Using citizen scientists to monitor macro plastic litter along the beaches of the Western and Eastern Scheldt

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Date: 02/01/2020

UNIVERSITY OF APPLIED SCIENCES

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Summary

Today the awareness about anthropogenic waste and litter in the marine environment is rising. There is evidence on the threat to marine ecosystems through plastic litter, all over the world. To understand this issue better citizen science projects, help to gather data about the distribution and origins of marine plastic litter. One goal of this study was to monitor macro plastic litter study on the coasts of Zeeland. Citizen scientists were recruited who used the OSPRA and the Litterati app methods for categorisation of macro plastic litter on 3 beach locations at the Western Scheldt and 2 beach spots at the Eastern Scheldt. During this study 278 plastic items were found on the 100m stretches on average. 99% of the categorised litter was made from plastics and 60% originated from the fishing industry or offshore activities. The majority have been blue strings and chords (VisPLuis) originating from fishing nets. The two monitoring methods yielded comparable results regarding the litter composition. The Litterati app method was received slightly more convenient by the citizen scientists and more items were picked up on average than with the OSPAR method. Weather conditions and the motivation of the citizen scientists were driving the quantity and the quality of the monitoring. A comparison of our monitoring results with a previous 5 years study at other beaches was difficult because of too many distinct factors that may have influenced the results. Complementary to the method comparison, the participants filled in a survey regarding their motivation, experience and assessment of both methods. Most participants were motivated to join the project for environmental interest and the opportunity to contribute to a good cause. Offering incentives like study credits motivated the students as well. Using universities or schools as a source for recruiting citizen scientists is a promising approach to organise future monitoring projects. The results of this study suggest extending the knowledge base on the plastic litter pollution in Zeeland by a long-term study including more beach locations along the Western Scheldt and the Eastern Scheldt over a period of 5 years.

Figure 1- Strings and chords (Vispluis) found on the Beach in Vlissingen (source: Janine Vink)

1 Introduction

Plastic pollution on the coastlines of oceans and seas has become a global issue. The sources of the plastic pollution are diverse. It is caused by many public littering as well as bad urban and industry waste management systems. Wind carries litter from landfills into rivers, from which it will be transported into the sea, before being deposited on shorelines or settling on the bottom of the oceans and seas (Veiga J. M., 2016). Plastic litter in the sea can also originate from fisheries or ships.

75% of the waste found in oceans is made from polymers. Only five percent of produced plastics are recycled and 40% ends up in landfills, up to 30% are ending up in ecosystems like the ocean (Bondareff, 2017). The results of an analysis of a pan-European dataset of 679 surveys demonstrated that 84% of all items found on beaches were made from plastic (Addamo, 2017).

The impact of marine plastic pollution to humans, wildlife and ecosystems, is well documented by many publications. Studies show that every week humans already ingest the weight of a credit card in plastics (de Wit & Bigaud, 2019). Besides the potential threat for humans there is a big impact on biodiversity due to plastic intrusion (Pawar, Shirgoankar , & Patil, 2016).

Plastic litter that ends up in the environment can be categorized by their size. Macro plastics are clearly visible, can be picked up easily and do not have direct impact on the food chain (Lehner, 2015). When those macro plastics reach the ocean, physical processes such as UV radiation start to break down the plastic. It will not biodegrade but only break down in smaller plastic particles. Such particles are called micro plastics. These micro plastics are only 1-5mm of size, but the effects for ecosystems are devastating.

To gain a better insight into the numbers and origin of plastic waste on coastlines, reliable and comparable data are needed. Marine litter monitoring is one way of collecting data and classify the type and origin of plastics collected at the shores.

First insights in the litter pollution of Dutch beaches is provided by the Annual Report “OSPAR Beach Litter Monitoring In the Netherlands 2010- 2015” (Hougee & Boonstra, 2016). The beaches in Veere, Noordwijk, Bergen an Zee and Terschelling were monitored during the 2010-2015 period. 97 surveys were performed using the OSPAR Beach Monitoring Guideline. In this report the top 80% found items and the probability of their source is provided. Most of the items that are included in the plastic / polystyrene category are nets and ropes which have a high probability to originate from the fishing sector. Support by volunteers (citizen scientists) has become a common way in the collection, analysis and interpretation of plastic litter.

Some inhabitants of Vlissingen in Zeeland were already participating in clean-ups in the port as well as at the beach (Verlosdezee, 2019). These clean-ups were organised among others by the HZ Green Office, who mobilised students and citizens to gain awareness of plastic pollution and get involved in the clean-up and reduce efforts. However, no systematic data collection took place. We use the experience of the HZ Green Office with citizen scientists to conduct the study.

With this report, we provide data of a systematic marine plastic collection using citizen scientists on the shores of Eastern and Western Scheldt. We compare the two methods for monitoring: the OSPAR standard method (Schulz, van Loon, Fleet, Baggelaar, & van der Meulen, 2017) and the app called Litterati (Litterati, 2019), however, we only monitor macro plastic particles and not micro and meso plastics. In chapter 2.1.2 you can see the exact definitions for plastic debris size classification. This study is limited to a time span of 4 months in which the research needs to be concluded. The

litter collection will be applied at 3 beach locations at the Western Scheldt and 2 beach spots at the Eastern Scheldt.

Complementary to the monitoring study, we conduct a survey with the citizen scientists asking for their motivation to participate, their experiences with the two methods and possible improvements.

Following the above study outline, we defined four research questions:

- Which method is most effective for monitoring macro plastic waste along the beaches of the Western and Eastern Scheldt?
- Is the data generated from the events comparable to similar studies at the Dutch coast?
- What is the personal motivation of the citizen scientists to participate in the study?
- Which of the two plastic waste monitoring methods is most effective for gathering data according to users?

This research study was initiated by the Rijkswaterstaat in cooperation with the HZ University of Applied Sciences. The organisation of the study was supported by the HZ Green Office.

2 Theoretical Framework

2.1 Plastics

Plastics are important and valuable materials for production of goods and their production process. They are flexible to form, light and relatively cheap and therefore grew to be very important for household items and economic processes. This is reflected in the production rate of plastics. Since the 1950's the rate of yearly produced plastics and polymers has increased more than 230 times (Busse, 2019). A lot of these plastics are single use plastics like water bottles and food packaging. They are very durable they take a long time to be decomposed in natural processes. Although this is known, there is not an adequate plastic waste management system in a lot of places to store or recycle the 348 million tons of plastic, produced globally in one year (Busse, 2019). So, it is inevitable that plastic waste accumulates in the environment, putting the animals and plants at risk.

2.1.1 Micro, meso and macro plastics

There are different definitions of marine plastics and litter. For this paper the definitions of the United nations Environment Program (UNEP) have been adopted. The UNEP divides plastic debris into 5 categories.

- Macroplastics are defined as litter that is larger than 2 cm, such as plastic bottles, bottle caps and plastic bags.
- Mesoplastics have the size between 5-10mm. One example for this are virgin resin pallets that are used for plastic manufacturing processes.
- Microplastics are as big as 5mm. Those plastic particles come from macro plastics breaking down due to UV-rays and fraction over time.
- Nanoplastics are very small microplastic particles with a size of 0.2-2mm.
- Microbeads are tiny plastic particles that derive from personal care products such as toothpaste and shower gel.

The study is focussing on monitoring the macro-plastic litter only.

2.1.2 Plastic pollution in global water systems

75% of the waste found in oceans is made from polymers. Only five percent of produced plastics are recycled and 40% ends up in landfills, up to 30% are ending up in ecosystems like the ocean (Bondareff, 2017). These include bigger plastic pieces or macro plastics which are shopping bags and plastic bottles and plastics which are bigger than 5mm, but also micro plastics, tiny plastic particles (between 5mm and 1mm) that result from macro plastics breaking down, or from cosmetic products.

Although most of the plastic pollution in the ocean is caused by a few countries in south east Asia, the consequences are measurable globally (Leberton, et al., 2017). Due to its buoyancy, the ocean currents distribute plastic waste all over the world. Because a lot of plastic waste is stored in landfills, wind, rain and other weather events like storms and runoff transports deposited plastic waste towards water ways and rivers. Through those rivers and canals the plastic waste reaches the ocean due to flow and tide patterns (Jambeck, et al., 2015).

There are different areas the plastic can end up in. Tiny micro plastic particles are dangerous for animals since they ingest them. As an example of the invasiveness of plastics in the oceanic environment: The micro particles get covered with a biofilm, making them sink to the ground and integrate with the sediment (Van Cauwenberghe, Devries, Galgani, Robbens, & Janssen, 2015). This shows how the ocean floor could be a sink for plastic particles. Some of those particles are also roughly the same size as planktonic organisms, leading to the ingestion by animals that feed on plankton. Even though macro plastics are bigger and therefore it's easier to evaluate their impacts, they are also very dangerous. Those plastics cause entanglement and get ingested by surface hunting seabirds for example. Organisms can hold on to the indestructible plastic parts, using it as a raft, travelling for long distances, increasing the exposure of certain environments to invasive species. It is also a secondary source for micro plastics since it gets broken by UV-B rays and physical abrasion by waves and other objects in the water (Van Cauwenberghe, Claessens, Vandegehuchte, & Janssen, 2015). In addition to entangling and ingestion there are other factors that are increasing the risk of plastic pollution in the ocean. For example, some of the chemicals used in the production of plastic to make it more flexible, are being washed out in the ocean and absorbed by organisms.

2.1.3 Plastic pollution on beaches

Resulting from the plastic in the oceans, beach environments around the world are struggling with plastic litter. The plastic pieces that end up on the beaches are either coming from land sources and being transported to the beaches with the wind, rivers or drainage channels, or it is coming directly coming from the vessels on the ocean (Patricial, 2008).

The plastic waste that is coming from land sources such as landfills or public littering has a great chance to end up the ocean and stay in that environment for a long time. The beach is also where environmental and economic interests are overlapping. From an economic perspective, tourism is an important factor for the economy of Zeeland. But not only the tourists enjoy the beach, also local citizens. Sandy beaches are valued highly by society and they are used more than any other shoreline (Schlacher, et al., 2007). Sandy beaches are important for recreational purposes, therefore underlining many coastal economies such as tourism. But beaches also have a quite important range of biodiversity, providing a harbour for several hundred species of invertebrates. Another often underappreciated function of beaches that is threatened, is the ecosystem services they provide. Beaches provide critical habitats like birds which are an important part of the coastal ecosystem, therefore supporting the coastal fisheries as well. In addition to that they also filer big amounts of

sea water and recycle nutrients (Schlacher, et al., 2007). Plastic pollution could hinder all these functions and has a devastating effect on coastal biodiversity.

Already in the year 2004 a research paper that evaluated the plastic debris on beaches on the Hawaiian Islands was published. The conclusion was that small plastic particles occurred on all beaches. What is interesting though, is that the highest by weight concentration of plastic debris the study found, was on the most remote beaches of the Hawaiian archipelago (McDermid & McMullen, 2004). This shows again how every coastal nation will have to adapt and try to reduce plastic waste pollution. During 12 years of monitoring the Dutch coast there have been found on average 380 pieces of litter per 100 meters of beach. About 90% of the litter was plastics or polymers. The study also recorded that there was no significant reduction of the amount of plastic waste during the 12 years of observation. It is Interesting to see is that more than half of the debris was identified to come from the fishing industry (Boonstra, 2014).

2.1.4 Marine plastic waste origins and sources

A common categorisation for the origin of the plastic waste, is dividing the items between land based and sea-based input. Sea based origins referrers to waste that is emitted directly by vessels, offshore installations and other maritime activities. Land based origin relates to littering directly at the coast or to more distant sources, from which the waste was transported to the sea by wind and water. There are many litter items that cannot be linked directly to a source or a pathway on which it travelled. This includes plastic bottles which could be littered anywhere at sea or on land where they travel to the sea via rivers and other waterways (Veiga, et al., 2016).

The OSPAR method was developed with indicator items that are indicating the origin of the litter item. The figure below was extracted from (Veiga, et al., 2016).

Source	Indicators
Fisheries, including aquaculture	Jerry cans. Fish boxes. Fishing line. Fishing weights. Rubber gloves. Floats/buoys. Ropes/cords/nets <50cm, and >50cm, respectively. Tangled nets/cords. Crab/lobster pots. Octopus pots. Oyster nets and mussel bags.Oyster trays. Plastic sheeting from mussel culture ("Tahitians")
Galley waste from shipping, fisheries and offshore activities (*non-operational waste*)	Cartoons/tetrapacks. Cleaner bottles. Spray cans. Metal food cans. Plastic gloves. Plastic crates.
Sanitary and sewage-related waste	Condoms. Cotton bud sticks. Sanitary towels/panty liners/backing strips. Tampons/Tampon applicators.
Shipping, including offshore activities (*operational waste*)	Strapping bands. Industrial packaging. Hard hats. Wooden pallets. Oil drums (new and old). Light bulbs/tubes. Injection gun containers.
Tourism and Recreational activities	4-6-pack yokes. Plastic shopping bags. Plastic bottles/containers for drinks. Metal bottles/containers for drinks. Plastic food containers. Glass bottles. Crisp/sweets packets and lolly sticks.

Figure 2- OSPAR Indicator categories for trash origin

2.2 Citizen Science

Although environmentalists agree that plastic pollution is one of the biggest threats to ocean´s biodiversity, it is difficult to collect reliable data about the pollution. This is because the scale patterns of the problem that require the gathering of vast amounts of data over a longer time span (Bonney, et al., 2009). Some of these monitoring researches rely on indicator bird species like in the

North Sea (Avery-Gromm, Provencher, Morgan, & Bertram, 2013). If there is not such an indicator species data collection has to be carried out in person. The consequence is that those research projects would be very expensive and time consuming for professional scientific researchers. However, there is a way to gather big data sets that are spread over a bigger geographical areas and time spans. Using citizen science could be an opportunity for scientists as well as for citizens. Citizen science refers to volunteers participate as field/research assistant to use monitoring equipment, observe and collect data (Cohn, 2008). These projects are commonly set up by a research group or a researcher who will then analyse the data collected by the participants. The idea to involve citizens into research is not new. The definition of activities that fall under the idea of citizen science is not always clear. In general, the term refers to the integration of members of the public in scientific research. In the Oxford dictionary the term is defined as "scientific work undertaken by members of the general public, often in collaboration with or under direction of professional scientist (Eitzel, et al., 2017). In this regard, Charles Darwin could have been considered to be a citizen scientist since he was not hired to be a professional scientist on the Beagle, but just gathering data on his own behalf (Silvertown, 2009).

2.2.1 Different citizen science projects

Decades ago, The National Weather Service Cooperative Observer Program started a citizen science project in 1890, to help observe weather events (Garbarino & Mason, 2016). Some things have changed for citizen science projects since then. The activity is no longer an exclusive chance for privileged persons, but everybody has the chance to participate, thanks to more easily accessible technical tools and education. The internet is one of those tools, allowing for more customised field guides and software. Software however is still less accessible to the public than paper publication. Even despite the big organisational effort that is connected to the paper medium (Silvertown, 2009). Another factor pushing citizen science is the realisation of scientists, that interested and motivated citizens pose a source of free labour, skills and computing power for example (Cohn, 2008). But not only the scientists are benefiting from the upcoming interest in citizen science. Citizens can learn about their environment and the way scientific research is done (Silvertown, 2009). Participating citizens will be enticed to inquisitive thinking, learning more about natural history, biology or the overall environment. This will also help generate trust towards the research institutes, which is important to make changes in society based on the gathered data. However, the means to organise this effectively are just evolving over the past two decades (Bonney, et al., 2009).

However, this approach is not easily organised but has some perceived challenges for the researchers and the participants. For example, ensuring the integrity of data collected by amateur researchers and then integrating them into a scientific model. Another important factor is keeping the volunteers engaged for a longer time (Kylie, Quinn, Huijser, Jonathan, & Broberg , 2014).

To summarise, citizen projects have a lot of benefits and at the same time there are threats for downfalls as well. Some of the best benefits that a citizen science research offers over conservative research techniques include the cost effectiveness way of gathering big amounts of data as well as the potential to gather big data sets with high quality data. Although the quality of the data can vary it can be expected that, if the data is collected appropriately and there is some quality assurance, the data will be valuable for scientific research. It can be more feasible to have long term observation and monitoring through committed volunteers than through scientific personal. But there are also benefits for the volunteer. Volunteers are increasing their inside in scientific research and engage more with environmental issues while learning about the topic as well.

There are some obvious downfalls for citizen science projects. It is limited to a rather simple approach. It is likely that participation will decrease when the protocols and tasks are increasingly complex. Another downfall is that participants need to be recruited, which takes time and effort. Although citizen science projects are cheap in the data collection process in general, they are not always cheap in setting up and evaluating (Pocock, Chapman, Sheppard, & Roy, 2014).

