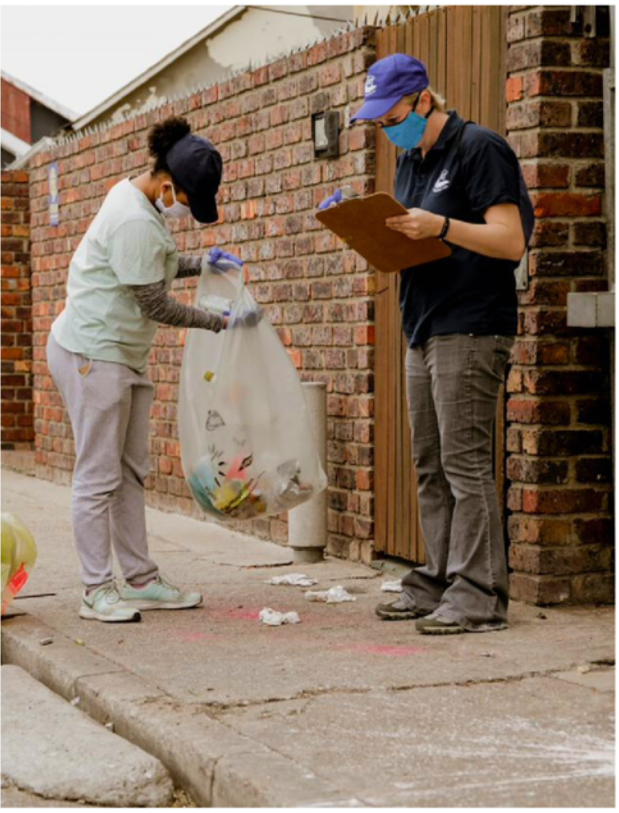

2023 Edition

AFRICAN LITTER MONITORING MANUAL

Norwegian Embassy
Pretoria

SST | AFRICAN MARINE NETWORK

EDITED BY: TOSHKA BARNARDO, DANICA MARLIN, ANTHONY J RIBBINK & LORIEN PICHEGRU

AFRICAN LITTER MONITORING MANUAL

2023

This publication is dedicated to our partners and friends from the WIOMSA Marine Litter Monitoring Programme

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Published by African Marine Network, Sustainable Seas Trust. Gqeberha, South Africa.
Visit the website: www.sst.org.za
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Cover images: © Africa Climate & Environment Foundation (top left), © The Litterboom Project (top right), © Sustainable Seas Trust (bottom left), © Nipe Fagio (bottom right).

Contributions gratefully received from: Kenya Marine and Fisheries Research Institute (KMFRI), Kenya; CÉTAMADA, Madagascar; University of Mauritius, Mauritius; Lúrio University & Fisheries Research Institute (IIP), Mozambique; The Ocean Project Seychelles, Seychelles; Nipe Fagio, Tanzania.

Citation:
Barnardo T, Marlin D, Ribbink AJ, Pichegru L (eds). 2023. *African Litter Monitoring Manual*. 2nd Edition. African Marine Network, Sustainable Seas Trust. Gqeberha, South Africa.

Acknowledgements:
The Sustainable Seas Trust (SST) has pleasure in acknowledging the core support of the Ministry of Foreign Affairs, Norway, to the African Marine Network programme. A special word of thanks is warmly extended to our partners and friends in the WIOMSA Marine Litter Monitoring Programme who piloted litter sampling protocols and provided feedback to improve upon them. We also thank the Western Indian Ocean Marine Science Association (WIOMSA) for supporting the operational aspects of the Monitoring Programme from 2019–2022. This manual would not have been possible without the support of the organisations mentioned above, and the hard work and dedication of its authors.

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FOREWORD

It is with great pleasure that I introduce the second edition of the *African Litter Monitoring Manual*, expanded and renamed since the first edition, which focused only on marine litter. The broader focus recognises that tackling the pressing issue of marine litter in Africa requires a more concerted effort to address the primarily land-based origin of litter.

The manual evolved from an initiative in the Western Indian Ocean region that was spearheaded by WIOMSA (Western Indian Ocean Marine Science Association) and Sustainable Seas Trust. The first edition created considerable interest across Africa, but this second edition assumes even greater significance given the endorsement of a historic resolution at the UN Environment Assembly (UNEA-5) in March 2022 to End Plastic Pollution and forge an international legally binding agreement by 2024. The resolution reflects a crucial milestone in countries' commitment to address the full lifecycle of plastic pollution, since the treaty now being developed will encompass plastic production, design and disposal, while also fostering enhanced international collaboration, technology access and capacity building.

Within the context of the global plastics treaty, it becomes imperative for countries to understand their plastic baselines, set ambitious goals, and monitor progress toward achieving those goals. The *African Litter Monitoring Manual* provides the necessary guidance and standardised methods for measuring and monitoring plastic litter, ensuring that results obtained across different countries in Africa can be compared and evaluated effectively.

Western Indian Ocean countries have made notable commitments and have implemented innovative measures to combat plastic pollution. In line with these commitments, Kenya, Madagascar, Mauritius, Mozambique, Seychelles, South Africa and Tanzania are actively engaged in the plastic waste monitoring programme initiated by WIOMSA and Sustainable Seas Trust. These countries have recognised the importance of consistent and reliable data collection to inform management strategies and guide action plans. This manual enables countries elsewhere in Africa to benefit from the experience and collect data in the same way so that, for example, countries in the Abidjan Convention could compare successes with those of the Nairobi Convention, and further harmonise methods.

This second edition of the manual incorporates valuable insights and feedback from the dedicated teams working in the field. It introduces new methods to assess litter upstream, including land-based sources and waterways, reflecting the growing importance of addressing plastics at their source. The manual has been meticulously designed to be accessible to citizens, citizen scientists and scientists alike, ensuring that all stakeholders can contribute valuable data, regardless of their background or level of expertise.

As we advance towards establishing the global plastics treaty, the importance of the *African Litter Monitoring Manual* amplifies. Countries will require accurate tools to measure their levels of plastic pollution on land and in water, and to assess the impact of strategies to reduce such pollution. This manual provides the scientific rigour, feasibility and reproducibility that these endeavours require.

Finally, I would like to thank Sustainable Seas Trust and all of the individuals and organisations who contributed to the creation of this manual. Your dedication and collaborative efforts are critical in addressing the triple planetary crisis of climate change, biodiversity loss and pollution.

Let us use the *African Litter Monitoring Manual* as a compass to guide us toward a future free of plastic pollution in the Western Indian Ocean region, and indeed the rest of Africa too, to protect human and environmental health for future generations.

Dr Arthur Tuda,
Executive Secretary, WIOMSA

THE LITTER CRISIS

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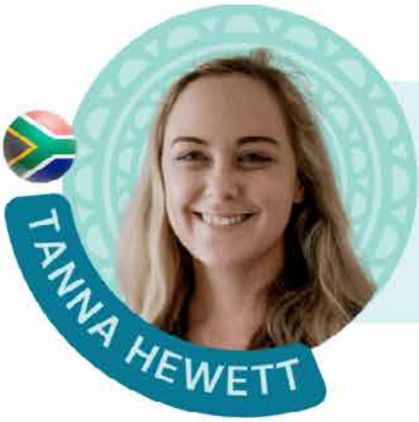

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The current situation in Africa

The continental and island states of Africa are collectively considered to have the highest rate of mismanaged waste globally, with up to 89% of waste not disposed of efficiently[1]. Nearly 50% of municipal solid waste (MSW) in Africa ends up in poorly managed landfills and open dumpsites (**Figure 1**), from which litter (**Figure 2**) may be dispersed via wind and runoff into the surrounding area[2]. Estimates show that sub-Saharan Africans will produce 3 Mt (million metric tons) of waste per day by 2100[3], so it is vital that actions are taken to mitigate irresponsible and inefficient waste disposal.

There are several reasons why African countries struggle with waste management. In Africa, waste management is hindered by poor infrastructure, human and financial capacity, and education and training necessary to manage waste[2]. Of these, financial capacity is most critical as human capacity and infrastructure can be built if funds are available[6]. The waste management issues are exacerbated by population growth, high levels of urbanisation, and rapid economic development[2]. With more people, more waste is generated, and waste-collection systems cannot keep up, leaving African cities and towns burdened by dumpsites and unhealthy living environments[7,8]. In addition, Africa's waste crisis is compounded when first-world countries pay to export their MSW to low-income countries that are already struggling with waste management[9].

BOX 1
IMPORTANT DEFINITIONS

Municipal solid waste (MSW)

Any items discarded by households or commercial businesses. This includes organic waste, which makes up about half of MSW in Africa[4]. In *this* publication, the term 'waste' is used to refer to solid material that has been made by humans and then discarded (thus excluding organic waste).

Mismanaged waste

Municipal solid waste that has been inappropriately discarded or stored (e.g. in open dumps), and therefore has an increased risk of entering the environment as litter.

Litter

Man-made waste that has been thrown away, lost or abandoned in the environment[5]. Biological and natural materials like plants, fruit and animals are not considered litter (**Figure 2**). The term 'litter' excludes waste found in formal or informal dumpsites.

Figure 1: In Africa, a large portion of municipal solid waste (MSW) is mismanaged. This results in high levels of solid waste pollution on land (A), in water systems (B) and in the marine environment (C). Nearly 50% of MSW in Africa ends up in open dumpsites, from where it may spread into the surroundings (D).

Figure 2: In this publication, the term 'litter' refers to any man-made item that has been thrown away inappropriately or has ended up in the environment.

A focus on plastic pollution

Since plastic makes up a large portion of MSW and litter in the environment[1], most pollution-related issues focus on plastic. Plastic pollution is a global crisis posing a significant threat to people and the environment. An estimated 12% of the world's MSW is plastic, amounting to about 242 Mt[10] – equivalent to the weight of some 40 million African elephant bulls. Plastic packaging, including wrappers and bottles, accounts for nearly 50% of plastic waste produced annually, because almost all packaging becomes waste within a year of its use[11,12].

Although some plastic waste is recycled and much of the rest either landfilled or incinerated, about 22% of all plastic waste generated each year is mismanaged and likely to pollute the environment[12]. By number, plastic items reportedly make up 56–70% of street litter in large cities[13] and 64–88% of marine litter globally[14–17]. The quantity of plastic entering the oceans is projected to reach 23–37 Mt per year by 2040 if adequate interventions are not implemented timeously[18].

Plastics – past and present

The English word 'plastic' originates from the Greek word *plastikos* and the Latin word *plasticus*, both meaning 'able to be moulded'. The first man-made semi-synthetic plastic, referred to as Parkesine, was created by Alexander Parkes in 1860[19]. Parkesine was made by treating naturally occurring cellulose (the main structural component of plant cell walls) with nitric acid and a solvent[20]. Parkesine set the basis for John Wesley Hyatt to modify the formula and create 'celluloid' in 1870, initially as a substitute for ivory in billiard balls[21,22] (**Figure 3**). The first fully synthetic plastic, called Bakelite, was invented in 1909 by Leo Hendrik Baekeland and was more durable, more heat resistant, and less expensive than celluloid[23].

After World War II, global production of plastics increased twentyfold between 1950 and 1970 to over 25 Mt[24]. Plastic steadily took the place of steel in cars, paper and glass in packaging, and wood and textiles in furniture. Between 1980 and 2020, the amount of plastic produced more than quadrupled[24,25] (**Figure 4**).

Figure 3: Billiard balls, previously made from wood or ivory, are today made from plastic in the form of phenolic or polyester resins.

GROWTH IN GLOBAL PLASTIC PRODUCTION PER YEAR

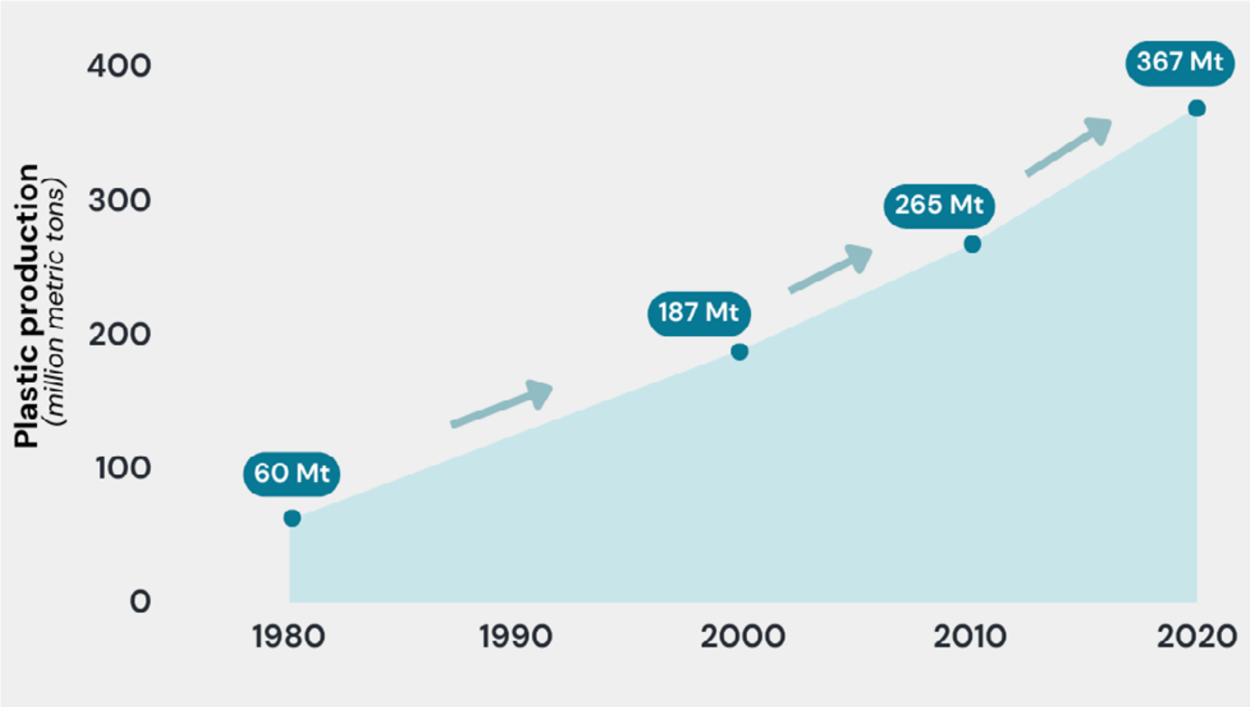

Figure 4: Global production of plastic since 1980[24,25].

PLASTIC AS AN INVALUABLE PART OF MODERN LIFE

Figure 5: Modern-day items made from plastic.

Today, plastics are an integral component of modern life, providing an enormous number of conveniences. Different types of plastics can be found in our cell phones, our car tyres and even our clothes. Since its invention, plastic has facilitated major advances in technology and medicine, and has increased the standard of living for people globally (**Figure 5**).

Apart from bioplastics, which are made from renewable resources such as sugarcane or corn, all plastics are now produced from fossil fuels such as natural gases, crude oil or coal[26]. These fossil fuels undergo refining, cracking and polymerisation processes to break them down into simple monomers that are chemically bonded into polymers (**Figure 6**). Polymers are long chains of molecules, and it is the length of these chains, the atoms comprising the molecules, and the patterns in which they are arrayed that give plastics their different properties such as strength, weight, durability and flexibility[22,27,28].

Since the production of plastic requires the burning of fossil fuels, which releases carbon dioxide and other greenhouse gases into the atmosphere, plastic production contributes to global climate change[29]. However, greenhouse gas emissions from plastic production are relatively small (less than 3.6% throughout the plastic lifecycle)[12] compared to other sources such as road transport (11.9%) and livestock and manure (5.8%)[30].

Of greater concern, perhaps, is that the same characteristics that make plastics vital to modern life, such as durability, low cost and weight, are also the reason that plastics may threaten the environment if not managed correctly. Given that plastic is purposely made to last for a long time, plastic waste can take centuries to degrade[31,32]. It has been reported that two-thirds of all plastic ever produced remains in the environment in some form today[33].

Ramifications of solid waste pollution

Man-made solid waste may take hundreds of years to degrade, and may never break down completely, depending on what material it is made of and what conditions it is found in[31,32] (**Figure 7**). Degradation takes place when litter is exposed to ultraviolet (UV) light, heat, air, water and microorganisms[34,35]. Litter in aquatic environments can also be degraded by mechanical processes such as

Figure 6: Plastic products are derived from either fossil fuels (crude oil, coal or natural gas), or from biomass (renewable resources such as sugarcane, corn or wood chips).

ESTIMATED DEGRADATION TIME OF DIFFERENT TYPES OF LITTER

Figure 7: Different types of litter are estimated to take anywhere from weeks to millennia to break down completely[31,39,40].

wave action and abrasion by sediment[36,37]. Once fragmented into smaller pieces, litter can disperse over great distances and have negative impacts far from its original source. In deep marine environments, where oxygen and UV radiation are limited, plastic litter may take centuries or millennia to degrade[36,38].

Plastic litter is found everywhere on the planet, including some of the most remote regions of the world[32,41,42]. For example, plastics are found in the Arctic[43] and Antarctic[44], in the deepest waters of the Mariana Trench[45,46], and in the middle of oceans, where it accumulates in large patches[47]. In fact, plastic is so ubiquitous in the environment that it is considered a key geological indicator of the 'Anthropocene Epoch', the geological age in which humans have come to significantly impact the natural world[48].

