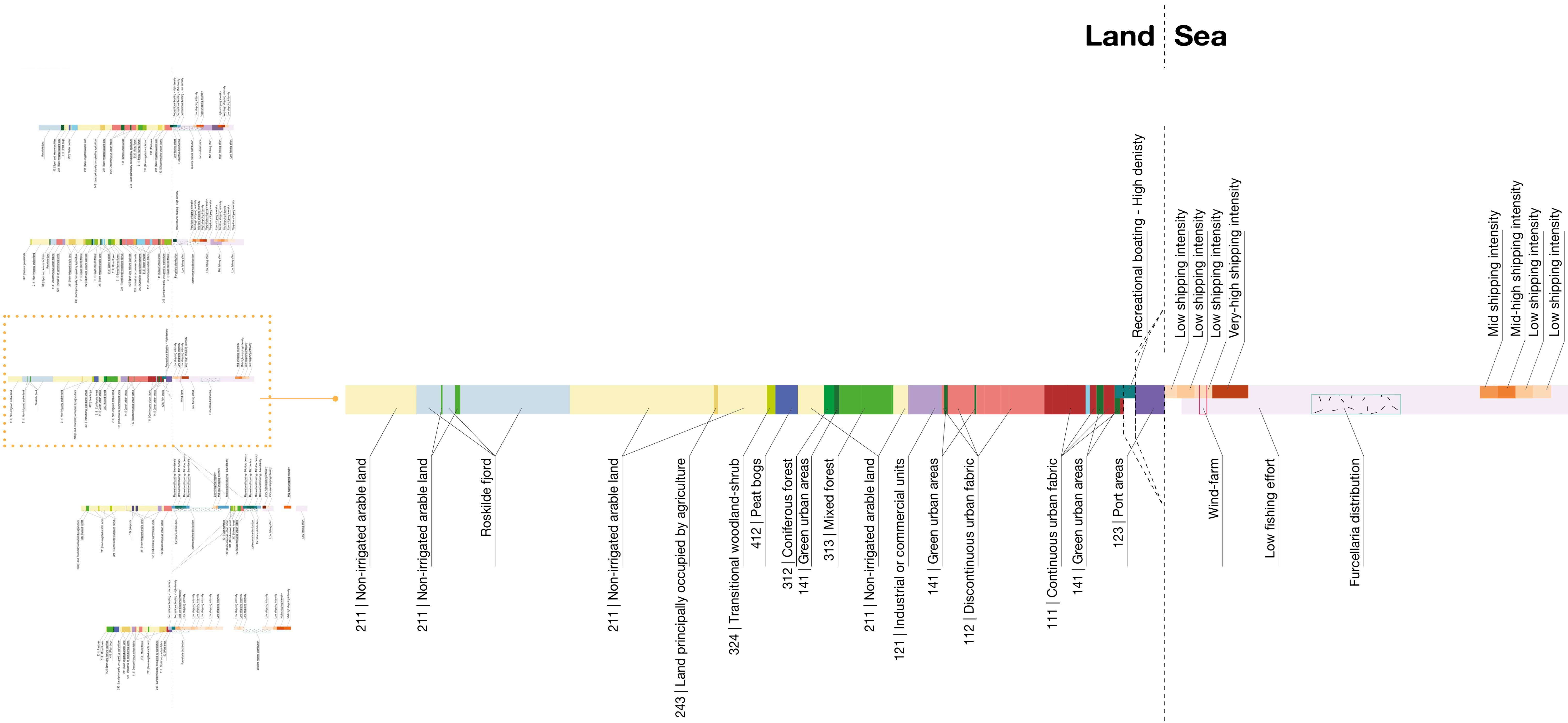
The DNA sequence shows in the northern part of the Copenhagen case the balance and clear delimitation of different land-uses such as agriculture (yellow shades), urbanized (red) and diverse natural environment (green shades). On the sea space, there is an intense use for recreational boating along the coast and the low fishing activities that increase by moving away from the coast.

COPENHAGEN case
DNA sequence



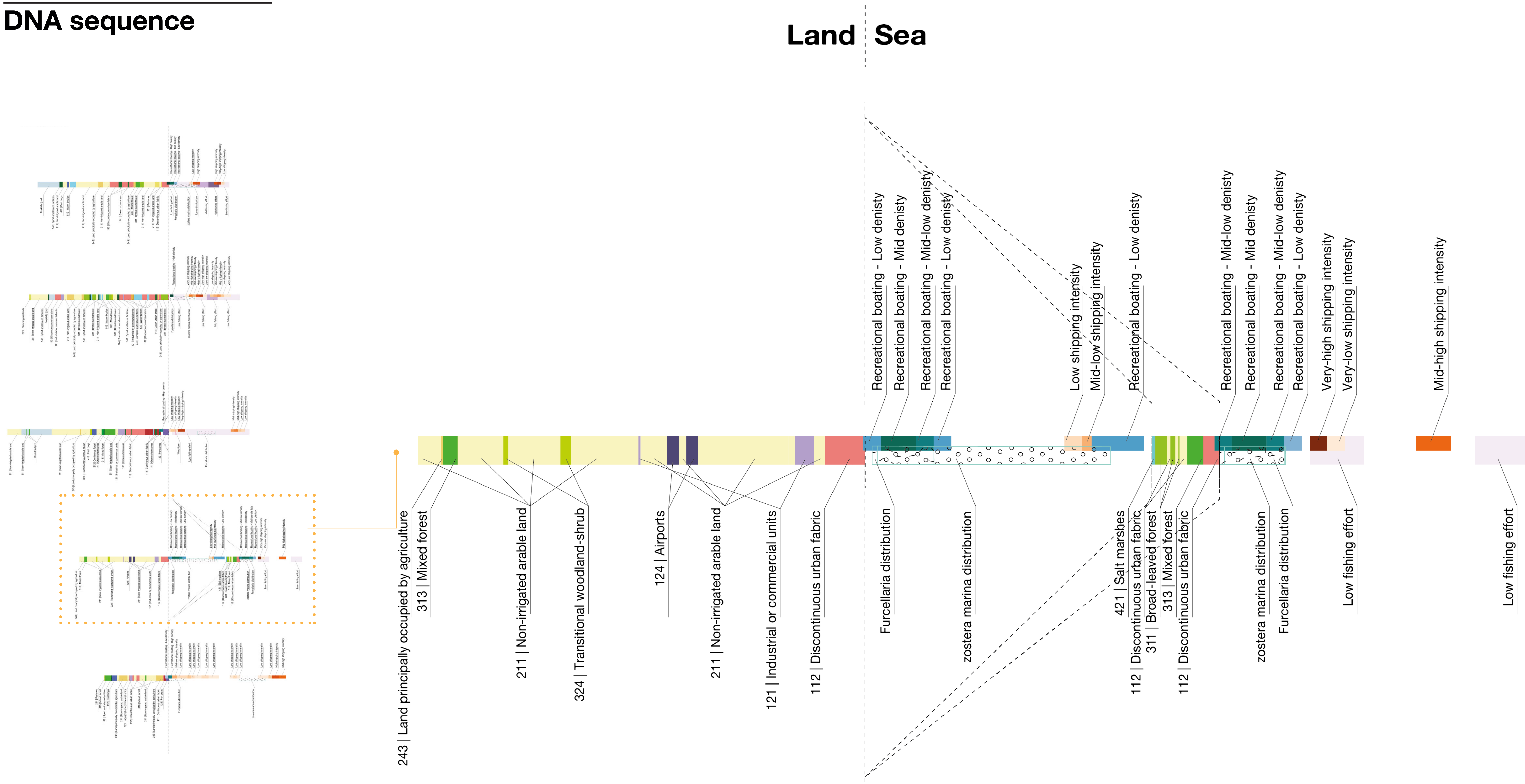
The DNA sequence highlights an intensified type of built and natural environments. Closer to the coastal shore the environment is more urbanized but divided from the sea by a forest buffer. Inland a productive landscape is composed of agricultural fields and natural elements interspersed with each other. The sea space is slightly less used for recreational boating since the shore is less urbanized. Along the coast there are important priority habitats such as Furcellaria and Zostera marina.

COPENHAGEN case
DNA sequence



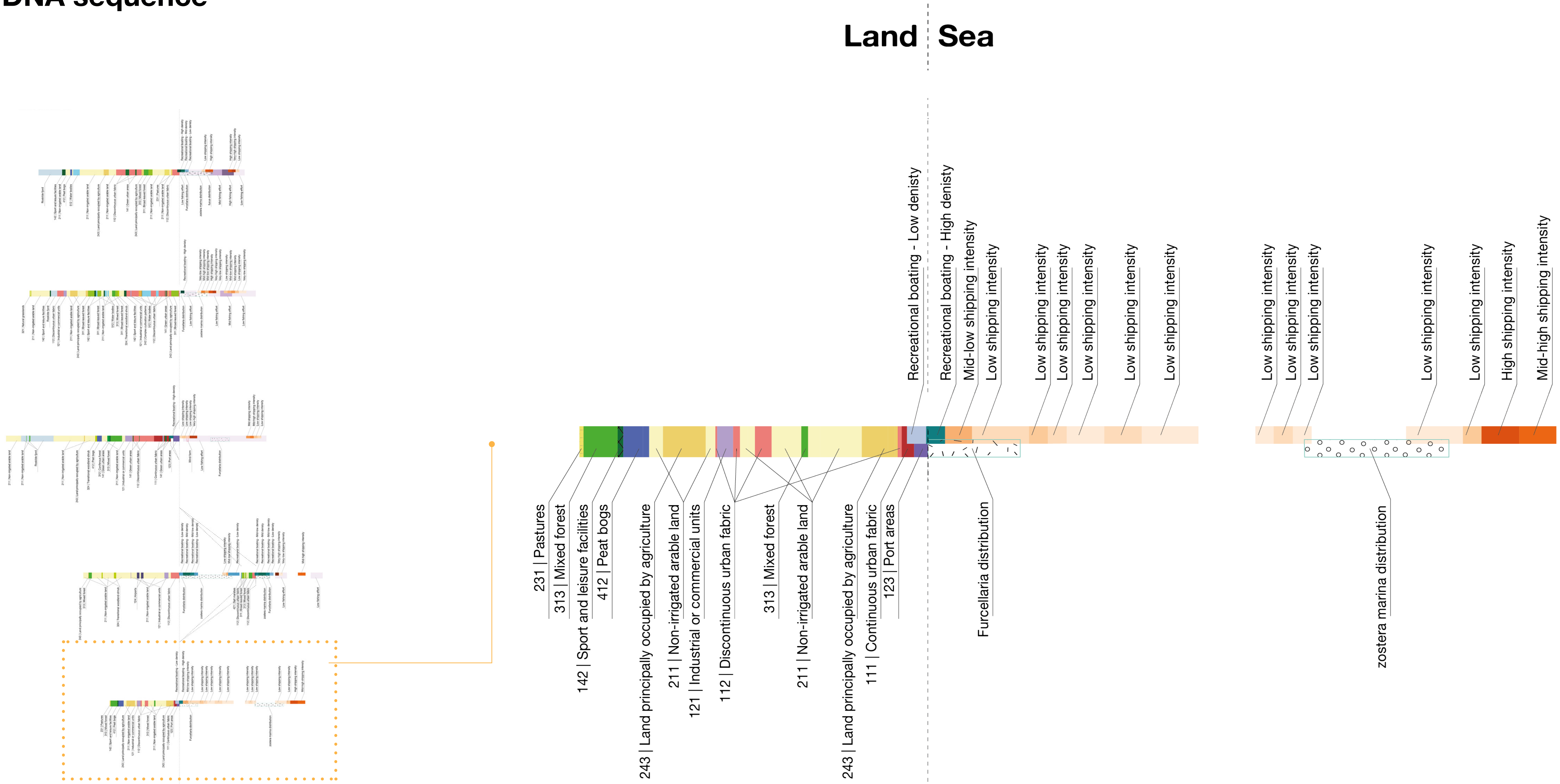
The DNA sequence shows that we are precisely in the city centre of Copenhagen. It is understandable from the different shades of red that represent a different intensity of urbanization and whereas when moving out of the city the decreasing of urban density becomes clear (light red) also surrounded by industrial and commercial use. Outside the inner city, the landscape is characterized by more agricultural production areas. The canal that divides the city in two from the sea is characterized by high intensive recreational boating and shipping uses, with no relevant marine habitats.

COPENHAGEN case
DNA sequence



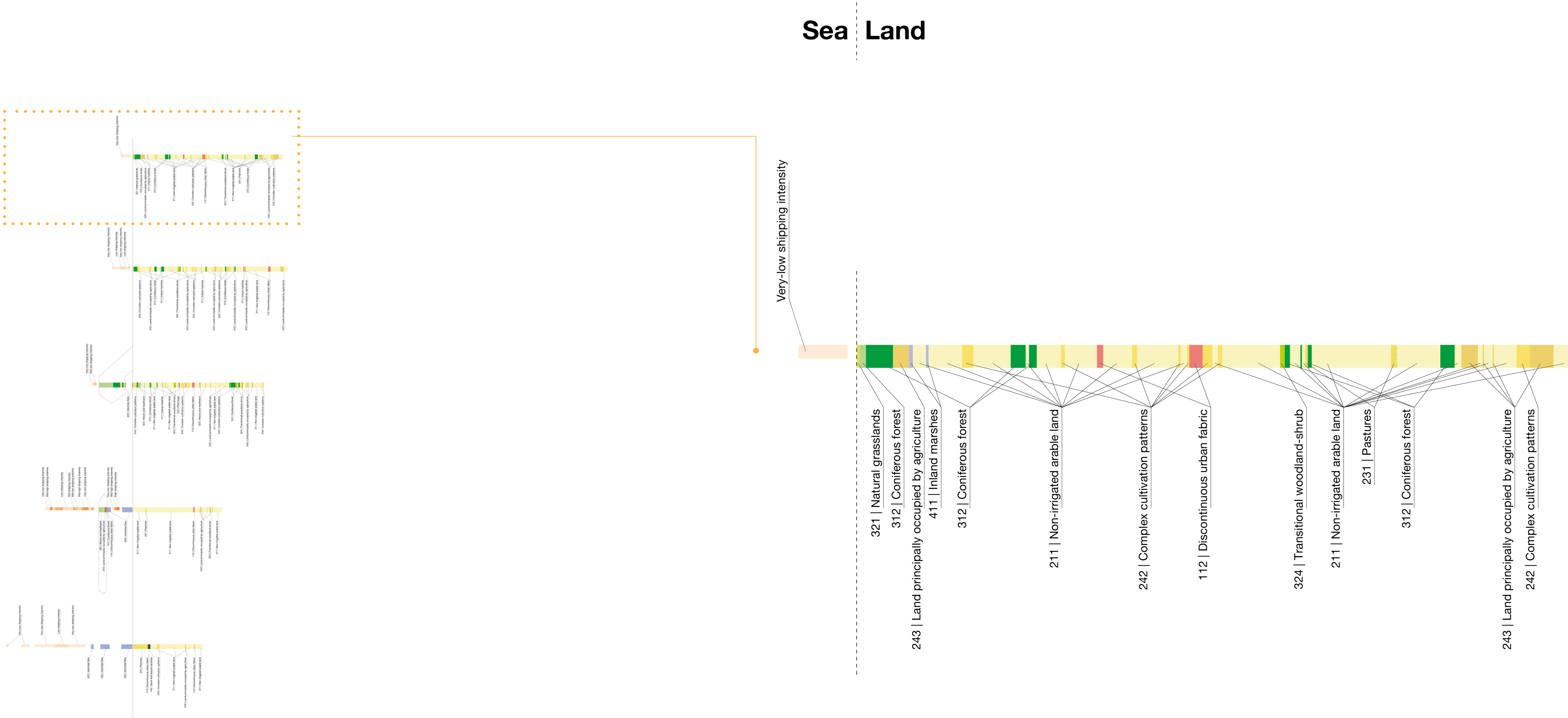
The DNA sequence shows the southern outskirt of Copenhagen that is characterized by a low density urbanized area on the shoreline and internal agricultural areas with some specific industrial and infrastructure uses. The sea area is highly used from recreational uses that pressure important natural marine habitats for spawning and nursing of marine species.

COPENHAGEN case
DNA sequence



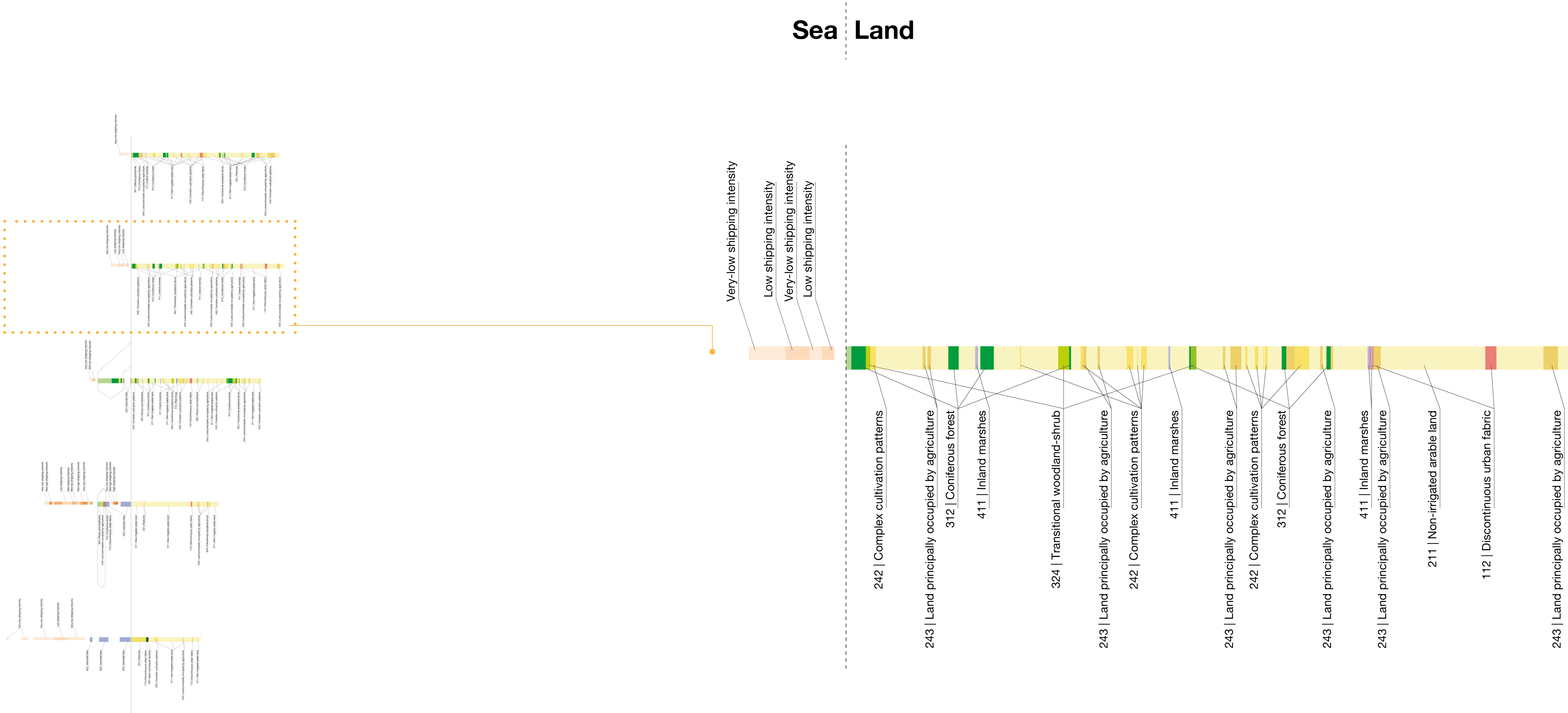
The DNA sequence shows a fragmented landscape composed of a high and low urbanized area, more inland interspersed from agricultural uses. Since the city of Køge has a commercial port, there is a medium intensity of shipping activity near the coast.

ESBJERG case
DNA sequence



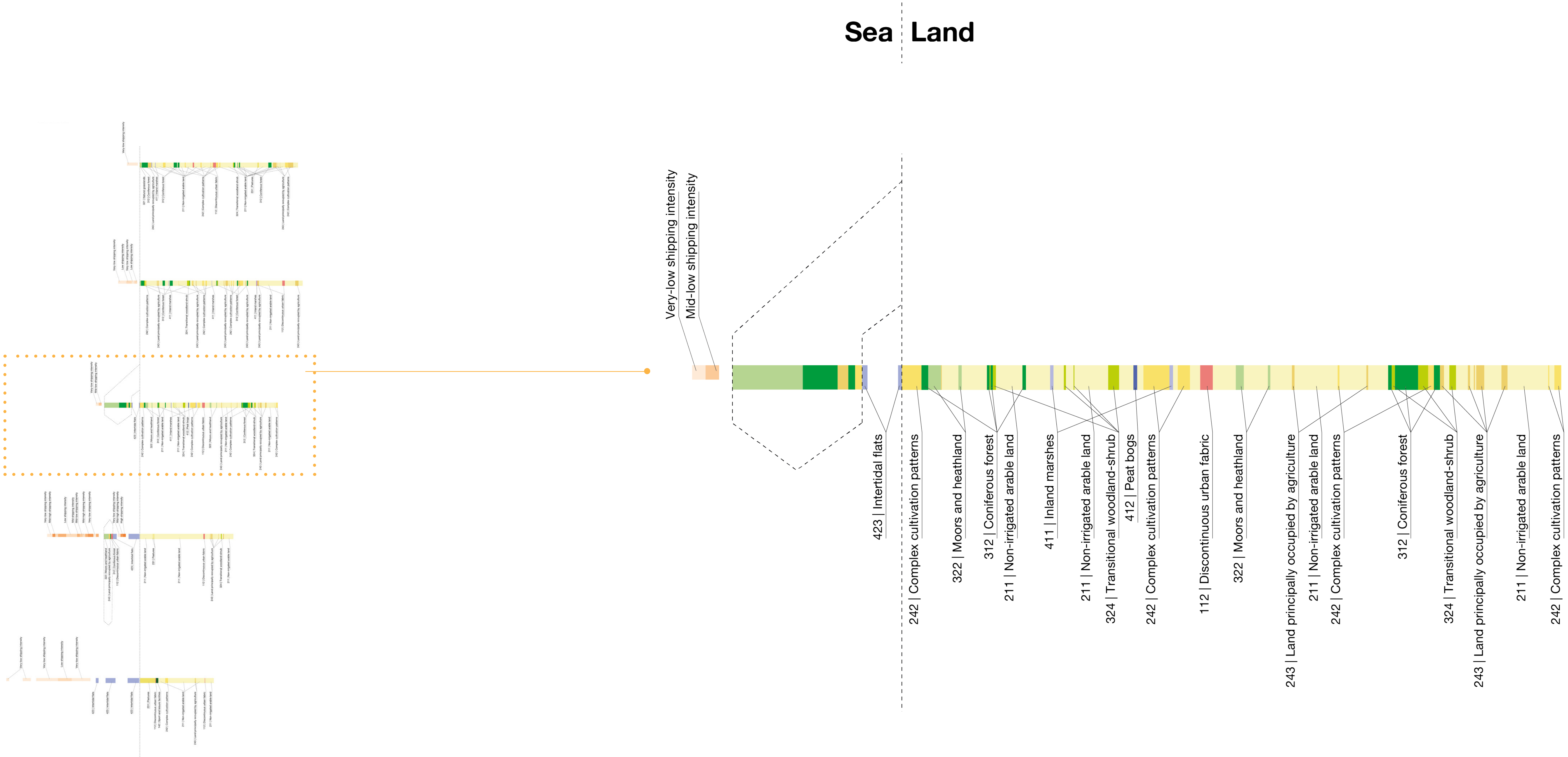
The DNA sequence presents a very low, almost absent urbanized area; the landscape is mostly agricultural with a few natural spread areas.

ESBJERG case
DNA sequence



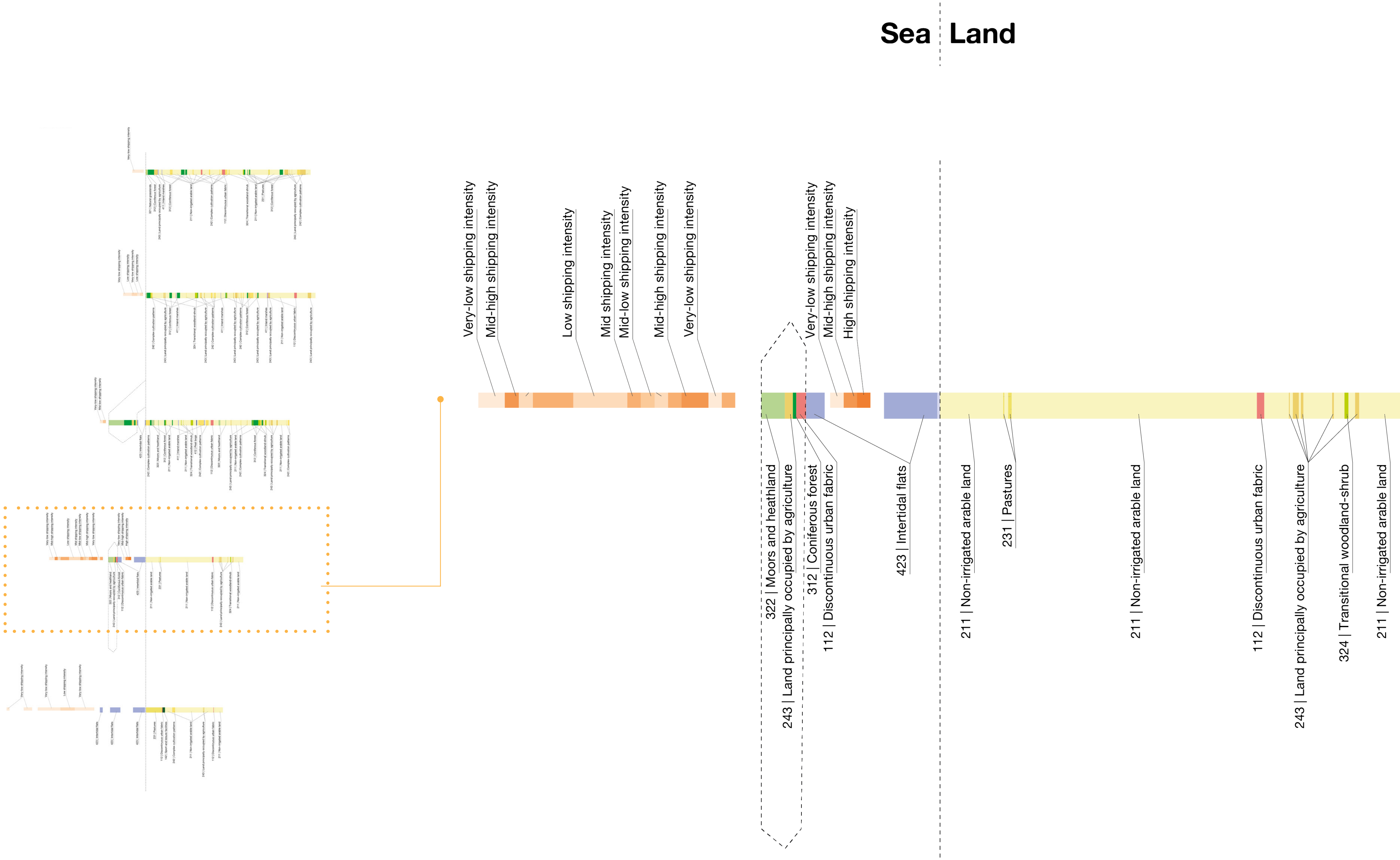
The DNA sequence shows a primary mixed agricultural landscape fragmented by small natural areas and low density urbanised towns.