2.2.2 Citizen science and plastic pollution

Concerning citizen science and plastic pollution, there have been studies researching on different aspects of this. A study in Chile that was observing the distribution and abundance of micro plastics on beaches, validated data obtained by over 1000 students participating in the research. The research approached volunteers through a nationwide call, inviting schools and social associations as data collectors while at the same time engaging scientists, activating them as local advisors at different study sites. This study made sure that the data collected will be valuable by providing clear sampling protocols, simple data forms and support material for the activities. During the sampling activities/ monitoring events the students first identified the sampling area, marked the area and then sorted and counted the materials. To count the materials 2 cm of the top sand was removed from the sampling quadrant and then sieved with a 1 mm mesh. In the case that the sand was to wet to be sieved, the students took the sand to school in a bag. There it could be dried and then sieved. The items obtained through sieving where then placed on a tray. There the small plastic items were separated from other items and then classified. After those items were added to the data form used to keep track of the items, the items were placed in a labelled and sealed plastic bag and send to the central laboratory of this research. There the data was revaluated in a lab environment to make assumptions about the value of the data gathered. With this method the research managed to show that the data collected from the students have been relevant and useful data for the research (Valeria & Thiel, 2013). Although this sampling technique is only viable for micro plastics, the overall principles can apply to other citizen science projects. It shows that with the right training and guidance students can provide helpful data for scientific research.

Another good example for the use of citizen science for data collection concerning plastic pollution is a 10 years study on litter on British beaches. For this, beaches have been assigned to specific regional sea areas according to the nature conservation committee for an easier evaluation later. During this study, the number of surveys, surveyors and other factors such as time span were varying. Due to these varying factors, the scientists developed a formula to bring slightly different surveys to a collective dataset. The participants surveyed the beach by walking from the water to the back end of the beach, documenting what kind of waste they found. A litter identification guide would help the citizen scientists identify litter as well as trainings that have been offered at the beaches. The research paper estimates a high value of citizen science for science and society. It enabled society to remove 2,376,541 items of litter from the beaches all over the country. It showed that this is a good example for cheaper research labour. The data collection, if carried out by professionals, was estimated to cost at least 500.000 British pounds. Additional to this, the project increased the public appreciation of the environment and its issues. This can be especially important since public littering is one of the biggest sources for pollution and a greater awareness could reduce this stress on the environment. These effects are only additional to the original purpose of collecting big data sets for scientific analysis (Nelms, et al., 2017).

Some limitations to the method of citizen science is that citizen scientists tend to not collect as much data as professionals. This can have different reasons. Some things might be harder to detect, highly mobile organisms could be counted several times but also the misclassification could be a limitation (Kremen, Ullman, & Thorp, 2010).

2.2.3 Motivation of citizen scientists

It is important to understand the motivation of the volunteers so that future projects can be better designed and planned. Based on the study called "Galaxy Zoo", researchers from different organisations tried to identify the main motivation that drives people to attend a citizen science project. The participants in the study were asked to help in identifying and evaluating characteristics of galaxies in an online data set about those galaxies (Raddick, et al., 2009). During the research, the participants have been interviewed and based on their answers the research team settled on twelve categories describing the participants motivation. Every answer could be traced to one or more categories of motivation. The categories settled on by the research team are:

- Contribute: "I am excited to contribute to original scientific research"
- Learning: "I find the site and forums helpful in learning about astronomy"
- Discovery: "I can look at galaxies that few people have seen before"
- Community: "I can meet other people with similar interests"
- Teaching: "I find Galaxy Zoo to be a useful resource for teaching other people"
- Beauty: "I enjoy looking at the beautiful galaxy images"
- Fun: "I had a lot of fun categorizing the galaxies"
- Vastness: "I am amazed by the vast scale of the universe"
- Helping: "I am happy to help"
- Galaxy Zoo project: "I am interested in the Galaxy Zoo project"
- Astronomy: "I am interested in astronomy"
- Science: "I am interested in science"

3. Methods

The setup for the research is both comparative and explorative. At the collection events on the beach, the quantity as well as quality of the collected plastic litter was evaluated. This part is the explorative part of the project. It was determined what kind of plastic waste was found where and how much exactly. The comparative research aspect was comparing the monitoring methods OSPAR and Litterati app in the field.

Complementary the study was supplemented by a survey asking the participants of the events about their motivation and experiences during the collection events.

3.1 OSPAR Method

The OSPAR standard method is a method developed to create a standardised methodology for plastic waste evaluation (Schulz, van Loon, Fleet, Baggelaar, & van der Meulen, 2017). It was developed by the Marine Conservation Society (MCS). For this method there is a standardized catalogue as a guidance document. It states that each surveyed area should be 100 meters width and reach from the dunes all the way to the water. It is advised to start monitoring one hour after high tide. The citizen scientists walk up and down the research area, collecting all the plastic waste they can find, while at the same time categorizing it with the help of the guidance catalogue guide that helps identifying the plastic pieces. The catalogue consists of a list that is divided in categories such as: plastic, metal, wood, rubber, sanitary items and more. Each category then has a list stating all the items that could be found that need to be categorized to this section. In addition to this, there a catalogue is provided with one example picture for each item category. The participants then mark the item with simple tick marks behind the name of the item. Figure 3 illustrates two examples from the categorisation catalogue.

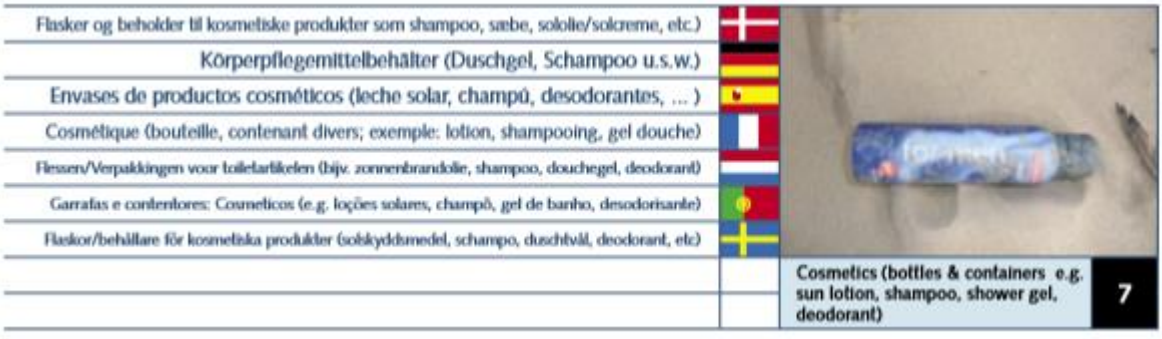

Figure 3- Example for cosmetic bottles from the OSPAR categorisation catalogue

Figure 4- Example for plastic bag ends from the OSPAR categorisation catalogue

3.2 Litterati app Method

The second method is available by using a smartphone app. The app is called Litterati (Litterati, 2019). The app was designed so that volunteers can take photographs of litter, tag or categorize it and then upload it to a collective database. This was proposed by Rijkwaterstaat for this research study, because they were interested in the user friendliness as well as the sharing potential of the data gathered. The principle is based on picture analysis. The participants will take pictures of all the gathered litter. The app automatically connects your geolocation to the picture you take from each piece of litter. The litter can be tagged and uploaded immediately or at any moment after the event. he tags that is added by the user, is supposed to identify the waste that was photographed. For the categorisation there is an artificial intelligence software (AI) implemented in the app that will propose tags to you. If you confirm the tags the AI will learn from the input, increasing the categorisation precision over time. After the pictures have been tagged, they will be uploaded to the collective data base of Litterati. On the website of the Litterati they provide a map where you can see the overall gathered items for each location. However, there is no more detailed representation in a list or graphs yet. For this method we will use the same monitoring area sizes and walking pattern as with the OSPAR method.

Figure 5- Example screenshots from the Litterati app

3.3 Collection instructions

For both methods we will explain the same approach for the sampling area independent from the location. We will split the participants in groups of 4-5 people. Then we will instruct them to gather at the outmost corner of their sampling area closest to the dunes. They will fan out over a width of 5 metres so each participant observes a 1.5 meters strip and walk parallel with the beach to the other end of their sampling area. Then they will shift the 5 m strip of observation closer to the water and walk back parallel to the beach. While walking up and down they will pick up items, call them out for the person categorizing to note them (OSPAR) or take a picture (Litterati app) and then dispose them. This will be done until they will have surveyed the complete sampling area.

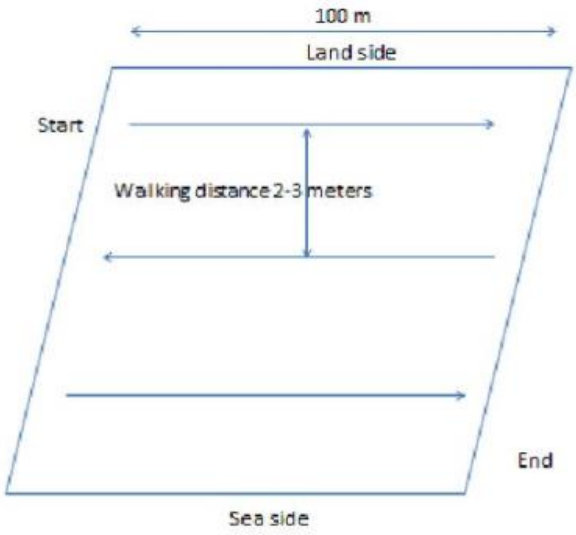

Figure 6- Walking pattern for both methods during monitoring

3.4 Area analysis

The study sides were selected to ensure as much as possible comparable conditions for the two methods, meeting requirements of the OSPAR methods guidelines.

For the selection of the study locations these factors were determined to be ideal:

- The beach needed to be either on the Eastern or Western Scheldt.
- The study areas should be in a close proximity to Vlissingen so that the citizen scientists can join for a day.
- The beaches should be accessible and easy to navigate and should have a place to dispose the collected trash.
- The beaches should be composed of sand or gravel and exposed to the open sea.
- The areas should be accessible to the surveyors all year around
- The locations should be accessible for ease of marine litter removal
- The beaches should have a minimum length of 100 meters and if possible, over 1km in length
- No buildings all year around
- Not subject to any other litter collection activities

The beaches on the Eastern Scheldt and Western Scheldt cannot meet all criteria. For example, one location is exposed to the Eastern Scheldt and not the open sea (De Roompot). On some beaches there are year-round buildings due to the touristic nature of many of the beaches in Zeeland.

The beach clean-up and monitoring sessions will be carried out in 3 different areas at the Western Scheldt and 2 different locations at the Eastern Scheldt. These areas ae selected to ensure that they are not too close to each other and comply as much as possible with the OSPAR method guidelines for the locations. Due to time limitations it will only be possible to monitor each of the two locations at the Eastern Scheldt once. All locations at the Western Scheldt will be monitored twice, testing each method one time.

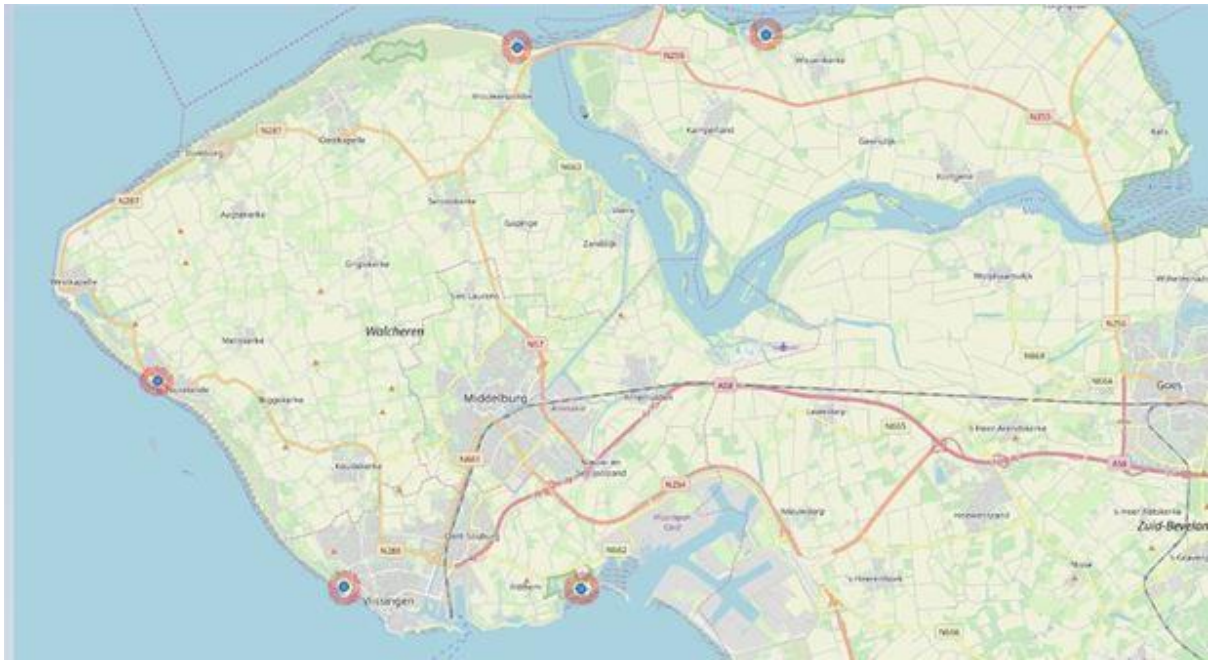

Figure 7- The 5 monitoring locations at the Eastern and Western Scheldt

3.5 Recruiting citizen scientists

The citizen scientists that will take part in this research will be predominantly students and tutors from the HZ University. Every week we will publish an event post on Facebook, as well as promotion through the Instagram channel. In addition to this we will write an email that invites everyone who is interested to join the events. This email will be distributed through the HZ Green Office as well. Finally, I will be available at the Office for interested people to approach me, ask questions and get information about the events before joining.

3.6 Monitoring events schedule

A time schedule is developed prior to the data collection. However, the schedule needs to be flexible to consider the availability of the participants, the weather conditions, locations and other unforeseen conditions.

Organisation dates of the events:

1. Nollestrand beach: Monitoring event 1: 4th October: Clean up #1 beginning 13:00
2. Nollestrand beach: Monitoring event 2: 25th October: Clean up # 2 beginning 15:00
3. Ritthem beach: Monitoring event 1: 8th November: Clean up #1 beginning 13:00
4. Ritthem beach: Monitoring event 2: 15th November: clean up #2 beginning 13:00
5. Zoudelande beach: Monitoring event 1: 22nd November: Clean up #1 beginning 13:00
6. Zoudelande beach: Monitoring event 2: 27th November: Clean up #2 beginning 13:00
7. Breezand beach: Monitoring event: 6th December: Clean up #1 beginning 13:00
8. Roomport beach: Monitoring event: 13th December: Clean up #2 beginning 13:30

3.7 Survey outline

The survey (see appendix I for the questions) is a complementary component of this research. It mostly deals with the methodologies that have been used and with questions that aim to evaluate the differences between the methodologies regarding the setup of the method, the perceived efficiency and user friendliness

The Survey contains 11 questions regarding either the participants motivation or asking them to rate the different methods on a scale. The participants that will be present at a monitoring event will be asked to fill out the surveys right after the event concluded.

The data collected from the questionnaires will be evaluated in two ways. Questions regarding the motivation of the participants will be categorized into the different motivational categories as discussed in chapter 2.2.3. These categories will be adjusted depending on the answers generated through the survey. This will give an insight into the most common motivations to join the research events. Questions regarding the methods will be evaluated by calculating an average score of the Method on each question.

4. Results

For all monitoring events we used the same approach towards the sampling area. I chose the surveying areas beforehand using the mapping software QGis. I did this to roughly estimate the length of the beach so I could already tell beforehand how many groups could survey their independent area. When I reached the beach together with the monitoring group, I roughly advised them on how to divide on the beach and how many sampling areas we could monitor with how many people. This was strongly influenced by the number of volunteers for each event. I then advised the individual groups to estimate the 100m stretch on the beach because this resembles

something that the participants will have to do in a real project since not all of them might have access to mapping software.

After every group picked their 100 m stretch, I explained quickly how to go over monitoring in the sample area. The simplest method is to form a line with the participants, about 2-3 m wide, on the top of the beach closest to the dunes. We would walk 100m along the beach while surveying the 2-3m stretch. When the group reached the end of their 100m stretch we simply shifted the pattern closer to the water and walked back.

4.1 Nollestrand beach monitoring

Figure 8- Sampling areas on Nollestrand beach

The Nollestrand in Vlissingen is located north-west of the Vlissingen boulevard. The beach meets the following criteria of monitoring:

- It is composed of sand
- Accessible to the surveyors all year around
- Accessible for ease of marine litter removal
- Have a minimum length of 100 meters and if possible, over 1km in length

The beach has a long row of small seasonal used beach houses and the Stichting Strandexploitatie Veere (SSV) is emptying the trash bins and collect the trash close to them once a week.

