PLAST-EXPERIMENTET

The Plastic Experiment 2022/23
Final Report

VA-Report 2024:2

FORSKAR FREDAG
En del av European Researchers' Night

UNIVERSITY OF GOTHENBURG

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Authors: Bethanie Carney Almroth, Emil Larsson and Magnus Bergquist at Gothenburg University.
Editors and Graphic Design: The Keep Sweden Tidy Foundation and Lotta W Tomasson, VA (Public & Science).
Photo on front: St Eskils gymnasium in Eskilstuna.
Translation: Helen Garrison, VA (Public & Science).

This report is an English summary of a report (in Swedish) called Plastexperimentet - slutrapport 2022-2023.
The full report can be found at **www.plastexperimentet.se**

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THE PLASTIC EXPERIMENT 2022-2023

Summary

The Plastic Experiment was a collaboration between the Keep Sweden Tidy Foundation, VA (Public & Science) via ForskarFredag, as part of European Researchers' Night, and the University of Gothenburg.

The project received funding from the research council Formas and the European Commission under Horizon Europe in the framework of the Marie Sklodowska-Curie actions, GA 101061464. The scientific lead of the project was Professor Bethanie Carney Almroth, a researcher in Ecotoxicology and Zoophysiology, research assistant Emil Larsson and Magnus Bergquist at the Department of Psychology at the University of Gothenburg.

This report presents both the individual results from 2023 along with combined results with the data collected in 2022. For details regarding individual results from 2022, see the Plastic Experiment - interim report (in Swedish)[1]. The Plastic Experiment had a total of four data collection periods in 2022 and 2023. In 2022, the period was 17 April–31 May, and a period in conjunction with the ForskarFredag science festival, the 1 September–13 October. In 2023, the experiment ran from 17 April–31 May and 1 September–13 October.

A valuable finding was that the majority of participants collected material from new locations in 2023 compared to the preceding year. This means that the results could be combined to create a more comprehensive picture of the situation (assuming that littering patterns remain consistent year on year).

Some of the results:

- Over 59,000 plastic items were collected and categorised with a total weight of 477 kilograms.
- ***Nature areas*** showed the highest mean value in total number of objects per square meter, while ***swimming areas/beaches*** exhibited the highest weight of plastic per square meter.
- The most common categories of plastic litter were:
    - 21% Cigarette butts
    - 16 % Soft plastic packaging
    - 10 % Hard plastic packaging

The results confirm what is already known from previous studies, for example the Swedish national litter survey 2023[24], namely the overrepresentation of cigarette butts in plastic littering. Several categories of plastic identified in the Plastic Experiment are now covered by the EU's Single-Use Plastics Directive[25], which either bans them or sets national targets to reduce their usage. The question is where can most easily achieve change and have the most impact, and whether the way to achieve change differs depending on the type of litter.

A follow-up study on young people's attitudes and motivations towards littering was conducted. A total of 174 children and adolescents participated, and the results indicate that willingness to reduce littering of plastic is linked to two factors:

- Perceived personal obligations to not litter
- Attitudes towards littering

Furthermore, the research shows that:

- The desire to reduce littering is more strongly linked to attitudes than knowledge.
- Both concern and hope are strongly linked to the desire to reduce littering of plastic.

Image 1: Professor Bethanie Carney Almroth, a researcher in Ecotoxicology and Zoophysiology and her research assistant Emil Larsson sorting litter following the Plastic Experiment's methodology in a laboratory at the University of Gothenburg. *Photo: From the instruction film at www.plastexperimentet.se*

THANK YOU

We would like to thank the Danish organisation Astra, Kristian Syberg, a Lecturer at the Department of Natural Sciences and Environment at Roskilde University, and everyone involved in Denmark for providing the excellent background material and methodology[20].

We also want to thank the National Resource Centre for Chemical Teachers Resource Center (KRC) for helping with the quality assurance and risk assessment of Part 2 of the Plastic Experiment for schools[21].

Above all, we want to thank all of the participants. We hope you had great fun being part of this and thank you for contributing to this important research!

More information about the project can be found at
www.plastexperimentet.se

BACKGROUND

One of today's greatest environmental challenges is plastic pollution, which is a concern at at local, national, and global level. Unwanted emissions happen at all stages of the material's life cycle, from production, distribution, use and waste management of plastic products. Each stage presents risks of adverse impacts on the environment, public health, and economic interests[2]–[4].

The production of plastic depends on fossil fuels, contributing to related emissions. Various chemicals are used in plastic manufacturing, which, when coming into contact with living systems, can cause behavioral changes, disruptions in hormone cycles and organic growth, and even cancerous tumors, among other effects[5]-[7]. Plastic litter is ingested by living organisms at both micro and macro levels, leading to a false sense of fullness in animals, internal damage to organs, and the potential for entanglement and drowning in oceans and lakes[8], [9].

Plastic items that end up in waterways can be carried across the world, introducing invasive species to new habitats and causing ecological disturbances[10]. Plastic pollution is found globally, washed up on shores of Antarctica, in sediment in the deepest parts of the ocean, and on all isolated island chains in the world's oceans, far from human activity[11]-[13].