ESBJERG case
DNA sequence



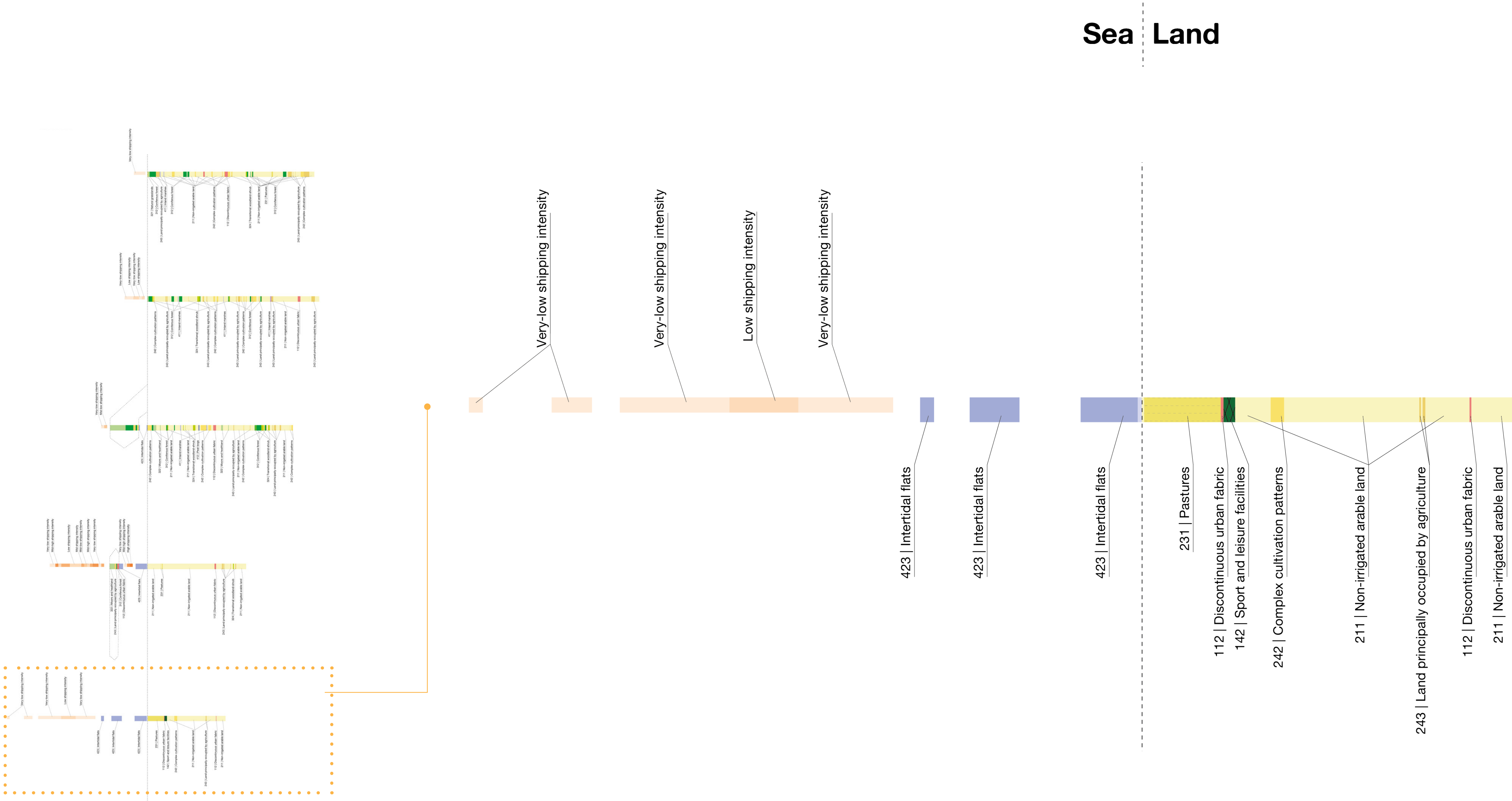
The DNA sequence shows on the peninsula a great natural environment that can also enhance the resilience of the coastal area. The inland territory is interspersed with agricultural (primarily), natural and low urbanised areas.

ESBJERG case
DNA sequence



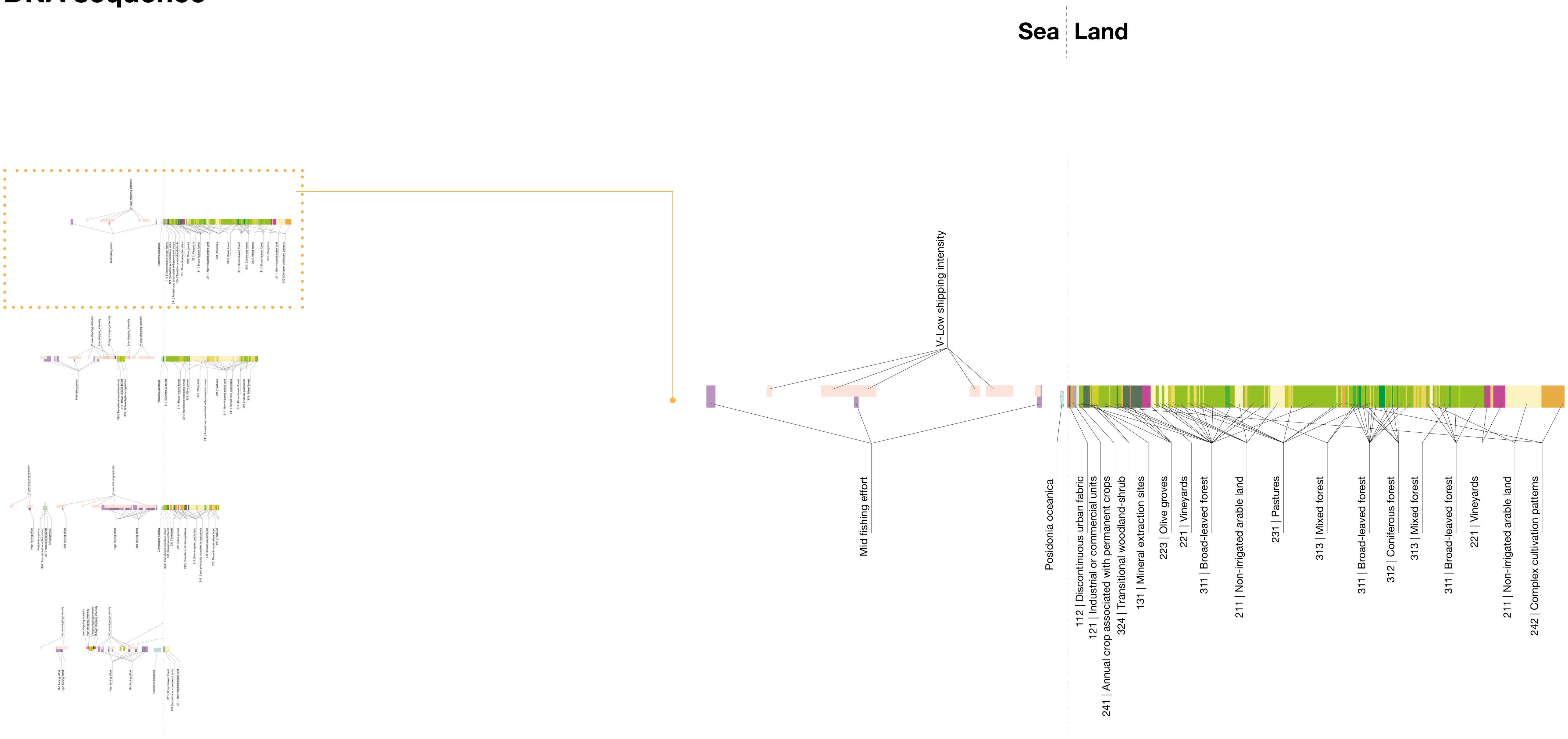
The DNA sequence shows inland a landscape predominantly agricultural. The marine area is characterised from intensive shipping traffic due to the Esbjerg port. Very relevant is the intertidal zone; the northern part of the Wadden Sea that is recognised as a world heritage for its globally unique geological and ecological values.

ESBJERG case
DNA sequence



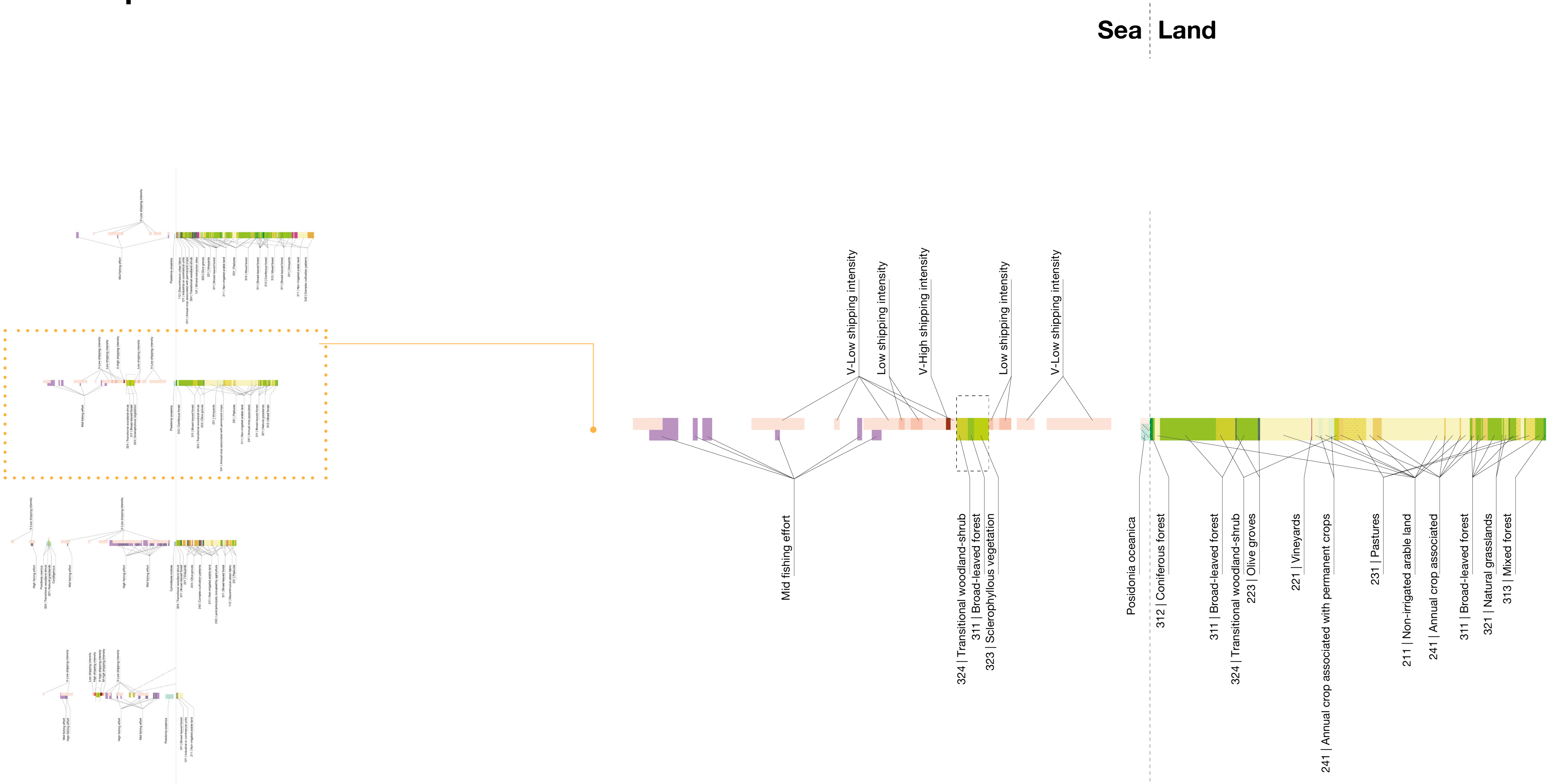
The DNA sequence shows on inland agriculture and farming, and on the shore, a landscape that can interfere by polluting with the intertidal flats of the Wadden Sea.

Piombino and Orbetello case
DNA sequence



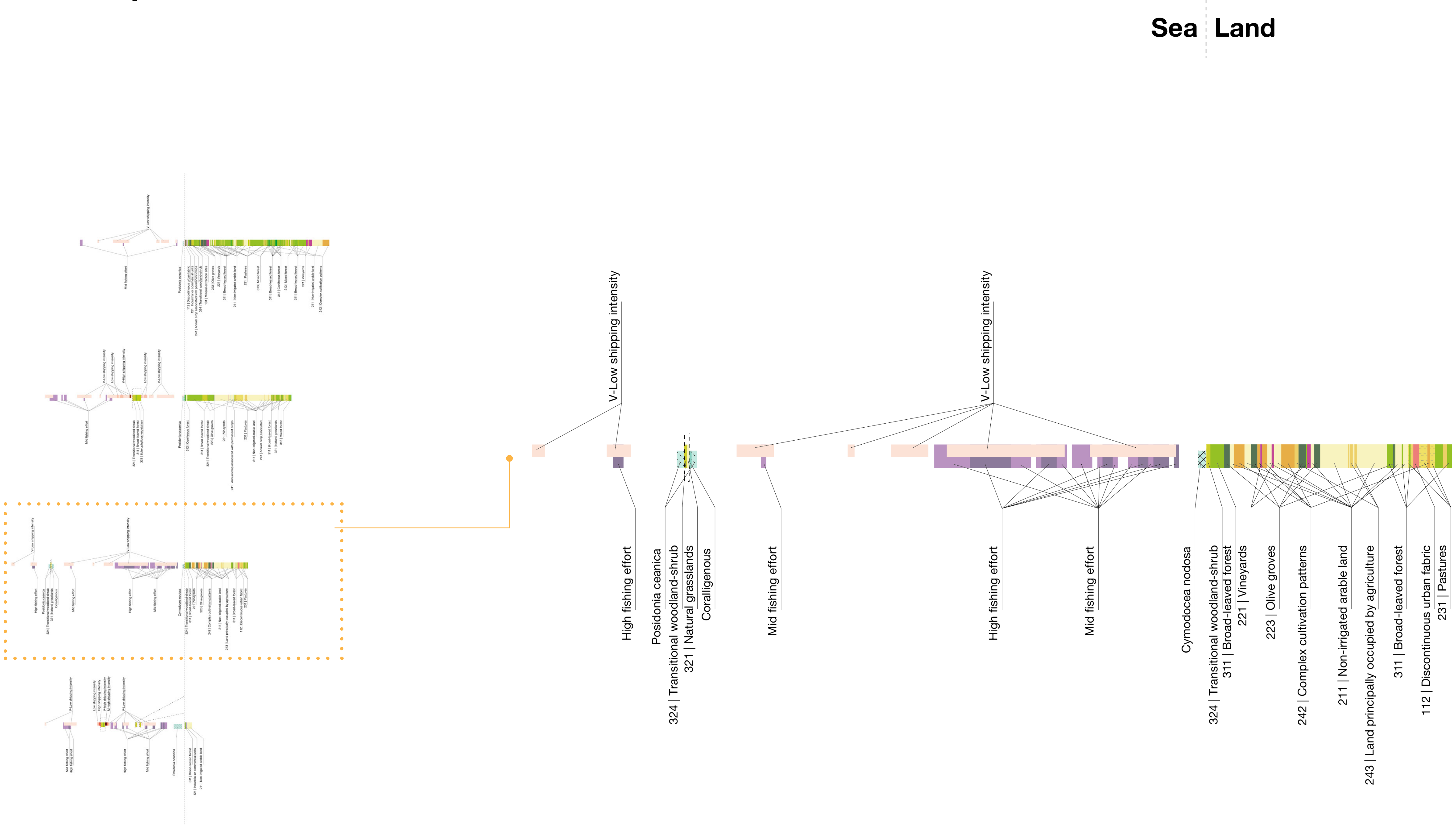
The DNA sequence shows predominantly mixed forested elements and specific agricultural productions such as vineyards, olive groves and some arable crops. The sea area presents a low spread fishing effort and very low shipping intensity.

Piombino and Orbetello case
DNA sequence



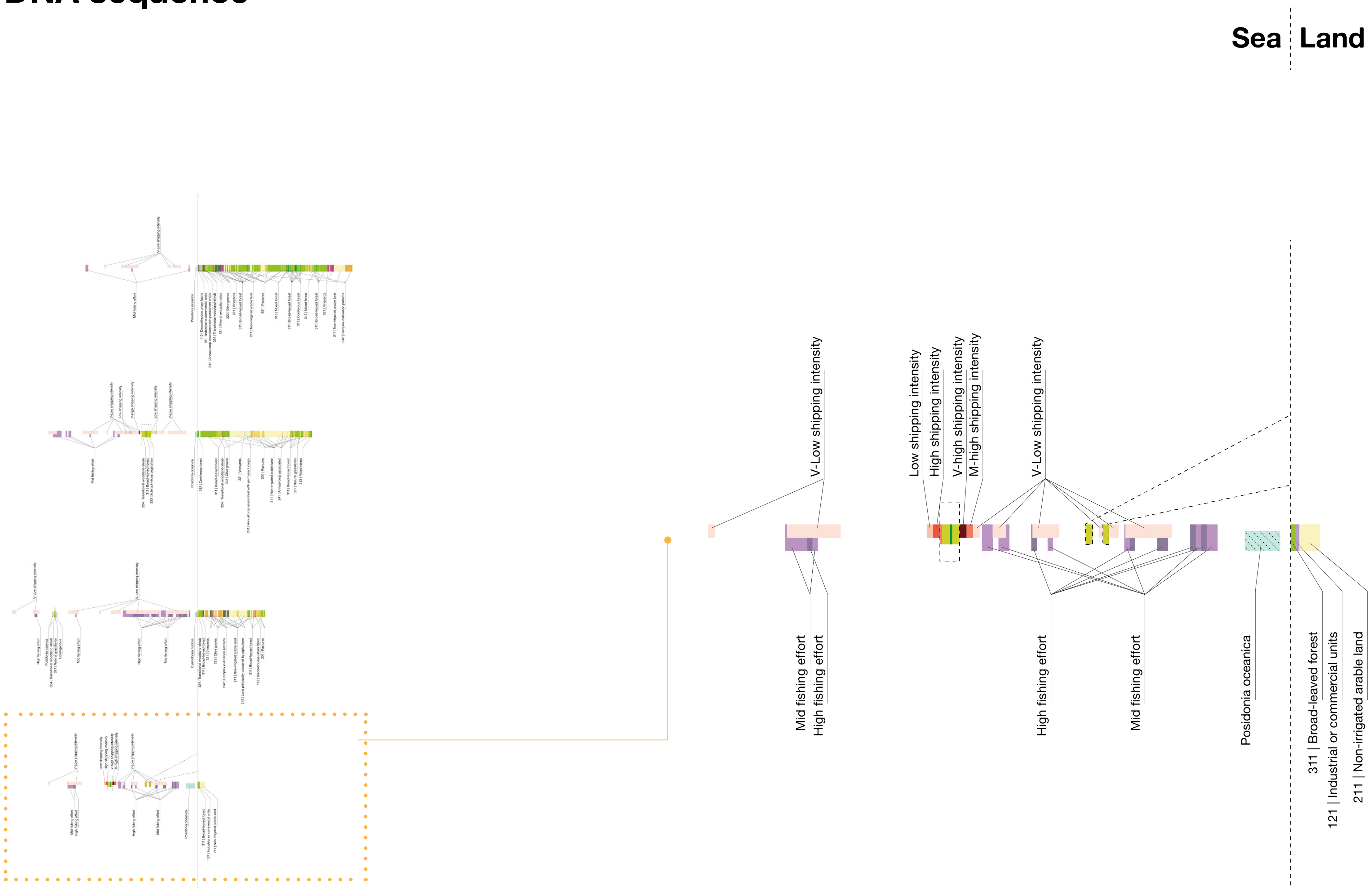
The DNA sequence shows a highly natural landscape on the coast, followed by a more agricultural landscape inland that is delimited from a natural element (buffer). The sea space is characterised by medium-low shipping intensity and low spread fishing effort.

Piombino and Orbetello case
DNA sequence



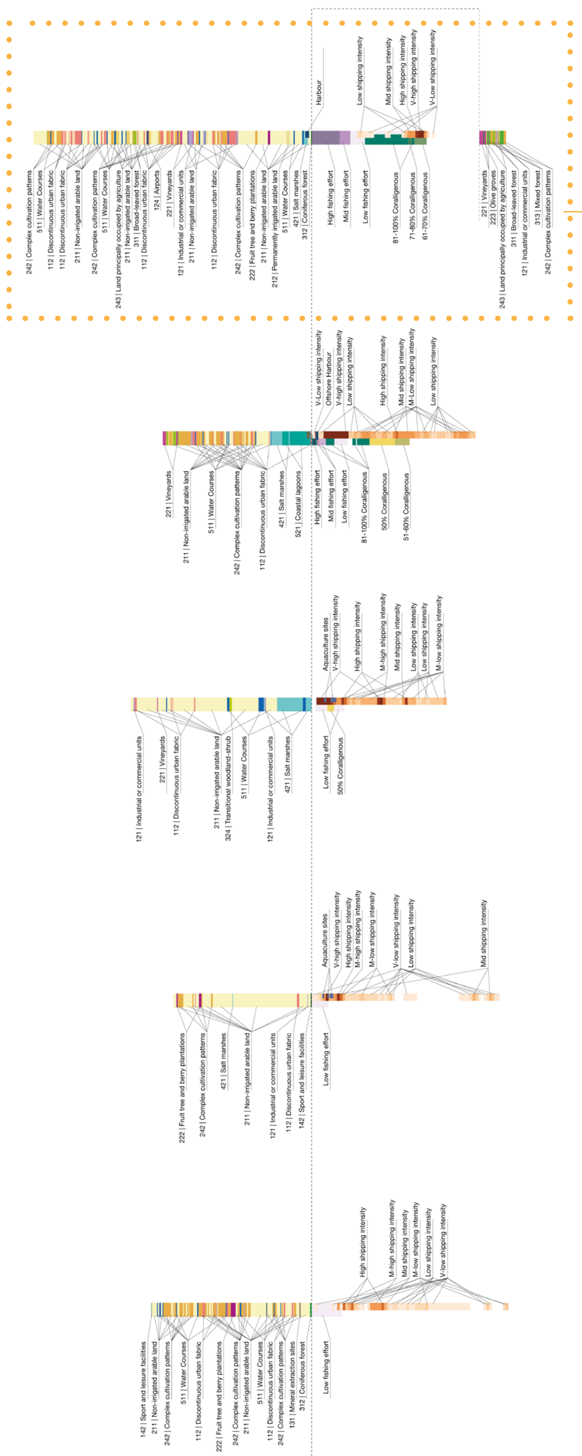
The DNA sequence shows a very fragmented inland landscape composed of diverse land-uses such as natural areas, different agricultural areas, farming and low-density towns. The sea area has a high fishing effort and a low shipping intensity. The seashore has limited space composed of Cymodocea Nodosa (priority marine habitats) that have a double function of being a nursery and spawning area, that can decrease the intensity of the sea currents directed to the coast.

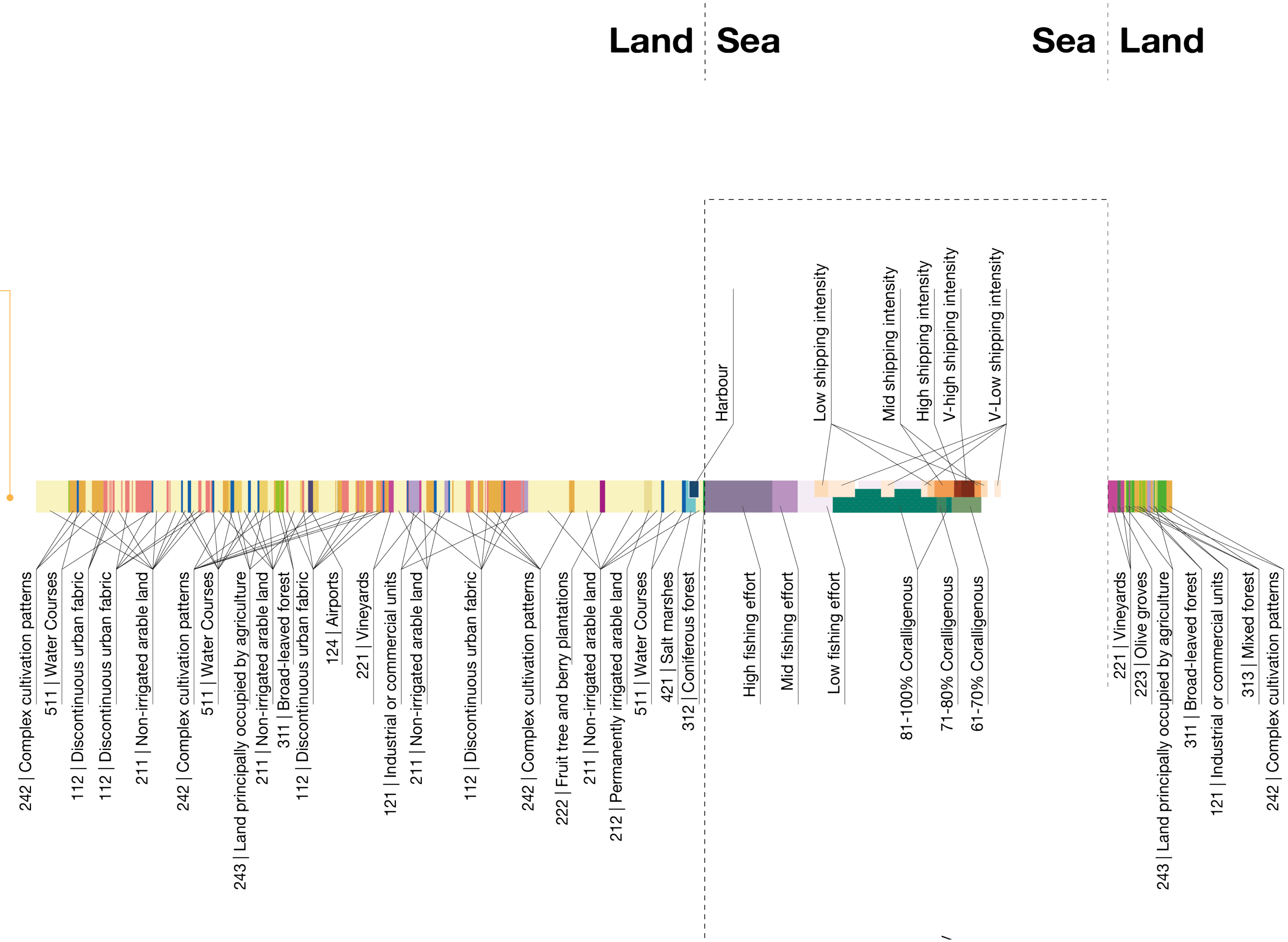
Piombino and Orbetello case
DNA sequence



The DNA sequence shows primarily the sea space that has a high fishing effort spread from the open sea till the coast. On the seashore, there is a Posidonia Oceanica area (priority marine habitats) that has a double function of being a nursery and spawning area, that can decrease the intensity of the sea currents directed to the coast.