4.1.1 Monitoring event 1

Table 1- Conditions at Nollestrand monitoring event 1

Location	Nollestrand beach
Date	4th October 2019
Time	13:00 – 15:00
Method	OSPAR
Citizen scientists	12
Temperature*	15°C
Wind speed*	35-36km/h with 51km/h Gusts 13
Precipitation*	1.0 mm

* All meteorological data ex world weather online

Figure 9- Monitoring group on Nollestrand in Vlissingen (source: Janine Vink)

For this combined litter monitoring and beach clean-up the group met at the beach post in Vlissingen Nollestrand. There was a lot of wind when we met up. After the group was complete with 12 persons, I quickly explained the method that we would use and the research set-up in general. Then we formed groups of 4 people working together at the beach. Every group got a picker and a sustainable trash bag from the HZ Green Office and the gemeente Vlissingen to use. We applied the sampling method described above for each sampling area.

Because it was raining heavily and it was getting cold, we decided to collect all the trash on the areas on the beach for around 1.5h and then categorize the found materials inside where it would be dry and warm. This was not only because of the comfort inside, but mainly because it is hard to collect the data on a sheet of paper with hard winds and rain.

So, after we finished picking up the litter at the beach, we went inside the beach post again, emptying the trash bags on the floor. Then one participant would handle the pen and paper while the others would call out the piece of trash they found. After a little bit of trying the most effective method would be to roughly sort the trash on the floor and then go by category. This sped up the whole process a bit. It was observable that especially those with pen and paper got more efficient over time, understanding quickly where on the list said item needs to be marked.

In general, this approach is a more comfortable approach that is especially useful if there is a warm and dry place nearby that is accessible. It took more time to do this. So, on top of the 1.5 h of monitoring we spend close to 1 h on categorizing the trash of two groups. Most participants could not stay longer which prevented us from evaluating the data of the third area.

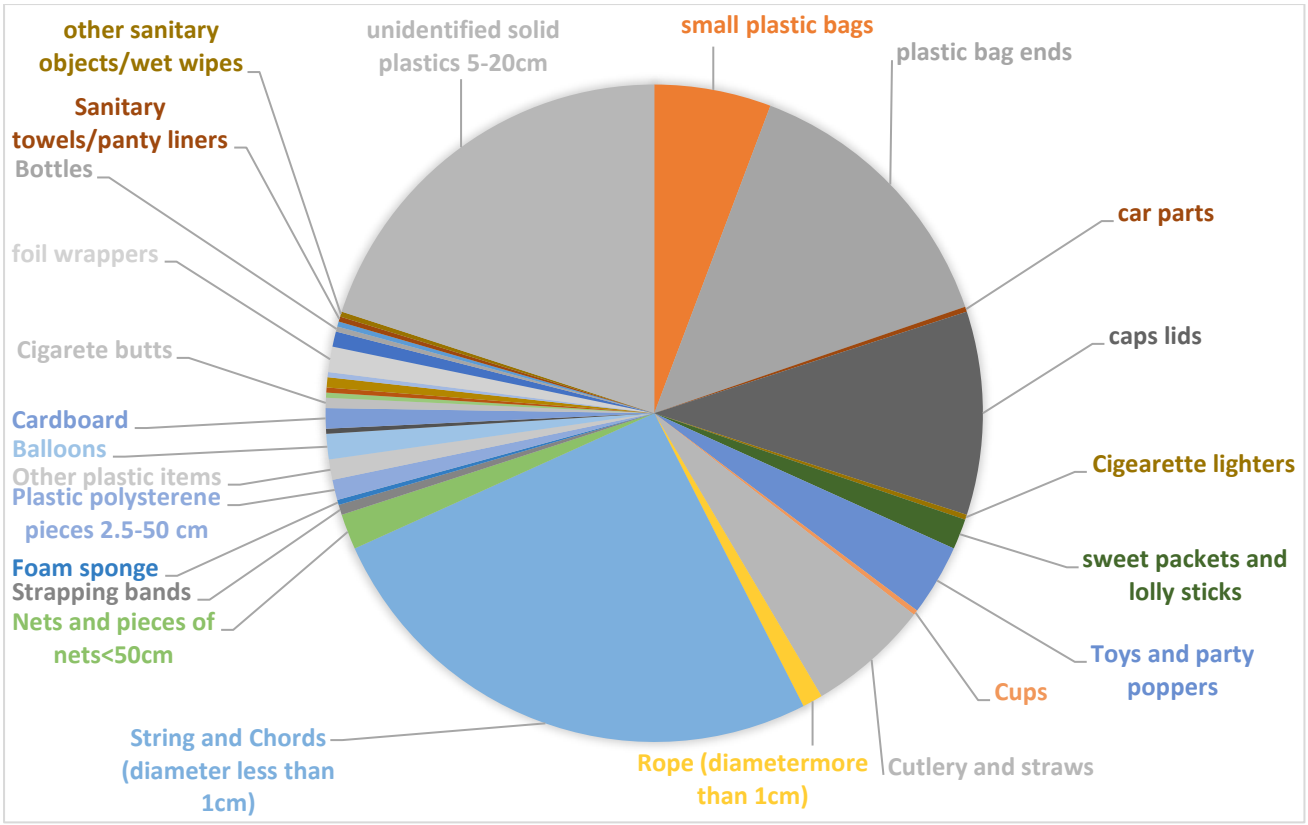

Figure 10- Monitored items found in Area 1 on Nollestrand using the OSPAR method

The top 5 items found in area 1:

1. Strings and Chords: 103 Items = 26%
2. Unidentified solid plastics: 80 items = 20%
3. Plastic bag ends: 56 items = 14%
4. Bottle caps and lids: 40 items = 10%
5. Cutlery and straws: 24 items = 6%

Overall Items monitored: 400

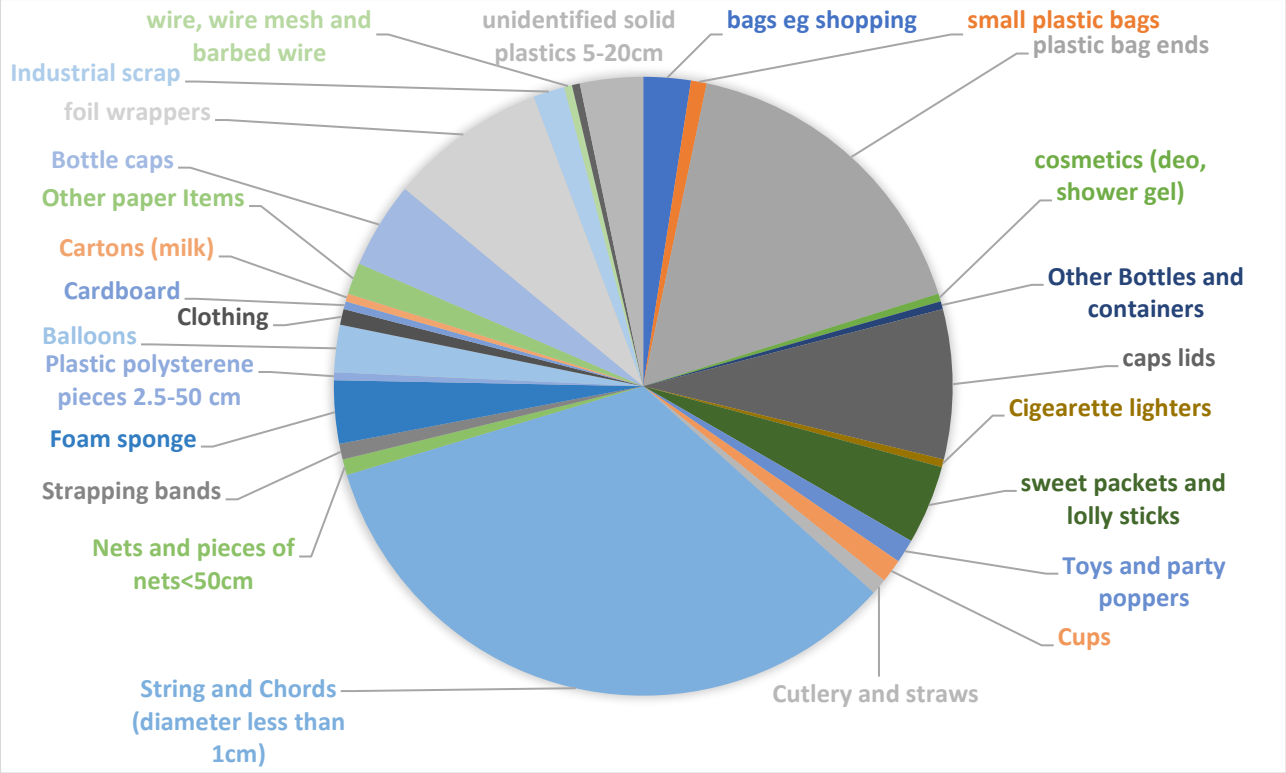

Figure 11- Monitored items in Area 2 on Nollestrand using the OSPAR method

The top five items found in area 2:

1. Strings and Chords: 82 items = 34%
2. Plastic bag ends: 41 items = 17%
3. Bottle caps and lids: 20 items = 8%
4. Foil wrappers: 19 = 8%
5. Metal bottle caps: 11 items = 5%

Overall items monitored: 243

4.1.2 Monitoring event 2

Table 2- Conditions at Nollestrand monitoring event 2

Location	Nollestrand beach
Date	25th October 2019
Time	15:00 – 17:00
Method	Litterati app
Citizen scientists	12
Temperature	15c felt like 14c
Wind speed	29-31km/h with 50km/h gusts 13
Precipitation	0 mm

The combined litter monitoring and beach clean-up did also take place at the Nollestrand in Vlissingen. This time we tested the Litterati app, so I had to shortly explain the principle to the participants and then we formed groups. We formed groups of at least 4 people. Two group members would walk, pick up trash and put it into the trash bag, while one group member would hold the trash bag and another member would take a picture of every piece of trash before it was tossed in. During this event the weather overall was good, but it was windy and turned cold quick. However, the groups still managed to survey for around 2h. The preparation time was moderate, but the participants had to come prepared with their phone charged, the app downloaded and a profile as well. The students chose to not tag the data in the app immediately but do that later.

Unfortunately, I could only obtain the data of one group from this event.

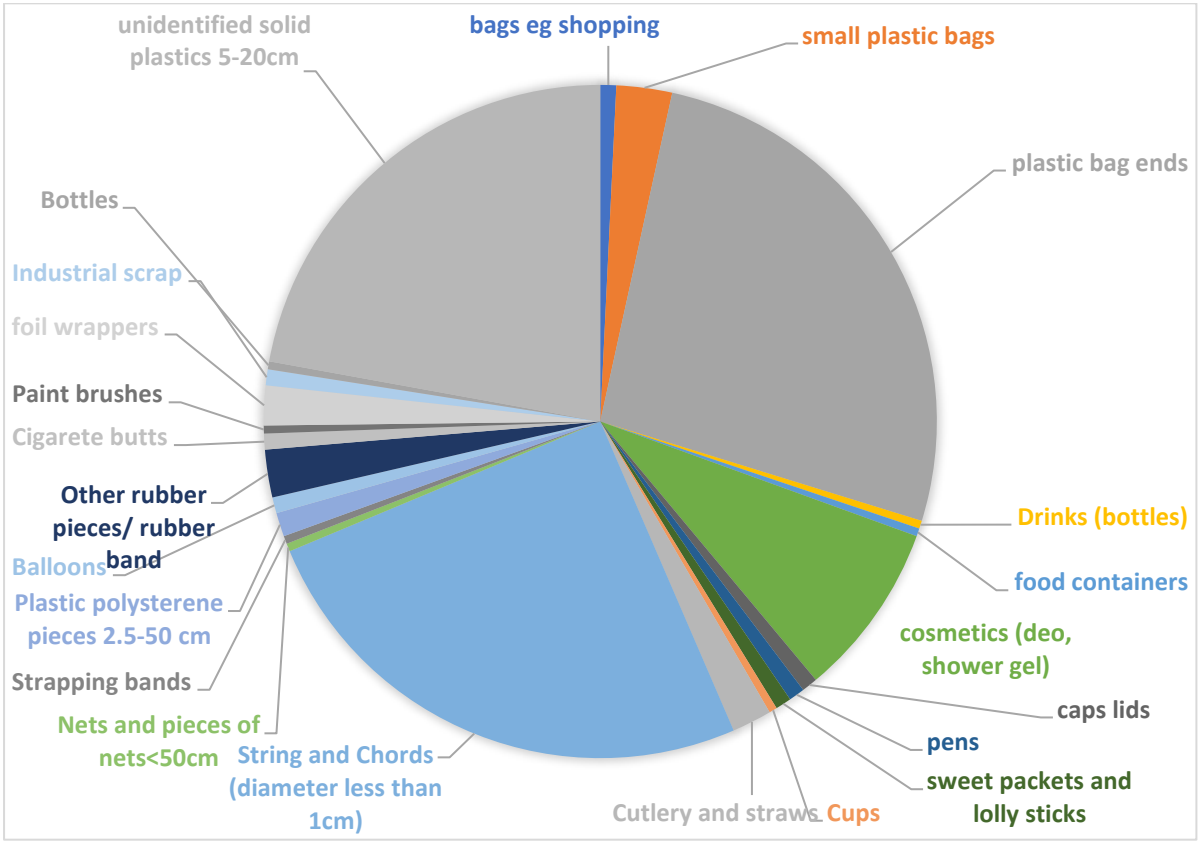

Figure 12- Monitored items from Area 1 on Nollestrand using the Litterati app method

Top 5 items found:

1. Plastic bag ends: 69 items = 26%
2. String and Chords: 66 items = 25%
3. Unidentified solid plastics: 58 items = 22%
4. Cosmetics (deo, shower gel etc): 22 items = 8%
5. Small plastic bags: 7 items = 3%

Overall items monitored: 262

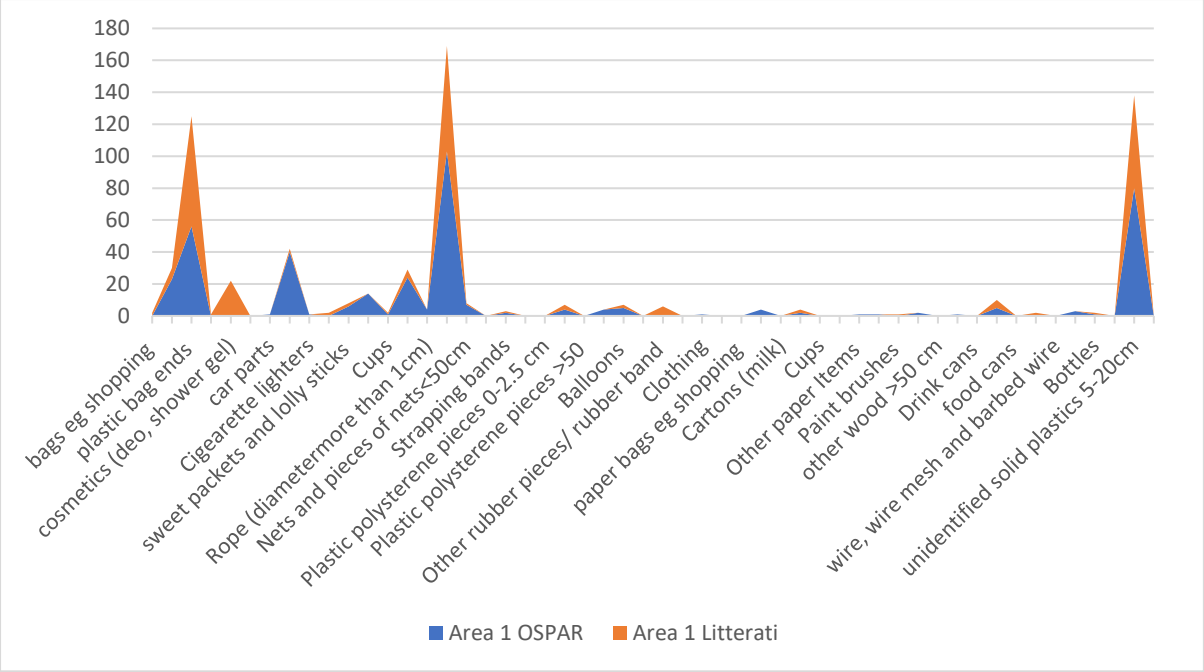

Figure 13- Comparison of items monitored in Area 1 on Nollestrand using OSPAR and Litterati app method