Plastic litter in the environment can have numerous deleterious effects. For example, plastics can harm and possibly kill wildlife (**Figure 8**). The first scientific records of negative interactions between marine life and plastics come from as early as the 1960s[49]. Subsequently, cases involving more than 550 species of marine animals[50] and at least 44 species of freshwater and terrestrial

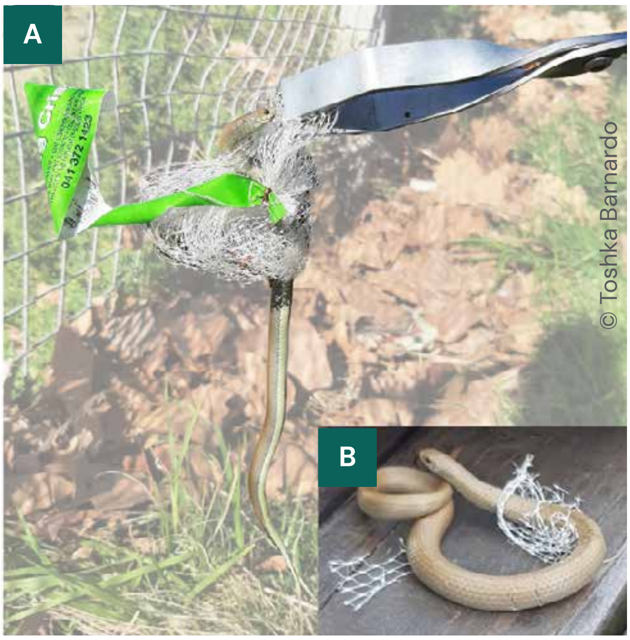

Figure 8: A slug-eater (Duberria lutrix) tangled in a plastic mesh bag in Gqeberha, South Africa (A). The snake was freed but had suffered lacerations (B).

animals[51] were documented. Today it is estimated that plastic pollution negatively impacts 90% of observed marine species[52].

Litter may also have a range of negative economic consequences. For example, houses located in areas with a noticeable litter problem have been found to decrease in value over time[53]. Litter issues could also reduce the number of visiting tourists, which would be detrimental to economies that are heavily reliant on tourism as a source of income[54], as is the case for many African countries[55]. Plastic litter sometimes causes flooding when it blocks waterways, resulting in costly infrastructure damage that constrains economic activities. Other economic impacts associated with litter include the costs of clean-ups, dump management and waste transportation, as well as lost opportunities to recover, reuse or transform litter into a valuable resource[2]. Clean-up operations alone can be extremely expensive. For example, in Aldabra Atoll, one of the outer islands of Seychelles, the cost to remove 95% of plastic litter on the atoll has been estimated at US$4.68 million[56].

Litter also poses a health and safety risk to humans through physical injury (e.g. cuts and abrasions) and illness[57]. Plastic blockages in waterways may result in stagnant water that promotes breeding of organisms that serve as vectors or intermediate hosts of diseases such as malaria, yellow fever and bilharzia[18]. More recently, studies have found that microplastics can be taken in by humans through the ingestion of contaminated food and water, and even through inhalation[58]. This is concerning because microplastics may carry toxic chemicals and pathogens[59]. Furthermore, there is a correlation between mental well-being and the state of the environment in which residents live[60,61]. Dirty or polluted environments could therefore have a negative psychological effect on communities, potentially leading to eco-anxiety, environmental grief, and an emotional disconnect from environmental issues[62]. Creating and maintaining a clean space is therefore imperative in contributing to the health and wellness of Africa's people.

Sources and pathways of litter

To address pollution in an area, it is important to understand where waste and litter is coming from (the *sources* of litter) and how it is transported from the source into the surrounding environment (the *pathways* of litter). Sources include the activities (e.g. littering) and sectors (e.g. agriculture) that contribute to solid waste pollution (**Figure 9**). Common pathways of litter from a source include dispersal via wind, runoff, rivers, currents and oceanic tides[63,64].

It is more practical to deal with waste and litter at the source rather than after it disperses in the environment, when it is more difficult and costly to collect and manage. Furthermore, as litter disperses it becomes degraded, often to the point where its value for recycling is lost. Even litter from areas far inland may end up in the sea after entering stormwater drains and being transported to the coast by rivers. These land-based sources of marine litter contribute a far greater portion of marine litter than sea-based sources such as merchant shipping and fisheries[65].

A stronger focus on terrestrial litter is therefore essential, especially in African countries, where plastic pollution on land is expected to increase. While much research has focused on marine plastic litter[66], plastic pollution is 4–23 times greater on land than in the sea[67]. By identifying the sources and pathways of litter, more effective strategies can be developed to tackle plastic pollution.

Commitments and actions to address solid waste pollution

Numerous international, regional and national policies exist to address mis-managed waste, and specifically plastic pollution. The responsible disposal of waste, including plastics, is covered in five of the 17 Sustainable Development Goals (SDGs) of the United Nations[68] (**Figure 10**). The SDGs are at the heart of the 2030 Agenda

SOURCES AND PATHWAYS OF PLASTIC WASTE

Figure 9: The sources and pathways of terrestrial and marine litter.

for Sustainable Development, which all UN Member States adopted in 2015. All signatories (including all African countries) have therefore pledged to address plastic pollution to promote a cleaner, healthier and more sustainable environment.

SUSTAINABLE DEVELOPMENT GOALS RELATING TO WASTE

Target 6.3: Improve water quality by reducing pollution, eliminating dumping and minimising release of hazardous chemicals and materials, halving the proportion of untreated wastewater and substantially increasing recycling and safe reuse globally.

Target 11.6: Reduce the adverse per capita environmental impact of cities, including by paying special attention to air quality and municipal and other waste management.

Target 12.5: Substantially reduce waste generation through prevention, reduction, recycling and reuse.

Target 14.4: Prevent and significantly reduce marine pollution of all kinds, in particular from land-based activities, including marine debris and nutrient pollution.

Target 15.5: Take urgent and significant action to reduce the degradation of natural habitats, halt the loss of biodiversity and, by 2020, protect and prevent the extinction of threatened species.

Figure 10: The Sustainable Development Goals (SDGs) relating to waste management and plastic pollution, which all United Nations Member States have adopted.

In March 2022, many African countries were among the 170 UN Member States at the United Nations Environment Assembly (UNEA-5.2) that adopted a resolution to combat plastic pollution by developing an international legally binding agreement by 2024[69]. The 'global plastics treaty' will promote sustainable production and consumption of plastics, and ultimately aims to stop plastic pollution[69].

Other international plastic pollution-related treaties to which African countries have committed include the International Convention for the Prevention of Pollution from Ships (MARPOL) and the Bamako Convention. The Bamako Convention prohibits the importation of all hazardous (including radioactive) waste into Africa and aims to minimise and control trans-boundary movement of such waste within the continent. At the third Conference of the Parties in February 2020, a decision was adopted on actions to prevent plastic waste pollution and its trade in and surrounding the continent. Four regional conventions exist for the protection of the marine and coastal environments in Africa (**Figure 11**). The Abidjan and Nairobi Conventions cover the continent's western and eastern seas, respectively, the Barcelona Convention covers the Mediterranean Sea, while the Jeddah Convention covers the Red Sea and Gulf of Eden. Signatories of these conventions commit to reducing waste and plastic pollution.

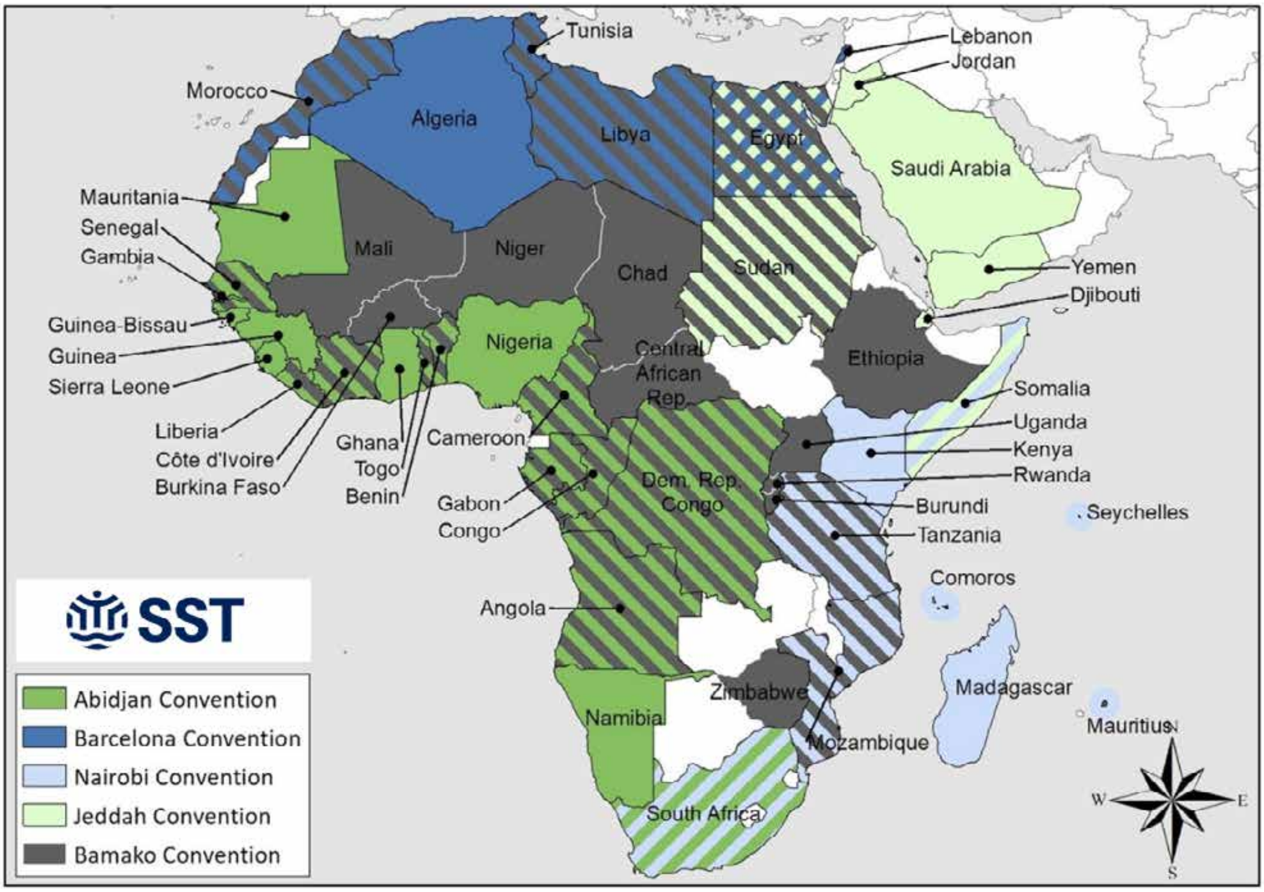

Figure 11: African countries that have ratified regional conventions calling for the protection of Africa's environment, including the seas and coasts.

African countries have implemented numerous interventions to fulfil their commitments to the various international and regional treaties to mitigate plastic pollution. By 2020, 34 of the 54 African countries had set precedents by passing laws to ban (either partially or completely) specific plastic items[70]. For example, in 2005 Eritrea was the first African country to implement a ban on plastic bags, and in 2019 Rwanda was the first to issue a complete ban on all single-use plastics[70]. It should be noted that plastic bans need to be considered within a lifecycle approach to responsible waste management, as they may have negative socio-economic consequences such as price increases on packaged goods and job losses[71].

Another tool, known as Extended Producer Responsibility (EPR), provides a mechanism to sustainably finance waste management streams. In EPR schemes, producers of a specific product are responsible for end-of-life options, as well as health and safety issues, pertaining to their product. In Africa, EPR on plastic packaging is only mandatory in South Africa and Kenya[6], but some other countries are considering its introduction or implementing voluntary schemes.

In addition to these bans and EPR, numerous regional, national and local action plans and strategies have been developed by African countries and regions to prevent litter from entering the environment. However, a lack of data about waste in Africa[6] compromises the ability to assess the efficacy of these plans and strategies, and to identify appropriate actions to reduce plastic pollution.

The need for harmonised data collection

For global and regional plastic treaties to succeed, data must be collected to establish baselines and to guide interventions along the entire plastics lifecycle, from upstream (production) through midstream (manufacture and use) to downstream (disposal and end-of-life treatment). Through continued monitoring, stakeholders can assess the efficacy and impact of interventions, identify emerging problems, verify compliance with targets, report on findings, and guide adaptive management[72]. To successfully monitor and address plastic production, use and pollution on a global scale, monitoring methods must be feasible and flexible but produce comparable and reliable results.

Litter monitoring, which is essentially the measurement of trends in litter over space and time, provides data on plastics at the end of their lifecycle once they end up in the environment. As such, litter monitoring provides a direct assessment of the success of treaties to reduce plastic pollution. It is therefore critical to use harmonised methods of litter monitoring to ensure that reliable data are collected and are comparable on local, regional and global scales.

The African Litter Monitoring Manual

Various guidelines and methods exist to monitor litter[73-76]. However, inconsistent approaches often make comparing data and results difficult. Furthermore, many monitoring approaches are not suitable for use in Africa, where conditions and circumstances (e.g. resource availability) often require special consideration, as discussed in **Chapter 2** (*A Guide to Litter Monitoring in Africa*). To address these needs, Sustainable Seas Trust (SST) partnered with the Western Indian Ocean Marine Science Association (WIOMSA) to produce the *African Marine Litter Monitoring Manual* (1st Edition) in 2020. The manual was subsequently used as the primary guiding document for the WIOMSA Marine Litter Monitoring Programme – a regional litter monitoring project involving seven countries in eastern Africa[77]. Consequently, litter baselines now exist for beaches of the WIO region of Africa[14,78,79]. The manual was also used in litter monitoring training workshops in South Africa and Kenya, and formed the basis of an online course on beach litter monitoring (**accessible here**).

Despite the success of the first edition, there was a need to incorporate alternative methods and make the manual more accessible to citizen scientists and amateur surveyors. The new *African Litter Monitoring Manual* (2nd Edition) provides litter monitoring protocols in more habitats (hence the removal of the term 'marine' from the title), and includes updates based on in-field experiences and feedback from partners of the WIOMSA Marine Litter Monitoring Programme and other stakeholders from across Africa and globally. **Chapter 2** provides an overview of the aims and objectives of this manual, the research questions that can be answered using the protocols provided, and important considerations for litter surveys.


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A GUIDE TO LITTER MONITORING IN AFRICA

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2

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Introduction

African nations have committed to various global and regional treaties to combat waste mismanagement as well as plastic pollution, but lack the necessary data to inform interventions and monitor progress in meeting treaty targets, as discussed in **Chapter 1** (*The Litter Crisis*)[1,2].

The *African Litter Monitoring Manual* (2nd Edition) presents methods to measure and monitor solid waste pollution, especially plastic pollution, in the environment. By establishing baselines and tracking changes in pollution over time, litter monitoring (**Box 1**) aids in identifying key areas for interventions and helps to evaluate the efficacy of action plans.

Key concepts

The first step to improving waste management and reducing plastic pollution in an area is to consider the following questions:

1. How much litter is in the area? This is also known as the litter amount, abundance or *load*.
2. Which types of litter are the most common (*litter composition*), and what items are problematic?
3. Where is the litter coming from? *Sources* of litter may include shopping centres, schools, landfills, tourists, etc.
4. How is the litter being transported to the site from the source? *Pathways* of litter may include rivers, wind, stormwater systems, etc.

These questions can be answered by doing litter surveys, which involve collecting, categorising, cleaning, counting and/or weighing litter at a given study site. This information can then be used to tackle plastic waste at the source before it ends up in the environment. Examples of interventions to address pollution are: public awareness campaigns, education initiatives, liaising and partnering with the local municipality, and involving interested stakeholders (e.g. schools, businesses, community members) in initiatives.

The initial estimate of the amount and type of litter in an area is called the 'litter baseline'. Historical data can be used as a baseline where available and appropriate[3]. However, since these data are lacking for many African countries[1,2], it may be necessary to establish a litter baseline against which to compare future data (**Box 2**). By monitoring changes in litter loads over time, surveyors can determine the efficacy of waste reduction measures[5]. Monitoring therefore forms the basis of adaptive management (**Figure 1**) because it facilitates the tracking of trends and detects emerging problems or non-compliance with regulations[3].

BOX 1
WHAT IS LITTER MONITORING?

Litter monitoring is the measurement of trends in the amount and types of litter over space and time, involving regular and consistent litter surveys over a predetermined period. While short-term monitoring is valuable for understanding the pollution impact of events such as floods, festivals or large-scale clean-ups, long-term monitoring provides information on how litter loads in the environment change over multiple years.

BOX 2
ESTABLISHING A RELIABLE BASELINE

The first survey in a series of surveys at a site can be used as the baseline, but because many variables influence litter loads daily, weekly and monthly, it is better to combine the results from the first few surveys to get an average estimate of litter[4]. The number of surveys needed to determine a reliable baseline depends on how precisely past and future data will be compared, and how much natural variation is expected in the data. More surveys are needed to detect small changes in litter loads and if data are expected to be highly variable[5].

For example, to establish a reliable baseline for beach litter (which is highly variable), it will be necessary to conduct at least four surveys per year for three to five years[5]. However, this may not be practical if time and money are limited. Where possible, multiple litter surveys are therefore recommended over at least one year to establish a reasonable baseline against which to compare future estimates.

Litter monitoring needs in Africa

Large data gaps exist around plastic pollution in Africa[1,6]. This lack of data to guide decision-making puts African countries at a disadvantage in mitigating – and ultimately stopping – plastic pollution and may prevent them from reaching targets set by international or regional conventions and treaties. Although there are a variety of methods to study litter[7–11], many of them may not be suitable or feasible for use in Africa, where financial resources are scarce.

