From Source to Sea

An investigation into hotspots for marine plastic pollution along the English North Sea coast

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Abstract

Marine plastic pollution is a ubiquitous problem and poses a severe threat for people, wildlife and ecosystems. It is both a global and a local issue, as plastic pollution occurs around the globe and it is of a transboundary nature. Still, degree of pollution depends on local circumstances, but governments are unable to cope with the growing amount of plastic. Existing international agreements and regulations seem to be insufficient and do not offer suitable governance instruments to address the problem of marine plastic pollution specifically. In addition, diffuse transport pathways and often unknown sources hamper the efforts to prevent plastic input into the marine environment. This lack of knowledge and the inherent complexity lead to difficulties in governing the issue. In order to shed light on the origins of plastic, this research investigates the hotspot entry points for macro plastic originating from human land-based activities. The focus area is the English North Sea coast, as a contribution to a broader research project in the North Sea area. Moreover, the institutional setting in the focus area is examined to gain insights for a more successful management of plastic waste. In order to do so, a mixed-method approach is chosen for this research, as it combines the analysis of statistical data to identify hotspots with the personal perceptions and experiences of experts.

The results of the analysis show, that the highest contribution of plastic input into the North Sea comes from three districts: North East Lincolnshire, Northumberland and Stockton-on-Tees. The pollution occurs mostly due to a high harbour activity and a high degree of land-based industry. Furthermore, intentional littering is perceived as one main reasons of why plastic enters the marine environment, as well as human ignorance and a lack of strict enforcement of regulations. Even though marine plastic pollution is a global problem, the reasons for plastic entering the oceans are highly context dependent. In order to prevent marine plastic, a coherent institutional framework needs to be designed and enforced, that also addresses the local context.

Key concepts: marine litter, marine plastic pollution, macroplastic, ocean governance, mixed-methods research

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ARSU	Arbeitsgruppe für Regionale Struktur- und Umweltforschung GMBH
GIS	Geo Information Systems
GBP	Great Britain Pound
GPML	Global Partnership on Marine Litter
LAU	Local Administration Unit
MARPOL	International Convention for the Prevention of Pollution for Ships
NUTS 3	Nomenclature of Territorial Units for Statistic Level 3
ONS	Office for National Statistics
OSPAR	Convention for the Protection of the Marine Environment of the North-East Atlantic
UK	United Kingdom
UNEP	United Nations Environment Program
UN	United Nations
USD	United States Dollar
UV	ultraviolet

1| Introduction

Plastic pollution of the marine environment has become an often-discussed topic in the recent years, as more scholars dedicated their research to the topic of marine plastic (see Fig. 1). Thus, more information became available about the degree of pollution and harmfulness for environment and public health. It is estimated that more than five trillion pieces of plastic litter are floating in our oceans (Eriksen et al., 2014). The United Nations Environment Program (UNEP) considers the problem of marine plastic pollution to be a "common concern of humankind" (UNEP, 2016 p. 116). Other scholars see the marine plastic pollution not as an issue anymore but refer to it as a crisis (Vince & Stoett, 2018). The pollution of the marine environment is ubiquitous all around the globe and it is also irreversible (Villarrubia-Gómez et al., 2018). The raised awareness lead to lots of initiatives to reduce plastic and manage waste with the aim of keeping it from entering and polluting the marine environment. Latest regulations include the planned or already implemented ban of plastic bags and single-use plastics in many countries all over the world. Yet, marine plastic pollution is continuously growing and is reaching a critical point where irreversible damage to the marine ecosystem is done (Raubenheimer & McIlgorm, 2018).

The amount of plastic in our ocean shows a great variability which makes it more difficult to identify sources, pathways and estimate trends (Li et al., 2016). To successfully prevent plastic from entering the marine environment it is crucial to know where the sources of litter lie as well as understand who is contributing to the pollution and for what reason (Veiga et al., 2016). Pollution caused by shipping is one part, but research shows that land-based litter accounts for around 80 % of litter entering the ocean (Sheavly & Register, 2007). Hence, identifying risk hotspots for plastic entering the marine environment is of great importance. According to Löhr et al. (2018), any measures taken (prevention, mitigation) should preferably aim at the location of these hotspots as well as at other cost-effective positions. This research

shall contribute to the task of unravelling the location of hotspots for marine plastic pollution from land-based sources. The focus is on the North Sea, more concretely on the English North Sea coastline. This work is contributing to a broader research on identifying sources of plastic in the North Sea and the English North Sea coast is still a gap in this research. Finding hotspots is achieved with an analysis of statistical data, that is used as an indicator for waste contribution. The analysis and mapping of data show the hotspots where litter enters the ocean and which sector is the main source. Linking the findings to the theoretical background and the institutional perspective can provide hints on where waste management needs improvement in order to prevent or mitigate plastic pollution. As plastic is ongoingly entering the marine environment, there is a need for effective environmental planning strategies and strict regulations to reduce marine plastic pollution. Therefore, this thesis shall fill a knowledge gap on the origin of plastic entering the North Sea and help to identify possible institutional barriers and enablers.

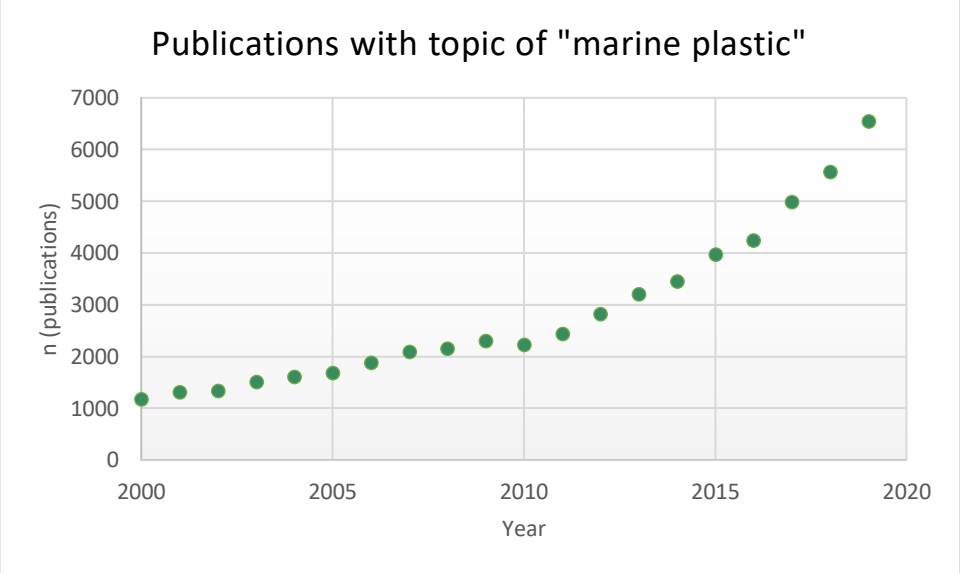

Figure 1 Number of scientific publications investigating the topic of marine plastic in the last 20 years. Numbers are based on a search on the webpage "Science Direct" searching for the term "marine plastic" (Graphic by author).

1.1| Societal and scientific relevance

Plastic pollution of our oceans is one of the major topics in current environmental debates and has a large impact on society, as more and more awareness of the dramatic

state of pollution can be observed (Villarrubia-Gómez et al., 2018). Clean and healthy oceans are of great importance for society as according to the United Nations (UN, 2020), more than three billion people depend on the marine and coastal environment. A wide range of problems occur from polluted seas and oceans. The effects range from injuring or killing marine wildlife to economic costs for coastal regions and different sectors such as fisheries and tourism (Critchell et al., 2019; Sheavly & Register, 2007). Another crucial risk is public health: Not only species living in the oceans are affected by plastic pollution, but the extent of pollution has reached all trophic levels and can even enter the human body through the consumption of sea food or fish (Gibbens, 2019). However, this research will focus on macroplastic (pieces > 5mm) which means that the main concern is larger household and industrial items entering the ocean. Furthermore, the ocean is one of the main destinations for recreational activities and the tourism sector depends on a clean appearance of beaches and bay areas. Therefore, it is important to gain knowledge of the sources of marine plastic and gain insights on how to improve current institutional designs to help mitigate the amount of plastic entering the ocean.

The scientific community dedicated much research to the topic of marine plastic (see Figure 1). Still, there is a lack of knowledge about the origins and pathways of plastic entering aquatic habitats from land-based sources. There is a need to identify risk hotspots at the coastline to successfully manage plastic input into the ocean (Löhr et al., 2017). Hence, this research contributes to the *Macroplastic* project by the University of Oldenburg, aiming for a relative quantification of the amount of plastic entering the North Sea. The project tries to understand the drivers of macroplastic pollution in the North Sea. Therefore, different parts of the North Sea coastline are analysed independently to create a complete picture at a later point. The English North Sea coast of interest, as the North Sea current possibly transports plastic from the North along the English coastline toward The Netherlands and Germany. By identifying which types of land-use/sector are responsible for the pollution, better strategy frameworks and regulations can be developed to mitigate

the input. The analysis from an institutional perspective helps to identify possible institutional voids, barriers or enablers and can offer a better understanding on how to improve institutional frameworks in order to prevent or mitigate plastic entering the ocean.

1.2| Research objective and research questions

The following chapter delves that the ways of transport and pathways of plastic are diverse and uncertain. In addition, the sources of plastic input into the ocean remain even more dubious. Movement patterns of plastic can be modelled to a certain degree, yet it remains difficult to track plastic items back to their source, as the behaviour of plastic in the ocean is not always predictable. The behaviour and transport processes of plastic will be further elaborated on in the following chapters. In this research, the sources of plastic are identified by reversing the approach: instead of tracking plastic items back to their source, human activity and types of land-use that are contributing to marine plastic pollution are investigated.

The aim of this study is to uncover the sources of marine litter along the eastern English coastline and answers the question on which sector has the largest proportion on macroplastic input into the North Sea. Furthermore, the research provides insights on how to improve the management of entry points and thereby help to mitigate further plastic pollution of the North Sea.

In order to achieve the expected outcomes, the focus of the work lies on the following research question:

“Where on the English North Sea coast are the “hotspot” entry points for macroplastic into the marine environment and what insights can be gained to improve coastal waste management?”

To answer this question, it is crucial to find out where the plastic is coming from and what kind of regulations and frameworks are present in the research area to handle plastic waste. More precisely, the following sub-questions need to be answered:

I) What is a "hotspot" for marine plastic?
II) Which kinds of land-use are present along the English North Sea coast?
III) What type of land-use produces most plastic waste in the research area?
IV) Which regulations/institutional frameworks on plastic waste management are present?
V) What insights can the analysis of the institutional setting provide on why plastic enters the marine environment?

To answer these sub questions, different kinds of data are needed. The conceptualisation of the research is introduced in Chapter 2.5. This research aims at providing a better assessment of plastic input into the North Sea and supports the search for better management strategies by analysing the research area through an institutional lens.

1.3| Outline of the research

After a basic introduction on the topic has been provided in the first chapter, with a focus on the importance of the topic for science and society, the next chapter covers theoretical basis for this research. It entails information about the general topic of marine plastic pollution, as well as its impacts and risks for ecosystems and society. The theoretical part then provides an understanding on the origins of plastic and identifies the problems for the governance of the issue. It highlights the importance of gaining a deeper understanding of the underlying institutions and why it is essential for governance and planning. In the last section, the conceptual framework on the research design is introduced. In the third chapter, a detailed explanation of the methodology is provided. Furthermore, the chapter also includes a comprehensive description on where the utilized data is retrieved from and why it is chosen.

Afterwards, an explanation for the creation of pollution maps and for the conduction of the interviews is provided. In the first part of the fourth chapter, the created maps, showing the sources of plastic pollution, are presented. Moreover, the second part of the chapter shows the results of the conducted interviews. In the next chapter, the presented findings are analysed and discussed and linked to the theoretical context. The main and secondary research questions are part of the discussion and are answered in the process. Afterwards, the chapter provides a reflection on the methodology, results and the overall research approach. Moreover, an outlook and opportunities for further research are provided. The last chapter summarizes the findings of the research.

2| Theoretical background

This chapter provides necessary background information in order to gain a better understanding of the implications of plastic pollution and hence get a better grasp of the importance of this research. The theoretical background consists of a review of scientific literature from the fields of environmental sciences, ecology and planning. At first, this chapter elaborates on the general background information on marine litter, its pathways, impacts and sources. Furthermore, this chapter gives an overview on current regulations on marine plastic pollution and discuss the difficulties of governing the issue.

2.1| Sources and origins of marine litter

Improperly discarded, lost or abandoned products in the natural environment are referred to as *litter*. Hence, marine litter summarizes all processed or synthetic items that have been lost or discarded in the marine environment or that have been indirectly transported from land to the sea (Veiga et al., 2016). This can include various items or fragments ranging from cigarette stubs, lumber to plastics such as

packaging or fishing gear (Li et al., 2016; Veiga et al., 2016). Littering has been a common practice over centuries (WWF, 2020), however the composition of littered items changed (Van Franeker et al., 2011) from biodegradable litter to persistent materials such as containers or packages, which create a deleterious impact on the marine environment. Nowadays, around 80 % of all marine litter consists of plastic items (Dauvergne, 2018). This research therefore focuses on larger plastic items (*macroplastic)* which pose a great threat to society, economy and the environment.

Two types of sources have been identified by scientific researchers: land-based and sea-based sources (Li et al., 2016; UNEP 2016; Veiga et al. 2016), which in themselves contain a great variety of pathways and sources for litter entering the marine environment. The quantities of plastic entering the marine environment is determined by various factors, such as population density related to geographical differences or intensity and type of land use (UNEP, 2016). Hence, it is crucial to determine the origins of plastic litter and how it finds its way into the marine environment, as well as to help to answer the question who is littering and for what reasons. In the following sections the sources and impacts of plastics entering the marine environment are further elaborated upon.

2.1.1| Plastics

Marine plastic pollution has raised much scientific attention and concern during the past years (Borrelle et al., 2017). It is estimated that around three quarter of all marine litter consists of plastic and that approximately nine million metric tonnes of plastic enter our oceans annually – tendency increasing (Jambeck et al., 2015). Marine plastics can be found globally – from Arctic to Antarctic sea ice, in coastal regions and even in the Mariana trench (Jamieson et al., 2017). Plastic production increases every year around 5 % and is not expected to be restricted any time soon, due to the importance of plastic in everyday life (Löhr et al., 2017). Plastic is made of synthetic polymers which have the advantage that they are strong, durable and cheap in

production and transport because of their light weight (Derraik, 2002). The global production of plastic is exceeding 300 million tonnes annually whereof half the amount is disposed after single-use only (Xanthos & Walker, 2017). Thence, many plastic items or fragments find their way into the marine environment, where nowadays more than five trillion plastic particles with a weight of more than 250,000 tonnes are floating (Eriksen et al., 2014; Xanthos & Walker, 2017). Once disposed, plastic items do not stay in the original shape, they tend to break down into smaller pieces or photodegrade by ultraviolet (UV) radiation, directly in the sunlight on the surface or in the water column (Li et al., 2016). However, it is unknown how long it takes for plastic items to fully degrade within the seawater (Li et al., 2016), although studies estimate that it could last several decades or centuries (Ioakeimidis et al., 2016).

Plastics are generally divided into two categories: micro- and macroplastic. In this study, the emphasis is on the latter but both categories will be explained shortly. The first category, microplastic, is defined as items with a size below five millimetres (UNEP, 2016). Microplastics are designed in the first place for companies who desire to form their own products out of these small particles. However, these microscopic small items can have severe environmental impacts if they are handled or disposed incorrectly or due to spilling accidents (Veiga et al., 2016). Transported by physical processes such as wind they can thence reach the marine environment. Additionally, microplastics are often used in cosmetics or hygienic products and can enter water bodies through the sewage system (UNEP, 2016).

The category of macroplastic includes pieces with a size of five millimetres and above. Items of this category are visible to the eye and include mostly larger pieces of industrial or household litter. The pollution with macroplastic items is a global problem and also one of the most severe kinds of pollution of the coastline and oceanic water bodies. These larger pieces of plastic can have deleterious effects on the marine environment and organisms, such as entanglement or habitat destruction (Xanthos & Walker, 2017), and regardless of their size, even ingestions of these larger items by

marine organisms have been reported (Li et al., 2016). The impacts of plastic on marine wildlife and the ecosystem is further elaborated on in section 2.1.4. Macroplastics tend to break down into smaller pieces due to chemical and mechanical weathering, UV radiation, mechanical forces such as wave activity and turbulences (Li et al., 2016). These processes cause a further fragmentation of larger items into small pieces which are then referred to as secondary micro plastics (UNEP, 2016). For this type of plastic, it is especially difficult to determine the geographical origins, as the original product remains mostly unknown and many sources and pathways are possible (UNEP, 2016).