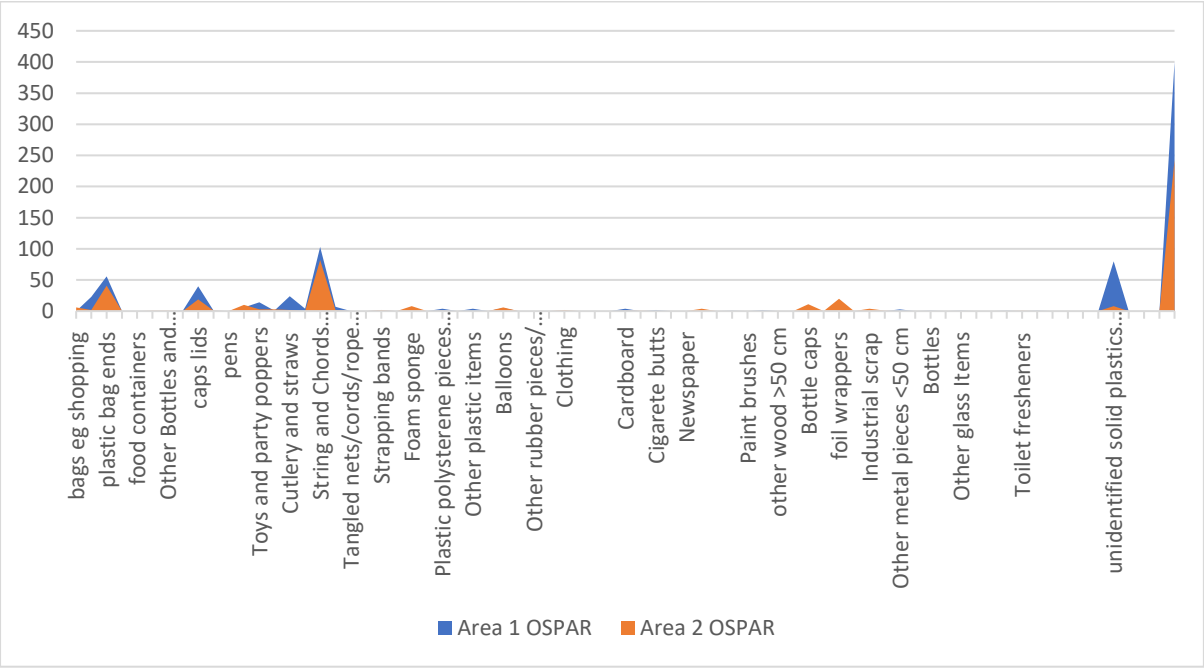

Figure 14- Comparison of monitored items in Area 1 and 2 on Nollestrand using the OSPAR method

4.2 Ritthem beach monitoring

Figure 15- Sampling areas at Ritthem beach

This beach in Ritthem is fulfilling all preconditions set by the OSPAR monitoring guidelines:

- Be composed of sand or gravel and exposed to the open sea
- Accessible to the surveyors all year around
- Accessible for ease of marine litter removal
- Have a minimum length of 100 meters and if possible, over 1km in length
- Free of buildings all year around
- Not subject to any other litter collection activities

The beach is mostly used for recreational purposes since it is one of the few beaches in the area where citizens can walk their dog all year around. It is closely located to the industrial zone in Ritthem.

4.2.1 Monitoring event 1

Table 3- Conditions at Ritthem monitoring event 1

Location	Ritthem beach
Date	8th November 2019
Time	13:00 – 15:00
Method	OSPAR
Citizen scientists	5
Temperature	8c felt like 6c
Wind speed	12km/h SSW with 13km/h gusts
Precipitation	0 mm

Figure 16- Ritthem beach (source: Liliane Geerling)

For this combined litter monitoring and beach clean-up we met up at the 't Smoske in Vlissingen and travelled with the car to the project location close to Ritthem. We have been a group of 5 volunteers, so we decided to only form one group and observe just one area. We started on the east side of the beach, walking west. At first, we had two participants holding the bags, one participant writing down and the rest would gather data. During the observation we adapted a bit with two students writing down, coordinating who is responsible for what kind of item. For example, student 1 would only write down the unidentified solid plastics so that the other student could concentrate on other items. This accelerated the whole process. It also helped that some participants already knew a bit about the list from last time. This way, finding items on the list did not take as much time as it did the first time using it. We managed to gather data from that area in about 1.5h.

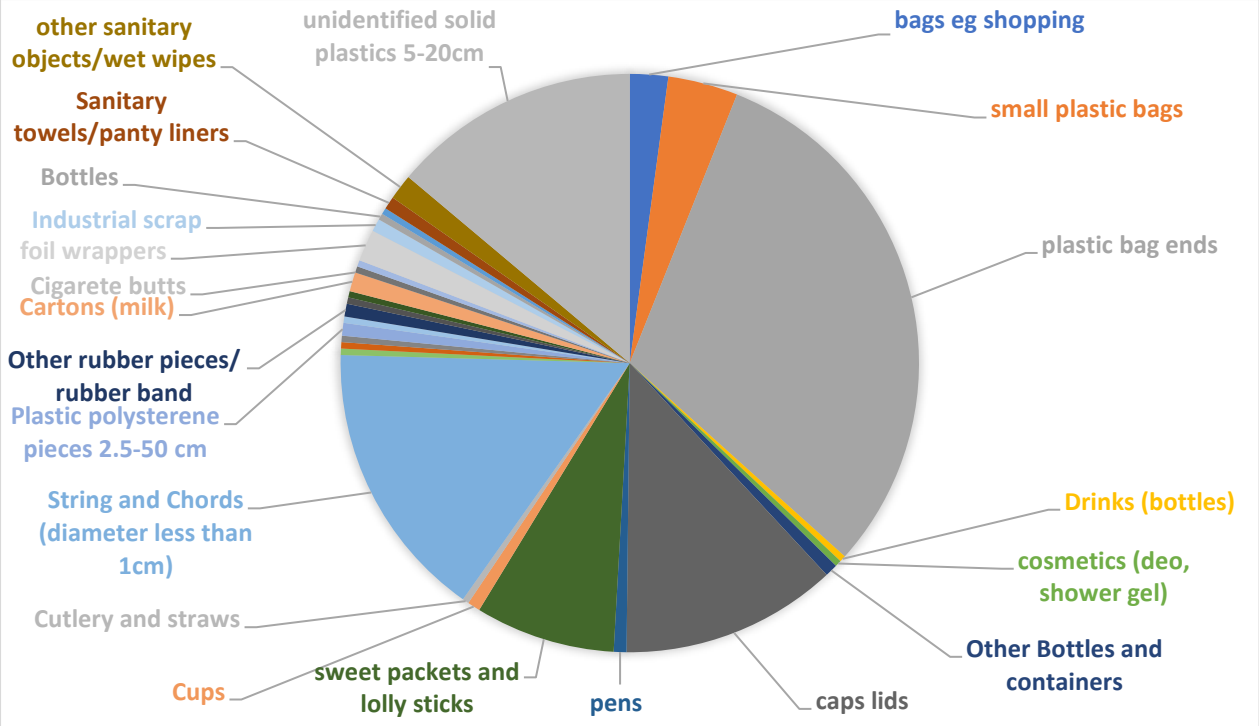

Figure 17- Monitored items found in Area 1 on Ritthem beach using the OSPAR method

Top 5 items found:

1. Plastic bag ends: 86 items = 31%
2. String and Chords: 44 items = 16%
3. Unidentified solid plastics: 39 Items = 14%
4. Bottle caps and lids: 34 items = 12%
5. Sweet packets and lolly sticks: 22 items = 8%

Overall items monitored: 281

4.2.2 Monitoring event 2

Table 4- Conditions at Ritthem monitoring event 2

Location	Ritthem beach
Date	29th November 2019
Time	13:00 – 15:00
Method	Litterati app
Citizen scientists	4
Temperature	9c felt like 5c
Wind speed	22km/h NNW with 31km/h gusts
Precipitation	0.1 mm

When we observed the beach of Ritthem again with the Litterati App there have been only 4 participants. The weather was calm and sunny. We decided to survey two areas but keep the group together so that we did the sections in sequence. Overall, we observed the beach for around 1h and

50 mins. For this time, we changed the method of taking the pictures slightly. Instead of taking the picture before tossing it into the bag we decided to collect a few items, place them in a line on the floor for the participant with the camera. He/she would quickly take successive pictures while the collector started to toss the items in the bag after. This turned out to improve the pictures a lot due to camera focus, mostly the same distance to the item, etc.

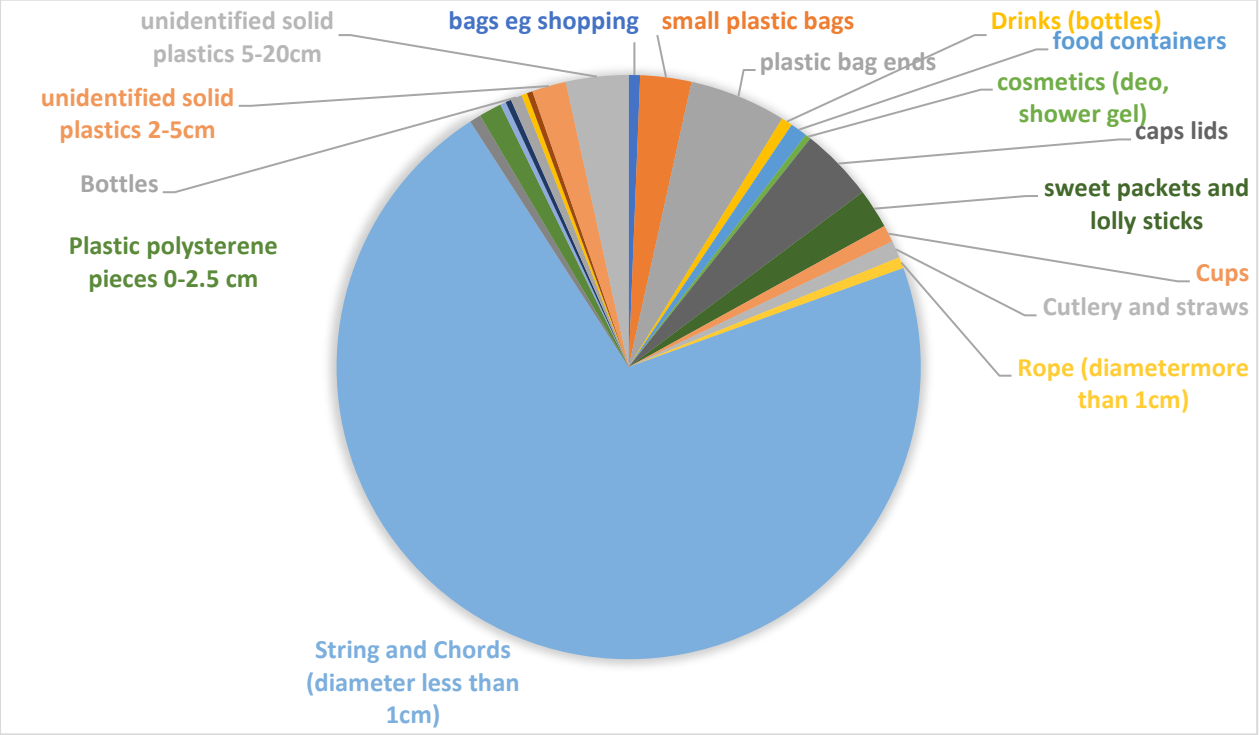

Figure 18- Monitored items in Area 1 on Ritthem beach using the Litterati app method

Top 5 items:

1. Strings and Chords: 227 items = 71%
2. Plastic bag ends: 17 items = 5%
3. Bottle caps and lids: 13 items = 4%
4. Unidentified solid plastics: 11 items =3%
5. Small plastic bags: 9 items = 3%

Overall items monitored: 316

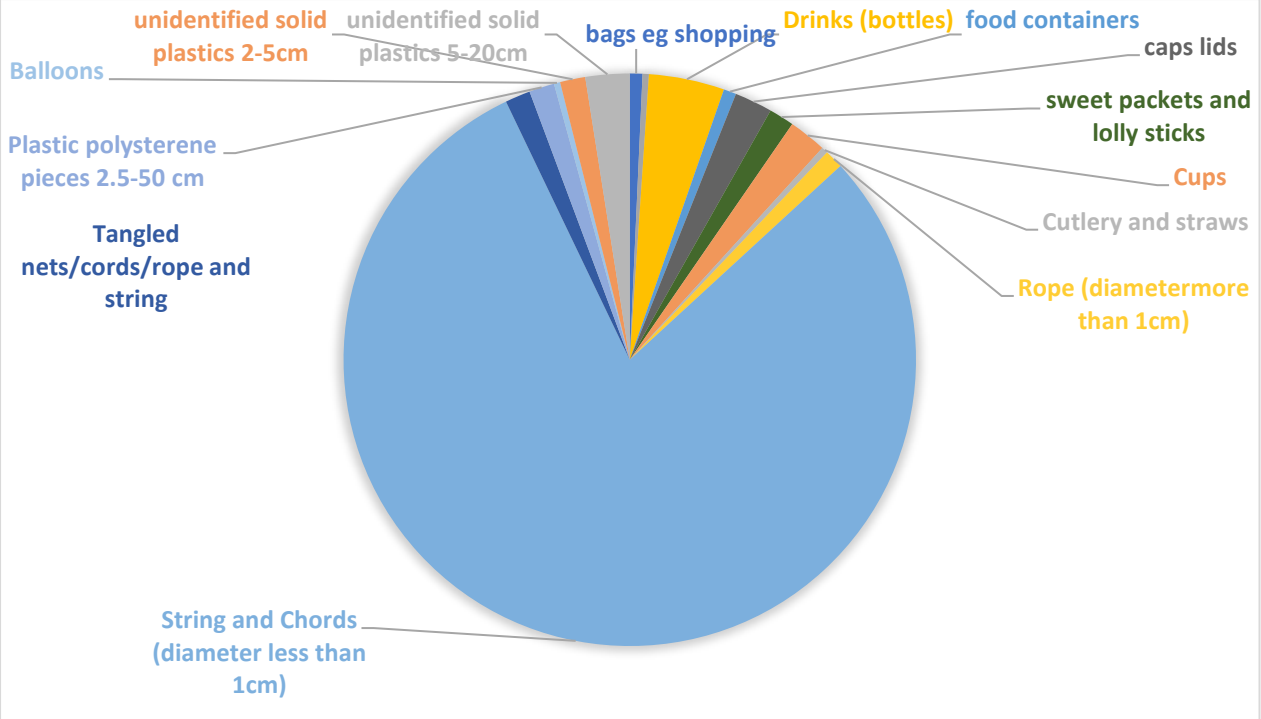

Figure 19- Monitored materials found in Area 2 on Ritthem beach using the Litterati Method

Top 5 Items:

1. String and chords: 224 items = 80%
2. Drinking bottles: 12 items = 4%
3. Unidentified plastics 5-20cm: 7 items= 2%
4. Cups: 6 items = 2%
5. Bottle caps/lids: 6 items = 2%

Overall items monitored: 281

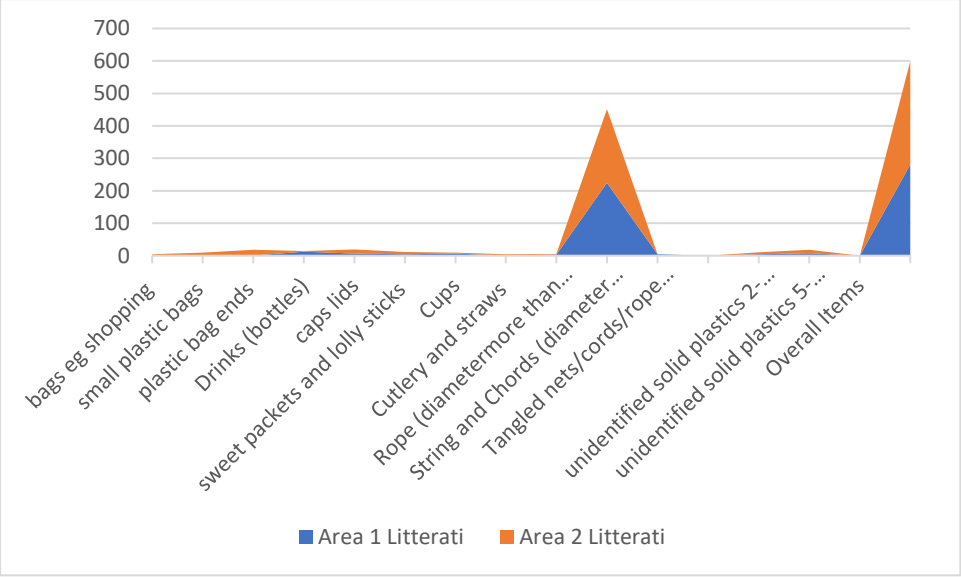

Figure 20- Comparing the monitored items from Area 1 and 2 on Ritthem beach using the Litterati app method

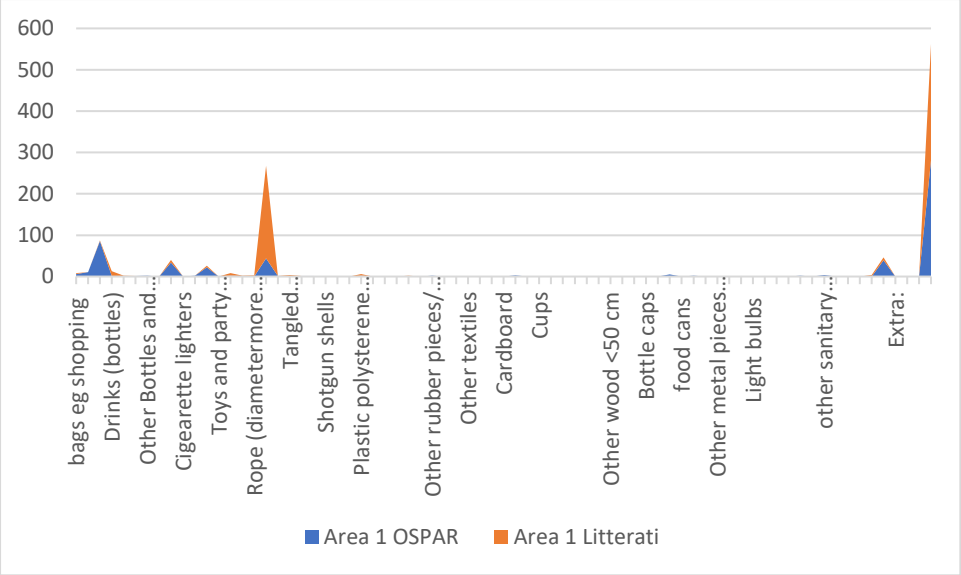

Figure 21- Comparison of Area 1 on Ritthem beach using the OSPAR and Litterati app method

4.3 Zoutelande beach monitoring

Figure 22- Sampling areas at Zoutelande beach

The beach on Zoutelande is almost completely applicable to the research principles as well. Because there is a pavilion it clearly has a building there.

