Sources of Marine Plastic Pollution:

Searching for hotspots and the role of harbours in marine plastic pollution at the Dutch Wadden Sea Coast

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Declaration of Authorship

I hereby declare that I have authored this thesis independently, that I have not used other sources or resources than I declared, and that I have marked all passages which have been quoted either literally or by content from the sources used.

Abstract

The topic of marine plastic pollution has been gaining traction in the last years. Still the research into the sources from which the problem stems is lacking. The lack of knowledge makes an appropriate approach of governing the field of environmental management difficult. It poses the question how much centralization is necessary to address marine pollution. This research contributes to the topic by firstly developing a tool that is able to identify the main sources of plastic, called hotspots here, on a stretch of coastline, based on the spread of human activity. Secondly it is exploring the implications and possible input streams of plastic that stem from the area of port operation. The overall focus is put on macro plastic particles, that have a size of more than 5 millimeters, and solely on land based activity as sea based pollution far more diffuse in its spread.
To do this a Mixed Method Research (MMR) approach has been chosen that combines the statistical data used to search for the hotspots with the experiences of practitioners that are gathered in interviews. The statistical search focused roughly on the Dutch Wadden Sea coast. A study by the "Arbeitsgruppe für regionale Struktur- und Umweltforschung"(ARSU) determined the probability with which a plastic particle found in a beach cleanup originates from what human activity. The results of this study indicate five main forms of land use that contribute to the pollution of the ocean with macro plastic objects. The categories are tourism, port operation, land based industry, mismanaged municipal waste and storm-water overflows. Indicators are then attached to the categories and their spread over the study area is mapped with the help of Geo Information Systems (GIS). By connecting the spread of the categories with their contribution it is calculated where on the coastline hotspots are situated. This approach provided two very clear hotspots on the island of Texel and in the city of Delfzijl. Delfzijl is also the main port in the area and therefor the focus of the search for the waste sources within the harbour. An interview with the port authority was conducted that provided valuable insights into the internal governance of plastic waste. The main sources of waste are the handling of ship waste within the port, the mismanagement of water side plastic debris, ship maintenance and leftovers from the repair of fishing gear.
Still it is not warranted that the port itself is the main source of plastic due to authority not only being aware of the plastic sources but also actively addressing them. This uncertainty is furthered by imprecision that is caused by the transfer of the ARSU study from the German to the Dutch context.
While the information on the specific case of the harbour of Delfzijl is to a degree inconclusive, the overall map of hotspots and the main sources of plastic have been identified. In the future a systematic use of the employed tool could lead to a governance model that reduces the pollution of the ocean with plastic debris. The reduction is based in addressing what is commonly known as the tragedy of the commons through uncovering what areas and activities are responsible for the pollution.

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Acronyms

ARSU Arbeitsgruppe für regionale Struktur- und Umweltforschung GMBH

CBS Centraal Bureau voor de Statistiek

ESPO European Sea Ports Organization

EU European Union

GIS Geo Information Systems

IMO International Maritime Organization

MARPOL International Convention for the Prevention of Pollution for Ships

MMR Mixed Method Research

MSFD Marine Strategy Framework Directive

OSPAR Convention for the Protection of the Marine Environment of the North-East Atlantic

UNESCO United Nations Educational, Scientific and Cultural Organization

WFD Water Framework Directive

1 Introduction

The problem of marine plastic pollution has gained a lot of public attention in the last years. Since the discovery of the big pacific patches in 2001 and the detection of micro plastic particles in every link of the food-chain in the 1990s (Ryan 2015) the topic is becoming increasingly important, not only for scientists and ecologist but also for politicians and the greater public.
This development is in line with a general rise in awareness for environmental issues. Since the 1970s environmental protection has become an increasingly important field of governance. The early governance has been largely in the hands of governments that force regulation as a reaction to the occurrence of environmental disasters (Mol 2016). From the mid 1980s it became obvious that this mode of governance only served to patch and repair weak spots after the damage had been done. This lead to rising demands for proactive governance (Lemos and Agrawal 2006; Mol 2016). In the process of trying to find ways to prevent environmental damage in the future it became very obvious that it is often not easy to locate the true origin of the problems. Possible solutions to environmental problems bring major implications for other fields like society or economy (Reed 2008Jordan 2008).
On a time scale this also coincides with what is called the communicative turn in spatial planning (Healey 1996). Before the turn, planning was mostly accounting for objective facts, after subjective believes and ideas became relevant for developing society. Instead of the strong state that regulates everything through "command and control", the role of more localized and community based groups gained importance (Lemos and Agrawal 2006). It was recognized that the most effective strategies to combat environmental problems can be found on a local scale. Still localization brings its own set of problems, that need to be addressed through a shared framework (Zuidema 2016). Many of the problems are bound to the uncertainty of where the environmental issues actually originate (Chen 2015). Finding the origins can help in determining where the boundaries between centralization and decentralization need to be drawn. That is where this research will try to contribute to the field of marine pollution prevention, by exploring how to redesign the planning and governance of plastic waste in the future.
Even though the problem of plastic pollution is broadly recognized, research and knowledge on the issue is lacking behind (DM Fleet et al. 2017; François Galgani, Hanke, and Maes 2015). While the spread through the ocean system is correlated with the normal movement of water-bodies is a very complex issue because small shifts in wind or wave action can lead to an enormous change in transport direction(Ryan et al. 2009; Neumann, Callies, and Matthies 2014). This has lead to

plastic objects being found on every shoreline of the planet, from remote Pacific islands to the shores of Antarctica human made debris can be found (Barnes et al. 2009).

Even more dubious than the transport vectors are the sources that release the plastic into the ocean. The movement patterns are unpredictable, what makes it difficult to track the origin of the debris. At the same time the processes on land are also dubious, proposing the question where the plastic actually does come from. This is the main issue that will be further explored over the next chapters, it will be done by reversing the equation. Instead of following the particles back to where they originate, the idea is to take a look into the human activities that are responsible for the pollution and how they are spread out. To do this the research "Erfassung der Quellen der Mülleinträge ins Meer an der deutschen Nordseeküste: Praxisanwendung der Matrix-Scoring-Methode" (Schäfer, Scheele, and Papenjohann 2019) that has been undertaken by the "Arbeitsgruppe für regionale Struktur- und Umweltforschung GMBH (ARSU)" will be utilized. It used a matrix scoring method for analyzing beach litter found on a number of German beaches and linking the found objects to different human activities. The goal will be to use the outcomes of that study, in order to map, where on the coastline of the southern North Sea the main sources of plastic pollution are located. This is done for a start on the regional, coastal level to determine what areas are of interest for further research. This work, as an offer from the macro plastics project from the University of Oldenburg aims to quantify the influx of plastic pollution into the north sea. Right now data on this topic is based mainly on estimations (Jambeck et al. 2015).

The research is done in cooperation with the project "Makroplastik Nordsee" located at the University of Oldenburg (Aden 2016). The project has the goal of gaining a deeper understanding of the driving forces behind the macro plastic pollution in the North Sea, more specifically the Wadden Sea area. To do that the whole coast of the Wadden Sea is split up into areas that are all analyzed simultaneously but independently and can be integrated at a later point to gain a complete picture. The focus taken here will be on the Dutch Wadden sea coast, excluding the areas at the Afsluitdijk, as shown in figure 1 on the next page.

The study of Schäfer, Scheele, and Papenjohann (2019) did their analysis based on quantitative statistics and probabilities. To get a more complete picture, the role of harbour operation is further explored in a qualitative manner based on expert interviews. Theses two on a methodological level very different approaches are culminating into what is called a MMR approach that aims to explore how the statistics and the story behind them align.

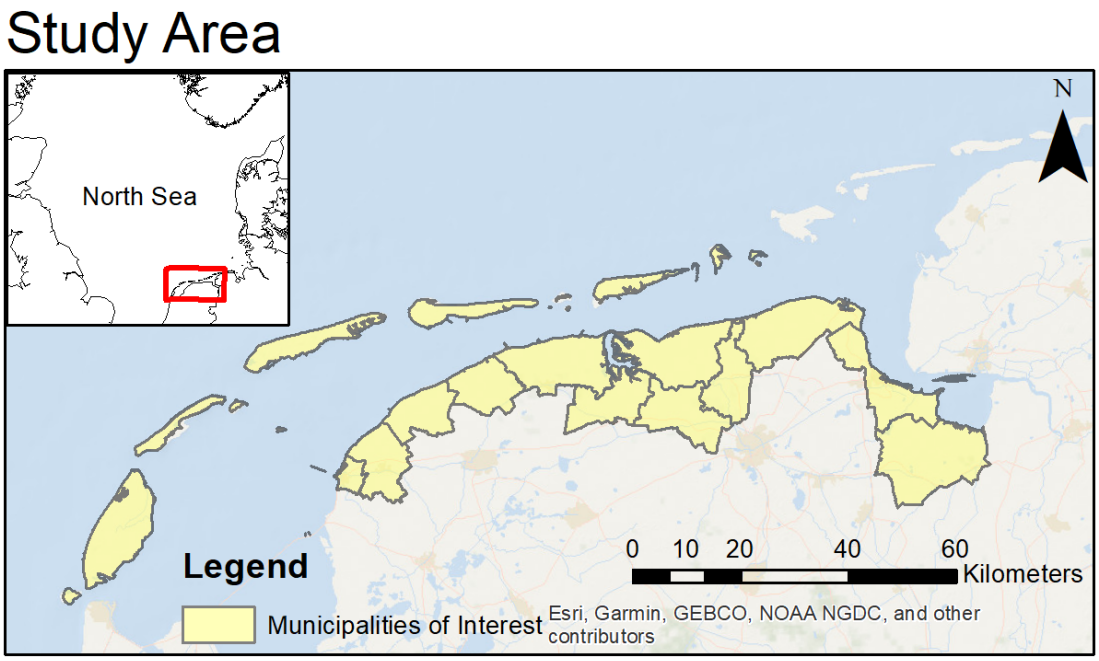

Figure 1: Map of the Study Area on the southern coast of the North Sea. In yellow the Municipalities can be distingushed

Structure

The first chapter will introduce the topic of plastic pollution, its implications and risks. It will in greater detail shed a light on why a deeper understanding of the issue is of vital importance, for the fields of governance and science. Included as well will be a concise set of research questions that will help to guide the research towards a solid result. The second chapter does provide a literature based framework for making it easier to understand how the plastic pollution works, where plastic comes from and where the problems in addressing it are located. The third chapter will introduce a conceptual framework on how the research is designed and based in scientific theory. The concrete research methods used are then introduced in chapter four, including where and how the utilized data is taken from, how the pollution source map is constructed and how the interviews are conceptualized. A general presentation of the generated activity maps as well as a summary of the interview will be made available in chapter five. The analysis of the encountered data will be the first part of the second to last chapter. What follows after is the discussion on the main research questions and how the collected data can be interpreted. The last chapter will round up and summarize the findings, provide a reflection on the methods, the results and the overall progress and it will give an outlook on how the topic should be approached further in future research.

1.1 Marine Plastic Pollution

As mentioned in the beginning, the topic of marine plastic pollution has garnered a lot of attention in the last years (Ryan 2015). Leading to a number of projects trying to mitigate or reduce the amount of plastic that is inserted into the global ocean system (Vince and Hardesty 2017; Xanthos and Walker 2017). The latest step undertaken in this regard has been the banning of a number of single use plastic goods such as straws or one time cutlery in the European Union (EU) by the year 2021 and a combined push by the Group of Twenty(G20) to reduce marine plastic pollution in June 2019 (Hasegawa 2019; G20 2019). At the same time a push from environmental groups can be felt that want to address the problems in their communities (Colvin, Witt, and Lacey 2016). These developments signify the importance of the issue that still is only partially understood (Nursey-Bray et al. 2014). The topic is currently in the politics agenda opening a window of opportunity for implementing lasting improvement.
In the strife for reducing human negative environmental impacts, it is of the highest importance to identify the sources of the problem. While ship based littering is surely a problem the main problem globally is land based (Jambeck et al. 2015; Ryan 2015). A portion of the waste that is produced on land, finds its way into the oceans, be it through water flows in the form of precipitation runoff, rivers or transport by the wind (Barnes et al. 2009).
At first it should be introduced why the plastic pollution is an important environmental issue. Since the second world war plastic as the main container material has been on the rise, it is durable, lightweight, produced mainly from the abundant fossil carbon sources making it cheap and therefore commonly available(Ryan 2015; Hammer, Kraak, and Parsons 2012). A massive rise in the use of plastic has occurred due to the benefits in the last decades, almost all consumer goods either contain or are contained in plastics (Charles J Moore, Lattin, and Zellers 2011). On a global scale this leads to about 10 percent of all waste produced being plastic. The buoyancy of the most common plastics in use makes them account for the majority (about 80 percentThiel et al. 2013,) of the swimming debris (Ryan et al. 2009; LI, Tse, and FOK 2016).
Plastic found in the ocean is roughly categorized into two groups, land based and sea based debris (François Galgani, Hanke, and Maes 2015) based on where they originate from (LI, Tse, and FOK 2016). The release of plastic waste on the open oceans has been banned in 1988(François Galgani, Hanke, and Maes 2015). It was among the first things to be addressed (Jambeck et al. 2015; Ryan 2015) but on the open ocean it is difficult to ensure compliance with the regulation(Vince and Hardesty 2017). The regulation on land based plastic is far harder. The main

contributing factors to the abundance of plastic littered into the ocean from an area are population size and waste management schemes (Jambeck et al. 2015). Littering and mismanagement of public waste are the main contributors to land based pollution (LI, Tse, and FOK 2016). In combination the main source of marine plastic is located in medium income countries with a booming economy and underdeveloped waste management(Jambeck et al. 2015). The most apparent cases of management schemes and population density aligning, and therefore the biggest contributors to global plastic pollution can be found in Asia (Most influential nations being China, Indonesia and the Philippines) (Lebreton et al. 2017). An example from Indonesia can be seen in figure 2, it is a sharp reminder what the abundance of plastic leads to if not contained by a management scheme.

Figure 2: This picture serves to signify what abundance the littering can reach, there is a river below all this debris. The main components of the waste are originating from households. This points towards major weaknesses in the public waste management scheme (Source: Wardhana 2017).

Apart from the visible problems connected to mishandling the waste a big share of the littering can be traced directly to tourism and recreational use. At the coast or beach the amounts of plastic encountered can have a very seasonal character(Ariza, Jiménez, and Sardá 2008; Bravo et al. 2009). These align with the main touristic seasons.

But plastic pollution is not only of great importance in the pacific, the North Sea is also affected severely (Neumann, Callies, and Matthies 2014; Schulz, Neumann, et al. 2013). While the states surrounding the North Sea are among the globally most rich and developed, understanding the plastic pollution here may generate valuable insights and lessons (Schulz, Clemens, et al. 2015) that the poorer or developing countries could call back on to learn (Peck 2011).
Once the plastic is in the system it becomes problematic to get rid of it (Hammer, Kraak, and Parsons 2012). The vastness of the open ocean leads to a far spread of singular objects and the main gyres are located far away from the coast. Cleanups are hindered by the following factors:

- It is economically not feasible to collect and recycle the plastics as it is cheap and commonly available, diminishing the attractiveness of such endeavours(UNEP and GRID-Arendal 2016; Hopewell, Dvorak, and Kosior 2009).

- The natural decomposition of plastics is severely hampered in the ocean. Most plastics are decomposed by heat and Ultra Violet(UV) radiation, both of these factors are cancelled out by the water, absorbing the UV light spectrum and normalizing the temperature (Andrady 2015; Corcoran 2015; Bouwmeester, Hollman, and Peters 2015).

- Plastics are also overgrown by microorganisms, shutting them off from oxidation. The overgrowth also decreases the buoyancy of the litter, causing it to sink into deeper waters or to the bottom of the ocean where its effects are uncertain (Andrady 2015; Pham et al. 2014).

Plastic is considered harmful to the environment due to a number of factors, the first is its adverse effects on the biosphere. The first and second item, indigestion and entanglement are also portrayed in figure 3.