In plastic pollution research, the focus is often on plastic waste found in the oceans. The OSPAR Convention is one of several initiatives that aims to highlight the problem of plastic pollution in the oceans and map its sources and distribution pathways, specifically in the Northeast Atlantic[14]. The bulk of plastic pollution originates from land, with inadequate waste management and the use oof disposable items being key contributors[9], [15], [16]. A study suggests that the amount of plastic currently observed in oceans accounts for only 4.7 % of all mismanaged plastic waste[17].

Image 2: Professor Bethanie Carney Almroth, scientific lead of the Plastic Experiment. *Photo: Johan Wingborg.*

Current methods for mapping plastic waste often depend on data collected along waterways and very rarely incorporate land-based data. Research conducted during the COVID-19 pandemic showed that the use of single-use items associated with it, like face masks, may have amounted to 11 billion tons globally, with 25,000 tons already entering the world's oceans[18]. Hence there is a need for better understanding of when, where, and how plastic is dispersed in nature initially, not just when it reaches the oceans.

Collecting data at a global scale presents a challenge for individual researchers. Citizen science has emerged as a solution to this issue and has been used in several large-scale studies[19]. A Danish citizen science initiative proved to be highly successful in engaging school classes and other volunteers, with around 57,000 pupils successfully mapping plastic litter at 3,452 different locations across Denmark[20]. The Plastic Experiment builds upon the methodologies developed in the Danish project.

The Plastic Experiment is a collaboration between the Keep Sweden Tidy Foundation, VA (Public & Science) via ForskarFredag, as part of European Researchers' Night, and the University of Gothenburg.

The project received funding from the research council Formas and the European Commission under Horizon Europe in the framework of the Marie Sklodowska-Curie actions.

The scientific lead of the project was Professor Bethanie Carney Almroth, a researcher in Ecotoxicology and Zoophysiology, research assistant Emil Larsson and researcher Magnus Bergquist at the Department of Psychology at the University of Gothenburg.

Methodology

Citizen science

Citizen science is a research method that involves researchers and volunteer "citizens" working together to generate new knowledge, as outlined in *Image 3*. Typically, it is researchers who enlist the help of the general public to collect or review large amounts of data. As a participant, you may, for example, report observations of plants, transcribe old manuscripts, or review images of animals and nature.

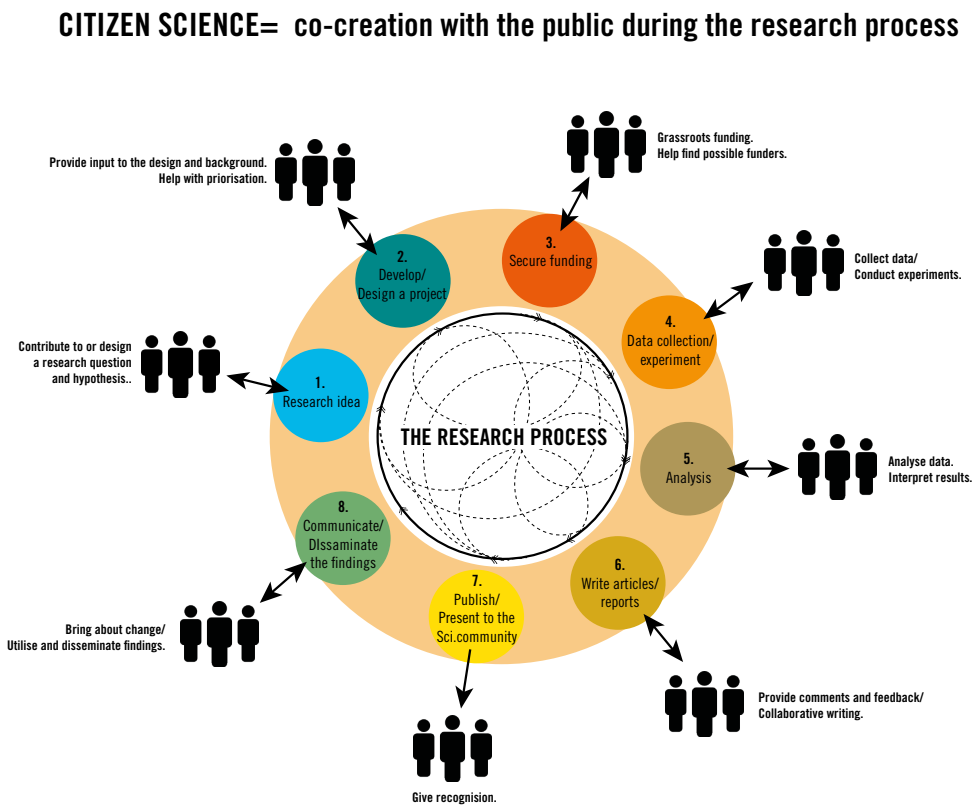

Image 3. Citizen Science involves researchers co-creating with the public in some way during the research process.
Illustration by: Lotta Tomasson/VA CC BY-NC 2.0

The Plastic Experiment was conducted over four periods in 2022 and 2023. It took place during both springs in conjunction with Keep Sweden Tidy's Cleanup Days and during both autumns as part of ForskarFredag (European Researchers' Night).