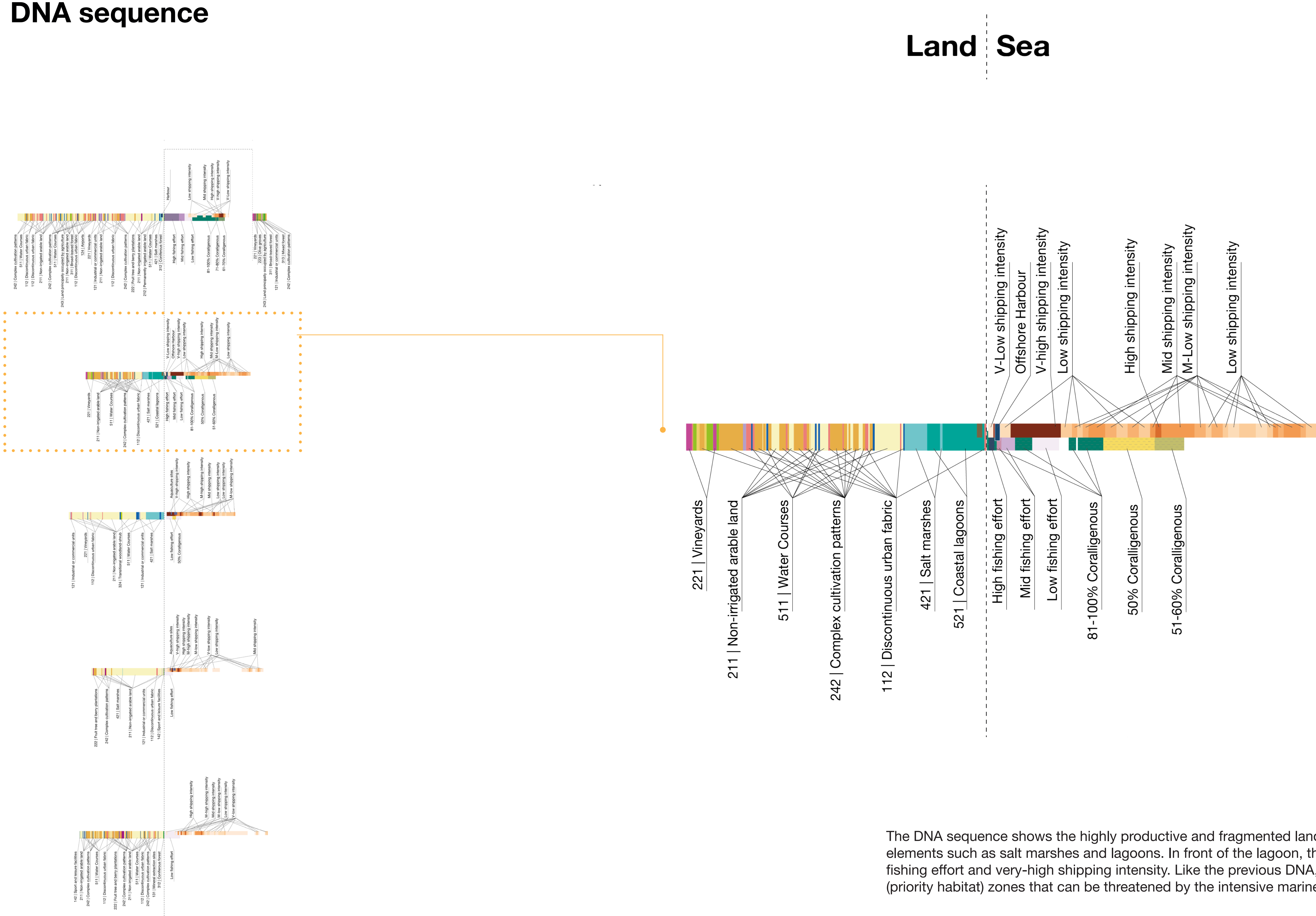
VENICE case
DNA sequence





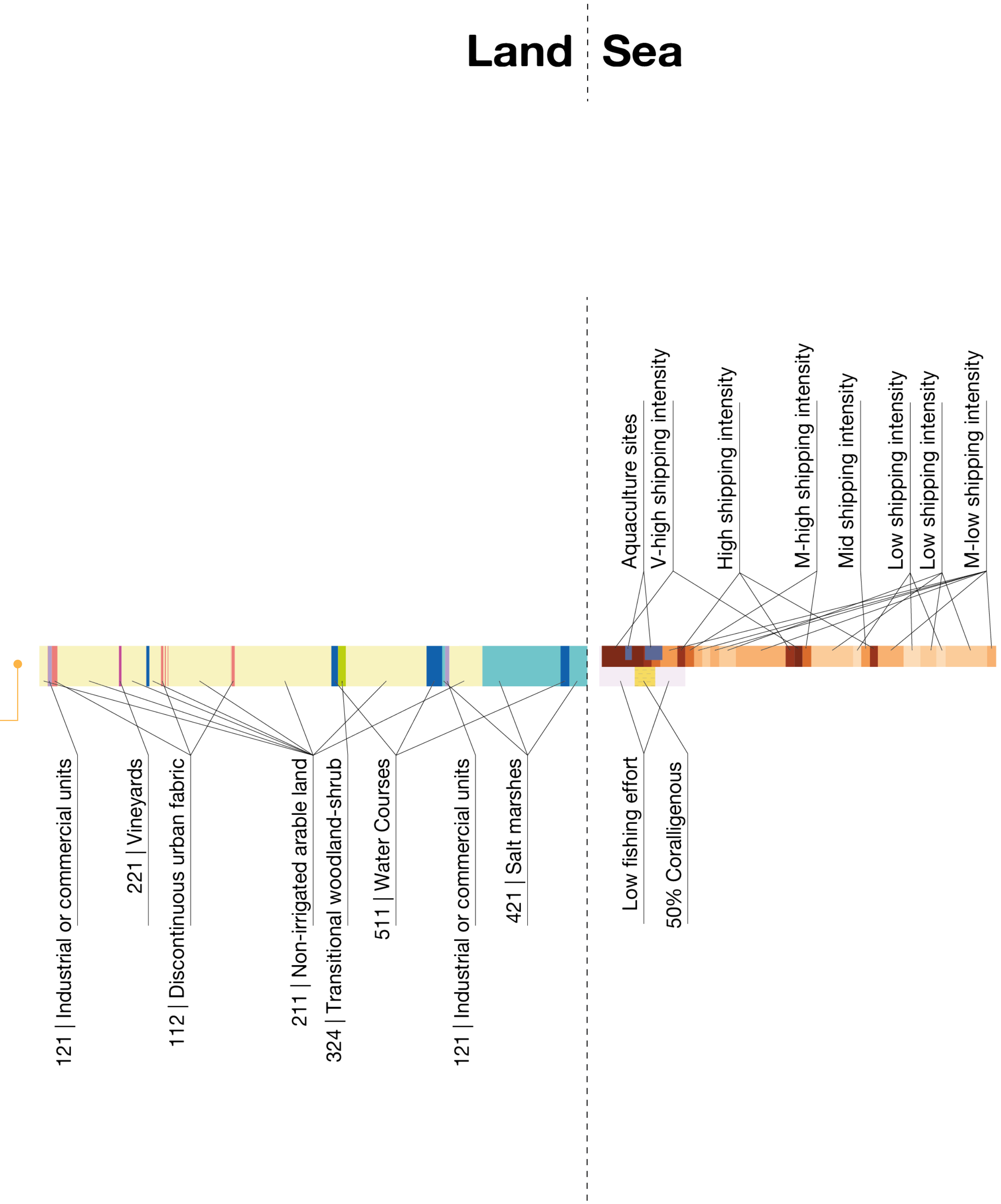
The DNA sequence shows the fragmentation of the Veneto region due to urban sprawl dynamics which results in a territory without strict boundaries and with a dense and heterogeneous built environment that has shaped a very productive but less green landscape. The highest quantity of uses on land is also reflected in sea space, which is characterised by a high fishing effort and shipping intensity. In the same area, there is a large area of coralligenous that can be threatened by this intensive use.

VENICE case
DNA sequence



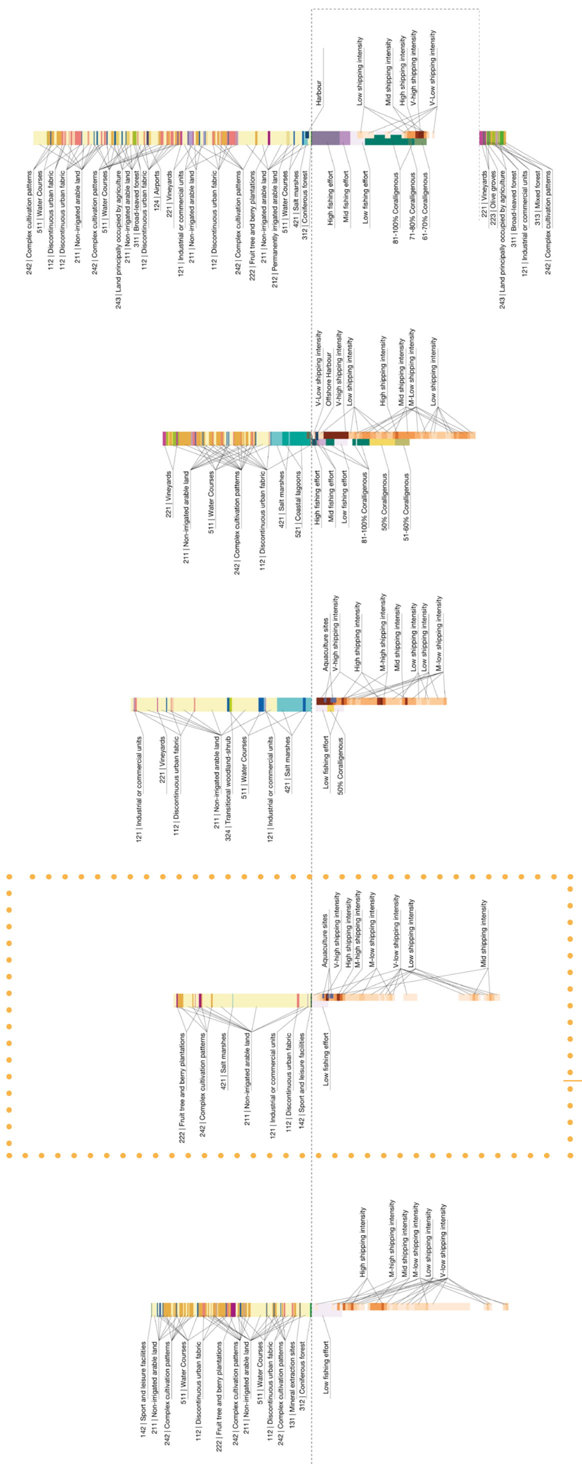
The DNA sequence shows the highly productive and fragmented landscape and the presence of valuable natural elements such as salt marshes and lagoons. In front of the lagoon, the sea is characterised from medium-high fishing effort and very-high shipping intensity. Like the previous DNA, also this area has important coralligenous (priority habitat) zones that can be threatened by the intensive marine human activities.

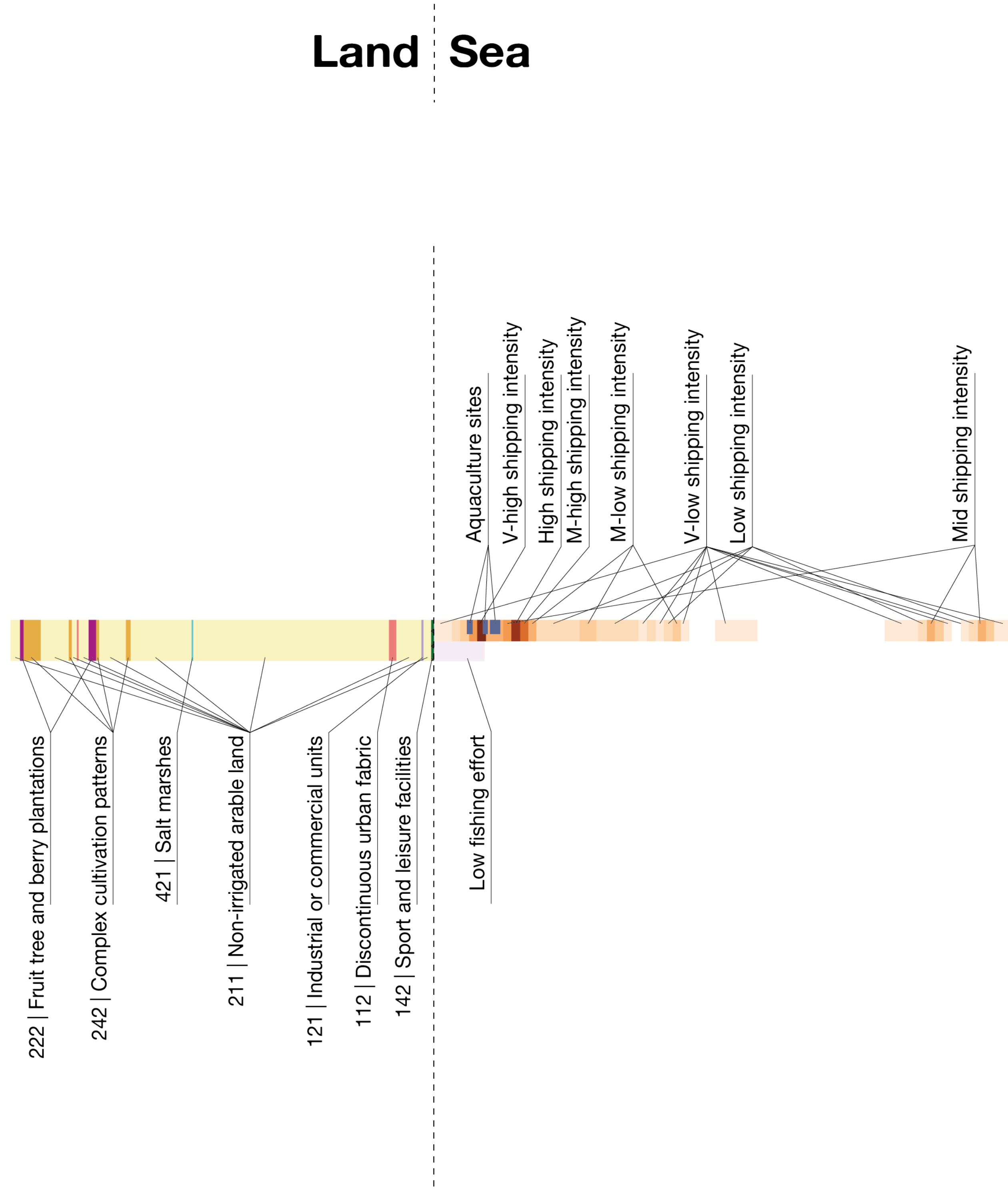
VENICE case
DNA sequence



The DNA sequence shows a predominantly agricultural landscape that ends on a salt marsh on the coast that has the double function as a buffer for the sea; as a cleaner of pollutants generated from agricultural production and as a natural levee that reduces the effect of sea-level rise and coastal flooding. The sea space, like the previous DNA, has very high shipping activities both close to the coast and on the open sea and has a presence of aquaculture activities.

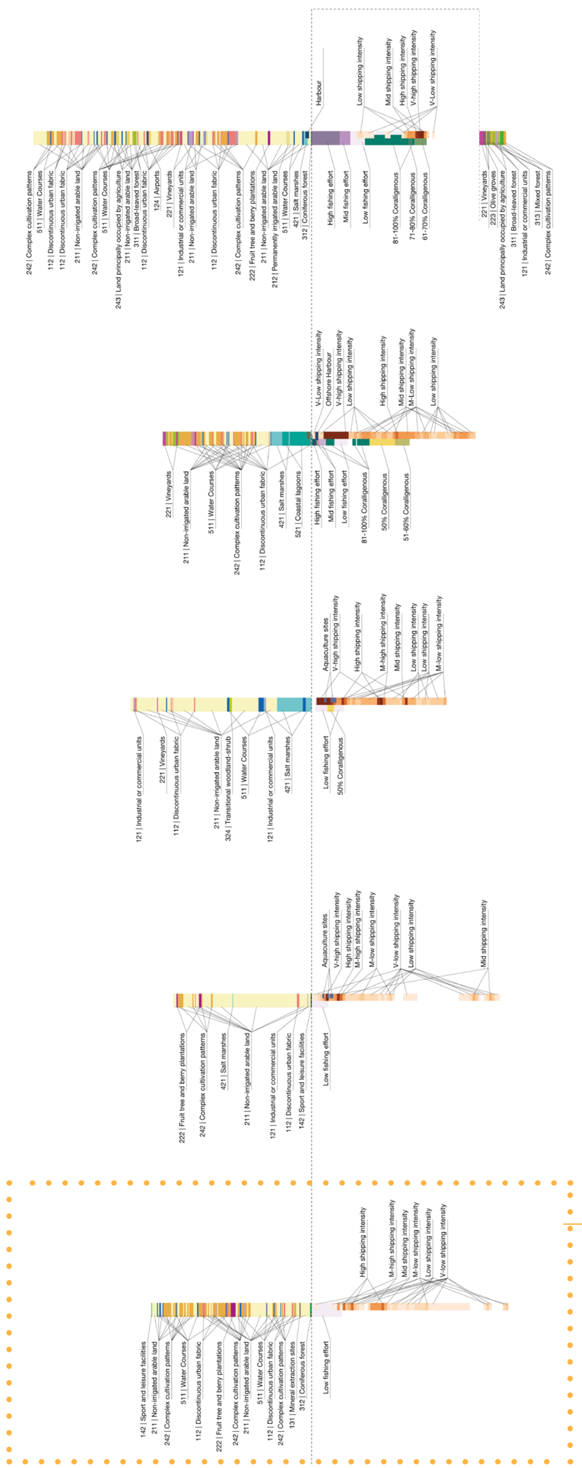
VENICE case
DNA sequence

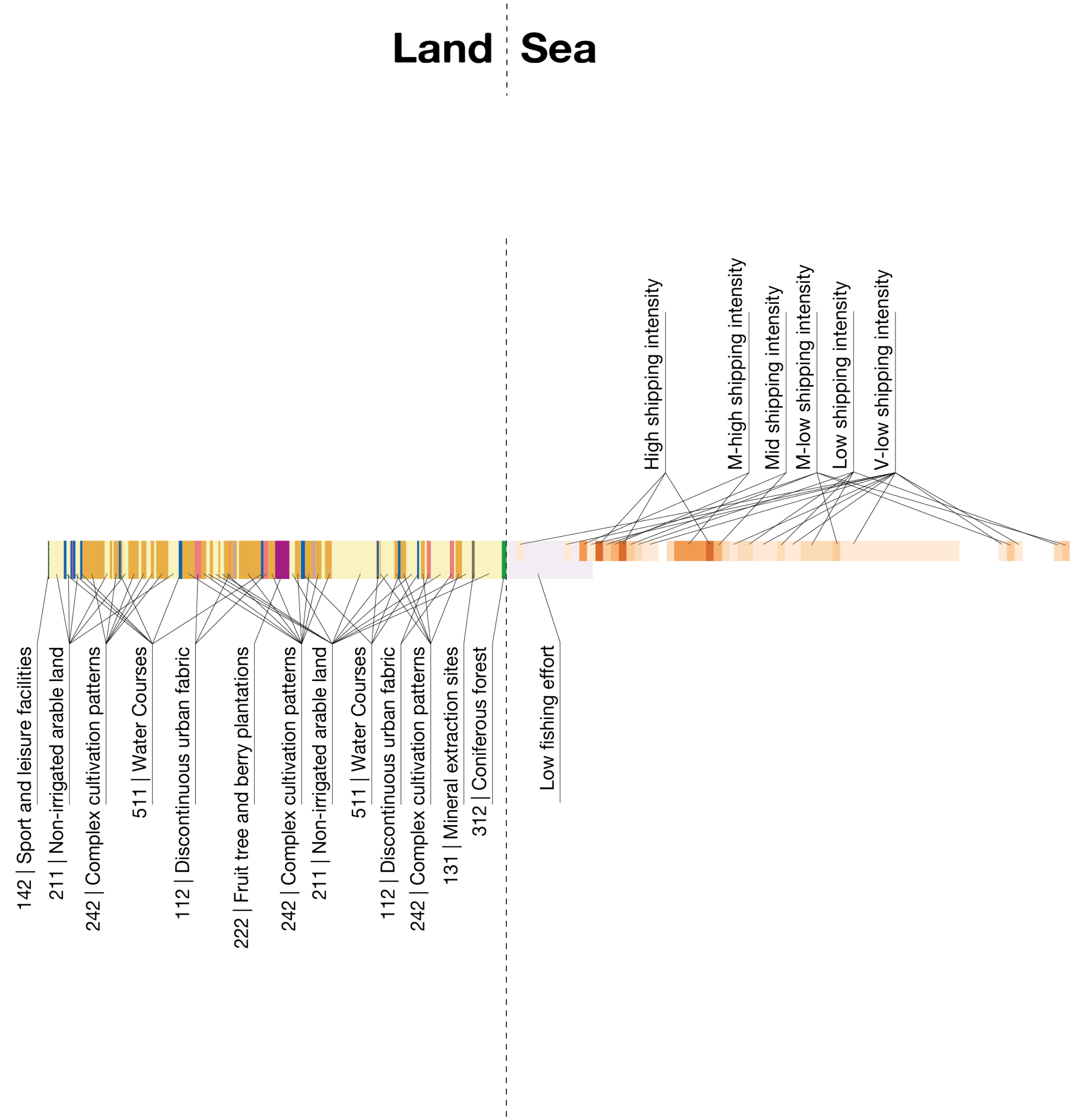




The DNA sequence shows a predominantly agricultural landscape and on the sea high and medium-high shipping intensity.

VENICE case
DNA sequence





The DNA sequence shows a high fragmentation of the landscape, with different agricultural productions and spread low-dense urbanisation. The sea is mainly characterised from a medium shipping intensity.

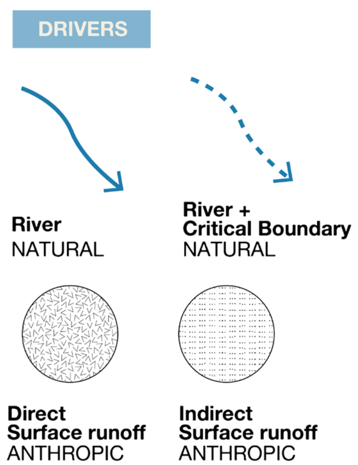
3.6 Coastal transect for a coastal glossary

This section aims to illustrate the results from the second phase of the mapping analysis, based on the transect method.
The objective of the second phase of mapping analysis was to identify the components that shape coastal territories.
This mapping phase is based on a transect analysis whereby the data is sorted into categories that are then reintegrated into the coastalscape elements map.

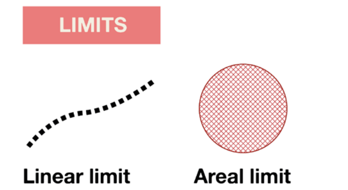
While working on the transect mapping analysis for the Zealand and Copenhagen case study, I discovered that the University of Copenhagen's database could give me valuable data about the imperviousness of the surfaces in the metropolitan city of Copenhagen, so I decided to use these data in my research.
For the other case studies - Esbjerg, Tuscany and Veneto - I utilised the urbanization and industrial land use data to draw conclusions about the relative levels of imperviousness, as, according to the literature, these types of land tend to have a higher percentage of impervious surfaces.

The Transects >The coastal glossary
In the transect analysis, I identified four components - drivers, limits, buffers and edges - of coastal areas relevant to the discourse on land-sea interactions.
They may be defined as follows:

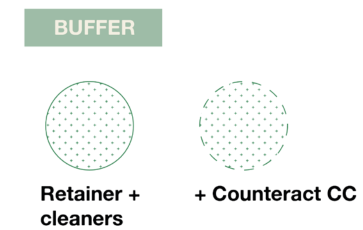
1. **Drivers.** In the discourse on land-sea interactions, drivers are seen as 'motorways' that connect land and sea. In general, they form a sort of continuum between the land and sea environments. Drivers can be both natural or anthropic, but they have the same function, that of driving the flow of pollutants. Natural drivers include rivers and creeks, whereas anthropic drivers are the productive and urbanized areas.



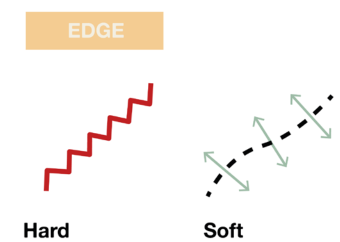
2. **Limits.** Limits are hard infrastructures that divide territories and do not allow a continuum. They can compromise ecological corridors wholly or partially and can shape a fragmented territory. They may be linear, such as rail networks and road networks or areal such as industrial areas, ports and production zones. Rail and road networks along coastal areas can obstruct and interrupt natural passageways. Industrial areas on coastal borders not only break the continuum, but can also be direct generators of pollutants.



3. **Buffers.** Buffers are different natural elements that have several functions in the coastal territory, such as retaining and cleaning the pollutants generated by human activities. Some buffers, such as wetlands, marshes, dunes, marshes and lagoons, also have the capacity to attenuate extreme events linked to climate change.
For example, dunes naturally flex and evolve to provide a self-replenishing barrier acting as a sea defence.
Wetlands are known to naturally counteract coastal flooding and storm surges. Usually coastal buffers are located adjacent to or on the interface between land and sea.



4. **Edges.** Edges are usually conceived as boundaries between two other components or elements in the coastal territory. They can be hard breaks such as seawalls, break-waters, walls and urbanized waterfronts; or soft breaks such as beaches, dunes, intertidal zones, wetlands, marshes and lagoons.
Depending on the type of edge, they may form barriers, and can be more or less penetrable. For example, seawalls and breakwaters do not allow waves to pass through them, but at the same time they form a very clear border between land and sea.
On the other hand, soft edges are more open. For example, dunes, lagoons or wetlands have smooth interactions between the sea and the land, forming a permeable interface that shapes a valuable and rich coastalscape.



The four componets of the coastal glossary

DRIVERS	Natural	Rivers
	Anthropic	Direct Surface runoff
		Indirect Surface runoff
LIMITS	Anthropic	Linear
		Areal
BUFFERS	Natural	Retainer and cleaners
		+ counteract CC events
EDGES	Natural	Soft
	Anthropic	Hard

The transect analysis process was carried out using different mapping analyses, which enabled me to better organise the knowledge already gained from the two literature reviews and from the first phase of mapping analyses.
The complexity of coastal areas is mainly due to the overlapping of anthropic activities and infrastructures with the natural environment. Furthermore, both human and natural elements contribute to shaping coastal territories. This overlap is particularly important because, as each case study shows, none of the components mentioned above (drivers, limits, buffers, edges) exist in isolation.
To sum up, coastal hard edges are created by limits, resulting from urbanization and human activities; soft edges are generated by natural buffers, maintaining the ecological network; drivers can condition the quality of the coastal and marine environments, depending on the pressures produced by the inland anthropic activities.

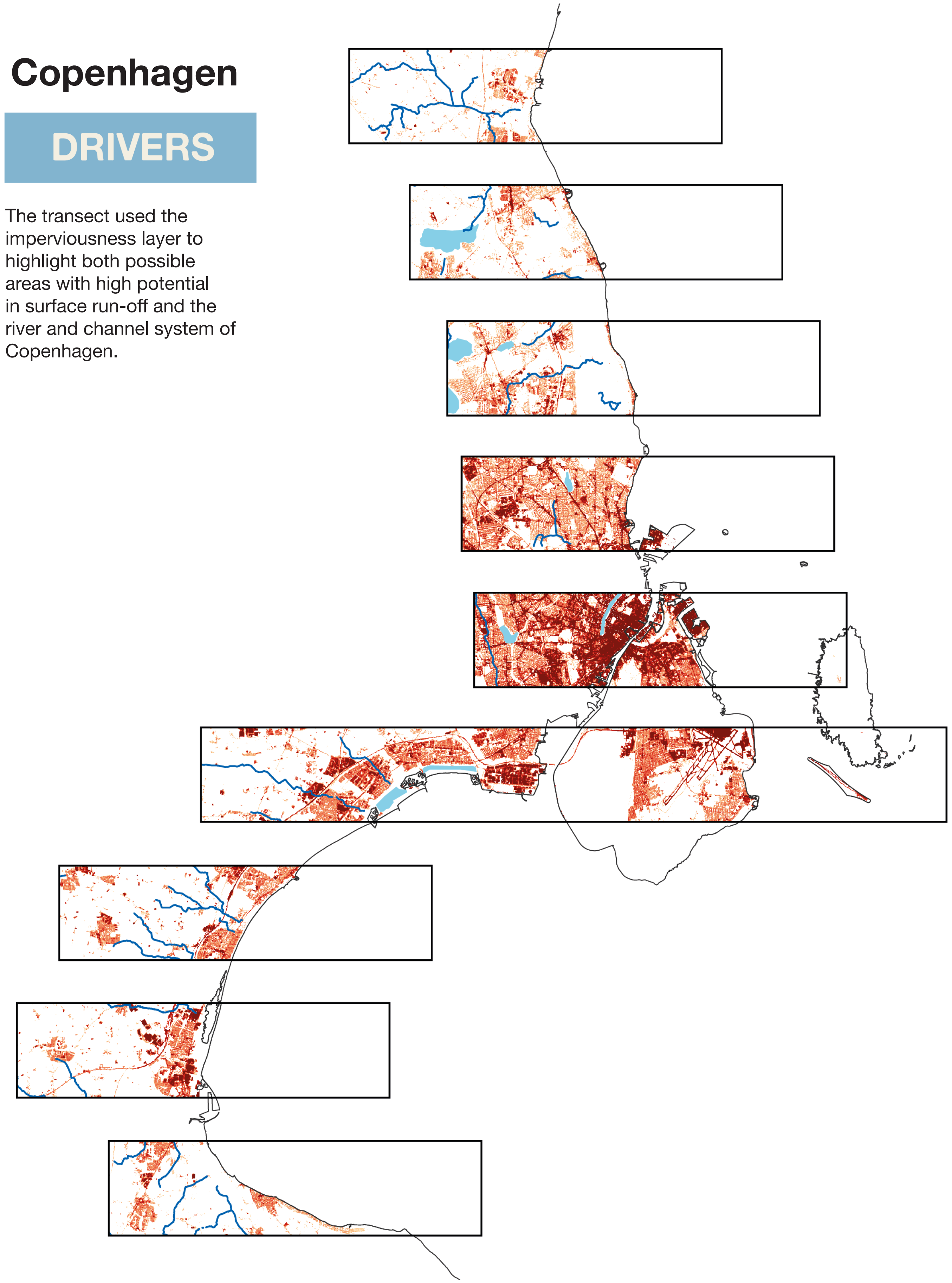
The transect analysis aims to provide further information about dynamics on coastlines through the element types that describe land-sea interactions.

From the analysis, it emerged that there are basically two types of edge: hard and soft. Hard edges are shaped by human needs, as in the case of a coastal city; soft edges are usually shaped by natural elements, such as dunes, wetlands or simply a natural shoreline.
Edges have different levels of permeability depending on how much the waterfront is anthropized. Coastal cities' waterfronts can also have different levels of permeability; port areas are not permeable, but other public sections of the waterfront may have higher permeability due to there being less infrastructure. On the other hand, soft edges, which are generally natural, such as wetlands, lagoons and marshes, create a so-called ecotone, which is the transition area between two different ecosystems (land and sea).
In fact, edges are more complex because they are also shaped by limits, which are actually hard boundaries that interrupt both human and natural coastal territories. Limits

Copenhagen

DRIVERS

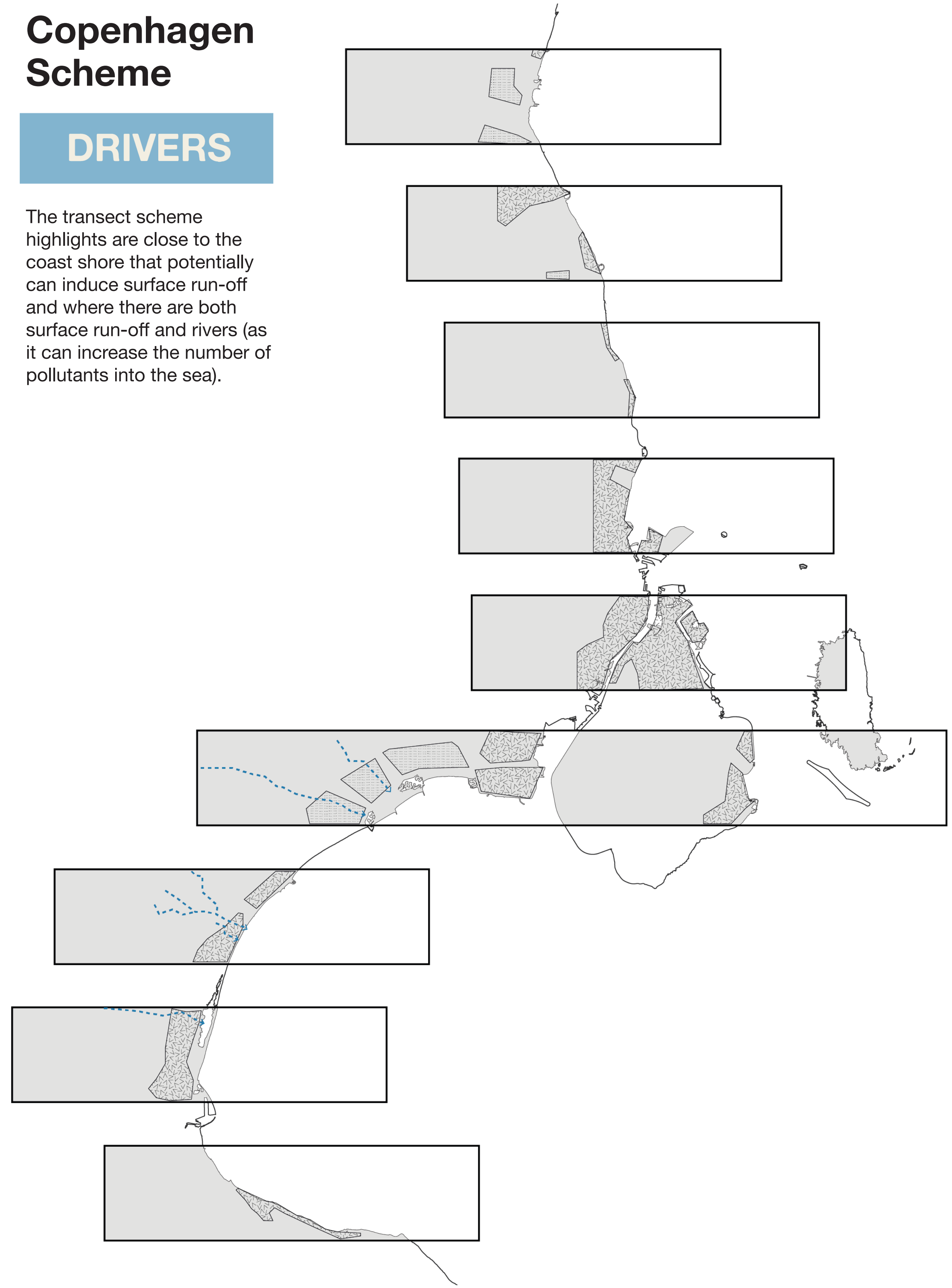
The transect used the imperviousness layer to highlight both possible areas with high potential in surface run-off and the river and channel system of Copenhagen.