1. Animals are not familiar with plastics objects and have problems distinguishing it from their natural food items, they consume plastic objects, but these can not be digested and are to big to be secreted in the natural way (Panti et al. 2019). Instead the plastic objects culminate in the stomach of the animal leading to it starving on a full stomach (Kühn, Rebolledo, and Franeker 2015). This was discovered in 1975 and was the very first indicator for the looming of a plastics problem (Ryan 2015).

2. The next problem is entanglement, marine biota get stuck in the plastics objects, this is especially connected to stretches of lost fishing nets (also called ghost nets (Lively and Good 2019)) and the carriers of cans or bottles. The animal looses a part of its mobility at best, but far more severe is if they are encumbered to a degree that they are unable to keep up their vital needs such as breathing or gathering food. Worst of are those animals that get stuck in the plastics objects while still in growth, they are strangled and afterwards the tight bonding prevents them from developing in the regular way.(Panti et al. 2019; Kühn, Rebolledo, and Franeker 2015)

3. Some other smaller problems arises from the concentration of hydrophobic toxic substances on the surfaces of plastic objects. And for the eco-system the swimming plastic objects are vessel for the spread of invasive species into new areas(Charles James Moore 2008). Plastic particles can travel enormous distances in the global ocean conveyor belts, making the spread of micro organisms or polyps possible(Hammer, Kraak, and Parsons 2012; Barnes et al. 2009)

Figure 3: (Left)This carcass of a Fulmar is a sharp reminder of the effects macro plastic pollution has on the Biosphere. The carcasses have been among the very first indicators that the dumping of plastics into the ocean has got severe adverse effects (Clark 2018). (Right) The Seagull is stuck in a plastic holder for six-packs of cans, a very common macro plastic litter item. This is by comparison a minor case of entanglement, still the bird is limited in its free movement (Source: Grundy 2018).

Together these effects lead to a shift in the basic parameters of the marine ecosystems(Kühn, Rebolledo, and Franeker 2015). Like with the topic of global warming, the specific consequences of this shift on a local level are hard to predict but a lasting change in the biosphere, that is irreparable, seems inevitable (Hammer, Kraak, and Parsons 2012).

Apart from the thread to the biosphere, there are a number of problems that do effect human society more directly. A first point in this is the loss of aesthetics while on the open ocean this may not be very visible, people hardly enjoy the sight of litter on the beach, around diving sites and in harbours (Charles James Moore 2008). The newest of all the problems and the biggest amount of unknown is connected to the topic of micro and nano plastics. The differentiation will be introduced in the next section. These extremely small particles of plastic can be found in every body of water, they are culminating in the organs and flesh of animals, and in the case of fish are then also introduced into the human consumption(Charles James Moore 2008). The effects of the small particles on the health are at this time largely unknown but possible interaction with human hormone balances and other adverse effects are postulated(UNEP and GRID-Arendal 2016 p.20; Bouwmeester, Hollman, and Peters 2015). The smallest particles originate from either direct production such as in toothpaste, peeling creams, or raw production substance or they are a product of the disintegration of the bigger particles(Bouwmeester, Hollman, and Peters 2015; Charles James Moore 2008).

If the problem of marine plastic pollution is not addressed the consequences will increase in severity making the identification of sources necessary. While ideas to clean up the oceans from plastic waste are getting a lot of attention, scientists warn that this will not be enough as it tries to reduce the symptoms and not the root of the problem (Vince and Hardesty 2017).

In order to address the problem at its root it will be necessary to facilitate a change in the general governance of plastic, either in the formulation of new societal rules punishing littering behaviour and incentivising the right behaviour (Velis 2014). Or alternatively trying to facilitate a transition of societal values and norms achieving the same result in the long run. Both share the need to understand where regulation can be effective and efficient (Nursey-Bray et al. 2014). Addressing pollution is a topic that requires an understanding of the physical and societal processes that enable the current state (Velis 2014). If inefficient measures are taken a false feeling of accomplishment may spread making the implementation of uncomfortable but necessary regulation more difficult (Newman et al. 2015).

The topic is at the moment very prevalent in the media, the lost cargo of the MSC Zoe in January 2019 garnered a lot of public attention to the topic, see figure 4. At the same time a more broad push towards more sustainable environmental policy is arising in the public. The British Premier Minister Winston Churchill is attributed with the Quote: "Never let a good crisis go to waste." This also holds true for the situation surrounding the topic of macro plastic pollution. The development of a new, more fitting approach to governing the sources of macro plastic is right now impeded by lacking knowledge. It offers a chance for preserving nature for the future while also exploring possible approaches for other global regions to take when reinventing their environmental planning (Velis 2014). Adding to the missing knowledge and thereby helping to utilize the current window of opportunity is the goal of this work.

Figure 4: Aftermath of the MSC Zoe catastrophy on the island of Schiermonikoog (Source: nillson90 2019).

Definition of Macro Plastic

To specify how the plastic talked about in the following part is conceptualized, it is important to separate the different classifications and give an idea what is entailed within them. For this work the size of a macro plastic object is bigger than five millimeters, everything below is either micro- or nano plastic (Masura et al. 2015). This means more specifically that the main concern is big household and industrial items entering the ocean. The topic of raw plastic granule or other micro or nano objects is not elaborated upon further, but it has to be mentioned that these smaller objects are also caused by the erosion of macro plastic objects, a process called secondary micro plastic production (Masura et al. 2015) and therefore are also influenced by macro plastic dynamics (Ryan 2015).

1.2 Research Questions

In order to get a better focus in the work it is important to define the research questions. The main question is:

> Where on the coastline of The Dutch Wadden Sea and Frisiean Islands is the main contribution to Macro Plastic pollution comming from?

This question poses two basic sub questions, the first is where hotspots are located and the second is whether the harbour operation qualifies for a source of plastic pollution. To be more precise the questions are:

I To what degree can the Harbour of Eemshaven and Delfzijl be considered a hotspot for oceanic macro plastic pollution?

II What are the main entryways for marine macro plastic pollution in the harbour operation of Eemshaven and Delfzijl?

These two sub questions do necessitate two very different sets of data, how this can be conceptualized will be introduced in chapter 3.1. The main goal of this work is the development of a tool for the use in ocean sciences and environmental governance. The tool supports both the assessment of current developments and a forecast of the impact future developments through the lens of reducing ocean pollution.

1.3 The Harbours

The focus of the research, in order to identify the underlying processes that can cause plastic pollution, is put on the industrial port of Eemshaven and Delfzijl; the ports are focused upon together due to the fact that they share their administration from Groningen Seaports (Groningen Seaports 2019). As they are administered as one unit it is not seen as necessary to differentiate between them. The two harbours represent the biggest port in the whole study area. They are located in and close to the town of Delfzijl at the mouth of the Ems river, across from the German town of Emden. Both are right next to the United Nations Educational, Scientific and Cultural Organization (UNESCO) World Heritage site Wadden Sea, making a thorough environmental management necessary. The location of the ports is marked on the map in figure 5 on the next page.

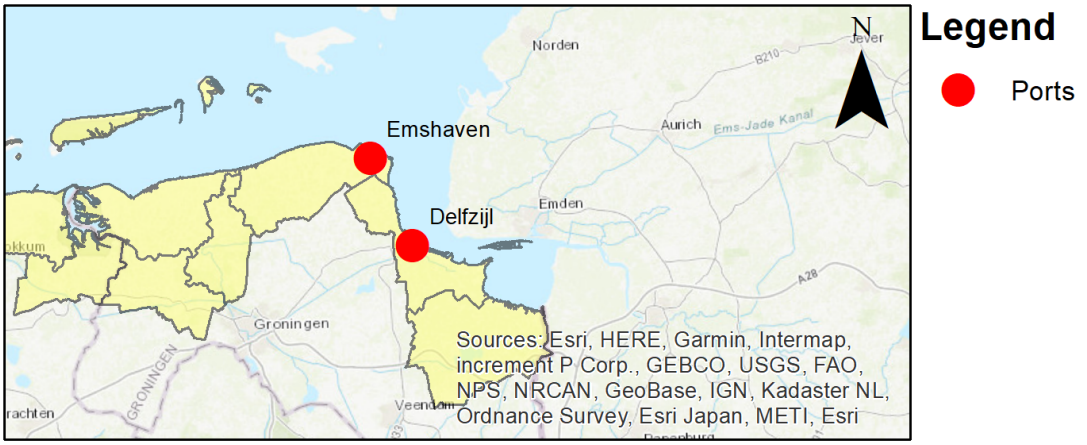

Figure 5: Location of the Ports in the Eastern Parts of the study area.

Of bigger interest is the harbour of Delzijl, the main activities are clustered around the chemical industry park that is easily accessible by ships. In the park a major aluminum mill is situated, as well as companies producing plastic films and other chemical appliances and a waste incineration plant.
The Harbour of Eemshaven is specialized in the power sector, the maintenance and construction of the wind-park "Gemini" is mainly undertaken from here and a large power stations have been build here. At the same time close to the harbour the power generated offshore is landed and one of the main data cables is also emerging here. In combination these two have lead to the emergence of a vast Google data center. Apart from that the harbour houses a malt roastery, a company dealing with the recycling of building materials and a ferry station for traveling to the German island of Borkum.
From the institutional standpoint the harbour is located in the province of Groningen making them the highest regional authority, on the local water management level the waterboards "Waterschap Noorderzijlvest" and "Waterschap Hunze en Aa's" are responsible for securing the quality of water in the area. The water boards are a specifically dutch authority that have been historically responsible for ensuring flood safety. Nowadays they are also responsible for the treatment of wastewater as well as ensuring general water quality, and the administrations of the waterlevels in the polders (Lazaroms and Poos 2004).
The harbours have in the last years been awarded the ECO port certificate, provided by the European Sea Ports Organization (ESPO) for their continuous improvement of the environmental management (Yahya 2019). This makes them, together with the activities especially in the Delfzijl area, an interesting case for further exploring the influence harbours have got on the processes for the management of plastic waste.

2 Theoretical Background

The next section will provide the background information necessary to understand the research questions and their discussion as well as the deeper theoretical implications.

2.1 Ways of Plastic transport

To understand how the plastic litter moves, it is important to take a look at the main processes, natural and anthropogenic, that are responsible for the transport. Without a grasp on what drives the transport, the model that is searching for the sources can not be made coherently.

2.1.1 Physical Transport processes

At first, the physical modes are carriage by wind and or water (Ryan et al. 2009; François Galgani, Hanke, and Maes 2015). For a significant amount of waste that is produced not directly at the coast this is most likely the main source. The main sources of plastic waste apart from the fishing equipment tends to be of light weight, polymers that are buoyant and can therefore easily be transported by water (Ryan et al. 2009).
Rivers have been one of the driving factors for the development of cities and industry (Cengiz 2013) all throughout human history. Charles J Moore, Lattin, and Zellers (2011) showed that rivers running through cities are carrying enormous amounts of plastic particles of all sizes, these originate directly from human dumping or from stormwater or wind transport. River transport has been identified as the main source of marine plastic (Charles J Moore, Lattin, and Zellers 2011; Carpenter and Wolverton 2017). Rainwater can take plastic items directly into the river or seepage areas where it can accumulate and be flushed out in the case of extreme rain events(Ryan et al. 2009).
The transport by water is complimented by wind bound carriage either directly into the ocean, as the coast is connected to strong winds or into rivers or overflow areas. The eolian transport of plastics is also made more easy by the nature of a lot of the human plastic waste such as plastic bags or food packages that are light and have a lot of contact surface (United Nations 2009). Due to the wind a certain stretch of land, that is a possible source of plastic, along the coastline and major estuaries will be taken into consideration for the hotspot map.

2.1.2 Anthropogenic Transport processes

Transport that is directly linked to humans is a complex issue. Almost all transport of plastic is done or facilitated by humans, this section will be more about how different basic kinds of human behaviour cause plastic littering. The following list of reasons for littering is sorted by the amount of consciousness it entails in undertaking.

1. Dumping
   Dumping is the conscious act of throwing the plastics into the environment for direct profit or convenience, in spite of the awareness about what consequences acting that way has got or in willing ignorance of the consequence.

2. Mindlessness
   This is characterizing acts, like putting waste next to full bins or not watching over the produced litter, thereby making it possible for the other kinds of transport to take over. This is also strongly connected to education and awareness, a group or individual may not be aware of the consequences of their actions or the damage done by littering.

3. Accidents
   A number of plastic waste introductions may also be connected to accidents, a braking garbage bag or the loss of cargo in a storm can be attributed here. The condition to count as an accident is, that an active effort is undertaken to avoid littering but it is happening non the less.

Of these reasons, the last one, accidents, is the most straight forward to address, after one accident occurs it needs to be analyzed, the procedures and safety measures that lead to the occurrence need to be adjusted in order to prevent the events from reoccurring in the future (Johnson 2003 p. 9f). Apart from that accidents are not a kind of littering further discussed in this work as they cannot be accounted for directly and if they are frequently reoccurring they change the category towards mindlessness.
The most direct form of pollution, dumping, is generally an outlawed practice. On the high seas the Annex V of the International Convention for the Prevention of Pollution for Ships (MARPOL) convention bans the practice in international waters (IMO 2019). European Countries also are required to ban the practise of dumping through both the Marine Strategy Framework Directive (MSFD) and the Water Framework Directive (WFD) that drive a push towards a good ecological and chemical status in all European waters (Veiga et al. 2016; Francois Galgani et al. 2013).

This includes the prevention of plastic pollution. The main challenge on the corporate or profit side in addressing dumping is therefore enforcement of the rules already in play, through both investigating the origins of plastics as well as punishing the offenders against the regulation (Slavin, Grage, and Campbell 2012).
The harder part is reaching out to those who willingly litter because they think it is not a big deal, here the overlap to the second category is fluid but the answer is the same. The area of mindlessness is the most broad problem, few people actively try to pollute the environment, but a lot of people do not consider the consequences of their actions when handling litter (Brown, Ham, and Hughes 2010; Slavin, Grage, and Campbell 2012). This has its roots in the education and background of the culprit. Surveys in protected areas have shown that by signifying the consequences of littering to tourists, close to a situation where littering is convenient, greatly reduces the likability of it happening (Rodriguez-Rodriguez 2012; Schultz et al. 2013). Similar results are achieved by keeping areas clean implying litter does not belong there, as well as strategic placement of bins (Brown, Ham, and Hughes 2010).
There is a distinct overlap here also with the different forms of physical transport. People not familiar with the coastal environment easily misjudge the effects of their actions. They do not account for the wind, by not securing their litter and therefore are contributing to the pollution (Brown, Ham, and Hughes 2010). Here a great amount of progress can be made through tourist education.
The last category for plastic transport is in between anthropogenic and physical transport, it is transport by animals. Scavenging animals such as seagulls or rats are exploiting insufficiently secured waste management such as bins or directly go for stealing food together with the packaging from stores or people (Katlam et al. 2018). They also thrash open garbage bags, allowing for wind to rip open the damaged material and therefore release more waste into the environment (Barnes et al. 2009). These losses will be accounted for mainly in the tourism and waste management sections.

Hotspots

For the further research, it is necessary to define what is meant when the term hotspot is used in the context of this work. A hotspot in biology is an area where a critical mass of endemic species and a threat to the habitat meet on a small space (Myers et al. 2000; De Vries et al. 2013). While it seems to be a cruel reflection of the term to use it in this context, the same basic principles apply. Instead of species different human activities are summed up and instead of the danger to the area, the danger emitted from the area is categorized, so in this

case plastic litter. Using the same approach to generate hotspots can be very helpful for visualizing comparisons on one map. It could help to signify where these two things are regionally closely linked. In the field of biology a certain degree of all species on the planet has to be found in an area to be recognized as a hotspot (Myers et al. 2000). Here the scope is the study area, there are 17 Municipalities in the focus area the thresholds for hotspots will be determined in the analytical parts from the local spread of the results. If the municipalities are all contributing to the problem on a comparable scale, it will not be possible to generate significant results. But if, as it is expected, a fairly uneven spread of activity is identified, it will be possible to determine hotspots. There is a use for both a listing of the overall pollution hotspots as well as the hotspots for the different land use categories. The overall hotspot will help researchers to generate better, more accurate models of the spread of plastics in the ocean, while the land use hotspots can signify to policy makers where interventions in order to reduce the plastic outputs should be located.