The Swedish public was invited to collect, catalogue, and map plastic litter found in their local environment with the aim of encompassing as much of the country's area as possible and obtaining an overview of the state of plastic pollution, similar to a Danish study conducted in 2020[17].

Data collection

Data was collected during four periods: in 2022 from 17 April to 31 May, and from 1 September to 13 October. In 2023, the periods ran from 17 April to 31 May, and from 1 September to 13 October. The experiment was designed for school pupils in Grade 4 up to upper secondary level, and was also open to other volunteer participants across Sweden.

Instructions were made available on the Plastic Experiment's website, where participants could also submit their findings using a web-based tool.

Table 1: The types of natural environment that participants could choose from along with subcategories.

Type of environment	Collection area
Swimming area/beach	At a lake On the coast
Waterway	Along a river/canal
Park	Park Playground
Nature area	Forest Meadow Green area Walking trail/exercise track

Participants were invited to select from four types of natural environment as outlined in *Table 1*.

Image 4: Upper secondary pupils conduct a polymer analysis in part 2 of the Plastic Experiment.
Photo: St Eskils Gymnasium in Eskilstuna.

The collection area was restricted to a length of 100 meters and a width of 1–50 meters to accommodate diverse areas such as open parks, forests, trails, etc. The data collection process then began with the picking up of all litter found on the ground, which was then sorted into 25 plastic categories as outlined in *Table 4* (non-plastic litter was collected and disposed of in appropriate bins). The number of items in each category was recorded along with the total weight, type of environment, total area of the data collection site, presence of items too large to carry, etc.

Additionally, there was a second analysis part designed for school classes in grades 7–9 and upper secondary school (requiring laboratory equipment with fume hoods). This involved an optional polymer analysis, allowing pupils to examine the unidentified plastic pieces found during the collection phase.

Instructions for conducting all both parts of the experiment along with guidance for teachers were available on the Plastic Experiment website[21, 22].

Results and discussion

Overview, Statisticon Report and data quality

In 2022, the data collection comprised 177 approved submissions from participants, documenting 33,158 individual plastic items, amounting to over 200 kilograms in weight. The surveyed area spanned 454,200 square meters.

The greatest participation was noted in the Stockholm area and along the west coast between Gothenburg and Malmö, with additional participants dispersed throughout the country, as illustrated in *Figure 1a.*

The data collection in 2023 comprised 171 approved submissions from participants, documenting 26,811 individual plastic items, totaling over 270 kilograms in weight.

The surveyed area spanned 373,500 square meters.

Similar to the 2022 collection, the highest participation was observed in the Stockholm area and along the west coast between Gothenburg and Malmö, with additional participants scattered across the country, as depicted in *Figure 1a.*

Table 2: Key figures for both years' data collection.

	2022	2023	TOTAL
Number of participating groups	220	256	476
Completed data collections	177 (80%)	171 (67%)	348 (73%)
Number of objects	33 158	26 861	59 969
Weight ***(g)***	206 785	270 000	467 758
Area ***(m^2)***	454 200	373 500	827 700
Average weight per area ***(g/m^2)***	0,46	0,72	0,59