2.1.2| Sources and transport of plastic litter

It is important to understand the transport processes of plastic from land into the ocean as well as its behaviour within the marine environment in order to determine its sources and origins and hence, prevent the input. Plastic in the natural environment can be transported to the ocean by physical processes such as wind. Plastic that is produced or discarded in proximity to the coast is likely being transported this way. The nature of plastic is encouraging this way of transport due to its light weight and structure. For instance, plastic bags or packages are light weight and offer a large contact surface and are hence carried away easily. Transport by water is another natural way for plastics, which are not only light weight but also mostly buoyant. River systems are one of the main drivers for plastic input into the ocean, as they transport plastic from its source to the marine environment (Li et al., 2016). Studies show that rivers are one of the key sources and ways of transport for plastic (Löhr et al., 2017). Rainwater and natural extreme weather events such as flash floods can directly transfer plastic into the marine environment or into rivers, where it thence runs into the ocean (Li et al., 2016). Once entered the marine environment, floating plastic can travel long distances, throughout all oceans, due to ocean currents and winds (Eriksen et al., 2014; UNEP, 2016). This can lead to the accumulation of plastic in large (sub-tropical) plastic gyres (Van Gennip et al., 2019), which are regions

where the current slows down and plastic is carried into its vortex (UNEP, 2016). However, not all plastic is floating through the oceans. Many plastic items are washed and buried ashore or degraded and sunken to the deep-sea sediments (Ritchie & Roser, 2018). Another way of plastic reaching the (marine) is directly linked to human behaviour, which includes intentional littering, accidents and mindlessness. Dumping or littering is the intended act of throwing litter away, mostly due to convenience or profit, regardless the awareness of the consequences this action might entail for the environment (Mehlhart & Blepp, 2012). Mindlessness on the other hand includes acts where litter is thrown away, but the group/individual is not aware of the consequences of their action. Accidents also contribute to litter entering the marine environment. Accidents can happen despite of prevention measures and they include for example broken garbage bags or loss of freight. However, both legal and illegal litter handling and disposal are contributing to marine plastic pollution (Sheavly & Register, 2007).

The chance for plastic escaping into the marine environment can occur at any stage of its lifecycle: from the raw materials, manufacture, usage and as waste. There are different entry points where plastic could leak into the ocean (UNEP, 2016), which will be further elaborated on the following section. The quantities of plastic ending up in the marine environment depend on different criteria such as population density, maritime activity or land use (Eriksen et al., 2014). It is estimated that around 10 % of all plastic produced ends up eventually in the marine environment (Mendenhall, 2018). Generally, sources of marine plastic can be divided into two categories: sea-based and land-based.

2.1.2.1| Sea-based

Sea based sources of macroplastic are mainly the fishing sector, due to abandoned or lost fishing gears, the aquaculture sector (e.g. buoys, nets, packaging), shipping, offshore industry and ship-based tourism. For the last three sectors, mostly personal

goods and packaging account as sources (Löhr et al., 2017; UNEP, 2016). Fisheries are of highest importance as a source sector according to UNEP (2016). Entry points for plastic into the marine environment can be directly on the ocean or from coastal areas.

2.1.2.2| Land-based

This category includes all litter that is discarded directly along the coast. Around 50 % of the world's population currently live within 60 kilometres of the coastline and around three quarter of all large cities are located by the sea (UNEP, 2016). Hence, these are the places where many activities such as producing industry and tourism take place, which means that the production, consumption and post-consumption of plastic happens within proximity to the coast and the ocean. Research estimates that around 80 % of all plastics entering the marine environment originates from a land-based source (Li et al. 2014; Sheavly & Register 2007)- whereas other scholars like Jambeck et al. (2015) imply that this number is not supported by strong data. Nevertheless, plastic concentration and therefore also plastic possibly entering the marine environment, is in a direct correlation with population density (Lebreton et al., 2017). Population size and mismanaged waste on land are said to be the main factors for plastic ending up in the ocean (Jambeck et al., 2015). A main reason for plastic entering the environment is intentional littering by humans (Mehlhart & Blepp, 2012). Plastic pollution starts in the public space, such as parks and parking lots but can also occur on the factory premise. From there the plastic can be transported or discharged into river systems or directly into the ocean. Rivers are a key entry point for plastics into the marine environment. In studies by e.g. Löhr et al. (2018) it is estimated, that 67 % of the total amount of plastic entering the marine environment is transported by only 20 rivers. Schäfer et al. (2019) identify different sectors that with a high contribution to plastic from land-based sources. In the following, these sectors are further elaborated upon. At the end, Table 1 summarizes the relevant sectors, their relative contribution to the overall plastic pollution from land-based sources and possible ways of measuring their contribution.

Tourism

Tourism and recreational sites are often located in densely populated areas and/or close to the sea or other water bodies (UNEP, 2016). Plastic pollution can occur through multiple pathways and routes as a variety of activities and facilities are involved in the tourism sector, which includes not only accommodation but also hiking, water-sports, ship cruises and many more. Hence, coastal tourism accounts for a significant amount of plastic waste input into the marine environment (UNEP, 2016). Packaging, which consists mostly of plastics, plays an important role in the tourism industry sector. Catering for tourists or guests leads to vast amounts of food and other goods which implies large amounts of packaging. Food wrappers and other packagings are beneficial for tourists or visitors to take to the beach. However, after consumption the packaging might be littered due to convenience or the absence of waste management infrastructure (UNEP, 2016). The tourism sector is predicted to continue to grow further in most countries, subsequently the problem will be exacerbated in the future. This is especially problematic as many touristic regions lack efficient waste management or are located near urban areas which increases the pressure on the local waste management infrastructure (UNEP, 2016). Additionally, norms and values of people play an important role. Many tourists are less aware or careless when it comes to the consequences of plastic littering. The effect of regulations and informal institutions in relation to marine plastic pollution will be further discussed in section 2.2 and 2.4. In order to estimate the contribution of the tourism sector to marine plastic pollution, the development of the tourism sector is decisive. According to De Vries et al. (2013), the spread of employment in a sector can be used as an indicator for the development status. In case of the tourism sector, a look into the employment numbers and types within the sector could indicate the distribution in this field (De Vries et al., 2013).

Harbour activity

Litter from harbour activities consists mostly of ropes, packaging or food containers. Also, practices of ship maintenance include the regular cleaning of ship hulls via an air blasting method, which contains small plastic particles. These particles have benefits compared to sand that was previously used due to their higher durability (UNEP, 2016). If washed out, these plastic particles can pass the wastewater treatment and enter thence the marine environment (Li et al., 2016). Ropes and nets can be an indicator for ship maintenance activities or fixing of fishing gear within the harbour. Even though there are many international instruments and regulations to avoid littering (Onwuegbuchunam et al., 2017), e.g. MARPOL Annex V, that prohibits any kind of direct waste disposal into the water, working in close proximity to water may cause pollution. Human error, accidents or items that are not consciously disposed but simply blown away by wind can be directly introduced to the marine environment. To measure the contribution of harbour activity to marine plastic pollution, the freight that is handled by the harbours, can be used as an indicator, which includes both large vessels and smaller ships.

Land-based industry

This section focuses on the impacts of land-based industry, which includes the producing industry sector as well as the agricultural sector. In the agricultural sector, plastics play a part in many uses. For an effective distribution of water to the crops, the use of irrigating pipes made from plastic is a common practice. Other needed products include for example containers, meshes and sheets to protect the crop. All of these plastic products will be disposed at the end of their life cycle and might eventually end up in the marine environment (UNEP, 2016). Another common practice is the usage of fertilizers which are encapsulated in plastic. This is on the one hand especially beneficial for the production, as fertilizer can be used more precisely and on the other hand for the environment, as an overall reduction in the

concentration of nutrients in the soil and water is reached (UNEP, 2016). However, the plastic capsules in the soil are polluting the ground and might partly dissolve and reach the water system as small particles. Another contributor to plastic pollution is the land-based producing industry. The produced products generate the main income for the companies and therefore they are handled with care. However, scraps, leftovers and over-produced goods might not be taken care of according to the companies' waste management/recycling or dumped illegally if no sufficient waste management facilities are provided (Ichinose & Yamamoto, 2011). Due to the previously discussed transport processes, this litter might end up in the marine environment. Another contributing factor is the use of plastic for packaging or protection for transport or the construction industry (UNEP, 2016). This includes an increased amount of needed packaging for home delivery as well as plastic films for the protection of industrial products. To identify the contribution of the land-based industry sector to marine plastic pollution, two indicators can be considered: the number of employees in the sector and the area that is covered by the industry sector. These factors provide a good indication on how the sectors are distributed across the research area and how big their contribute to the plastic pollution might be. The covered area by agriculture and industry can as well indicate the degree of activity in this sector. For both indicators only an area in close proximity to the coastline is taken into account, as the further away industry and agriculture do not have the same impact and most likely no direct contribution.

Municipal waste

A fourth source of marine plastic pollution is municipal waste. Plastic waste entering the marine environment can be caused by intentional littering, by insufficient waste management systems or mismanaged waste (Jambeck et al., 2015). In modern urban areas, large quantities of waste need to be handled, which is produced not only by the beforehand mentioned touristic activities but mainly by inhabitants. Errors in

handling these vast amounts can occur and hence mismanaged waste is the main contributor to macroplastic pollution on a global scale (Jambeck et al., 2015; Raubenheimer & McIlgorm, 2017). This is due to often inadequate waste collection or also partly caused by intended littering of individuals, despite of available waste management facilities (UNEP, 2016). Waste management infrastructure can differ from dumps to landfills, incineration or recycling. However, some waste items can still manage to escape into the natural environment. If landfill sites or dumps remain uncovered, items can be transported by winds and hence enter the marine environment or river systems. If waste management facilities are located close to the coast, waste can be easily carried away by the water (UNEP, 2016). Another way of plastic entering aquatic habitats is via wastewater. Large items can enter the marine environment if wastewater treatment is insufficient or if the system is overwhelmed in case of heavy rainfall events, where enormous amounts of water are passing through (UNEP, 2016). Smaller particles can escape the wastewater treatment and enter aquatic environments. The contribution of municipal waste and potential household waste losses can be indicated by the population number in the municipality, as the occurrence of plastic waste losses can be directly linked to the population.

Table 1 Summary of potential land-based sources of plastic waste input into the ocean, their relevance for the total waste contribution of land-based sources and possible ways of measurement. The numbers for relevance are based on the ARSU study (Schäfer et al., 2019)

Source	Relevance [%]	Possible measurement
Tourism	47,5	Employment numbers and job distribution
Harbour	20	Handled freight
Land-based industry	17,5	Employment and occupied area
Municipal waste losses	15	Population number

2.1.3| A "hotspot" entry point for marine plastic

This research focuses on finding hotspot entry points for marine plastic. Therefore, this section elaborates upon the question what a hotspot for plastic is. The term hotspot derives from the field of biology. A hotspot in the field of biology is a biogeographic region that is sustaining a critical mass of endemic species and biological diversity and where a threat to the habitat is present simultaneously (Chepkemoi, 2017). In this research, the term hotspot is used to refer to sources of macroplastic, as the elementary principles are similar for this context. The plastic litter that is emitted out of the area and entering the marine environment can be seen as equally to the threat to the habitat. Furthermore, the endemic species in this context are replaced by widespread and diverse human activities. In this case, the diversity of activities coming from the scope of districts in the research area, with different categories of sources within each district. It is expected that the degree of contribution is not distributed evenly and, therefore, a detection of hotspots is possible. The use of the hotspot approach can be valuable for planners and policymakers in order to identify where interventions are needed.

2.1.4| Impacts of marine plastic pollution

Inadequate waste management and intended littering, resulting in a plethora of plastic in marine environment, can have numerous harmful effects on marine organisms, human health and the economy (Schuyler et al., 2018; Villarrubia-Gómez et al. 2018). Marine plastic pollution can gravely affect all levels of ecosystem functions, habitats and ecological communities (Villarrubia-Gómez et al., 2018). In the following, the ecological, economic and societal impacts are discussed in order to develop an understanding on the effects of marine plastic pollution and thereby provide an idea on why this topic is framed as a serious problem.

Ecological impacts

The impacts of litter on the marine environment is most visible when it comes to entanglement of marine species. Packaging, fishing gear or ropes: many of the materials that cause entanglement consist of plastic. Studies estimate that each year more than six tonnes of fishing gear are lost or abandoned in the ocean. Lost nets endure in the water and can continuously entangle marine species. This problem occurs worldwide, and all higher taxa are affected, such as mammals, sea turtles, birds and crustaceans (Eriksen et al. 2014; Li et al. 2017; UNEP, 2016; Xanthos & Walker, 2017). Incidents of entanglement can lead to mortality through drowning, suffocation, as well as through the decreased ability to catch prey or the increased possibility to be caught (Li et al., 2016). Another harmful environmental impact on marine species is the direct ingestion of plastic particles. The often small size of plastic items and their occurrence in all pelagic and benthic ecosystems makes them available for various species, which can mistake them for plankton or other food sources (Xanthos & Walker, 2017). Plastic can be found in numerous marine species around the globe, including sea birds, turtles, bivalves, crustaceans, fish and mammals (Li et al., 2016). Studies estimate that the ingestion of plastic will further increase and that by the year 2050 nearly all sea-feeding bird species will have plastic ingested

(Perkins, 2015). Ingestion of plastic does not in every case cause immediate death of the organism, although its effects can be directly linked to mortality of many organisms. Ingestion on macroplastic can cause inter alia blockages of the intestinal tract, reduced food consumption, decreased fitness as well as other long-term or chronical consequences (Li et al., 2016, UNEP, 2016; Xanthos & Walker, 2017). Much concern is also related to smaller plastic particles that are ingested by small organisms: Plastic can absorb and transport waterborne organic pollutants which can bioaccumulate to higher trophic levels and enter the human food chain through fish, shellfish or bivalves which can lead to impacts on the human health (Li et al. 2016; Xanthos & Walker, 2017). The long-term and toxicological effects of plastic ingestion on organisms and humans are still unclear and need further research (Xanthos & Walker, 2017). Furthermore, marine plastic can have a severe impact on marine habitats, such as reefs, mangrove forests or salt marshes. The weight and shading effects of marine plastic can damage vegetation and decrease needed availability of light. Sensitive ecosystems such as coral reefs are also affected by plastic pollution such as fishing gear, which can lead to a damage of colonies (Kühn et al., 2015).

Economic impacts

Marine plastic pollution has severe economic impacts especially for the tourism, fishery and food sector. Economic losses for fisheries are associated with lower catching rates due to so-called *ghost fishing*, caused by lost or abandoned fishing nets in the ocean (NOAA Marine Debris Program, 2015). Another impact is the death of species or the reduced quality of the catch due to ingestion of plastic, e.g. in crustacea, bivalves or echinoderms. For the tourism sector, marine plastic pollution can hamper economic development and reduce tourism numbers significantly (Jang et al., 2014; Xanthos & Walker, 2017). This is especially due to a reduced aesthetical value related to plastic that has been washed ashore. Sites where plastic has accumulated create a negative perception of the location (Sheavly & Register, 2007). Despite the aesthetics

and the possible decreasing tourist numbers, local municipalities and industry have to handle the cost of beach clean-ups on their own (Sheavly & Register, 2007). Floating marine plastic also impacts all kinds of recreational activities, damages equipment, can transport invasive species and can pose a danger of public health (Xanthos & Walker, 2017). Estimations suggest an economic impact of more than 13 billion USD annually, related to marine plastic pollution. Whereas still the cost of the loss of species and damage of habitat is difficult to monetarize (Xanthos & Walker, 2017).

Societal impacts

Marine plastic pollution has an impact on society due to effects on public health and food safety. Research confirms that plastic items are bioaccumulating in the food chain and can be found across all trophic levels (Li et al., 2016; Sheavly & Register, 2007), including fish and seafood. The long-term effects of the consumption of plastic via for instance seafood, as well as the effects of the exposure to chemicals absorbed by plastic items, remains unknown. Other impacts on human health are injuries caused by floating or stranded plastic items as well as the loss of income especially in the tourism and fishery sector (Sheavly & Register, 2007; UNEP, 2014; UNEP, 2016).

2.1.5| Marine plastic pollution – A global issue

As the previous sections have shown, marine plastic pollution can have various sources and pathways and it has severe effects, not only on wildlife and nature, but also on societies and the economy in all regions. This makes it clear: marine plastic pollution is a global problem that affects everyone. And it is estimated to exacerbate due to higher production and demand. Hence, the question remains on how to deal with this problem? Is there a global solution on preventing plastic from entering the

oceans? The following section discusses the global governance of marine plastic pollution and current regulations. Thenceforth, I will dive deeper into the argument for the need of understanding the institutional background in order to effectively manage plastic waste. Within the sections, the importance of identifying the origins of plastic will be highlighted, and it will be clarified why, despite of marine plastic being a global issue, the research of regional circumstances, as undertaken in this study, is vital.

2.2| Global governance for plastic pollution

Currently, several regulations and frameworks are in place on a global scale to manage and limit the marine plastic pollution (Lauth, 2015). This variety of laws and regulations have changed foremost common practices of sectors that are operating at and in proximity to the sea. In following, mostly global formal institutions such as internationally binding laws and regulations are described, which are directly addressing marine plastic pollution.

MARPOL – Annex V

MARPOL is an international convention for the prevention and pollution from ships which was implemented by the International Maritime Organization (IMO) in 1983. This convention is in place to prevent pollution from litter caused by ships as it prohibits ships to dump litter into the ocean from aboard. It was revised in 2013, prohibiting ships from throwing all kinds of plastics, including fishing nets and ropes overboard (Dauvergne, 2018). With this regulation, direct pollution of the ocean from ships might be regulated, but the problem of waste pollution is not solved, but rather shifted to the harbour or marina.