Africa's large population is among its most valuable resources for large-scale data collection. Each community member or interested party is a potential data collector. Indeed, most people tackling plastic pollution and gathering waste data

LITTER MONITORING AS THE BASIS OF ADAPTIVE MANAGEMENT

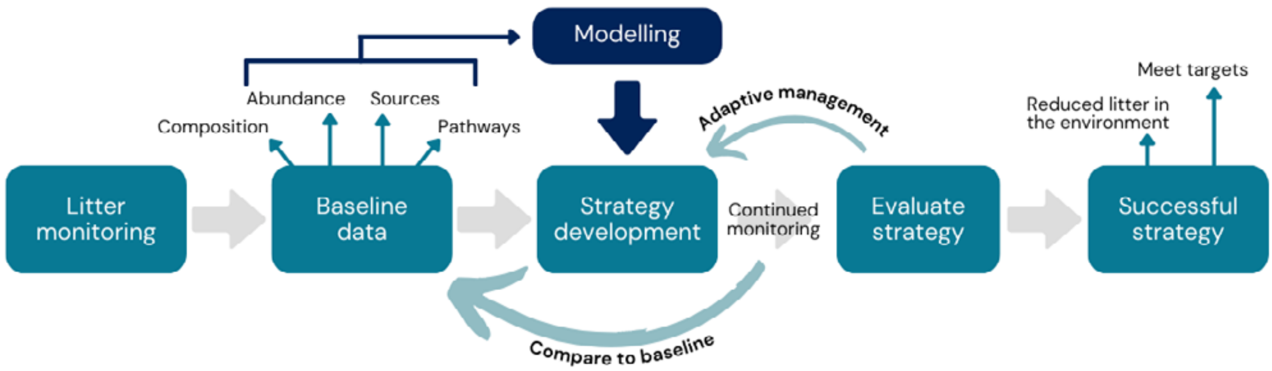


Figure 1: Litter monitoring forms the basis of adaptive management and supports the achievement of the Sustainable Development Goals (SDGs).

in Africa have not received formal education or training on the subject (most African schools and universities do not incorporate modules relating to plastic waste into their syllabuses)[6,12]. By providing user-friendly methods to study litter, the pool of potential data collectors is extended to community scientists (community members who collect data that will be analysed by professional scientists) and professionals with limited or no experience in litter research. This increases the reach and impact of litter research, as community members can access areas that are logistically or financially inaccessible to researchers.

With proper training, community scientists have been shown to collect reliable data on par with that collected by experienced researchers[13,14]. Community or citizen science is therefore a valuable resource in countries with large data gaps and limited funding for research. In turn, communities may benefit socially and economically from citizen science or volunteer initiatives, as they are empowered to participate in and learn from activities that promote a healthier environment and standard of living within their immediate environment (**Figure 2**). By sharing data with local NGOs or other organisations that operate internationally, community members are also able to contribute to the global fight against plastic pollution. A user-friendly guiding document is therefore essential to promote large-scale collection of reliable waste data in Africa and beyond. This is especially important in light of the developing global plastics treaty since litter data are essential to guide successful interventions, monitor progress, and verify compliance with targets.

The African Litter Monitoring Manual

The *African Litter Monitoring Manual* addresses the specific litter monitoring needs of Africa. The manual presents simple, user-friendly protocols for harmonised litter monitoring in various environments (including surveys on land, in waterways and in coastal habitats). As with the first

Figure 2: Children from the local community assist with beach litter surveys in Madagascar.

edition, the methods presented here are scientifically robust and feasible even with limited resources and experience. Despite its Afrocentric focus and approach, the *African Litter Monitoring Manual* may be used anywhere in the world, especially in developing countries where resources for litter research are limited. This manual is a valuable tool to promote the use of citizen science in litter monitoring projects anywhere.

A focus on macrolitter

Litter monitoring methods and management approaches are determined by the size of the litter targeted[4]. The three size categories (**Figure 3**) most often discussed in relation to litter monitoring and management are macrolitter (>25 mm), mesolitter (5–25 mm) and microlitter (<5 mm). This manual includes the 2–5 mm size range in mesolitter survey protocols because plastic pellets, or nurdles, make up a substantial portion of shoreline litter[15]. Apart from selected chapters on mesolitter, the manual focuses on macrolitter monitoring since macroplastics represent more than 90% of the total weight of plastic leaking into the environment in various African countries[16–19].

Furthermore, compared to microlitter studies, macrolitter surveys follow relatively simple techniques, can be done with easily obtainable equipment, and do not require extensive training[4]. Macrolitter is therefore cheaper, easier and more feasible to study than smaller litter. By reducing macrolitter pollution, secondary meso- and microlitter are simultaneously prevented, since a large portion of litter <25 mm originates from the degradation and fragmentation of larger items (**Figure 4**)[20].

Figure 4: Addressing macrolitter pollution will also prevent the formation and spread of smaller litter fragments in the environment.

Figure 3: Litter classification by size categories.

Objectives and research questions

Since monitoring protocols are goal dependent, it is necessary to consider what questions need to be answered when designing a litter monitoring programme. Depending on the questions asked, the type and quantity of data obtained and the way they are collected will differ. The protocols provided in this manual were prepared with specific objectives and research questions in mind (see below) but can be modified for other uses.

Specific objectives

1. Determine litter baselines,
2. Identify litter hotspots,
3. Identify sources and pathways of waste,
4. Share data to support decision-making and management of pollution,
5. Measure changes in litter over time,
6. Evaluate the efficacy of interventions/ Measure progress towards meeting targets/Verify compliance with treaties.

Examples of research questions

- Where are the litter 'hotspots' or areas where litter is most prevalent?
- How much litter occurs on the shores and in the waterways of City X?
- What is the composition of litter in terms of material type (e.g. plastic, paper, glass)?
- What are the most littered, or problem, items (e.g. plastic bags, cigarettes, paper)?
- What are the principal sources of litter?
- What are the transport pathways that litter follows from sources to coastal and marine environments?
- Does the amount of litter vary between sites and over time?
- Are the remedial actions having a positive impact?

To ensure that litter surveys are feasible and that they answer pressing questions, various aspects need to be considered, such as:

- What is the mandate of the organisation conducting the monitoring project?
- What is the aim of the litter survey?
- What are the core competencies of the team?
- Given the research questions and available resources, what particular areas of research can the team practically embark on?
- How should the project be planned in light of the team's strengths and weaknesses?
- Would the work support the national drive to reduce plastic litter?

Before embarking on any litter surveys, ensure that the study objectives, research questions and other factors that will determine the way forward have been carefully considered.

Structure of the manual

All chapters in the manual are stand-alone, allowingsurveyors to download and print (if necessary) only the chapter of interest and the accompanying ***Datasheets***. In addition, detailed information that is applicable to multiple chapters is provided in ***Appendices*** to reduce repetition. To promote ease of use, the protocol chapters (**Chapters 3–12**) are grouped into sections based on the habitat/ environment in which litter is monitored (**Figure 5**). Each of these sections has a *Section Introduction* providing an overview of the litter problem and the need for litter monitoring in that specific habitat, so that the chapters can focus on the monitoring protocols. The final chapter – **Chapter 13** (*The Way Forward*) – provides guidance on how data from litter surveys can be used to make a positive difference.

Adjustable methods

Sampling protocols need to be adaptable to different circumstances. Specific research questions, available resources and pollution levels at study sites will determine how applicable and feasible various steps of the protocols are to surveyors. To promote

Figure 5: This manual provides litter monitoring protocols for four different habitats/environments – land, waterways, beaches and mangroves. It includes revised versions of chapters from the first edition (published in 2020) as well as some new chapters.

the flexibility of sampling protocols, three different protocol standards are provided as guidelines on how the methods can be adapted – a *Gold, Silver* and *Bronze Approach* to sampling. The *Gold Approach* is tailored to researchers at academic institutions, while the *Bronze Approach* may be more suitable for community scientists.

The recommended minimum requirements for reliable surveys are provided in the *Bronze Approach*, while the *Gold Approach* represents the preferred methods. Protocol chapters primarily describe the *Gold Approach*, but notes are given to show how methods can be modified. For example, where the *Gold Approach* may require a study site length of 500 m, it may be more feasible, if available resources are limited (i.e. funding, number of volunteers, time, equipment), to sample a smaller study site in the case of very polluted environments.

The **Alternative Methods** are summarised at the end of each protocol chapter.

Quality control

It is imperative to ensure that the data collected during litter surveys are of a high quality, especially since data collection in the field is expensive and time-consuming. To ensure that time and funds are not wasted, and that results can reliably guide anti-pollution interventions, quality control measures should be implemented across all stages of a litter survey (i.e. the planning, sampling and processing stages). Aspects of quality control are discussed below.

Select appropriate study sites
Selecting appropriate and representative study sites is one of the most important steps of a litter survey. The number and locations of study sites will be determined by the research questions. For example, when research questions pertain to a specific area or location (e.g. 'How much litter is found on Beach X after the annual Festival X?'), the study site would be within that area (i.e. Beach X). To answer broader research questions that are not site-specific (e.g. 'How much litter is found on beaches around City X?'), litter surveys must be conducted at several sites, since many factors may contribute to the amount and types of litter found at a site (e.g. proximity to dumping grounds or urban areas, availability of waste removal services, frequency of clean-ups[21]. Sites should be chosen based on theoretical knowledge of potential litter inputs and would include sites near river mouths, stormwater outlets, popular tourist beaches, etc.

Other research questions (e.g. 'Are rivers major contributors to beach litter in City X?') may require multiple study sites, where as many factors as possible are kept constant between sites so that the impact of the factors of interest (e.g. rivers) can be measured. For example, if the intention is to study how a nearby river affects beach litter, it is advisable to have multiple study sites that are similar in all aspects besides their proximity to a river. Too many differences between study sites may make it difficult to identify the factors responsible for litter patterns. Once potential sites have been identified by desktop research, site visits must be undertaken to confirm that the sites are suitable and safe for conducting litter surveys.

Consider the sampling schedule
A sampling or survey schedule (i.e. how long, how often, and when to sample) will depend on the research questions and type of litter survey. For example, monitoring projects investigating changes in macrolitter over time will likely have to be repeated relatively frequently (e.g. quarterly), since macrolitter loads can change rapidly and are influenced by factors such as season and population density[21]. Long-term monitoring periods (e.g. five years and longer) will provide more comprehensive data on macrolitter loads that are not heavily influenced by random or rare events[5]. In contrast, monitoring projects that study changes in mesolitter on beaches over time would not have to be completed as frequently, since buried mesolitter loads remain relatively constant over decades[15].

Lead surveyors must plan an appropriate survey schedule that ensures the safety of their helpers and enables them to answer the research questions reliably. Survey schedules must be stipulated in the planning phase of a survey (i.e. before starting a survey). Key factors to consider when planning a sampling schedule are:

- The research questions of the study,
- The type of survey (can anything about the type of litter or the specific site influence the sampling schedule?),
- The influence of seasons or weather on litter and surveying conditions,
- The influence of oceanic tides (for surveys along shorelines),
- The occurrence of public or other events,
- The accessibility of the sites (some sites may only be accessible over certain periods),

Figure 6: A lead surveyor explains the litter datasheets to a group of community scientists at a pre-survey training workshop.

- The available time and resources (e.g. are there sufficient funds to conduct regular and long-term monitoring?).

Train helpers

The more helpers used in a survey, the greater risk there is of human error or bias. For example, different helpers may define the site boundaries differently, categorise litter differently, and may even have different abilities to spot litter (e.g. some helpers may overlook dull-coloured items). Special efforts have been made in this manual to make the protocols as clear and concise as possible. This includes the use of graphics, diagrams and detailed explanations for clarification. However, the best way to ensure data quality control for comparable results is to train helpers properly before and during litter surveys (**Figure 6**).

Lead surveyors are responsible for training the helpers. Helpers should understand the survey aim, where and how to survey, and how data will be collected and used. Additionally, to ensure consistency among helpers at a site, it is recommended to have at least one experienced team member who has previously conducted a litter survey at that site. If possible, the same team should be used for each survey. Lead surveyors must also establish rules to ensure consistency in how the data are collected. While guidance is provided on how to conduct surveys, lead surveyors will likely need to establish their own rules and standards given the countless possibilities of items that can be found and situations they may encounter.

Ensure that data are recorded and transferred accurately

One of the most important aspects of any scientific survey is to ensure that the data are recorded correctly (**Figure 7**) and in a way that can be understood by someone other than the data collector. Ensure that all helpers are familiar with the datasheets by the time the survey begins. The lead surveyor must check all the datasheets on the day they are completed to identify any discrepancies or issues. Data are often processed months after collection – at which point small details that influenced the data may have been forgotten.

Figure 7: Helpers must be trained to complete data-sheets. Lead surveyors must review the datasheets at the end of each surveying day to ensure there are no blank fields or discrepancies.

Data that have been recorded on datasheets will eventually need to be transferred to a software program (e.g. Microsoft Excel) for further analysis. Data transfers must be done meticulously, as mistakes can easily be made. To ensure that data are entered accurately, a second (and even third) person must confirm that the electronic file reflects the same information as the physical datasheets. All calculations must be double-checked.

General precautions and safety measures

When undertaking litter monitoring surveys, the safety of surveyors in the field is paramount. Some general precautions to practise include:

- Wear appropriate clothing and gear, such as protective gloves, closed shoes and sun hats. Safety or 'high visibility' vests may be required when working near traffic.
- Carry sufficient drinking water and an adequate first aid kit. A qualified first aider should preferably be included in the survey team to tend to emergencies such as cuts and abrasions, animal bites or stings, and heat stroke.
- Check the weather and, where relevant, tidal charts before going into the field. Surveys should not be conducted in extreme weather conditions. At sites with large tidal ranges, or where the high tide extends to the back of the study area, plan survey times accordingly to avoid being trapped by the tide.
- Obtain the necessary permission or permits to enter an area of land, waterway and/or intertidal zone to perform surveys and collect samples. Even where these areas are not private property or within a protected habitat (e.g. mangroves), permits or environmental authorisation may be required to excavate sediment and collect samples.
- Undertake monitoring in pairs and/or groups and be vigilant of potential threats in the surroundings.
- Notify a third party of the expected return time from the field and inform them when the team returns.
- Carry a means of communication (e.g. cellphone) to request assistance in the event of an emergency.
- Do not touch or lift large, heavy or potentially hazardous items. The appropriate authorities should be notified of potentially hazardous items.
- Avoid or minimise contact with any unsanitary items (e.g. condoms, feminine hygiene products, diapers). These items must be recorded and disposed of as soon as possible and with minimal handling. Dry and clean proxies can be used to estimate the weights of unsanitary items.
- Ensure monitoring does not damage the environment or disrupt local flora and fauna, especially endangered species.

Please contact SST (info@sst.org.za) or the relevant authors if you have any questions or recommendations.

SECTION A
INTRODUCTION

LITTER MONITORING ON LAND

BY TAYLA GIFFORD, ASANDISWA NONYUKELA & TOSHKA BARNARDO

Estimates show that the countries of sub-Saharan Africa currently generate close to 500 000 metric tons of municipal solid waste (MSW) – including plastics, glass, metals and organic waste – every day[1]. Many of these countries lack sanitary landfills and rely on open dumpsites as a means of waste disposal (see **Box 1** for definitions). Where proper waste management services are lacking, citizens often resort to littering, illegal dumping, and burning of waste[2]. Consequently, up to 90% of MSW in sub-Saharan Africa is not disposed of effectively, leading to high levels of pollution on land[2,3].

BOX 1
IMPORTANT DEFINITIONS

Sanitary landfills

Engineered waste disposal facilities where actions are taken to reduce the impact of waste on the environment (e.g. collecting leachate to reduce contamination of groundwater, compacting waste in layers, covering waste).

Legal open dumpsites

Designated waste disposal sites where waste is disposed of legally but with limited or no measures to reduce the impact of waste on the environment (e.g. waste is not covered and can thus be dispersed via wind to the surrounding environment).

Illegal open dumpsites

Open spaces where waste is illegally and deliberately dumped, resulting in pollution of the environment.

**Definitions modified from the African Waste Management Outlook[3]*

Waste generation is expected to increase in the coming decades as developing countries in Africa experience rapid urbanisation rates, economic growth and improved living standards[4]. It is therefore essential to improve understanding of solid waste pollution to effectively address this growing environmental hazard[5].

Urban litter pollution may have serious ramifications for the local community and the environment. The accumulation of plastic and other solid waste reduces the aesthetic value of an area, decreases real estate value, and poses a physical risk to humans and animals. Litter can block drains and cause flooding, spread diseases, attract pests and injure humans (e.g. sharp and broken pieces)[6,7]. Decomposing or degrading waste (especially plastics) in open dumpsites (whether legal or illegal) may contaminate soil, waterways and groundwater with hazardous chemicals[2,8]. Furthermore, degrading plastics have been shown to release greenhouse gases when exposed to sunlight[9], indicating that plastics in open dumpsites are also contributing to human-induced climate change. These impacts are not limited to urban areas, since land-based litter can be transported over great distances via wind, rainwater runoff and waterways[10,11]. Identifying pollution hotspots (**Figure 1**) and the sources of urban litter is therefore key to ensuring a cleaner, safer environment.