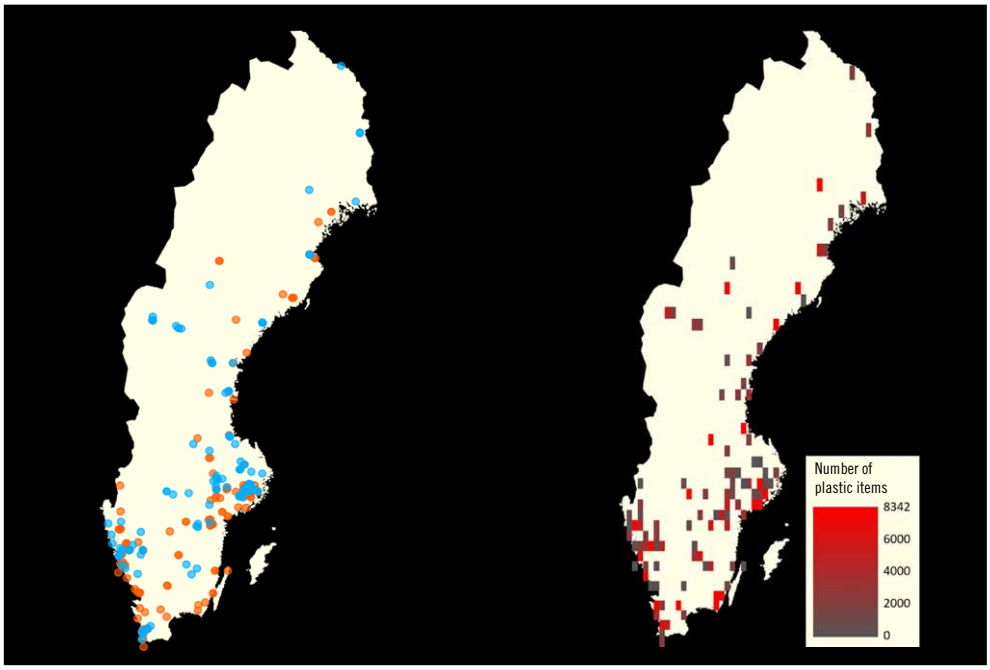

Figure 1 a) Distribution of data collection areas: orange 2022 and blue 2023. **b)** Overview of the amount of litter that was collected

Some participants submitted the total amount of litter but omitted other important information regarding the data collection, such as the search area or choice of location, and were therefore excluded from the results. Given that this report focuses on the overall amount of litter collected across both collection periods, participant groups that only omitted information about the collection date are included, as this detail is irrelevant for the analysis.

In *Figure 1b*, we see a general overview of how many items were found at each location. There appears to be a higher concentration of items nearer to major cities such as Stockholm, Gothenburg, and Malmö. However, the distribution across other parts of the country is currently insufficient to draw conclusions regarding variations in littering patterns across different regions, considering factors like population density and urbanisation. A comparison with the Danish study upon which this experiment is based[20] underscores the significance of high participation in citizen science initiatives. The Danish study, facilitated by Astra, the authority for science and education, engaged school classes nationwide, achieving a participation of 57,000 individuals. Furthermore, Denmark's population is

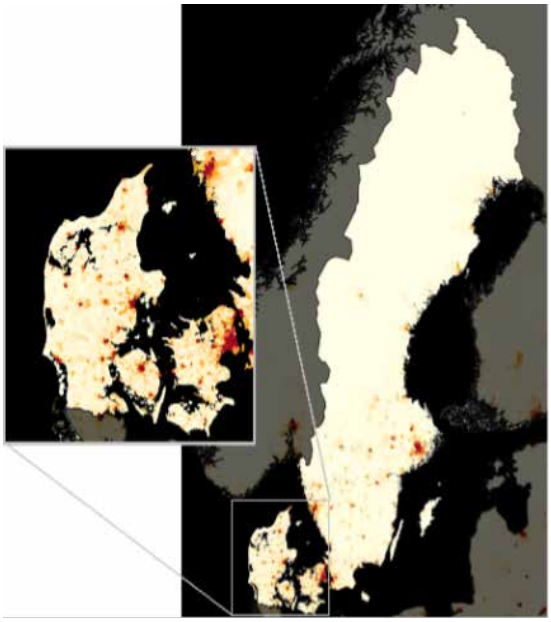

Figure 2: Comparison of population density in Denmark and Sweden. Higher levels are depicted in red and lower levels in white.

more evenly spread across the country, as illustrated in *Figure 2*, unlike Sweden, where the population is predominantly concentrated in the southern regions. To attain national coverage and gain insight into plastic dispersion in nature, it would be valuable to increase participation in rural areas and northern Sweden.

On behalf of the Keep Sweden Tidy Foundation, an analysis was conducted by the company Statisticon in December 2022 and December 2023 (Only in Swedish in the appendices of the Swedish report – see *bilaga 2 and 3*). Their analysis includes information on participant behaviour, where we see, for example, that 64% of participants completed the data reporting correctly, whilst data from the remaining 36% was rejected due it being incomplete (some results were partially filled, others left completely blank).

The reports also detail how participants are distributed across the subcategories of the types of environment, and we see that Park areas account for approximately half of all surveyed areas.

We observe trends regarding the most common categories of litter, with cigarettes, plastic bags, plastic packaging, and other items being the most common. This aligns with what is outlined in this report.

The number of participants included by Statisticon and in this report differs significantly, so they should be seen as complementary to each other rather than used for any deeper comparison. The analysis in this report includes some incomplete data. For example, if participants reported the total amount of litter collected but omitted the surveyed area, they were included in graphs and tables related to the total number but not in the normalised results.

Results and graphs

Figures 3–6 show the distribution of plastic items across all the data collections, how they were distributed among different types of environments, and the average number of items and mass per square meter for each environment type and category of litter.

Using the geographical data provided by participants, it appears that only one area was revisited multiple times, whereas the rest of the locations were unique to each collection period.

Assuming that presence of plastic in nature remains consistent year after year, the data could be merged into a large dataset. This would result in more dependable values for the average number and weight of litter in each type of natural environment.

Table 3: Percentage of items collected for each type of environment.