2.2 Land Uses and their Plastic Waste Production

It can be assumed that different forms of land use lead to different profiles of the composition and amount of plastic waste that is produced and thereby can be introduced to the environment. This assumption is the basis for the study undertaken by the ARSU (Schäfer, Scheele, and Papenjohann 2019) that forms the foundation on which this research is conducted.
In order to identify where the litter, that is found in beach cleanups, does come from they used a statistical and a probability calculation for every category of waste defined by Convention for the Protection of the Marine Environment of the North-East Atlantic (OSPAR) (Schulz, Loon, et al. 2017). This has been done for seven different locations on the German North Sea coast. The OSPAR categories of beach litter have been classified by how likely it is that an encountered activity is responsible for this specific item. Afterwards the overall classes of items where summed up by the land use sectors. Through the amounts of plastic encountered overall, it can be determined how big the contribution of the single activity sectors are and therefor how likely it is that a random item found on a beach originated from for example tourism.
The different land based categories of activities from the study are introduced in the next sections.

Tourism

By far the biggest source of plastic items found on beaches that stem from land use are connected to tourism (Schäfer, Scheele, and Papenjohann 2019). This is due to the fact that a vast quantity of items found is connected to food packaging. As discussed in the littering section the norms and believes of the people form an important factor when it comes to littering (Brown, Ham, and Hughes 2010). For tourists this entails three very distinct reasons as to why it is a problem.

1. The first reason is that tourists often come from an urban background where the issue of littering is less prevalent or alternatively better accounted for, because cities employ personal for the removal of litter. It also leads to the tourists believing that if they encounter litter, it is a common occurrence to just dump the litter into the environment, lowering their threshold to do so (Brown, Ham, and Hughes 2010).

2. Secondly also connected to the first points many tourist are less aware of the consequences of their actions when it comes to littering, waste that has been washed away is no longer visible and beach administrations will try and keep highly frequented areas relatively clean as waste reduces the attractiveness for the tourists (Rodriguez-Rodriguez 2012).

3. The third point is convenience, studies have shown a correlation between the distance between parking lots and rest places and areas of high littering density (Schultz et al. 2013). Tourists tend also to bunch up around and close to parking lots, artificially increasing the density of the use and thereby also the amount of stress put on the waste handling infrastructure, such as bins. When the handling infrastructure is overflowing tourists are more likely to just dump the waste next to it, leaving the litter prone to the wind (Rodriguez-Rodriguez 2012).

At the same time when tourists are not on a tour, they contribute to the regular stream of municipal waste. Therefore, they need also to be accounted for on the municipal level. To do this tourist overnight stays are converted to residents and added to the regular population of the municipality, shifting the population balance. For the research, it will be important to develop indicators that help to approximate the spread between the municipalities.
The beach tourists need to be accounted for separately in the research approach taken here. They are close to the water and tend to picnic on the beach. The number of daily visitors per beach section would be great in order to differentiate how the beach tourism is spread out. To determine the development status of the tourism sector, it also can be beneficial to take a look into the spread of jobs

in the field of tourism. The jobs roughly indicate how the field is spread out (De Vries et al. 2013). Lastly to account for the remaining tourist the visitors only arriving for a day-trip also need to be considered separately to the beaches, because they also contribute while undertaking activities close to the coastline, but to a lesser degree. Overall it is hard to locate the movement patterns of the sector, tourist may stay in one central place and take a tour around the area making them appear multiple times in the calculations.

Figure 6: This beach is a prime example of the waste tourists leave when they are gone and do not care for the environmental implications of their actions. Seabirds or winds do only need to carry the litter over a small distance in order to reach the ocean. At the same time the figure serves to signify the loss of attractiveness that is connected to an accumulation of waste (Source: Batson 2018).

Harbour Operation

The second largest land based contribution to marine pollution, according to (Schäfer, Scheele, and Papenjohann 2019), comes from the operation of harbours. The litter is mainly composed of differing sizes of rope, building- and industrial packaging materials and food containers of all shapes and forms. This points towards a number of possible sources, there is hardly certainty on the issue. The rope and building material, as well as the packages, point towards maintenance work that is undertaken while within the protected harbour. The workers may

not be trained to avoid the dumping of litter or are preoccupied with other tasks leading to a negligent stance towards the management of waste. At the same time rope and net scraps are an indicator for the repair of fishing gear in the harbours. At the same time ships are due to the MARPOL Annex V not allowed to dump their non food waste offshore (IMO 2019), making a harbour waste handling scheme necessary. The schemes are designed to secure that no waste enters the water but human error as well as the circumstances of working all day and night on all weather conditions could lead to limited spilling. Working close to the water causes items that are carried away by wind or dumped to be introduced to the ocean immediately, without the chance found on other land based uses to get stuck somewhere and returned into the regular plastic management cycle. This does include plastic containers of varying size or other packaging material coming from both working on the pier and maintaining the ships. The accumulation and effort of cleaning the harbour can be seen in figure 7.

Figure 7: This Figure shows the employees of the public waste handling service in the city of Bremerhaven, who have to clean up the waste that the industrial fishing port produced. The fishing port is enclosed from the sea through a sluice, so all waste has its origin within the harbour (Source: Hinkelmann 2018).

To measure how much activity takes place in the harbours the amount of freight handled is the indicator, this due to the fact that it is able to portray both the handling of a few big ships, and at the same time the handling of many smaller vessels.

Land Based Industry

The on shore industry needs, like tourism to be looked upon with a greater degree of precision. Here the two main contributing sectors are agriculture and producing industry. The producing industry is contributing directly through the processing of plastic materials. While the produced goods are the main source of income and therefore taken care of with great caution, the discards and scrap that are left over from the production are getting attention for recycling but still in general just need to be gotten rid off (Al-Salem, Lettieri, and Baeyens 2009). This can lead directly through illegal dumping and indirectly through negligence in the company waste management system to the seeping of macro plastic waste into the natural transport systems (Charles J Moore, Lattin, and Zellers 2011). A second important factor is more indirect and not only connected to the plastic producing industries, namely the packaging used for transport. While with the rise of home shipping online markets, like Amazon and others, households are a rapidly rising group of package material users they pale in comparison to the amount of plastic films used to secure industrial products (Hou et al. 2018). The expectation towards suppliers to deliver undamaged products makes large amounts of securing package material necessary. The vast amount again makes the implementation of proper waste management in the companies necessary (Verghese and Lewis 2007). The dilemma that arises from this will be introduced in 2.3.
As it is hard to quantify the influence of the single companies a more general approximation of the degree of activity within the municipalities, in comparison to each other has to be taken. To do this the number of workers in the industrial sector is the first chosen indicator, as it gives a good indication how work is spread out and on average how big the contributions to the plastic pollution are. At the same time the area that is taken by industry also is able to provide a measure of activity. In order to get a better picture and to include the physical dynamics to the picture the amount of space that is taken up by industry, in certain distance to the coastline, is also taken into account. This industry is prone to the earlier mentioned windbound transport. The average degree of activity between these two indicators will provide the degree of contribution to land based industry.
In the agricultural sector the main forms of plastics in use are plastic films and tubes. The films are used for sealing the ground, protection of hay bales and for greenhouses. Plastic tubes are needed for the use in irrigation systems (Scarascia-Mugnozza, Sica, and Russo 2011). Of these the biggest potential to end up in the ocean is on the films as they are prone to being transported by wind. If large amounts of plastic tubing is found that should be an indicator for deliberate dumping as they are hardly transported by winds.

The films, if not properly weighted down, can be picked up by wind and transported over large distances. At the same time an amount of regular municipal waste will occur as there is habitation in agricultural areas (De Stephanis et al. 2013). To find out the amount of agriculture that takes place in the municipalities the area it covers will be compared. For the Municipalities on shore again a stretch of land that is prone to wind will be taken into considerations, while the islands are calculated completely, as no matter where wind comes from it is possible to transport plastics into the ocean.

Household Waste Management Losses

Some of the most prevalent waste items found on the beaches are food containers, bottles and cigarette butts (JJ Dagevos et al. 2013). The waste is at large emitted not only by the earlier mentioned tourists, but also by regular habitation that introduces, everyday objects into the ocean. The plastic waste can find its way into the environment by the before mentioned way of littering or from errors in waste management systems (Jambeck et al. 2015). Vast amounts of waste need to be handled, in order for modern cities not to drown in it. This is an expensive task that is common place in Western countries, therefore not a big problem in the study area. On a global scale this is the main contributor to macro plastic pollution (Jambeck et al. 2015). In less developed countries the river is used as a disposal site for all regular waste and the leftovers that remain on the street are flushed into the river systems by storm events (Charles J Moore, Lattin, and Zellers 2011) (See figure 2).
There are a number of ways to get rid of the occurring waste that can be pursued by the governmental administrations. The most relevant are recycling, burning and landfills(Bovea et al. 2010).

- Recycling is a complicated endeavour that, while being the most environment friendly, requires a high technological standard and is in comparison the most expensive of all the approaches (Hopewell, Dvorak, and Kosior 2009;Gradus et al. 2017).

- Burning is the most far spread in the western context. Polymers are often based on mineral oil and other organic compounds that burn just as good as coal or oil for the processes of producing electrical energy. Burning is a convenient way to get rid of the plastics, as power plants are currently needed to sustain energy supply and waste is available in abundance. Some countries like the Netherlands have even imported foreign plastic waste to incinerate it in the recent past (Van Dijk, Doorn, and Alfen 2015). The

residue can be used in road construction or other processes, making this approach very space efficient.

- Landfills are the most common form of waste management in lower development countries(Doka 2003, p. 15). The process here is to dump the waste from a region in a single place and once a certain amount has accumulated it is buried under a layer of earth. If managed appropriately this can be a functional, but shortsighted, strategy of disposing waste (Bovea et al. 2010). If management is not suitable landfills are a constant source of plastic debris. When the mountains of waste pile up the exposition to wind increases. As does the exposition of the waste to animals, that see it as an attractive source of food, therefore contributing to spreading the waste even further, as can be observed in figure 8. The EU has set strict standards for the use of landfills, leading to many countries opting out of the practise (Scharff 2014). As necessary measures fences for catching wind transported debris are required as well as the daily sealing of the dumps, because of this the positioning of landfills is less relevant for this research.

Figure 8: This figure shows a landfill that is managed. The Bulldozer in the back is covering the waste with a layer of earth, still there is an enormous amount of seabirds trying to get something out of the waste. If the landfill was not managed properly in addition to the birds the exposition to wind would increase dramatically leading to even worse environmental effects (Source: Anderson 2019).

The study Cieplik (2019) determined landfills to be a non issue in the European context as well, therefore it will not be taken into consideration more deeply, in another international context this needs to be addressed differently.

The next important factor is the collection scheme for the waste. While in general no waste should be leaking out of the collection bins, human errors and overloaded systems can leak waste items into the environment. If bags are collected they can be damaged by overloading, bad handling or animals and spread waste into the environment (Katlam et al. 2018;). If the system is not set up carefully the residents of an area will default to dumping their waste where they believe to get away with it.
The last important contributor here is storm-water overflows, the ARSU study did recognize that two percent of all waste on the beaches is coming from these events (Schäfer, Scheele, and Papenjohann 2019). For the sake of simplicity this is bundled, in this work, with the overall municipal waste losses. The Netherlands are internationally known for their meticulous water management so it is unlikely to be spread out significantly differing in style across the study area. If that is the case the waste produced by storm events should be locally correlated with the available waste and therefore it will not be included as a completely own category. If special data on this issue can be acquired it can be used with the percentage of two percent on its own.
An indicator for the spread of municipal waste contribution is local population, as the focus area is small a comparable behaviour between the inhabitants can be expected. As the behaviour and applied management system is viewed as equal the occurrence of plastics is directly linked to the population.

2.3 Inherent Complexity

As indicated in introduction the field of environmental planning needs to be redesigned in order to cope with the arising problems. The best solutions to a problem can often be found locally (Lemos and Agrawal 2006). That makes a governance approach flexible enough to allow for creative solutions, as long as they deliver results, necessary. Still decentralization is not a universal solution, governments without an incentive for environmental improvements will often fail to implement them (Zuidema 2016). The reason for this is that the flexibility necessary to account for local circumstance is exploited to opt out of efficient reforms. Underlying are a number of societal processes that will be explained in the next section. The main planning theoretical arena is the balance between centralization and decentralization that needs to be found in order to govern plastic pollution efficiently.

The problem of marine plastic pollution is made into a complex issue by a number of attributes that are also encountered in the more general field of environmental governance (Sheavly and Register 2007). These problems include prominently the weak profile, the diffuse sources and the scope of the issue (Zuidema 2016) among others.
The first problem, weak profile means that the accumulation of the biggest masses of plastic is occurring on the open seas in the big ocean gyres. These gyres are located on the high seas where no single nation has sovereignty, leading to no nation feeling responsible. While everybody is willing to exploit the fish resources and space for shipping, caring for the sustainability is less attractive. This phenomenon is known as the tragedy of the commons (Hardin 1968).
In no small margin the tragedy of the commons can be attributed to lacking knowledge, it is hard for anyone to develop responsibility when it is not clear who "owns" the problem. The principles for environmental governance that fit here neatly are the "polluter pays" and the "correction at source". The polluter pays principle means that those responsible for a pollution need to bear the cost. The correction at source principle entails that the least amount of effort needs to be invested when an environmental problem is tackled right where it originates (Seht and Ott 2000).
When someone is trying to address the problem of marine plastic pollution, the first hindrance arises from the fact that an estimated 80 % of the litter is land based and directly tied to human use. Still, there is a lack of knowledge in regard to the sources and causalities. For example 90 % of plastic waste in the ocean is attributed to just 10 river catchments (Schmidt, Krauth, and Wagner 2017). The processes leading to such a development are eclectic and hard to pin down. The following dilemmas help to understand the complexity:

1. Is the person throwing their waste in the river responsible or the government providing not enough facilities to manage their waste.

2. Is it the fault of the market that everything is packed and packed in plastic films and bags or is it society asking for convenient and cheap goods, like food and clothing.

3. Are the public institutions like schools responsible for educating the population on correct behaviour or is the wider society responsible for conveying an appreciation of nature and a felt need to protect it.

These dilemmas do not have definitive conclusions and show, that trying to solve the issue by just analyzing facts and numbers will not be able to come up with answers and solutions that reflect the societal reality. It is further complicated by the fact that the societal reality is in constant shift. Practises and values do change constantly and far quicker than the physical environment. A good example for this are debates around nuclear power. While it has always been a controversial topic, the public perception shifted rapidly in connection with the Fukushima catastrophe, while the physical safety of other power plants was not impeded at all. Complex systems to strongly carry over into the temporal dimension.

The same questions that make the issues complex also carry over into the field of governance and make it hard to address the problem as one entity. To find out where to start and what to do, a more complete understanding needs to be achieved. As the ocean is one global connected system, fixing single countries, while others keep up with their polluting behaviour, will produce limited results. At the same time if single countries are investing and committing to the reduction of plastic they are facing adverse effects. Either by weakening their local economy due to new or harder regulations that reduce their competitiveness or by incentivizing loose regulations in single countries that see an economic benefit (Zuidema 2016). A tangible reduction in plastic output will also reduce the incentive for single states lacking behind at the moment to become active. Together, this leads to the fact that all laws and regulations have to be negotiated on an international level. Through this necessity the situation also needs to account for differing national and regional cultures and circumstances (Vince and Hardesty 2017; Mukhtarov 2014).

Second problem created by the interconnectedness is that the ones polluting are not necessarily the ones feeling the consequence. While a polluting upstream community can have little to no problems with the accumulation of plastics in their area, all communities downstream will have to deal with the plastic objects entering their area and polluting the water. This makes every solution an issue of negotiation between different regional activities and needs.