Land-based litter monitoring provides information about litter polluting the terrestrial environment and helps to identify where litter is coming from (the source) and how it is dispersed into the environment (the pathway). By monitoring litter near its original source on land, surveyors can identify the drivers of pollution and detect potential changes or issues early on. In contrast, downstream litter monitoring (e.g. in rivers, along shorelines or in the sea) is confounded by multiple litter sources, making it more difficult to interpret results. Stopping pollution at its source is important

Figure 1: Litter pollution is found in various urban locations.

since clean-ups are more expensive once litter disperses in the environment. Land-based litter surveys can be used in conjunction with downstream litter surveys, and/or remote sensing and Geographic Information System (GIS) technology, to gain a more complete understanding of the sources of litter and its pathways through the environment.

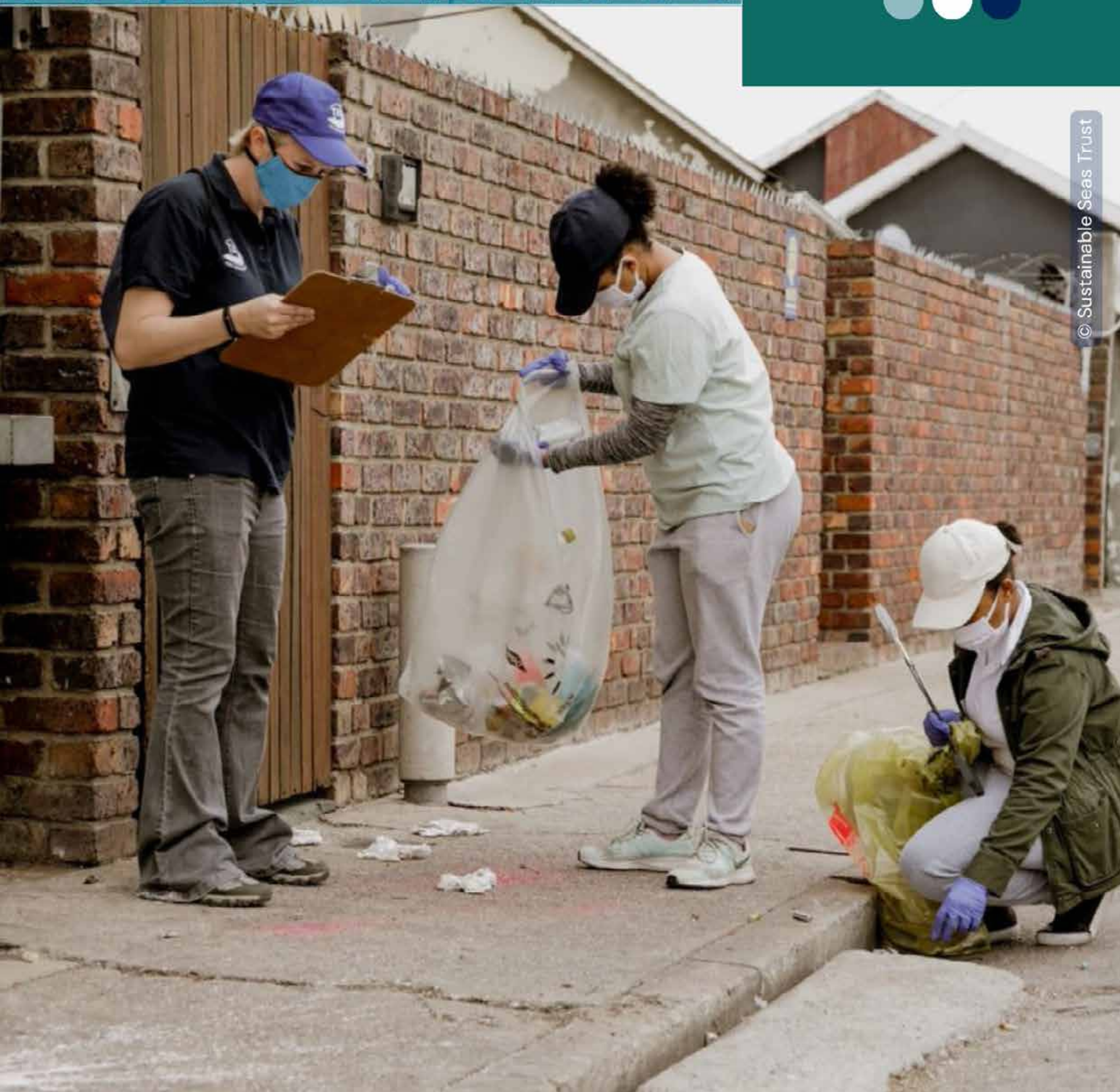
Despite the usefulness of studying pollution on land, protocols and user manuals for terrestrial litter surveys are lacking. This section provides methods to assess litter at low (i.e. street litter and windblown litter) and high (i.e. dumpsites) densities (**Figure 2**). The methods to collect and assess street litter or scattered litter are provided in **Chapter 3** (*Urban Macrolitter Surveys*). The goal of these surveys is to determine the sources and pathways of litter in order to stop litter at its source. In contrast, information about the location of illegal dumpsites and the amount and types of waste they contain can be used to aid local authorities with clean-up efforts. The methods to collect such information (without handling any litter) are provided in **Chapter 4** (*Dumpsite Mapping and Visual Characterisation*). Since the line between heavily littered sites and dumpsites may be blurred, lead surveyors must decide which of these two approaches are the most suitable and feasible in each situation.

Figure 2: Different litter monitoring protocols are used for dumpsites and sites with scattered litter. Lead surveyors must decide which methods are most suitable based on the research questions and conditions at the study site.

URBAN MACROLITTER SURVEYS

3

Toshka Barnardo, Asandiswa Nonyukela & Peter Ryan



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Introduction

Littering is a widespread problem in many African countries, resulting in areas of high human activity (e.g. public parks and roadsides) being strewn with litter[1,2]. A study in two major South African cities found that over 95% of litter items along urban streets were seemingly littered deliberately[2]. Another study in Nairobi, Kenya, found that nearly 90% of people interviewed indicated that they had observed people littering (although only 60% admitted to littering themselves)[3]. Littering, whether through deliberate or negligent behaviour, has been linked to personal value systems and personality traits[4], lack of infrastructure (e.g. bins)[3] and inadequate environmental awareness[5,6]. While these systemic issues need to be addressed by the relevant experts and authorities, litter researchers/surveyors also have an important role to play in the battle against littering and urban pollution. By monitoring litter along roads and in public areas, surveyors can increase understanding of the extent of littering, the problem items, the sources of litter and the drivers of littering. Such information is useful when implementing initiatives to reduce urban litter and then measuring the success of these efforts.

Urban macrolitter can be monitored in various ways. This includes the use of remote sensing technology (e.g. images obtained by satellites or drones) time-lapse images and physical collection of litter. This chapter provides protocols for measuring the accumulation of urban litter at fairly low densities (i.e. street litter and scattered litter) by collecting and analysing litter at regular intervals. It also describes how to process litter (clean, sort, count and weigh) and record results. The preferred methods of sampling and data collection (ensuring the most reliable data) are given, supplemented by notes on how the methods can be altered to suit local conditions and needs.

Protocols

The protocols for urban litter surveys require that surveyors choose an appropriate study site and collect all man-made macrolitter (>25 mm) from within the site. The litter is then processed (cleaned, sorted, counted and weighed) and the data analysed to determine the litter loads. A summarised guide on how to modify the protocols based on the available resources or specific research questions can be found in **Figures 12** and **13**.

TYPES OF SURVEYS
URBAN MACROLITTER SURVEYS

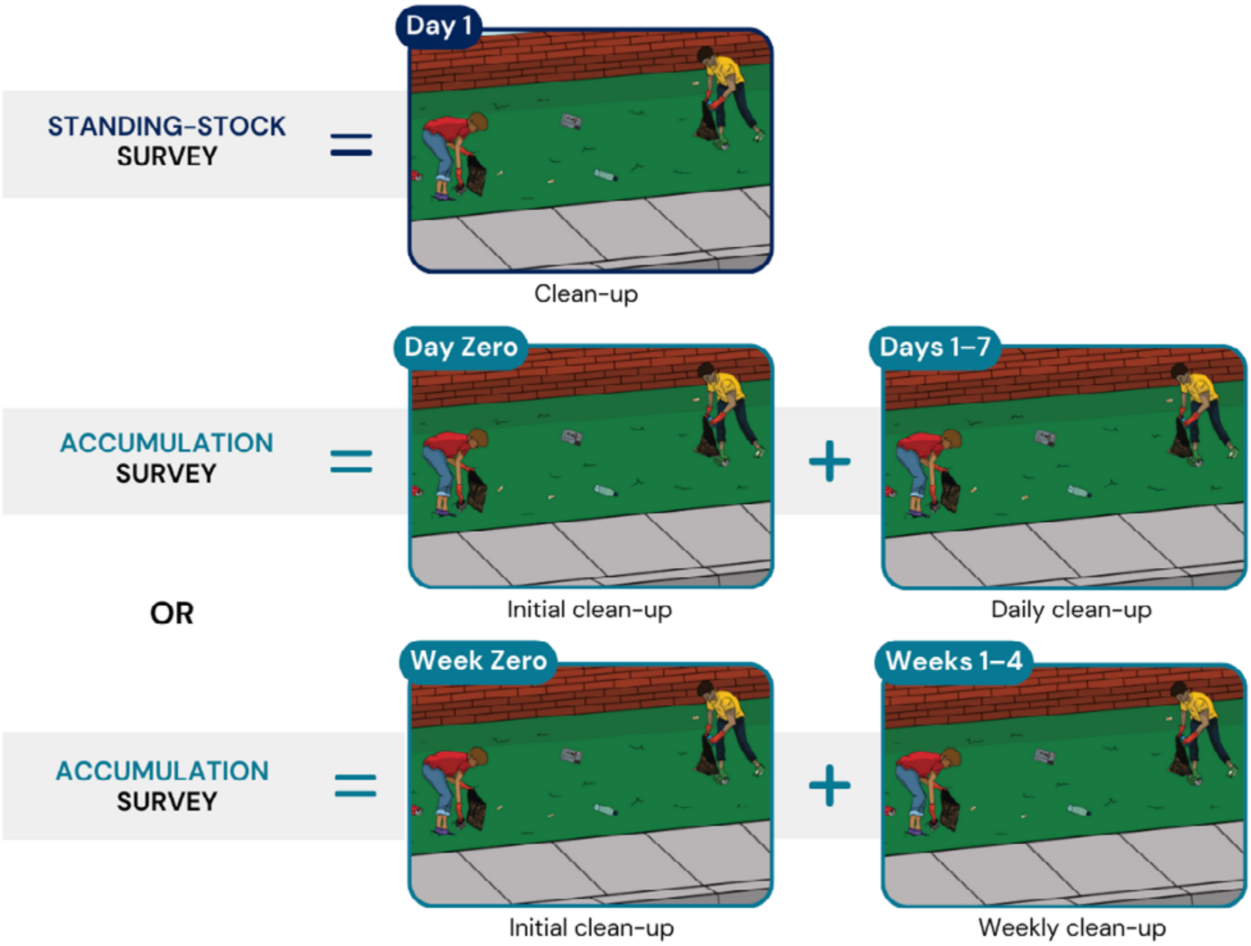

Figure 1: The survey period for standing-stock versus accumulation surveys.

This chapter provides two ways to study urban litter at relatively low densities (**Figure 1**). *Standing-stock surveys* are done at one specific point in time (e.g. in a single day) and provide a 'snapshot' of litter at that time. They are useful in identifying litter hotspots but provide limited information regarding the sources and pathways of waste and how litter loads change over time. The steps of a typical standing-stock litter survey are shown in **Figure 2**. *Accumulation surveys* are repeated regularly over short periods (ideally daily or perhaps weekly) to measure the build-up rate or accumulation of litter over a unit of time. The longer the interval between surveys, the greater the risk of litter loss through litter turnover processes (litter washed or blown away or picked up by formal or informal cleaning efforts), hence the preference for daily accumulation surveys. Accumulation surveys give a more comprehensive estimate of litter generation and are useful in determining the sources and pathways of waste. The steps of a litter accumulation survey are shown in **Figure 3**.

The differences between accumulation and standing-stock litter surveys are explained in more detail in **Appendix 1**. The type of survey selected will depend on the particular research questions and study site as per **Chapter 2** (*A Guide to Litter Monitoring in Africa*). It is recommended that the daily accumulation of litter is measured for up to seven consecutive days (as opposed to a once-off standing-stock survey). This is because street/urban litter loads may vary substantially during the week. For

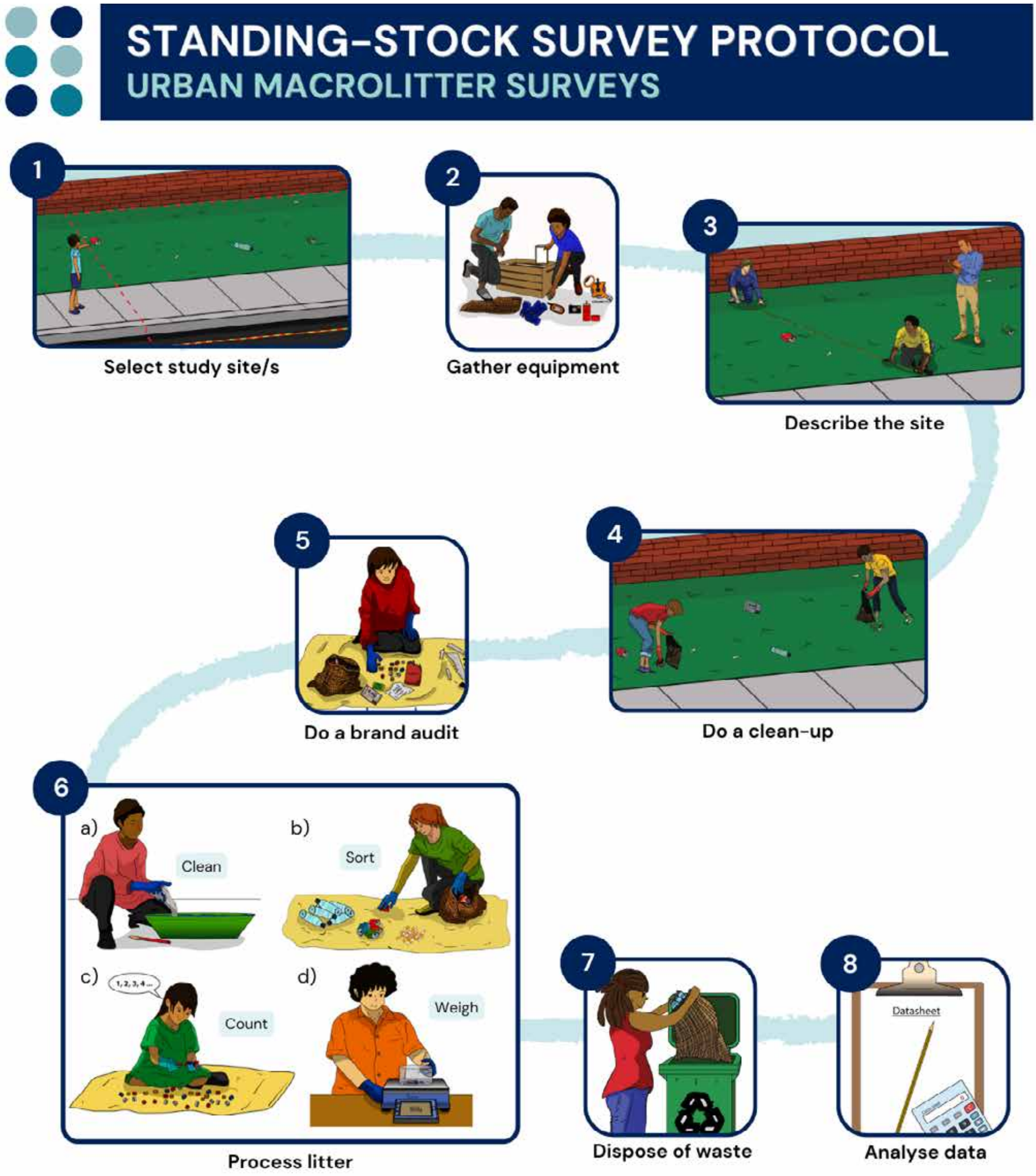

Figure 2: The protocol for a standing-stock macrolitter survey in urban areas consists of eight steps.

example, weekend litter loads may differ from weekdays, and in countries with curbside household waste collection, street litter may increase significantly on refuse collection day, especially if informal waste collectors tear open refuse bags to remove recyclables[2]. Daily accumulation surveys enable surveyors to study litter before it is dispersed or removed and provide insight into the sources and drivers of urban litter.

Optional: Where daily surveys are not possible, weekly accumulation surveys can be done for four weeks (excluding *Week Zero*). However, the longer interval between sampling events increases the risk of litter loss, thus underestimating litter loads.