- Be composed of sand or gravel and exposed to the open sea
- Accessible to the surveyors all year around
- Accessible for ease of marine litter removal
- Have a minimum length of 100 meters and if possible, over 1km in length
- Not subject to any other litter collection activities

4.3.1 Monitoring event 1

Table 5- Conditions at Zoutelande monitoring event 1

Location	Zoutelande beach
Date	15th November 2019
Time	13:00 – 15:00
Method	OSPAR
Citizen scientists	4
Temperature	5c felt like 1c
Wind speed	26km/h NE/ENE with 33km/h gusts
Precipitation	0 mm

Figure 23- Monitoring group at Zoutelande beach (source: L. Geerling)

In Zoutelande we have only been a group of 4 people using the OSPAR method. Here the waterline was high up only leaving a relatively small area with dry sand. Overall there has not been a lot of waste at this beach at that day. This might be because of the tides. The wind was cold. We had only one group member take the pictures while one member held the bag and the other members collected the litter. For this event we decided to not categorize the blue chords and strings (Vispluis) at the beach but collect it in a separate bag and count it afterwards. This came from my observations that the participants would sometimes miss on categorizing items that are on the beach in a high quantity due to the increased effort. We continued this for the next event in Ritthem, as well as the last event in Zoutelande to see if there is a difference in the results.

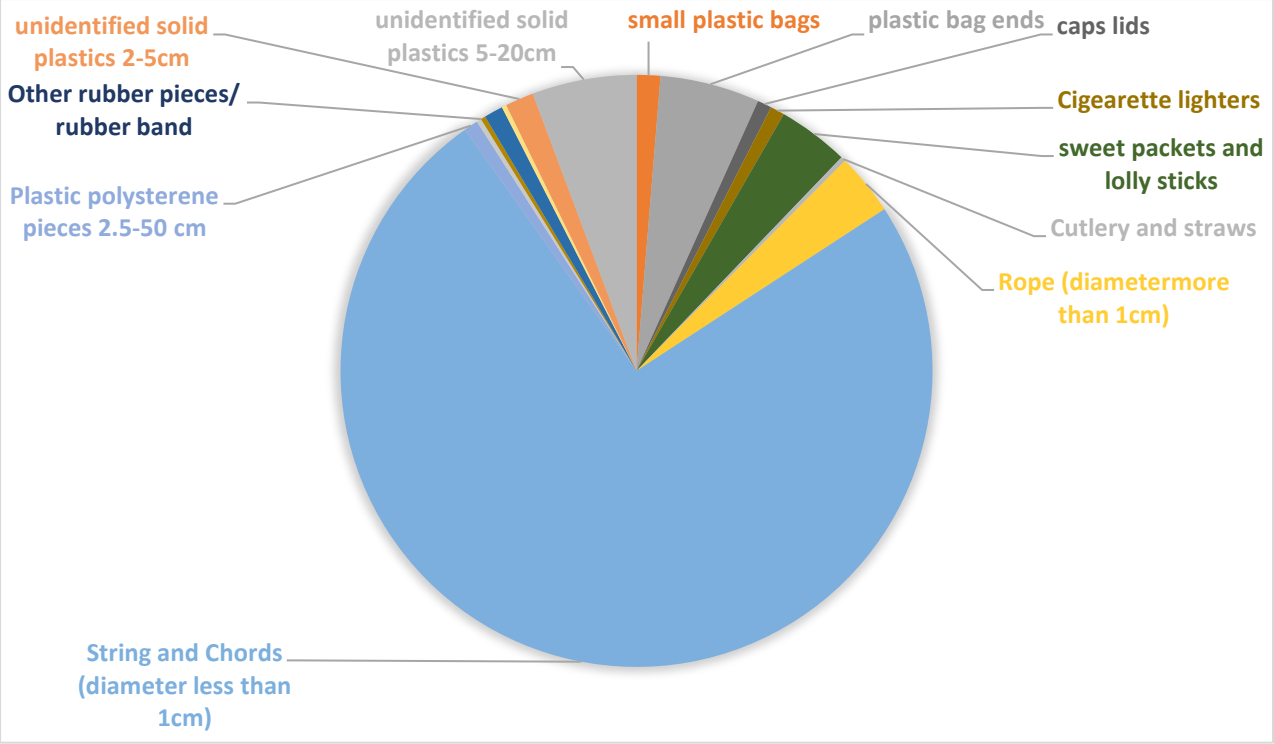

Figure 24- Monitored items found on the Zoutelande sampling area 1 using the OSPAR method

Top 5 items found:

1. String and chords: 287 items = 74%
2. Unidentified solid plastics 5-10 cm: 22 items = 6%
3. Plastic bag ends: 21 items = 5%
4. Sweet packets and lolly sticks: 15 items = 4%
5. Rope diameter larger than 1cm: 13 items = 3%

Overall items monitored: 386

4.3.2 Monitoring event 2

Table 6- Conditions at Zoutelande monitoring event 2

Location	Zoutelande beach
Date	27th November 2019
Time	13:00 – 15:00
Method	Litterati app
Citizen scientists	4
Temperature	11c felt like 8c
Wind speed	35km/h SSW with 59km/h gusts
Precipitation	0.4 mm

For this combined litter monitoring and beach clean-up we gathered around 16 people. We divided the beach in Zoutelande into 3 areas again, dividing groups so that there were always two people collecting and picking up the trash while one held the bag and one took the pictures with the

Litterati app. It was a bit cold but overall perfect weather to survey. The whole group surveyed the 3 different areas for 1.5 h.

My group tried to implement the same method as we have done in Ritthem for the pictures we took. I could also only obtain the data from one of the two other groups monitoring.

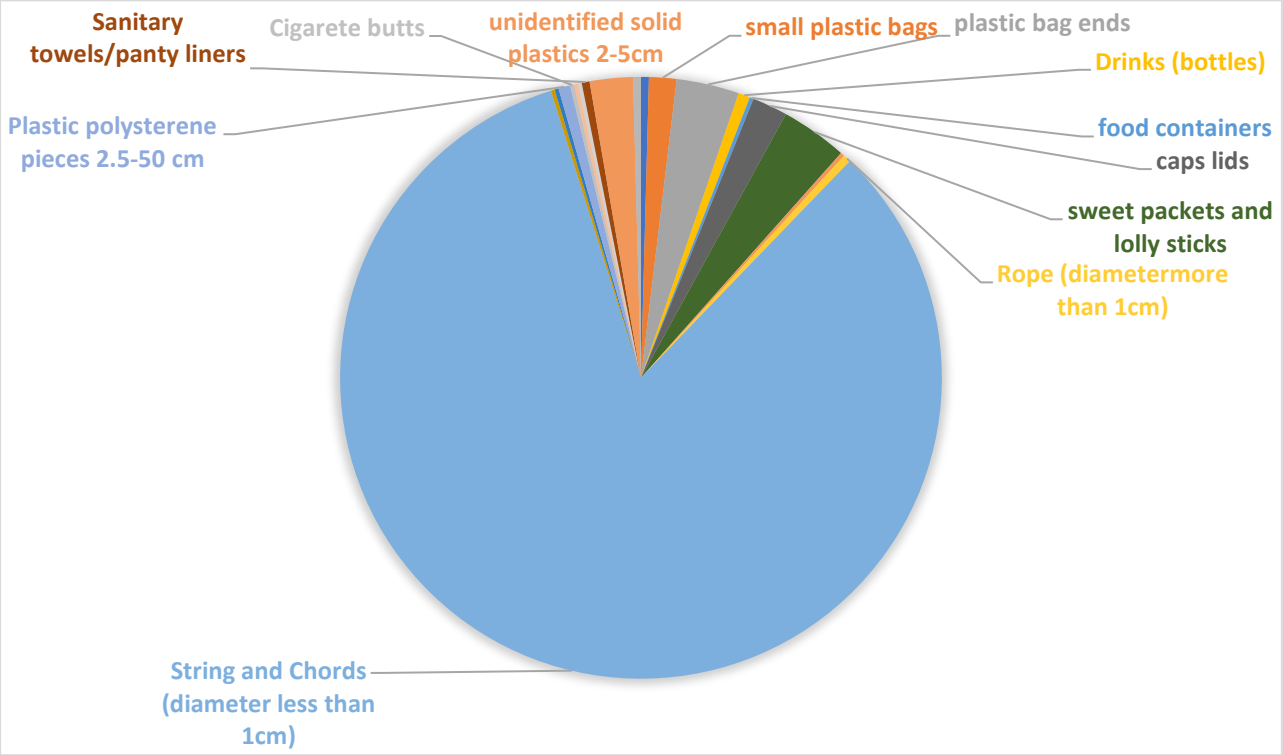

Figure 25- Monitored items found at Zoutelande beach in Area 1 using the Litterati method

Top 5 items found:

1. Strings and chords: 394 items = 83%
2. Sweet packets and lolly sticks: 17 Items = 4%
3. Plastic bag ends: 16 items = 3%
4. Unidentified solid plastics: 11 items = 2%
5. Bottle caps and lids: 9 items = 2%

Overall items monitored: 486

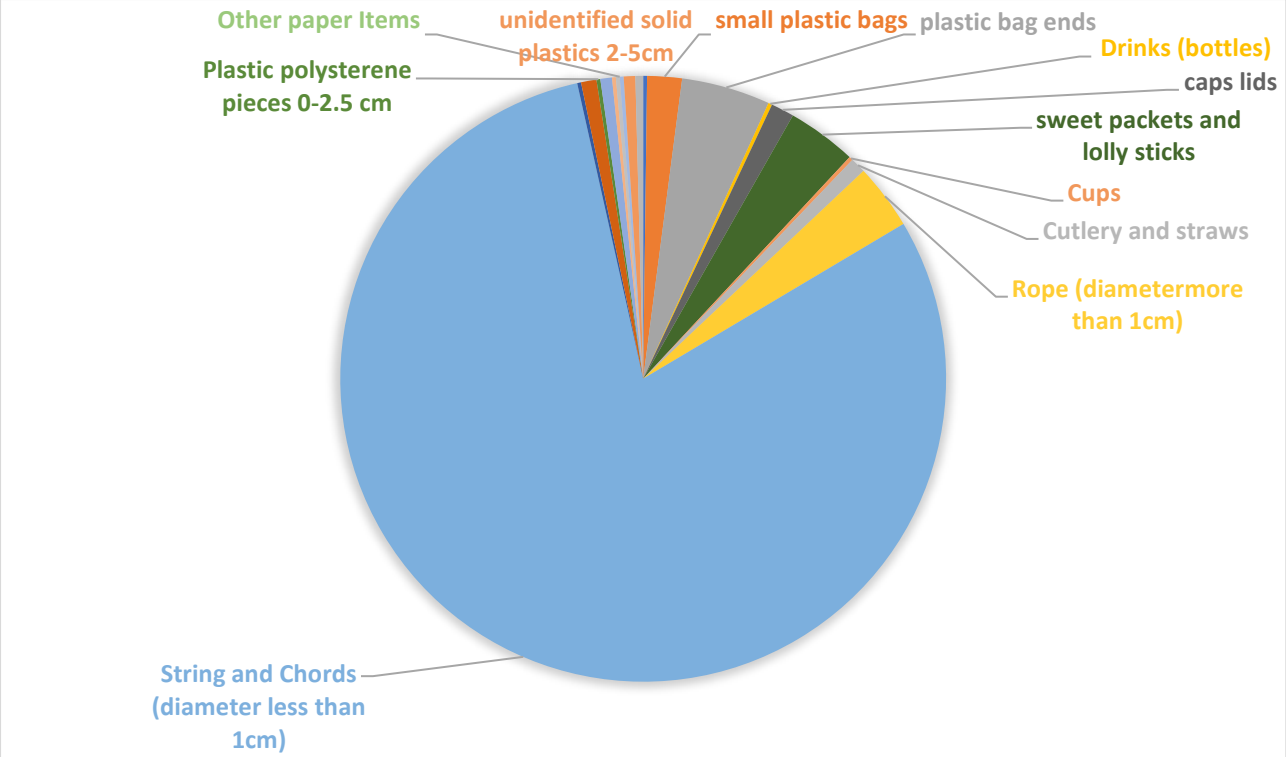

Figure 26- Monitored items at the Zoutelande beach in Area 2 using the Litterati app method

Top 5 items found

1. Strings and chords: 389 items = 80%
2. Plastic bag ends: 23 items = 5%
3. Sweet packets and lolly sticks: 18 items = 4 %
4. Rope diameter more than 1cm: 17 items =3 %
5. Small plastic bags: 9 items = 2%

Overall items monitored: 47

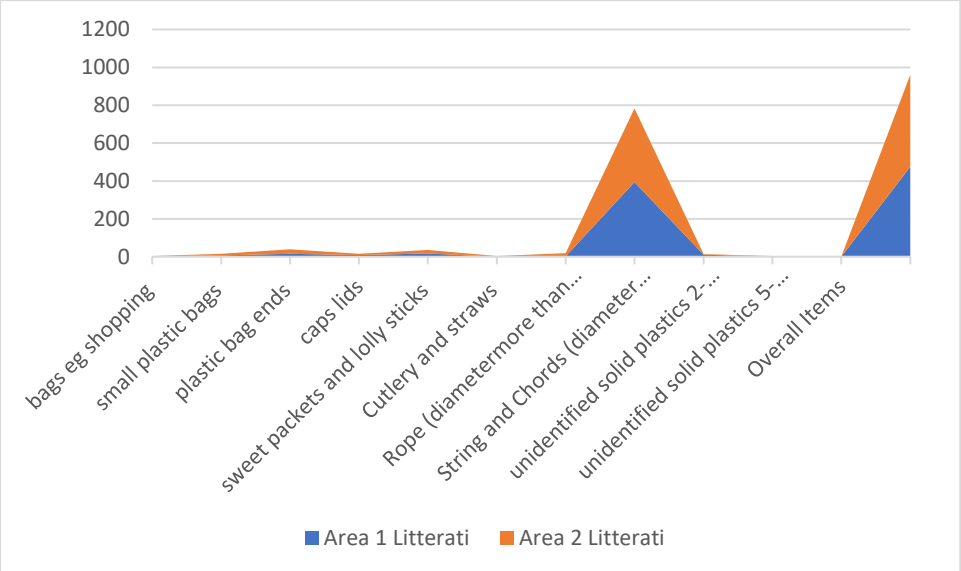

Figure 27- Comparison of monitored items in are 1 and 2 on the Zoutelande beach using the Litterati app method

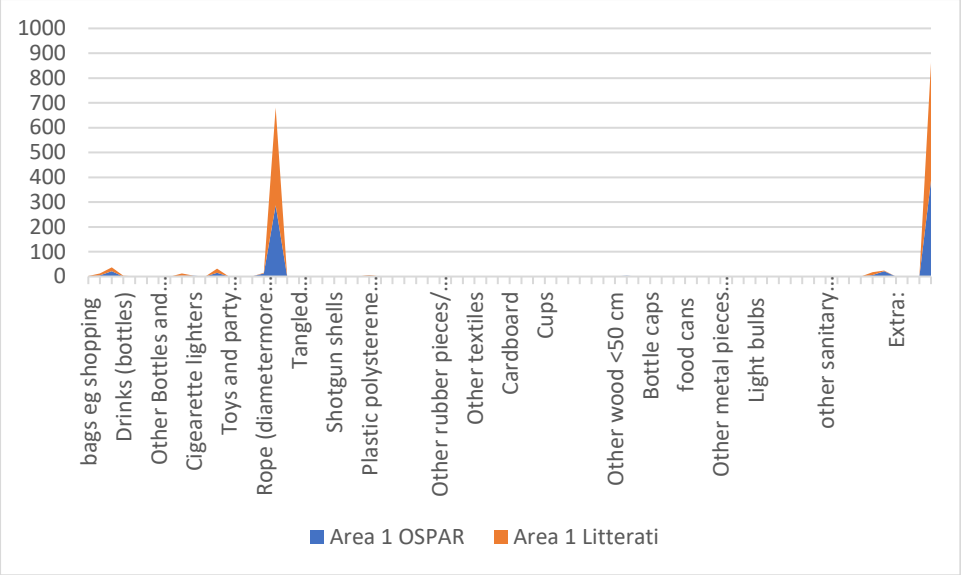

Figure 28- Comparison of items monitored in Area 1 on Zoutelande using the OSPAR and Litterati app method

4.4 Breezand beach monitoring

Figure 29- Sampling areas at Breezand beach

The beach of Breezand is a very broad beach. As you can see above, we adjusted the areas due to this and the lack of trash we could find far away from the water. As you can see there are some structures and a beach pavilion on that part of the beach.