Honolulu Strategy

The Honolulu-Strategy is a global partnership on marine litter, which provides a framework for preventing and managing marine litter (Dauvergne, 2018; UNEP & NOAA, 2011). It is meant to help reduce the impacts of marine litter pollution by providing sets of strategies linked to three main goals: reduce amount and impact of land-based litter, sea-based sources and accumulated marine litter on shore, benthos and pelagic waters (Löhr et al., 2017; UNEP & NOAA, 2011)

Global Partnership on Marine Litter

The Global Partnership on Marine Litter (GPML) was introduced during the Rio +20 conference in 2012 (Maes et al., 2018). It is voluntary and aims at multi-stakeholder coordination by bringing together policymakers, public and private actors from different fields to discuss problem solutions. (Löhr et al., 2017; UNEP, 2016). It is meant to encourage cooperation between private and public, and thereby reach its objectives of reducing impacts of plastic pollution, promoting knowledge and information sharing, promoting resource efficiency and increasing awareness (UNEP, 2016).

Bans and self-organized initiatives

Plastic pollution of the marine environment has become an often-discussed topic in the recent years. More information became available about the degree of pollution and harmfulness for environment and public health. This raised awareness lead to initiatives to reduce plastic and manage waste with the aim of keeping it from entering and polluting the marine environment. Latest regulations include the planned or already implemented ban of plastic bags and single-use plastics and microbeads in many countries all over the world. Also, more and more self-organized initiatives took

place as awareness rose. In the year 2017, more than eight thousand metric tonnes of plastic, metal and glass were collected by volunteers during beach clean-ups and other events (Dauvergne, 2018). However, in comparison to the pollution, this has limited effects.

Agreements on an international scale are hard to develop and take a long time to be implemented (Haward, 2018). Although many frameworks and regulations are in place, the ongoing and increasing plastic pollution of the marine environment shows that current governance practices are not prepared for the emerging challenge of dramatic plastic pollution of the marine environments.

2.3| Marine plastic pollution – A complex endeavour

The challenge to govern marine plastic pollution results from the inherent complexity of the problem. Complex problems are characterized by intrinsic uncertainty and unpredictability, that includes unexpected and nonlinear responses to intervention (Moroni, 2015). This means, changes and responses can be asymmetrical, where a small alteration can have a large effect on the whole system and vice versa (Duit & Galaz, 2008).

But what is the inherent complexity in governing marine plastic pollution? The problem poses a great challenge for governance to design and implement a functioning institutional framework, as the complexity lies within many components of the problem, their interactions and knowledge gaps. Uncertainties exist about the sources and pathways of plastic as they are diverse and often unknown (Haward, 2018). Additionally, the transboundary nature of marine litter adds to the complexity of the problem.

Furthermore, another challenge for governance is the weak profile (Zuidema, 2016) of marine plastic litter. This means that the problem is mostly invisible and has long-term impacts that are not easily grasped and, hence, do not seem urgent. The

environmental benefits of a clean ocean are hardly expressible in financial terms, and therefore often overlooked (Zuidema, 2016b). These reasons contribute to the lack of people feeling responsible or 'owning' the problem. Moreover, even though most plastic originates from land-based sources, the majority of it accumulates on the high sea, where no country has the sovereignty. This results in a limited feeling of responsibility of the countries, relating back to the "tragedy of the commons" (Vince & Hardesty, 2018): the interest in exploiting the resources of a common source is high, however, when it comes to taking responsibility on environmental challenges, the willingness has constraints. Taking responsibility or acting upon the problem occurs rarely, as "[t]he individual benefits as an individual from his ability to deny the truth even though society as a whole, of which he is a part, suffers" (Hardin, 1968, p. 1244). Many policy instruments rely on concepts such as the 'polluter pays', meaning that the party that is responsible for the pollution, is being held accountable for compensation payments for environmental damage (Luppi et al., 2012). However, as there is no full certainty on where the plastic originates from, these concepts are limited in their effectivity because no one can be held accountable. Therefore, the identification of sources, as undertaken in this study, plays an important role to support policymakers. Moreover, the involvement and the effects on numerous stakeholders is challenging for governance (Rochman et al., 2015). Not only do regional differences exist in terms of contribution and effects (Dauvergne, 2018), also the impacts on society, economy and corresponding ecosystems differs and unknown consequences and developments in the future need to be considered.

The discussed reasons elucidate, that many known unknowns exist. However, complexity implies that there are additional unknown unknowns about future developments and hence the question on how to plan for and govern unknown events raises. In contrast to non-complex phenomena, there is no simple solution to complex problems and the traditional coordinative governance model reaches its limits. However simple measures such as clean ups should not be neglected, as they may not solve the whole problem but contribute to improving the situation. These simple

measures need to be embedded in or be a part of different governance strategies. Hence, depending on the nature of the problem, diverse governance strategies are needed. Consistent with this, Figure 2 represents a framework with complexity serving as a criterion for governance strategies (De Roo, 2003). A problem can be considered simple, complex or very complex depending on the goal (single or multiple goals) that is tried to be reached and the degree of collaboration. The choice of governance strategy can be determined by an imaginary diagonal axis from the upper left to the lower right corner. The degree of complexity determines the degree of collaboration and scope of goals that have to be considered in order to deal with the problem.

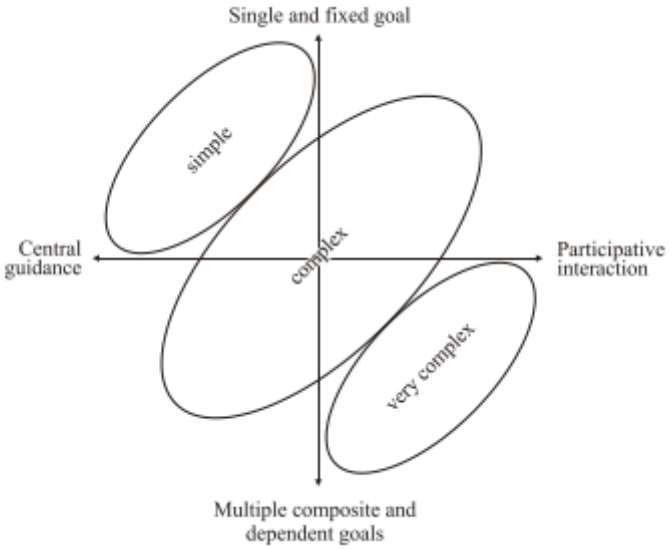

Figure 2 Framework for planning-oriented action in which complexity serves as a criterion (Source: De Roo, 2003)

In line with the previously mentioned reasons that the governance of marine plastic can be considered to be complex, Vince & Hardesty (2017) also stress the importance of the global and transboundary nature. Dauvergne (2018) sees fragmented policies and little coordination between different sectors, countries and jurisdictions as one of the main problems for the failing governance of marine plastic pollution. Too many inconsistent standards, loopholes and lack of action by international standards lead to inefficient implementation of regulations. Yet, simple

standard solutions are unlikely to be effective for a complex phenomenon. Therefore, this study will shed light on the sources of plastic in order to increase the degree of certainty and then use this enhanced insight to develop a more sophisticated strategy.

Adding to the complexity of governance is the interconnection of the oceans on a global scale. Even if a single country proposes and implements a governance strategy, it will have a limited effect if other countries continue polluting. On the other hand, this particular country can face severe disadvantages on the global market caused by the implementation of stricter regulations and hence weakening its own economy (Zuidema, 2016b).

Difficulties for implementing regulations also arise with increasing power and stakes of the plastic industry (Dauvergne, 2018; Löhr et al. 2018). Resistance of the industry to regulations or bottom-up governance initiatives inhibits their effectiveness and leads to poor implementations. Additionally, procedures that are believed to be effective measures, like recycling of plastic, stay insufficient. In 2014, China and Europe had the highest recycling rates, with only 25 to 30 % recycled plastic (Dauvergne, 2018). This shows, that an improvement of this rate could serve as solution starting at the source rather than 'end of pipe' measures. In line with the previous argumentation, another reason why governing marine plastic pollution seems to be failing are uncertainties about the amount of plastic that is actual in the ocean: Due to its characteristics plastic break down into smaller pieces, travels unknown pathways, can absorb pollutants, bioaccumulated up all trophic levels and can diffuse into soil, marine and freshwater (Kühn et al., 2015; Rochman, 2015). There are many sources and pathways of plastic but only little easy solutions to achieve a reduction of marine pollution. As there is currently no effective solution to get plastic and especially micro- and nanoplastic out of the ocean, preventing it from entering the marine environment is a crucial step. Additionally, there is no regulation present that addresses impacts on environment and human health through the whole lifecycle of plastic (Raubenheimer & McIlgorm, 2018). There is a clear need for global regulation and a policy framework that enacts the role of the industry sector in order

to take the responsibility from the public sector to prevent and mitigate mismanaged waste (Raubenheimer & McIlgorm, 2017). Scholars call for better defined goals to protect the marine environment from plastic pollution (Löhr et al., 2017) and for more and comprehensive regulations (Dauvergne, 2018). Existing regulations and frameworks not only have to be more effective but also have to be fully implemented and enforced (UNEP, 2016). For the long-term a reduction of plastic produced, and the implementation of circular economy seems to be the most promising solutions (Löhr et al., 2017; UNEP, 2016). However, there are also examples of successful implementation of international legislation and regulation, such as the Montreal Protocol, a multilateral and legally binding agreement to phase out substances that harm the ozone layer. Hence, scholars suggest instruments based on the Montreal Protocol could be successful at increasing recycling rates through incentives for the recycling industry (Raubenheimer & McIlgorm, 2017). Still, it has to be considered that the success of the instrument relied on available and suitable alternatives for the previously used substances. In the case of plastic pollution, it might be more challenging to apply as alternatives are limited.

Raubenheimer & McIlgorm (2017) see the main cause for the problem of marine plastic pollution in the failure of land-based waste management, yet, the international and regional response to policies is not sufficient to successfully protect the marine environment from pollutions by land-based sources (Raubenheimer & McIlgorm, 2017; Van der Zwaag & Powers, 2008).

This section shows clearly the inherent complexity underlying the problem of marine plastic pollution and why its governance has failed so far. As the problem is of a global scale, laws and regulations must be developed at a global level, while taking into account the context-specific local circumstances (Mukhtarov, 2014). Governance solutions to a complex problem need a certain degree of flexibility and allow for creativity, which can often be found if solutions are tailor made to the local context (Lemos & Agrawal, 2006). As highlighted in this section, not one government has been successful in handling the problem in a clear top-down manner. Therefore, the

discussion of governance, particularly considering complexity of environmental management which includes institutional arrangement needs a special focus. To find solutions, it is hence useful to look not only at laws and regulations but also to the societal circumstances in a region. This will provide insights on people's behaviour due to their values and practices. Therefore, the next section focuses on institutional theory in order to identify the differences in institutions and why it is important for research.

2.4| Plastic pollution: An institutional perspective

The topic of plastic pollution can be analysed from an institutional perspective, looking at the 'rules of the game'. Hence, understanding the rules, the players and the challenges within the game is crucial to tackle the problem of marine plastic pollution. This perspective can help to show occurring gaps and barriers which have to be overcome to prevent and deal with plastic pollution. Therefore, it is especially important to understand the differences within the term institutions and thence identify which institutions that address plastic pollution are already in place. The institutional perspective can offer insights into how and why people act in a certain way.

Many tools and instruments can be used to regulate the way of how plastic is entering the marine environment. These instruments are categorized as formal and informal institutions. Institutions can be defined as sets of rules and regulations that represent how we perceive and act upon our environment (Ostrom, 2011). They can be described as human-made boundaries of individual or organisational action through formal and informal actions. Formal institutions entail policies and regulations, which include a set of rules, such as legislation and laws where a violation will be punished by certain measures (Lauth, 2015). Informal institutions refer to values and norms (Buitelaar et al., 2007), that are a construct of society and shaped and adapted through our everyday life (Ostrom, 2007). Hence, they can be designed

and transformed intentionally (Alexander, 2005). Institutions are a crucial part of planning, as they offer a framework and context for planning to take place (Verma, 2007). According to Alexander (2005), there are two ways of changing people's behaviour: changing the individual or changing institutions. Therefore, it is crucial to unravel and understand both, the larger scale, formal and the context-specific, informal institutions to identify possible barriers and to enable change (Alexander, 2005). The theory by Ostrom (2008), where it is analysed how institutions are regulating harvesting practices, can also be applied to the marine plastic pollution problem: Institutions regulate and limit our polluting practices, but the absence of effective institutions, for example waste management regulations, can therefore result in overly polluted environments. Hence, there is a need for effective regulation and their strict execution regarding the problem of marine plastic pollution to mitigate the input from land into the ocean. To tackle the problem of marine plastic pollution formal as well as informal institutions must be considered, as the sources and pathways of plastic are local issues, but the overall problem of marine pollution is global. Informal institutions play an important role in influencing norms and practices (Lauth, 2015). They include "traditions, customs, moral values, religious beliefs, and all other norms of behavior that have passed the test of time" (Pejovich, 1999, p.166) and symbolise society's predominant perceptions (Pejovich, 1999). They are not formulated in legal documents or carried out by authorities but refer to social interactions, cultural norms, behaviour and habits (Dahl & Pedersen, 2004), in the case of plastic pollution this means for example how people handle plastic waste, how they perceive the problem or how they act upon it. Informal institutions are thus clustered within socially connected people in geographical proximity that share interest, values and identities (Dahl & Pedersen, 2004). Identifying informal institutions can provide insights on how and why people behave in a certain way and thus help to uncover possible points where intervention might lead to a successful change in behaviour

Next to the traditional command-and-control approach, such as bans or regulations dictated by authorities, another possible approach can be economic incentives (Schuyler et al., 2018). Studies show that effective implementation of economic incentives can decrease the amount of plastic (in this case beverage containers) by a significant amount (Schuyler et al., 2018). This is in contrast to disincentives, such as taxes or fees, which can have possible negative effect, for instance illegal dumping in order to avoid taxes. Even though incentives are often more expensive to implement, the benefits including the avoidance of cleaning illegal dumps prevail. A significant reduction in plastic pollution through economic incentives appears as a result of consumer behaviour and due to the increase of recycling of materials (Schuyler et al., 2018). This success is apparent in highly developed countries with a working waste management infrastructure and societal awareness, showing the effectiveness even of small incentives (Schuyler et al., 2018).

However, these regulations pay attention to the formal institutional settings, which cannot always grasp the whole extent of the problem. In addition to formal institutions, informal institutions are an important factor when it comes to tackling the problem of marine plastic pollution, as they influence people's norms and values. Campaigns that raise awareness, educate or address the change of behaviour seem to be a successful instrument to reduce marine plastic pollution. Investments in campaigns result in decreased quantities of waste entering the marine environment compared to investments in policies (Willis et al., 2018). These programs include campaigns such as clean-ups, illegal dumping campaigns and recycling and other actions to raise awareness and address a change in behaviour. Especially community programs that engage members of the local community and involve them in beach clean-up actions. As littering at the beach is often the result of a lack of awareness, anti-littering actions can have a large effect on the reduction of marine plastic pollution (Willis et al., 2018). Education and raised awareness are seen as a powerful instrument to address plastic pollution, as raised awareness within a community can lead to local initiatives and actions that can improve the situation significantly

(Derraik, 2002). Clean ups by initiatives or industry are most effective if they focus on the flux of plastic near the coast, as they remove plastic before entering vulnerable oceanic ecosystems and before it sinks, floats away or is ingested by marine organisms (Sherman & Van Sebille, 2016). The input of plastic into the ocean will persist until the source is stopped. Hence, source reduction via waste management is more effective than clean ups (Rochman, 2016; Sherman & Van Sebille. 2016). To prevent larger plastic items to enter the marine ecosystem, an effective waste management strategy as source reduction (Jambeck et al., 2015) in combination with clean ups is needed (Rochman et al., 2015).

However, waste management to prevent the pollution of the marine environment is a complex issue where there is no universal solution (Rochman et al., 2015). There is a need for a broad and holistic approach to control plastic disposal, that consists of global regulation and local implementation as well as community actions combined with scientific support (Haward, 2018). Many approaches seem promising but still there is a lack of implementation or widespread execution. Hence, the problem of marine plastic pollution needs to be addressed through an assembly of different approaches, which include bottom-up initiative and governance as well as national and international legislation (Schuyler et al., 2018). The problem of plastic pollution remains a global issue that needs effective regulations that are implemented locally depending on the circumstances and the local context.

2.5| Conceptual model

As Chapter 2 has shown, the issue of marine plastic pollution is a complex problem that needs more research regarding the identification of sources of plastic input into the marine environment. In addition, more knowledge about the context-specific institutions in order to develop new strategies to mitigate and prevent the consequences of plastic pollution is needed. The conceptual model (Fig. 3) aims at identifying possible sources of land-based activities and the underlying (formal &

informal) institutional background. As a result, insights for an improved management of the sources can be gained and minimization strategies can be developed. The formal and informal institutions in the research area influence the behaviour of individuals and groups and determine the land-based sources of plastic litter entering the marine environment. The theoretical analysis in Chapter 2 identifies different sectors (Land-based industry, harbour, tourism and municipal waste) as the main contributors to plastic pollution. Determining the contribution of each sector to plastic pollution provides an idea on how much plastic is actually being released and who is the main polluter within the research area. By disentangling the underlying institutions, the scale of the problem can be identified, i.e. if the problem is of a formal or informal nature. Thereby, context-specific "lessons" can be learned on why plastic waste is being mismanaged and what kind of instruments could be used to strategically tackle the context specific situation and possibly change the specific institutions. If instruments can successfully change the institutions, the land-based sources should be minimized, and less plastic will enter the North Sea.