ACCUMULATION SURVEY PROTOCOL
URBAN MACROLITTER SURVEYS

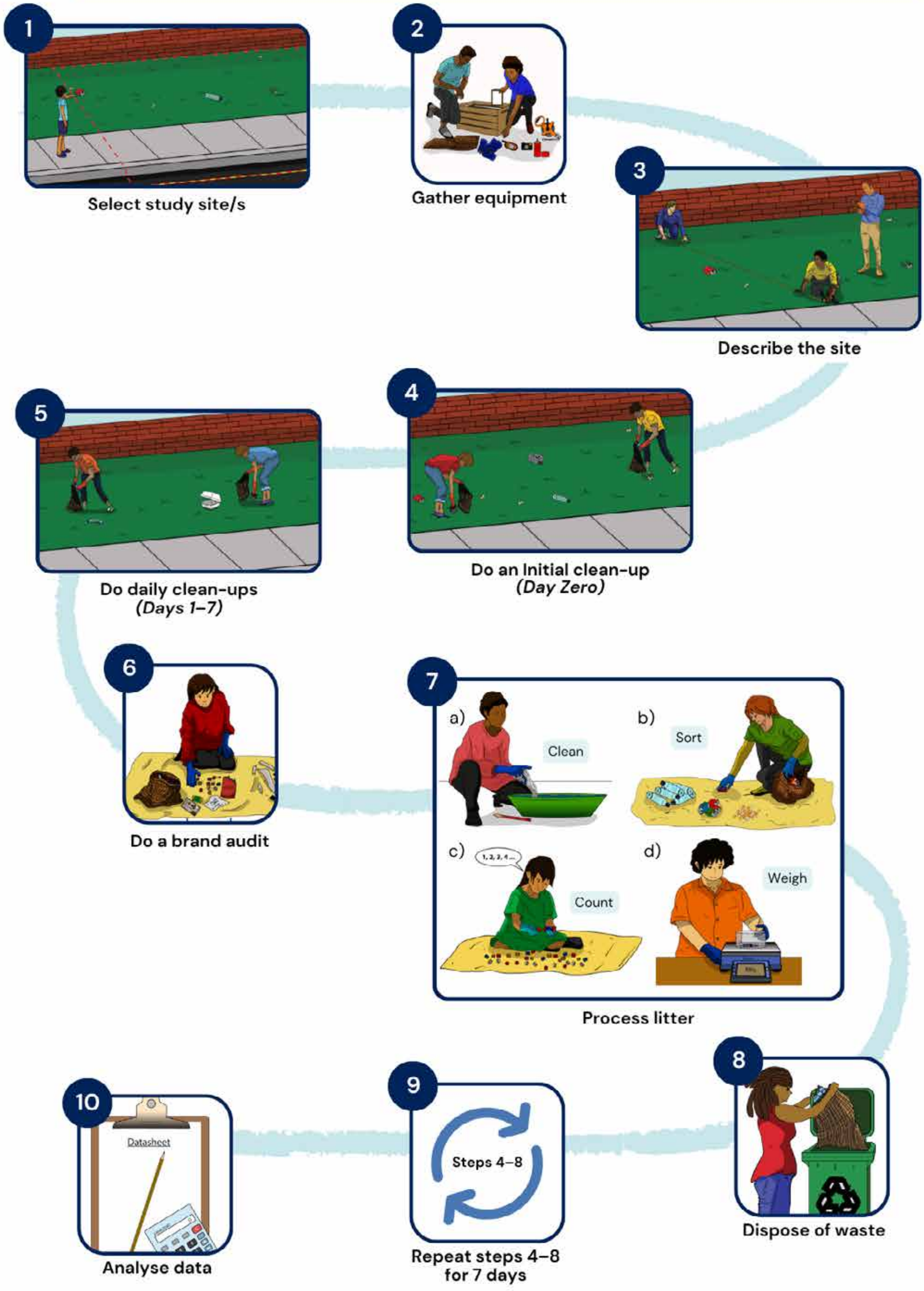

Figure 3: The protocol for a macrolitter accumulation survey in urban areas consists of 10 steps.

Select study sites

As discussed in **Chapter 2**, the research questions of the study will determine where surveys need to be conducted, but some general considerations for selecting sites are provided below for surveys designed to identify sources and pathways of urban macrolitter. It is best to have multiple study sites to be able to compare and interpret the results.

Study site features

Urban litter surveys can be done at two different types of study sites (**Figure 4**). Linear sites follow a specific path or route (e.g. road verges, fence lines and footpaths) and litter load or amount is expressed per metre (m). In contrast, non-linear sites encompass a defined area (e.g. school yards, public parks, parking lots, train yards and taxi ranks) and litter load is expressed per square metre (m^2).

The protocols for collecting and processing litter are the same for the two types of study sites, but the boundaries will be different for each site. To account for variability in litter loads within a site (i.e. some spots have high litter loads and others have low

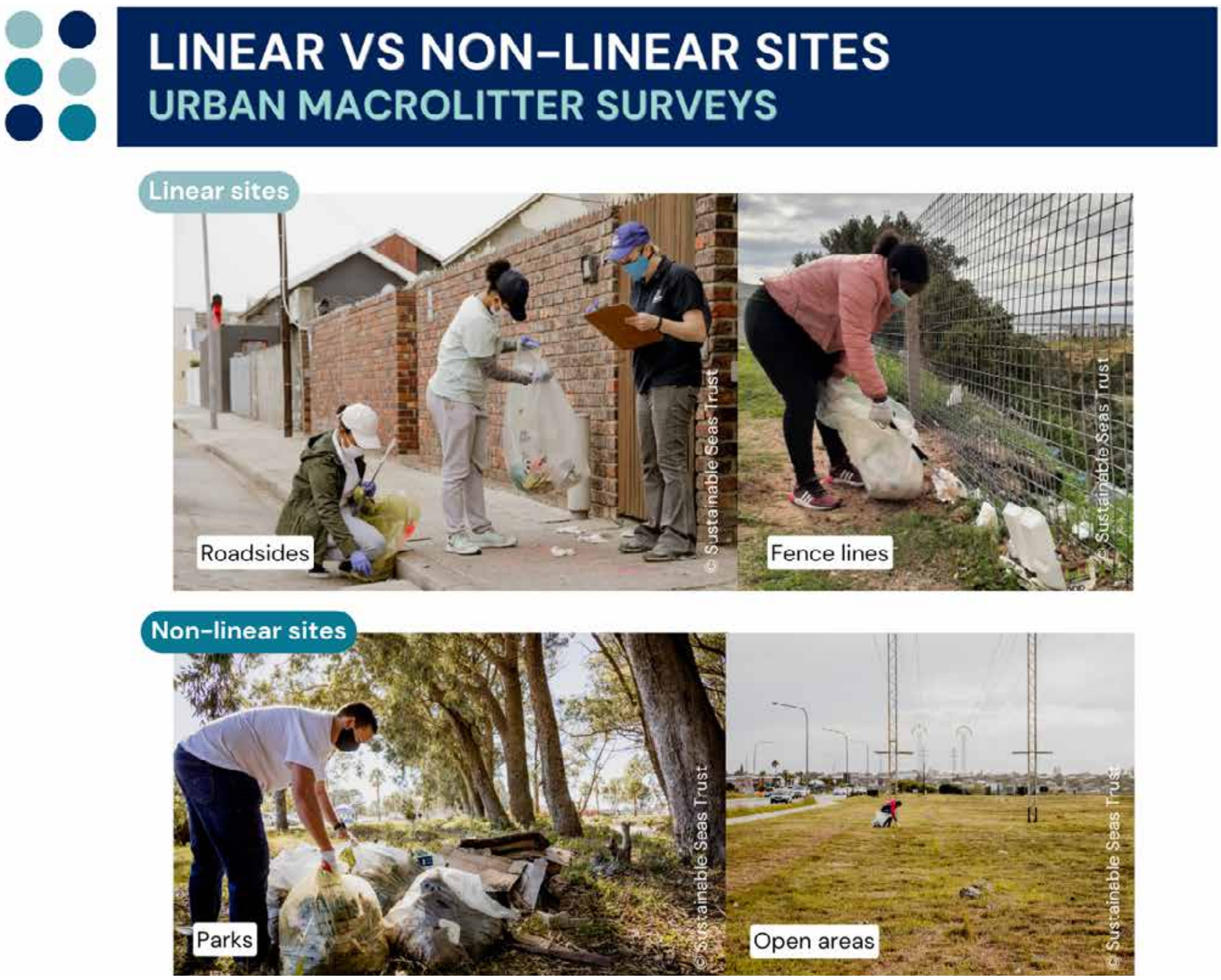

Figure 4: Urban macrolitter surveys can be done along specific paths (i.e. linear sites) or within larger defined areas (i.e. non-linear sites).

litter loads), it is recommended that linear sites are at least 100 m long and that non-linear sites have a total area of more than 200 m^2. For the most accurate results, linear sites should ideally be sampled on either side of the road/fence/path. Guidelines for the selection of survey area size and other important factors are provided at the end of this chapter.

Survey area boundaries

The lead surveyor is responsible for identifying and pointing out the boundaries of the survey area (the area where clean-ups will be conducted) before the start of each survey. Boundaries must be well documented (through use of fixed GPS points and supporting photos) to allow repeat sampling at the site and ultimately assess temporal changes in litter loads.

There is no one-size-fits-all solution to selecting boundaries, but some basic guidance is provided below:

- **Linear sites**: Roadsides are the most obvious linear sites to survey. Roadside surveys are conducted along road verges on one or ideally both sides of the road (**Figure 5**) and normally span from the side of the road to a barrier/obstacle (e.g. fence, wall, building, hedge). In cases where verges are very wide, surveyors must set a width limit (e.g. 3 m from the edge of the road) beyond which they do not sample. This maximum width must be kept consistent between surveys. This is also important for surveys along fences or footpaths, where there may not be natural boundaries to help define the sampling width.
- **Non-linear sites**: The boundaries of non-linear sites are dependent on the specific research questions and available resources. For example, a study on littering at a public park must ideally sample the entire park but may sample smaller portions of the park (e.g. areas close to and distant from picnic areas) if resources are limited. As with linear sites, the boundaries can be determined by existing barriers or obstacles, such as fences, walls, roads and pathways (**Figure 6**). Remember to record and, where possible, mark the boundaries of the survey area before the start of a survey.

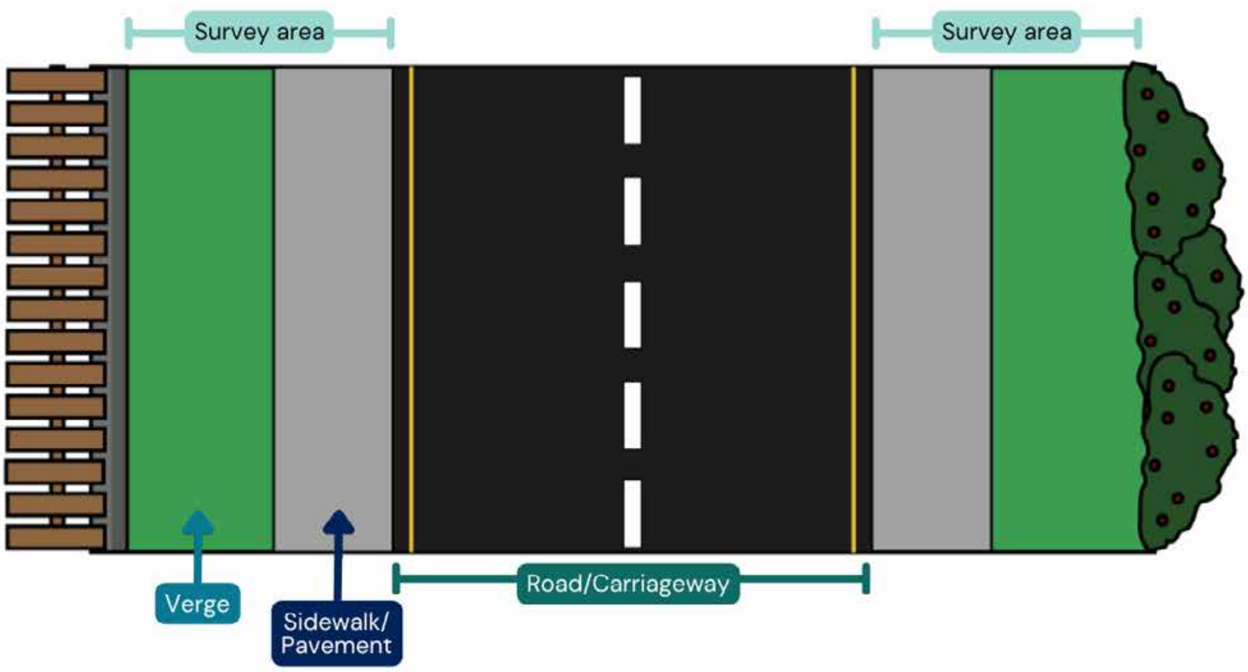

Figure 5: Roadside litter surveys are conducted along road verges and may include the sidewalk. Barriers such as fences or dense vegetation often determine the site limits.

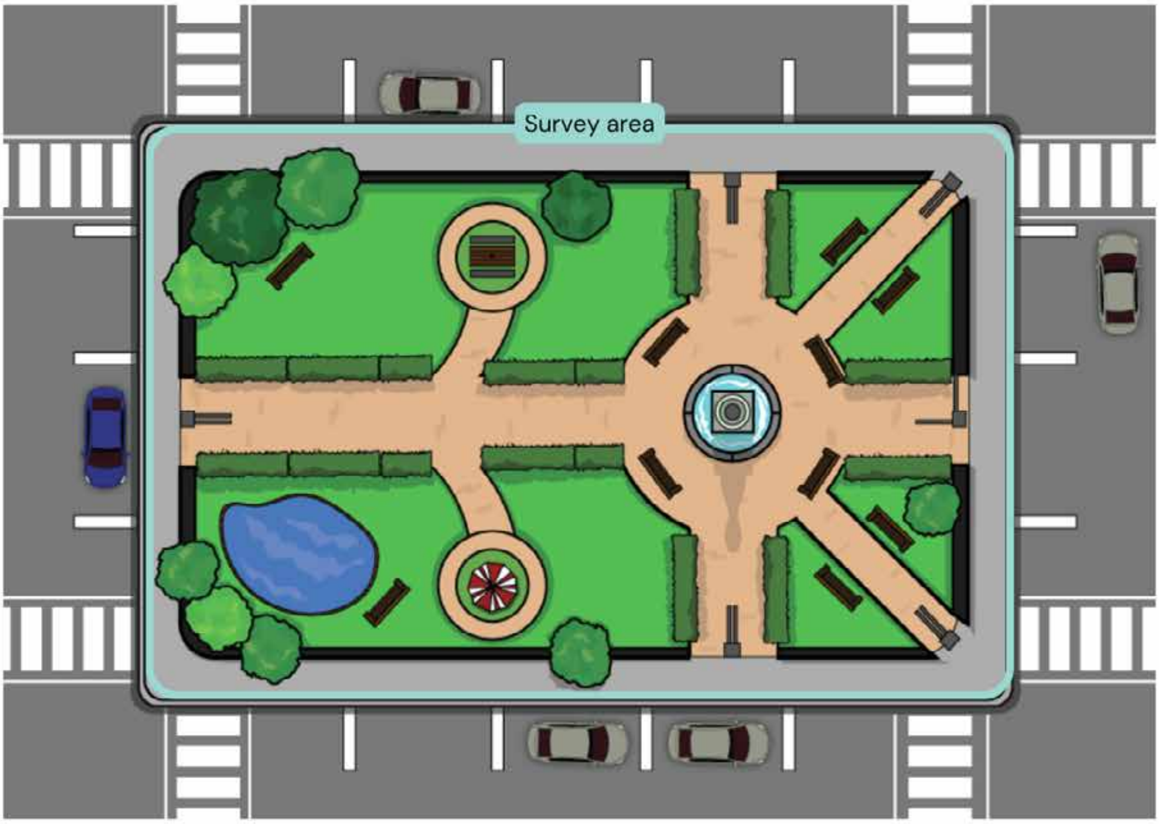

Figure 6: The lead surveyor must determine the boundaries of the survey area. At large or very polluted study sites, representative sections of the site can be sampled.

Study site considerations

Ideally, study sites for urban litter surveys should have the following characteristics:

- **Accessibility**: Sites should be accessible to surveyors for the entire duration of the study. Permission or authorisation should be obtained from landowners or relevant authorities, where applicable.
- **Absence of clean-ups by third parties**: No regular public or municipal clean-up activities should take place at the study site. If potential sites are cleaned regularly, surveyors should make the appropriate arrangements with local authorities and stakeholders to ensure that survey areas are not cleaned during the entire period of the survey. Alternatively, surveyors may collaborate with formal collectors, measuring their impact through a dual collection (they collect as usual, then surveyors do a comprehensive clean-up to ensure all litter is collected). This requires having access to their collections for processing.
- **Safety**: Surveys should not be conducted at sites where surveyors may be at risk. High-crime areas and other locations that are potentially unsafe to survey (e.g. very steep verges, unsafe traffic conditions) should be avoided.
- **Low environmental impact**: Surveys should in no way disrupt or harm endangered or protected habitats and species. Care must be taken to avoid disturbing nesting birds or trampling sensitive groundcover, which could result in habitat destruction and erosion.

Gather equipment

A printable checklist of the equipment needed to conduct urban litter surveys is provided in **Figure 7**.

Describe the study site

It is important to collect information about the site to help understand trends or patterns in the results. See **Datasheet 1** (*Site Description: Land Surveys*) for the information needed to describe the site (e.g. GPS coordinates, site dimensions). The area of non-linear sites can be easily obtained by drawing polygons around them in Google Earth. This datasheet should only be completed once per survey.

Daily changes in weather conditions and activities or factors that may influence litter accumulation need to be recorded on **Datasheet 2** (*Daily Site Conditions*) on every day of a survey.

Do an initial clean-up (*Day Zero*)

To measure the daily accumulation of litter, it is important to do a thorough initial clean-up of the survey area (**Figure 8**). This initial clean-up is referred to as the *Day Zero* clean-up, as it prepares the site for an accumulation survey by removing all litter from the site. Upon returning to the same site the next day, surveyors can reliably measure how much litter has accumulated at the site in the last 24 hours.

At very dirty sites, it may be necessary to do two successive *Day Zero* clean-ups to ensure all existing litter has been collected.

Litter collected on *Day Zero* can be used as a standing-stock survey but will not be processed and analysed with litter from the accumulation survey.