In order to address the problem as a complex issue it is important to include the story behind the data. For the framework used in this thesis it means that a combination of data will be necessary, not only the pure statistical accumulation of activity but also the identification of processes and practises that explain the encountered reality need to be explored (Turner, Cardinal, and Burton 2017). The issue is located on a cross section between a technical reality that is measurable and a communicative reality that explains the deeper process. The technical is not able or even attempt to explain why the measured plastic gets into the ocean,

only that it does. The pure communicative approach can not be taken, as it is not up to discussion if plastic enters the sea, there is a distinct reality that can not be dismissed in a communally constructed discourse. While the character of the pollution being a problem could be discussed, this is as demonstrated earlier in this chapter not up to debate (Allmendinger 2017, p.64).
The governance approaches between centralization and decentralization are direct reflections on the two different realities. The central government has accountability towards all its citizens, in order to fulfill this it is necessary to take decision on a broad objective scale. Regulations need to be made and enforced equally and reasoned for by necessity (Allmendinger 2017, p.64). The decentralized view is tailored far more to communication, what really matters or what to do in order to address the problematic of plastic, is dependent on the local context. Society has to decide in discourse what will be regulated or what development needs to be followed up on (Allmendinger 2017, p. 221).
The MMR approach presented in the next chapter does aid in navigating the complexity by allowing for both approaches, communicative and technical to combine (Turner, Cardinal, and Burton 2017). Thereby it provides the best potential results.

2.4 Marine Pollution Regulation

A number of different treaties and laws exist that are already trying to reduce or limit the amount of plastic that is introduced into the ocean system. The most global ones are directly connected to ocean bound pollution. The International Maritime Organization (IMO) has implemented the so called MARPOL convention that outlaws pollution to the environment originating from seafaring vessels. It has got six annexes that deal with specific categories of this waste, of special interest here is Annex V that forbids the dumping of waste and necessitates the handling of waste in the harbour environment(IMO 2019). This regulation is good, but shifts the problem of waste management to the port, how this is handled will be of interest later in the research.
On an international stage below that are the next regulations, especially on the European level the MSFD for national coastal areas and WFD for inland waters care for the quality of water. And also connect them to the land use. Each body of water is required to reach the so called good environmental status. Among criteria for chemical water quality, and biological vividness a criterion is that no big amount of plastic waste is found (Francois Galgani et al. 2013). This forces the European states to include anti plastic legislation into their national codes of law and a responsibility to monitor their progress towards the good environmental

status. More localized this is undertaken by the sea basin coalitions for the Dutch coast OSPAR is the responsible organization. The role OSPAR takes is on one hand the monitoring of the abundance of plastic, on the other they coordinate between the member states to implement effective governance (OSPAR 2019).
The next unit are national legislation in the Netherlands the regulation is collected under the term NeRF Maritime. It bundles all international law and national law into one framework. This is important because the EU for example leaves the member countries some leeway in the specific implementation into national law (Ministry of Infrastructure and Water Management 2019). At the same time it makes it easy to overlook what regulation has to be complied with in the national Dutch context.

3 Research Framework

After the introduction to the theoretical background knowledge necessary to understand the research done here, the next step is to conceptualize the research approach into a framework that indicates how and why the method introduced in the next chapter has been taken.
The very first point to address is the complexity of the issue mentioned in chapter 2.3, while a non complex issue can be addressed by looking purely at facts, complexity introduces the issue of uncertainty and a need to explain what the data produced means (Zuidema 2016, chapter. 3). It also necessitates a discourse on how the results encountered come to exist and if the data produced is reflective of the experienced reality. To encompass both needs the framework set up for researching the topic of hotspots of plastic pollution and the role of harbours in it needs to include both, a quantification to find hotspots and a qualification of the composition of harbour activity, leading to port based marine pollution. This duality is introduced in the next section that will provide the basic idea for the research.

3.1 Mixed Methods Research

As the set up sub research questions imply two very different kinds of information are combined in this research. The first question about the hotspots is using statistical, quantitative data that is generated independent of human opinion or the point of view of the researcher. The second question is asking for qualitative data, that is, while still being gathered from a person of expertise on the issue, strongly dependent on the worldview and position taken by the interviewee. These two approaches seem very conflicting as they stem from two different schools of thought.
The first being the realist approach that is deeply rooted within the culture of modernism, it has got a positivist view of the world that sees the world surrounding us as an in depth measurable entity (Allmendinger 2017, p.63f). The data is viewed as being an independent value, if a hotspot of plastic is detected somewhere based on the data it becomes a part of the factual truth. The second school of thought is relativism, it sees the world as being dependant on the very person observing it, the values of the person, the experience and opinions (Allmendinger 2017, p.193). All these subjective things are true for the viewer and are therefore a valid and true fact. Being opposed on the very basis of their epistemology how can it be that these two methods are able to provide any answer to a question like the one set up in this thesis.

The answer lies in the concepts of MMR and the philosophy of pragmatism. Mixed Method Research specifically aims to combine the two schools of thought (Timans, Wouters, and Heilbron 2019). Its main goal is to provide the story behind the statistics. The goal is to increase the quality of the answer to the original question. This is also where the concept of pragmatism is introduced into the picture, as it is aware of the strengths and weaknesses of the realists and the relativists worldview but does consciously not try to dabble in the discussion on what truth actually is. Instead it puts the focus back on the question (Allmendinger 2017, p.128f.). The main goal is to answer the question in a way that is useful to the greater society.

As with all more broadly utilized forms of theoretical research framework for MMR there also have been attempts to standardize the approaches it takes. But this practice also tends to miss the main idea of MMR, namely focusing on the best way to get an answer. Due to that only a very rough classification will be provided here. The research undertaken here can in general be framed as an explainatory research design. This is one of the most basic categorizations, it means that the collection of data is undertaken at first in the statistical part and after that in the qualitative part. Meaning after the search of hotspots an explanation for the role of harbour operations is searched. This is due to the fact that the reasoning for believing the harbour is a major contributor is taken from the study of Schäfer, Scheele, and Papenjohann (2019), they did a statistical and probability analysis. They did not delve into the search for the reasons for the role as view by the port operators or the regulatory bodies responsible. While it is difficult to argue against the statistical results produced by Schäfer, Scheele, and Papenjohann (2019) the self perception could be a different one allowing for an interesting discussion of the original research question.

3.2 Conceptual Model

In order to make the intend and approach taken for the research clear, the next section will provide visual representation of the processes and ideas that guided the design of the research. All sources that are not in the concept are excluded from further consideration for the time of the study, see figure 9.

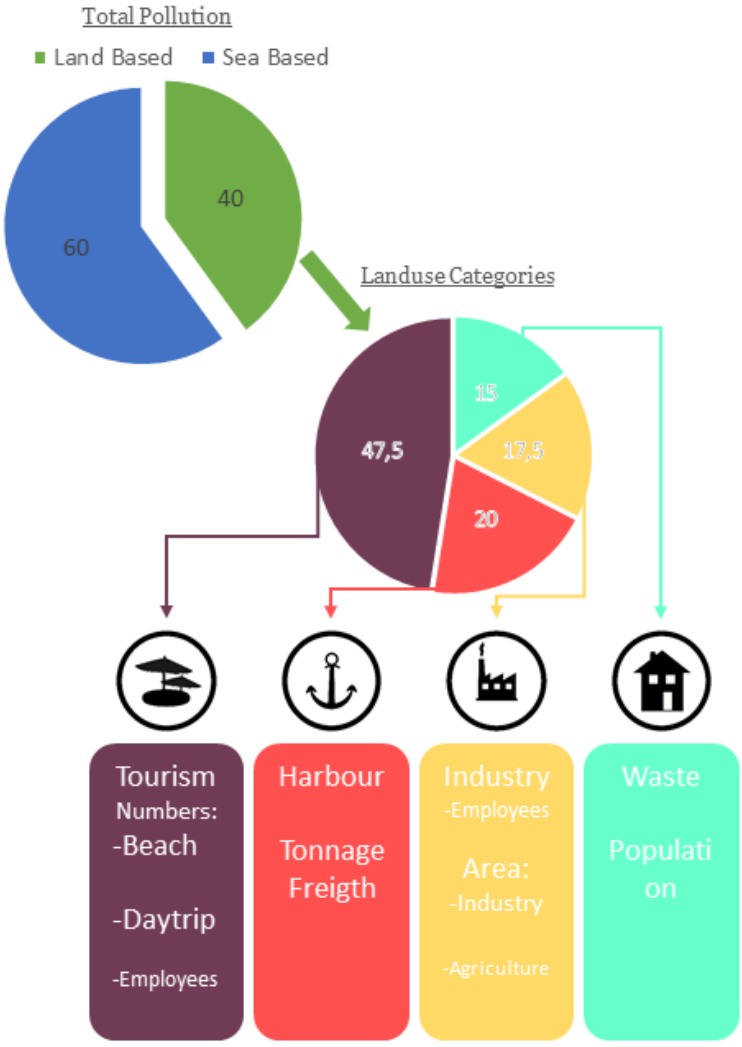

Figure 9: Conceptualization of the origin of waste found in the beach cleanups.

A pragmatic view is taken for this research, the concrete amounts of plastic that are produced are another complex issue because of the flow dynamics within the ocean make a precise estimation impossible. Therefore, the Pollution is seen as a fixed variable. The second fixed variable is the composition of the waste, that has been provided by Schäfer, Scheele, and Papenjohann (2019), while there will be a discussion on the transferablity of the data it will be done after the main map has been produced. The research is tailored towards the spatial allocation and identification of highest accumulation points.

At the same time the interview is seen as an additional source of information and as a possibility to verify the results from literature as well as the allocation of sources as done by Schäfer, Scheele, and Papenjohann 2019. It can be conceptualized as follows in figure 10.

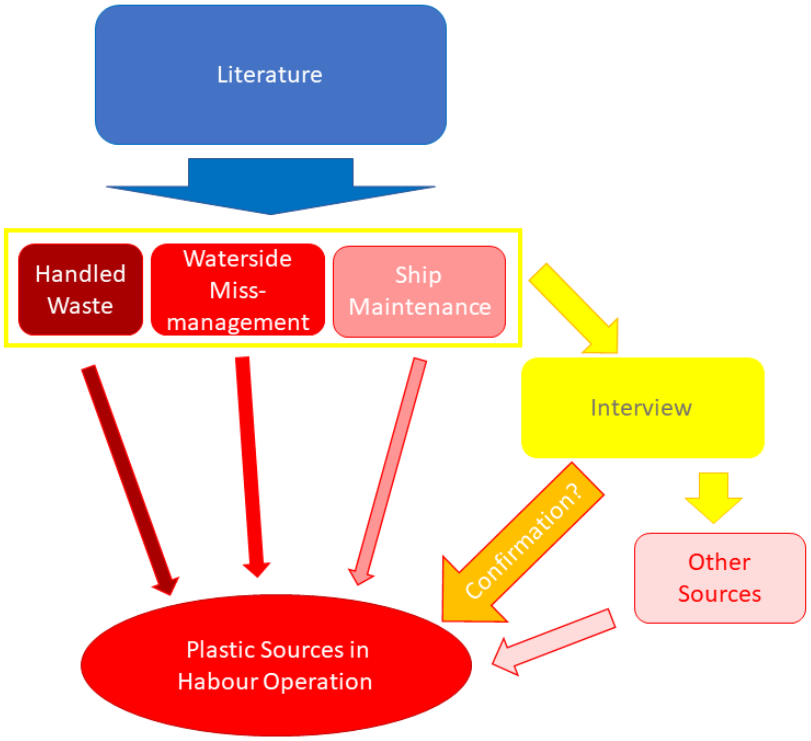

Figure 10: The role of interviews in the research.

A mixed method approach is taken as the best possible one, the next important step is the conceptualization of the research strategy, this section will provide a visual representation and sequence of the steps to take in order to answer the research question, see figure 11.

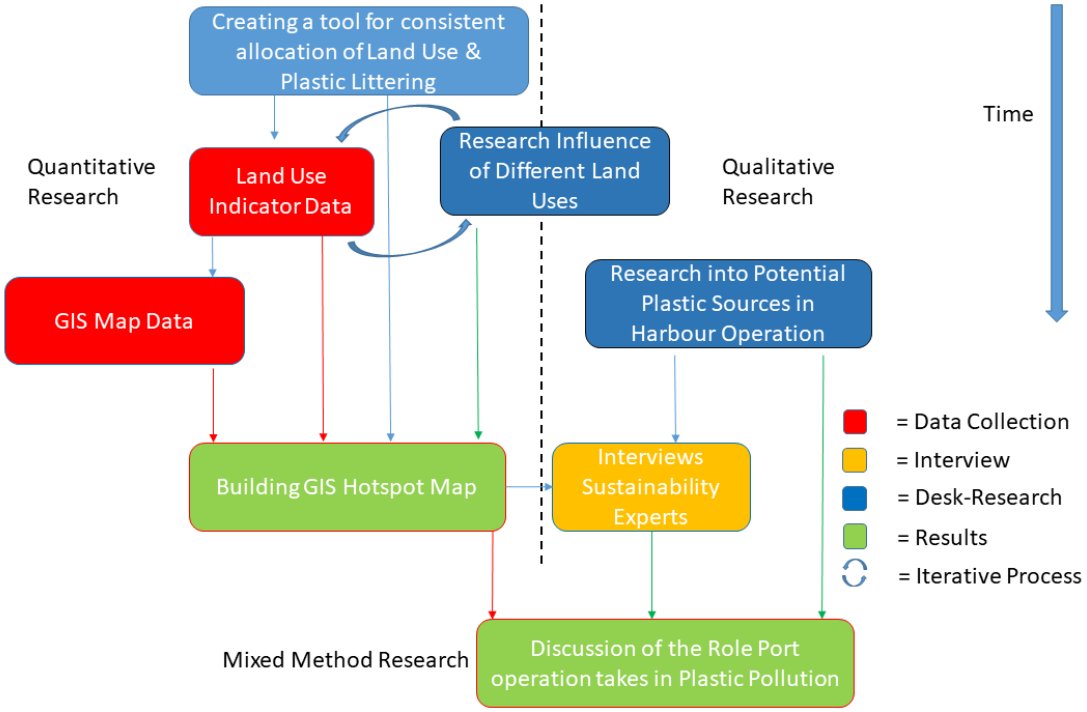

Figure 11: Research Strategy, for MMR

The results of the desk research (the blue boxes in the model) have been presented in the theoretical background, the gathering of data through interviews (yellow) and data collection (red) as well as the implementation of the tool developed in the beginning will be the topic of the next chapter on methodology. The analysis of the hotspot map as well as the discussion of the research question will be the content of chapter 6.

4 Methodology

As introduced in the last chapter a mixed method approach will be taken for the research, this next section will provide in the beginning a general overview on the concrete research approach. The subsections afterwards will describe the methodology step by step in detail.
In order to answer the main research question: Where on the coastline of The Dutch Wadden Sea and Frisiean Islands is the main contribution to Macro Plastic pollution comming from? A set of sub questions need to be answered. Firstly, what is a hotspot of pollution as well as where are the hotspots of macro plastic pollution? Secondly what activities are present in the harbours that would make it a hotspot?
The quantitative statistical analysis is addressed first. The goal is to find out where in the focus area most plastic theoretically is emitted. To achieve this at first the sectors of coastal activities have been searched for indicators in the literature. The results have been presented in chapter 2.2. The next step is done by taking a look at the emissions different sectors of coastal land-use produce and where on a local level these inputs add up the most. In this way hotspots are identified. In order to identify where most activity is situated the municipalities in the area are compared by calculating the degree to which they contribute to the total activity within the sectors. The focus is on the coastal zone of the municipalities, so only a proportion of their overall activities is included to the calculation, where it is possible from the dataset.
Then the data is analyzed spatially by adding up the contributions within the municipalities. A map is generated with the help of GIS, that provides an overview where the hotspots are situated. To get a more precise impression of the situation the map of the municipalities is then overlayed with the CORINE land cover data that shows, based on remote sensing, where the concrete locations of activity are situated. Of special interest for the research is a strip that has been set to a width of 1.5 km along the coast, rivers or major canals. This should suffice in order to account for aerial and water transport of plastic. If hotspots on both of these layers can be traced to the harbour this could be a strong indication for the role as a main source of pollution.
The qualitative approach is taken afterwards. It is addressing where in the operation of harbours plastic waste could escape the management systems and thereby reach the ocean environment. To achieve this as has been introduced in the last chapter a more concrete case would be needed in order to limit possible inputs and keep the research bounded. This case will be the combined ports of Eemshaven and Delfzijl. As the method of research for this part semi structured interviews

with experts are the most promising method for providing qualitative information on the movement of plastic waste and possible sinks into the sea.
In combination the two parts will be able to provide answers firstly on the relevance of the harbour on a regional scale and secondly on the internal workings of the waste management. Allowing for a reasoned discussion of the original research question. In culmination the qualitative and quantitative data are used to reach a greater understanding on the issue.