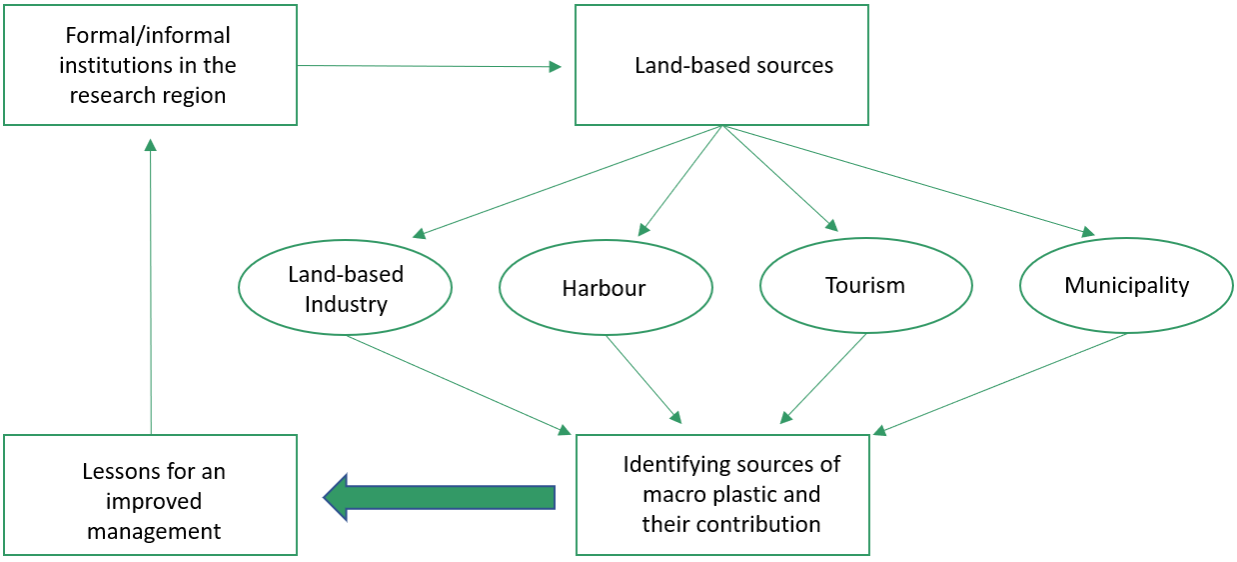

Figure 3 Conceptual model (source: author)

3| Methodology

The previous chapter introduced the theoretical background information that is needed to gain knowledge about the research topic and its importance. In order to highlight the importance of the topic, a graph (Fig. 1) was created, showing the increasing number of publications of the topic of marine plastic pollution. The numbers for the graph are retrieved from scientific online databank *Science Direct*, using the search function for the term 'marine plastic'. This chapter elucidates the research approach and the methodology used to answer the research questions. As argued in Chapter 2.3, the topic of marine plastic pollution is of a complex nature which includes the issue of uncertainty. Hence, a solely quantitative approach does not suffice to grasp the whole extent of the problem (Zuidema, 2016a). Therefore, this research focuses on a mixed methods approach to address the complexity. The focus on a quantification to find hotspots and create a degree of certainty is the first step. Afterwards, a qualitative data collection is used to unravel underlying institutional factors and to explain what the collected data means.

The main research question

"*Where on the English North Sea coast are the "hotspot" entry points for macroplastic into the marine environment and what insights can be gained to improve coastal waste management?"*

is answered by first focusing on a set of sub questions (see Chapter 1.2):

I) What is a "hot spot" for marine plastic?
II) Which kinds of land-use are present along the English North Sea coast?
III) What type of land-use produces most plastic waste in the research area?
IV) Which regulations/institutional frameworks on plastic waste management are present?
V) What insights can the analysis of the institutional setting provide on why plastic enters the marine environment?

Sub-questions I) and II) are addressed using scientific literature and the results are presented in chapter 2.1.2 and 2.1.4. The quantitative analysis aims to find out where in the research area the most plastic is theoretically emitted, and which sector contributes to which degree (Sub-question III). This is done by looking first into the literature to find the most contributing categories of land-use and to find indicators. In order to identify hotspot entry points along the coast, indicator data is gathered and the degree of contribution of each category and the summed-up degree within the different districts is calculated. This data is then analysed spatially and visualized in maps using the software ArcGIS.

In the next step, the focus lies on answering research question IV and V. This is done with the help of qualitative data, i.e. interviews. It is addressing questions about the institutional background within the research area and includes personal viewpoints on the topic of different interviewees. Additionally, the interviews shall provide information about possible ways and actions where plastic might escape the waste management system and reach the marine environment. Combining the two parts, quantitative and qualitative analysis, will provide insights on how waste management in the research area might be improved in order to prevent plastic from entering the North Sea.

3.1| Units of analysis

The units of analysis are determined by defining the spatial boundary, timeframe and theoretical scope (Yin, 2003).

The spatial boundary of this research is contained within England, more precisely the English North Sea Coast. The focus will be on 18 districts (Local Administration Units) from Northumberland in the North to the District of South Holland in the South (Fig. 4).

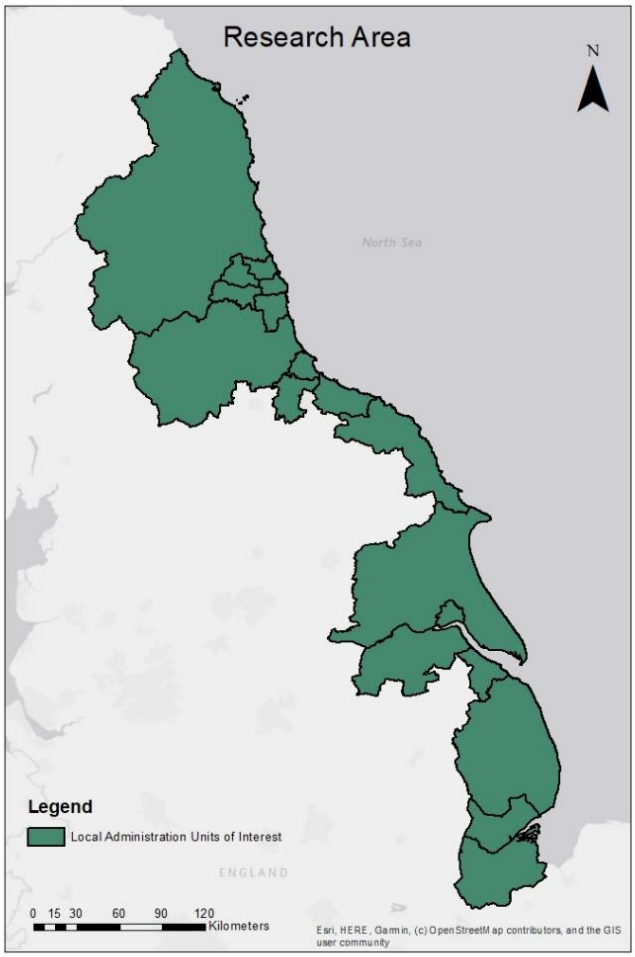

Figure 4 Map of the Research Area along the English east coast. The studied districts (Local Administration Units) are highlighted (Map by author, data source: ESRI library)

The research is divided in (1) the desk research and quantitative and spatial data analysis and (2) qualitative research with the help of interviews. The first part took place in the beginning of the year 2020. The second part of data collection (qualitative) occurred in the in the second quarter of 2020.

The theoretical scope is defined based on a literature study on marine plastic pollution, institutional theory, environmental planning and environmental science literature. It is aiming at finding information on the sources of macroplastic and indicators for measuring the degree of pollution. As a result, a map will be produced to visualize the land-use activities and their degree of contribution to waste pollution.

However, it will not produce a map with facts on precise quantities of waste pollution but be giving an idea about the degree of the contribution of land-uses and their distribution within the research area. In a second part, qualitative data will be gathered and uncover in combination with the quantitative data the story behind the analysis of the statistical data.

3.2| Data collection

Following the conceptualization of the research, Figure 5 presents the data collection strategy.

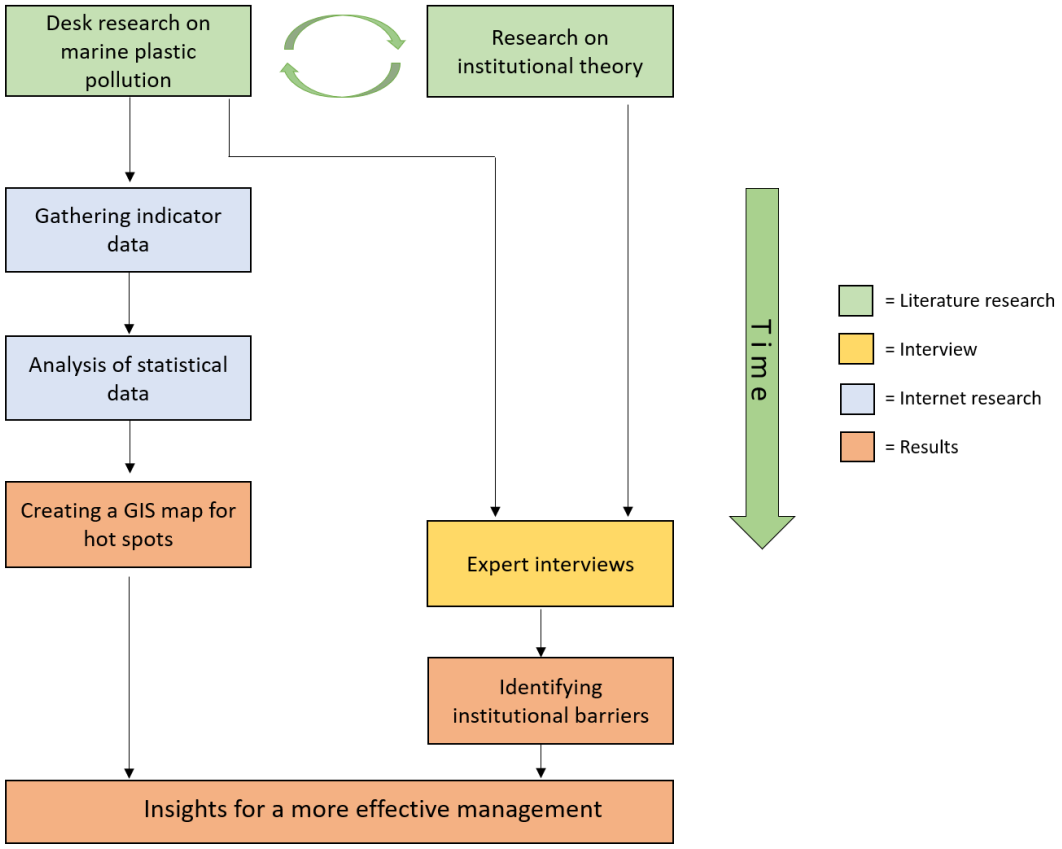

Figure 5 Research Approach (Source: Author)

The first step of data collection is desk research, with a focus on two main research areas. The first part includes research on the general topic of marine plastic pollution, its effects and impacts on ecosystems and society, as well as a general search for possible indicators on how to measure land-based activities. The second

area of the desk research emphasizes on institutional theory. For both areas, scientific literature, either peer reviewed papers or published books, are taken into account for the study. For the first part, the ARSU study by Schäfer et al. (2019) and the master's thesis by Müller (2019) serve as a starting point for the desk research and methodology.

The next step after the desk research is collecting the needed statistical data for the quantitative analysis. Important for this step is the open accessibility of the data, allowing on the one hand for a reproduction of the research and on the other hand for authentication, as it can easily be examined and checked for possible errors. Consequently, this contributes to the overall integrity of the research. Another important factor of gathering indicator data is the availability of data for all districts under study. The aim is to only use data on one indicator if the dataset is available for all districts. However, problems can occur, as some data is only available on a higher administrative level. This issue will be further discussed in Chapter 5 and will play a role in the reflection on the research (Ch. 5.4). The selection of data is focused on public institutions on national or international level, if possible, the data on different indicators is selected from the same institution to provide further integrity and allow for a certain continuousness. In the following list, the used datasets for the indicators and their source will be presented.

1. Land Cover

   The data on land cover is needed to approximate the degree of land-based industry and agricultural land use in the research area. Additionally, the data is used to show the location of possible hotspots within a district. For this analysis, the needed remote sensing data is provided by the European remote sensing program CORINE. The landcover data is openly accessible on the website of the Copernicus Land Monitoring Service (Copernicus Land Monitoring Service, 2020). The boundaries of the districts in the research area has been taken from the ArcGIS ESRI library and has been provided by the European Statistical Office *Eurostat*. From the dataset "Local Administrative

Units Level 1, 2018 Boundaries", the districts within the research area have been extracted for the further use.

2. Population & distribution

   The UK Office for National Statistics (ONS) provides publicly available statistics on population numbers and densities on different levels of authority. The statistics for the population number in the research area have been taken from the dataset "Median age of population for local authorities in the UK, mid-2001 to mid-2019", which provides mid-year population number estimates from 2001-2019 (Office for National Statistics, 2020). For this research the 2018 data was used, as the most recent numbers for the other indicators were also from the year 2018.

3. Harbour activity

   Harbour activity is measured by the gross freight volume of each harbour. The data is provided by the UK Office for Maritime Statistics and the dataset "UK major port traffic, total tonnage and units, by port, quarterly from 2009" has been used (Maritime Statistics, 2019). The most recent data (2018) for the six major ports within the districts of interest was retrieved from the document and used for the further analysis.

4. Tourism activity

   The degree of tourism activity results from the number of jobs within the district. Unfortunately, data on employment in the tourism sector is not available on a local level. The Office for National Statistics was contacted for information on tourism employment, however, without a response on time. With help of the *Geodienst*, the spatial expertise centre at the University of Groningen, data was found on a slightly higher administrative level, the *Nomenclature of Territorial Units for Statistic Level 3* (NUTS 3 level). For some

districts, the local administrative level and the NUTS 3 level are equal, therefore this change only affected some districts. However, for some areas, the change to data from a higher administrative level increases the spatial radius significantly and adds areas that are not in proximity to the coast. Therefore, a research for an indicator to calculate the employment on a NUTS 3 scale down to a local administrative level was conducted. Yet, there was no consistent indicator found that would allow to downscale tourism employment numbers from a higher level of authority to a local level in an appropriate manner. Consequently, it has to be assumed that numbers in tourism employment are distributed equally within the NUTS 3 level and hence within the affiliated districts. For the numbers of employment in the tourism sector, the dataset "Employment data by tourism industry for NUTS 3 areas", provided by Office for National Statistics (Office for National Statistics, 2016) is used.

5. Land-based industry

   The degree of land-based industry contains of two components: Activity of the producing industry sector and agricultural activity. The activity of industry is indicated by the number of employees in the industry sector. The dataset "Summary of analysis: Tables looking at Occupational Employment at UK regional, NUTS3 and Local Authority Level" is provided by the Office for National Statistics (Office for National Statistics, 2018). Additionally, the area covered by industry is used as an indicator for the degree of land-based industrial activity. This data is provided by the CORINE Land cover category 121 (Industrial and Commercial Units) within the dataset of the CORINE Land Cover. The degree of agricultural activity is measured by the area covered by farmland. The applicable categories for agriculture, provided by the CORINE land cover dataset (Copernicus Land Monitoring Service, 2020), are:

   I) 211: Non-irrigated arable land

   II) 231: Pastures

III) 242: Complex cultivation patterns

IV) 243: Land principally occupied by agriculture

3.3| Data processing and calculation

To determine and visualize the hot spot entry points for macroplastic into the North Sea, the most important tool is Geo Information Systems (GIS). In this research, the used software is ArcGIS version 10.5.1, which is an often-used program that offers all the possibilities to process and visualize the indicator data for this research. For each category of land-use, the proportion of each district to the overall contribution is presented. Afterward, the contributions of each district are summed up and weighed by the category -specific contribution factor, based on the ARSU-report. This provides then an overall contribution map of each municipality and degree of contribution of the different types of land-uses within.

3.3.1| Calculation of contribution

The calculation of the values for the contribution of each category is based on the study by Schäfer et al. (2019). In this study, litter items collected at beach clean ups at the German North Sea coast were analysed and tracked back to their potential origin. Based on that, the contribution of different land-use categories was estimated. The study estimates that in the North Sea area, 40 % of all waste entering the marine environment is land-based. A similar amount was also estimated in different studies, where 40 to 50 % of waste was attributed to land-based activities (UNEP, 2016). It is assumed that the values are similar on the English North Sea coast due the proximity of the research area to the German North Sea coast. Figure 6 visualizes the distribution of land-based waste in different categories.