Copenhagen Scheme

DRIVERS

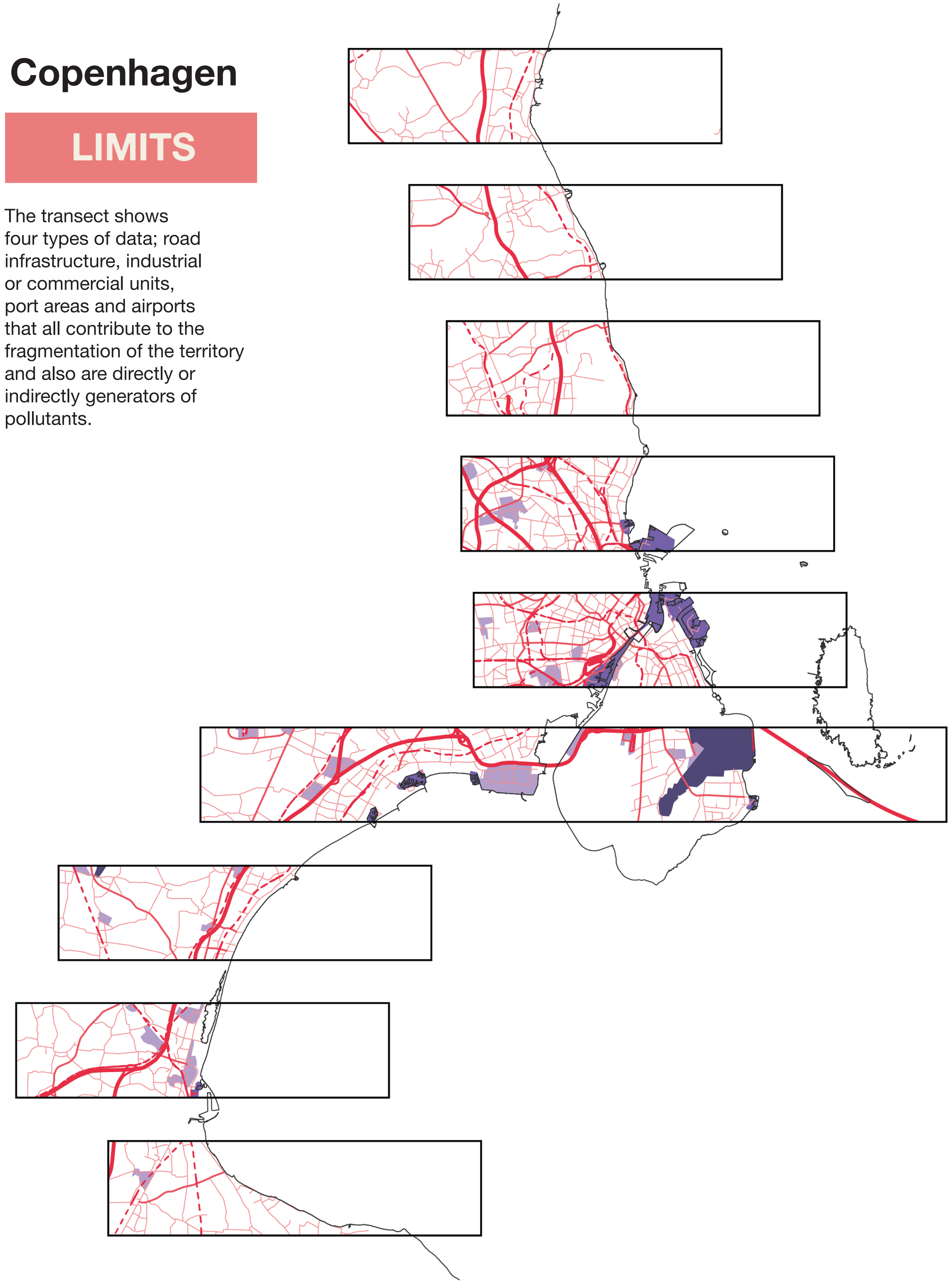
The transect scheme highlights are close to the coast shore that potentially can induce surface run-off and where there are both surface run-off and rivers (as it can increase the number of pollutants into the sea).



Copenhagen

LIMITS

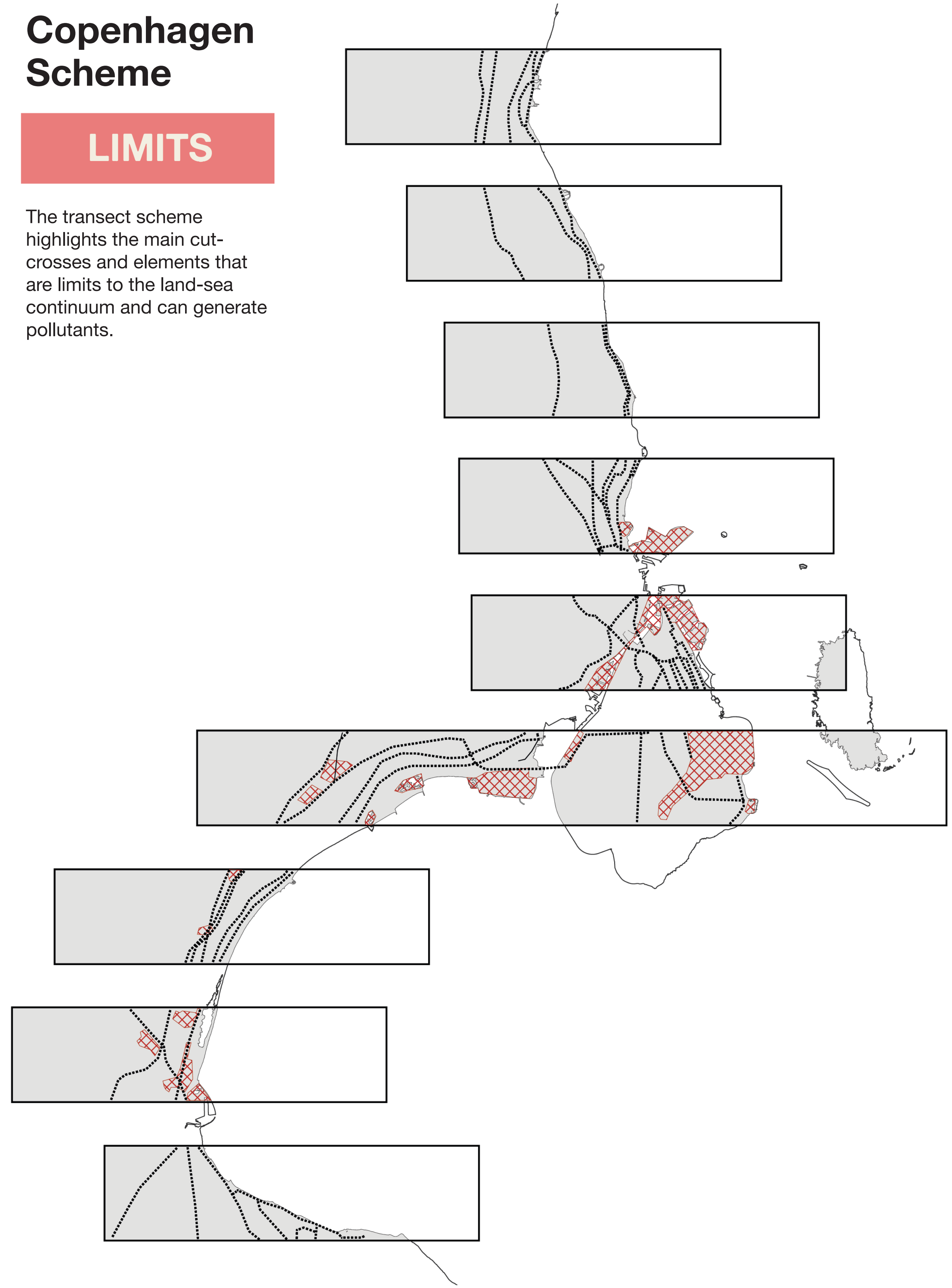
The transect shows four types of data; road infrastructure, industrial or commercial units, port areas and airports that all contribute to the fragmentation of the territory and also are directly or indirectly generators of pollutants.



Copenhagen Scheme

LIMITS

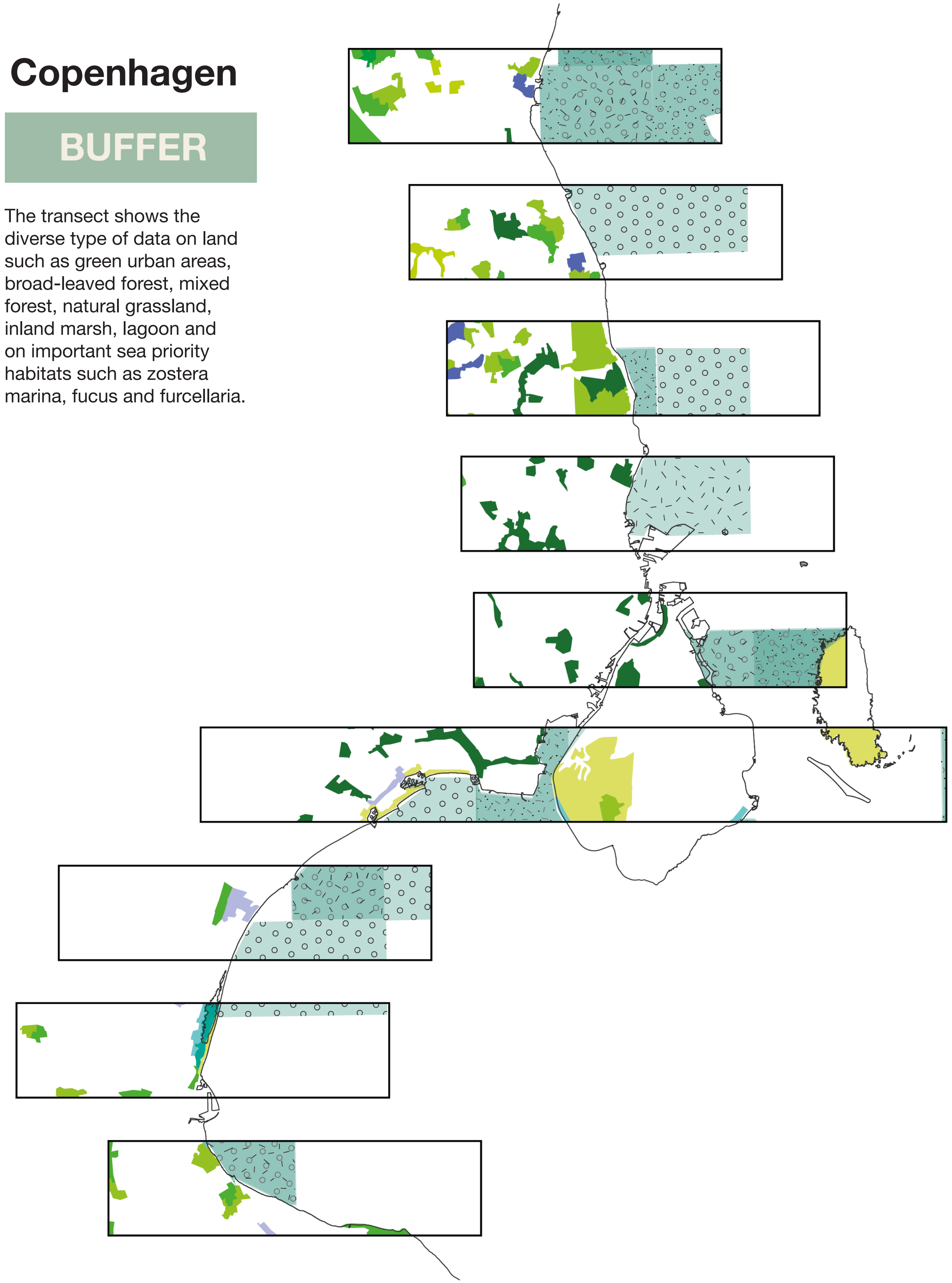
The transect scheme highlights the main cut-crosses and elements that are limits to the land-sea continuum and can generate pollutants.



Copenhagen

BUFFER

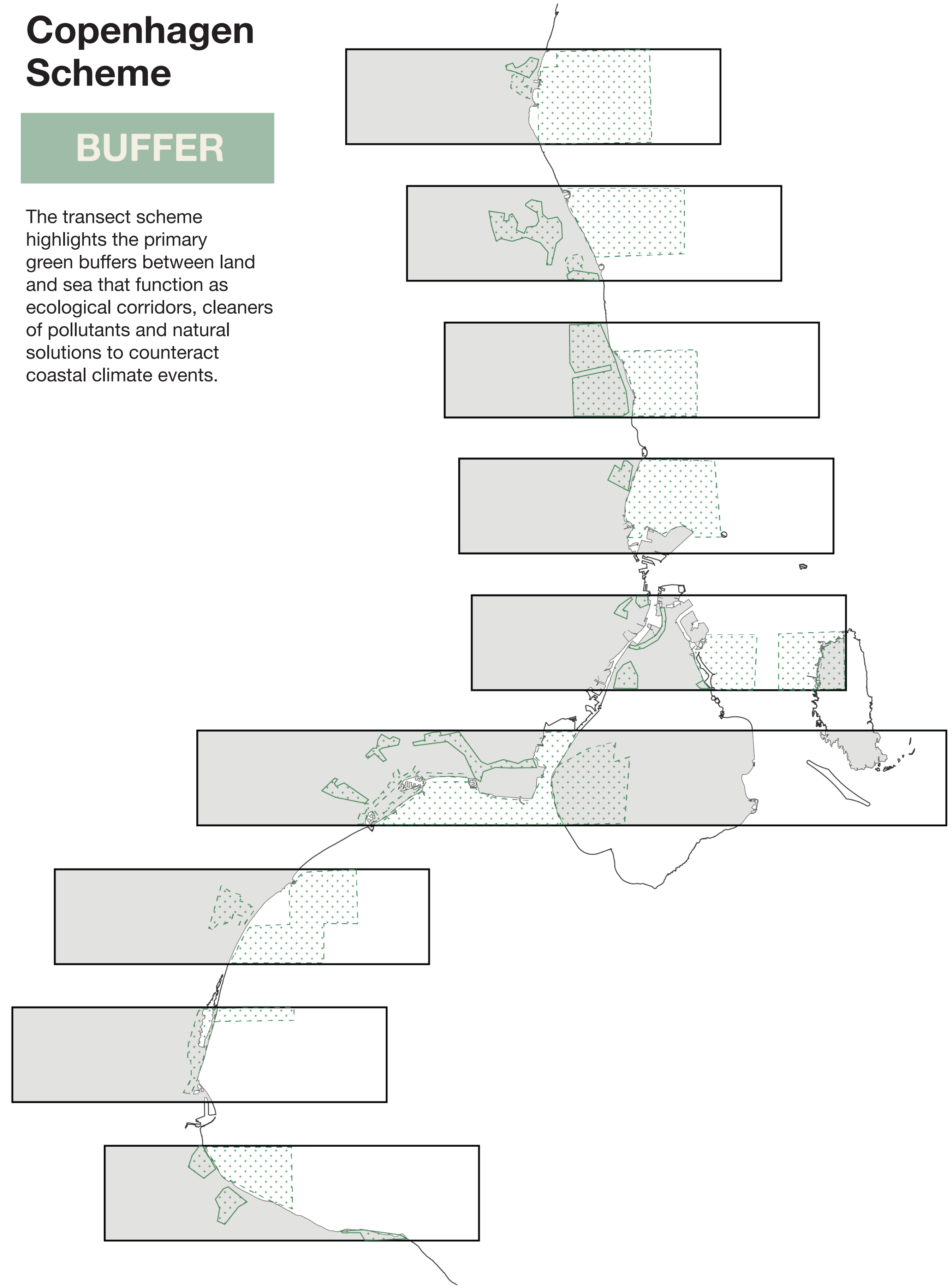
The transect shows the diverse type of data on land such as green urban areas, broad-leaved forest, mixed forest, natural grassland, inland marsh, lagoon and on important sea priority habitats such as zostera marina, fucus and furcellaria.



Copenhagen Scheme

BUFFER

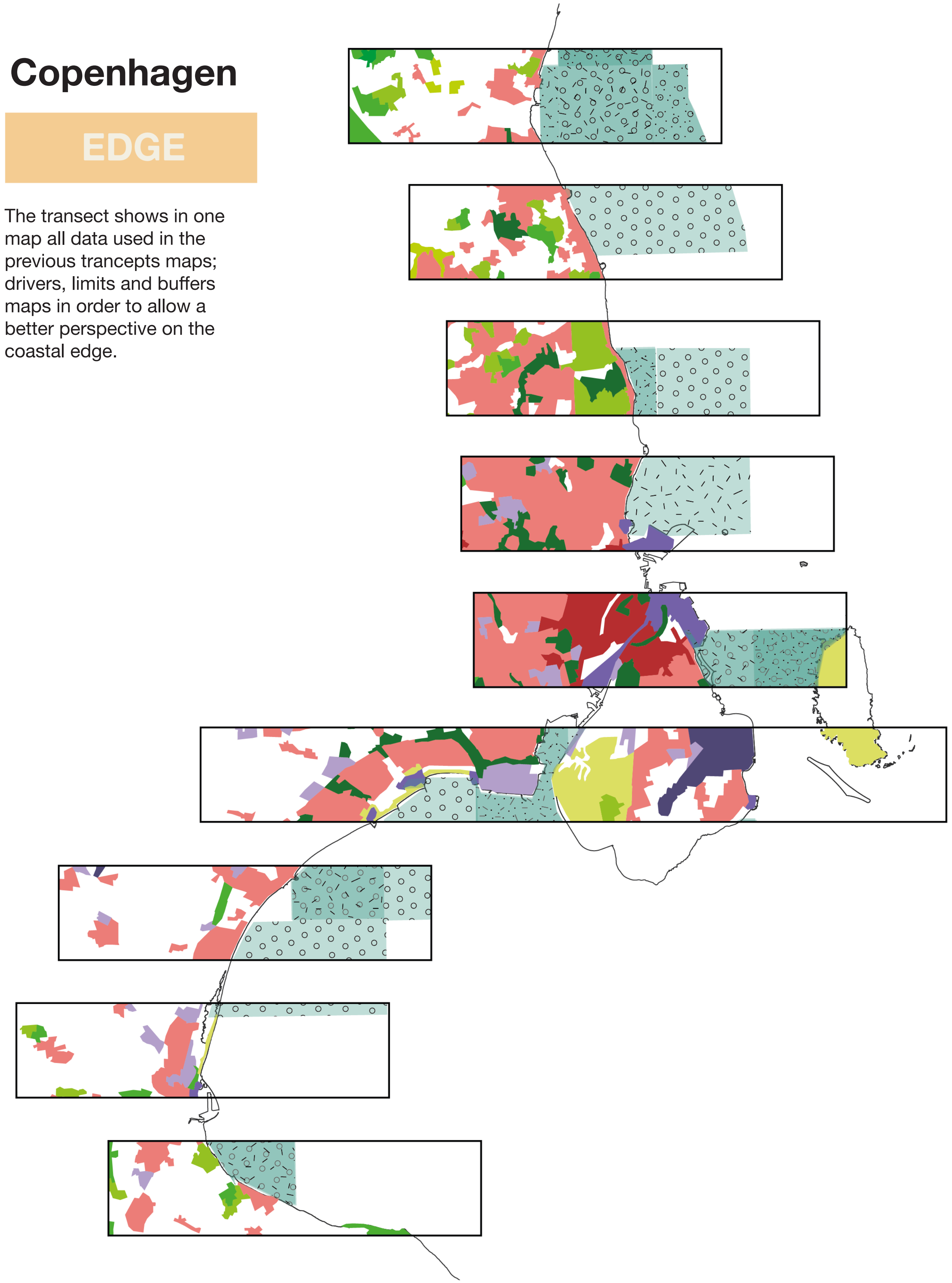
The transect scheme highlights the primary green buffers between land and sea that function as ecological corridors, cleaners of pollutants and natural solutions to counteract coastal climate events.



Copenhagen

EDGE

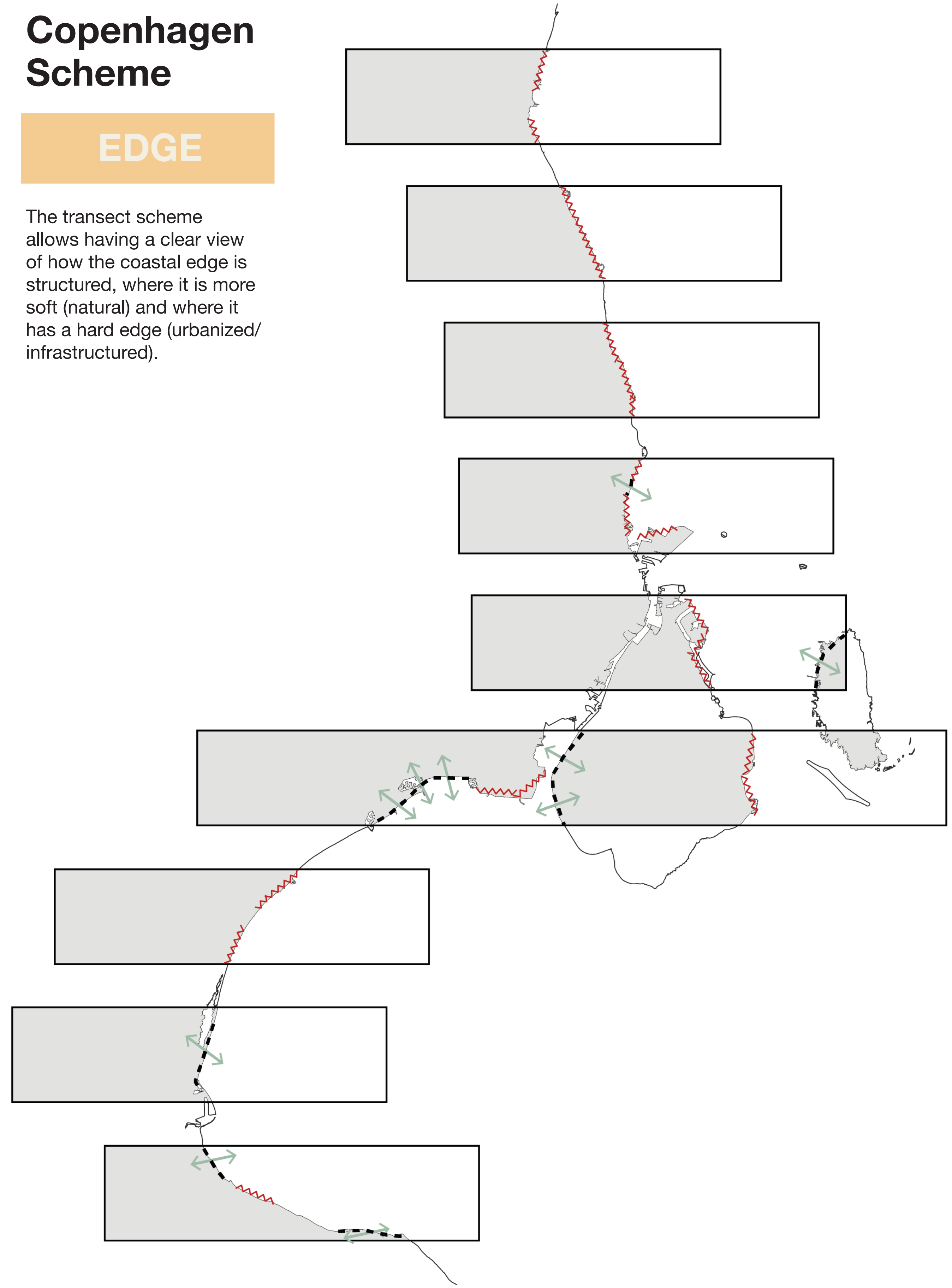
The transect shows in one map all data used in the previous trancepts maps; drivers, limits and buffers maps in order to allow a better perspective on the coastal edge.



Copenhagen Scheme

EDGE

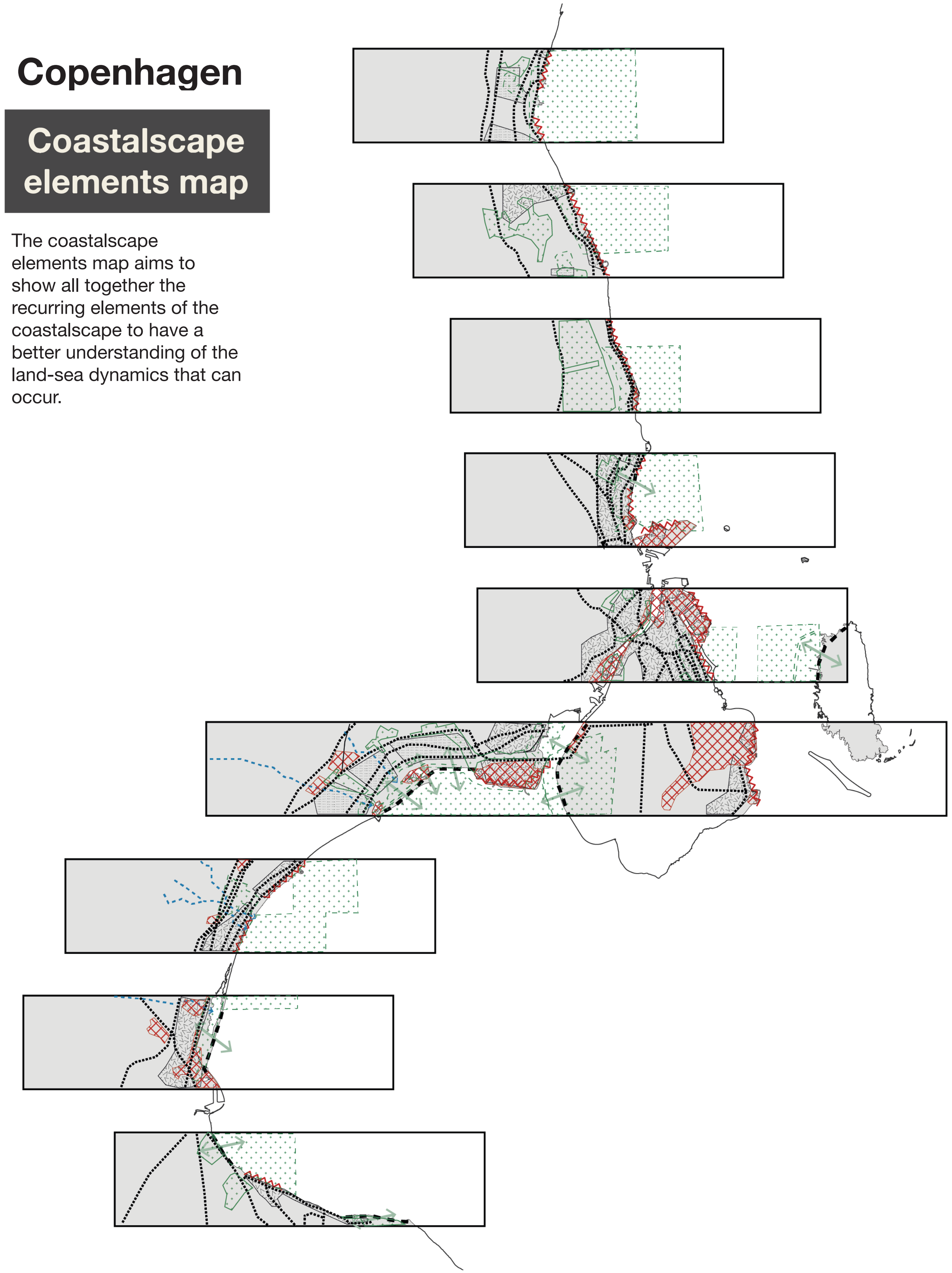
The transect scheme allows having a clear view of how the coastal edge is structured, where it is more soft (natural) and where it has a hard edge (urbanized/ infrastructured).