Boundaries

The geographic area to which the systems boundaries will be set is the southern North Sea coast. To be more precise the area is, the Dutch Wadden Sea coast from the Dollard at the German border in the east, to the city of Harlingen in the West, as well as all Dutch Frisian Islands. The boundaries are excluding the Ijselmeer part of the Wadden Sea, because the area would add a vast amount of complexity, as bigger assumptions about the origins of the plastics would need to be made and could be traced back into the whole Rhine Delta.
The theoretical scope is aimed at finding the sources of macro plastics through quantitative data, and getting a qualitative idea about the sources of macro plastics in the harbour operation environment. The aim is to produce a map that links the municipal areas and the local land uses to the specific activities mentioned earlier. The design is tailored to identify trends on the land not allocate precise numbers of waste contribution. In combination these two sets of data are linked through the mixed MMR in which the unfolding story behind the raw statistics is explored.

4.1 Gathering of Data

Quantitative research is reliant on statistical data. Where to find the data that is used to generate the hotspot map will be the topic of this section. It will also provide in detail an insight to where exactly the data is coming from and what the sources are.
Following the research strategy introduced in figure 11 after the conceptualization of the whole process the first step was desk research into the general topic of marine plastic pollution, and possible indicators for the allocation of land based activities. For the desk research the starting points have been the study undertaken by the ARSU and a broad research into the topic of macro plastic pollution in scientific literature. As this literature either peer reviewed papers or published books have been taken into consideration. The main platforms for the search for literature have been Google Scholar, and the library services of the Universities

of Groningen (SmartCat) and Oldenburg (Orbis). From the basic reading a web of studies emerged that helped in forming the theory presented in chapter 2. The research into the theory of planning further supplemented by the material that has already been encountered during the previous process of studying at the University of Groningen. For the research into the organizations connected to the macro plastic pollution their official websites have been included as valid sources. The organizations like OSPAR or Groningen Seaports themselves should provide the most precise outline of their function and structure.
As can be seen from the research framework strategy (figure 11) the search for data has to be the step after the desk research. The data collection is undertaken with a focus on accessibility and availability. The accessibility aspect means that the data has to be open for access and be comprehensible to the non dutch speaking researcher. By guaranteeing accessibility the research undertaken gains a degree of both verifiability and reproductivity. If the results of the research would be put under scrutiny this way it becomes easy to check were possible errors occurred. In this way verifiability and reproductivity are contributing to the integrity of the overall research. To further aid the integrity the selection of possible sources for the statistics is limited to renowned public institutes on national level or above or it would include peer reviewed data if that was available. The aspect of availability is more directly tied to the applicability of the data sets. If it is not possible to use a set of data, on one indicator, for all municipalities on the chosen scale this data has to be excluded. If mixed datasets were allowed it would make the origin of the different sets confusing. And it would bring the problem of possibly including different collection methodologies into one data set, opening a window for errors.
The process of searching the literature for sector indicators and searching the data providers for these indicators is repeated iteratively. It goes on until a set of data has been found that, in coordination with the supervision, has been judged as suitable to represent the spread of land based activity.
The land cover data is a subset of the overall data collection. The CORINE land cover data used has been a request from the macro plastics work group at the University of Oldenburg. It fulfills the other requirements set up for data collection and is also in use for comparable researches to this one on the German coast. It is introducing a number of categories for the land use, the ones fitting per indicator have been listed in the following enumeration for the sources of the data.

The open availability of data makes the results easy to reproduce and a repetition of the analysis can be repeated at a later point in order to trace developments.

1. Land Cover: In order to estimate the degree of agriculture and industry in the focus area as well as refining the location of hotspots within the municipality area landcover data is needed. The remote sensing data used to perform the analysis has been acquired from the European remote sensing program CORINE, the land cover data is made available on the website: (Copernicus Programme 2019). The map of the municipalities has been taken from the Arc GIS ESRI library and has been provided by the Dutch "Centraal Bureau voor de Statistiek" and "Kadaster". The Data set "Gemeentegrenzen 2017" has been used and the Municipalites in the focus area have been extracted from the document. The shape of the European coastline also has been taken from the ESRI service.

2. Population & Distribution: The Dutch government operates the independent statistics authority Centraal Bureau voor de Statistiek (CBS) that provides detailed statistics on societal issues. These statistics are publicly available and have been taken from the dataset "Population dynamics; birth, death and migration per region". The dataset provides population numbers for the first of January in every municipality (CBS 2019).

3. Tourism Activities: The activity in the tourism sector is determined through the number of jobs in the municipalities. The Dutch website Waarstaatjegemeente 2019 is providing data on a municipal basis for the chosen municipalities. To derive the total numbers of employees in Tourism the total number of workers is multiplied with the degree of jobs in comparison to the whole. Both numbers are directly extracted from the stat items "Banen Totaal [Antal]", and "% Banen Recreatie and Toerisme [%]".

4. Harbour: The amount of harbour activity is measured through the freight volume that is put through. The data for shipping in the ports has been gathered at the data portal of the European Union, EUROSTAT, the numbers for the two main ports in the area Harlingen and Delfzijl have been extracted there from the set "Gross weight of goods transported to/from main ports - Netherlands (mar_go_am_nl)" (Eurostat 2019b).

5. Industry: The indicator for industrial activity is the number of workers in the field, the data on employment is provided as within tourism by the website "waarstaatjegemeente", the relevant items are "Banen Totaal [Antal]", and "% Banen Industrie [%]" (Waarstaatjegemeente 2019). The area of industry is provided by the CORINE landcover category 121, Industrial and Commercial Units, agricultural workers have been left out due to the fact that agricultural activity is measured through the farm areas. The areas fit for agriculture are the CORINE categories 211 non-irrigated arable land, 231 Pastures, 242 Complex cultivation patterns and 243 Land principally occupied by agriculture.

4.2 Data Processing

The most important tool for the determination of hotspots are so called Geo Information Systems (GIS). These systems allow for a connection of properties, like land use or population, to locations or areas, thereby allowing for the uncovering of spatial correlations(Fazal 2008). GIS are a combination of software and hardware elements that have been used by geographers for a long time, dating back to the middle of the 19th century(Koch 2004). They combine statistics and data management approaches with maps and Computer Aided Design(CAD) technology. On a basic level they consist of a set of points, lines or polygons that get values attached to them. The points can be defined individually by geographical location, or a set up raster for a uniform covering of an area. Since the rise of computer technology a simplification in use has been achieved as it allows for the inclusion of large sets of statistical data on a large grid of measurement points.
In this research a correlation of the different categories of plastic producers to the different municipalities along the coastline is undertaken. The software used will be Arc-GIS Version 10.5.1, it is a broadly used GIS, that is able to perform all steps necessary for the solution of the task.
The municipalities are viewed as whole units, as a more detailed set of data will be hard to come by. They are for the purpose of statistics ordered by name. The different categories of land use are attributed with their proportion to overall plastic pollution based on the ARSU study that has been introduced in (2.2). The sub categories right now are weighted just by proportion.
Each municipality is assigned the contribution in permille to the overall activity within a category of land use. The contributions of the municipalities are weighted by the land uses impact and after that summed up. This provides the overall contribution of each municipality to the macro plastic pollution.

4.2.1 Calculation Basis

The concrete formulas used to calculate the contributions introduced in the following section. At first a number of variables need to be defined, that will be used across the calculations.

1. W is referring to absolute amounts of Waste, W_{tot} is the total amount of Waste that enters the ocean, W_{lb} is all waste that is introduced from land based sources. This is always given as a fraction of the total amount, of pollution. An estimation of what quantity of macro plastic is assumed to be in the study area for the identification of the hotspots it is not necessary.

2. C is always referring to a category of land use so C_T is referring to tourism for example. This also refers to the proportion within the category, following the first example if $C_t = 0,5$ this means 50 % of all tourism.

3. F_C is combining the waste and category as it provides the factor to which the category contributes to the total waste production, it is equal to the degree the category contributes to W_{lb}. This value is therefore taken from the ARSU study(Schäfer, Scheele, and Papenjohann 2019).

4. N_i is the activity of a niche, or sub category, within the municipality in comparison to the whole focus area. It is determined by the ratio in the indicators between the local value and the total sum in the study area. As different niches are present in each category the naming convention will be N_t1 refers to "niche tourism 1" that in effect means beach tourism, the numbers are provided per category later in this section.

5. M_n is referring to all added up activities within a municipality, the n is pointing to the number of the municipality at hand. This is the value that will be compared in search of the hot-spots, like all values except for the direct indicators, it is a dimensionless value. To get an estimation what the calculated degrees actually add up to a total amount of waste entering the ocean is needed.

6. F_N is the contribution factor of a niche, signifying how a niche contributes to the pollution in a category. Right now this can be calculated by the proportion of the niche in comparison with others. With further research into the effects of different activities this can be further modified to account for the differing impacts. For example if research shows that beach tourism is responsible for twice as much litter as camping tourism, the weight of the former in the calculation can be increased. Through this, the model can be adjusted to resemble reality with greater precision.

The contribution is always calculated in the same manner. The sum of all niche activities in a category is added up per municipality. After that the categories are multiplied with their contribution to W_{lb} and then summed up, giving the absolute contribution.

In mathematical terms generalized the following equations are undertaken

$$N_n = \frac{Indicator_{local}}{Indicator_{absolute}} \tag{1}$$

After determining the local contribution to the niche the next step is to multiply that contributions with their corresponding specific factor. These are then added up in the categories and multiplied with the category factor. Finally all of the categories are combined to get the total contribution of a municipality summed up, this culminates in the formula for the complete contribution.

$$M_n = \sum_{C}(F_C \cdot \sum_{N_i}(N_n \cdot F_{Ni})) \tag{2}$$

The contribution is rounded off after the third digit as this provides a tangible measure of activity in every one of the 17 municipalities without creating an illusion of precision that would originate from providing more significant digits. All calculated contributions in the municipalities finally need to sum up to the complete degree of land based plastic, to fulfill the requirement from the conceptualization of waste dynamics, that the total waste produced and the amounts as provided by the ARSU are fixed variables.

$$W_{lb} = \sum_{W} M_n \tag{3}$$

Calculating Tourism Activity

Tourism accounts for the biggest share of the pollution output, it represents 19 percent of W_{tot} or 48 percent of W_{lb} according to Schäfer, Scheele, and Papenjohann (2019), this is also the F_C for tourism.
The factors for the niches should be categorized in three categories, beach visitors, day trip guests and employment in the tourism sector. Out of these only the employment is available in the fitting resolution. The implications of this circumstance will be discussed further in chapter 6.5. The niches and corresponding indicators and factors for Tourism are: $EmployeesTourism_{absolute} = 9954$ Due to there only being one category for tourism, the $F_{NT} = 1$

Calculating Harbour Activity

Harbours are contributing about eight percent to W_{tot} leading to a W_{lb} of 0,2 so the F_C for harbours is 0,2. The lack of knowledge about different harbour activities or niches and their contribution is one of the driving factors for the second part of this work that is aiming to gain an idea what could be feasible. So right now the chosen indicator is the amount of cargo handled, as it allows for both the inclusion of large harbours dealing with international trade as well as smaller fishing or specialized harbours.
$CargoAmount_{absolute} = 7755000Tonnes$

Calculating Industrial Activity

The estimated impact of industrial land based activities is seven percent of W_{tot} leading to an W_{lb} and F_C of 0,19. The factors for the niches are determined by an equal spead leading to both having an F_{NI} of 0,5. The main niches and their indicators are:

1. Agriculture the indicator for agriculture is the amount of land dedicated to it within the coastal area
   $AgriculturalAreas_{absolute} = 317,34km^2$

2. Producing Industry to get an idea where the industry is strong a view is taken at employment in the area
   $EmploymentNumbers_{absolute} = 18473$
   As well as the area occupied by industry
   $IndustryAreas_{absolute} = 14,8km^2$

Calculating Municipal Activity

Inhabitant or municipal activities contribute a total of six percent to W_{tot} according to the ARSU study, to get this number the contributions from waste management and storm water management are combined both are based within unwanted consequences from inhabitation. They have a W_{lb} and F_C of 0,15.

1. Waste Escaped from Management, the factor is seen as flat across the municipalities the indicator is the total population in the area
   $Population_{absolute} = 237411$

The complete tables will be added as the Appendixes I-V. An in depth analysis and discussion of the results will take place in the chapters 5 and 6.

4.2.2 Using Arc-GIS

In Order to produce the map in Arc GIS a number of steps need to be followed. At first out of the shape-file of all Dutch municipalities to all municipalities of interest are exported. Then this shape file is multiplied of the different categories. In each category the attribute-table is expanded to contain enough variables. For each niche two new attributes are generated, the first is the local number of the indicator and the second is its degree of contribution, that is calculated the same way N is. The last additional attribute is the contribution to the whole category of a municipality. The contribution is then shown in the map.
After that another copy of the focused municipalities is generated, the total contributions of all categories are imported into this map, then as announced in the calculation part they are multiplied with their category factors and added up generating the total contribution map.

CORINE Land Cover Data

Of special interest for the Corine Data analysis is the stretch of 1500m along the coastline and major waterways as well as the complete islands. For generating the map, the islands are exported from the municipality list. Then the Buffer tool is used on the coastline shape and the Lauwersmeer with a one sided stretch of 1500m. The buffered map is cut to the shape of the municipalities. These two are then merged into one map and dissolved, they will serve as the mask for the land-cover analysis.
The CORINE data is extracted through the mask. To get the amount of raster points that belong to the categories the "tabulate area" tool is used. The raster is the land cover data from the mask, the shape is the original borders of the municipalities.

The categories are for industry number 121 and for agriculture 211, 231, 242, 243. The areas are then added up and the generated table provides the information on how many square meters are present in every municipality per category. The agricultural areas are then added up to gain a combined picture of the spread.

4.3 Interviews

For the second part of the thesis interviews have been chosen as the preferred method of research, as they are a good source of the qualitative data that is required for the MMR approach. Interviews are among the most commonly used tools in societal research (Whiting 2008) and can be roughly divided into three approaches based on the amount of structure that the interviewer sets up (Brinkmann 2014).
The approach taken will be semi structured, open question interviews, as they are able to provide qualitative data with a preset expectation towards the topic, while not to the outcome (Brinkmann 2014). Structured interviews would lead to a more narrow, quantitative set of information that is less desired for the open, explanatory goal of the research (Whiting 2008).
Unstructured interviews focus more on the interviewees priorities, these may be in line with the overall research goal but run the risk of strolling of the set path (Brinkmann 2014).
In his work Brinkmann (2014) distinguish between two different approaches to semi structured interviews. Of these the receptive style that focuses on the classical interviewee and listening focused style is the best fit, for finding out what contributes to the pollution in the harbour environment. From this follows that the main challenge will be to validate the reports given by the interviewees. In the case of the harbour it is done by cross examining with literature research. The idea that validity is the main criterion for selecting interviews is also in line with Whiting (2008) who sets up three criteria that a good interviewee needs to fulfill.

1. A deep knowledge of the topic.
2. The ability to reflect upon the topic.
3. The willingness to participate in the interview.