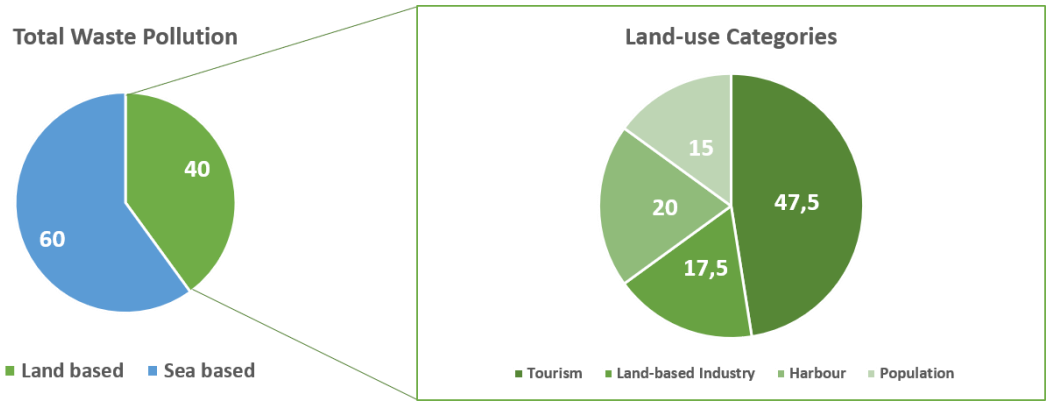

Figure 6 The distribution of the origin of waste by Schäfer et al (2019). The numbers are based on collected waste in beach clean-ups and analysed in the study (Graphic by author; data by Schäfer et al. 2019).

The calculation of the contributions for each category of land use is based on the methodological tool by Müller (2019). The calculations are done in the same manner to allow for a better comparability of the different research regions. The used variables in the following equations are further explained in the following section.

3.3.2| Calculation formulas

The degree of contribution of each land-use category is calculated equally:

$$(1) \quad N_n = \frac{Indicator_{local}}{Indicator_{total}}$$

With N_n being the contribution of a district to the niche category. $Indicator_{local}$refers to the indicator in a district (= on a *local* level) and $Indicator_{total}$ refers to the total number of an indicator category, e.g. the total amount of employees in the tourism sector for the category Tourism (further explained in the next section).

To calculate the total contribution of a district to the overall waste pollution, all the categories are summed up:

$$(2) \quad M_n = \sum_{C} (F_c * \sum_{N_i} (N_n * F_{Ni}))$$

The calculated contributions of all districts are required to add up to the whole degree of land-based plastic

$$(3) \quad W_{lb} = \sum_{W} M_n$$

Explanation of variables

1. W refers to the amount of *waste* that enters the marine environment. It can be distinguished between W_{tot} and W_{lb}, whereas the former describes the total amount of waste entering the ocean and the latter refers to waste that is introduced through land-based activities. Both variables are described as proportions of pollution, as a precise quantification of plastic waste is not needed in order to identify where hot spot entry points of macroplastic are located.
2. C refers to a category of land-use. In this study, four categories are analysed: Tourism, Land-based Industry, Harbour and Population
3. F_C gives the factor to which the category C contributes to the total waste pollution. It equals the proportion of the contribution of category C to the waste from land-based sources W_{lb}. The values for F_C originate from the ARSU study by Schäfer et al. (2019).
4. N_i presents the activity of a niche (sub-category). It equals the proportion of the value of the local (= on district level) indicators from the total sum of the research area.
5. F_N refers to the contribution of a niche within a category. The activity of a niche is represented by the ratio of which the niche indicator contributes to the category. For example, if a category consists of two niches and both contribute equally to the value of the category, N_i is 0,5.

6. M_n describes the sum of all activities within a local unit (in this case in a District). This value will provide information about possible hotspot entry points.

All variables, except the direct indicators, are dimensionless as they describe proportions.

In the following, the calculation basis for the four different categories of land-use is explained in more detail.

3.3.3| Calculating the degree of tourism activity

The land-use category of tourism activity accounts for 19 % of all waste, according to the ARSU report by Schäfer et al. (2019). This represents 48 % of all land-based waste; hence, this category has a W_{lb} and F_c of 0,48. This category of land use is subdivided in three niches: beach visitors, day trip visitors and employees in the tourism sector. Due to the unavailability of data for the former two niche categories, only employment in the tourism sector is used as an indicator, resulting in the following variables for calculating tourism activity: $Employees_{Tourism\ total} = 231127$ and $F_{NT} = 1$, as a result of there only being one niche category for tourism.

Consequently, tourism activity is calculated as:

$$(4) \quad C_{Tourism} = 0{,}48 * \left(\frac{Employees_{Tourism\ local}}{Employees_{Tourism\ total}} * 1\right)$$

3.3.4| Calculating degree of harbour activity

The estimated contribution of harbour activity to the total waste W_{tot} is 8 %. Consequently, W_{lb} and F_c are 0,2. Currently, there is no information available on potential different niches within the category of harbour activity, hence, there is no contribution factor for F_{NT}. The indicator choses to estimate the amount of waste

contribution is the quantity of freight handled by a harbour. The total amount of freight tonnage handled by the six major ports in the research area is:

$Freight\ tonnage_{total} = 101{,}9$ million tonnes

The degree of harbour activity is calculated in the following manner:

$$(5) \quad C_{Harbour} = 0{,}2 * \left(\frac{Freight\ tonnage_{local}}{Freight\ tonnage_{total}}\right)$$

3.3.5| Calculating degree of land-based industry

The contribution of land-based industry is 7 % of W_{tot} and therefore has a W_{lb} and F_c of 0,175. Within the category, two main niches are identified. The niche factors are equally distributed, leading to a F_{NI} of 0,5. The following niche categories and attributed indicators are used:

I) Agriculture

The indicator for agricultural activity is the area covered by agricultural land within the coastal zone.

$Area_{Agriculture\ total} = 1202219{,}1$ ha

II) Industry

For this niche, the indicators are the total employment within the industry sector as well as the area dedicated to industry. The average of both proportions is used for the calculation.

$Area_{Industry\ total} = 25907{,}5$ ha

$Employees_{Indusrty\ total} = 387791$

The factor for the niche category Industry is:

$$(6) \quad Industry = \left(\frac{Area_{Industry\ local}}{Area_{Industry\ total}} + \frac{Employees_{Industry\ local}}{Employees_{Industry\ total}}\right) * 0.5$$

Consequently, the degree of land-based industry is calculated as:

$$(7) \quad C_{lb\ Industry} = 0{,}19 * \left((\ Industry * 0.5) + \left(\frac{Area_{Agriculture\ local}}{Area_{Agriculture\ total}} * 0{,}5 \right) \right)$$

3.3.6| Calculating the degree of district activity

According to the ARSU study by Schäfer et al. (2019), the population within an area contributes 6 % to the total amount of waste, which accounts for 15 %of all land-based waste. This leads to a W_{lb} and F_c of 0,15. This number is based on the amount of waste that escapes the waste management and the storm water management. The indicator for this category is the total population of the area and no niche activities are present. Therefore, the contribution of the districts is calculated in the following manner:

$$(8) \quad C_{Population} = 0{,}15 * \left(\frac{Population_{local}}{Population_{total}} \right)$$

The total population of all districts in the research area is:

$Population_{total} = 3196842$

3.4| Usage of ArcGIS

This section explains the necessary steps in order to create the plastic pollution maps in ArcGIS. First, a base map and the shapefile with the boundaries of all the districts in England were taken from the ArcGIS Esri library. The desired districts of the focus area were extracted from the shapefile dataset. The new shapefile is then multiplied in order to produce one map for each category. Within each category, a field was added to the attribute table, that contains the calculated degree of contribution of this category for each district. This contribution is then visualized in the map by displaying the distribution in graduated colours. Additionally, another copy of the district within the research area for the overall contribution map is generated. The next step is importing the total contributions of all categories into the map multiply them with

their specific contribution factor (see Ch. 3.3). The calculated contributions are summed up and hence creating the overall contribution map.

In order to get the information on the area cover of the industrial activity and agriculture, the CORINE Landcover dataset is used. The data is imported to the map with the outline of the districts of interest and clipped to the area by using the clipping tool. Then, the data from the categories 121 for industry, 211, 231, 242 and 243 for agriculture that is containing the information about the square meter of the area, are added up. The table provided then the information for each district for the category of industry and agriculture.

3.5| Interviews

In order to explore a phenomenon in its specific natural context, semi-structured expert interviews can provide important insights (Kaiser, 2014). The term expert in this context refers to a person with an explicit knowledge of the specific topic and research objective. However, this person does not necessarily have to be an expert in the scientific community or provide scientific knowledge (Kaiser, 2014), but rather have a deep understanding of the specific contextual situation. In order to acquire data that cannot or only insufficiently be retrieved by literature review, semi-structured interviews have been chosen as the preferred method for the qualitative analysis. In contrast to other methods of data retrieval, interviews can acquire detailed information about the examined phenomenon (Kaiser, 2014). Semi-structures interviews provide a structured guideline, that supports to steer the interview in the anticipated direction while still offering the opportunity for the interviewee to provide detailed answers (Kaiser, 2014).

However, due to the outbreak of the corona virus in the beginning of the year 2020, it was not always possible to get in touch with the preferred interviewee. Therefore, questionnaires have been included as a mean to collect qualitative data, as they are less time consuming for the interviewee to provide a written answer and can

be done even during lock-down situations. The aim of the qualitative data collection is to get information about perceptions and views of persons from different sectors within the research region.

The interviews and questionnaires consist of closed and open questions, in order to achieve two goals: the closed questions on the one hand are asked to validate previously researched information, while the open questions on the other hand provide more explanatory information and give insights of personal perceptions and opinions. The interview guide and the questionnaire can be found in Appendix VI.

The choice of interviewees is made based on the conceptual model of this research. It is desired to get insides from different perspectives. Therefore, each angle that is taken into account for the quantitative analysis of statistical data, should also be considered for the qualitative part. Additionally, the perception of experts from the academic branch are included in the research to be able to collect data from a wider pool of experience and knowledge.

In the following, the different categories of angles are highlighted and the kind of information, that is hoped to be gathered, is elucidated.

1) Research expert

   Experts in the field environmental science with a research focus on marine plastic pollution are asked to confirm the introduced categories of land-use as the main contributor to marine plastic pollution, as well as the effects on the ecosystem. Furthermore, the experts may provide insight on the underlying institutions and people's general attitude towards handling plastic. Moreover, research experts are asked to give their opinion on the questions on who should be held responsible for the pollution of our oceans and what strategies for an improved management they would suggest.

2) Harbour operators

   As harbours are one of the main sectors contributing to marine plastic pollution. Therefore, the personal perception of harbour operators on the

issue plastic pollution is of interest. Additionally, interviewees could provide information about different activities, in which phase plastic might escape and the presence and state of waste management facilities. This information would be helpful, in order to identify if waste management facilities on harbour sites are sufficient or need improvement. Furthermore, the personal assessment of responsibilities and management (who is responsible, who should act) is of great interest.

3) Industry perspective

   Land-based industry is another sector that is contributing to marine pollution. Hence, it is interesting to get an insight from the perspective of this sector. The information that is desired to be gathered equals the description in the section for *Harbour operators*.

4) Citizen perspective

   The perspective of a citizen within the research area is of interest in order to gain insights on the personal perception of plastic pollution, as well as information about where and when plastic might escape the waste management system. Furthermore, the availability and type of waste management facilities is of interest. This is important local knowledge, as it can hint at a possible need for improvement. As for the other interviewees, the personal assessment of responsibilities and management (who is responsible, who should act) and the personal perception of people's behaviour is of great interest. Unfortunately, it was not possible to find an interviewee who could provide the desired input; therefore, this data could not be collected.

5) Tourism perspective

   The tourism sector is one of the main contributors of land based human activities. It would be interesting to get insider knowledge of the perception of representatives of this sector. However, it was unfortunately not possible

to get in contact with an eligible person and hence, the desired data could not be gathered.

Overview of data collection

The following table (Table 2) summarizes collection of qualitative data. In total, three interviews were conducted, and two questionnaires were answered. In the following, as well as indicated in Table 2, all participants are referred to as *Interviewee*, regardless the type of data collection. All interviewees are considered as representative, as they either conduct research on the topic of marine plastic pollution or have a deep knowledge on the situation in their respective sector due to their professional position and responsibilities in the firm.

Four ethical key values are followed, in order to guarantee that the qualitative data collection is conducted responsibly and morally defendable. These are, ensuring that no harm is done to participants, data is collected with informed consent of participants, consider the participants' privacy, and data collection takes place without the attempt of deception (Gray, 2014)

As ethical consideration of the interviewees' privacy, each interviewee is assigned a number and an interviewee ID. The interviewees are taped or transcribed, nonetheless the raw data is not part of this document due to reasons of discretion. Taking into account the different background of the interviewees and the respective kind of knowledge that was hoped to be gathered, the questions during the interview/of the questionnaires differed, as shown in Appendix IV.

Table 2 Qualitative data collected during the research, showing the number of the interviewee, interview ID, position and location of interviewee (RA= research area), type of data collection and the date.'

Number of interviewees	Interview ID	Position/Background of interviewee	Type	Date
1	200611	Industry [RA]	Questionnaire	11.06.2020
2	200612	Industry [outside RA]	Interview	12.06.2020
3	200618	Research Expert [outside RA]	Questionnaire	18.06.2020
4	200619	Harbour [outside RA]	Interview	19.06.2020
5	200630	Research Expert [outside RA]	Interview	30.06.2020

3.6| Research area: The English North Sea coast

This research focuses on the English North Sea coast, which is of special interest due to the current within the North Sea. The counter clockwise oriented current is coming from North (Neumann et al., 2014) and might transport plastic items in the water southwards and eventually towards the coasts of the Netherlands, Germany and Denmark.

The flow of the current is visualized in Figure 7. Hence, plastic waste that enters the North Sea along the English coast might be washed ashore in one of these countries or travel further northwards. An accumulation on the surface waters has not been found yet (Neumann et al., 2014), therefore plastic it is most likely that plastic strands at the beach. Additionally, the English North Sea coast remains a research gap within the *Macroplastic* project as in the past only the Dutch and German North Sea coasts have been investigated.

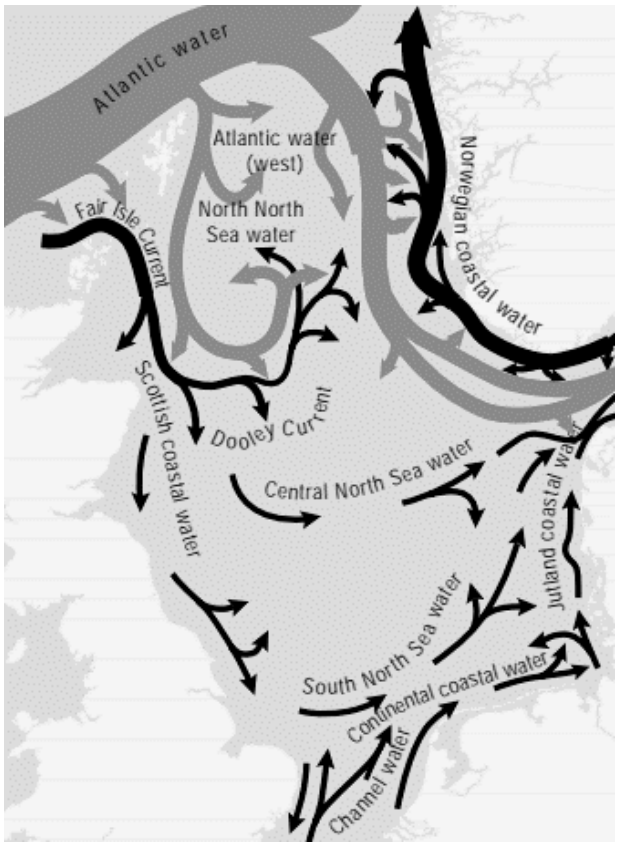

Figure 7 Schematic diagram of the currents in the North Sea (black arrows). Retrieved from: OSPAR (2000)

The research area entails 18 districts or local authority units and a total of six major harbours lies within the area (Fig. 8). In 2015, the British parliament introduced a fee for the usage of plastic bags, whereas England was the last country within the United Kingdom to implement this fee (Xanthos & Walker, 2017). In England, this fee was appointed a five pence levy, which resulted in a drop in the usage of plastic bags of 85 % within the first year, which equals approximately the usage of six billion fewer bags (Smithers, 2016). This shows in line with the reasoning in Chapter 2.3, that despite the complexity of the problem, simple solutions can show an effect. However, England's growing litter problem remains, as especially the numbers of littering of food wrappers and beverage cups by individuals and groups increased drastically (Rowe, 2019). It is estimated that the English authorities spent around 50 million GBP in 2014/15 to remove the damages of illegal waste dumping (Rowe, 2019). Statistics

also show the negative perception of people on plastic waste and the severe impacts on wildlife (Department for Environment, Food and Rural Affairs, 2019; Rowe, 2019). On beach clean-ups in 2016 on the English coast, 546 items of plastic were found per 100 m beach (Department for Environment, Food and Rural Affairs, 2019). These numbers show that England has a severe problem with plastic waste and potentially a large amount of plastics entering the marine environment. Hence, there is a need to identify the sources from where the plastic waste originates and what the underlying causes for littering are.