Copenhagen

Coastalscape elements map

The coastalscape elements map aims to show all together the recurring elements of the coastalscape to have a better understanding of the land-sea dynamics that can occur.

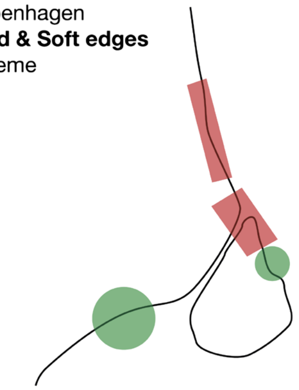


can be linear or areal; the linear ones are rail or road networks and all the structures that cross-cut the territory, while areal limits are identified as densely urbanized areas, industrial areas, dredging sites and port areas creating clearly delineated borders on the coast or inland and fragmenting the coastal territory.
Another category of coastal elements is buffers, which as we can see from the mapping analysis, can be located close to the shoreline or inland.
Buffers located mainly on the coast include wetlands, lagoons and so on, and they usually have a high ecological value and a wide range of biodiversity that also forms a direct ecological corridor between the marine and land ecosystems. The other types of buffers are natural areas, such as forest, mixed forest and grassland.
These two distinct types of buffers each function in different ways in retaining and cleaning pollutants produced by human activity. Some buffers, like for example wetlands, also play a role in counteracting coastal climate events.

An interesting example of mixed hard and soft edges can be seen in the case of Copenhagen. The city of Copenhagen has hard edges located to the north outside the inner city (urbanized areas up to the shoreline) and within the inner part of Copenhagen (densely urbanized areas, industrial areas and the main port of the city).
To the south-east and south, there are a number of soft edges created by the municipality, like Amager Strandpark and Brøndby Strand, artificial islands (featuring a mix of green and grey infrastructures) that enhance the natural buffering and permeability of the coast.

Drivers are elements that can further change the coastal and marine ecosystems. They can be anthropic or natural; anthropic ones are shown by areal limits, and the high percentage of imperviousness in these areas generates a lot of surface runoff. These anthropic drivers are spatialised on maps as urbanized and industrial areas. Depending on their territorial location, anthropic drivers can directly generate surface runoff to the sea or indirectly

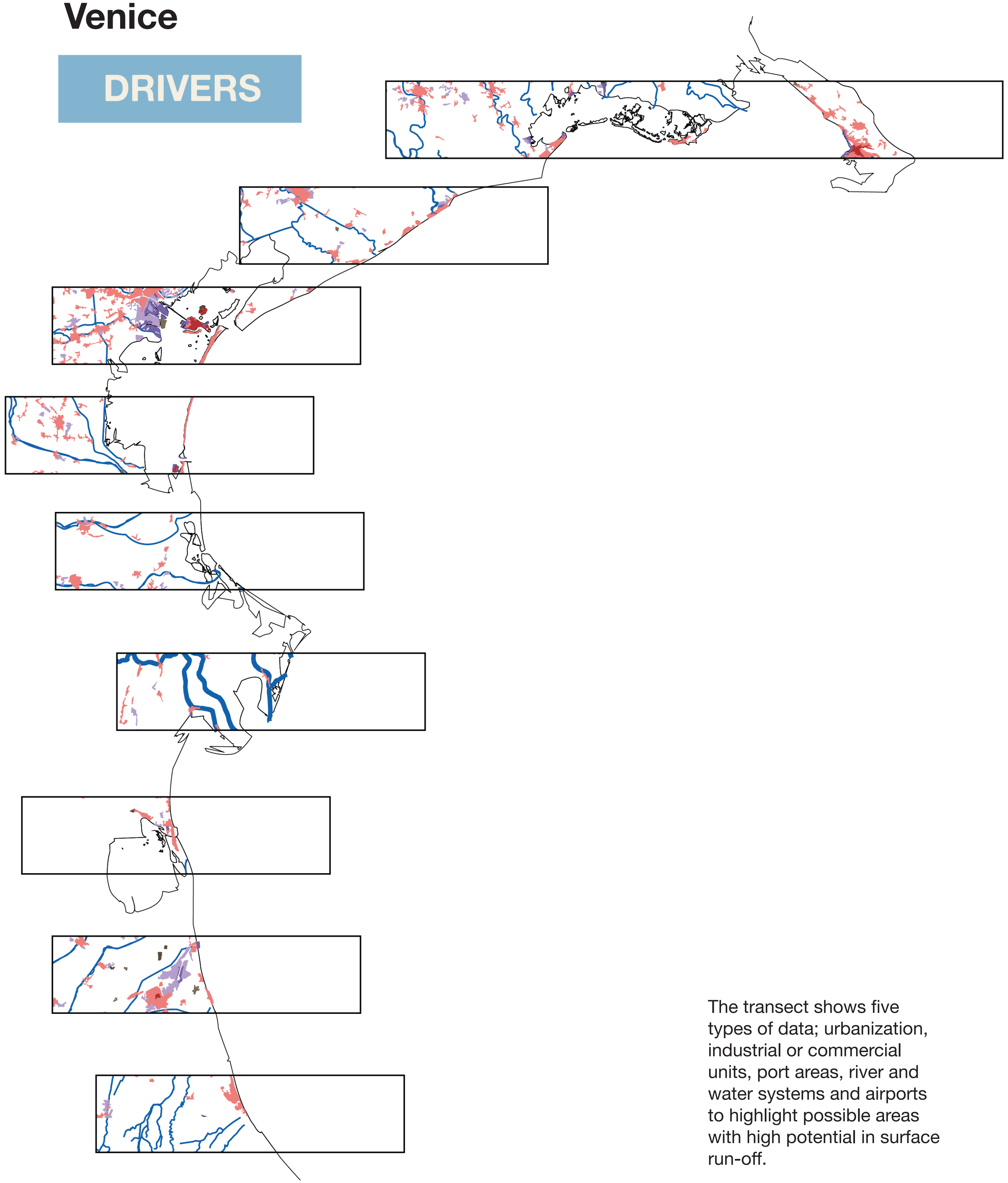
Copenhagen
Hard & Soft edges
scheme



The main **wetland** types are marshes and peat bogs, with subtypes including mangrove forests, floodplains and many others. The water in wetlands is either freshwater, mixed, or saltwater. Wetlands can be tidal or non-tidal.

Venice

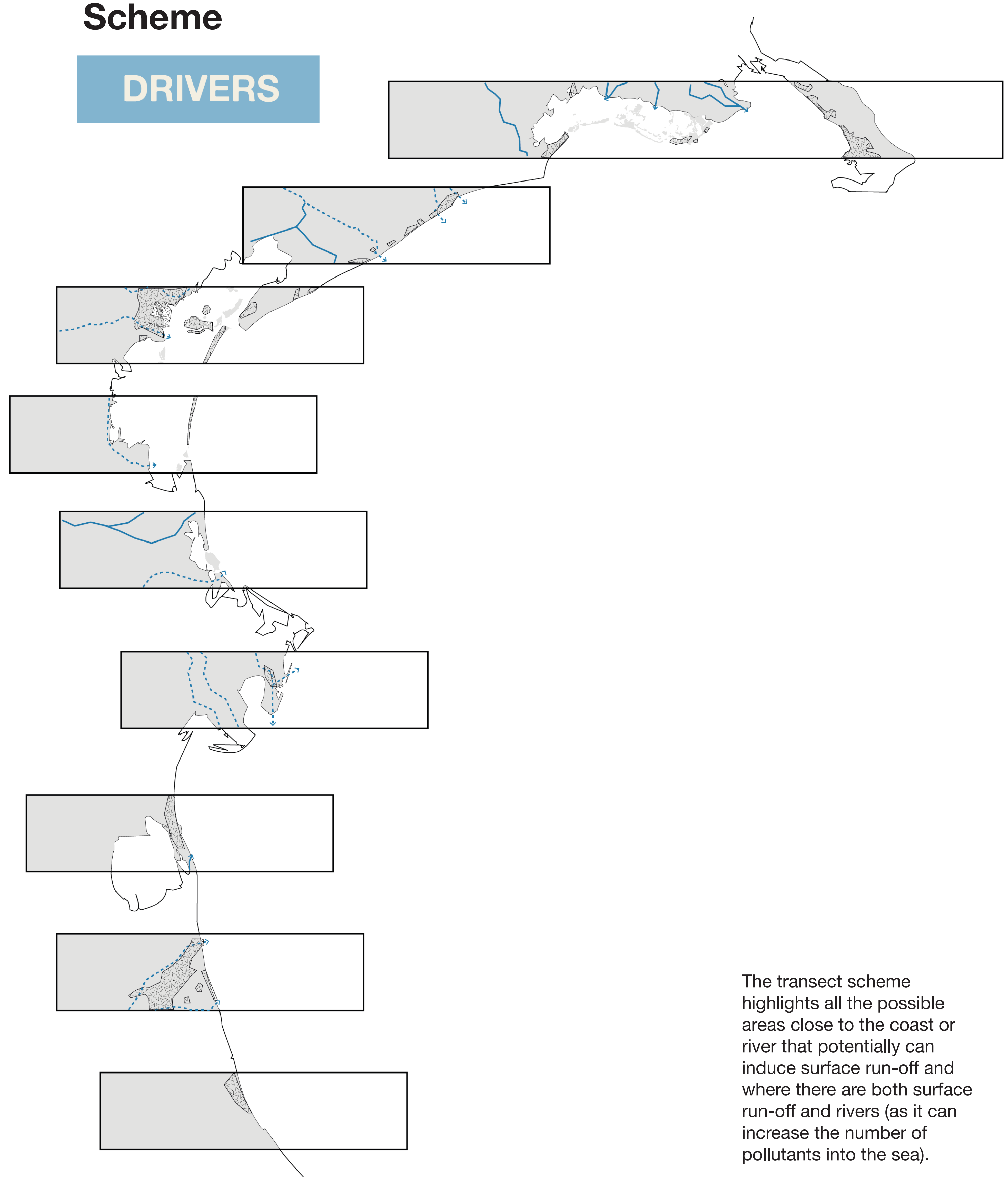
DRIVERS



The transect shows five types of data; urbanization, industrial or commercial units, port areas, river and water systems and airports to highlight possible areas with high potential in surface run-off.

Venice Scheme

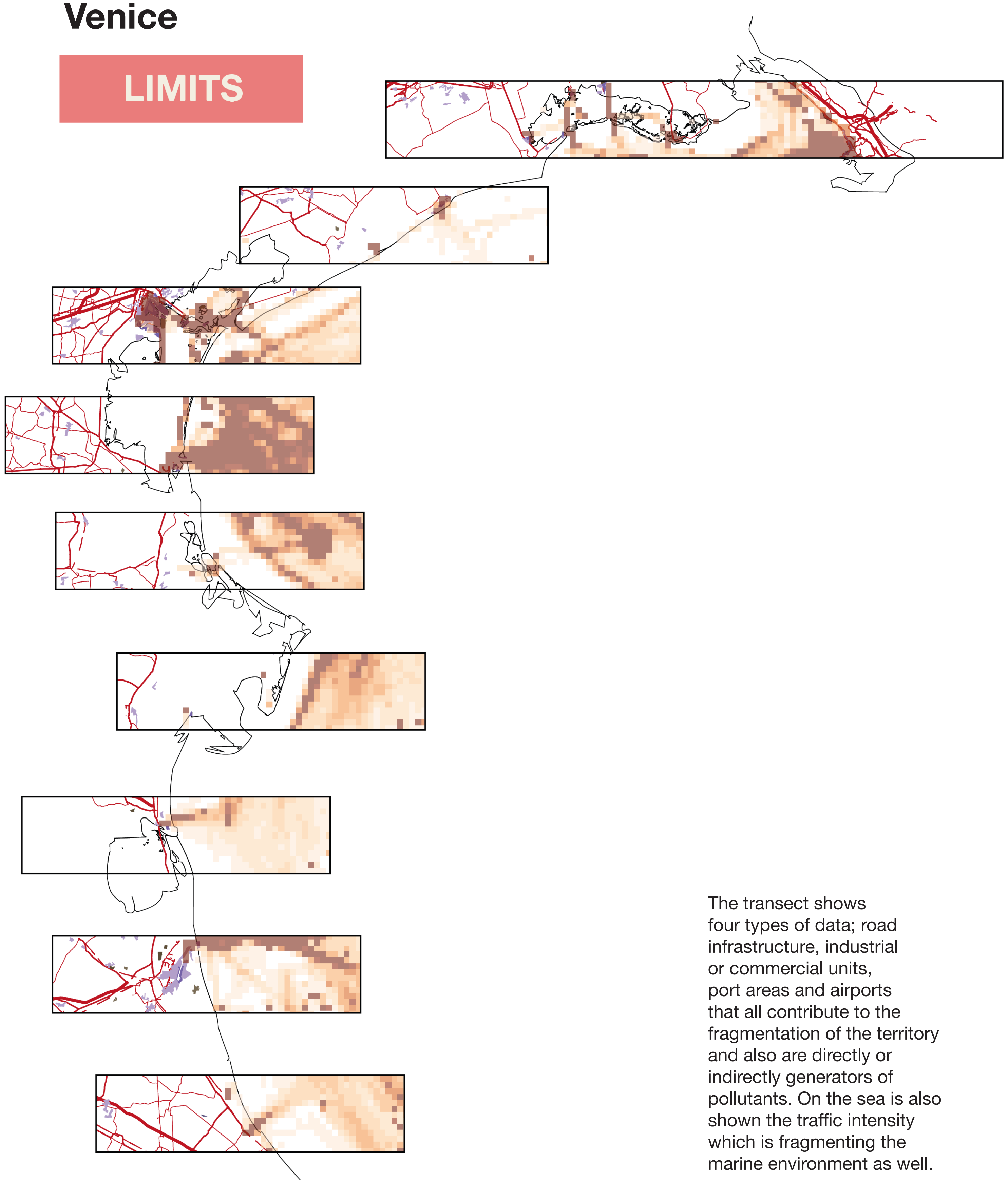
DRIVERS



The transect scheme highlights all the possible areas close to the coast or river that potentially can induce surface run-off and where there are both surface run-off and rivers (as it can increase the number of pollutants into the sea).

Venice

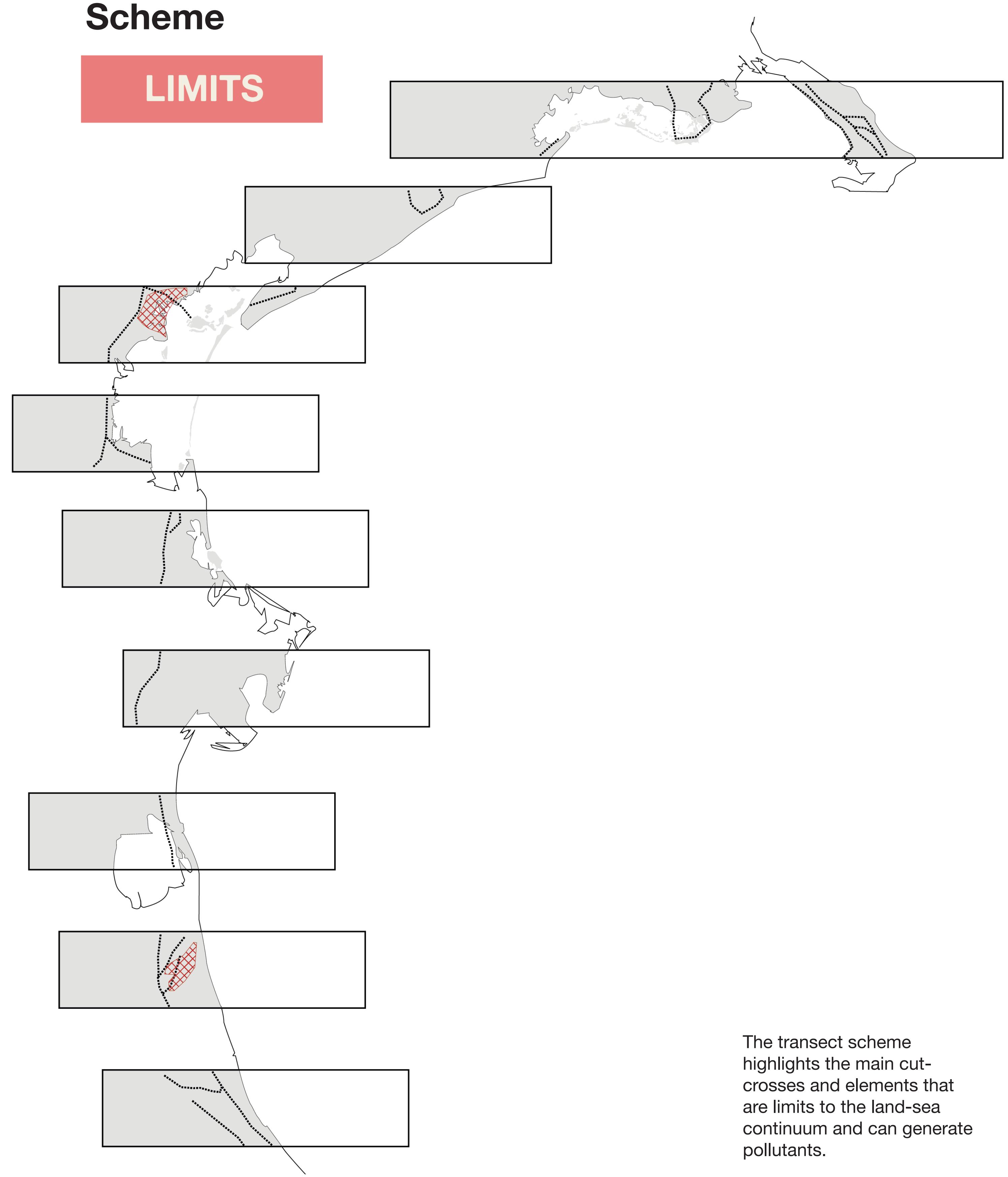
LIMITS



The transect shows four types of data; road infrastructure, industrial or commercial units, port areas and airports that all contribute to the fragmentation of the territory and also are directly or indirectly generators of pollutants. On the sea is also shown the traffic intensity which is fragmenting the marine environment as well.

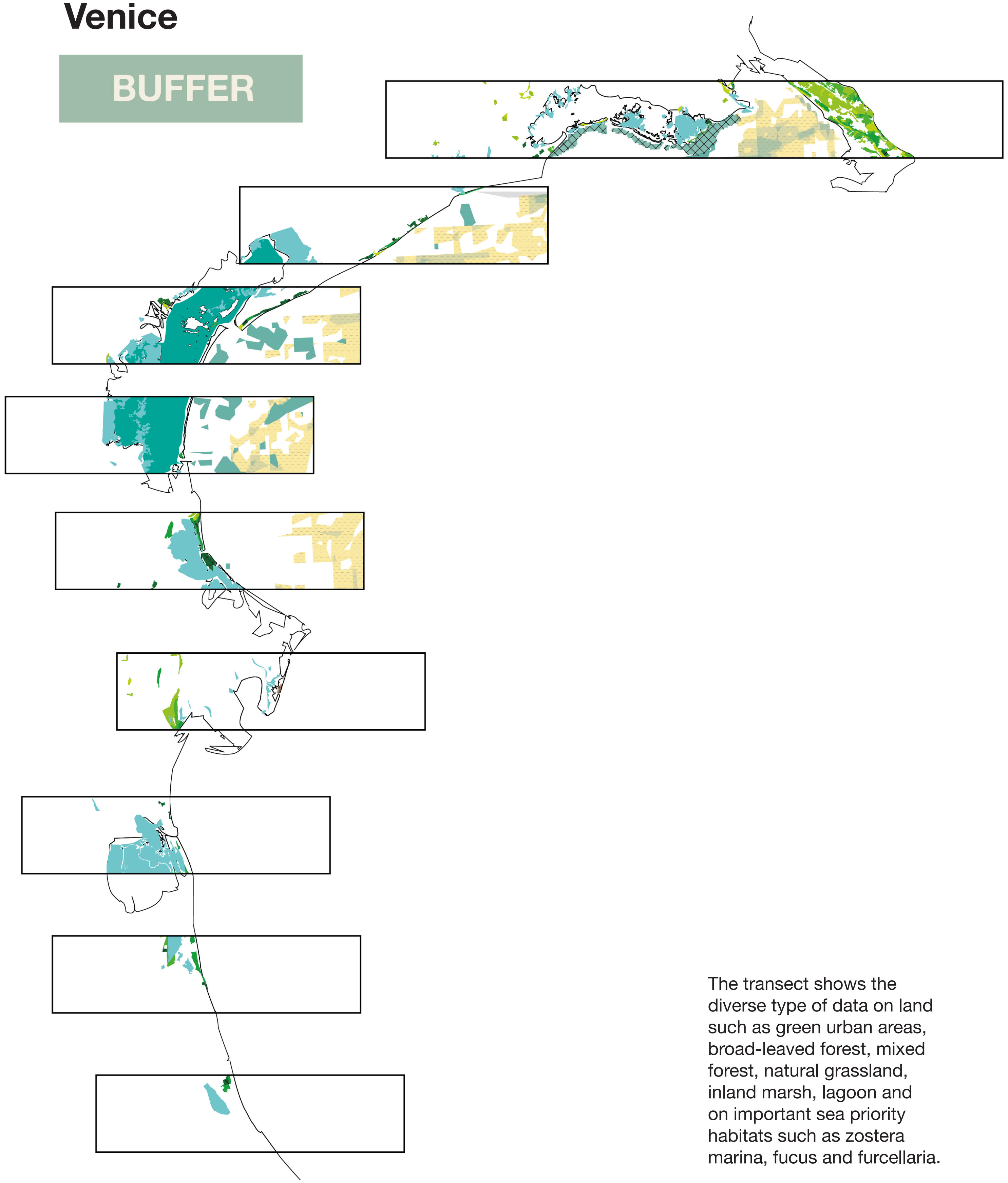
Venice Scheme

LIMITS



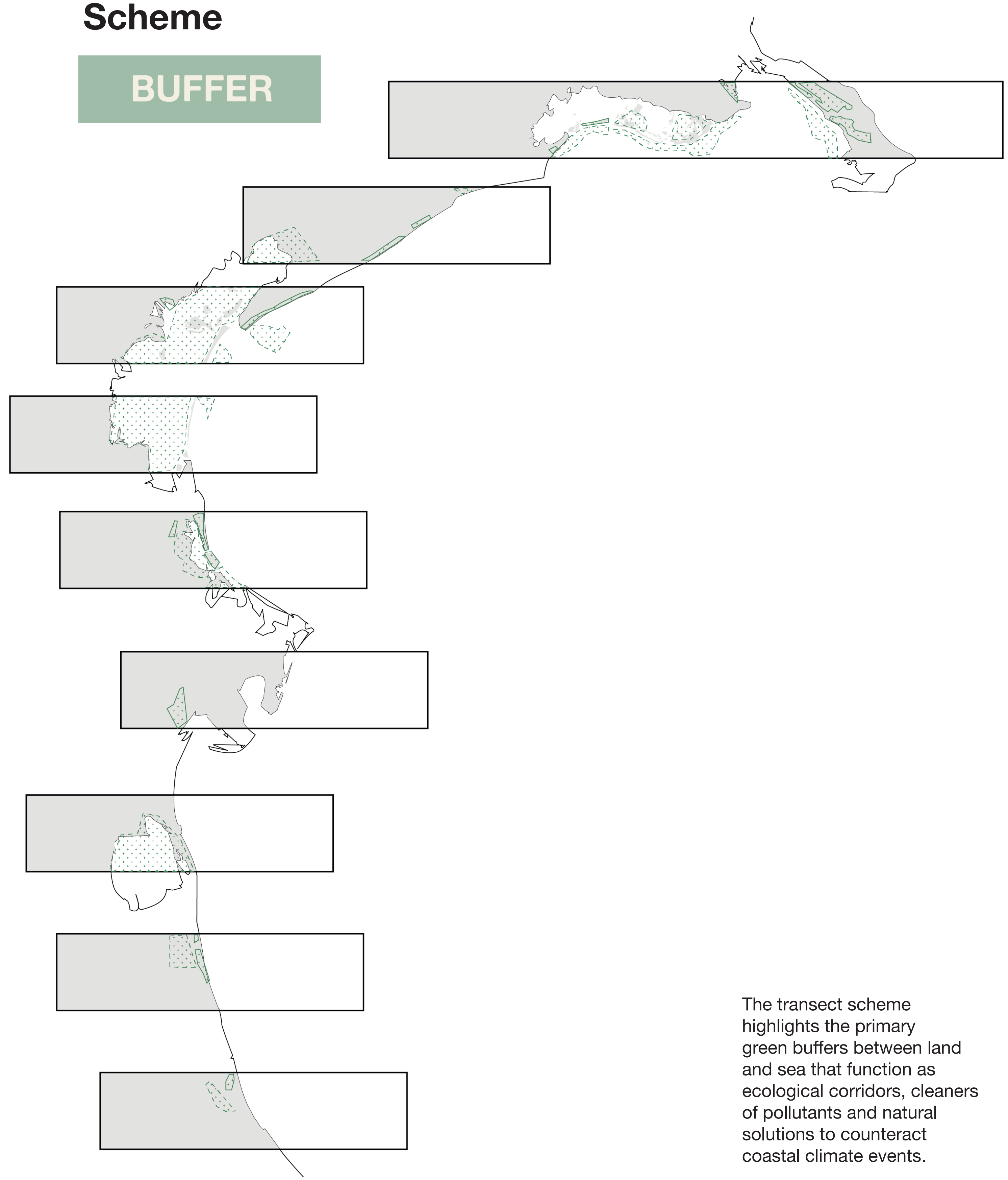
The transect scheme highlights the main cut-crosses and elements that are limits to the land-sea continuum and can generate pollutants.

Venice



The transect shows the diverse type of data on land such as green urban areas, broad-leaved forest, mixed forest, natural grassland, inland marsh, lagoon and on important sea priority habitats such as zostera marina, fucus and furcellaria.

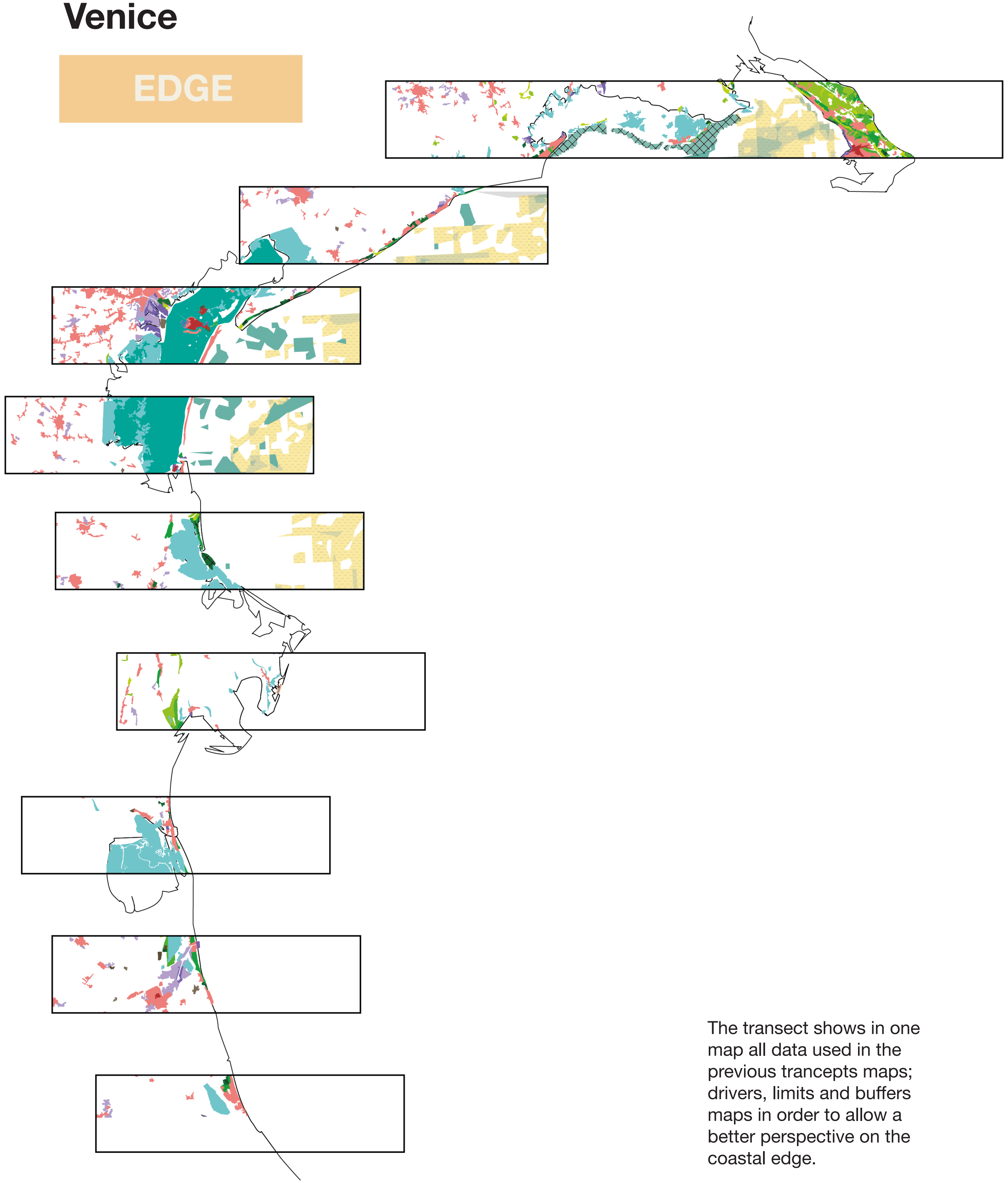
Venice Scheme



The transect scheme highlights the primary green buffers between land and sea that function as ecological corridors, cleaners of pollutants and natural solutions to counteract coastal climate events.