This necessitates for all chosen interviews an interviewee who is employed within environmental or sustainability management division of the organization.
The interviews themselves are either conducted at a meeting or if not possible in this way via a video feed, namely the software Skype. The physical connection arising from a meeting interview is most likely to produce the best results,

interviewer and interviewee are able to connect more efficiently leading to better outcomes and a better opportunity to feel themselves into the interview and be creative (Brinkmann 2014). The video feed interview is less wanted, it allows for a smaller degree of connection, but through the video feed it still is able to carry over the body language leading to an acceptable result. The video interview has the benefit of making it easier to schedule due to traveling for both the interviewer and interviewee to be unnecessary and the fact that it can be set up for a time of convenience.
The goal is to conduct as many interviews as possible, to generate a spread of differing opinions in connection to possible sources from the harbour. This is, as can be seen in the research strategy framework (figure 11), done after the collection of the statistical data has been concluded. The surrounding conditions are left to the interviewees as long as the set date still is set within the possible time frame for this research, namely the beginning of August. The approach serves to create a comfortable ambience for the interviewee that helps, just like the preferred method of meeting personally to facilitate an informative conversation(Brinkmann 2014).

4.3.1 Interviewees

The contacted interviewees and their relevance for the topic will be introduced in this section in order of localization and proximity to the port.

Groningen Seaports

The first partner of interest for an interview is Groningen Seaports. They are the administrative body that is responsible for the running of the ports of Eemshaven and Delfzijl. The harbour has been certified as an ECO port for the last 6 periods that this certificate has been tendered by the ESPO. The certificate needs to be reapplied for every two years and for each round improvements in the reduction of environmental impacts from the port have to be proven as well as the fulfillment of goals set over the last certification duration. In this a great amount of awareness for the issue of macro plastic could be found and a story of what has been identified and addressed as a problem. Groningen Seaports perception, on where problems within their own processes do occur, are extremely valuable, as they are most likely to recognize faulty systems early. In their Annual report for 2018, they also state that they are in constant exchange with the trilateral Wadden Sea administration and other ports in the Wadden Sea area. The cooperation's are cultivated in search for best practise examples to implement into their harbour.

Waterboards Noorderzijlvest and Hunze et Aa's

The waterboards of Noorderzijlvest and Hunze et Aa's are responsible for the ensuring of the water quality. To do this they need to monitor the water bodies on a regular basis. The monitoring is most likely to reveal what the main plastic objects found within the port are. At the same time the waterboard is an elected body that is accountable to its electorate, making them open to discussions on water quality issues with the public. As the organizations that are also responsible for the management of waste water their expertise can help to identify patterns in plastic waste origins. On their websites neither of the waterboards does concern itself further with the plastic problematic, it is therefore of interest to see their self perception towards the issue.

Province of Groningen

The local government authority responsible in the area is the Province of Groningen, their duty is the assurance of both an economic future for the province as well as sustainability for its nature. This dilemma could pose an interesting position on how the problem is conceptualized. The province is also the main authority that is responsible for authorizing structural developments. This makes it necessary to get a feeling for the environmental impact or the implications on the quality standards set up by the WFD and MSFD. The expertise coming from the formal standards to comply with, will make environmental managers from the province more aware of trends and developments in the sector and could facilitate them being able to provide inside into plastic pollution processes.

Wadden Sea Forum

The Ports are in direct proximity to the UNESCO world heritage site Wadden Sea, therefor it is of great interest how the people invested in its protection are perceiving the operation of the harbour. They are most likely to be critical of port operation as their main interest is the protection of the nature area. Their contribution could be a focus on practises or happenings that are overlooked by the other interviewees. As mentioned in the Groningen Seaports section the port administration provides the information that they are in constant contact with the Wadden Sea administration, it would be interesting to investigate how this relationship is perceived from the other side.

4.4 Assumptions

In order for the model set up here to work a number of assumptions and simplifications have to be made, these are described in the next section.

1. The study that is the main reference for the proportion of plastics has been conducted in German waters, it is assumed that due to the close proximity and comparable use these values also hold true for the Dutch coast.

2. General behaviour of the population within the study area is overall constant, it is presumed that people who live in Texel are as polluting as people who live in Oldambt. It is assumed that comparable activity leads to comparable contributions, in reality this would need further research due to different local culture or self image. (Mukhtarov 2014)

3. The different proportions are educated estimations, they serve to identify trends and find out where clusters of activity are located, they do not claim to provide precise data. Therefore limited imprecision in the indicators can still point towards the correct trend overall.

The results originating from the data that has been gathered and the applied method described in this chapter is presented in the next chapter. The discussion on what the findings point toward or mean will be done in the chapter after that.

5 Findings

This section will provide the pure data findings of the research, the interview is summarized and the maps resulting from the GIS analysis are presented as they have been produced in accordance to the processes described in the methodology chapter. An analysis of the raw data and the discussion on how to rate it will be the topic of the following chapter.

5.1 Results

At first a general overview is provided into the spread of the activities within the different sectors, the combined map will be presented in the next section.

Tourism

The tourism sector is portrayed in figure 12, the biggest share is located on the island of Texel, Terschelling and Ameland as well as the Municipality of Oldambt. The rest of the islands and land municipalities are spread out relatively evenly. The complete collected set of data is attached in Appendix I.

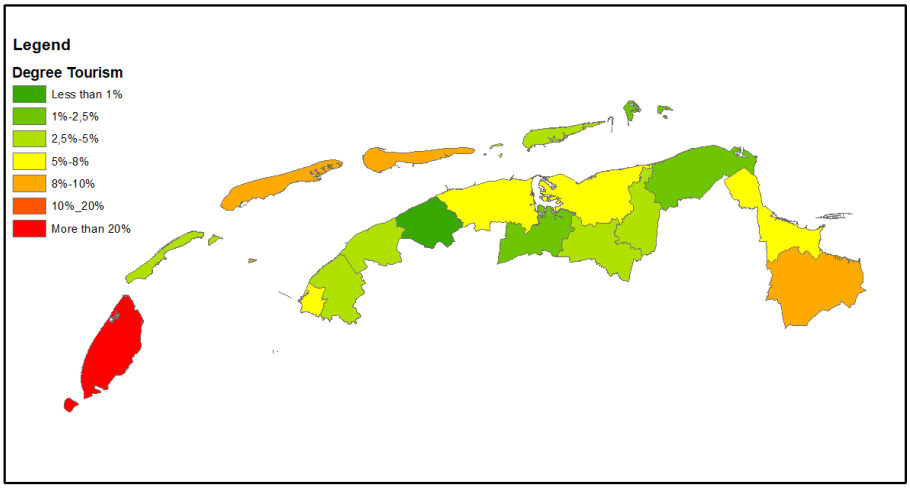

Figure 12: Spread of Tourism over the study area.

Harbours

The relevant ports in the Area are Delfzijl & Emshaven and Harlingen with the former two contributing about 94 percent of all port activity as one administrative unit in the focus area. The Harbour of Eemshaven and Delfzijl has been handling about 7,24 million tonnes of cargo in 2018, while Harlingen has handeld 0,52 million tonnes in the same time. The Table of the dataset is Nr. II in the Appendix

Land Based Industry

In the section of land based industry the island of Texel, Delfzijl and Harlingen stand out as major contributors. Harlingen gets the main contribution from producing industry, about 35 percent of all industry activity can be traced back here. The high amount of activity in Texel is vastly based on the large amount of agriculture in the area. Delfzijl is represented in both fields, leading to a strong contribution. The results are visualized as combined land based activity in figure 13.

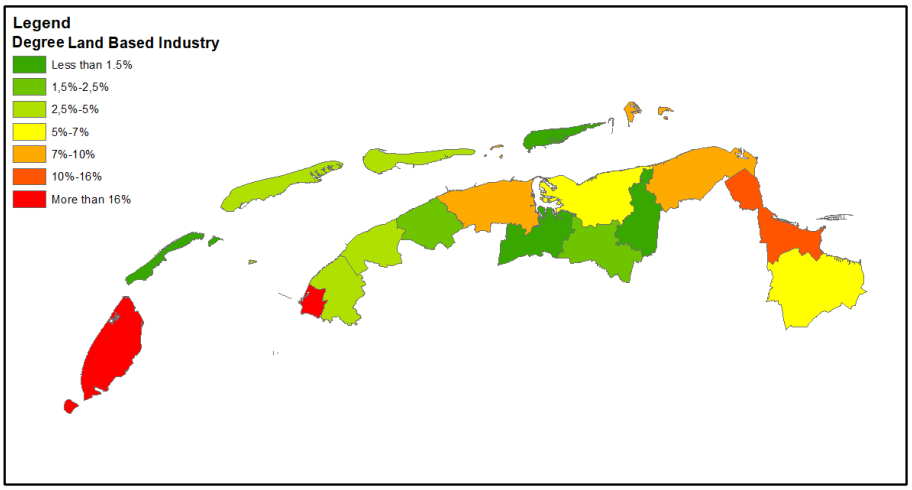

Figure 13: Spread of Land Based Industry over the study area.

The complete collected set of data is attached in Appendix III., for reasons of clear arrangement the Appendix is split in two parts. The first table focuses on the industry part, the second table contains agriculture and the conclusion on total land based contribution.

Municipal Waste

The biggest population is found in the municipality of Oldambt, followed up by Dongeradeel and Delfzijl. The spread is shown in figure 14, on the next page, while the complete set of data is provided in Appendix IV.

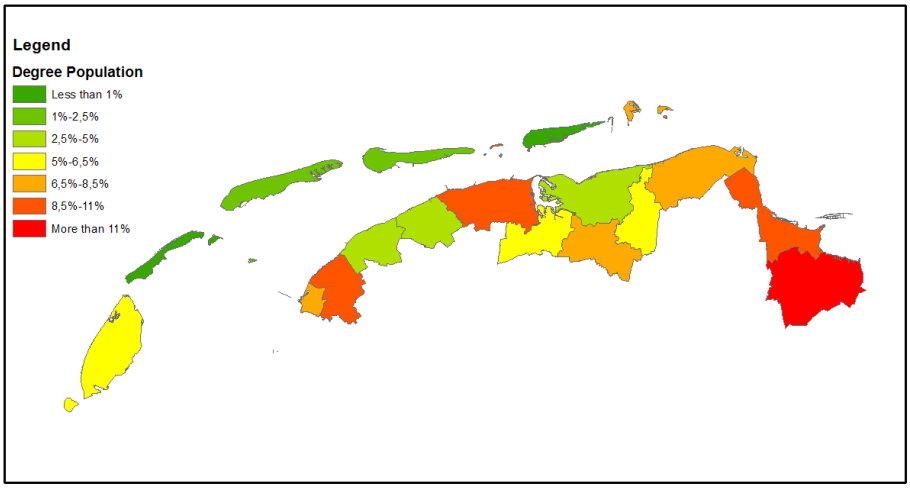

Figure 14: Spread of Population over the study area.

5.2 Expanded Pollution Map

The by far biggest contribution to the overall pollution is coming from the municipality of Delfzijl, followed by the island of Texel and then the Municipalities of Harlingen and Oldambt. The smallest amount of litter originates in the municipalities of Ferwerderadiel and Kollumerland. The data is portayed on a map in figure 15.

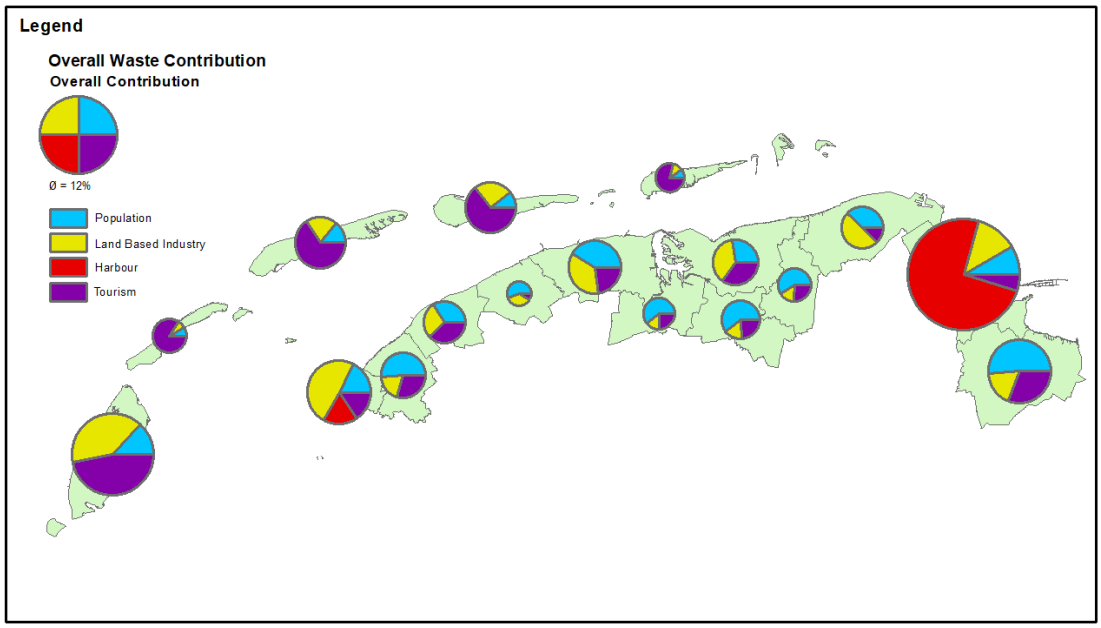

Figure 15: Combined Map of waste imputs from the municipalties, the size of the pie charts is indicating the amount of overall contribution, while the charts themselves indicate how the activity in the area is composed.

In the following table the municipalities are sorted by their contribution, it also provides the values of the activities coming from the individual sectors in each municipality. It also is Appendix V.

Municipalities	Deg. Tourism Activity in %	Deg. Harbour Activity in %	Deg. LandBased Total in %	Deg. Population in %	Total Waste Contribution in %
Delfzijl	5,9	93,3	15,4	10,5	25,7
Texel	20,4	0,0	17,5	5,7	13,6
Harlingen	5,8	6,7	18,3	6,7	8,3
Oldambt	9,8	0,0	5,6	16,1	8,1
Dongeradeel	5,6	0,0	8,8	10,1	5,7
Ameland	9,3	0,0	3,6	1,5	5,3
Terschelling	9,4	0,0	2,9	2,0	5,3
De Marne	5,3	0,0	5,8	4,2	4,2
Franekeradeel	4,9	0,0	3,1	8,5	4,2
Het Bildt (De Bildt)	4,9	0,0	3,5	4,4	3,6
Eemsmond	2,2	0,0	8,6	6,6	3,5
Zuidhorn	3,2	0,0	2,0	7,9	3,1
Vlieland	4,6	0,0	0,4	0,5	2,3
Winsum	2,5	0,0	1,5	5,7	2,3
Kollumerland	2,2	0,0	1,3	5,4	2,1
Schiermonnikoog	3,2	0,0	0,5	0,4	1,7
Ferwerderadiel	0,6	0,0	2,3	3,7	1,2
Combined					

5.3 Interview Summary

All institutions that were listed in chapter 4.3.1 have been contacted for interviews. The only reply on time has been from Groningen Seaports and also resulted in an interview. The summary of this interview is provided in the next section.