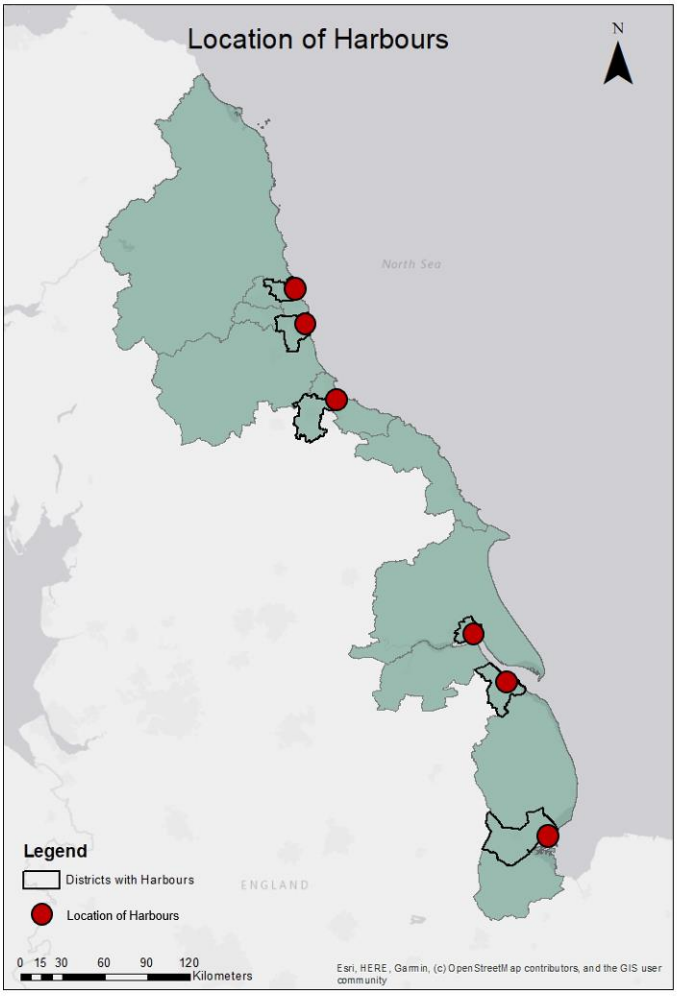

Figure 8 shows the location of the harbours in the districts belonging to the focus area (Map by author, data sources: see Ch. 3.2).

4| Results

This section will at first present the results of the quantitative analysis of this research. In the first section, the contributions for each category of land-use will be visualized in maps showing the research area and the districts within. Afterwards, a map combining the categories and the overall contribution of each municipality will be presented. The results of the interview will be presented in the last section.

4.1| Results of quantitative analysis

This section presents the results of the analysis of the statistical data for each category of land use.

Contribution tourism

The contribution of the tourism sector in each district is shown in Figure 9. According to the analysis, the highest degree of tourism activity can be found in the district of Northumberland, the most northern part of the research area, with almost 7 %. The second highest share of tourism activity is located around the River Tyne, including the districts of North and South Tyneside, Newcastle upon Tyne and Gateshead; followed closely of the most southern districts East Lindsey, Boston and South Holland, that score between six and 6,5 %. The least tourism activity can be found in the districts North and North East Lincolnshire, that have a share of around 4 %. It can be seen that the difference in tourism activity is only around 3 % comparing the highest to the lowest share. A detailed table of the distribution of tourism activity is provided in Appendix I.

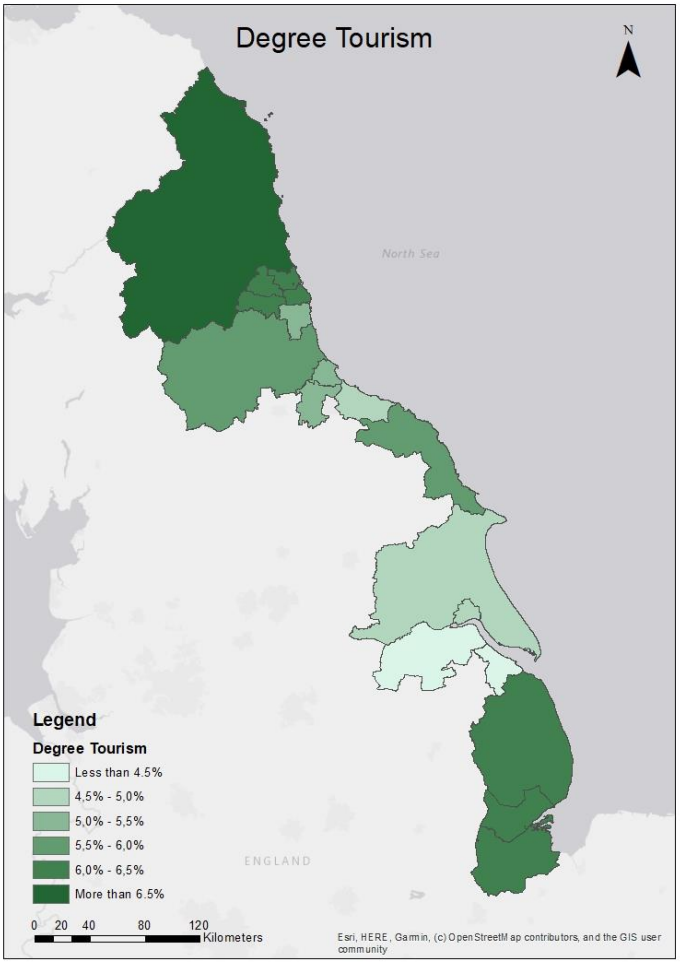

Figure 9 Map showing the degree of tourism activity in the research area. (Map by author, data sources: see Ch. 3.2).

Harbour activity

There are six relevant harbours in the research area (Fig. 8). Figure 10 shows the contribution of each district in the research area due to its affiliated harbours. The biggest share is located in the district of North East Lincolnshire, where the harbour of Grimsby & Immingham has been handling about 57,3 million tonnes in 2018. The smallest share, less than 1 %, can be found in the districts of Sunderland (Port of Sunderland) and Boston (Port of Boston), that have been handling 0,88 and 0,77 tonnes of freight in the same year. The complete dataset can be found in the table in Appendix II.

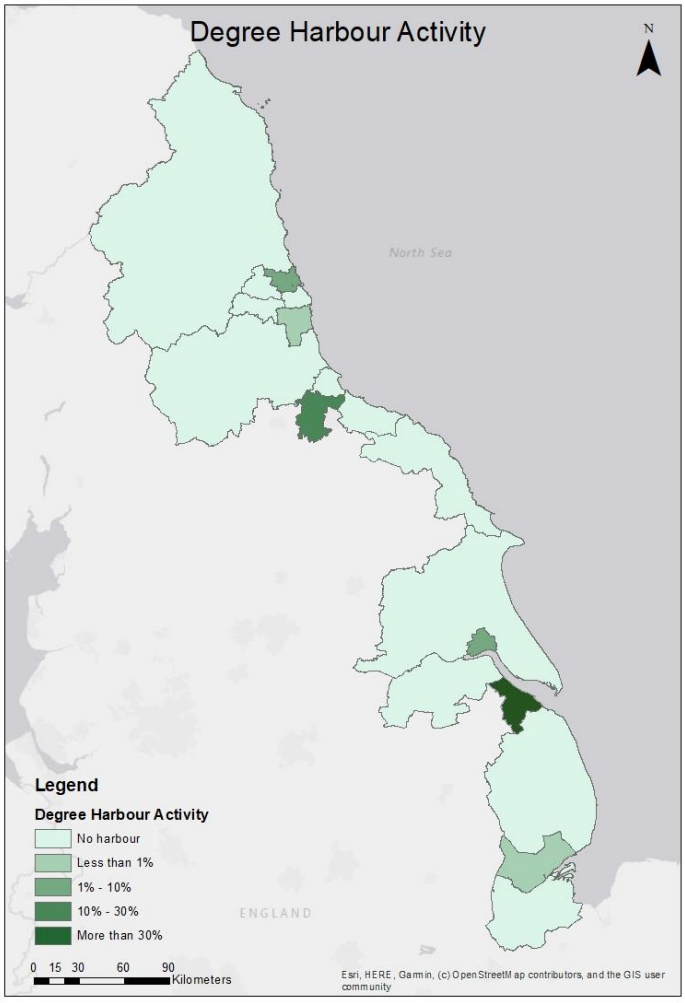

Figure 10 Map showing the degree of harbour activity in the research area (Map by author, data sources: see Ch. 3.2).

Land-based industry

The degree of land-based industry per district in shown in Figure 11. By far largest share of land-based industry can be found in the district of Northumberland, with a share of 35 %. This is mostly due to a large degree of agricultural activity in the district, which is around 62 % of all agricultural activity in the research region. The largest share in the subcategory of producing industry can be found in East Riding of Yorkshire, that holds around 11 % of all producing industry activity. The district Durham has an equally active agricultural and producing industry sector, allowing the Durham to score second after Northumberland with an overall share of 11 %. The districts of South Holland, Boston and South Tyneside, have the lowest share (less

than 2 %), mostly due to the low degree of agricultural activity (less than 0,3 %). The complete table for the category of land-based industry can be found in Appendix III.

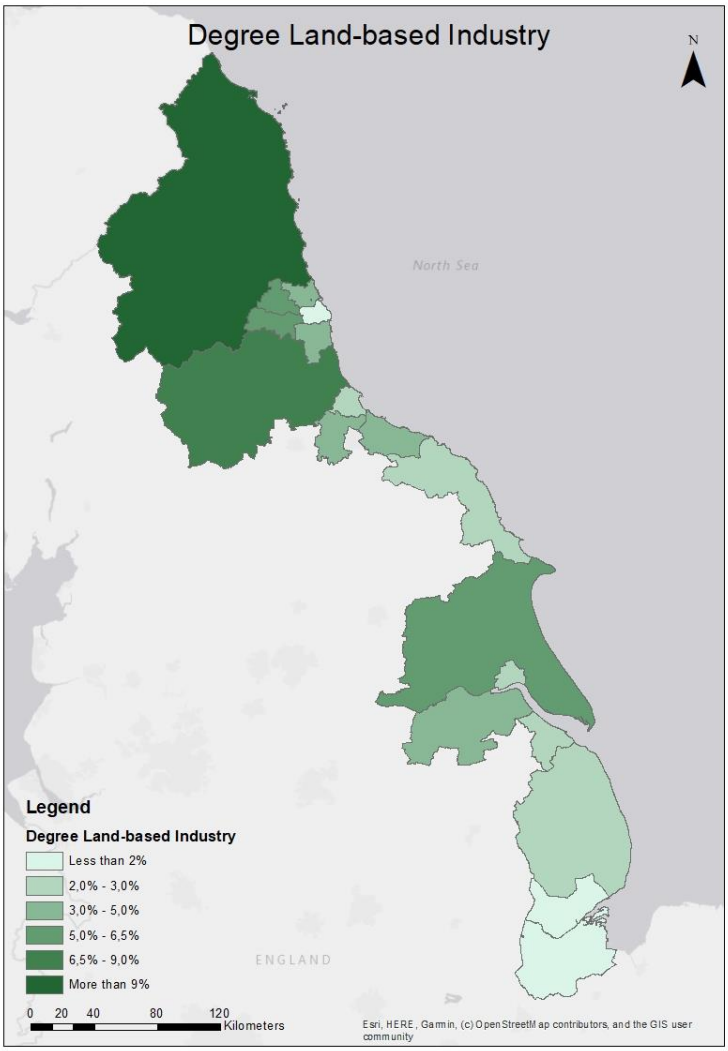

Figure 11 Map showing the degree of land-based industry in the research area (Map by author, data sources: see Ch. 3.2).

District contribution to waste

The degree of the contribution of the district to the overall waste is determined by the population. As shown in Figure 12, the largest population number can be found in East Riding of Yorkshire and Northumberland, with a share of more than 10 % of the research area. Following up are the districts Newcastle upon Tyne, Sunderland and Kingston upon Hull that have a share of more than 8 %. The lowest population numbers can be found in South Holland and Durham. The complete dataset for the population numbers and the contribution of each district can be found in Appendix IV.

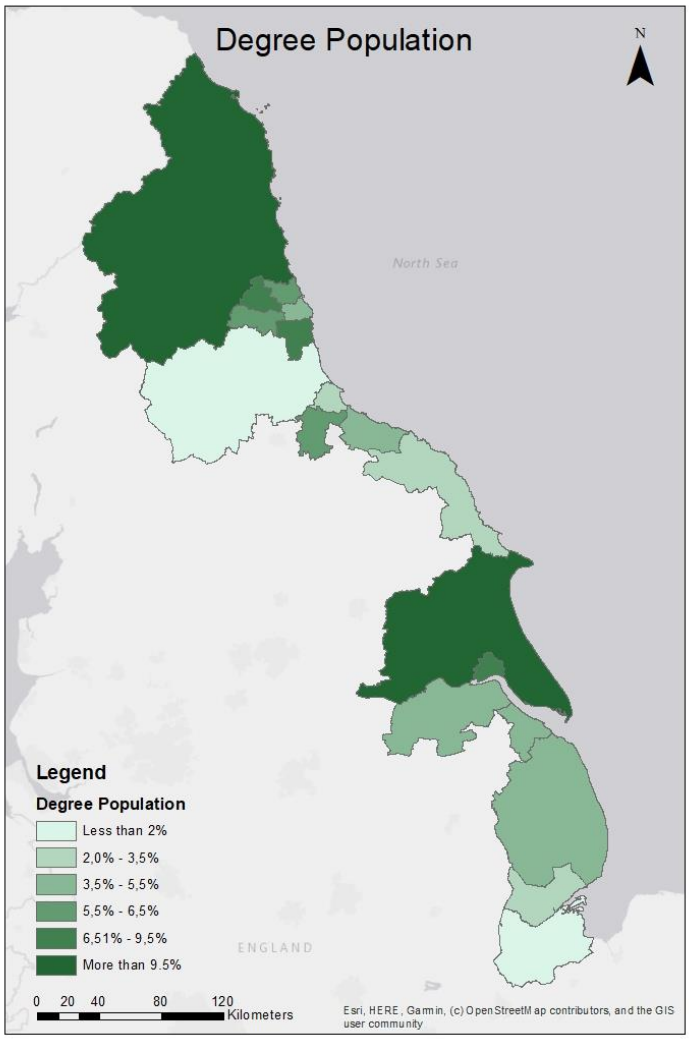

Figure 12 Map showing the degree of contribution by population in the research area (Map by author, data sources: see Ch. 3.2).

Overall contribution

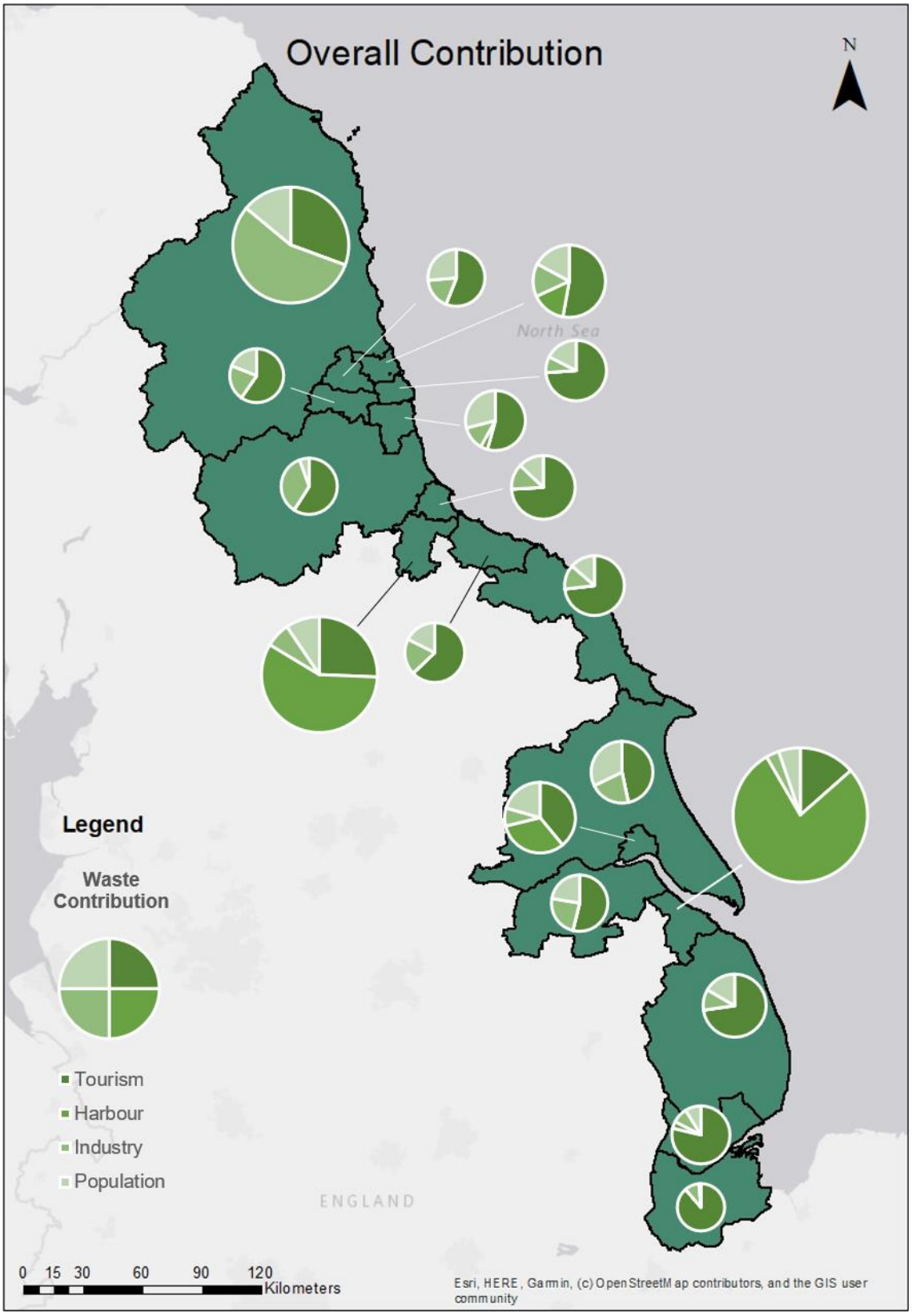

Figure 13 Map showing the overall contribution of all districts within the research area. For each district, the contributions of the four categories are visualized in a pie chart. The different sizes of the pie charts indicate the share of the district.