- Be composed of sand or gravel and exposed to the open sea
- Accessible to the surveyors all year around
- Accessible for ease of marine litter removal
- Have a minimum length of 100 meters and if possible, over 1km in length
- Not subject to any other litter collection activities

4.4.1 Monitoring event

Table 7- Conditions at Breezand monitoring event

Location	Breezand beach
Date	4th December 2019
Time	13:00 – 15:00
Method	OSPAR
Citizen scientists	8
Temperature	5c felt like 4c
Wind speed	7km/h S/SE with 10km/h gusts
Precipitation	0 mm

Figure 30- Monitoring group at Breezand beach (source: Fujia van Zetten)

At this day there were 8 participants joining the combined litter monitoring and beach clean-up. The weather was great. Since the beach was very wide, we decided not to survey all the way from the dunes to the water but rather the other way around until we could not find any plastics anymore. Most of the found litter was at the tide line. We formed two groups but overall there was not much to find on these beaches. This could be because it is immensely broad. One student categorized while one held the bag and the rest picked up the litter. However, since it was hard to find a lot of trash, we placed the bag somewhere close and all the members looked closely for 10 m of area and then take the bag to the next spot to do the same.

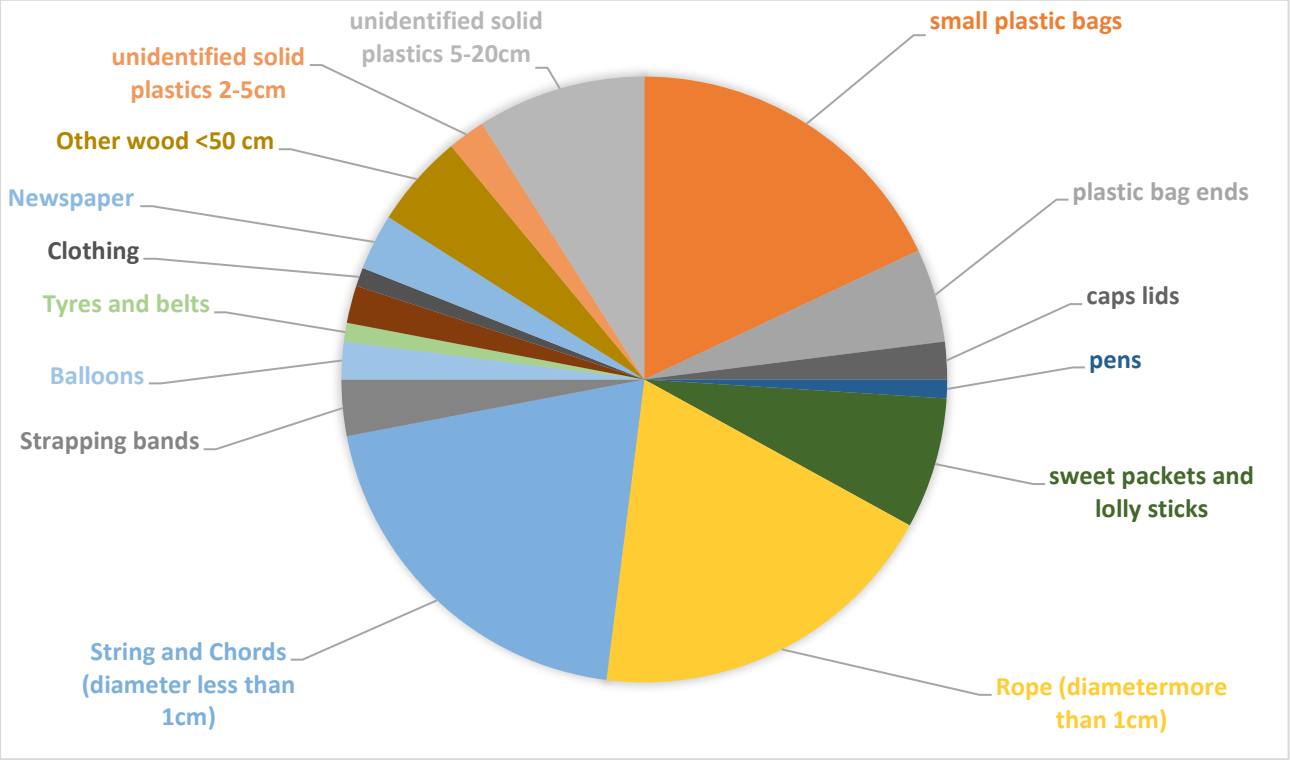

Figure 31- Monitored items at Area 1 of Breezand beach using the OSPAR method

Top 5 items found:

1. Strings and chords: 20 items = 20%
2. Rope diameter more than 1 cm: 19 items = 19%
3. Small plastic bags: 18 items = 18 %
4. Unidentified solid plastics 5-10cm: 9 items = 9%
5. Sweets packets and lolly sticks: 7 items = 7 %

Overall items monitored: 100

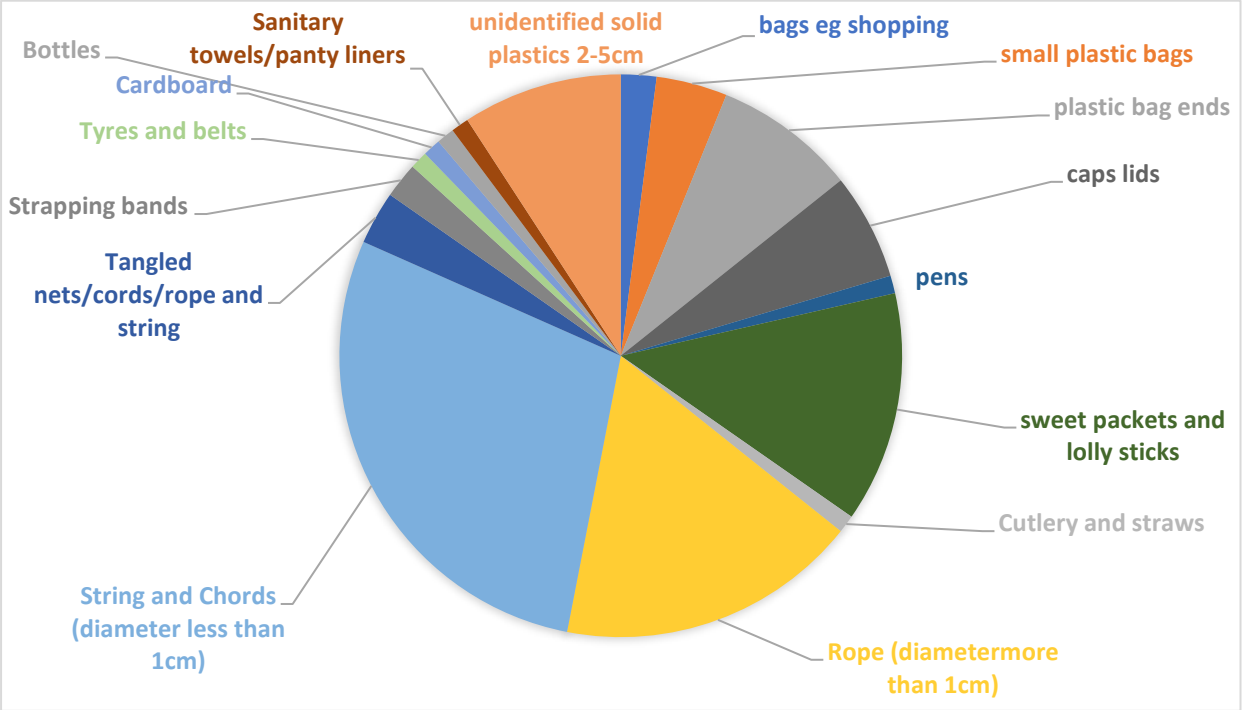

Figure 32- Monitored items at Area 2 of Breezand beach using the OSPAR method

Top 5 items found:

1. Sting and Chords: 28 items = 29%
2. Rope diameter more than 1cm: 17 items = 17%
3. Sweet packets and lolly sticks: 13 items = 13%
4. Unidentified solid plastics 2-5 cm: 9 items = 9 %
5. Plastic bag ends: 8 items = 8%

Overall items monitored: 98

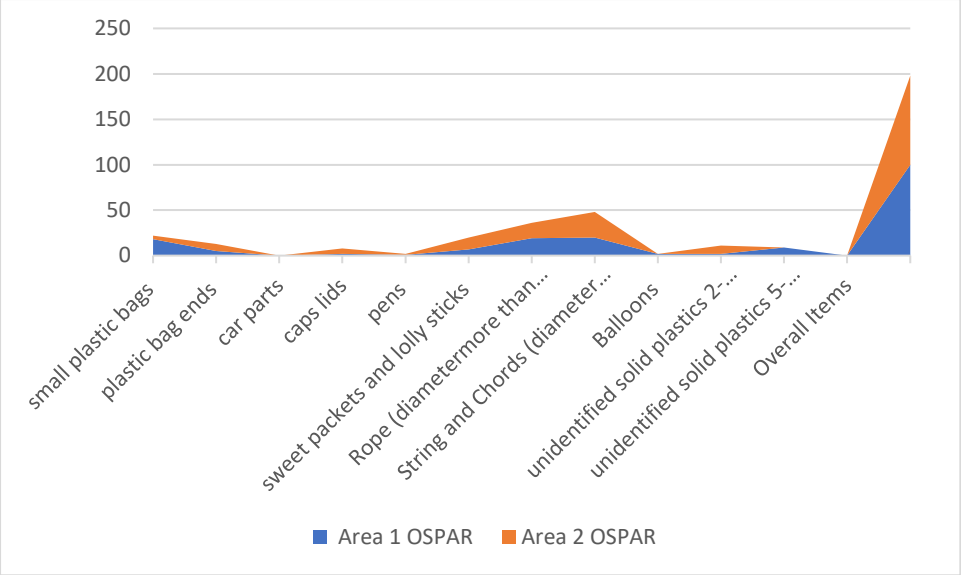

Figure 33- Comparison of Area 1 and 2 at Breezand beach using the OSPAR method

4.5 Roompot beach monitoring

Figure 34- Sampling areas at Roompot beach

The beach in Roompot is an interesting beach for observing. It does not meet all the guidelines from OSPAR since you can again see the structures and beach houses that are used for tourists year-round. In addition, we met someone managing the structures during the event and she stated that they empty the trash bins and clean the surrounding every few days.

- Be composed of sand or gravel and exposed to the open sea
- Accessible to the surveyors all year around
- Accessible for ease of marine litter removal
- Have a minimum length of 100 meters and if possible, over 1km in length

4.5.1 Monitoring event

Table 8- Conditions at Roompot monitoring event

Location	Roompot beach
Date	6th December 2019
Time	13:00 – 15:00
Method	OSPAR/Litterati app
Citizen scientists	16
Temperature	9-10c felt like 5c
Wind speed	42km/h SSW with 65km/h gusts
Precipitation	1.8 mm

Figure 35- Monitoring group at Roompot beach (source: L. Geerling)

The last beach we observed during a combined litter monitoring and beach clean-up was the beach in Roompot. We have been 16 participants and we decided to divide into 3 groups. We used the Litterati methods on the outside areas and the middle area was surveyed with the OSPAR method. We monitored for about 1 h and 10 mins while there was a lot of wind and some rain. Wind and slight rain during the event are the reasons the surveying time was cut to this. The participants also actually managed to survey their area almost completely before losing their motivation. The two Litterati app groups did the same method of taking the picture of the trash as discussed in the "Ritthem" Litterati approach above.

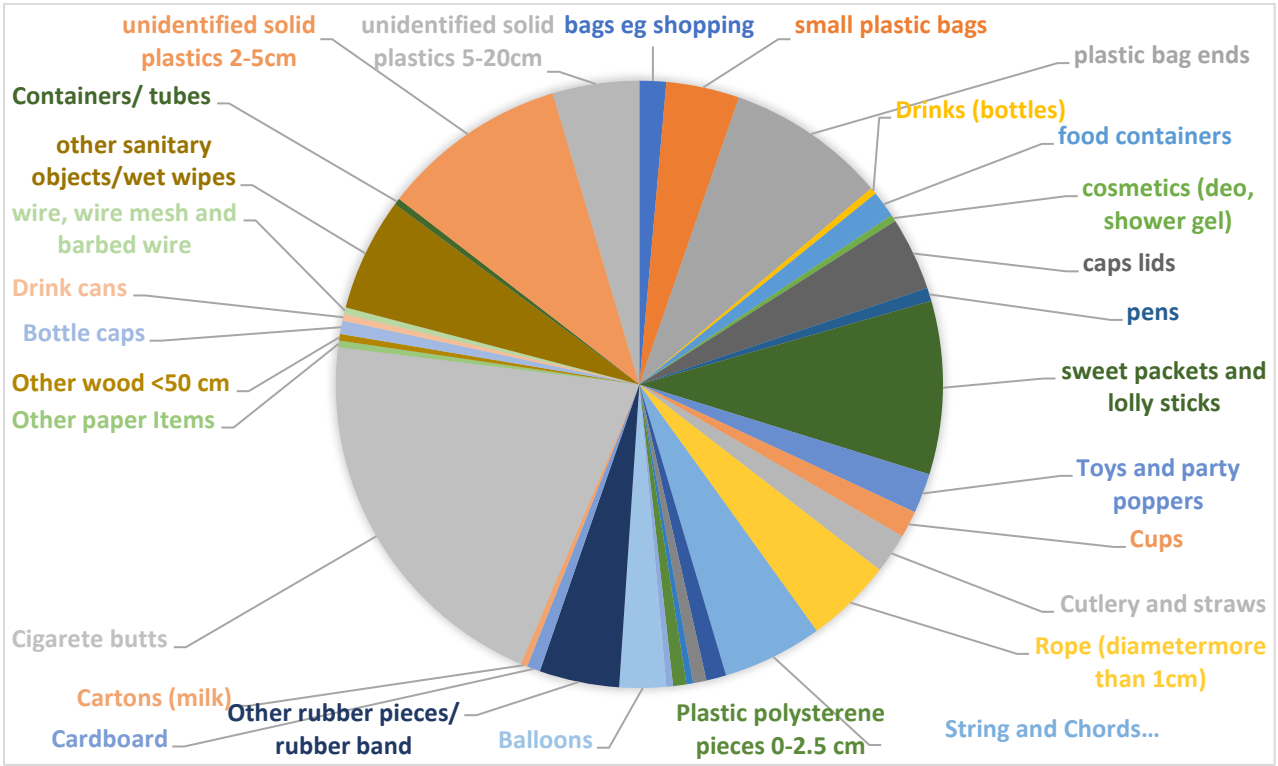

Figure 36- Monitored items in Area 1 at Roompot beach using the Litterati app method

Top 5 items found:

1. Cigarette butts: 58 items = 21%
2. Unidentified plastics 28 items = 10%
3. Sweet packets and lolly sticks: 26 items = 9 %
4. Plastic bag ends: 24 items = 9%
5. Strings and chords: 15 items = 5%