Interview with Groningen Seaports

The interviewee is Geert Jan Reinders, who is a staff officer for Groningen Seaports, he has been pointed to as the best possible contact by his colleagues.
The interview has been conducted on the 26.07.2019 in Delfzijl at the port-side.. The meeting started on 15 00 at the Seaport Administration building and has been moved on the interviewees suggestion. The interview took roughly an hour to complete.
After a short introduction to the specifics and reason for the interview, an open conversation ensued. The first talking point was the handling of ship-waste. In earlier times Mr Reinders stated this used to be a big problem. The waste was handled in large plastic bags. These bags where prone to wind and seabirds taking out debris and thereby littering the harbour water. But this practise is in the process of being replaced by a new form of management, namely the employment of dedicated waste containers. These containers are closed and sturdy enough to withstand and avoid the previous causes for littering.
The next topic raised was the the general awareness for littering. The harbour in accordance to Mr Reinders is patrolled a couple of times per week by an employee. This employee is looking out for accumulation within the harbour basin as well as on the lots that are given to companies on the waterside. The port

authority is then, if waste is found to accumulate, politely reminding the companies of their responsibility to keep the harbour environment clean and clean up the waste they caused. Other waste that accumulates on the public areas of the harbour is addressed directly by the port administration.
The third source of pollution addressed where maintenance works that ships crews undertake within the harbour, this is a topic that used to be of importance. Nowadays however, the port forbids any maintenance outside dedicated docks. The example to signify this was the small port authority measurement vessel. Even the small boat is not allowed to be maintained within the harbour itself.
The last main possible source discussed in the interview where the vestiges occurring from the repair of fishing equipment. Mr Reinders was proud to announce that the port authority has struck a deal with a recycling company that enables a take back of the rope and net material. The fishermen themselves as well as the port authority do not need to pay for the recycling company to fetch the leftovers of nets preventing the dumping of the material that was common in the past. Even though the fishing industry has shrunken considerably this is addressing a major source of plastic pollution.
After the sources where addressed the next topic was the role and development of the ports environmental management system. This was started with a short reiteration of the story surrounding the MSC Zoe that unraveled in January 2019. The large container ship lost a number of containers during a storm north of the German island of Borkum. The containers opened and spilled their contents all along the Dutch and Geman coast. The harbour was littered by this in a major way and the costs for the clean up where collected and have been forwarded to the Mediterranean Shipping Company (MSC) for compensation. At the same time it is a sharp reminder of what the influence of unconfined plastics pollution is. This reignited the interest in the plastic pollution problem at the whole coast. The port authority has been in constant cooperation with the Wadden Sea Secretariat in Leuwaarden, this has been an overall very productive cooperation, even though at times a little bit of understanding for the processes within the harbour is missing. But the communication most of the time is working out and lead to a continuous improvement.
This improvement is also the main component leading to the port receiving the Eco Port certificate straight up for the last six periods. The plastic that is still found within the harbour is partly flushed there by wind and currents. Overall the port authority is very aware and satisfied with its plastics management system. While macro plastic is not the top priority, once an issue occurs it is addressed right away. Right now improvements are a little slow but this is due to a reorganization of the management system to make them more effective. Once

practises like the container based waste management system become mandatory, not voluntary as at the moment, even less plastic will be introduced into the ocean. And in case an accident or spill event the releases a large amount of plastic into the harbour containment plans are in place allowing for swift and effective reaction. But while they do their very best to reduce their impact on the environment a limited disturbance of the environment can not be prevented from international shipping.

6 Discussion

The following part will combine all the information that has been gathered in order to provide answers to the main and sub questions. Which have been introduced in chapter 1.2 and will in this way conclude the thesis.

6.1 Analysis of the expanded System

The overall spread of the plastic pollution sources, following the approach layed out in the last chapter, allows for a clear identification of hotspots. If the spread was completely even, every municipality would contribute about 5,88 percent. Two municipalities are responsible for more than double this number, Delfzijl and Texel and two more contribute more than eight percent namely Harlingen and Oldambt.
Somewhat surprising the municipality of Oldambt, due to its by comparison to the rest of the study area, large population, scores relatively high on the overall scale of pollution. The main factors holding the municipality back from scoring even higher are the small amount of area in the relevant activities along the coastline as well as the low relative degree of workers in tourism. Delfzijl is pushed to the high degree by the harbour data, that is almost completely attributed there and will be discussed in chapter 6.3, what already can be underlined is that the choice to focus on the port was the right decision for a critical case. These observations also align with the overlay of the CORINE landcover data, Delfzijl and Harlingen are the main areas where industry is taking place directly at the shoreline, the industrial ports are connected directly into industrial parks. These provide also jobs, leading to an accumulation of population around the area, increasing the other contributing activities. On the islands the opposite can be observed, the focus here is put on tourism, that prospers due to people enjoying their environment and being away from industry. This is also most likely connected to the amount of space that is necessary to accommodate the tourists leading to comparatively small populations. Here Texel is the clear exception, with its big population and a lot of jobs in the tourism area as well as in comparison to the other islands a bigger share of industrial workers lead to a clear hotspot.
While raising a couple of questions the picture painted in the analysis is clear, the next section will try to shed light on how this relates to the experiences that are connected to the operation of harbours.

6.2 Plastic coming from Harbour Operation

As can be read in the interview summary, there is awareness within the harbour for the main categories of waste that are expected on location from literature. These can be summarized as waste originating from the handling of occurring crew waste, the maintenance of the ships, the breaking down of rope and net material and container materials such as flat bands, large boxes and jerrycans (Schäfer, Scheele, and Papenjohann 2019). This awareness has lead to the harbour taking precautions in order to reduce or nullify the impacts and main entry ways.
The use of dedicated waste handling containers as mentioned by Mr Reinders, is a promising approach. Not only is it more resistant to wind that pulls waste out of the classically used waste bags, the containers will also be, due to their higher mass and worth, secured and handled more consciously. This leads to a reduction in the danger of losing the whole container filled with waste. The container is also more resistant to ripping or tearing that could spill the waste. In combination this reduces the influence of seabirds or other animals, that help to spread the litter out into the environment and thereby the ocean.
Controlling the port perimeter for waste accumulation on a regular basis is able to address the next large problem, packaging material. If it is prevented that the potential plastic or other waste material accumulates close to the water, it leads to a reduction of the vulnerability to natural transport processes or accidental spill. At the same time clear allocation of the responsibility to the companies to remove and/or pay for the pollution they cause will strongly incentivise an efficient waste management strategy.
In forbidding the undertaking of maintenance work on the outside of the ship within the harbour a huge problem and source for potential litter is generally shut down. This only leaves smaller scale repairs open for the production of litter as well as accidents like small bits of fastening or apertures, like light bulbs, slipping away and getting into the water. The most common items found on beaches can be traced to fisheries, dolly ropes, net fragments and thin rope. By offering a possibility to fishermen to get rid of the discard and scrap, that accumulates from the repairs necessary to their fishing gear, an environmental improvement can be achieved. This is especially valuable for the fishing sector, that while contributing disproportional, has been in decline in the last decades. While the ARSU study does allocate fishing as its own, sea based source of pollution, this inclusion into the port environment is very sensible.

Overall the basic problems and sources that have been identified by the study have been confirmed, and the dumping of fishing gear as a possible entry way in harbours has been added to the consideration. What has not been pondered deeper is how far these single sources contribute in the first place, as the main focus was put on the qualitative exploration not the quantitative side of the data. This also makes it problematic to develop a picture of how big the contribution of these single measures is. The problems have been addressed, how this relates and what it means in combination with the applied hotspot map will be discussed in the next section.

6.3 The Harbour a Hotspot?

Following the hotspot map methodology it has to be declared that the municipality of Delfzijl is a major contributor to plastic pollution. According to the data it provides 26 percent of all plastic that reach the ocean from a land based source. This makes it almost 50 percent more severe than the next contender, the island of Texel. While due to the relatively large population living and working in Delfzijl a hot-spot is to be expected, the degree to which it sticks out is overwhelming.

The port complex is by far the biggest port in the study area, from the results that have been produced in the study of Schäfer, Scheele, and Papenjohann (2019) this makes them a large contributor to the problem, but here one of the assumptions may be faulty.The original study, as undertaken by the ARSU, has been done for beach clean ups at the German coast. The German coastline though is far more plastered with big ports, Wilhelmshaven, Bremerhaven, Bremen to a degree and Hamburg are far larger than Delfzijl (Eurostat 2019a) and their influence will be far bigger for the beaching, making the degree of 20 percent for the complete litter originated from harbours out of the study area questionable. While the area is bigger and a lot more activity will take place along the coastline. The gross freight volume handled at the German North Sea is more than 30 times as much as handled by the two ports of the study area (Eurostat 2019a). For the estimations to keep applicable the other activities would need to be compared as well, for the model to work properly the proportions need to be roughly comparable. While this seems plausible on other aspects on first glance in the port operations sector it does not add up. To fix this the study would need to be up-scaled to incorporate more port areas in order to adjust for the monumental position the Emshaven and Delfzijl harbour has got right now. At the same time, due to the mean flow direction within the North Sea (Neumann, Callies, and Matthies 2014), it is quite possible that plastics from the harbour of Emshaven and Delfzijl

ends up on German beaches while the other way round this is far less likely.
This view is also supported and furthered by the interview with Mr Reinders. The harbour is addressing the waste categories assigned to them by the ARSU study (Schäfer, Scheele, and Papenjohann 2019). This makes it difficult to attribute them with the enormous amount of plastic that would need to originate there. The qualitative and quantitative data are majorly at odds.
To sort this out it is important to take a deep look into the local context. The sources that have been attributed to harbours have been confirmed, but an extensive governance structure has been introduced that addresses precisely these confirmed sources of plastic. In the case of this specific harbour in the regional context of the Wadden Sea, without including the Dutch ports of the south, that are handeling far greater amounts of cargo (Eurostat 2019b), the numbers do not work out. This insufficiency indicates how a niche structure for the correct allocation of port contribution should be designed in order to allow for a broader generalization of the results over the current boundarys of the study. The gross transport volume of freight needs to be connected with a factor, that accounts for the state of the environmental management system within the port for the issue of plastic pollution.
The main niches should be ship waste , ship maintenance and waterside companies. The values for the niches need to include how developed the management in the harbour is. For example, a well developed port waste handling through containers is reducing the danger of waste spill by three quarters, this also should decrease the contribution in the niche accordingly. The factor needs to reflect how important the niches are when compared to each other on a more general scale.

6.4 Addressing Uncertainty

When looking at the implications for the dilemma connected to the amount of centralization necessary, in order to address the problem of macro plastic pollution, that has been introduced in chapter 2.3 it becomes apparent, that the map and information uncovered are directly helping in dealing with the uncertainties. The tragedy of the commons is often directly connected to no one being made responsible for the action, as all people could harm the environment it is hard to pinpoint single sectors that have to improve. The map does help in doing exactly that, it brings certainty on the areas that do contribute the most. In coordination with the principle of "correction at source" it becomes visible where the main sources are located. Redeveloping the environmental governance in the areas of highest impact becomes the highest priority, the community can then on site de-

sign solutions that fit their specific local context. At the same time the sources itself are shown. In Texel the biggest source is tourism, followed by agriculture so in order to reduce their plastic impact it is important to find solutions on a local scale there. The centralization does come in through either making it mandatory to act for identified hotspot areas or by using the "polluter pays" principle. The regions with the highest contributions are necessitated to pay more in order to help mitigate negative impacts of plastic pollution, like beach clean ups.
For the case of the harbour Emshaven and Delfzijl the dichotomy between the statistical allocation of waste and the uncertainty coming from the interview and the measures taken, proves why the complexity view on the issue is of importance. As stated in chapter 2.3 for introducing effective legislation, both sides need to be heard. A governance approach, that would try to force the port to further reduce their plastic output, based purely on the generalizations arising from statistics could lead to a lot of resistance, due to them already having worked towards a good status. As mentioned regulation in a complex world needs to include flexibility to a certain degree, as the port is working with best practise examples, it could be more promising to try and implement best practises broadly in all ports and after that continue from the generally lower state. The problem of complexity remains though, the locations of the sources have been identified, but the uncertainty about what to do is still a topic that has to be discussed and evaluated. In this process the hotspots can be included as a helpful guidance and legitimization for the enactment of environmental policies.
An additional survey on a smaller scale is necessary to reach a good local picture on the pattern of pollution. Only on a local level optimal solutions can be negotiated between different parties. On the larger scale the study does help in finding workable limits to the pollution. The qualitative analysis did show that specific measures are able to reduce the effects harbours have got on the environment. These should provide examples and inspire a train of thought that identifies the current problems and does try to find solutions step by step.
When taking a look from the decentralized municipal view the map also is able to help the communities to find out in which directions they can become active in their region. A part of complexity is as mentioned the temporal component. The pollution map as well as the study on the composition of waste are always snapshots in time. Still the goal of the reinvented environmental planning system is achieving a long term good status. So it becomes very important to redo the studies with a certain regularity, in order to monitor the successes that have been achieved as well as identify new trends in plastic pollution to address. The same applies for the hotspot areas, with an addressing of the local sources improvements should be made, leading to a shift to new areas that are of interest for

improvements. Ultimately a record of the overall amount of pollution encountered would be helpful in the long run, to quantify that the situation overall is developing into a cleaner future.
From the environmental governance perspective, the method could not only be applied at other coastal areas but also pose the idea to implement such a system for rivers. If the composition of the plastic waste coming from a river system is analyzed in a way comparable to the study by Schäfer, Scheele, and Papenjohann (2019), an analysis could be made where the plastic pollution hotspots are within the river system, leading to benefits comparable to the governance of waste in coastal waters that are the focus of this research.

6.5 Availability of Data

Most important attributes for the indicators are an ability to provide a realistic approximation and a broad applicability or availability across at least the whole study area for the research. Optimally the data would also be available for the complete Netherlands, as this would make a general study for all of the whole national coastline possible. The current analysis of the system is impeded significantly because of the data availability. Especially in the tourism sector, basing it soley on the employment numbers is a stopgap, that should be fixed, if better data on numbers of beach visitors, numbers of day trip visitors as well as the number of overnight stays in the municipalities are known. Or, even better, smaller sub units maybe on a square kilometer base become available. As tourism accounts for almost 50 percent of the total land based waste an improvement in this sector would majorly improve the results as especially day visitors or beach visitors do not necessarily create jobs in an area they actually stay in. What is also not accounted for is the radius of movement the tourists have. While if they are staying on one of the islands they are hardly moving over long distances, tourists on the main land are able to visit the whole study area for single days. This also transfers into the municipal waste sector, the idea is to include the overnight stays of tourists into the regular inhabitants, that would give a more precise picture of the real occurrence of waste that needs to be managed and therefore potentially creates marine litter.
A similar problem occurs in the obtaining of data with regard to the ports. Industrial ports are the only ones directly reporting the gross freight volume that is handled on site. While the basic idea of using the quantity of goods transported as an indicator is still a valid one, data for example on the amount of goods that is transported to and from the islands is missing. There are according to the municipal statistics more than 23000 inhabitants on the islands not counting in the

tourists, these people need to be supplied with food, clothes and commodities. This amount of shipping is unaccounted for because data is missing on the issue. It would also help to mitigate the problems with the indicators as discussed in the last section as it provides a more true to reality picture of the situation. Instead of using the population spread as an indicator for the occurrence of municipal waste management losses, it could have been better to directly use the amount of waste collected within the municipalities, this approach became unavailable though due to the islands of Ameland, Vlieland and Schiermonnikoog not providing any data on the their waste amounts. It is also the reason no further research was undertaken into the amounts of ferry crossings to the islands as, firstly ferries are a sea based source of pollution according to the ARSU classification. Secondly the amount of day trip or overnight tourists could in theory be calculated from the differences in people entering and leaving the islands. The numbers are not openly available and they would only provide values for the islands, thereby they are not applicable.

Overall it needs to be acknowledged that the precision and resolution of the model is limited, this is due to the lacking availability of data. Still this limitation or even the roughness in the current system do not prevent the tool from doing what it aimed to do in the first place. The goal is to point towards the hotspots, they can serve as starting conditions for oceanographic waste spread models or can further be investigated to gain deeper insight into local effects that further marine plastic pollution.