Figure 13 shows a combined map of the overall waste contribution of all categories within the districts. According to the analysis, the biggest contributor to the overall waste pollution is the district of North East Lincolnshire, with a share of over 14 %, followed by Northumberland (> 10 %) and Stockton-on-Tees (> 9 %). The high overall contribution in North East Lincolnshire comes from the high degree of harbour activity and its contribution to the overall waste pollution. Northumberland scores high due to its agricultural activity (Category *Land-based Industry*) and tourism activity. Stockton-on-Tee is as well a high contributor to the overall waste due to its harbour and tourism activity. The lowest contribution to the overall waste pollution comes from the districts of South Holland and Hartlepool. The contributions of all districts to all categories are summarized in Table 3.

Table 3 shows the contribution of each category within a district and the summed-up overall contribution per district [in %]. The districts are sorted by their degree of overall contribution (Descending: highest – lowest). The top 3 districts with the highest share of the overall contribution are highlighted in bold and are underlined.

District	Tourism	Harbour	Land-based industry	Population	Overall contribution
North East Lincolnshire	1,94	11,25	0,45	0,75	**14,39**
Northumberland	3,29	0,00	5,96	1,50	**10,76**
Stockton-on-Tees	2,50	5,66	0,67	0,93	**9,76**
Kingston upon Hull	2,32	1,91	0,49	1,22	5,94
North Tyneside	2,98	0,86	0,83	0,97	5,65
Newcastle upon Tyne	2,98	0,00	0,93	1,41	5,32
Gateshead	2,98	0,00	1,06	0,95	5,00
East Riding of Yorkshire	2,31	0,00	1,04	1,59	4,95
Sunderland	2,44	0,17	0,57	1,30	4,48
Durham	2,62	0,00	1,57	0,25	4,44
South Tyneside	2,98	0,00	0,35	0,71	4,03
East Lindsey	2,89	0,00	0,42	0,66	3,97
Scarborough	2,74	0,00	0,50	0,51	3,75
Boston	2,89	0,14	0,31	0,33	3,67
Redcar and Cleveland	2,29	0,00	0,71	0,64	3,64
North Lincolnshire	1,94	0,00	0,86	0,81	3,61
Hartlepool	2,50	0,00	0,44	0,44	3,38
South Holland	2,89	0,00	0,32	0,04	3,26

4.2| Results of qualitative analysis

This section presents the results of the qualitative approach and gives insights on the interviews that were conducted and the provided answers of the questionnaires. In total, five experts interviewed in order to gain insights on their personal problem perception, their particular opinion on the question of responsibility and on their assessment of people's general behaviour regarding the handling of plastic. Additionally, the research experts were asked to validate the scope of the represented categories as source of plastic pollution and to assess present regulations and possible mitigation strategies.

Perception of the problem

The results of the qualitative analysis show, that all participants and interviewees unanimously perceive marine plastic pollution as a problem that has to be tackled. The participants named different possible reasons for the question on where plastic might enter the marine environment. As a general problem it is perceived that people are not following the rules of correct waste disposal on the premises, this includes for example leaving waste disposal containers open. This can lead to plastic being carried away by wind or by animals. More generally, the use of single-use plastic is seen as the main reason for plastic entering the sea. The design of many products is the reason for the products or part of the product to inevitably end up in the environment when used. As an example, Interviewee 3 lists inter alia liquid plastic in cosmetic products, dolly ropes from bottom trawl fisheries and tyres, as the abrasion will be blown or washed away by wind, respectively rainfall runoff. Additionally, intentional littering and human ignorance is seen as a main reason by all participants, that can occur during all activities on the factory premise, harbour or in any other place. Littered plastic items can them be transported by natural forces such as storm water runoff or wind drift. Even though a representative of the industry sector states that plastic is controlled as far as possible on the factory premise, it is not in their control how

plastic is handled once it is collected by the garbage collectors, hence, it could end up anywhere.

On a broader perspective, Interviewee 3 states, that the reasons for plastic entering the marine environment depend on the context of the respective country. Different circumstances are apparent, such as laws and regulations on waste handling, the degree of enforcement of these regulations, as well as the waste management practices. Additionally, the awareness of the public and the socio-economic status of the country play an important role. It is also country-dependent, what kinds of land-uses are present and on a smaller local scale, to what degree those waste generating land-uses are contributing to the overall input of plastic into the sea. The four categories of land-use (tourism, harbour activity, municipal waste and land-based industry) as main contributors to the overall plastic input are confirmed by the research experts (Interviewee 3 and 5), even though, those are quite general categories. The four categories can be broken down into smaller sub-categories, in order to direct measures more precisely. For example, the category tourism could be further divided into beach visitors, gastronomy, accommodation and recreational activities (Interviewee 5). Moreover, the importance of the contribution of rivers as a source of plastic should not be ignored, as most of the mismanaged waste seems to be dumped along riverbanks (Interviewee 3).

The question of responsibility

The question on who should be held accountable for plastic pollution of the marine environment and who should be responsible for the enforcement of measures was raised. On a sectoral level, the harbour should be held accountable for plastic pollution, especially when it comes to the enforcement of the rules and regulations (Interviewee 4). A stricter implementation and execution of existing regulations may reduce the amount of littered plastic. Also, vessels and the captains should be included in the system and be regulated more strictly (Interviewee 4). Preferably, the

people or parties who littered should be responsible as well as the producers, which would result in more pressure to littering persons to end littering practices and at the same time push producers to rethink their product design. However, this needs a strict enforcement and needs a fining procedure:

"If the chance of being held accountable are so slim and the fines are so small that those responsible simply take the risk and carry on as usual, that won't do the trick" (Interviewee 3).

The format of regulations and the enforcement of those should take place on different levels of authority. The legal and regulatory framework to prevent plastic entering the marine environment should be introduced on an international level, as it is usually the higher the level the wider the spread (Interviewee 3, Interviewee 5). On the other hand, implementing and enforcing various measures to mitigate or prevent plastic input must take place on a regional or local level, in order to be able to consider the context-dependent small-scale circumstances.

In general, the whole society is responsible for plastic entering the marine environment and "[we] *need an increased awareness for this problem in the complete society on global a level"* (Interviewee 4).

Assessment of people's behaviour

In the interviewees' opinion, people's behaviour is one main reason for plastic entering the marine environment. Human ignorance of the regulations on one hand and the effects of plastic in the environment are part of the problem, even though a lack of awareness of the problem and impacts does not seem to be the issue. However, people seem not to care about the problem or do not want to change their behaviour in order to create an impact. Intentional littering occurs in all sectors, during all activities and in all places. One common practice is the dumping of cigarette subs, which is often not even realised as dumping waste anymore. Even though cigarette

subs contain plastic and other toxic substances, dumping occurs everywhere to a high degree.

"People don't even really notice stubs anymore. However, cigarette stubs are globally the most abundant type of litter item found" (Interviewee 3)

Regulations & strategies

Interviewee 3 does not see a lack of regulations but rather a lack of strict enforcement of the rules. Regulations exist for a range of activities, from for example the dumping of ship waste on-sea to smaller-scale issues, such as the mentioned example of cigarette subs. Continuing with this example, which is forbidden by legislation and can be fined, however it is mostly not reported to the police or punished.

Change needs to happen all over the globe and on all scales. As each region's geographical, cultural and economic setting differs, concrete measures on a local level are effective. Consequently, small-scale, local measures such as local bans of single-use plastic should be encouraged. Even though small-scale measures seem like a "mere drop in the ocean" (Interviewee 5), they have a large potential. 'Small' measures may not solve the whole problem of marine plastic pollution, but, in the end, the sum of local measures can have a large impact.

Strategies and measures to combat waste pollution are diverse and there is not 'the one' strategy. There is need for a range of hard and soft measures such as, inter alia, laws, regulations and adequate enforcement as well as, more suitable product designs, awareness rising and a need for rethinking the overall consumption (Interviewee 3).

5| Discussion and critical reflection

In this chapter, the results of the previous chapter will be combined and discussed in order to provide an answer to the main research question and sub-questions. Additionally, the research approach will be critically reflected and suggestions for improvements will be offered.

5.1| Finding sources of marine plastic

The results clearly show an uneven spread of sources of plastic over the different districts within the research area. Thus, identifying hot spot entry points is possible: the districts of Stockton-on-Tees and Northumberland contribute approximately double to the plastic pollution compared to the average of all districts, which is around 5,6 %. According to the analysis, the main contributor, the district of North East Lincolnshire, is responsible for almost triple of the average contribution. The district of Northumberland accounts for a high contribution due to its large size, which explains the high number of contributions from population. Additionally, tourism plays an important part in the overall contribution of this district. However, the high degree of agricultural activity is mainly responsible for the high score in the category of land-based industry. The districts of Stockton-on-Tees and North East Lincolnshire are scoring high due to harbour activity, as they combined have a handled freight tonnage of more than 85 million tonnes per year. This suggests, that harbours are relevant source of plastic waste input into the North Sea at the research area.

Even though tourism has, according to the ARSU data collection, supposedly the highest contribution to plastic input into the North Sea, on the first look it does not seem to be apparent in the research area, as tourism is not a decisive criterion in the hot spot areas. Tourism accounts for over 45 % of the overall contribution of the research area and the contribution is almost evenly distributed across the districts. In many districts, the tourism sector accounts for more than half of the overall contribution of the whole district, in some, for example South Holland and Boston, for

even more than three quarter. Albeit not being the most contributing districts in general, this is important to consider in order to keep tourism in focus for mitigation measures, even though the sector does not seem to be an important factor in determining the three top contributing districts.

To sum up, the combined overall contribution map in Fig. 13 helps to visualize the degree of which each category of land-use in each district contributes to the overall emission of plastic. With a focus on providing an answer to sub-question III (What type of land-use contributes most?) it can be said, that tourism has the highest contribution, however, it seems also evident that the degree of harbour activity is more decisive in regard to forming a "hotspot", the presence of a harbour and degree of its contribution is not evenly spread across the area.

5.2| The importance of data quality

The most decisive criterion of the quantitative analysis is the quality of the indicator data, as it must provide a realistic image of the situation in the region, and optimally, the same data needs to be available within the research region. However, in this research the availability of data is a significant limitation factor on the quality of the results. This is especially apparent in the category of tourism. The analysis of the contribution of the tourism sector solely relies on the number of employees within this sector, disregarding the impacts of day-trip tourists, beach visitors or overnight stays due to unavailability of coherent datasets. As day-trip tourists or beach visitors do not necessarily have an impact on the number of employees in the tourism sector in the respective location they visit, these niche-categories have to be considered, in order to improve the quality of the analysis. This is especially important, as the contribution of the category of tourism accounts for almost 50 % of all waste from land-based activity.

Another point that has not been considered is possible movement patterns of tourists, as they might not be limited to one location but rather move around across

several districts. As tourists or visitors move around, they also have an impact on the waste contribution of the population within the district, as visitors use public disposal systems or add to the household waste of local people they are visiting. Hence, it could be beneficial to include overnight stays of visitors into the indicator data in order to create a more precise image of the situation. The problematic with the indicator data is also applicable in the category of port activity. Even though, transported freight is a valid and beneficial choice, it leaves out the possible generation of waste due the operation of ferries. Moreover, sub-categories within the harbour operation need further research, such as the degree to which ship maintenance contributes to the overall waste production at harbours. Therefore, it has to be considered that the precision and quality of the quantitative analysis is limited due to knowledge gaps about the contribution of niche categories and the lack of data availability. Yet, even though the limits of the model have to be acknowledged, it still offers a possibility to show the distribution of waste generating land-uses and possible displays hotspot entry points of plastic. This can be helpful as a starting point for governance approaches in order to reduce the contribution of certain sectors or regions.

5.3| How to tackle marine plastic pollution

This research is aiming at the identification of hotspot entry points and gaining insights for an improved management of marine plastic pollution. In order to answer the first part of the research question

"Where on the English North Sea coast are the "hotspot" entry points for macroplastic into the marine environment and what insights can be gained to improve coastal waste management?"

extended pollution map sheds light on the areas that contribute the most to plastic pollution. The districts of North East Lincolnshire, Northumberland and Stockton-on-Tees have eligible criteria to count as "hotspot" entry points, as they contribute to the overall pollution to a high degree and a diversity of categories are responsible for the

contribution of the districts. This identification creates a degree of certainty about the origins of marine macroplastic from land-based sources within the researched area. The identification of sources is a valuable step in order to implement strategies to reduce plastic pollution and to identify mitigation objectives (Pettipas et al., 2016). In order to improve the accuracy of source identification it is needed, that high quality indicator data is provided. Without sufficient data availability, the search for sources lacks precision and the results have to be carefully evaluated.

The qualitative analysis provided insights on how planning for and the management of plastic waste could be improved. A mutual perception of the interviewees is the lack of conscious behaviour of people when it comes to handling plastic waste. Intentional littering and human ignorance are seen as the main reasons of plastic entering the (marine) environment. During the interviews with the research experts, it was mentioned that generally, there does not seem to be a lack of regulation, rather a lack of enforcement. However, for the case in this research, Van Sebille et al. (2016) identified a lack of legislation that sufficiently regulates land-based sources of plastic input into the marine environment. Although international and European legislation are set up, an extensive policy response remains absent (Van Sebille et al., 2016). Therefore, it seems evident that the formal institutions in research region are not sufficient or not sufficiently implemented and policies are needed that aim at source reduction. Additionally, a strict enforcement of regulations needs to have a high priority. Moreover, it seems crucial to address human behaviour by drawing attention to the topic again, with a special focus to deeply embedded behavioural patterns and ‘business as usual’ practices such as dumping cigarette stubs. If people are more aware of the impact of their actions and misbehaviour is sufficiently fined, it might change their overall behaviour. The research aimed at identifying the underlying institutional context and it was possible to hint at informal institutions, however, more research with the inclusion of more stakeholders is needed in order to create a better picture.

Knowledge about the sources and the responsible sectors are crucial for concepts such as ‘correction at source’ or the ‘polluter pays’ principle. Therefore, this research can be seen as an important starting point for policymakers, as it reduces the uncertainty about possible entry points for plastic into the marine environment. However, complexity remains regarding the next steps that must be taken in order to tackle the plastic pollution. As still many stakeholders are involved in the area and even within a sector, a solely top-down planning approach with standardised policies will probably not achieve the desired result. As an example, the bans on single-use plastic in a certain region, enforced by governments or higher level of authority, can obviously have an impact if enforced correctly, however, this strategy will not solve the problem, as it remains a complex global issue. Still, developing policies in the area with the highest degree of contribution is inevitable and the design and implementation has to occur locally, within a participatory approach in order to address remaining uncertainties.

Generally, it is essential to identify the regions and sectors that are responsible for pollution in order to propose mitigation and prevention strategies and measure. However, not only the polluter alone is suggested to be responsible. A preferred solution would also include the producers in the question of responsibility, in line with the concept of extended polluter responsibility. Current research points at the importance of taking the local context into account, meaning that legislation and regulatory frameworks should be launched at an international level but implemented at a local level (Adam et al., 2020; Wu, 2020). Even though plastic pollution is a global issue, marine plastic is the result of local circumstances and the lack of proper local regulations and institutions (Alpizar et al., 2020). This takes small-scale, local circumstances into account, as it has to be considered that many countries or regions are not on the same level when it comes to establishing mitigation actions (Adam et al., 2020). Successful implementation and evaluation of measures should be a bottom-up procedure in order to tackle ignorance of the problem and create inclusionary problem perception. However, solely local action will not be adequately effective, they

have to be backed up by comprehensive global policies (Alpizar et al., 2020). A mixture of regulations, policies and market-based instruments, implemented in the specific local context, is seen to have the most successful outcome (Alpizar et al., 2020). In combination with other soft measures, such as awareness campaigns and education, the problem can be tackled from the both sides, economy and society.

Yet, as policymakers often develop solutions that do not grasp the entire scope of the problem (Alpizar et al., 2020), further research is needed, especially in terms of origins and distribution of marine plastic, the amount of already emitted plastic and where it ended up (Pettipas et al., 2016).

5.4| Reflection on quantitative analysis

The quantitative part aimed at an analysis of statistical data of the contributions of different districts and sectors. The method itself worked as intended and offered a great opportunity for the comparison of districts within the research area but also to make different areas comparable. However, the indicators used in the quantitative approach are much open to discussion and criticism. Especially problematic is the limited knowledge about niche activities, which leads to less precise data and analyses. This factor needs improvement and further research into the occurrence of different niches and their contribution in order to improve the accuracy of the research. This research considered four categories of land-use in the research area. To further improve the accuracy of the analysis, additional research into other potential land-use categories could prove useful.