Overall items monitored: 282

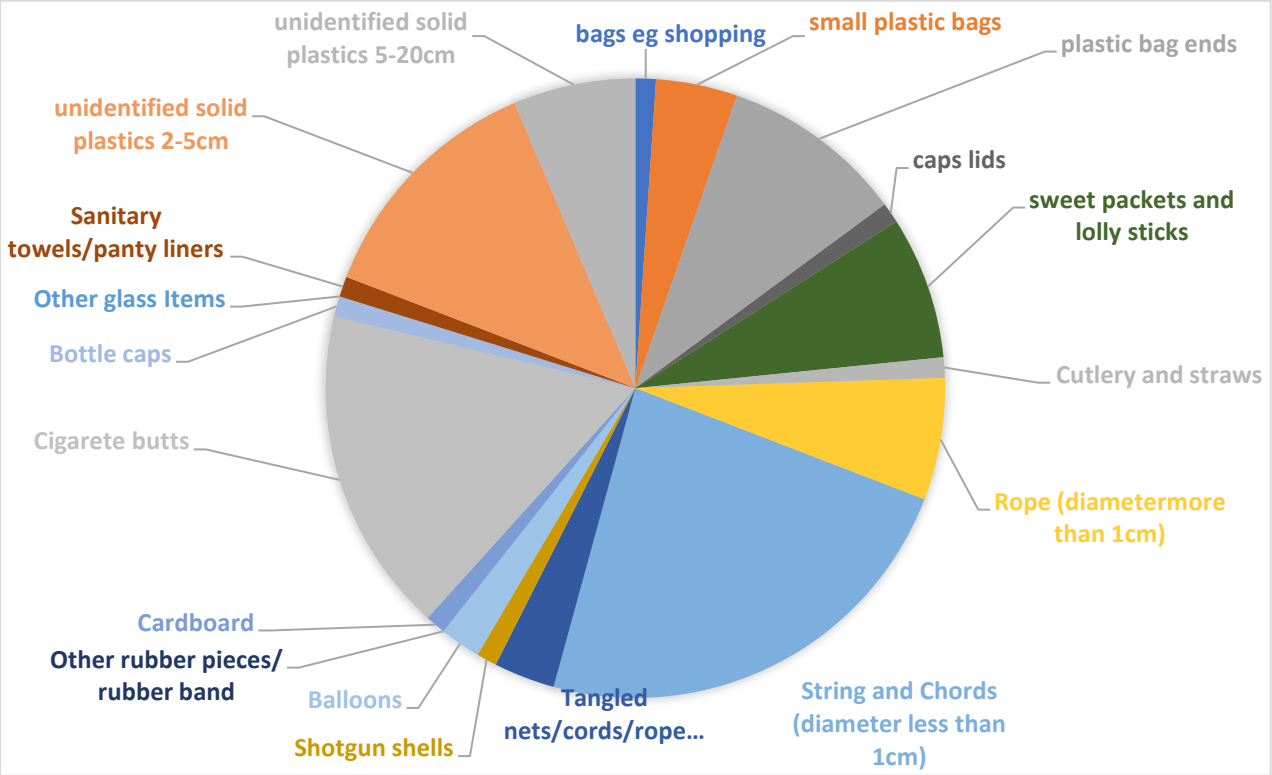

Figure 37- Monitored items from area 3 on Roompot beach using the Litterati app method

Top 5 Items:

1. Strings and chords: 22items = 23%
2. Cigarette buttes: 16 items = 17 %
3. Unidentified solid plastic: 12 items = 13%
4. Plastic bag ends: 9 items = 10 %
5. Sweet packets and lolly sticks: 7 items = 7%

Overall items monitored: 94

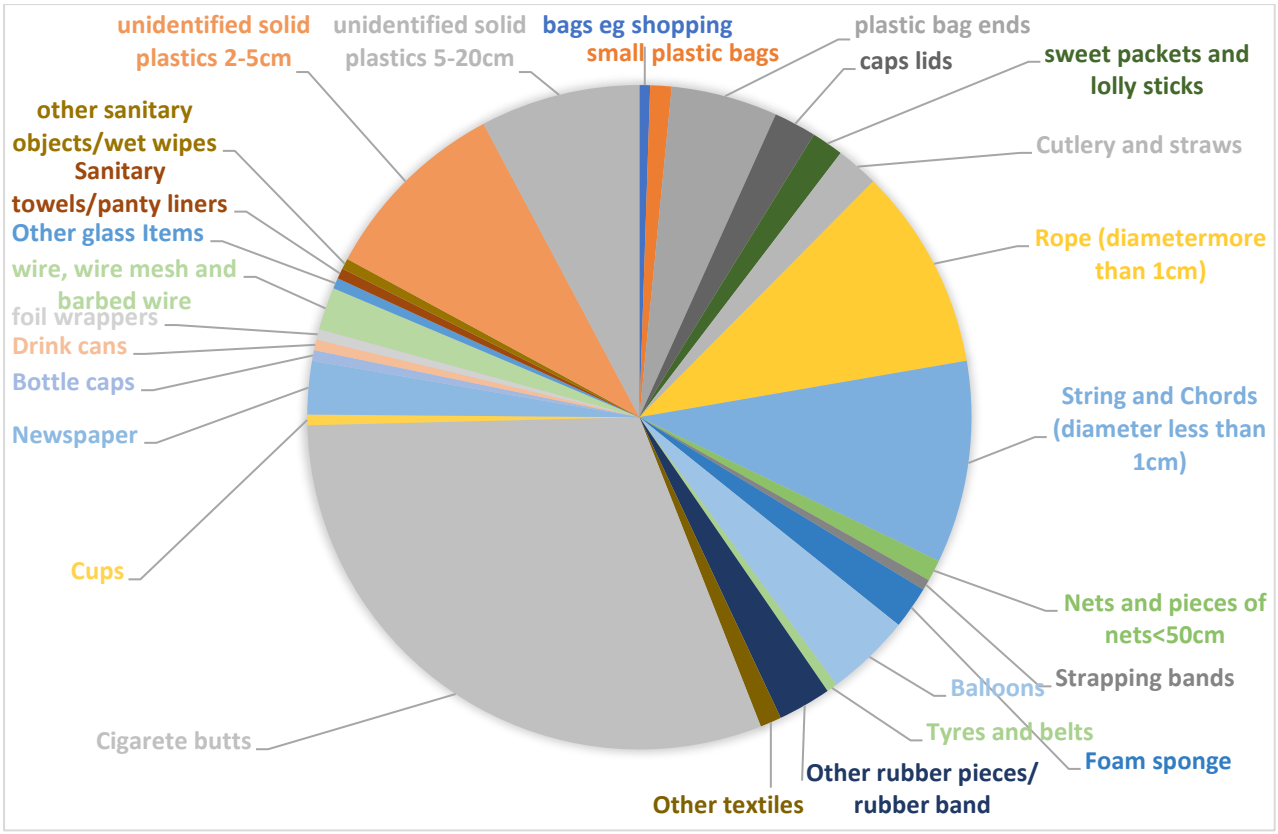

Figure 33- Monitored items at Area 2 on Roompot beach using the OSPAR method

Top 5 items:

1. Cigarette butts: 59 items = 31%
2. Rope diameter more than 1 cm: 19 items = 10%
3. Strings and chords: 19 items = 10%
4. Unidentified solid plastics 2-5cm: 18 items = 9 %
5. Unidentified solid plastics 5-20 cm: 15 items = 8 %

Overall Items monitored: 193

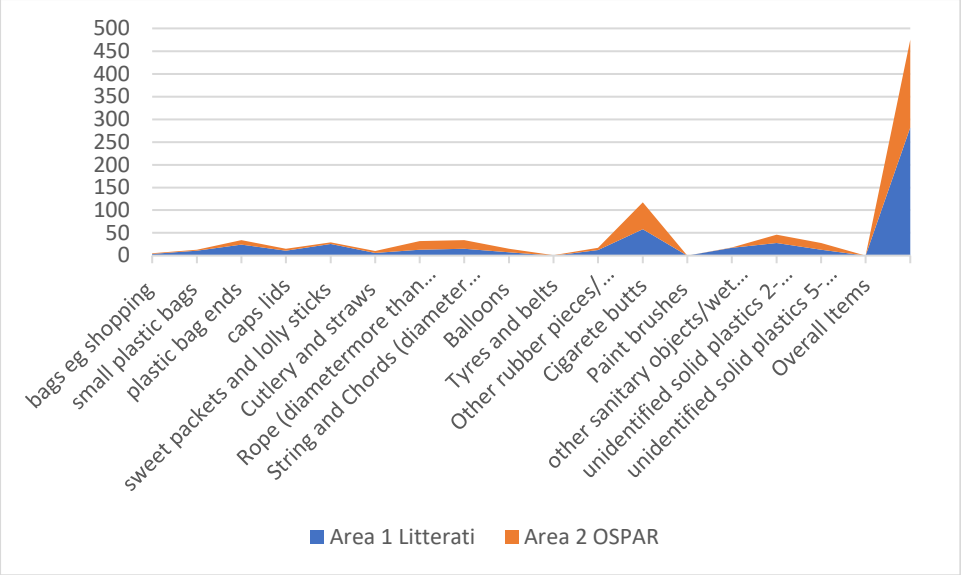

Figure 34- Comparing Area 1 and 2 on Roompot beach using the Litterati app and OSPAR method

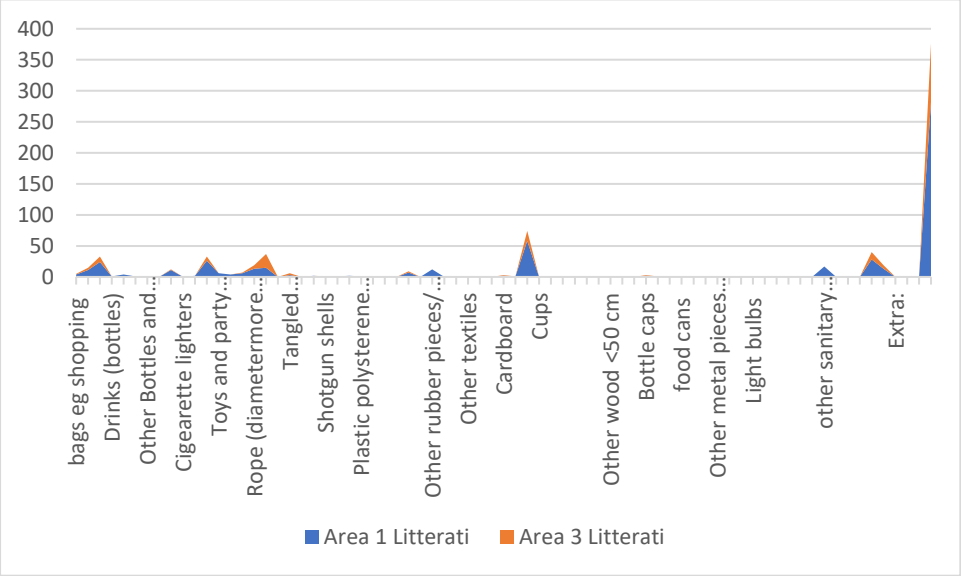

Figure 35- Comparison of Area 1 and 3 on Roompot beach using the Litterati app method

4.6 Survey results

22 volunteers that took part during at least one monitoring event filled in the survey regarding their motivation to join and their experience with the friendliness of the monitoring methods. The entire survey results can be found in Appendix 1.

4.6.1 User motivation

For the question on the motivation we provided several categories. Below question 1, the replies are listed by frequency of replies per category. The number indicates how many participants gave an answer that could be categorized to those categories.

Question 1: What are your reasons to join the participatory research and which one is most important for you?

- Environmental interest (13x)
- Credit incentive (10x)
- Contribution (7x)
- Scientific interest (5x)
- Fun (1x)
- Community (1x)

Question 2: Are you planning to participate in a research like this in the future and why?

20 volunteers answered the question with “Yes” and two with “No”. The main reason for the “Yes” was the interest to contribute to the environmental input of the research. The reasons by importance were as follows:

- Environmental interest (8x)
- Contribute (4x)
- Community (4x)
- Credit incentive (3x)
- Scientific interest (2x)
- Learn (2)

Two participants mentioned that they would like to join in the future, but such activities are seldom, or they did not know about any other project like this. The second obstacle was lack of time to join those activities.

Question 3: Did you participate in any participatory research activity before?

Here 18 volunteers stated that they have never participated in such an activity. Only two attended such an event before but they were part of the group organising these events.

Question 4: Did you feel like you learned something for your everyday life today?

19 participants confirmed that they learned something new during the research activities. These learnings varied but two items were more often stated:

- I learned that it is important to reduce your own trash (5x)
- What areas are polluted and where the waste originates (5x)
- To take more care about the environment (2x)
- How trash that we generate every day have an impact on the environment (1x)
- That this can be a fun activity (1x)
- How research is concluded and that it could help with future pollution issues (1x)

Question 5: Do you feel like contributing more when you monitor compared to just cleaning?

The majority of 14 participants felt that they would contribute more to the study when they monitored and not just cleaned. For them the reasons have been:

- It helps to get to the source of the plastic problem
- We learn more about the effects than just cleaning
- Because understanding the problem better leads closer to a solution
- The monitoring events can be used to guide the clean-up actions better for better success

5 volunteers answered with “No”, because:

- Monitoring is to slow so cleaning would generate a better result
- Monitoring only deals with the sampling areas leaving a lot of trash ignored outside of those areas

Question 6: Do you participate in other scientific or communal activities during your free time and if so why or why not?

Only 2 out of the 22 participants had already taken place in such activities. The reasons for not participating that were mentioned:

- Not enough time
- No knowledge about projects like that

Question 7: How interested are you in the data gathered and the outcomes? Rate on a scale from 1-10 (10 most interested)

1() 2() 3() 4() 5(1x) 6() 7(6x) 8(3x) 9(5x) 10(2x)

4.6.2 Monitoring methods

The second part of the survey relates to the comparison of the OSPAR method and the Litterati app method. The participants have been asked for their assessment which they should rate on a scale of 1-10 (10 highest rating). The numbers in brackets indicate how many participants chose the scale degree to answer the question.

Question 1: How difficult did you find classifying the plastics found on the beach?

OSPAR Method:

1() 2(2x) 3() 4() 5(4x) 6(1x) 7(3x) 8(2x) 9(2x) 10()

Litterati app Method:

1 (1x) 2(3x) 3(1x) 4(2x) 5(2x) 6 (2x) 7(2x) 8(1x) 9(2x) 10()

Question 2: How difficult did you find the overall setup of the method? What was the biggest challenge? (10=most difficult)

OSPAR Method:

1() 2() 3(2x) 4(1x) 5(4x) 6 (1x) 7() 8(4x) 9(1x) 10()

The volunteers rated the OSPAR method differently and formulated two challenges:

- To categorize using paper forms is very difficult during windy conditions and even with slight rain.
- Even with the detailed catalogue it is hard to exactly identify the item because it is very specific

Litterati app Method:

1(3x) 2() 3(3x) 4(2x) 5(4x) 6(2x) 7(3x) 8() 9() 10()

The Litterati app method covered a wide rating with these challenges:

- It is difficult to keep your phone out all of the time if it is cold or bad weather
- The battery needs to be fully charged before starting

Question 3: How efficient do you think the methods are in cleaning and monitoring? What do you think needs to change to make the research activity more efficient? (10= superefficient)

OSPAR Method:

1() 2() 3() 4(1x) 5() 6() 7(2x) 8(3x) 9 10

The OSPAR method is considered efficient. However, room for improvement is seen in various aspects.

Improvements:

- It is hard to find items on the list and some have not been on the list which makes it harder to identify
- It is very detailed already which is good
- We should collect on the beach and categorize it later
- Paper and pen are too old fashioned
- some items have not been in the list

Litterati app Method:

1() 2() 3() 4(1x) 5(1x) 6 7 8(4x) 9(2x) 10(2x)

The Litterati app method was assessed efficient. The participants stated that it is much easier to take pictures. 10 participants said that the app is good, and they don't see the need for changes. Others stated that "it is good because it is categorizing by itself at some point maybe". Still, suggestions were made for improvements.

Improvements:

- In groups there should be a more people that take pictures with the app
- In a bigger group this could have been more efficient
- This method could be improved by leaving the stand with more people at the same time
- So much plastic that it is almost impossible to take pictures of all of them
- When more participants have the app, it could improve

Question 4: Do you think you could do this method in a small group self-organised?

9 participants answered that they feel comfortable to organise the OSPAR method themselves in a small group. 3 participants did not feel like they would be able to.

10 participants felt comfortable to organise a monitoring event using the Litterati methodology. Most said they would prefer to organise events using the Litterati method compared to the OSPAR method.

Question 5. Do you feel like you are contributing to scientific research in a meaningful manner? If so why or why not?