Where to clean

The *Day Zero* clean-up should be completed within the area described previously (see *Survey Area Boundaries*). Lead surveyors must clearly define the boundaries and point them out to the helpers to ensure that the entire area is cleaned. Litter in the vicinity that might be blown into the survey area must also be removed on *Day Zero* but can be discarded without processing it.

Figure 7: A printable equipment list for urban litter surveys.

Figure 8: Helpers clean a public park on Day Zero of an urban accumulation survey in Motherwell, South Africa. Litter is separated into recyclables and non-recyclables for proper disposal.

What to clean

All visible macrolitter (>25 mm) on the ground surface or protruding from the ground should be removed from the survey area on *Day Zero*. Smaller items such as cigarette butts and plastic bottle caps/lids should also be removed, since these are common litter items in urban areas. Avoid removing natural materials from the area (**Figure 9**).

When collecting litter, walk in a zig-zag pattern to ensure that no litter items have been missed. At least one person, the 'sweeper', must do a final check to pick up litter items the surveyors might have missed.

Litter items that are too large (e.g. electrical appliances) or dangerous (e.g. chemicals, weapons, ammunition) to remove should be counted but not handled. Mark these items with paint or photograph them to ensure that they are not counted again in future surveys.

The weights of heavy or large items can be estimated by multiplying the estimated volume of the item by the density of the material as per **Appendix 2**.

Notify the relevant authorities of any large or dangerous items so they can be safely removed. Used hygiene objects such as diapers, condoms and feminine hygiene products can be removed, noted and disposed of responsibly. During litter processing, a clean and dry proxy can be used to estimate the weight of any unsanitary item recorded at the site (see **Appendix 2**).

Note: It is recommended that all visible litter is collected, even items that seem smaller than 25 mm, as they may be part of a larger, buried item. Items smaller than 25 mm can be removed during the processing stage.

NATURAL ITEMS VS LITTER

Figure 9: Only collect litter items during surveys. Natural items should not be removed.

Note: It helps to have the sweeper(s) walk in the opposite direction to that of the initial cleaners, as they may be able to spot missed items by approaching from a different angle.

Do daily clean-ups (*Days 1–7*)

The day after the *Day Zero* clean-up, another clean-up must be done at the site. Ensure that all surveyors (especially new helpers) know where to clean before starting each survey. Where possible, daily surveys should be repeated for seven consecutive days (*Days 1–7*) to account for the variation in daily litter loads due to external factors (e.g. weather, municipal waste collection days, littering by pedestrians). It is important that surveys are done at the same time every day to ensure that the time between surveys is constant. Where daily surveys are not possible, weekly accumulation surveys can be conducted for a complete month (i.e. *Week Zero*, then at weekly intervals for a minimum of four weeks).

As with *Day Zero*, all visible macrolitter (>25 mm) within the survey area should be collected. Natural items, personal belongings that are obviously still in use (e.g. clothes), and items used for cultural or religious rituals or activities (e.g. charms and ceremonial objects) must not be removed. Items too large, heavy or dangerous to remove must be counted and marked, but not handled. As for the *Day Zero* clean-up, the site should be walked in a planned pattern with a sweeper doing a follow-up check to ensure that all macrolitter items have been collected. Collection bags/containers should be clearly labelled to include the study site name and the date of collection.

Note: In the spirit of reducing single-use plastic waste, it is recommended that surveyors use reusable bags or containers to collect litter wherever possible.

Do a brand audit

Most consumer products have information about the product (or the brand owner of the product) printed on them (**Figure 10**). The recording of information from branded litter is called a 'brand audit'. The following product information should be recorded in **Datasheet 3** (*Brand Audit Information*):

- Brand name (e.g. Choco-Snow),
- Manufacturer (e.g. Barnadoo International),
- Where the item was produced/packaged (e.g. South Africa),
- Type of product (e.g. food packaging),
- Type of material (e.g. other plastic [#7]), and
- Number of layers (for plastic items).

It is recommended that a brand audit is done on the litter collected at each daily/weekly survey excluding *Day Zero* (see **Appendix 1** for the biases associated with litter from *Day Zero*). The detailed protocols for brand audits are provided in **Appendix 3**.

Process litter

Litter processing refers to the cleaning, sorting, counting and weighing of litter. The detailed methods for litter processing are provided in **Appendix 2** and a graphical summary is depicted in **Figure 11**. Macrolitter must be sorted, counted and weighed according to either **Datasheet 4** (*Basic Litter Datasheet* with 36 litter categories) or **Datasheet 5** (*Comprehensive Litter Datasheet* with >140 litter categories). Visual guides for these two datasheets are provided in **Appendix 4** and **5** respectively. **Appendix 6** can be used to measure macrolitter fragment sizes.

Separate litter datasheets should be completed for each day of the survey. A total of two datasheets must therefore be completed on each day of an accumulation survey:

0. Site Description Datasheet (only on *Day Zero*) – **Datasheet 1**
1. Daily Site Condition Datasheet – **Datasheet 2**
2. Litter Datasheet – **Datasheets 4** or **5**.

Note: Surveyors conducting more detailed, scientific studies may choose to weigh each piece of litter.

BRAND AUDITS
IMPORTANT INFORMATION ON BRANDED LITTER

*Figure 10: Brand audit data are useful when addressing plastic pollution. *Recording of manufacture/best before dates is optional.*

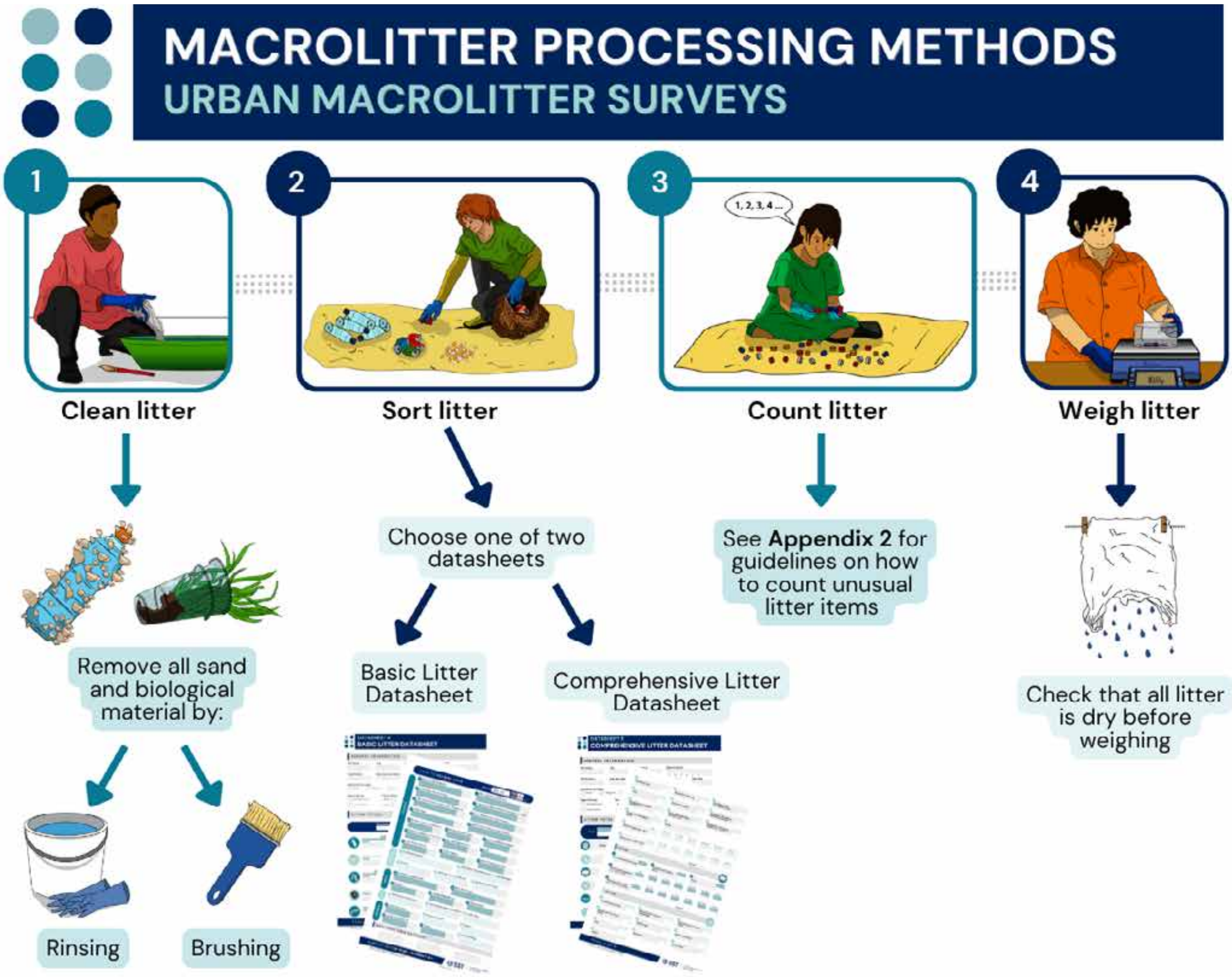

Figure 11: Summary of macrolitter processing methods. See Appendix 2 for a detailed description of the methods.

Dispose of waste

Once the survey has been completed, litter should be disposed of correctly or stored for further analysis. Biodegradable organic waste can be composted, and recyclable materials can go to recycling collection points or material recovery facilities (MRFs).

Analyse data

The total number and weight of items will be calculated either per metre (m) for linear sites (e.g. a street) or per square metre (m^2) for non-linear sites (e.g. a public park). While standing-stock survey results are presented as a total (e.g. 5 items/m or 20.0 g/m^2), accumulation survey results are presented as a daily or weekly rate of litter accumulation (e.g. 2 items/m/day and

0.5 g/m^2/day). These values can be used in mathematical models to estimate how much litter may be found in a given area (based on the total length of streets or area covered by open spaces, etc.).

The number and weight of litter items should be calculated as a total (i.e. all litter), per category (e.g. plastic) and per litter type (e.g. lollipop sticks). This will allow surveyors/researchers to compare broader results (per category and in total) between sites and over time. By repeating studies regularly at the same site, changes in litter composition and accumulation rate over the long term can be detected. This information is important to inform and monitor the effectiveness of litter reduction methods.

Note: If only one side of a linear site (e.g. road, footpath) has been surveyed, record which side was surveyed and multiply the results by two to estimate the total amount of litter for the site (i.e. litter/m). This must not be done at sites (e.g. fences, hedges, embankments) where one side is expected to accumulate significantly more litter depending on the prevailing wind direction or other external factors.

Alternative methods

The protocols discussed above are recommended for collecting the most reliable data. However, depending on the research questions of the study and available resources (e.g. funding, number of helpers, and time), simpler methods can be used. For this reason, three different protocol standards – *Gold, Silver* and *Bronze Approaches* – have been provided as guidelines to modify the survey protocols to suit specific needs. By allowing flexibility in the methods, these standards ensure that data from litter surveys are always reliable and comparable while surveys remain feasible and sustainable. **Figures 12** and **13** show how standing-stock surveys and accumulation surveys can be modified.

The minimum requirements for a reliable accumulation survey are provided in the *Bronze Approach*, while the *Gold Approach* is recommended for best accuracy. Survey methods can be customised within the range specified by the *Gold* and *Bronze Approaches.*

Note: Since results from different sites are standardised to litter per m or m^2, they remain comparable regardless of the survey area size. However, once methods are altered to below the standard of the *Bronze Approach*, the variation and uncertainty in the data increase substantially.

STANDING-STOCK SURVEY APPROACHES
URBAN LITTER SURVEYS

	GOLD APPROACH	SILVER APPROACH	BRONZE APPROACH
Size of litter to collect	>25 mm	>25 mm	>25 mm
Transect length (for linear sites)	500 m	100-500 m	100 m
Transect length (for non-linear sites)	Depends on the site characteristics	Depends on the site characteristics	Depends on the site characteristics
Transect width	Depends on the site characteristics	Depends on the site characteristics	Depends on the site characteristics
Days of surveying	1	1	1
Litter counts	Yes	Yes	Yes
Litter weights	Yes	Yes	Optional
Weighing individual pieces	Yes	Optional	No-Weigh per litter type (e.g. earbuds)

Figure 12: Using the guidelines above, standing-stock surveys can be modified according to available resources and the complexity of the study.

ACCUMULATION SURVEY APPROACHES
URBAN LITTER SURVEYS

	GOLD APPROACH	SILVER APPROACH	BRONZE APPROACH
Size of litter to collect	>25 mm	>25 mm	>25 mm
Transect length (for linear sites)	500 m	100-500 m	100 m
Transect length (for non-linear sites)	Depends on the site characteristics	Depends on the site characteristics	Depends on the site characteristics
Transect width	Depends on the site characteristics	Depends on the site characteristics	Depends on the site characteristics
Days of surveying	*Day Zero +* Days 1-7	*Day Zero +* next 3-7 days	*Week Zero +* Weeks 1-4
Litter counts	Yes	Yes	Yes
Litter weights	Yes	Yes	Optional
Weighing individual pieces	Yes	Optional	No-Weigh per litter type (e.g. earbuds)

Figure 13: Using the guidelines above, accumulation surveys can be modified according to available resources and the complexity of the study.

DUMPSITE MAPPING & VISUAL CHARACTERISATION

Ana Rocha & Mamlo Abdallah

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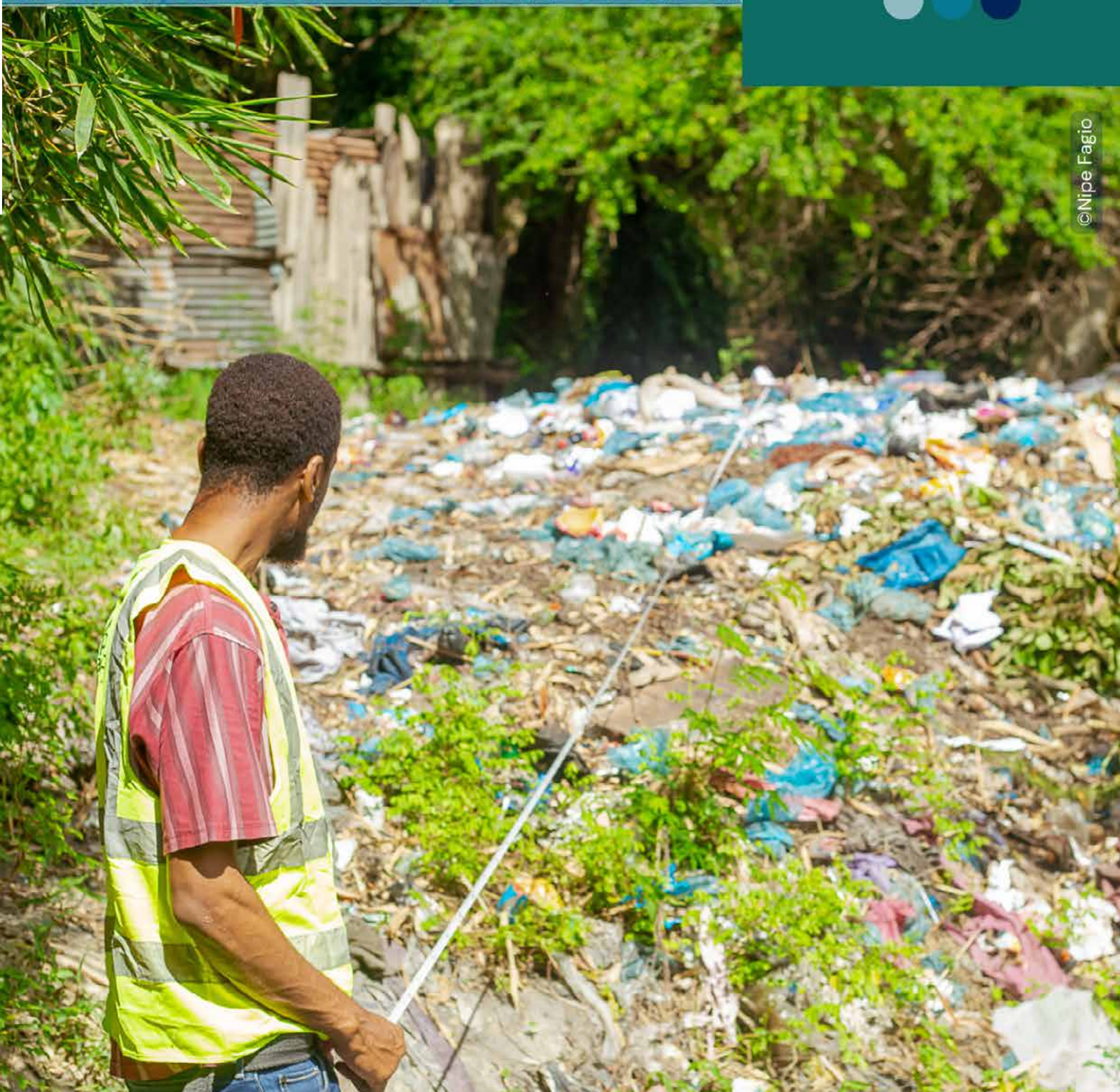

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Introduction

Open dumpsites (both legal and illegal) are common in developing countries with inadequate waste management services[1]. These dumpsites pose an environmental and socio-economic threat to many local communities[2]. Key factors that prevent proper management of open dumpsites are: 1) the rapid rate at which new illegal dumpsites are formed, and 2) the remote nature of the areas where dumpsites often occur. Identifying, recording and managing illegal dumpsites generally require a significant investment of funds and effort from local governments or waste management services. These resources are often lacking in developing countries and result in dumpsites going undiscovered and unmanaged[3]. Simple and efficient methods are needed to assist citizen scientists, municipal authorities or any interested stakeholders with collecting and sharing important information about local dumpsites.