Type of Environment	Percentage of items 2022	Percentage of items 2023	Total percentage of items
Park area	49 %	43 %	50 %
Nature area	28 %	25 %	28 %
Swimming area/ beach	16%	21 %	12 %
Waterway	7 %	11 %	10 %

In total, 339 locations were surveyed over the two years, and 59,969 plastic items were identified spread across an area of 827,700 square meters. The weight of the collected and mapped plastic litter exceeded 470 kg, as shown in *Table 2.*

The quantity of ***cigarette butts*** was clearly the highest among all categories, comprising 20.52% of all litter. ***Soft plastic packaging*** and ***other plastic*** followed, constituting 15.71% and 14.27%, respectively. For a complete overview, see *Figure 3.*

The items categorised as ***other plastic*** and ***unidentifiable*** appear to have been used interchangeably and vary significantly. They include a wide range of items, from unidentifiable plastic fragments to discarded garden furniture, so these figures do not reflect a homogeneous group.

Irrespective of the year, the same five categories remain at the top: ***cigarette butts, soft*** and ***hard plastic packaging***, ***unidentifiable items***, and ***other plasti***c, as illustrated in *Table 4.*

Table 4: Overview of results in numbers and percentages of collected material over both years.

Category	Number 2022	Number 2023	Total number	% of TOTAL
Cigarette butts	8,445	3,863	12,308	20,5
Soft plastic food packaging	4,488	4,933	9,421	15,7
Other plastic	6,074	2,483	8,557	14,3
Hard plastic food packaging	1,021	4,886	5,907	9,9
Unidentifiable	1,557	3,006	4,563	7,6
Small plastic bags	1,719	799	2,498	4,2
Ropes and strings	1,683	421	2,104	3,5
Large plastic bags	1,287	721	2,008	3,4
Rubber	307	1,657	1,964	3,3
Polystyrene	841	666	1,507	2,5
Plastic bottles	806	611	1,417	2,4
Loose corks and lids	799	584	1,383	2,3
Cellophane from cigarette packets	908	420	1,328	2,2
Snus canisters	371	490	861	1,4
Disposable cups	649	152	801	1,3
Straws	478	320	798	1,3
Wet wipes	319	158	477	0,8
Drink pouches	267	144	411	0,7
Balloons	286	82	368	0,6
Plastic cotton buds	297	44	338	0,6
Bag ties	155	158	313	0,5
Other sanitary items	217	69	286	0,5
Fishing lines	82	78	160	0,3
Disposable cutlery	92	68	160	0,3
Fishing nets	13	18	31	0,1
Total number of items	**33,161**	**26,811**	**59,969**	**100 %**