A second point of criticism is the overall data availability. Finding the data for all indicators on the same level of authority proved to be particularly challenging during the process of data collection. This procedure was time consuming and at the end an impossible endeavour. Eventually, it was decided to use data on a different scale and assumed that the data is equally distributed within the higher level of authority. As this is only an assumption, the data and following analysis might lack

accuracy. Hence, there is a need for better data on the desired level of authority in order to improve the process and provide a more accurate analysis. However, the used method and analysis still provides and good overview of the different contributions of sectors and districts.

5.5| Reflection on qualitative analysis

The qualitative analysis of this research was hampered by the unexpected outbreak of the corona virus, which lead to special circumstances in the research region and hence affected the data collection. Difficulties emerged regarding the availability of experts for the interviews, especially in the field of harbour operators and the tourism sector. Potential interviewees in these fields lacked responsiveness to posed interview request. This was probably due to being occupied with other task or because they were simply not able to work during the period of lockdown and due to other safety measures in the focus area. Unfortunately, these lockdown situations appeared exactly during the time of data collection. This difficulty in finding interviewees lead to a change in approaches, resulting in sending out questionnaire to chosen experts in the research region and including experts from outside the focus area for data collection. The advantage of questionnaires is, that they are less time consuming for the questioned person and no appointment has to be scheduled. This means more flexibility for the questioned expert and the possibility to contribute to the research even in those special circumstances. However, questionnaires lack the direct exchange and visual contact, that is apparent during interviews and the provided answers might therefore miss emotions. Additionally, possible additional questions or clarifications that might come up during an interview cannot be answered with a questionnaire. Written answers in the questionnaire are often shorten and only provide basic information, whereas it is more desired to gather detailed information with personal perceptions. Still, due to the special circumstances, the choice of

questionnaires proved to be an appreciated alternative to interviews and enabled data collection within the research area.

It was decided to include experts from outside the research area with the intention of adding additional data and insights. The experts were carefully chosen by their professional position and expertise, and it was made sure that they are frequently interacting with their respective sector in the research area or can otherwise provide useful information in order to answer the research question. Still, it has to be considered that experts from outside the research area lack the specific local knowledge, which is definitely a limitation to this research. As especially local knowledge is a crucial factor in order to give recommendations for governance, it would be an improvement for following research to improve upon this. Yet, the decision to include these experts proved to add valuable information to the research, that would not have been possible to gather in the special circumstances.

5.6| Reflection of personal process

In additional to the reflections on the theoretical foundation and the research approach, it is also valuable to reflect on the individual process conducting this study.

Generally, it might have been beneficial to reach out and approach experts at an earlier point during this research. Having more time available, it could have been possible to find more participants and interviewees despite the special circumstances. Moreover, for future research it would be advantageous for the qualitative data collection to include more experts and stakeholders from within the research area in order to maximize the provision of local knowledge from different angles and viewpoints. Yet, even though not everything worked out perfectly as planned, the process of this research highlighted my own adaptive capacity and I was able to adapt my methodology to the circumstances. It shows that, not only for planning processes but also for research and in this case writing a thesis, being adaptive is necessary in order to deal with uncertainty. Furthermore, in the beginning of the collection of

quantitative data, much time was wasted on trying to find the perfect datasets. It shows, that sometimes it is important to set ambitions aside under circumstances of a limited timeframe and focus on what is manageable and can deliver the desired results. The completion of this research shows however, that time management was successful and good results were achieved.

5.7| Outlook and opportunities for further research

After the limitations of the research have been presented, this section offers a look into the future and provides opportunities for further research. For the researched case of the English North Sea coast, it could be interesting to extend the research area and take more districts into account. This would create a more extensive overview of the region and also take river catchment areas into account, that have been left out in this research. However, rivers play an important role in transporting plastic towards the marine environment and can be seen as a major source of plastic. Additionally, more research could be conducted on an even more local level, looking more precisely into each district. If different, more local hotspots of plastic waste could be identified, it would help to design policies to mitigate plastic pollution more precisely and even more tailor-made to the local context. In order to gain more insights on a broader scale, the research could be repeated in different areas, for example whole North Sea area or in a completely different region on the globe, in order to be able to compare regions and show similarities or differences. However, this would need adjusted indicator data in order to be able to mirror the regional circumstances.

More research into the quality of indicator data is required, especially into niches and sub-categories. Deeper knowledge of the existent niches and more information about additional categories and their impact to the overall contribution would be available would significantly increase the accuracy of the methodology. Hence, a repetition of this research would be beneficial and more precise once more knowledge is available.

6| Concluding thoughts

This research aimed at unravelling the origins of plastic waste along the English North Sea coast, with a focus on determining where hotspots for plastic input into the marine environment might be and how waste management can be improved in order to mitigate further pollution. The research area was geographically determined to stretch from the district of Northumberland in the North and the district of South Holland in the South. Four categories of land-use have been considered for the quantitative analysis: tourism, harbour activity, land-based industry and population. The main contribution comes from the three districts: North East Lincolnshire (14,30 %), Northumberland (10,76 %) and Stockton-on-Tees (9,76 %), contributing almost triple (North East Lincolnshire), respectively double (Northumberland and Stockton-on-Tees) to the average of all districts. The identification of entry hotspots can be used as a starting point for tackling plastic pollution at the source before plastic can enter the marine environment.

The main objective of this research in identifying the origins of marine plastic from land-based sources has been a successful endeavour. The applied method on analysing indicator data and generating a map was useful and provided the desired outcome. However, the precision of the results is limited due to a lack of data availability and quality of chosen indicators. The used methodology allows to identify the distribution of sources and the degree of contribution across the research area. Therefore, the method is certainly eligible to also be applied in other regions, countries and contexts, although the indicator data might need to be adapted to regional circumstances.

The second objective of this research was to gain insights in order to improve the management of marine plastic pollution. The generated pollution map can be used as a starting point for measures aiming at source reduction, inter alia the concept of ‘correction at source’ or the ‘polluter-pays’ principle. In order to address the

uncertainty arising with problem of plastic pollution, interviews with research experts and representatives have been conducted to gain insights on the local circumstances and possible mitigation strategies. This qualitative approach enabled the gathering of qualitative data, showing people's perception and opinion on the problem. Intentional littering is perceived as one main reason for plastic entering the marine environment as well as human ignorance, that can occur in all sectors, during all activities and in all circumstances.

This research adds to the overall scientific discourse on the topic of marine plastic pollution and especially fills a research gap on the case of the English North Sea coast. This is especially useful, as it adds to a broader research project. In combination with other studies from the project, an extensive overview of the sources of plastic in the whole North Sea area can be provided. Moreover, it contributes to planning theory, as it provides insights on how to deal with complex problems. As it is often discussed that complex problems need complex solutions, it is argued, that simple solutions should not be neglected as a contributing factor to addressing complexity, even though they will not solve the problem itself. As the ban of single use plastic bags underlines, simple solutions can function if they are enforced and in sum, these solutions have an impact.

In order to tackle plastic from entering the marine environment, several mitigation and prevention strategies are being researched, however, there is no one-fits-all solution. Marine plastic pollution is ubiquitous and a global problem but the reasons for plastic entering the marine environment are deeply context dependent. Therefore, legislation and regulatory frameworks should be set up on an international level and the enforcement and implementation of measures must occur locally, keeping the specific local circumstances in mind. In the researched case, there are currently no comprehensive policies in line to mitigate plastic input from land-based sources. Hence, there is a need for the design and enforcement of regulations in order to reach are more successful waste management. In order to address marine plastic pollution, a range of measures need to be implemented that necessitates coordinated

and cooperative approaches across sectors and stakeholders. These measures include a combination of hard and soft actions that contribute to source reduction of plastic waste. Actions include laws and regulations, their enforcement, as well as awareness raising campaigns and effective clean-ups, in order to protect the coastline and the marine environment from more damage. On the long-term, it is inevitable to rethink economical structures and consumption and product design if the problem of plastic should be solved. Moreover, more research is needed to identify sources, pathways and distribution of marine plastic in order to create more effective mitigation and prevention policies.

However, regarding the speed of plastic accumulating in the oceans and the estimated growth rate of plastic input into the marine environment it is crucial to act fast and make sure the topic does not disappear from the political agenda, even in the time of other crises.

7| Literature

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8| Appendix

Appendix I – Tourism

District North-South	Employees tot.	Employees tourism [%]	Degree tourism activity [%]	Contribution to tot. waste in [%]
Northumberland	141700	11,63	6,93	3,29
North Tyneside	98490	10,53	6,28	2,98
South Tyneside	64928	10,53	6,28	2,98
Newcastle upon Tyne	136657	10,53	6,28	2,98
Gateshead	95850	10,53	6,28	2,98
Sunderland	126964	8,6	5,13	2,44
Durham	238051	9,26	5,52	2,62
Hartlepool	36323	8,84	5,27	2,50
Stockton-on-Tees	88219	8,84	5,27	2,50
Redcar and Cleveland	56281	8,1	4,83	2,29
Scarborough	288321	9,69	5,78	2,74
East Riding of Yorkshire	159265	8,16	4,86	2,31
Kingston upon Hull	118947	8,19	4,88	2,32
North Lincolnshire	79258	6,86	4,09	1,94
North East Lincolnshire	70226	6,86	4,09	1,94
East Lindsey	349351	10,2	6,08	2,89
Boston	349351	10,2	6,08	2,89
South Holland	349351	10,2	6,08	2,89

Appendix II – Harbour

District North-South	Freight tonnage tot 2018 (in million t)	Degree Harbour activity [%]	Contribution to tot. waste [%]
Northumberland	0,00	0	0,00
North Tyneside (Port of Tyne)	4,4	4,32	0,86
South Tyneside	0	0	0,00
Newcastle upon Tyne	0	0	0,00
Gateshead	0	0	0,00
Sunderland	0,88	0,86	0,17
Durham	0	0	0,00
Hartlepool	0	0	0,00
Stockton-on-Tees	28,85	28,31	5,66
Redcar and Cleveland	0	0	0,00
Scarborough	0	0	0,00
East Riding of Yorkshire	0	0	0,00
Kingston upon Hull	9,75	9,57	1,91
North Lincolnshire	0	0	0,00
North East Lincolnshire	57,3	56,23	11,25
East Lindsey	0	0	0,00
Boston	0,72	0,71	0,14
South Holland	0	0	0,00

Appendix III – Land-based Industry

a) Industry

District North-South	Employees tot.	Employment industry sector [%]	Employees Industry sector tot.	Degree Industry employment [%]	Area Industry [ha]	Degree Industry Area [%]	Deg.Ind. both [%]
Northumberland	141700	10,84	15361	4,43	2046,919411	7,90	6,16
North Tyneside	98490	9,22	9080	3,77	1031,994553	3,98	3,87
South Tyneside	64928	13,94	9051	5,69	447,3084003	1,73	3,71
Newcastle upon Tyne	136657	9,72	13283	3,97	1523,58689	5,88	4,93
Gateshead	95850	10,68	10240	4,36	1558,47632	6,02	5,19
Sunderland	126964	15,80	20066	6,46	1554,246872	6,00	6,23
Durham	238051	16,20	38565	6,62	2129,053502	8,22	7,42
Hartlepool	36323	17,39	6317	7,10	671,3046595	2,59	4,85
Stockton-on-Tees	88219	12,58	11095	5,14	2411,251976	9,31	7,22
Redcar and Cleveland	56281	14,90	8388	6,09	1533,182104	5,92	6,00
Scarborough	288321	11,66	33626	4,76	189,1567016	0,73	2,75
East Riding of Yorkshire	159265	15,21	24224	6,21	3807,446874	14,70	10,45
Kingston upon Hull	118947	12,87	15310	5,26	1521,431585	5,87	5,56
North Lincolnshire	79258	15,29	12118	6,24	3285,386978	12,68	9,46
North East Lincolnshire	70226	15,54	10911	6,35	966,8063967	3,73	5,04
East Lindsey	349351	14,33	50052	5,85	495,999222	1,91	3,88
Boston	349351	14,33	50052	5,85	336,524719	1,30	3,58
South Holland	349351	14,33	50052	5,85	397,423881	1,53	3,69

b) Agriculture + Industry & Agriculture Combined

District North-South	Area Agriculture [ha]	Degree Agriculture [%]	Degree Agriculture + Industry [%]	Overall Contribution [%]
Northumberland	745027,8719	61,97	34,07	5,96
North Tyneside	68031,32969	5,66	4,77	0,83
South Tyneside	3233,484146	0,27	1,99	0,35
Newcastle upon Tyne	69148,50671	5,75	5,34	0,93
Gateshead	83819,51756	6,97	6,08	1,06
Sunderland	3750,510152	0,31	3,27	0,57
Durham	126654,0615	10,54	8,98	1,57
Hartlepool	1713,018646	0,14	2,49	0,44
Stockton-on-Tees	5404,565626	0,45	3,84	0,67
Redcar and Cleveland	25217,5794	2,10	4,05	0,71
Scarborough	35504,0835	2,95	2,85	0,50
East Riding of Yorkshire	17509,81497	1,46	5,96	1,04
Kingston upon Hull	226,4576837	0,02	2,79	0,49
North Lincolnshire	3909,78002	0,33	4,89	0,86
North East Lincolnshire	1607,892347	0,13	2,59	0,45
East Lindsey	11197,57963	0,93	2,41	0,42
Boston	135,7747923	0,01	1,79	0,31
South Holland	127,2331311	0,01	1,85	0,32

Appendix IV – Population

District North-South	tot. Population in million	Degree pop. [%]	Contribution to tot. waste [%]
Northumberland	3,20274	10,02	1,50
North Tyneside	2,05985	6,44	0,97
South Tyneside	1,50265	4,70	0,71
Newcastle upon Tyne	3,00196	9,39	1,41
Gateshead	2,02508	6,33	0,95
Sunderland	2,77417	8,68	1,30
Durham	0,52698	1,65	0,25
Hartlepool	0,93242	2,92	0,44
Stockton-on-Tees	1,97213	6,17	0,93
Redcar and Cleveland	1,36718	4,28	0,64
Scarborough	1,08736	3,40	0,51
East Riding of Yorkshire	3,39614	10,62	1,59
Kingston upon Hull	2,60645	8,15	1,22
North Lincolnshire	1,72005	5,38	0,81
North East Lincolnshire	1,59821	5,00	0,75
East Lindsey	1,40741	4,40	0,66
Boston	0,69366	2,17	0,33
South Holland	0,09398	0,29	0,04

Appendix V – Combined Contribution

(Sorted by degree of contribution)

District	Tourism	Harbour	Land-based Industry	Population	Overall Contribution
North East Lincolnshire	1,94	11,25	0,45	0,75	**14,39**
Northumberland	3,29	0,00	5,96	1,50	**10,76**
Stockton-on-Tees	2,50	5,66	0,67	0,93	**9,76**
Kingston upon Hull	2,32	1,91	0,49	1,22	**5,94**
North Tyneside	2,98	0,86	0,83	0,97	**5,65**
Newcastle upon Tyne	2,98	0,00	0,93	1,41	**5,32**
Gateshead	2,98	0,00	1,06	0,95	**5,00**
East Riding of Yorkshire	2,31	0,00	1,04	1,59	**4,95**
Sunderland	2,44	0,17	0,57	1,30	**4,48**
Durham	2,62	0,00	1,57	0,25	**4,44**
South Tyneside	2,98	0,00	0,35	0,71	**4,03**
East Lindsey	2,89	0,00	0,42	0,66	**3,97**
Scarborough	2,74	0,00	0,50	0,51	**3,75**
Boston	2,89	0,14	0,31	0,33	**3,67**
Redcar and Cleveland	2,29	0,00	0,71	0,64	**3,64**
North Lincolnshire	1,94	0,00	0,86	0,81	**3,61**
Hartlepool	2,50	0,00	0,44	0,44	**3,38**
South Holland	2,89	0,00	0,32	0,04	**3,26**

Appendix VI – Interview Guide and Questionnaires

a) Interview Guide/ Questionnaire Research Expert

1) Do you perceive marine plastic pollution as a problem?
2) Would you confirm the following categories as the main land-based sources of marine plastic?
    - Tourism
    - Household waste
    - Harbour activity
    - Land-based industry (including agriculture)
3) What are in your opinion the main reasons for plastic entering the ocean?
4) What are the most important regulations for marine litter?
5) Where do you see a lack of regulations?
6) Who do you think should be held responsible for marine plastic pollution?
7) On which level of authority should prevention/mitigation measures be enforced?
8) Which strategies for the reduction of marine plastic pollutions would you suggest?

b) Interview guide/ Questionnaire Harbour & Industry

1) Do you perceive marine plastic pollution as a problem?
2) What is in your opinion the main reason for plastic entering the marine environment?
3) How is waste handled on the factory premise? (*Industry)* / How is waste handled during harbour operation activities? *(Harbour)*
4) During which activity could plastic escape the waste management system and enter the marine environment?
5) Have you been informed by your employer on how to handle waste at your workspace? / Do you inform your employees on how to handle waste at the workspace?
6) In your opinion, who should be held accountable for plastic input into the ocean and furthermore who should take responsibility to act upon the problem?
7) How would you assess people's behaviour when it comes to handling plastic waste?