7 Conclusion

The posed main research question has been, where on the coastline of the Dutch Wadden Sea coast and the Frisean islands the main contributions to macro plastic pollution is coming from. This has been answered, the spread is presented in section 5.2 of this report. The main contributions with an advance of 50 percent over the next municipalities can be found in Delfzijl (26%) and Texel (14%) and are therefore eligible to be called hotspots.
The overall goal of finding waste streams and hotspots has been successful. The tool for generating a map on the spread of activity worked out even if the precision is limited. The port authority confirmed that the main sources of plastic, coming from habours are losses from ship-waste, mismanagement of plastic debris and waste on the waterside, in port maintenance of ships and leftovers from fixing fishing gear.
The methodology that has been employed is able to generate a map, that points towards the areas that have the biggest amount of polluting activity. This should mean that the approach can be used also more generally, in other areas independent of the Dutch context. To do this though firstly the composition of the polluting plastic needs to be analyzed for its origin uses. Secondly the indicators need to be tailored to the new regional context. For example the practise of landfill waste management was not seen as a relevant factor in the northern European context. If the method would be repeated in a different cultural circle, landfill could become a major factor, that needs to be accounted for through an indicator. The research strategy could also be used to classify other diffuse origin areas for pollution, like plastic in river systems. As long as the composition of the waste can be attributed to different land uses.
The constrains with regards to the precision in the map are of limited severity as long as the chosen or found data is able to provide a general trend, that is providing a coarse but realistic model. The goal is identifying the bigger trends, the model on the chosen scale cannot portray the amount of detail that would be necessary in order to become a true to live, accounting for every local circumstance. But what it is able to provide, is a pointer towards areas that should be investigated to a greater detail.
The answer to the questions delving deeper into the role of the port Emshaven and Delfzijl is more diffuse. This aligns with the complexity that the whole issue of macro plastic pollution entails. The town of Delfzijl is a definite hotspot this is caused not only by the harbour but also by the connected industries and population. These factors are linked closely, industry thrives where a good connection to infrastructure is provided. Population tends to flock to industrial sites, as it is

a secure source of creating jobs. The port is the biggest in the whole study area, so in conclusion it is a notable source of plastics. These assumptions are in line with the data that has been encountered.
At that point the uncertainty starts, the probability based study that is at the core of the tool created for finding hotspots has been undertaken on the German North Sea coast. The German area includes a lot of big ports, this is in contrast to the focus area in the Netherlands, where the big ports are located at Rotterdam and Amsterdam, so outside of the study area. This is possibly distorting the picture to a degree. The perspective on the harbour further shifts when including the second, qualitative part of the research. In an interview with Groningen Seaports, the port authority responsible for Eemshaven and Delfzijl, it became apparent that there is a clear awareness of the possible sources of plastic entering the ocean from the harbour. The awareness lead the port authority to introduce a number of policies that address and reduce the impact of all sources known to them. While a small amount of littering can not be barred, the overall process has been certified by the European Port authority that granted the title of ECO port.
So in conclusion the question can be answered with, the harbour could be classified as a hotspot, but not just because of the port activity. All four categories of land use, tourism, port operation, land based industry and municipal waste culminate around the port.
For the decision making between more centralized or decentralized approaches to environmental governance, the map is mainly an aid in locating where change needs to be made first. If this information is not available, the so called tragedy of the commons occurs. That means no party is feeling responsible to act because the damages happen on communally shared area. This is addressed through the two principles of "polluter pays" and "correction at source" that can be attached to the information provided by the research easily. Responsible regions are allocated and if they are not acting they can be made to bare the costs. At the same time the map opens up opportunities for local communities to address "their own" problems or pollution sources within the area. The identification of the hotspots allows for the central government to let the regions come up with their own decentralized, tailor made, solutions while keeping a watchful eye on the culprits.

7.1 Reflection

After the research questions have been discussed, it is important to look back on the progress made, the methodology chosen and the lessons for further research.

Quantitative Approach

The picture that is emerging from the discussion is very critical of the results produced in the hotspot map. This is mainly in order to sharpen the idea on what went wrong and where the indicators need to be adjusted. The method in essence is very valuable to the governance of plastic pollution, it provides an incentive to deeper research the city of Delfzijl and the island of Texel. The two places have a large potential to produce plastic waste, this is the kind of information wished for in the conception of the thesis. The parameters that are employed in the model as indicators right now are very much open to criticism but the method itself is working exactly as intended. The biggest strength, that is hard to show within this work, is the ability to make different areas comparable, as long as a workable conversion factor is found, for example the total number of tourists between two areas. By working with percentages it is possible to compare two areas even though different indicators may be available locally. On the Wadden Sea level for example the number of tourist overnight stays per municipality is known in Germany, to compare these areas now it is not necessary to gather a new data set, including both areas in one survey, as long as a suitable indicator is found in both areas, they can be conceptualized in one map. In this example it could be said that there are about two times the number of tourists in the Dutch parts of the Wadden Sea than in the German part. By multiplying the Dutch values for tourism with contribution degree of 0,67 and the German parts with a degree of 0,33 the numbers can be integrated into one big model. This in combination with other ongoing research, especially into the factors to which the differing niches, contribute to the whole system has great opportunities to be used in the future.

Qualitative Approach

Through the approach first to care for the organization of the data and then in a second sequential step to care for the interviews, the interview period did get postponed into the holiday season. While communication and capacities for interviews still should be available, it turned out to be extremely difficult to get in contact with the potential interviewees. It has been an very lucky fortune that Mr Reinders from Groningen Seaports was willing to conduct an interview on a short schedule, doubly so because through him, the stakeholder of highest

interest, could be reached. The interview conducted right on the port side has provided a lot of insight into the port authority's view on the issue. Still receiving more feedback from the approached institutions would have provided a more rounded picture and a better discussion. In hindsight, a broader focus for the case, more on ports in general and less on Eemshaven and Delfzijl in specific, could have been beneficial. The bigger volume of possible interviewees could have lead to more interviews. On the other hand the focus on the port was based in the map, making it the valid case of highest interest.

Overall

In a more broad reflection, a big point for the work was to try and find the data in the publicly available space, provided by the CBS and other institutions. It was also combined with the contacting of experts from the University of Groningen to try and find better data sets. This turned out to be successful, as a pointer towards some of the data but did not provide the data, especially on tourism that would have been preferred. After completing the calculations based on the set used. It became apparent that two sources of data did not get tabbed. The first is a direct contact to the CBS, the statistics where not provided on the required scope but they still would have to be composed from somewhere. Following those data sets down to their very origin, a localized set that includes data on a municipal level could possibly have been generated.
In the overall progress of the work, the realization that certain sets of data are not available were the biggest hindrance. A lot of time was spend on an endeavour that did not turn out successful. The problem in this was the idealistic approach to the design, the indicators that could work out to produce an optimal picture were extracted from the literature. In the next step it was tried to find data for the indicators. A more optimized, while less ambitious, approach would have been to search for data first on a broad scale and then choose indicators from the available sets. Apart from convenience though the chosen path also leads to a better result as it provides a set of optimal indicators, that are to be collected in order to get the objectively best outcome instead of staying content with what is there already.
The simplicity and applicability of the hotspot tool that is at the core of the research, as well as the relevance of the issue macro plastic pollution have been a continuous driver for further developing the work.

7.2 Outlook

The following, last section is opting for a view into the future. It answers the question on what, from the authors perspective, should be done next and what are the long term implications for the field of environmental monitoring and governance. It could be of interest to further look into the municipalities, identified as hotspots and identify, if the pollution is again concentrated into more local hotspots of activity, further sharpening the resolution of the produced picture on spread of activity.

One of the most pressing issues arising from this work, is the need to repeat the study undertaken by the ARSU in the Netherlands. The countries cultures and landuses are comparable on the larger scale surface level, the local differences could be very distinct and the specific configuration of the pollution mix could differ in the Dutch context. The information gathered from an own Dutch study would help to solidify the data generated in this research, as it proves or disproves the foundation for the hotspot map.

The Harbour Operation is only one out of four different categories, a similar research into the differing effects and niches within the categories is needed. Especially the areas of Land Based Industry and Tourism could be explored further, because there at least, a number of key actors or focus zones can be identified. Trying to start from the insight generated in this research. A good example for deeper research into Tourism could be the island of Texel, while a good point to start and look for the influence of Land Based Industry could be the industry in Harlingen or the chemical plant in Delfzijl. The influences of municipal mismanagement are harder to quantify, while on the surface it is easy to put blame on the municipalities, the issue is also far deeper rooted in psychology and public mindset. Bigger populations will cause more pollution but not only big cities are responsible for polluting.

For improving the accuracy of the map, it is of great importance to achieve deeper insight into a number of the categories and niches. The current state of knowledge on almost all of the categories is lacking. To improve that and to unveil contradictions it is clear that a greater understanding of both, the quantitative and qualitative connections, needs to be generated.

As discussed in the availability of data section, the map in the current state is to a degree unsatisfactory. If in the future a better set of data, for example on the spread of tourists and their dynamics, becomes available it would be promising to redo the calculation. This could also be achieved with a greater cooperation with the Dutch CBS or alternatively with the single municipalities.

The research done in this manner are of limited time validity. If some of the

improvements that are the end goal, are implemented the whole analysis starting with the research approach taken by the ARSU will have to be undertaken again. This leads to the identification of new problem areas, that need to be addressed and improved. This can be introduced in a so called "Plan Do Check Act" (PDCA) circle that understands improvement as an iterative, continuous process. This approach is supported by the relative ease, with which the hotspot analysis can be undertaken, once the tool is developed to a satisfying degree the maintenance is not overly complicated. In cooperation with national statistical institutes as well as monitoring NGOs or international bodies (such as OSPAR) data gathering could be standardized and simplified. The data processing, when done on the current level of complexity, does not take an overly abundant amount of computation resources and could, as has been done here, be segmented on a national level in order to keep it this way.

The analysis of qualitative data will be more complex, it is required to give a chance to an increasing number of societal groups and include their views not only on harbours but on all niches and categories.

This work did focus on the main stakeholders and therefore took to pragmatic step to limit itself to those. But the focus bears the danger of overlooking important societal positions. It would therefore be of interest for the future, to keep up the effort to develop a deep understanding of the nesting, the issue of marine plastic pollution has got in society.

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Appendix

Appendix I Tourism

Municipalities	Employees Number	Emp. Tourism Sector in %	Emp. Tourism Nr.	Deg. Tourism Activity in %
Ameland	2.210	42,1	930	9,3
De Marne	3990	13,3	531	5,3
Delfzijl	11690	5	585	5,9
Dongeradeel	9710	5,7	553	5,6
Eemsmond	5340	4,1	219	2,2
Ferwerderadiel	2840	2,1	60	0,6
Franekeradeel	9790	5	490	4,9
Harlingen	6670	8,7	580	5,8
Het Bildt (De Bildt)	9790	5	490	4,9
Kollumerland	3780	5,8	219	2,2
Oldambt	15050	6,5	978	9,8
Schiermonnikoog	620	51,6	320	3,2
Terschelling	2680	35,1	941	9,4
Texel	8280	24,5	2029	20,4
Vlieland	800	57,5	460	4,6
Winsum	3780	6,6	249	2,5
Zuidhorn	5840	5,5	321	3,2
Combined			9954	

Appendix II Freight

Municipalities	Gross Freight Tonnag	Deg. Harbour Activity in %
Ameland		0,0
De Marne		0,0
Delfzijl	7237	93,3
Dongeradeel		0,0
Eemsmond		0,0
Ferwerderadiel		0,0
Franekeradeel		0,0
Harlingen	518	6,7
Het Bildt (De Bildt)		0,0
Kollumerland		0,0
Oldambt		0,0
Schiermonnikoog		0,0
Terschelling		0,0
Texel		0,0
Vlieland		0,0
Winsum		0,0
Zuidhorn		0,0
Combined	7755	

Appendix III Land Based Industry 1.

Municipalities	Employees Number	Emp. Industry Sector in %	Emp. Industry Nr.	Deg. Industry Emp. in %	Area Industry in m	Deg. Area Indust	Industrial Deg. Total in %
Ameland	2210	9	199	1,1	0	0,0	0,5
De Marne	3990	13	519	2,8	0	0,0	1,4
Delfzijl	11690	29,1	3402	18,4	3920	26,4	22,4
Dongeradeel	9710	27,5	2670	14,5	0	0,0	7,2
Eemsmond	5340	26,2	1399	7,6	1380	9,3	8,4
Ferwerderadiel	2840	35,2	1000	5,4	0	0,0	2,7
Franekeradeel	9790	7,2	705	3,8	0	0,0	1,9
Harlingen	6670	22,5	1501	8,1	9200	61,9	35,0
Het Bildt (De Bildt)	9790	7,2	705	3,8	0	0,0	1,9
Kollumerland	3780	20,4	771	4,2	0	0,0	2,1
Oldambt	15050	22,1	3326	18,0	0	0,0	9,0
Schiermonnikoog	620	8,1	50	0,3	0	0,0	0,1
Terschelling	2680	9,3	249	1,3	120	0,8	1,1
Texel	8280	9,5	787	4,3	250	1,7	3,0
Vlieland	800	7,5	60	0,3	0	0,0	0,2
Winsum	3780	10,3	389	2,1	0	0,0	1,1
Zuidhorn	5840	12,7	742	4,0	0	0,0	2,0
Combined			18473,16		14870	1	1

Appendix III Land Based Industry 2.

Municipalities	Area Agri. in m^2	Deg. Agriculture in %	Ind. Deg. Total %	Deg. LandBased Total in %
Ameland	21110	6,7	0,5	3,6
De Marne	32220	10,2	1,4	5,8
Delfzijl	26660	8,4	22,4	15,4
Dongeradeel	32880	10,4	7,2	8,8
Eemsmond	27680	8,7	8,4	8,6
Ferwerderadiel	5740	1,8	2,7	2,3
Franekeradeel	13730	4,3	1,9	3,1
Harlingen	5340	1,7	35,0	18,3
Het Bildt (De Bildt)	15910	5,0	1,9	3,5
Kollumerland	1420	0,4	2,1	1,3
Oldambt	7110	2,2	9,0	5,6
Schiermonnikoog	2890	0,9	0,1	0,5
Terschelling	14800	4,7	1,1	2,9
Texel	101340	31,9	3,0	17,5
Vlieland	0	0,0	0,2	0,4
Winsum	2200	0,7	1,1	1,5
Zuidhorn	6310	2,0	2,0	2,0
Combined	317340			

Appendix IV Municipal Waste

Municipalities	Population Number	Deg. Population in %
Ameland	3633	1,5
De Marne	10088	4,2
Delfzijl	24965	10,5
Dongeradeel	23901	10,1
Eemsmond	15656	6,6
Ferwerderadiel	8735	3,7
Franekeradeel	20215	8,5
Harlingen	15860	6,7
Het Bildt (De Bildt)	10493	4,4
Kollumerland	12872	5,4
Oldambt	38108	16,1
Schiermonnikoog	941	0,4
Terschelling	4859	2,0
Texel	13545	5,7
Vlieland	1085	0,5
Winsum	13596	5,7
Zuidhorn	18859	7,9
Combined	237411	

Appendix V

Combined Sorted by Contribution

Municipalities	Deg. Tourism Activity in %	Deg. Harbour Activity in %	Deg. LandBased Total in %	Deg. Population in %	Total Waste Contribution in %
Delfzijl	5,9	93,3	15,4	10,5	25,7
Texel	20,4	0,0	17,5	5,7	13,6
Harlingen	5,8	6,7	18,3	6,7	8,3
Oldambt	9,8	0,0	5,6	16,1	8,1
Dongeradeel	5,6	0,0	8,8	10,1	5,7
Ameland	9,3	0,0	3,6	1,5	5,3
Terschelling	9,4	0,0	2,9	2,0	5,3
De Marne	5,3	0,0	5,8	4,2	4,2
Franekeradeel	4,9	0,0	3,1	8,5	4,2
Het Bildt (De Bildt)	4,9	0,0	3,5	4,4	3,6
Eemsmond	2,2	0,0	8,6	6,6	3,5
Zuidhorn	3,2	0,0	2,0	7,9	3,1
Vlieland	4,6	0,0	0,4	0,5	2,3
Winsum	2,5	0,0	1,5	5,7	2,3
Kollumerland	2,2	0,0	1,3	5,4	2,1
Schiermonnikoog	3,2	0,0	0,5	0,4	1,7
Ferwerderadiel	0,6	0,0	2,3	3,7	1,2
Combined					