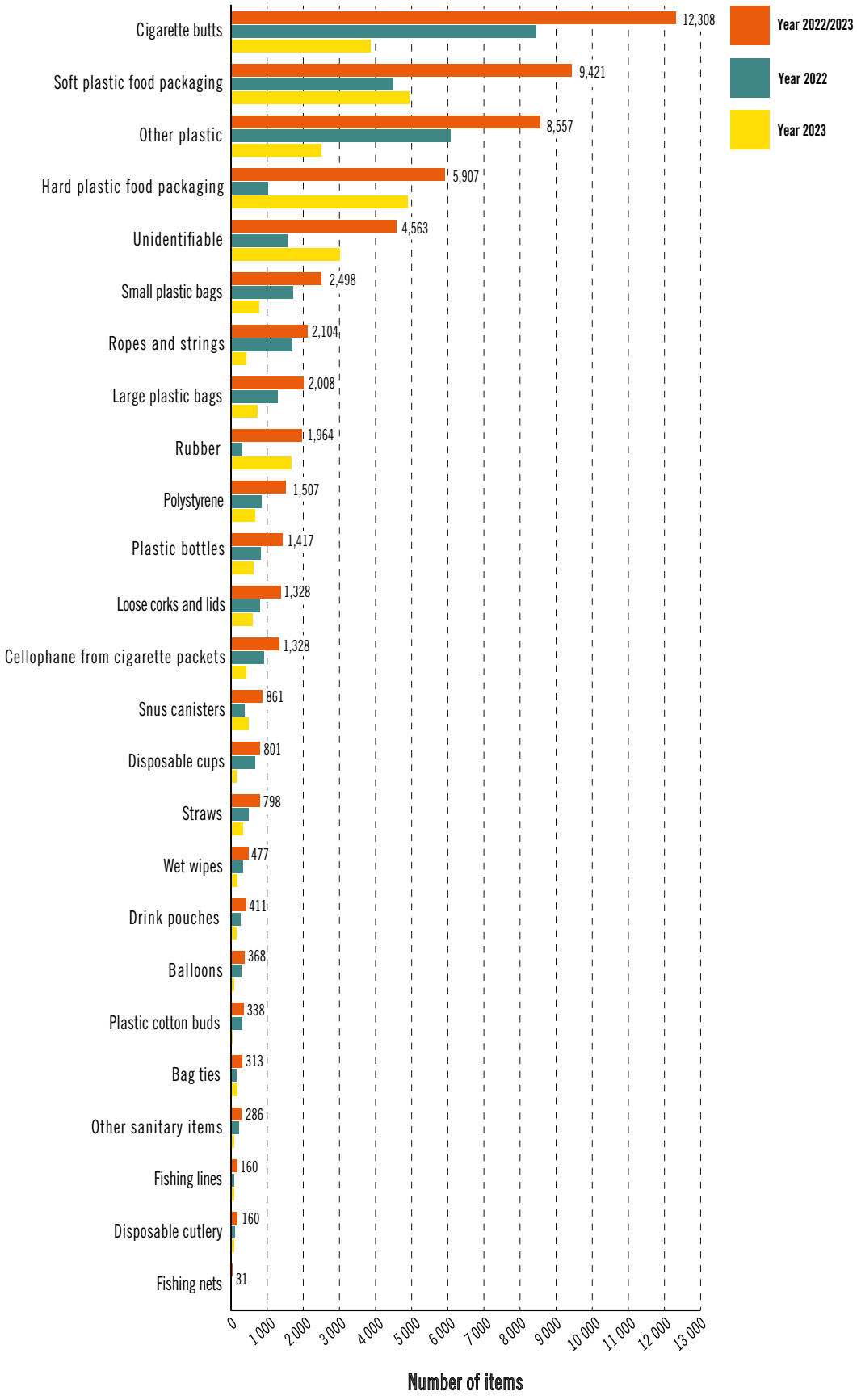

Figure 3: Total number of items collected per category of litter for both years as well as combined.

Table 3 highlights significant variation in participant numbers and collections across different types of environment, making direct comparisons between them impossible. To address this, the values were normalised to the average per given area rather than the direct number or weight.

Figures 4 and 5 show the occurrence of litter expressed as the average number of items per square meter and the average weight of those items per square meter for each environment type. These normalized values were calculated by taking the ratio of items found and the searched area for each sampling, then taking the sum of these values for all samplings, and finally dividing by the total number of samplings, as seen in *equation 1*. This was done for each individual litter category.

Equation 1.

$$\mathbf{n}_{normalized} = \frac{1}{\mathbf{n}_{samples}} \sum \frac{\mathbf{n}_{items}}{Area}$$

The average number per square meter was fairly evenly distributed among ***Nature Areas, Beaches/Swimming Areas,*** and ***Parks***, with respective values of 0.136, 0.124, and 0.109. There was a notable decrease in ***Waterways***, with a value of 0.075, as shown in *Figure 4.*

Beaches/swimming areas exhibited a significantly higher average weight per square meter, reaching 1.907 kg/m^2, whereas the other categories had a maximum of 0.782 kg/m^2, as depicted in *Figure 5.*

The only categories demonstrating a distinct pattern in where they were found were ***ropes and string, fishing nets,*** and ***fishing lines***, which were predominantly found on ***Beaches/swimming*** areas. Other categories of litter appear to be evenly distributed across all four types of environments, as shown in *Figure 6.*

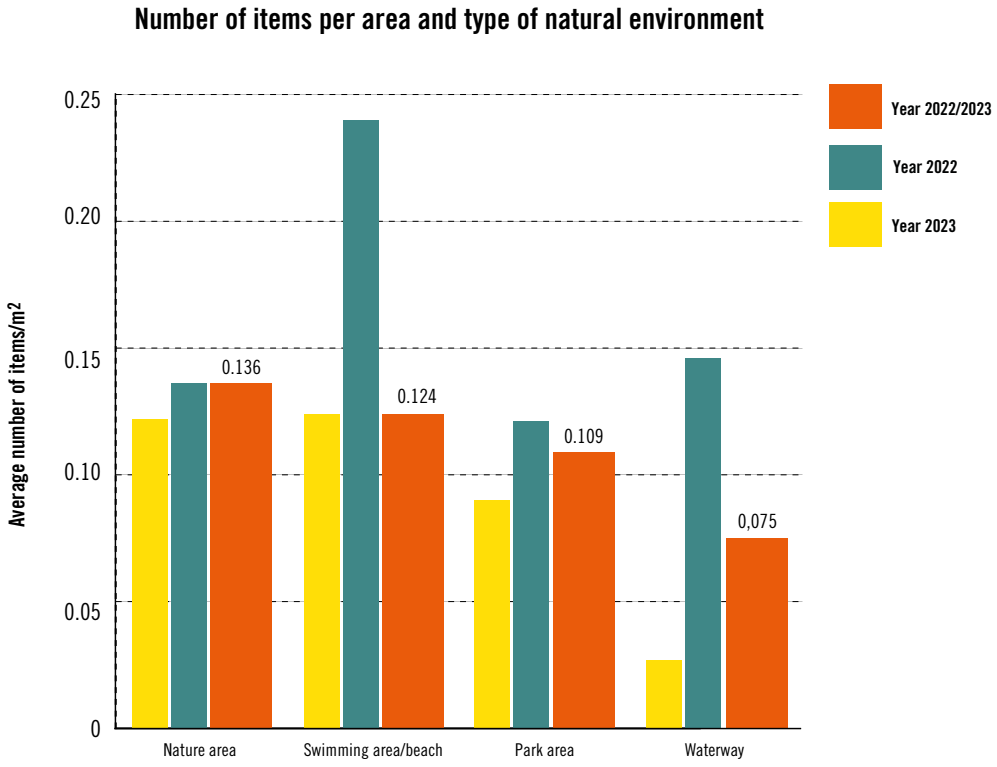

Figure 4: Average number of items per square meter for each type of natural environment.