Venice

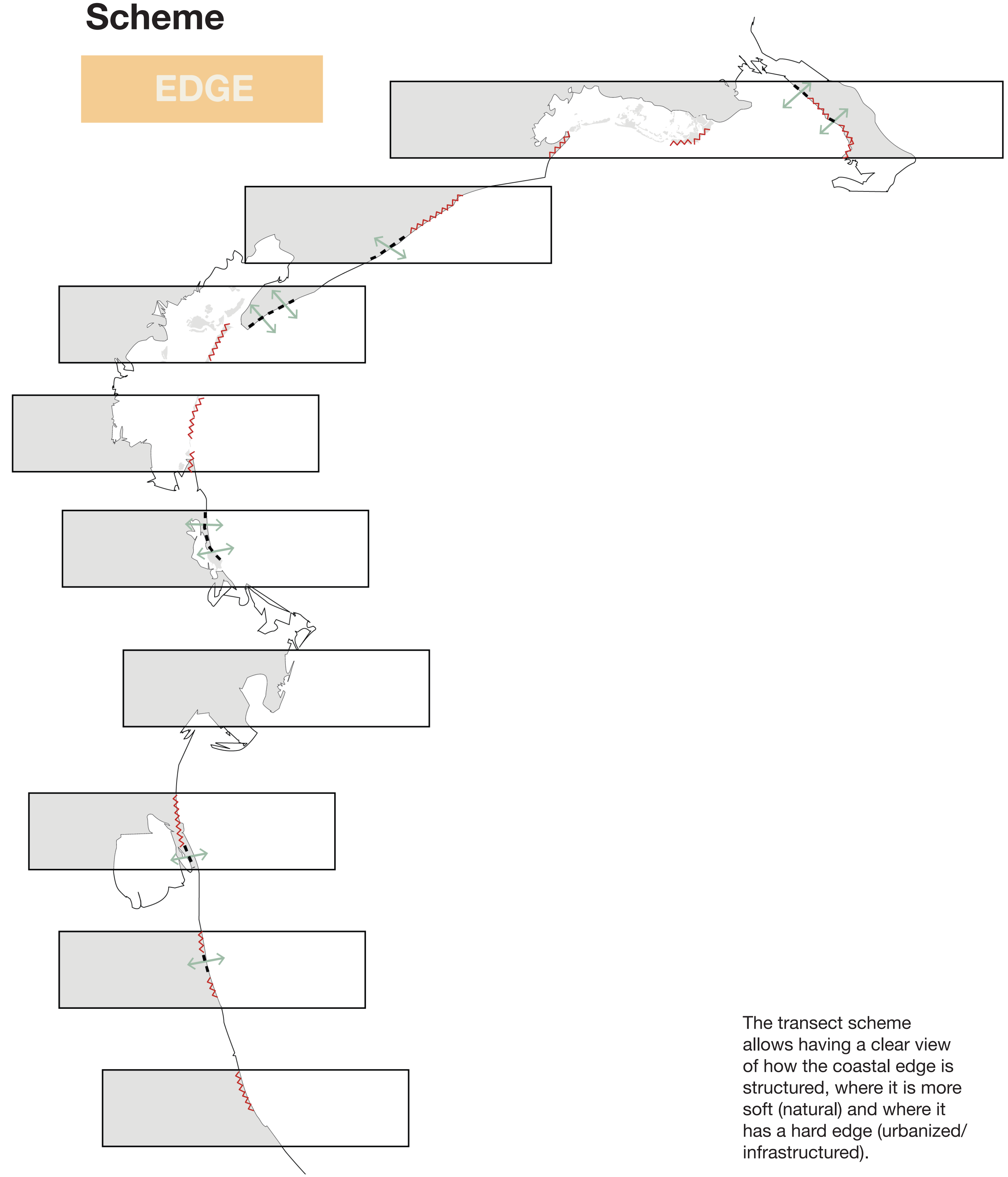
EDGE



The transect shows in one map all data used in the previous trancepts maps; drivers, limits and buffers maps in order to allow a better perspective on the coastal edge.

Venice Scheme

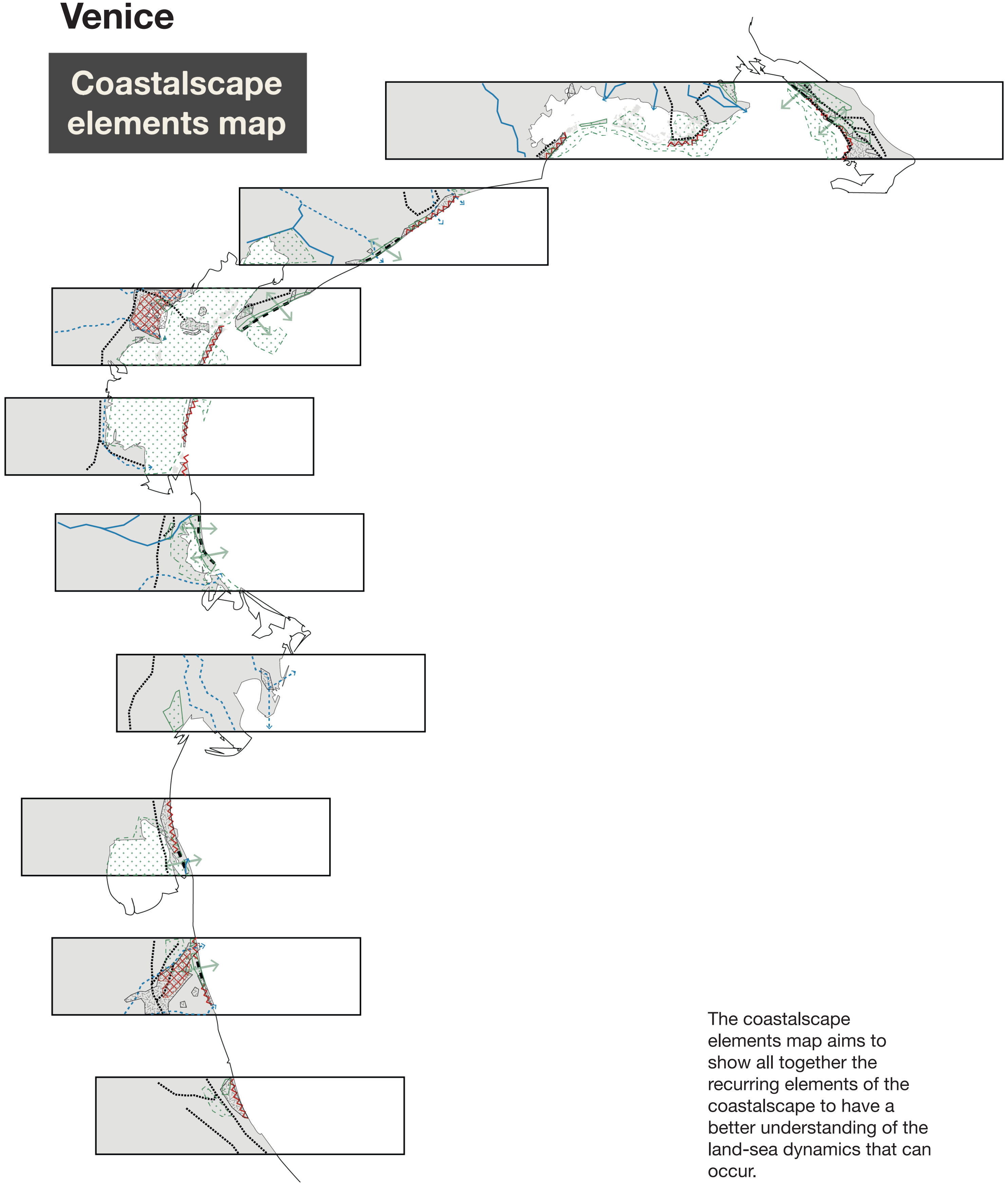
EDGE



The transect scheme allows having a clear view of how the coastal edge is structured, where it is more soft (natural) and where it has a hard edge (urbanized/ infrastructured).

Venice

Coastalscape elements map



The coastalscape elements map aims to show all together the recurring elements of the coastalscape to have a better understanding of the land-sea dynamics that can occur.

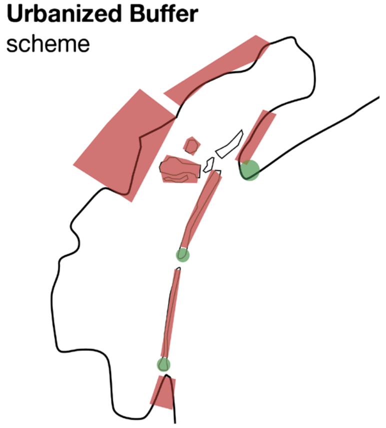
via another driver (e.g. a river).
Natural drivers include rivers and creeks that are part of watershed basins. As already outlined in the previous chapters, rivers function as transporters of all the discharged pollutants generated from inland and coastal human activities.

From the different cases mapped through the transect analysis, we can conclude that, when it is present, a hard edge means that a coastal area will mainly be composed of urbanised and productive areas. In most cases, these hard edges are shaped by linear and areal limits, such as port areas, dense city waterfronts and road networks; limits that at the same time function as drivers because of their imperviousness.

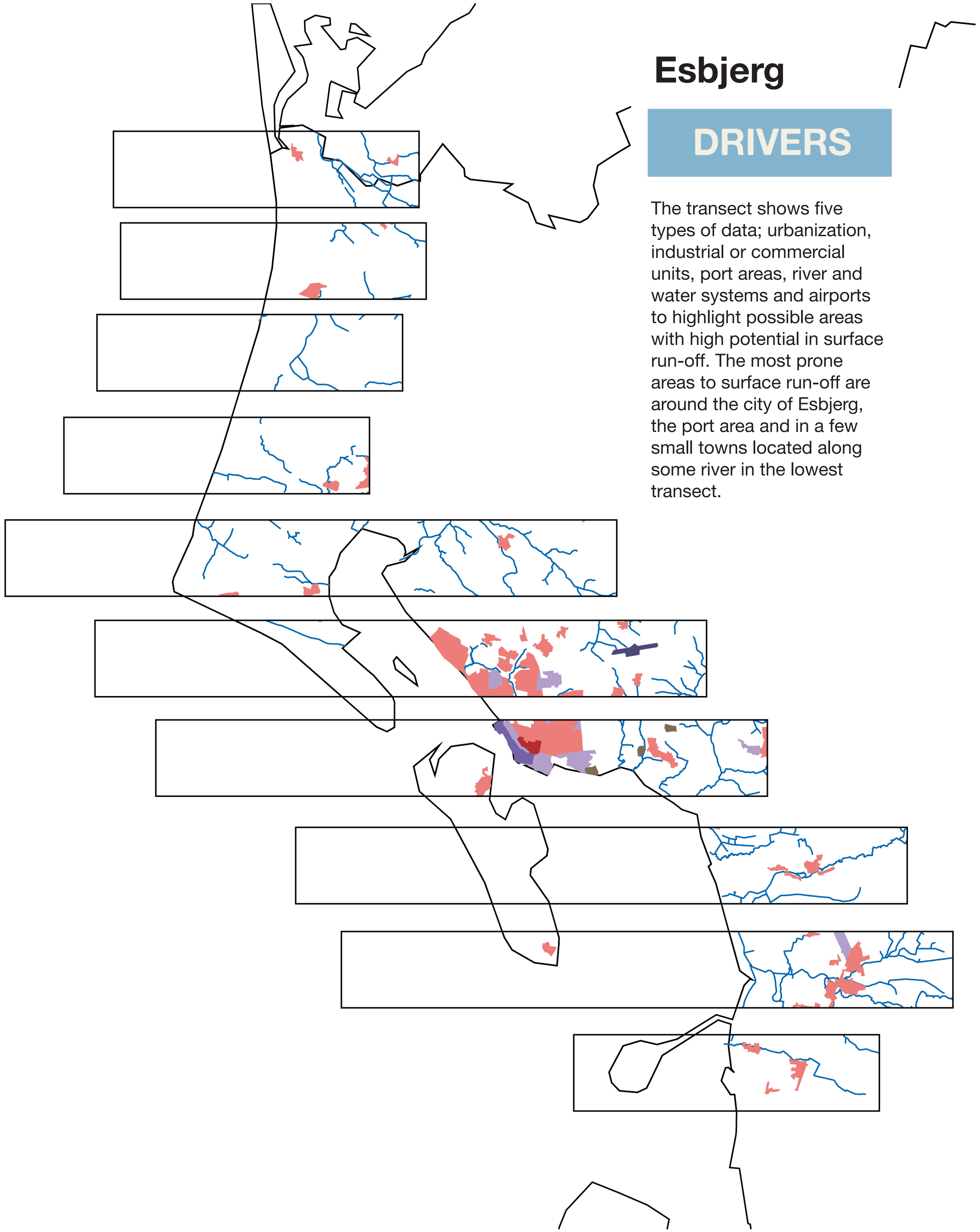
We can also conclude from the case studies that when urbanization decreases along a coast, it creates space for a more natural environment, shaped by rivers and creeks (drivers) and by different types of buffers- depending on the area's geography and morphology- and situated both on land and at sea.
Buffers and natural drivers together configure a soft edge, which allows different ecosystems to meet and so maintain a land-sea ecological continuum.

Data from the Veneto region and Venice case study also indicate that sometimes densely urbanized areas exist in and on the border of a natural buffer, which, in the Veneto case study, has led to the Venetian lagoon constantly being exposed to pressures from human activities and urbanization.
The lagoon is, in fact, hardly infrastructured on the borders with the port of Marghera and its chemical pole with all the towns located around the lagoon and with the densely urbanized lagoon islands. This urban spatialization leads to considerable pressures on an already vulnerable environment and forms a more fragmented and hard edge, in contrast to the inherent features of natural buffers.
This mapping process has had a twofold exploratory

Venice lagoon
Urbanized Buffer
scheme



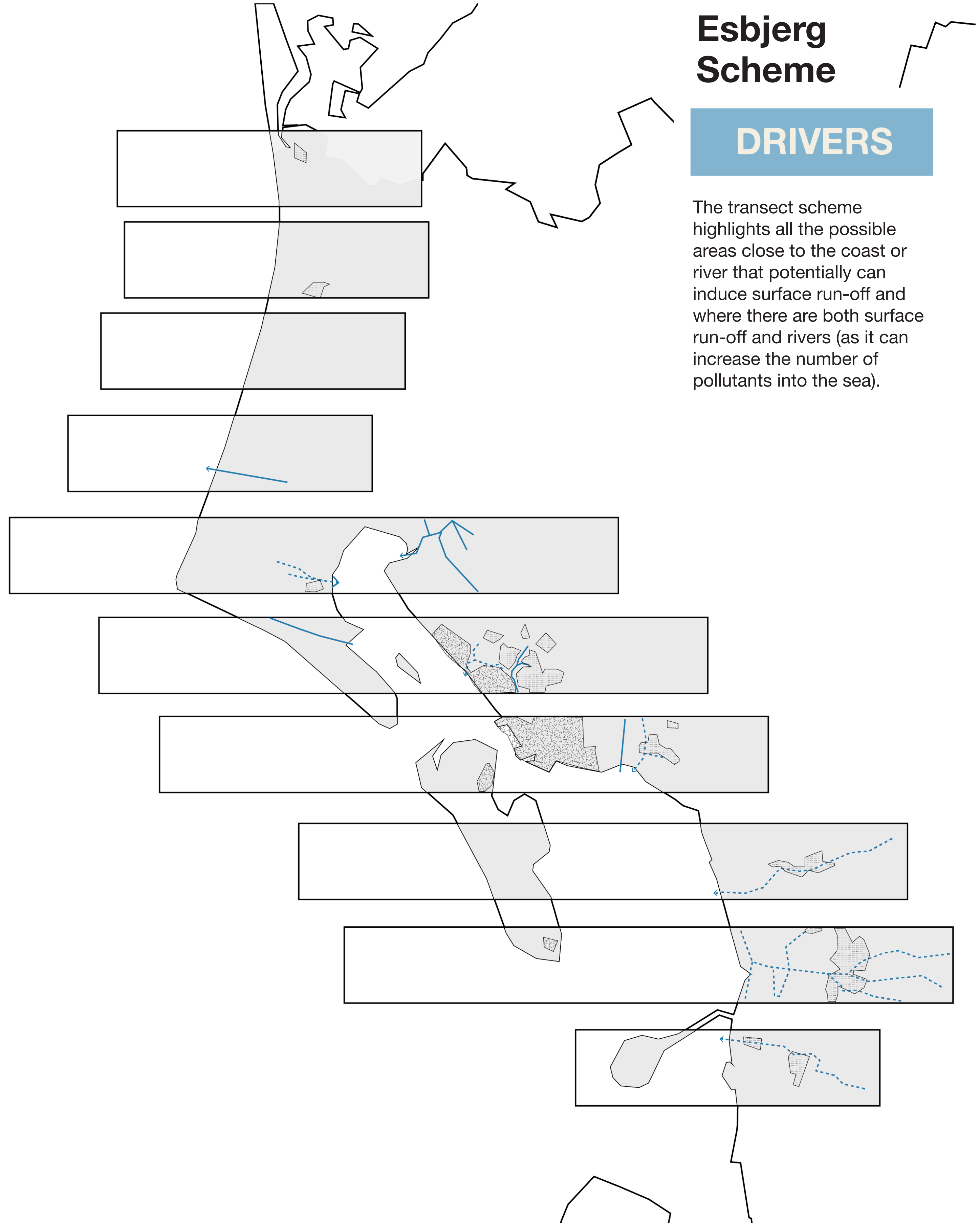
function: firstly, to develop the analysis methodology, and secondly to present visually the findings from analysing the coastal areas and land-sea interactions.
From a planning perspective, it is important to have information displayed in this way because some dynamics have a spatial dimension that can only be seen clearly through such a mapping analysis.
In carrying out the mapping analysis, I tried to represent the spatial dimensions between human activities and natural elements which go into creating coastal territories and to depict the common components necessary to describe them.



Esbjerg

DRIVERS

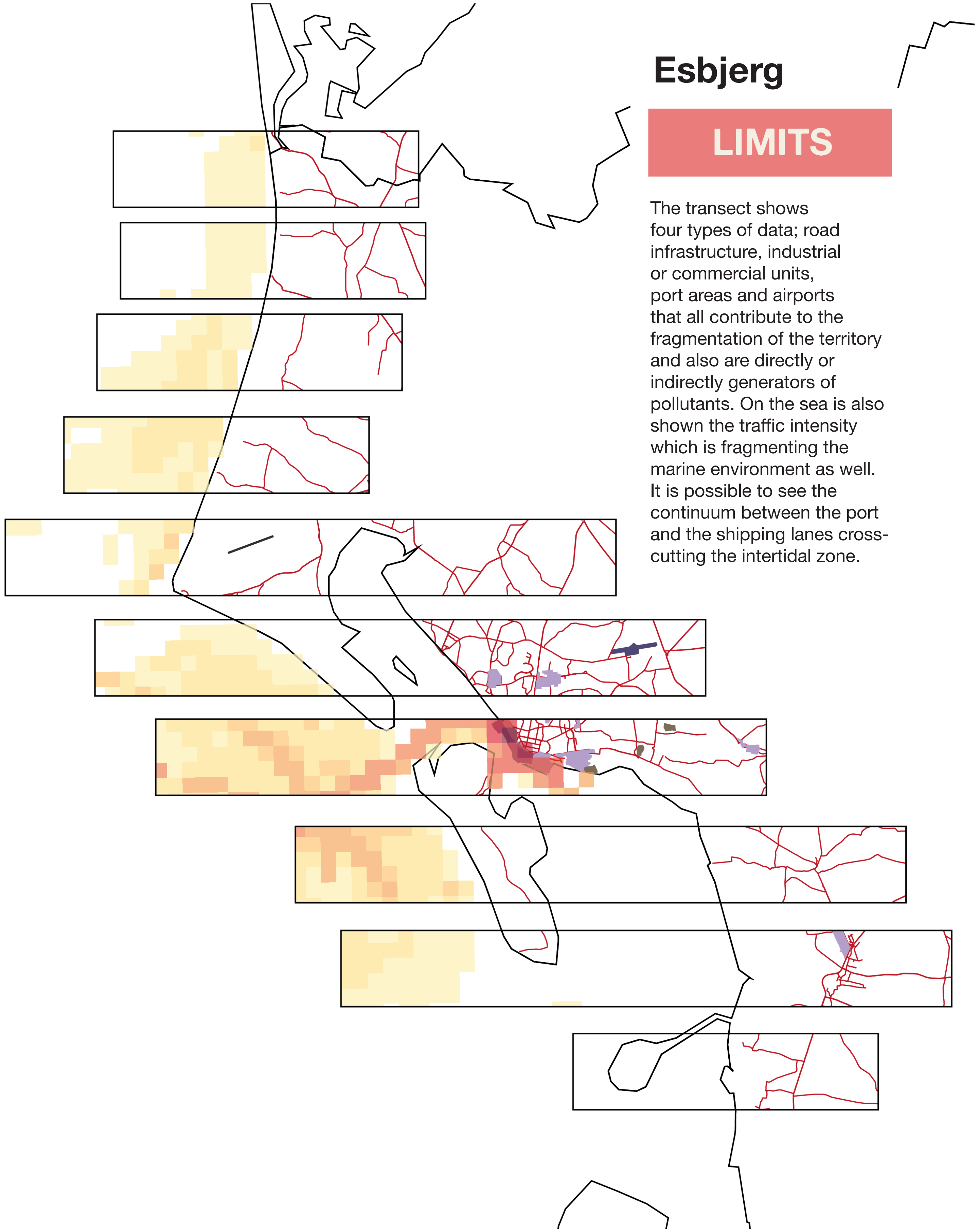
The transect shows five types of data; urbanization, industrial or commercial units, port areas, river and water systems and airports to highlight possible areas with high potential in surface run-off. The most prone areas to surface run-off are around the city of Esbjerg, the port area and in a few small towns located along some river in the lowest transect.



Esbjerg Scheme

DRIVERS

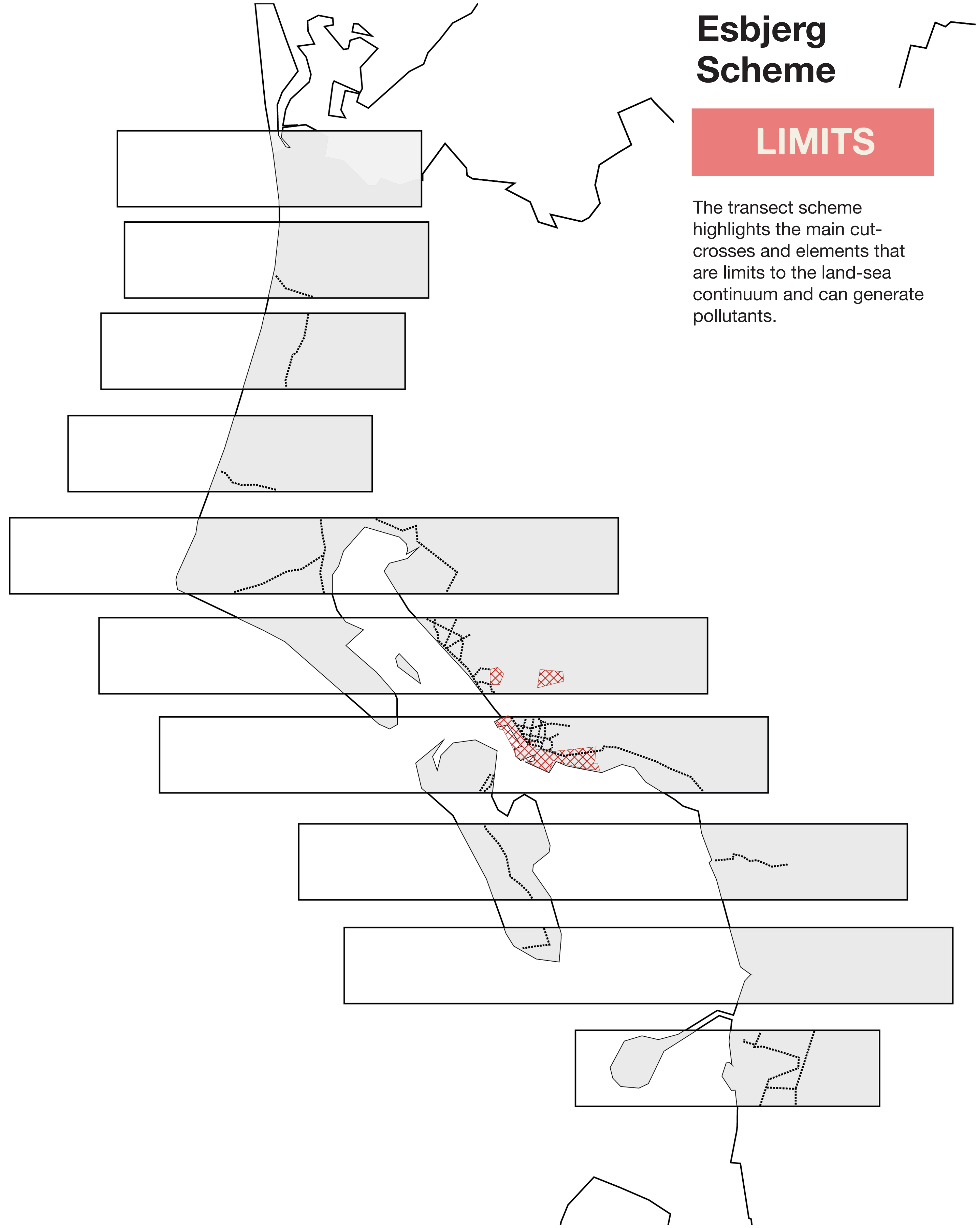
The transect scheme highlights all the possible areas close to the coast or river that potentially can induce surface run-off and where there are both surface run-off and rivers (as it can increase the number of pollutants into the sea).



Esbjerg

LIMITS

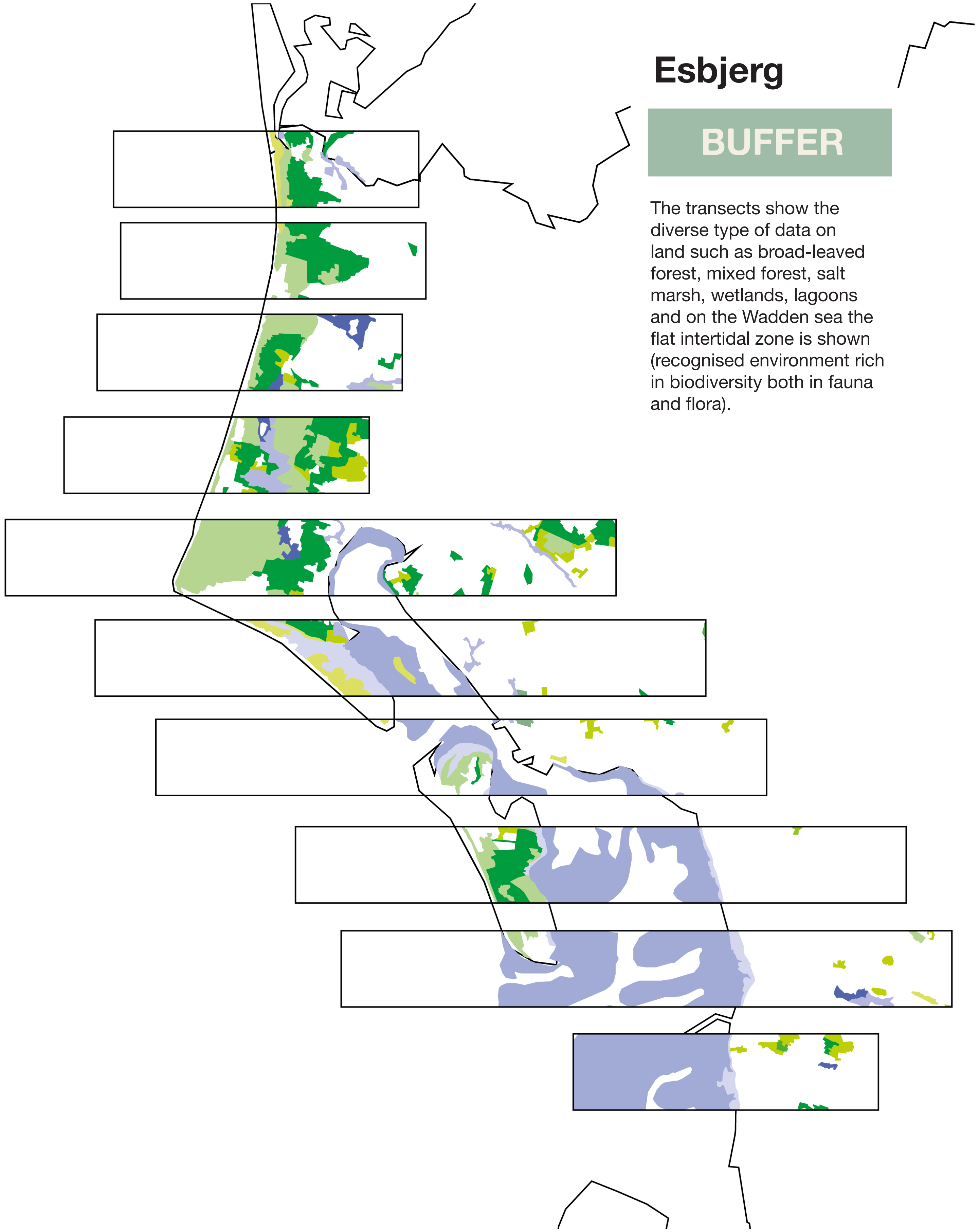
The transect shows four types of data; road infrastructure, industrial or commercial units, port areas and airports that all contribute to the fragmentation of the territory and also are directly or indirectly generators of pollutants. On the sea is also shown the traffic intensity which is fragmenting the marine environment as well. It is possible to see the continuum between the port and the shipping lanes cross-cutting the intertidal zone.