Only two participants said they did not feel like contributing, using both methods. The participants mentioned that if they know exactly how the data will be evaluated it would increase their feeling of contribution.

5. Discussions and Conclusions

In the following we discuss the results and present the conclusions. First the methods related research questions will be answered. Secondly, the results of the study will be compared to a similar study, and finally the survey results are discussed.

5.1 Monitoring

5.1.1 Nollestrand beach

For the sample area Nollestrand, the participants collected and monitored 400 items in sampling area 1 while the second group collected 243 items in sample area 2. The difference in the number of collected items suggests that the sampling area 2 was much cleaner or that the groups had different approaches of picking items up. Since both groups received the same introduction, the difference is mostly likely attributed to the cleaner conditions of sample are 2. The overall composition of the trash was comparable. In the first sample area 26% of the trash collected was the Vispluis while in the second sample area the percentage was 34%. Vispluis was the most collected piece of litter in both groups by percentage regardless of the amount of picked up items. Furthermore, the groups shared 3 of 5 items in the top 5 collected items in that area. These were strings and chords, bottle caps and lids as well as plastic bag ends.

When comparing the Litterati App method with the OSPAR method on the Nollestrand sampling area 1, we observed that two of the 5 “top 5 items” were equal: Plastic bag ends and strings and chords. The percentage of strings and chords collected have both times been the exact same with 25% while the plastic bag end percentage rose up to 26% making it the most gathered item in this sample area for this event. With the OSPAR method the trash was categorized in 26 different item categories and the Litterati App method listed items in 23 categories.

While the OSPAR method collected 400 items in sample area 1, with the Litterati App an overall of 262 items have been monitored. It is interesting to see that strings and chords were not the most found item anymore.

The results of the Nollestrand monitoring indicated that both methods are providing similar results in the composition of items, when the number of collected plastics is large.

5.1.2 Ritthem beach

On the beach of Ritthem we monitored the sample area 1 with the OSPAR method and sample areas 1 and 2 used the Litterati app 5 days later. The group using Litterati covered the two sample areas in succession due to the size of the group. Overall 316 items were gathered in sample area 1 and 281

objects in sample area 2 using the Litterati app method. From the “top 5 “found items, strings and chords (71% in area 1 and 80% in area 2), unidentified solid plastics (3% in area 1 and 2% in area 2) and bottle caps (4% in area 1, 2% in area 2) were in the same range.

During the monitoring event, two different ways of categorizing the litter were practised for the Vispluis (strings and chords). When the OSPAR method was applied, collecting and categorizing the Vispluis immediately on the spot, 86 Vispluis items had been categorized. Collecting Vispluis separately in a bag and categorizing the Vispluis independently later with the Litterati app, a higher the number of Vispluis items was detected. Strings and chords added up to 227 items in sampling area 1 when picked up independently. The difference between both ways of categorisation may be because the participants had to do very tedious work with these small plastic particles when collecting and categorizing them right away. This has led to instances where the Vispluis was not picked up or not monitored.

Comparing the results of the two methods on Ritthem beach, the number of other plastic items than Vispluis, was much higher with the OSPAR method than with the Litterati app method, although there has been less Vispluis gathered with the OSPAR method. One explanation for this finding could be the approach to collect and categorize the Vispluis separately which changed the focus of the participants more on these. For the OSPAR method there have been 23 different categories of plastic litter while for the Litterati app method the items re classified in 16 different categories.

In this case, the interesting finding was that once the participants had been told to treat one specific item (Vispluis) differently, it seemed to impact the outcome of the overall composition of the sampled items.

5.1.3 Zoutelande beach

The events at Zouteland beach suffered from the low number of volunteers in the OSPAR method group. Only 4 participants for the OSPAR method were available, while a big group of 15 people used the Litterati app method. While only one area could be observed with the OSPAR method due to the lack of participants, the 15 people during the Litterati event had been divided into 3 groups of 5 people. During both events, Vispluis was gathered and categorized separately.

In the sample area a total of 486 items were categorized with the OSPAR method. The group of sample area 2 collected 475 plastic items and categorized them according to the Litterati app method. The overall sample composition was similar on both areas. The two areas shared 4 of their 5 most found items: strings and chords, plastic bag ends, unidentified solid plastics and sweet packets and lolly sticks.

The results of both methods were similar, when the Vispluis was gathered separately. This is true for the overall composition but as well for the overall monitored items.

5.1.4 Breezand beach

The studies planned for the Breezand area turned out to become limited. Due to time limitations and unforeseen issues with the organisation of the events only two areas on the Eastern Scheldt could be monitored. Two groups of citizen scientists monitored the areas with the OSPAR method. No Litterati app monitoring was possible.

In sampling area 1 in total 100 items had been collected and monitored while in sampling area 2, 98 items were subject to the categorization with the OSPAR method. As the beach area is vast, not many items were collected, possible because they are distributed better. Therefore, Finding and categorizing the trash was more difficult which might have had an impact on the motivation of the

participants as well. The overall composition of the litter monitored in both areas was quite similar, sharing 4 of the top 5 gathered items: Strings and chords, rope, unidentified solid plastics and sweet packets and lolly sticks.

Though we could not compare the two methods at Breezand, the results from the OSPAR method at the two sample sides were comparable. From the observation on the spot, and despite the size of the area, most of the items were collected at the tideline. It remains to be researched if the tideline is representative for the pollution on the beach.

5.1.5 Roompot beach

During this event 16 participants were present, so we divided them into groups of 5 mostly. At this occasion we had the chance to use both monitoring methods at this one event. Sample areas 1 and 3 have been monitored using the Litterati app. Sample area 2 was observed using the OSPAR method.

This was one of the shortest events due to really bad weather. After 1 h and 10 minutes the event concluded. However, during this all the groups managed to finish their area.

When comparing area 1 and 2 in which different methods had been used for categorisation there is a discrepancy visible in the overall monitored items. In area 2, 193 items had been monitored using the OSPAR method. In area 1, 282 items have been monitored using the Litterati app. This difference could be due to the fact the OSPAR method was done with pen and paper and was very hard to do for the group due to rain and strong winds.

The overall composition of the items found was comparable, nonetheless. In the top 5 gathered items they shared all 5 categories. Those being Vispluis (strings and chords), cigarette butts, unidentified solid plastics, plastic bag ends and sweet and lolly packaging.

The OSPAR method was very difficult to apply in that weather conditions compared to the Litterati app. But still the composition of items was the same although the sample size was different. There was also an abundance of consumer waste on the beach that is most definitely originating directly on the beach due to touristic activity.

5.2 Comparison with previous study at Dutch coasts

We compared the average results of the monitoring events carried out during this research with the outcome of the study “OSPAR Beach Litter Monitoring in the Netherlands 2010-2015” (Hougee and Boonstra (2016), a 5 years study using volunteers and citizen scientists to monitor the Dutch coast at Bergen, Nordwijk, Veere and Terscheling.

Both studies monitored 100m stretches on beaches that comply with the OSPAR criteria for litter monitoring. The 5 years monitoring project recorded 380 plastic litter on average per monitored area. Using the same OSPAR method, we collected and categorized 278 plastic pieces on average, during our monitoring period between October and December 2019.

The 5 years monitoring project documented 90% of the litter as plastic waste. In our research study 99% of the litter picked up was made from plastics and while in 2015 more than half of the waste came from fisheries, our findings indicate that 60.6% of the plastic waste originated from fishery or offshore activities.

Both studies confirm that the OSPAR method provides good information about the quantities and source of plastic litter on the respective beach areas. The findings of both studies suggest that a huge part of the litter pollution comes from maritime activities. The number of blue chords found in our study is more than three times more. The fact that on average we monitored about 100 items

less on the beaches in Zeeland per monitored area compared to the other beaches monitored along the Dutch coast can have multiple reasons. We can only speculate that for instance seasonal changes, wind conditions, currents or wave dynamics in the areas had an impact on the quantity and quality of litter on the beaches. While we monitored during the autumn and beginning of winter, the other study was based on annual collections. May be the overall pollution decreased as it was indicated in the 5 years study and less plastics end up in the sea?

5.3 Personal motivation survey

From the answers to the survey questionnaire (n=22) it can be concluded that most participants were motivated to join the project by environmental interest and concern (59%). However, offering incentives like study credits motivated the students a lot as well (45%). The third big motivation was to contribute to a good cause (31%). The interest on scientific activities was still valuable but low compared to the other motivations (18%).

When asked, 20 of the 22 people said they would want to join comparable activities in the future as well. Those who said they would not mention their lack of time and a lack of exposure to those activities as a reason. It is also interesting to see that only 2 of the participants already took part in activities like this one. However, both are involved in the organisation of local participatory planning activities.

18 participants felt like they had learned something useful during the event. Most of the answers dealt with their own responsibility to reduce trash as well as learning about the areas that are most polluted and where those articles originate from.

Not all the participants felt like contributing more when monitoring compared to cleaning. 5 students would rather just clean up arguing that the monitoring activity slows down the progress of cleaning the area. However, 14 participants felt like they helped more during the monitoring. Mentioned reasons for this had been:

- the learning benefit you have from participating in a scientific activity
- contributing to understanding the pollution helps us a lot to find solutions
- because monitoring can guide clean-ups to the polluted areas better.

When the participants were asked to rank their interest in the data, they collected on a scale from 1 to 10 (10 most interesting) all the participants marked their interest equal or higher than 5. 27% rated their interest with a 7, 13% ranked their interest with an 8, 22% rated their interest on a 9. Finally, 13% where highly interested in the scientific results rating their interest with a 10.

5.4 Monitoring methods survey

The questions concerning the comparison of the methods had been constructed so that the participants can rate their experience from 1-10 (10 being most easy or most comfortable)

Rating the difficulty of categorising the plastics on the beach most participants rated the Litterati app method as easier with only 15% rating it as difficult as a 9 on the scale. In contrast 23% rated it on the second easiest step of the scale. Overall 69 % of all participants that rated the Litterati App method ranked it easier or as easy as a 5 on the scale.

The OSPAR method was perceived to be slightly more difficult. 50% of the participants rating the OSPAR method rated it lower than 5 or equal when it comes to categorisation. However, 14% perceived it to be as difficult as a 9.

Rating the setup for both methods, 23% rated the Litterati app method to set up the method would be a 5 on the scale. In contrast 30 % experienced the OSPAR method to be more difficult to setup and prepare. The biggest perceived challenges were the weather and for the OSPAR method to find the right category since the guide is very comprehensive.

When comparing efficiency both methods have been ranked to be quite efficient. Evaluating the OSPAR method 83% of the participants experienced higher or equal to a 5 on the scale. Litterati app method was about the same with 80%.

5.5 Overall conclusions

The results of both of monitoring methods, OSPAR and LItterati app have been comparable. For the OSPAR method on average 243 items were monitored per 100m stretch. With the Litterati app Method we monitored 313 items on average per 100m stretch. The Litterati method seems to be more efficient. This means that on average more items have been monitored in almost the same period and on the same area. Despite this, the composition of the litter picked up stayed consistent through both methods. The biggest impact on the collected data was how the items were handled. We did not tell the participants to primarily pick up the string and chords (Vispluis) but to only store them in a separate bag. This shifted the results and much more of these items were collected overall. Another important factor that turned out to have an impact was the weather conditions. On events with bad weather less items have been monitored and rain increased the difficulty of classification on site drastically.

When comparing this research study with the 5 years study on waste monitoring on beaches in Veere, Noordwijk, Bergen aan Zee and Terschelling from 2010-2015, we may conclude that the OSPAR method provided valuable information in both studies. However, a direct comparison of the results is critical because of too many different factors that may have influenced the results.

Most of the citizen scientists were driven to participate by the motivation to protect the environment and to contribute to a good cause. Offering an incentive for people such as credit points, seemed to encourage them to join the project. This way they are more intrigued showing up and increased the likelihood that some of them become regular participants. They are aware of the benefits that a research on this topic will have and very interested in the results, evaluation and communication of the generated data.

The Litterati app method was rated slightly better than the OSPAR method by the participants. The option to categorize later and not need to go through the categorisation list as with the OSPAR method was felt as a benefit of the Litterati app method. As most of the participants were young adults, they were used to use smartphone to take pictures for categorisation and process the data online.

6. Recommendations

The results of this litter monitoring study indicate that mobilising students and other interested people as citizen scientists is a practical approach. Educational institutes like the HZ but also other schools could be used as a hub to engage young volunteers that are interested in environmental work. The high motivation of the participants suggest that it is possible to generate a reservoir of citizen scientists who are available over a longer period. They should be trained by the supervisor in the monitoring methodology. A fixed stock of 10 volunteers would ensure that individual variations in the work is minimized. That group can go out to monitor regularly. A project leader (e.g. tutor or teacher) should be responsible for the monitoring, organising and supervising the events. The citizen

scientists should also be involved in the data evaluation and communication of results as a concluding activity, because this may enhance their commitment to the activity.
Depending on the situation both methods can be used. The OSPAR method provides a very clear and precise categorisation through the comprehensive catalogue attached. It is more precise in tagging the litter objects. The Litterati app can provide data and pictures directly to an online database which can be shared online. A combination of the benefits of both methods would be ideal for plastic litter categorisation.
This study provides first data on the monitoring of 5 beaches in Zeeland. It covers a period from October-December 2019. To extend the knowledge base on the plastic litter pollution in Zeeland, a long-term study would be supportive. That long-term study would deliver reliable and robust data over a longer period. We recommend conducting a monitoring study at 3 beaches along the Western Scheldt and 2 beaches along the Eastern Scheldt over a period of 5 years, monitoring 3x 100 m wide stretches at 4x per year. That study could provide data of the plastic waste pollution on Zeeland´s beaches which can be compared to the 5 years monitoring study of Bergen, Nordwijk, Veere and Terscheling.

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Appendices

Appendix I: Survey questions citizen science

Citizen Science & plastic waste monitoring

1. Demographics

1. What is your age?

2.What is your gender?

3.What is your nationality?

4.What is your occupation?

2. Motivation

1. What were your reasons to join this participatory research and which one was the most important?

2. Are you planning to participate in research events like this in the future and why or why not?

3. Did you ever before participate in a research like this before?

4. Do you feel like you learned something valuable for your everyday life, if so what?

5. Do you feel like contributing more while monitoring than just cleaning and why?

6. Do you participate in other scientific or communal activities during your free time and if so why or why not?

7. How much interest do you have in the data gathered and the outcomes? (10= high interest)

1 2 3 4 5 6 7 8 9 10

3. Methods

This section aims to compare the two methods. The Ospar method that was carried out with pen and paper will be referred to as “Method A” while the Litterati App is “Method B”. Please circle the appropriate answer for you.

1.How difficult did you find classifying the plastics found on the beach? (10= most difficult)

Method A) 1 2 3 4 5 6 7 8 9 10

Method B) 1 2 3 4 5 6 7 8 9 10

2. How difficult did you find the overall setup of the method what was the biggest challenge? (10= most difficult)

Method A) 1 2 3 4 5 6 7 8 9 10

Method B) 1 2 3 4 5 6 7 8 9 10

3. How efficient do you think the Methods are in cleaning and monitoring? what do you think needs to change to make the research activity more efficient? (10= super efficient)

Method A) 1 2 3 4 5 6 7 8 9 10

Method B) 1 2 3 4 5 6 7 8 9 10

4. Do you think you could do this Method in a small group self-organised, why or why not?

Method A)

Method B)

5. Do you feel like you are contributing to scientific research in a meaningful manner if so why or why not?

Method A)

Method B)

Appendix II: OSPAR categorisation list example

OSPAR Marine Litter Monitoring Survey Form **100 metre area**

OSPAR ID	Unep ID	Items	Total
		Plastic • Polystyrene	
1		4/6-pack yokes	
2		Bags (e.g. shopping)	
3		Small plastic bags, e.g., freezer bags	
112		Plastic bag ends	
4		Drinks (bottles, containers and drums)	
5		Cleaner (bottles, containers and drums)	
6		Food containers incl. fast food containers	
7		Cosmetics (bottles & containers e.g. sun lotion, shampoo, shower gel, deodorant)	
8		Engine oil containers and drums <50 cm	
9		Engine oil containers and drums > 50 cm	
10		Jerry cans (square plastic containers with handle)	
11		Injection gun containers	
12		Other bottles, containers and drums	
13		Crates	
14		Car parts	
15		Caps/lids	
16		Cigarette lighters	
17		Pens	
18		Combs/hair brushes	
19		Crisp/sweet packets and lolly sticks	
20		Toys & party poppers	
21		Cups	
22		Cutlery/trays/straws	
23		Fertiliser/animal feed bags	
24		Mesh vegetable bags	
25		Gloves (typical washing up gloves)	
113		Gloves (industrial/professional gloves)	
26		Crab/lobster pots	
114		Lobster and fish tags	

Appendix III: Figures and tables

Figures

Tables