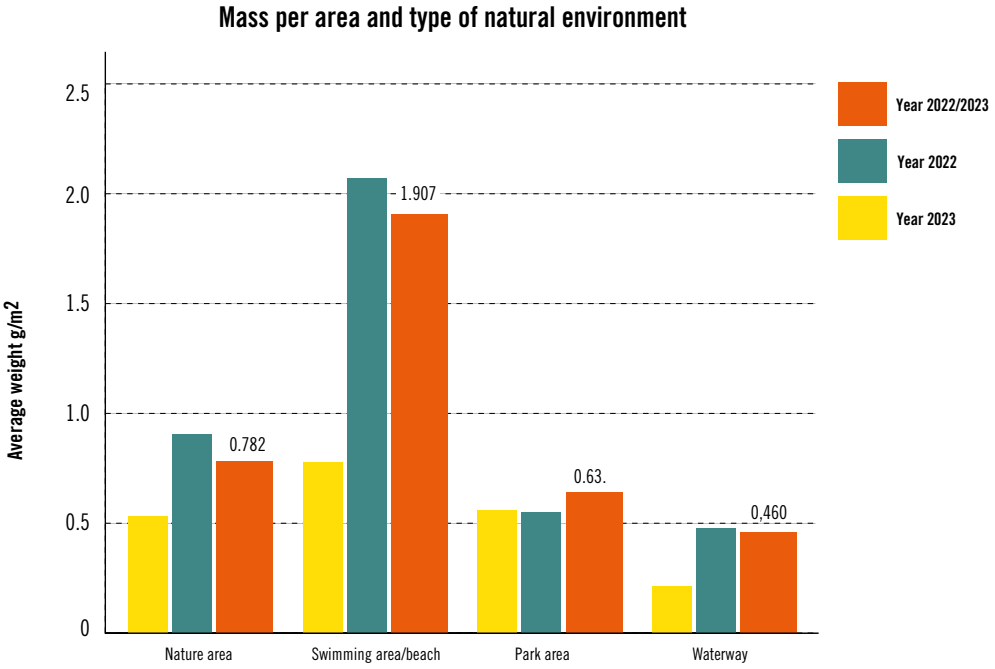

Figure 5: Average mass measured in grams per square meter for each type of natural environment.

Discussion

The findings of the Plastic Experiment resemble those in the Swedish national litter survey 2023[24], which showed that the most common categories of plastic litter are cigarette butts, followed by packaging for sweets, ice creams, and snacks.

The results confirm what is already known from previous studies, namely the overrepresentation of cigarette butts in plastic littering. The proportion of smokers in Sweden aged 16 and older who smoke every day was 9% in 2022[23], which is a historically low figure. Yet, cigarette butts outnumber plastic packaging and plastic bags. These are the categories of litter that are likely produced by a significantly larger proportion of the population. Further studies on the distribution of these items would be valuable to inform future initiatives. If it turns out that a small portion of the population produces a larger amount of litter, and that this litter spreads more easily, then we know what to concentrate our efforts on.

The question is where can most easily achieve change and have the most impact, and whether the way to achieve change differs depending on the type of litter. Should we focus on a smaller group of people who drop an enormous amount of cigarette butts, a larger group of people who drop food packaging and plastic bags, or can we, in a single stroke, reduce collectively reduce littering and reverse the trend across several categories?

New significant categories may arise as others decrease, for instance, e-cigarettes marketed as tobacco alternatives, and single-use plastic items incorporating electronic components.