Esbjerg Scheme

LIMITS

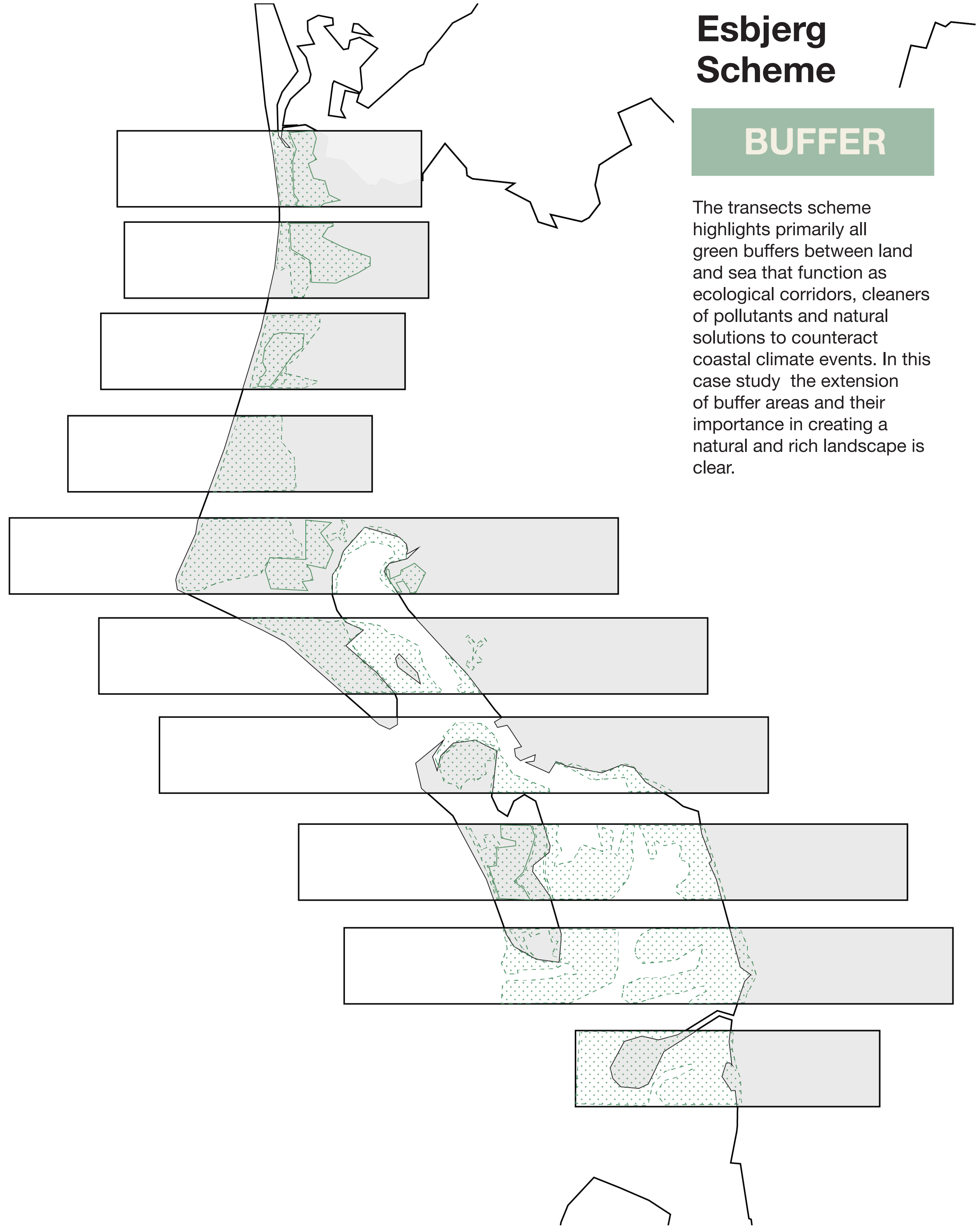
The transect scheme highlights the main cut-crosses and elements that are limits to the land-sea continuum and can generate pollutants.



Esbjerg

BUFFER

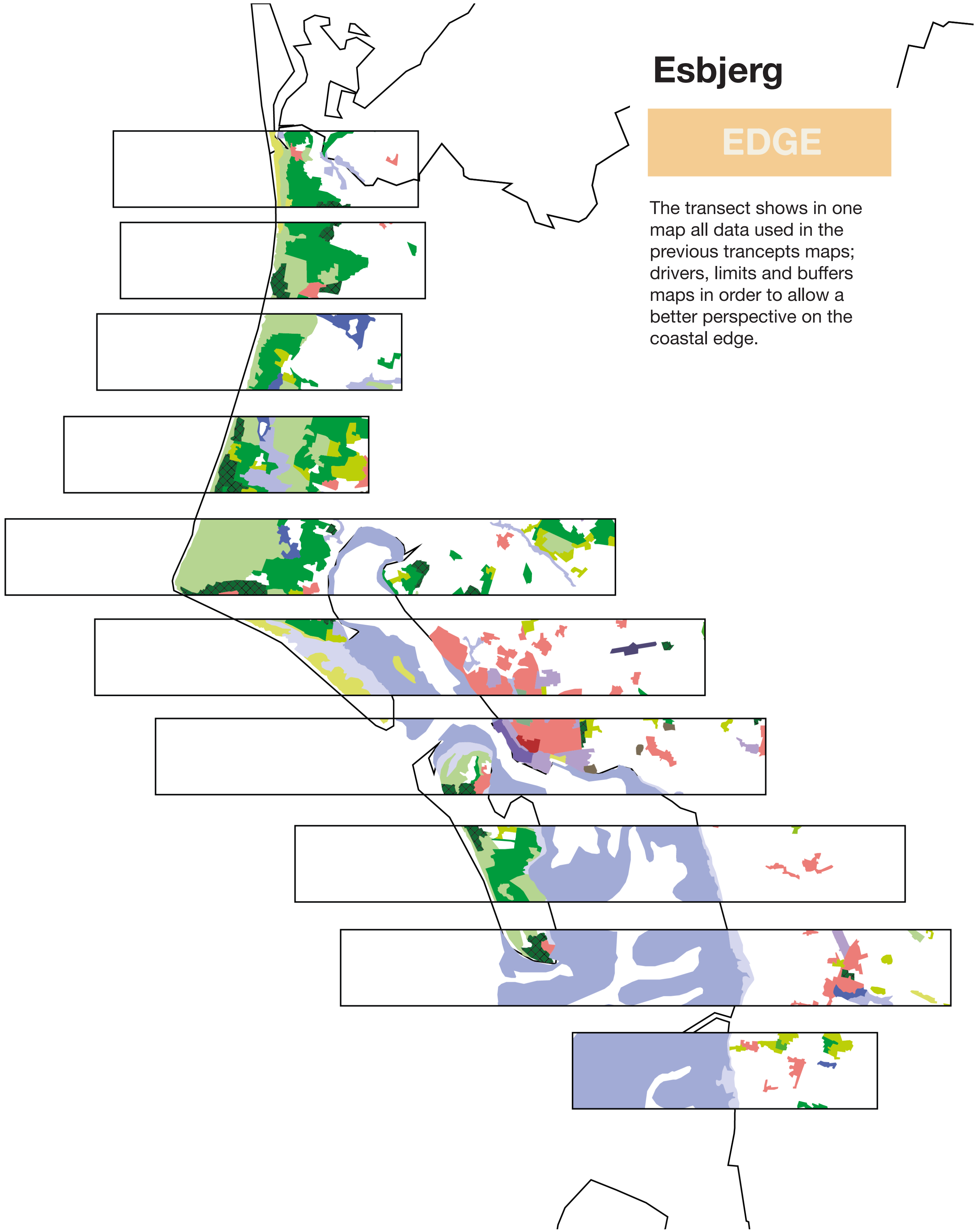
The transects show the diverse type of data on land such as broad-leaved forest, mixed forest, salt marsh, wetlands, lagoons and on the Wadden sea the flat intertidal zone is shown (recognised environment rich in biodiversity both in fauna and flora).



Esbjerg Scheme

BUFFER

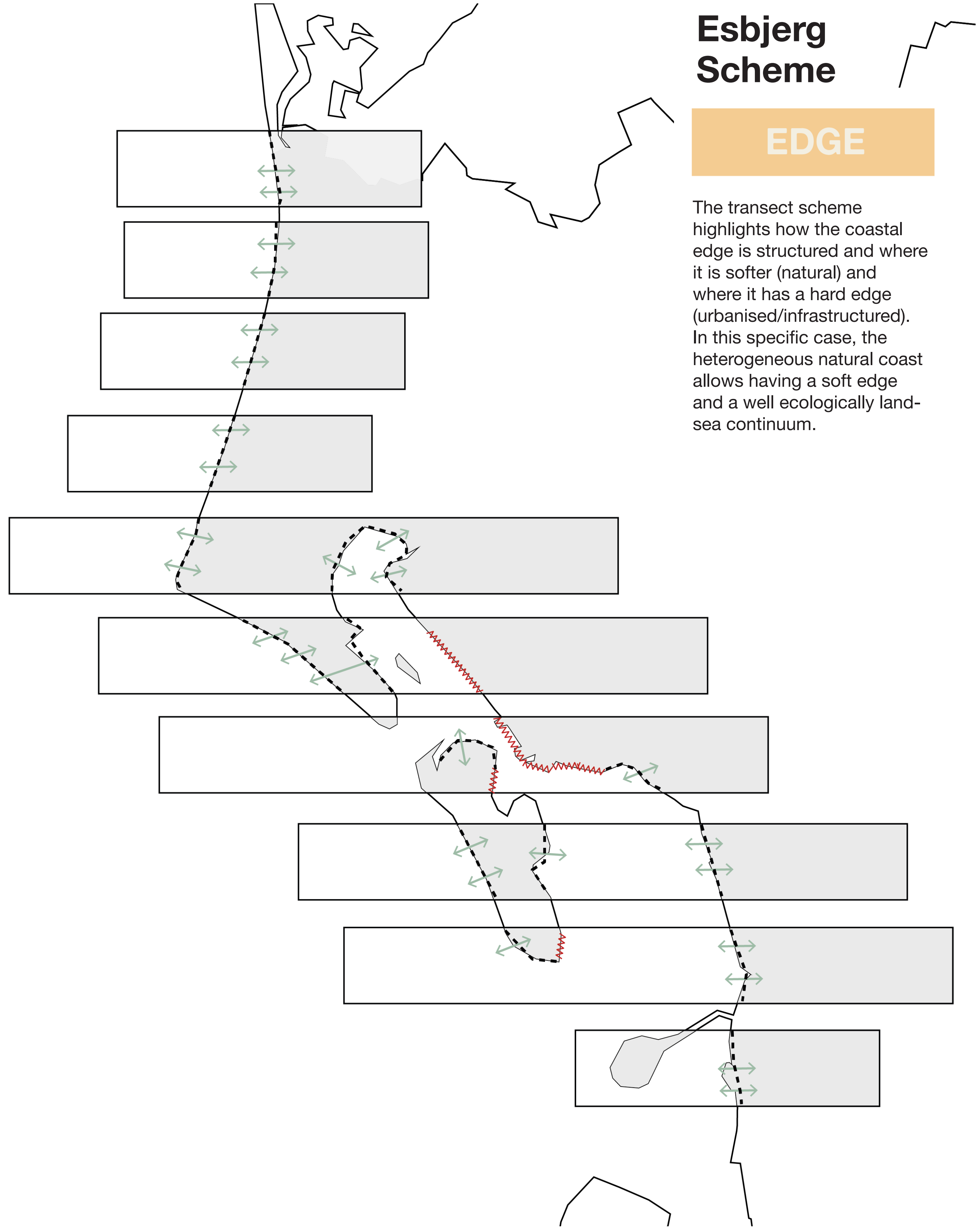
The transects scheme highlights primarily all green buffers between land and sea that function as ecological corridors, cleaners of pollutants and natural solutions to counteract coastal climate events. In this case study the extension of buffer areas and their importance in creating a natural and rich landscape is clear.



Esbjerg

EDGE

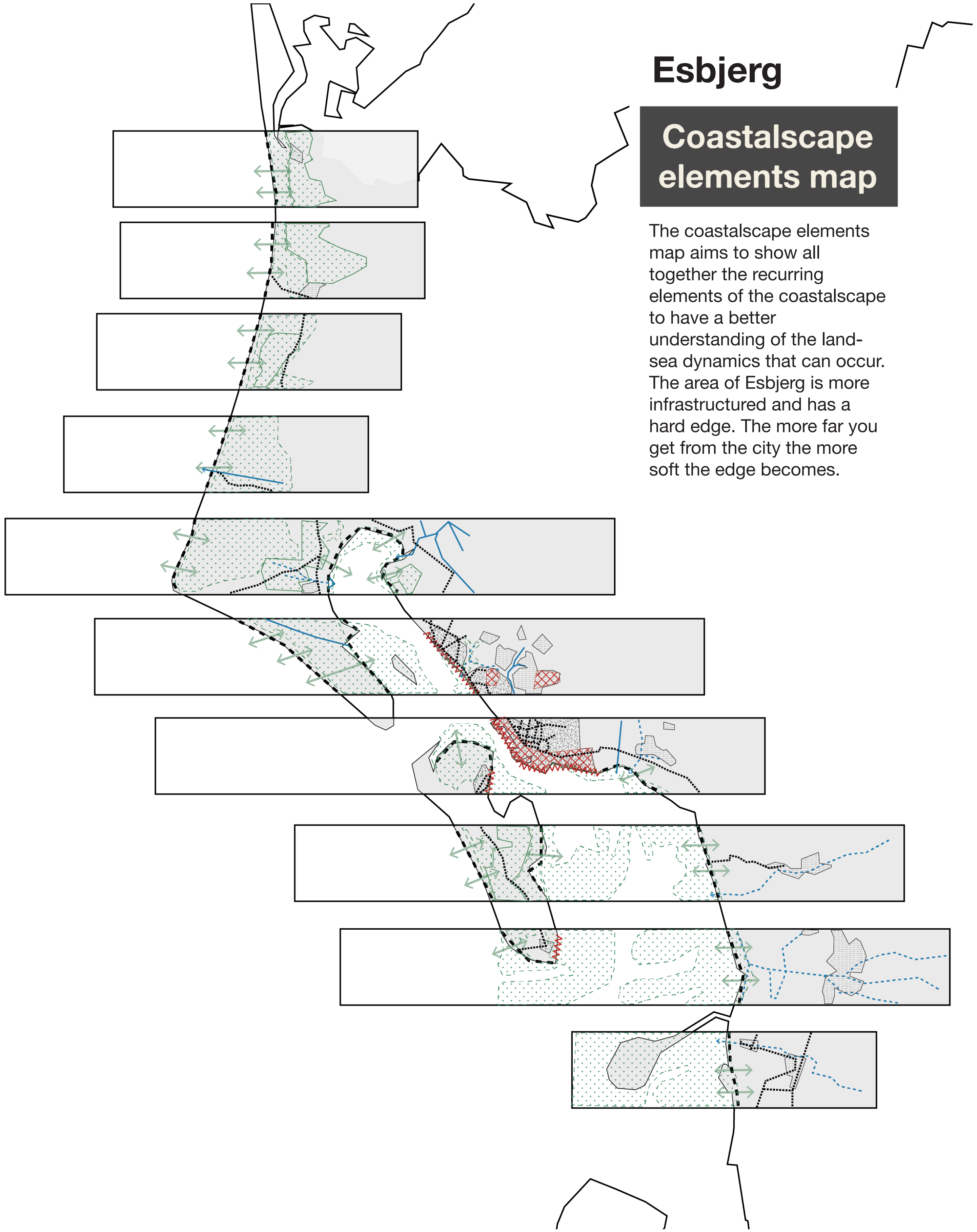
The transect shows in one map all data used in the previous trancepts maps; drivers, limits and buffers maps in order to allow a better perspective on the coastal edge.



Esbjerg Scheme

EDGE

The transect scheme highlights how the coastal edge is structured and where it is softer (natural) and where it has a hard edge (urbanised/infrastructured). In this specific case, the heterogeneous natural coast allows having a soft edge and a well ecologically land-sea continuum.



Esbjerg

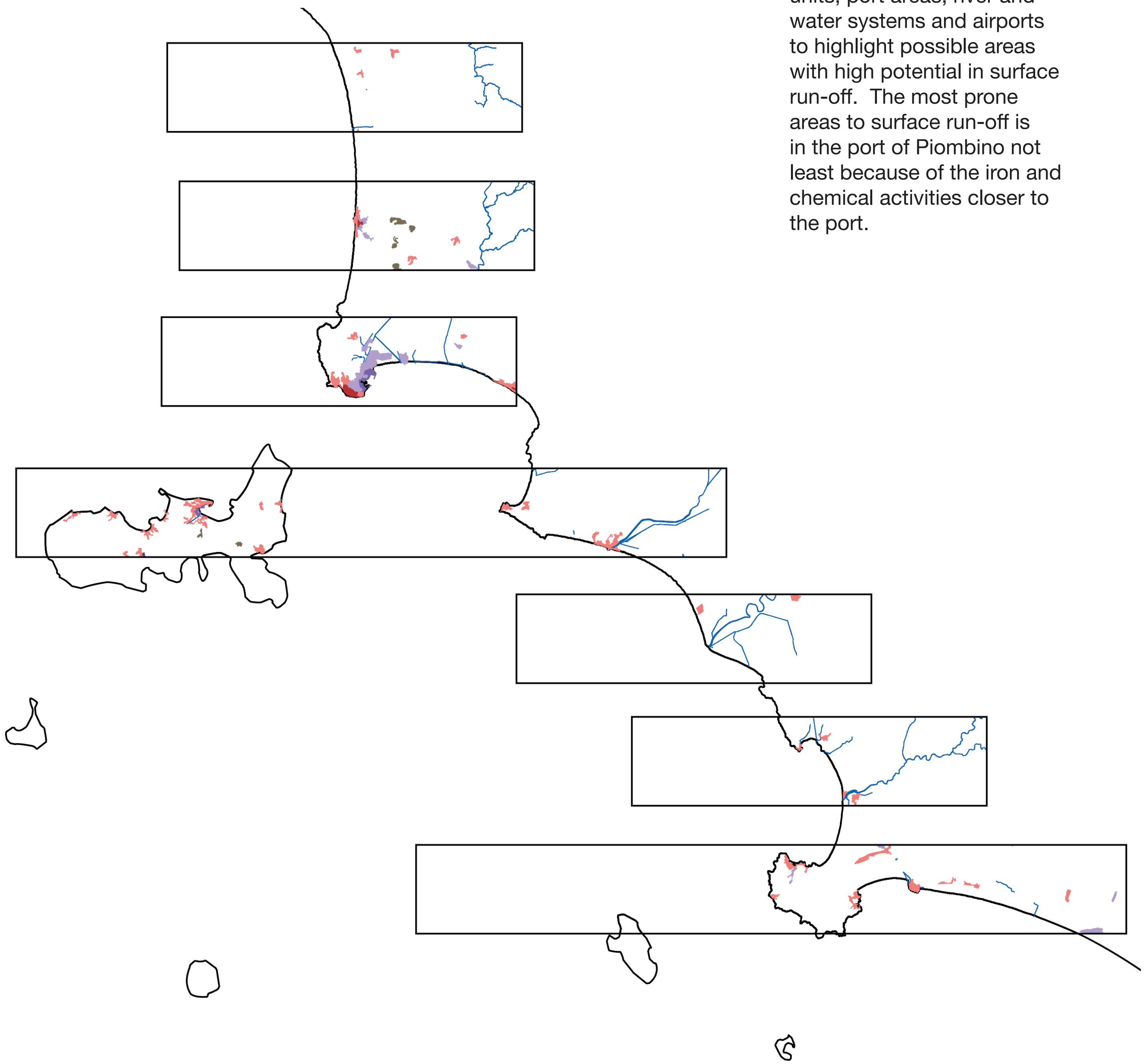
Coastalscape elements map

The coastalscape elements map aims to show all together the recurring elements of the coastalscape to have a better understanding of the land-sea dynamics that can occur. The area of Esbjerg is more infrastructured and has a hard edge. The more far you get from the city the more soft the edge becomes.

Piombino - Orbetello

DRIVERS

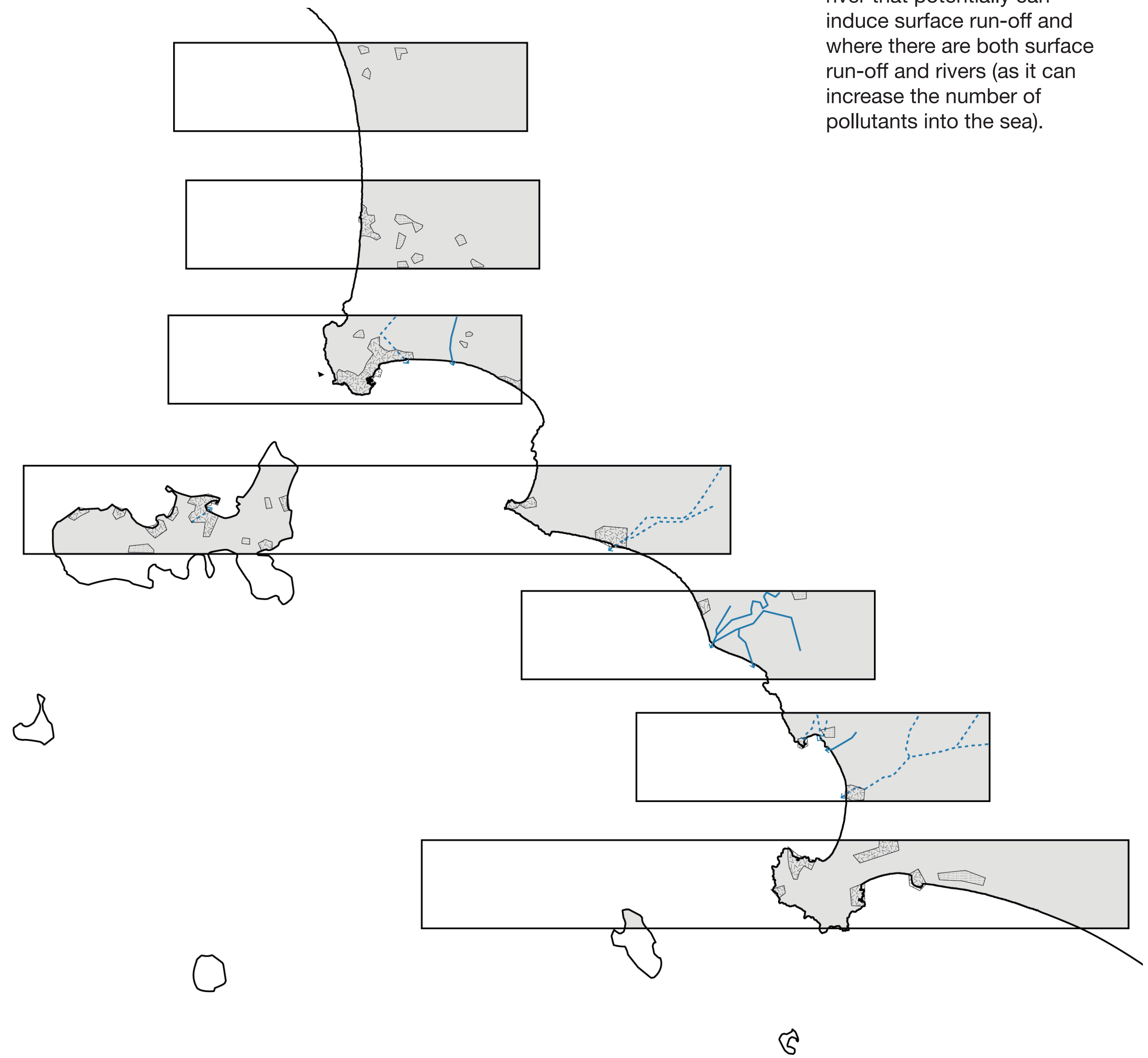
The transect shows five types of data; urbanization, industrial or commercial units, port areas, river and water systems and airports to highlight possible areas with high potential in surface run-off. The most prone areas to surface run-off is in the port of Piombino not least because of the iron and chemical activities closer to the port.



Piombino - Orbetello Scheme

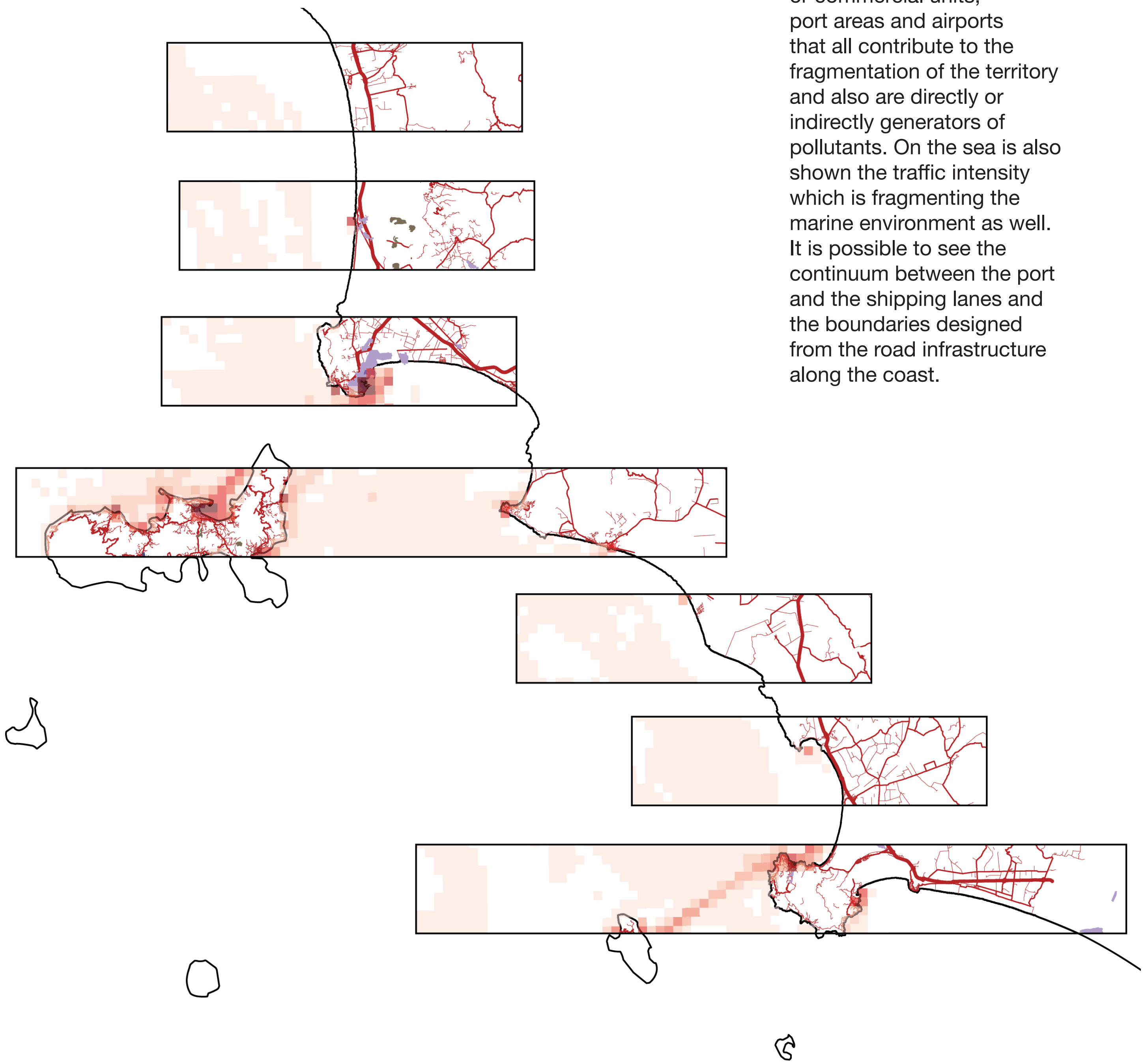
DRIVERS

The transect scheme highlights all the possible areas close to the coast or river that potentially can induce surface run-off and where there are both surface run-off and rivers (as it can increase the number of pollutants into the sea).