This chapter provides protocols to map and rapidly assess open dumpsites, when the main goal is to collect and share simple but important data about dumpsites to help local authorities and stakeholders manage them better. Dumpsite mapping provides an overview of the waste 'hotspots' in an area and can be used to measure growth rates of dumpsites over time. This information is useful in identifying priority sites for clean-ups and/or other waste management interventions. For example, pollution from dumpsites near waterways may threaten aquatic ecosystems and obstruct flows, magnifying the risk of flooding. Information collected using these protocols can thus be used to develop effective waste management strategies and policies, improve environmental remediation efforts and reduce the negative impact of waste on local communities.

Protocols

The first step of dumpsite mapping and characterisation is to identify or locate illegal open dumpsites (legal or formal dumpsites may also be included where relevant). Dumpsites within a study area can be located using existing maps, remote sensing technology such as drones and satellite imagery, and/or by searching on foot or by vehicle.

Once identified, dumpsites are inspected in person to verify the location and to collect relevant information (e.g. size, composition, accessibility). The dumpsites can then be digitally mapped and recorded in a database, ideally using Geographic Information System (GIS) software. The steps that are typically involved in dumpsite mapping and characterisation are summarised in **Figure 1** and will be explained in the following sections.

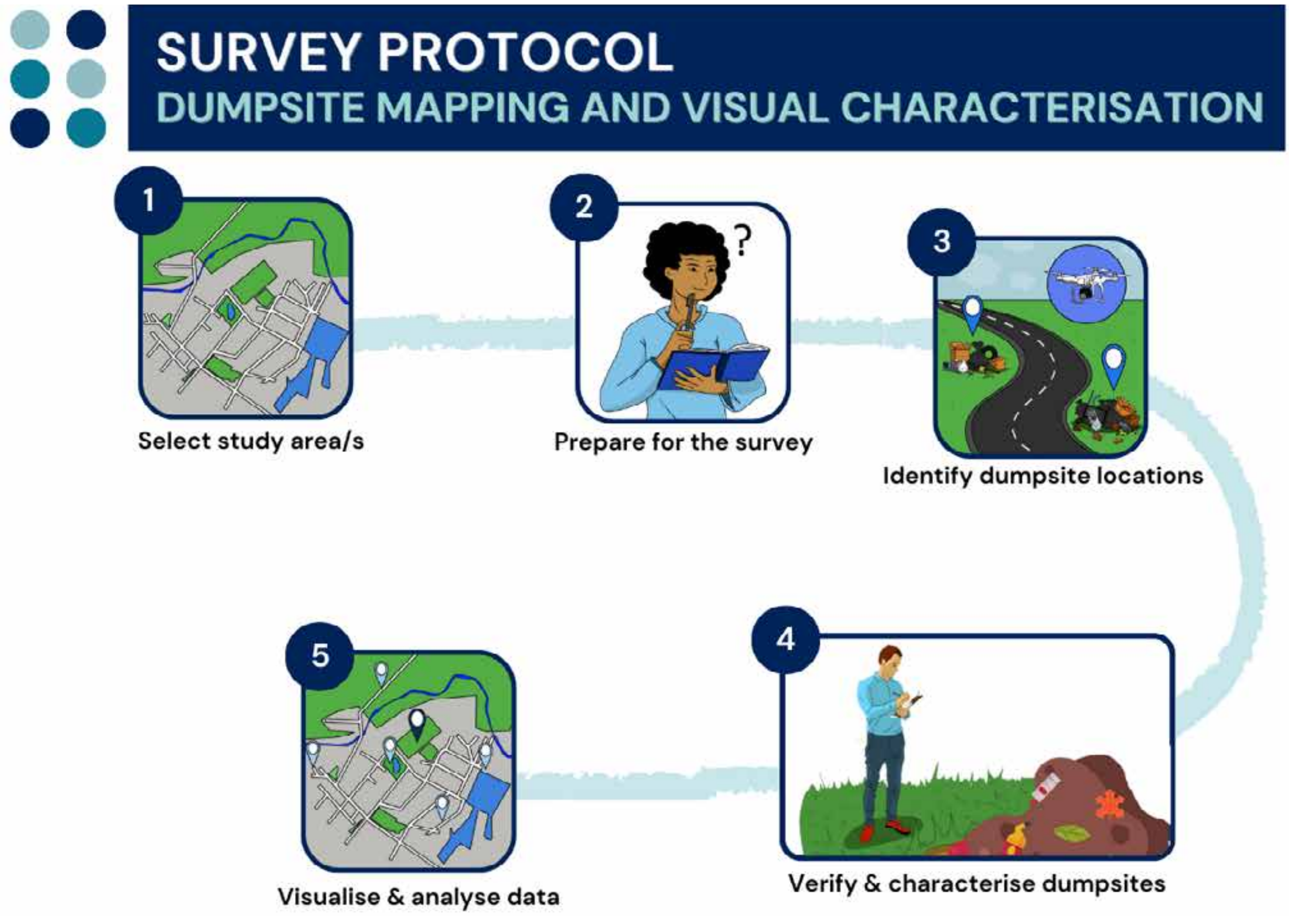

Figure 1: The protocol for dumpsite mapping and characterisation consists of five steps.

Select study area

The first step in dumpsite mapping and characterisation is to identify the area that will be mapped. The study area must be chosen in accordance with specific research questions as per **Chapter 2** (*A Guide to Litter Monitoring in Africa*), clear objectives (i.e. outlining the purpose of the mapping exercise, and the expected outcomes) and available resources. Surveyors must ensure that they can safely and feasibly map the chosen study area – especially in heavily polluted areas. Accurate mapping of a small area (e.g. a single neighbourhood) is better than imprecise mapping of a large area (e.g. an entire city). Given the investment of resources and time to conduct dumpsite assessments, surveyors must ensure that the data they collect are useful and reliable before expanding the study area. It is therefore important to carefully consider the location and size of the study area.

Note: Surveyors may choose to assess specific dumpsites and track changes over time. In such instances, a larger study area will not be mapped. While targeted dumpsite assessments are useful, it is recommended that studies are conducted over a larger area (incorporating all dumpsites within a defined area) for maximum impact.

Prepare for the survey

Once an appropriate study area has been identified, the following steps must be followed to prepare for a dumpsite survey:

1. **Develop a project plan**: Develop a detailed plan that includes timelines, budget and resources required. Select an approach to search for dumpsites, i.e. in-person searches versus use of drones and other forms of technology.
2. **Get the necessary permissions**: Obtain any permissions that are necessary from the relevant authorities before beginning the mapping exercise. This might include permission to access the dumpsites in restricted areas or to use drones for aerial surveys.
3. **Gather existing data on dumpsites**: This could include data from previous mapping efforts, government records or reports from the local community. Ward councillors and community members may be consulted to identify potential dumpsite locations.
4. **Prepare a map of *potential* dump-sites**: Using existing data, community reports and satellite imagery (e.g. from Google Earth, Google My Maps, QGIS), compile a map (*Map 1*) identifying all the potential locations of dumpsites (**Figure 2**). This may include remote areas, unused land, or areas near water bodies and can be a physical or digital map. The map provides the team with a starting point when searching for dumpsites.
5. **Recruit and train helpers**: Assemble a team of volunteers or experts with relevant skills and experience. Ensure that the team is trained on data collection methods, equipment usage, safety measures and ethical considerations (**Figure 3**).
6. **Prepare software and materials**: Ensure that all necessary software and materials are accessible and that helpers know how to use them.
7. **Gather equipment**: Collect all the equipment necessary to map and characterise dumpsites. An equipment checklist is provided in **Figure 4**.

Figure 2: An example of a map produced in Google Earth, showing potential dumpsites in a neighbourhood of Motherwell, South Africa.

Figure 3: Ana Rocha, Director of Nipe Fagio (a Tanzanian NPO), explains how to map and characterise dumpsites at a litter monitoring workshop in Kenya.

Figure 4: A printable equipment list for dumpsite mapping and visual characterisation.

Identify dumpsite locations

After identifying potential dumpsites, the next step is to do a proper search for actual dumpsites. The map of potential dumpsites produced during the planning phase (*Map 1*) provides some guidance on where dumpsites may be located. Searches for dumpsites can be conducted remotely (using technology) or in person (manually).

Remote identification

Technology such as high-resolution satellite imagery and imagery obtained from Unmanned Aerial Vehicles (UAVs), commonly known as drones, can be used to search an area for dumpsites. While both

BOX 1
USING DRONES TO FIND DUMPSITES

When using drones to identify dumpsites, it is important to consider the following tips to ensure safe and effective data collection.

Pre-flight considerations:

- Familiarise yourself with the local regulations and guidelines regarding drone operation before flying a drone. **Click here** to view drone laws by country.
- Appoint a licenced/qualified/competent drone operator. The ***DJI Tutorials*** **YouTube Channel** provides regular training videos for beginner drone operators.
- Develop a flight plan that covers the entire area that needs to be mapped. Conduct a risk assessment to identify potential hazards and vulnerabilities in the study area.

In-flight considerations:

- Fly the drone with caution and maintain a safe distance from people, structures and any sensitive areas.
- Keep track of the drone's battery life and plan the flight duration accordingly.

Post-flight considerations:

- Download the images, name the files accordingly and store them in a secure location (e.g. cloud storage or hard drive) for further use.
- When compiling the images, ensure proper overlap between images to facilitate accurate mapping.
- Process and analyse data.
- Images can also be uploaded to a crowdsourcing site (e.g. **OpenAerialMap**) to assist with unrelated projects.

can assist in identifying dumpsites in areas that are difficult to access, drones can also search areas hidden from view (e.g. in a road underpass). The use of remote searching allows quick data collection, precise mapping, and the coverage of a large area within a shorter timeframe than it would take on foot. For tips on using drones to locate dumpsites, see **Box 1**.

In-person identification

Surveyors can manually search for dumpsites by walking or driving around a pre-determined area and documenting the dumpsites they encounter (**Figure 5**). The following steps should be followed:

1. For safety reasons, helpers involved in the search should preferably be grouped into teams of two to three. Each team can then be assigned to assess different streets or areas.
2. The size of the area covered by each team will depend on the number of helpers available, the mode of transport and the overall size of the area that needs to be searched.
3. Provide each team with a copy of *Map 1*, produced during the planning stage, with their allocated search area marked out.
4. Ensure that all team members are equipped with appropriate safety gear, including gloves and masks.
5. Establish a communication system between the teams and a central coordinator to stay connected and report any issues or findings.
6. Once everything has been prepared, the teams can commence the search for dumpsites in their allocated areas. Any indication of deliberate dumping of waste in concentrated piles (i.e. not casual littering) must be noted as a dumpsite (**Figure 6**) by recording the GPS coordinates and taking photographs of identifying features.

Note: It is useful to include ward leaders and/or community members in surveying teams as they know the area best and will help to locate dumpsites more efficiently.

Figure 5: Teams may walk or drive (using a car, a scooter or bicycles) to identify dumpsites in person. Some sites will not be visible from the street and may need to be inspected on foot.

Figure 6: Examples of illegal dumpsites in Gqeberha, South Africa.

After the search has been completed, all teams should return to a central meeting point (e.g. an office) to compile the data. The GPS coordinates of dumpsites are then added to a map (*Map 2*) of the area using geospatial visualisation software such as Google Earth, Google My Maps or QGIS. *Map 2* now shows the dumpsites in the area that will be verified and characterised in the next step.

Verify and characterise dumpsites

With the administrative work and mapping completed, field assessments can finally be conducted to verify dumpsites (i.e. confirm their existence and location) and collect information about them. The steps to locate, verify and characterise dumpsites are provided below:

1. Dumpsites are located using *Map 2* that was produced after the search for dumpsites. Using the same steps described under *In-person Identification* above, surveyors must visit the dumpsite locations identified on the map.
2. Verify the location of the dumpsite by taking the GPS coordinates. If surveyors go to the coordinates of a dumpsite indicated on *Map 2* and the dumpsite is no longer there, these coordinates will *not* be taken again, and the site will not be included on the final map of dumpsites.
3. Take a photograph of the dumpsite. Be sure to capture the content and size of the dumpsite in the photo.
4. Use a tape measure to determine the length and width of the dumpsite (**Figure 7**). Recent satellite or drone images can be used to estimate the dimensions of very large dumpsites that cannot be measured in person.

Figure 7: A team member from Nipe Fagio measures a dumpsite in Dar es Salaam, Tanzania.

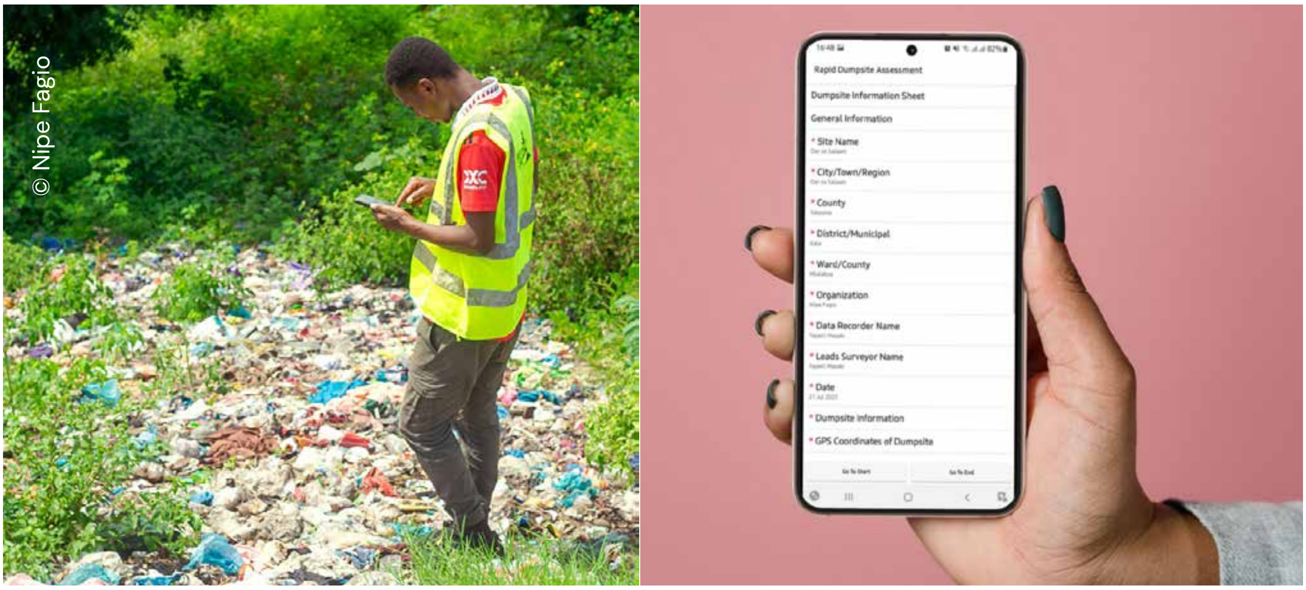

Figure 8: A Nipe Fagio team member records information (left) about an illegal dumpsite using a mobile app (right).

5. The dumpsite location, size and visible content must be recorded as per **Datasheet 6** (*Dumpsite Information*). The data can be recorded on a printed datasheet or on a mobile application (e.g. OpenDataKit (ODK); **Figure 8**). When using an app, be sure to include all the information from **Datasheet 6** and also take physical copies of datasheets in case the app cannot be accessed (e.g. due to connectivity issues, loss of battery power, or safety concerns).
6. Return to a central meeting point (e.g. an office) to compile the data.

Visualise and analyse data

Once all the necessary information has been collected, the data can finally be consolidated, visualised in a way that is easy to understand and then analysed. Data analysis involves processing and interpreting the information to gain insights and extract meaningful patterns. The following steps should be followed:

1. **Data consolidation**: Gather all the data collected by each team, including dumpsite locations, descriptions, photographs and any other relevant details. This will require obtaining the physical datasheets and/or exporting or syncing the data from the mobile application to a central database.
2. **Data coding**: Add all the data into a single spreadsheet or data management tool. Categorise the data based on variables such as location, dumpsite size, types of waste, etc.
3. **Data cleaning**: Review data for any errors or missing information and ensure that it is organised and structured for analysis.
4. **Spatial analysis**: Utilise GIS software or online mapping platforms to perform spatial analysis. This involves overlaying the dumpsite locations onto a basemap and examining spatial relationships with land-use patterns and other geographic features to understand the drivers of dumping and the potential environmental impacts of dumpsites. For example, dumpsite location, size or frequency may be compared with residential density, income levels, access to waste removal

services, and proximity to roads and waterbodies.

5. **Extract relevant data**: Take relevant data from the spatial analysis e.g. residential density or proximity to waterbodies, and add it to the spreadsheet from step 2.
6. **Interpretation**: Analyse the results and interpret the findings. This can be done by looking for patterns, trends or clusters of dumpsites (hotspots) that can provide insights into waste disposal behaviours, factors influencing dumpsite locations, or potential environmental vulnerabilities.
7. **Data visualisation**: Create visual representations of the data using graphs, charts or maps (**Figure 9**). To make a comprehensive map of dumpsites, import the data into GIS software and match the GPS coordinates to their corresponding dumpsite information (e.g. size, content, accessibility). Customise the map by adding relevant symbols or icons to represent dumpsites. Interactive maps are effective tools to engage local communities and authorities in clean-up efforts. Visualising the data aids in identifying patterns, trends and hotspots, and helps to communicate findings in a simple format.
8. **Reporting**: Prepare a report summarising the data analysis results, key findings and recommendations. Reporting is an important step to notify funders, local governments and other stakeholders of the findings of the project.