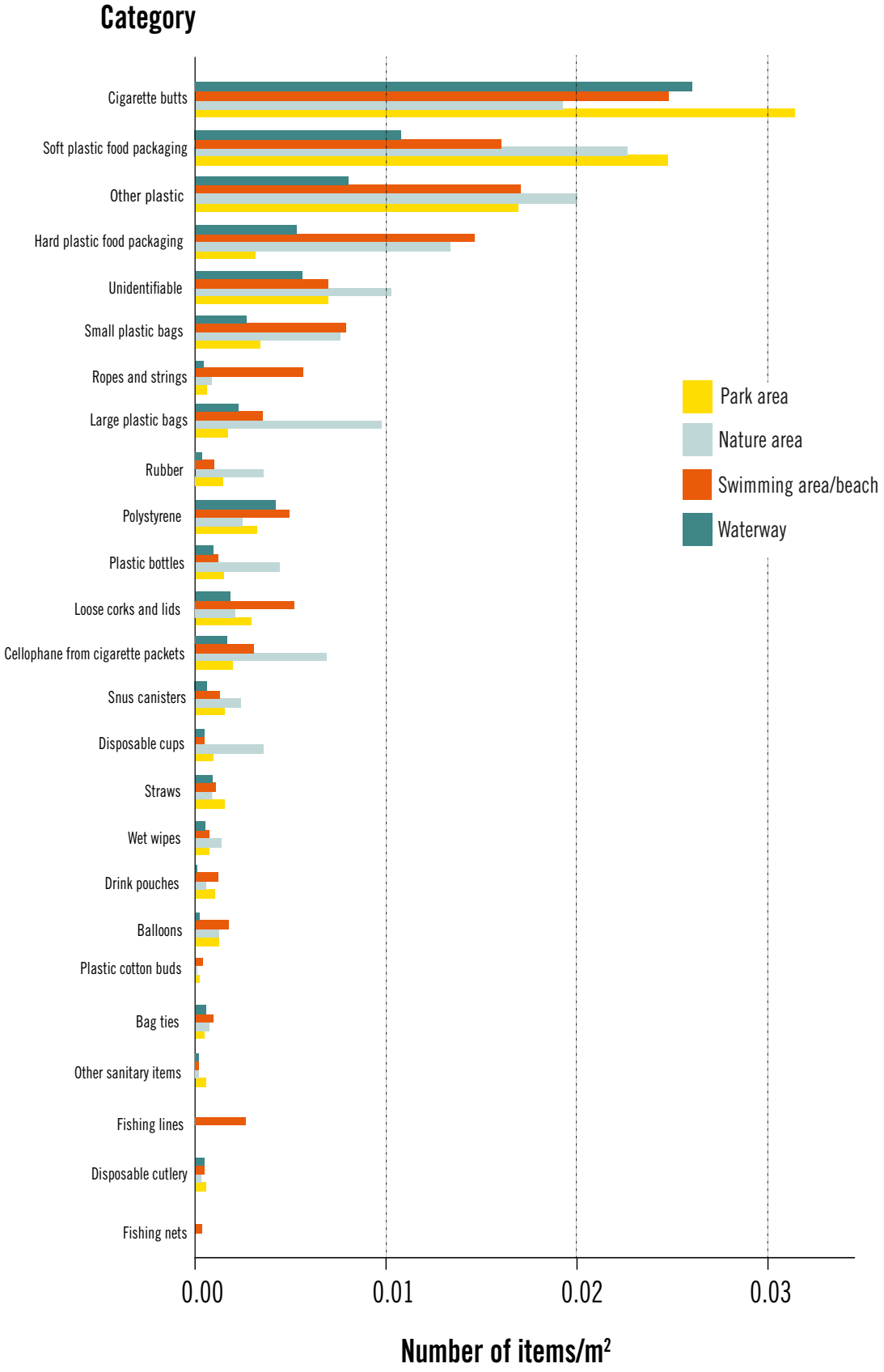

Figure 6: Overview of results of the number of objects per type of natural environment and category of litter.

Several categories of plastic found in the Plastic Experiment are single-use plastics, and are banned under the EU's Single-Use Plastic Directive[25]. This includes items such as straws, cotton buds, and disposable cutlery. Other categories of single-use plastics are covered by the directive in such a way that their use MUST be decreased. Examples of measures underway for several of these products include labeling, information campaigns, national reduction targets, increased collection targets, and extended producer responsibility. Hopefully, this will lead to a decrease in their presence as litter.

One of the challenges in the project has been reaching out to remote wilderness areas and gathering data on the spread of litter beyond urban areas. The advantage of citizen science is the large amount of data that can be collected over a short period of time, but a clear disadvantage is that it is mainly concentrated in urban environments which participants have easy access to. However, the information collected is still relevant, especially concerning plastic litter, which is essentially a by-product of humans. New methods need to be developed to enable sufficient data to be collected from remote locations to help us understand more about the natural distribution of litter.

It is also important to look at the psychological perspective when addressing these issues because it can help us anticipate future problems if people's behaviours and attitudes towards littering remain the same in the future.

What influences the willingness to pick up litter?

During the Plastic Experiment, a follow-up study was conducted in the form of an attitude survey by Magnus Bergquist at the Department of Psychology at the University of Gothenburg (For further information see appendix 1 – *bilaga 1* – in the Swedish version of the report*)*. The aim was to investigate children and adolescents' attitudes and intentions towards littering.

A total of 174 children and adolescents participated, and the results show that the willingness to reduce the occurrence and littering of plastic is linked to two factors:

- ***Perceived personal obligations*** to not litter
- ***Attitudes*** towards littering

Furthermore, the survey showed that:

- Participating in the Plastic Experiment was associated with increased ***knowledge***, ***interest***, and both ***hope and concern*** for, 34%, 30% and 37% of the participants, respectively.
- ***Both concern and hope are strongly linked to the willingness*** to reduce littering of plastic.

Image 5: Magnus Bergquist, Associate Professor in Psychology, University of Gothenburg ran the follow-up survey in connection with the Plastic Experiment. *Photo: Johan Wingborg*

The results call for further research into 1) creating engaging education and 2) strengthening percieved obligations to reduce littering.

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