Piombino - Orbetello

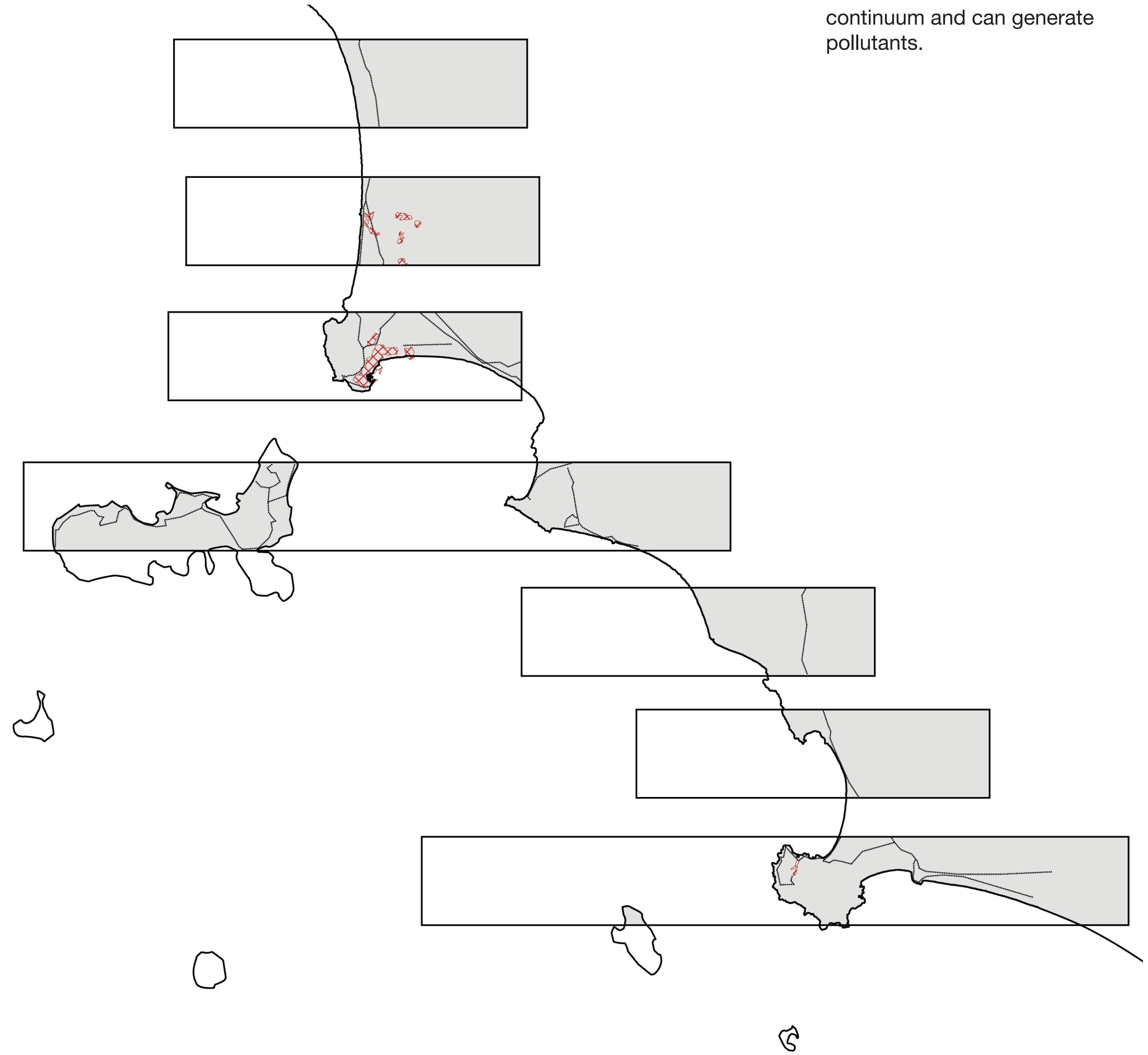
LIMITS



The transect shows four types of data; road infrastructure, industrial or commercial units, port areas and airports that all contribute to the fragmentation of the territory and also are directly or indirectly generators of pollutants. On the sea is also shown the traffic intensity which is fragmenting the marine environment as well. It is possible to see the continuum between the port and the shipping lanes and the boundaries designed from the road infrastructure along the coast.

Piombino - Orbetello Scheme

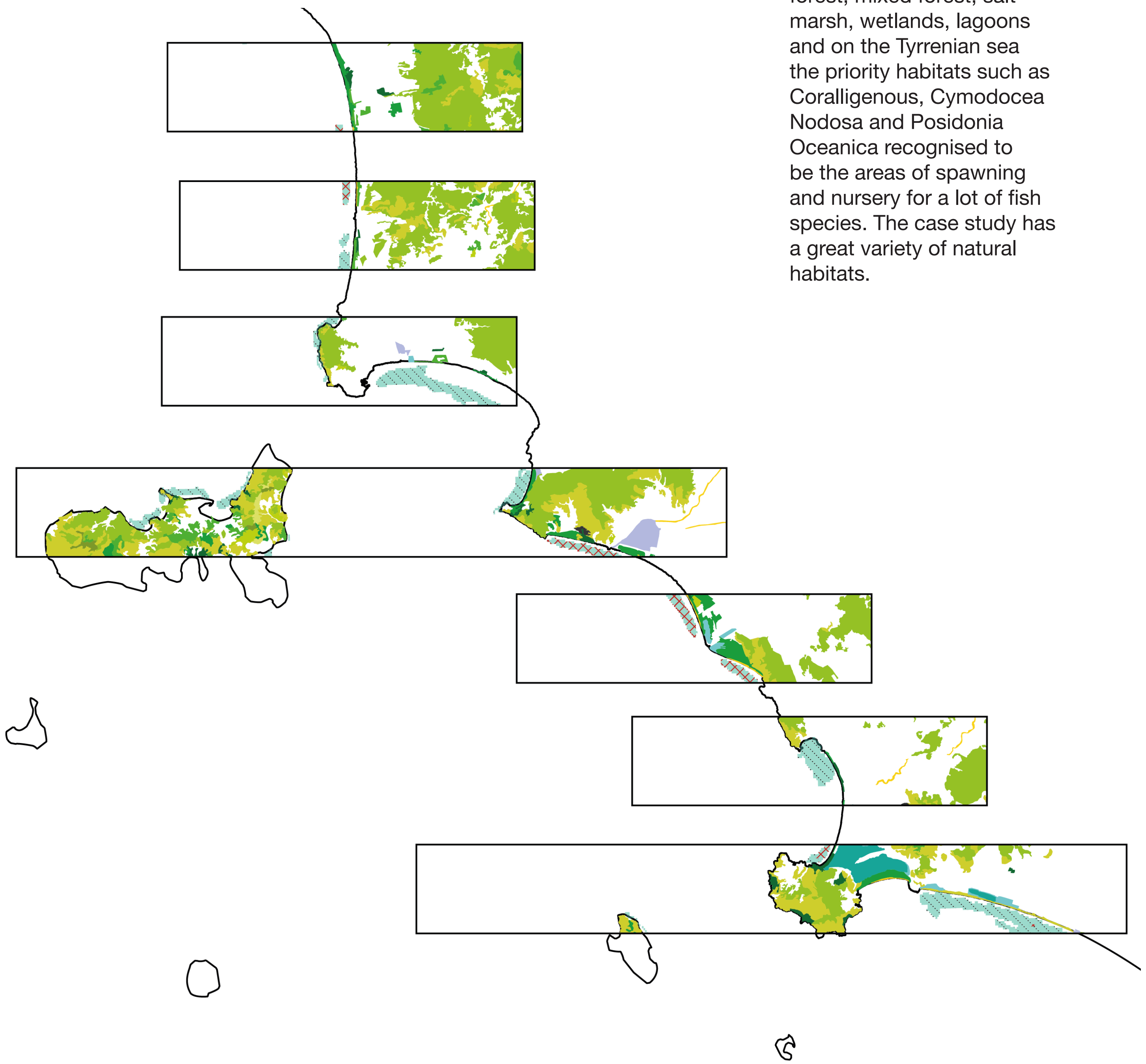
LIMITS



The transects scheme highlights the main cut-crosses and elements that are limits to the land-sea continuum and can generate pollutants.

Piombino - Orbetello

BUFFER



The transects show the diverse type of data on land such as broad-leaved forest, mixed forest, salt marsh, wetlands, lagoons and on the Tyrrenian sea the priority habitats such as Coralligenous, Cymodocea Nodosa and Posidonia Oceanica recognised to be the areas of spawning and nursery for a lot of fish species. The case study has a great variety of natural habitats.

Piombino - Orbetello Scheme

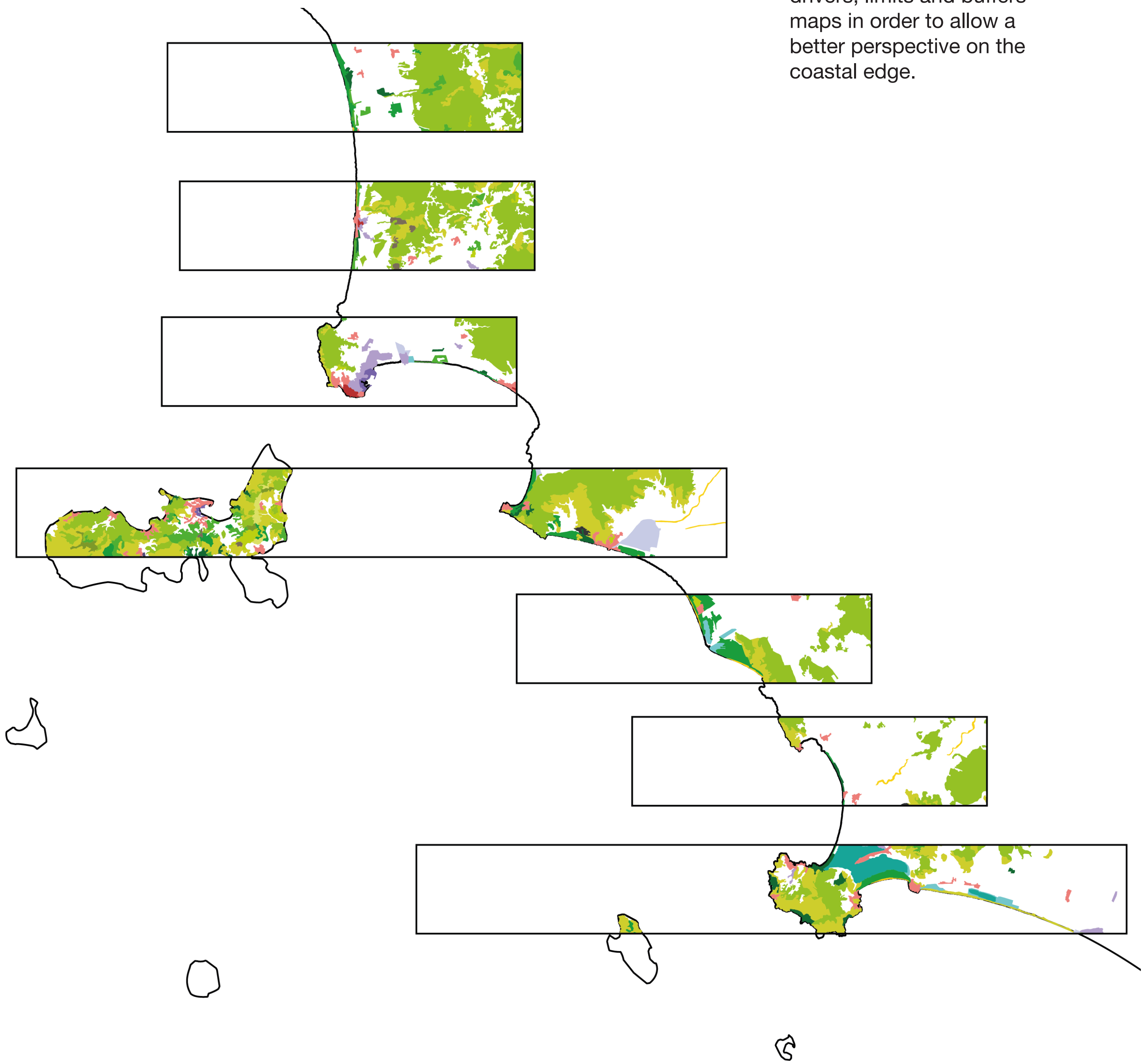
BUFFER

The transects scheme highlights primarily all green buffers between land and sea that function as ecological corridors, cleaners of pollutants and natural solutions to counteract coastal climate events. In this case study the extension of buffer areas is clear even though in many cases they are fragmented due to hard infrastructures.

Piombino - Orbetello

EDGE

The transect shows in one map all data used in the previous transects maps; drivers, limits and buffers maps in order to allow a better perspective on the coastal edge.



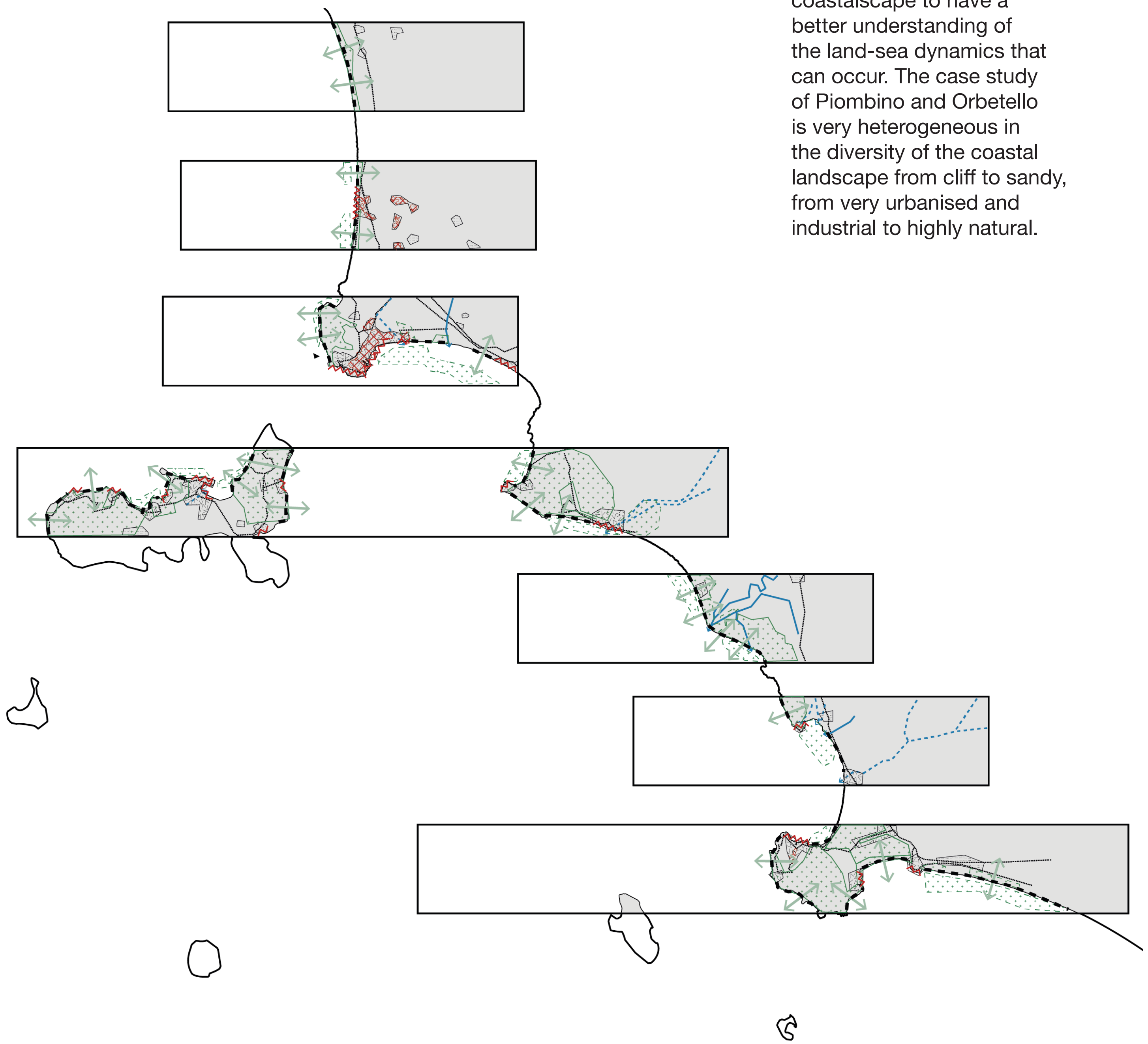
Piombino - Orbetello Scheme

EDGE

The transect scheme highlights how the coastal edge is structured and where it is softer (natural) and where it has a hard edge (urbanised/infrastructured).

Piombino - Orbetello

Coastalscape elements map



The coastalscape elements map aims to show all together the recurring elements of the coastalscape to have a better understanding of the land-sea dynamics that can occur. The case study of Piombino and Orbetello is very heterogeneous in the diversity of the coastal landscape from cliff to sandy, from very urbanised and industrial to highly natural.

A coastal planning framework

4. A coastal planning framework

My PhD research was motivated by the pressing need I saw to comprehend more fully the complexity of land-sea interactions on coastal areas.
The overall aim of my PhD research was to develop a framework that could support planning perspectives and processes to enable planners to adopt a holistic approach to managing coastal areas. This is important because, as well as the environmental and spatial conditions prevailing in coastal areas, there are myriad issues relating to multiple stakeholders, climate change, different administrative levels and composite environments that need to be addressed in a sustainable and integrated way.

This research project therefore aimed to answer these two research questions:
1. How can different fields of scientific investigation contribute to spatial planning research and practice in relation to land-sea interaction?
2. How can coastal area surveys of spatial land-sea phenomena advance knowledge to develop a framework that can help improving coastal planning?

In my research, I tried to tackle coastal issues by looking at them from many different perspectives and by addressing the topic using multiple approaches.
The research path has been divided into two parts, which I have called key milestones, with each one addressing one of the research questions.
The first key milestone was based on literature review methodology and the second key milestone on a multiple case study mapping analysis.

The first key milestone established several key facts: that land-sea interactions are subject to complex dynamics, that they stretch from far inland to the sea, and that they involve a great many different components. These components can be divided into categories according to their role in influencing land-sea interactions. The main categories identified are stressors, drivers, buffers and receivers. I defined stressors as the generators of the interactions, and within this category are included all the macro sectors and activities gathered from the literature review which I then collated into the Excel table.
From the literature review, it became clear that land-sea interactions are mainly caused by human activities, which led to a further collation of a list of these activities and their macro sectors. The second category defined is drivers, which in the discourse on land-sea interactions function as conductors or merely as the vehicles of the interaction. Drivers can be natural or anthropic; the natural ones are the creeks and rivers that are part of watersheds and link the inland territory with the sea. Anthropogenic drivers include the imperviousness of the territory, generally in urbanized or industrial areas, which results in surface runoff.
Surface runoff can directly affect the sea or indirectly increase the discharge of pollutants into natural drivers.
The third category constitutes receivers, which covers environmental components, macro sectors and activities that are affected by the interactions.
In this category are also included environmental components because, as described in the literature review, even if they affect other macro-sectors or activities, they always have some effect on coastal and marine ecosystems.
Last but not least are the buffers, natural elements that in coastal areas often shape coastal edges such as wetlands, marshes, lagoons, bottomland hardwood forests, forests and green areas, and which have a beneficial effect on land-sea interactions, functioning as retainers and cleaners of pollutants generated from human production.
An important insight about land-sea interactions is that the literature review, in the majority of cases, appears to refer to them as land-sea interactions rather than sea-land interactions. This is presumably because it’s easier to define land dynamics than marine ones.
Another important aspect to note is the impact that climate change events can have in exacerbating land-sea interactions by affecting coastal territories environmentally, socially and economically.

A final output from the double literature review is represented by the fluxes schemes, which visually present most of the conclusions highlighted above in a clearer and more accessible way.
These schemes enable us to visualise all the different types of interactions found and all components of each interaction. This output is aimed at facilitating links between different fields by making complex themes more easily comprehensible.

This first key milestone demonstrates the importance of having a holistic approach to spatial planning, and when exploring a complex theme, so as to establish the current state of art of the dynamics at play between different types of components, both natural and anthropic, in a non-defined area ranging from land to sea.
Spatial planning practice on coasts deals with a wide range of territorial issues, such as climate change events, urban sprawl and overexploitation of natural resources; only by forging strong links to other fields of research can we hope to improve planning practices to meet these challenges.

The first key milestone results should be seen as an initial step and not as a definitive set of conclusions on the topic of land-sea interactions. Thus they constitute an attempt to describe and interpret the state of the art of land-sea interactions from a spatial planning perspective, which although not exhaustive, is still significant as a first tentative step in moving towards a broader perspective of the topic by including all the elements that make up and influence coastal territories.
There is still a lot we need to learn about the topic, so this study should be seen more as an exploratory investigation into a very complex topic that involves a wide spectrum of different fields.

The second key milestone results revealed that coastal areas are also shaped in many different complex ways; this depends on factors such as the morphology of the territory, past spatial planning processes and present development initiatives.
Each map reveals some detail contributing to the whole exploratory process of analysing coastal territories, and, at the same time, each map is propaedeutic to the next map.
The thematic section map showed that, by focusing on specific layers of information and creating a single thematic map, this type of mapping analysis can enhance the understanding of spatially predominant dynamics, in order to better understand European coastal territories and to be able to identify probable land-sea interaction issues in the specific case studies.
The coloured section map is a cross-cut of the coastal territory from land to sea and is useful in visualising and measuring the degree of fragmentation of a coastal territory; this can provide valuable information on the orography, morphologies and urban types in a coastal territory. All this information is very relevant to land-sea interactions because with a very fragmented territory, there will typically be a much higher chance that diverse types of human activities will interact with the coastal interface.

The DNA sequence map is a conceptualization, shown as a coloured strip of information, developed from the previous mapping analyses. This tool enables us more easily to compare completely different territories in order to find similarities and differences between the DNA strips. This approach served to enhance my understanding of the topic and to make comparisons between completely different case studies to find similarities or contrasts.

The last section of the mapping analysis is based on the outputs from the first mapping analysis and from the second key milestone. I then put these results through a transect analysis with the aim of developing a visual form of the coast.
By combining four types of components in the transect analysis, all related to coastal territories and land-sea interactions, I attempted to simplify the complexity of

coasts to make visible and thus more comprehensible the dynamics, shapes and relations that can change coastal territories.

The whole mapping process was an exploratory investigation to try and highlight typical patterns that can contribute to shaping our coasts, to understand the spatial distribution of human activities on coastal areas, and to reveal relationships between land uses and land-sea interactions.

The mapping process and the analyses of the case studies are important tools for supporting spatial planning discourse, since every decision taken, anthropic activities, and natural processes all have spatial implications for the territory. The mapping analysis was adopted as an exploratory support tool in order to make recognisable patterns, relations and implications on the territory more easily identifiable through visualising them in a map.
At the same time, mapping cannot give exhaustive and definitive answers, because to apply the information contained in a map in a useful and appropriate way still requires considerable expert knowledge.

The results from the first key milestone allowed me to elaborate on the land-sea interaction definition given in a European report on the topic. The definition outlined in the European Union report "Addressing Land-Sea Interaction A briefing paper" describes land-sea interaction as "a complex phenomenon that involves both natural processes across the land-sea interface, as well as the impact of socio-economic human activities that take place in the coastal zone". As briefly explained in the report, there is some confusion regarding the meaning of interactions, since they are recognised as dynamics of land-sea both "between natural bio-geo-chemical processes" and "between socio-economic activities" (Jones et al., 2017). This second part of the definition can create ambiguity about what is and what is not a land-sea interaction.

Therefore, I expanded on this land-sea interaction definition as follows: "a complex set of dynamics, across the land-sea interface involving the impact of anthropic activities on and at sea affecting the natural environment, its processes and other anthropic activities. External drivers, such as climate change or human and natural disasters, should be incorporated since they can exacerbate the already existing dynamics on the coastal zone".

This research study has further attempted to address the communication gap identified between scientific research and policymakers (Mee, 2010) by translating the current very dense and technical information there is on the topic into more accessible forms, for example by using visualization tools, such as Sankey Matic, with the fluxes schemes and the whole mapping process.

One unexpected finding from the first key milestone was that some specific natural elements, for example wetlands, mangroves, marshes and bottomland hardwood forests, are not only beneficial for land-sea interactions in decreasing the negative effect of human activities, but also form a natural buffer between the land and sea, and so function as natural, self-regulating "horizontal levees" for dissipating storm surges and absorbing flood waters.

One of the limitations of the literature review is that the terms used were selected rather arbitrarily; changing these terms would also have produced different types of articles and maybe different results. In order to try to avoid this problem, I conducted a second literature review based on the bibliography of a recognised world-renowned paper addressing the land-sea interaction theme (Ramesh et al. 2015). Albeit the possible limitation of the first literature review, it appears that both literature reviews results were aligned.
The mapping analysis constituted an interesting exploratory investigation, but it cannot stand alone in addressing a complex topic like this. It is a very useful tool from a planning perspective since not all the information

necessary for building an adequate framework of knowledge can be obtained just from applying mathematical tools or similar. The mapping analysis can therefore be regarded as the go-to tool to bridge specific gaps that science alone may not be able to address.

In general, another limitation in mapping is the question of data. In my research, I tried to collect as much comparable data as possible, but even not comparable data - when used- added value enhancing knowledge on the topic.

This study provides evidence that knowledge about land-sea interactions and coastal areas draws on a wide range of different scientific fields and that spatial planners should integrate this knowledge into their practise. Thus a holistic approach is necessary if we are to find better solutions and answers to the challenges that coastal areas are facing and will have to face, so that we maintain a realistic and effective perspective on the anthropic and natural dynamics that shape coastal territories.

In conclusion, it seems that to build up a complete picture of land-sea interactions, it is necessary to consider a territory and its own dynamics in a holistic and integrated way in order to be able to respond more effectively to diverse issues, such as climate change and other unforeseen events. As well as examining information from different research fields, therefore, we need to find organic ways to integrate and synthesize these results to make them more comprehensible for both scientists and policy makers. Useful methods for achieving this include mapping and the visualization of information in various forms which, in addition to making the information more accessible, also make evidence of non noticeable information.

Last but not least, this research showed the role of spatial planning, not only as a discipline for designing and planning cities and territories, but also the role it has in linking diverse disciplines in order to better comprehend

coastal territories and thereby make them more resilient.

The limitations and unexpected results of a study should not be always seen as problems, as they can often be turned into opportunities.
As mentioned above, this is an exploratory study that does not in any way claim to be definitive or conclusive. It would be useful and interesting to follow up and expand on the framework of knowledge developed in this study by carrying out individual literature reviews for each category that I have outlined. This will yield new information that will make it possible to enhance the discourse on land-sea interaction in a more detailed way.

Another interesting area for further research would be to forge even more links between the framework of knowledge and the fluxes scheme by comparing existing coastal plans and management guidelines to establish how particular coastal issues are already being tackled.

Ultimately, the unexpected results that were obtained pave the way for tackling a crucial issue faced by coastal territories these days: their resilience.
As the research showed, natural elements play a number of crucial roles: enhancing biodiversity, decreasing the externalities produced by human activities, and finally providing natural solutions for coastal cities and areas to adapt to land-sea interaction. This will be an exciting theme to address in future research.

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Terminologies + definitions + abbreviations

Coastal Zone and Coastal Area
both of the terms are defined as the interface between land and sea, where the terrestrial and the marine components meet each other. These areas are recognised as important sites of diverse natural systems and resources.

Ecosystem
is a community of living organisms in conjunction with the nonliving components of their environment, interacting as a system (Schulze et al 2005)

ICZM | Integrated Coastal Zone Management
is a dynamic, multi-disciplinary and iterative process to promote sustainable management of coastal zones. It covers the full cycle of information collection, planning (in its broadest sense), decision-making, management and monitoring of implementation (EU).

IGBP | International Geosphere-Biosphere Programme
was launched in 1987 to coordinate international research on global-scale and regional-scale interactions between Earth's biological, chemical and physical processes and their interactions with human systems.

LOICZ | Land-Ocean Interactions in the Coastal Zone
the LOICZ project goal was "to provide the knowledge, understanding and prediction needed to allow coastal communities to assess, anticipate and respond to the interaction of global change and local pressures which determine coastal change."

LSI | Land-Sea Interactions

MSP | Maritime Spatial Planning
is a public process of analysing and allocating the spatial and temporal distribution of human activities in marine areas to achieve ecological, economic, and social objectives that are usually specified through a political process (UNESCO-IOC).

UNCLOS | United Nations Convention on the Law of the Sea
also called the Law of the Sea Convention or the Law of the Sea treaty, is the international agreement. The Law of the Sea Convention defines the rights and responsibilities of nations with respect to their use of the world's oceans, establishing guidelines for businesses, the environment, and the management of marine natural resources.