Refer to **Appendix 7** for a case study on how these protocols were applied to illegal dumpsites in Dar es Salaam, Tanzania. The resulting maps are being used by *Nipe Fagio* to raise awareness and combat waste pollution in the city.

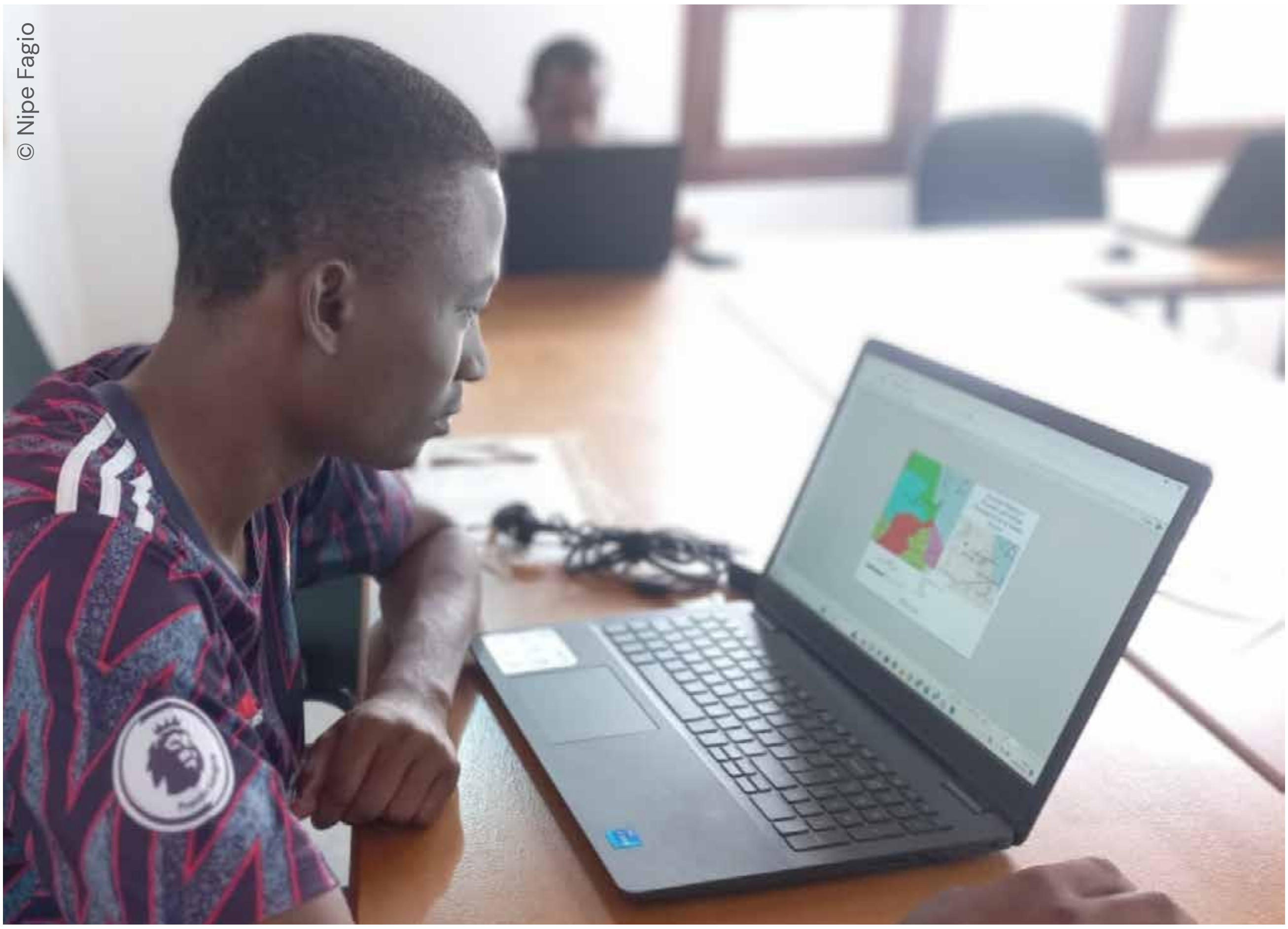

Figure 9: A team member from Nipe Fagio working on a map of dumpsites in Dar es Salaam, Tanzania.

SECTION
INTRODUCTION

LITTER MONITORING IN WATERWAYS

BY TOSHKA BARNARDO, TARA SCHECKLE, KYLE MACLEAN & PETER RYAN

It is estimated that 91% of mismanaged plastic waste, amounting to 73 million metric tons annually, is discarded in drainage basins, where it may be transported via surface runoff into stormwater canals and nearby rivers[1]. A large portion of this litter remains trapped in or along these waterways for years or decades[2–4], where it may break down into microplastics and have repercussions for the surrounding environment and communities. Despite these prolonged retention times, an estimated 0.8–2.7 million metric tons of plastic still reaches the oceans via rivers and canals each year, with urban waterways being among the most polluting[5].

To curb the leakage of plastic into urban waterways and ultimately the oceans, it is important to identify the upstream sources of pollution. This can be done by conducting regular litter surveys at key locations (e.g. near major stormwater outlets) in urban rivers and canals.

These surveys have three functions, namely:

1. Providing information about the amount and type of litter originating within a drainage basin, allowing local stakeholders to intervene to stop pollution at its source;
2. Measuring changes in litter loads over time to determine the efficacy of such interventions;
3. Assisting in estimating the total plastic leakage into the oceans from land-based sources.

The most practical and feasible way to study litter in waterways is to monitor buoyant litter floating at the surface or past predetermined points in a channel. Although the vertical distribution of plastic in waterways is not well understood, 57% of plastic produced[6] has a lower density than freshwater and is expected to float. It should be noted, however, that other factors such as biofouling and the condition of an item may also influence buoyancy. Regardless, a recent study on the Saigon River in Vietnam sampled the upper 1.3 m of the water column and found that nearly 90% of plastic was found in the upper 0.5 m of the water column[7]. Surveys of floating litter are therefore useful to sample a substantial portion of mobile litter in waterways.

Due to the wide range of available sampling techniques, few harmonised methods exist to measure and report floating litter[8]. Simple, cost-effective methods are needed to measure and compare litter loads between sites and over time within and between countries. The choice of method depends on the sampling objectives, the targeted size class of litter, practical limitations and resource availability.

Three approaches to study litter in urban waterways are provided in this section:

- Litter surveys using booms and nets (**Chapter 5**) – where semi-permanent barriers are used to trap, remove and study macrolitter (>25 mm) floating down rivers or canals;
- Trawl surveys for floating mesolitter (**Chapter 6**) – where nets are towed behind a boat to collect floating mesolitter (5–25 mm) at the water surface;
- Visual observations of floating macrolitter (**Chapter 7**) – where floating macrolitter (>25 mm) at the surface of a waterway is categorised and counted from a boat or bridge.

This section does not include a chapter about the STOP-net – a net designed by Sustainable Seas Trust to catch floating litter at the surface of a river from a stationary point on a bridge or boat. The STOP-net technique for surveying floating riverine litter is outlined in the first edition of the *African Marine Litter Monitoring Manual* (Chapter 7) but has been excluded here, as it had limited success in the wide and periodic rivers in Africa. However, these nets may still be useful in narrow perennial rivers with fairly consistent slow to moderate flows.

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LITTER SURVEYS USING BOOMS & NETS

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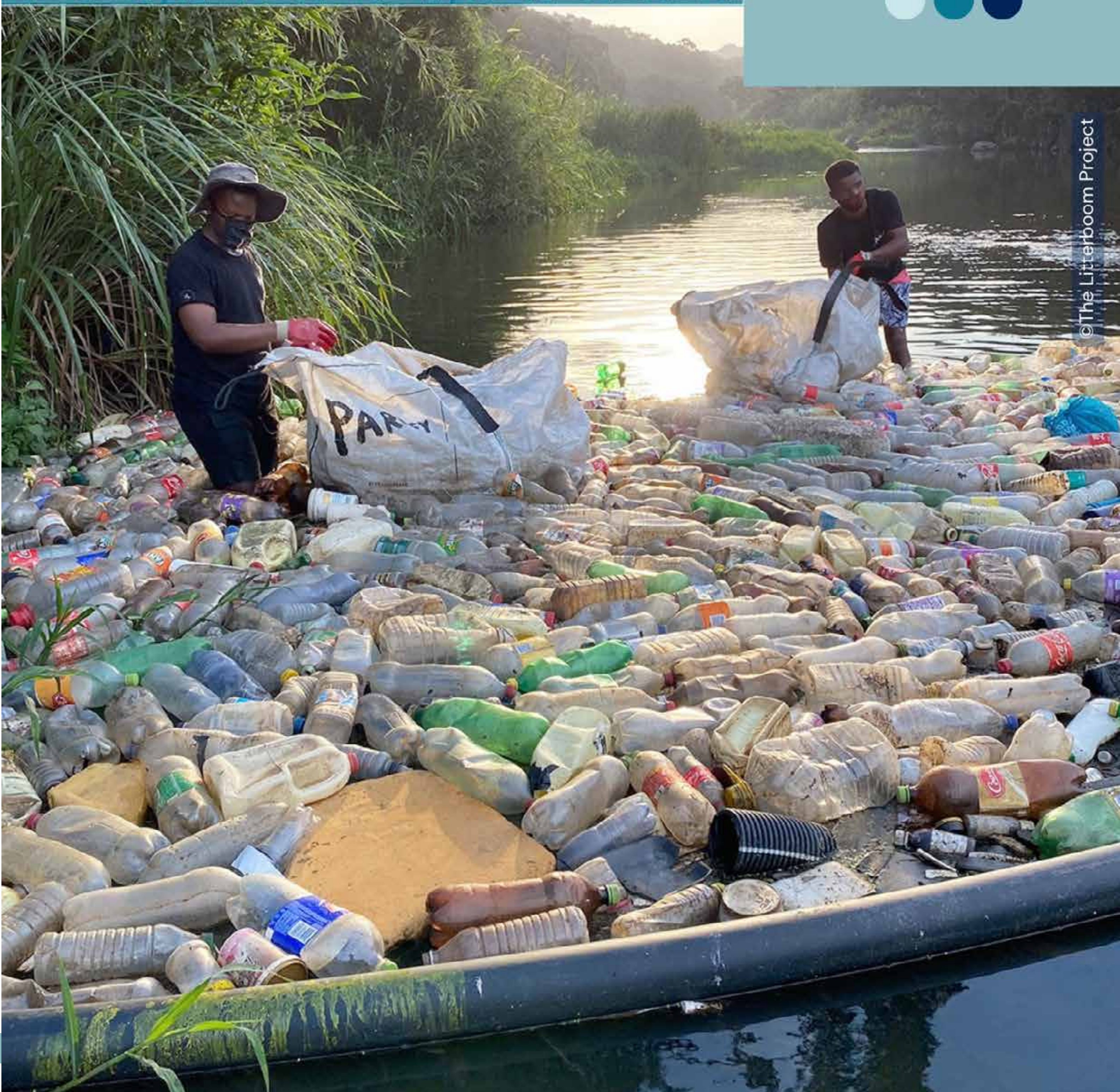
Kyle Maclean, Peter Ryan, Tara Scheckle & Toshka Barnardo



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Introduction

Until the many challenges of solid waste management on land have been resolved, one of the most effective ways to prevent further breakdown and dispersal of urban litter is to trap and remove macrolitter from waterways (i.e. rivers and canals) in cities and towns. Advanced technological devices such as automated watercrafts, bubble barriers and trash wheels have been used to intercept urban litter in some of the world's most polluted waterways (**Figure 1**).

However, these approaches are not feasible across much of Africa, where resources in the form of funding, technical capacity and physical security are limited. As a result, litter-trapping devices used within Africa have been relatively simple and low-tech[1]. These devices (e.g. grids, screens and booms) have been shown to effectively trap litter in African conditions[1–3] (**Figure 2**).

In addition to intercepting urban litter for its safe disposal, litter-trapping devices provide a way to study litter in waterways. Selecting appropriate trap designs is crucial, since each device has different advantages and disadvantages relating to trapping efficiency, costs, and operation and maintenance requirements[4].

This chapter provides various design ideas for litter booms and nets, gives guidance on the most suitable device to trap and monitor litter in different conditions, and explains how to survey litter using these litter-trapping devices.

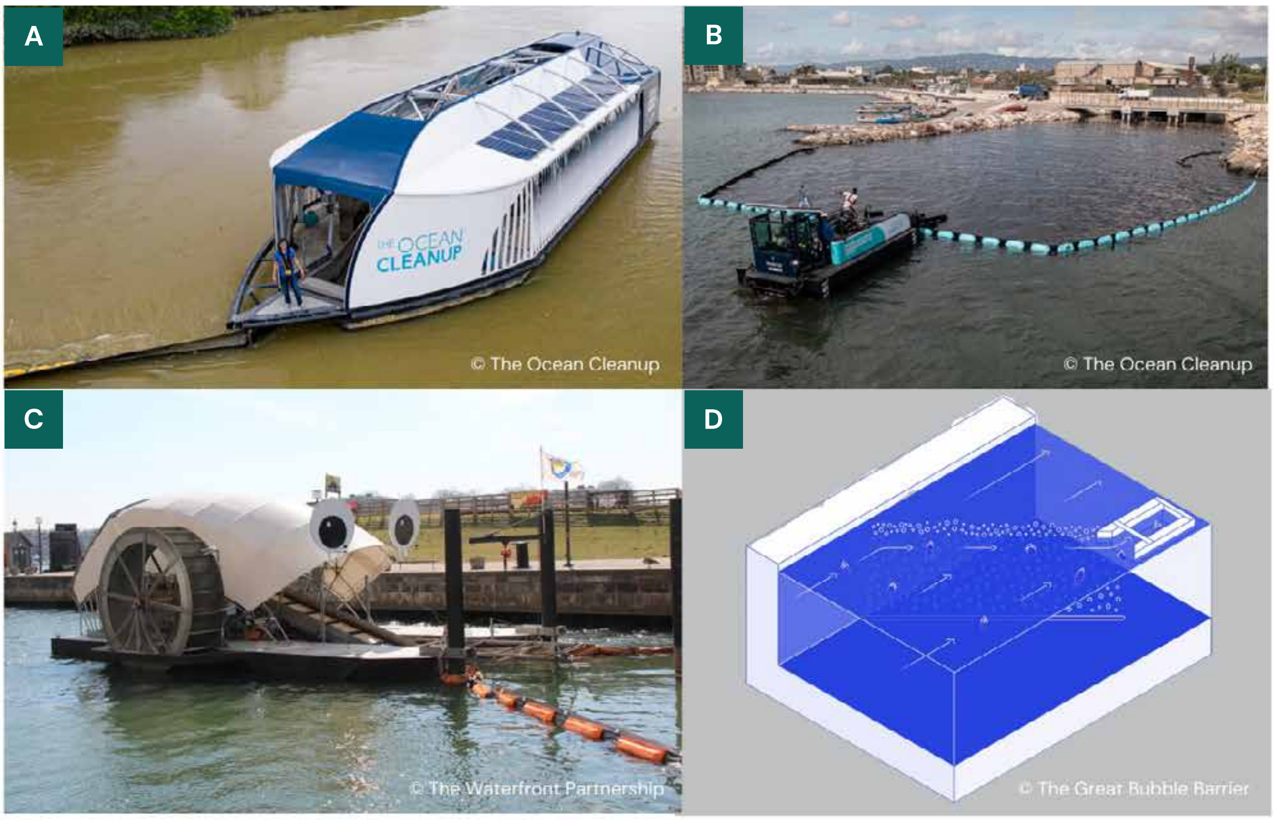

Figure 1: Examples of high-tech devices used to collect litter in waterbodies globally. (A) The Interceptor Original by The Ocean Cleanup uses a floating barrier to direct riverine litter onto a solar-powered conveyor belt that dumps the litter into bins for collection. (B) The Ocean Cleanup's more recently developed Interceptor Barrier and Tender allows the small vessel to service multiple anchored barriers. (C) Mr Trash Wheel, an initiative of The Waterfront Partnership in Baltimore, USA, uses hydropower and solar power to scoop up litter. (D) The Great Bubble Barrier uses air pumped through holes in an underwater tube to form a barrier of bubbles that diverts litter into a collection device.

Figure 2: Examples of low-tech devices used to collect litter in waterbodies. (A) An inclined grid screen installed by the City of Cape Town municipality on a canalised section of a river in Cape Town, South Africa. This system works well under low- to moderate-flow conditions if serviced regularly. However, it may rapidly become blocked during high-flow conditions, requiring an overflow basin with bollards (B) to trap larger debris items. (C) A series of nets with increasingly finer mesh installed by an NGO in Zandvlei, Cape Town. (D) Litter boom installed by The Litterboom Project (an NPO) on the Black River, Cape Town.

Protocols

Litter booms or nets are used as barriers to trap urban litter as it moves downstream in a waterway. After installation, the litter traps are cleaned on a predetermined schedule (e.g. weekly or after rainfall events). During cleaning, litter is sampled by collecting it in bags, while vegetation and other organic material is discarded appropriately. The litter-filled bags are counted and weighed on site, once excess water has been drained, and then taken to a suitable location, where individual pieces of litter can be cleaned, dried, sorted, counted and weighed. The steps of a litter-trap survey are shown in **Figure 3**.

SURVEY PROTOCOL
LITTER SURVEYS USING BOOMS AND NETS

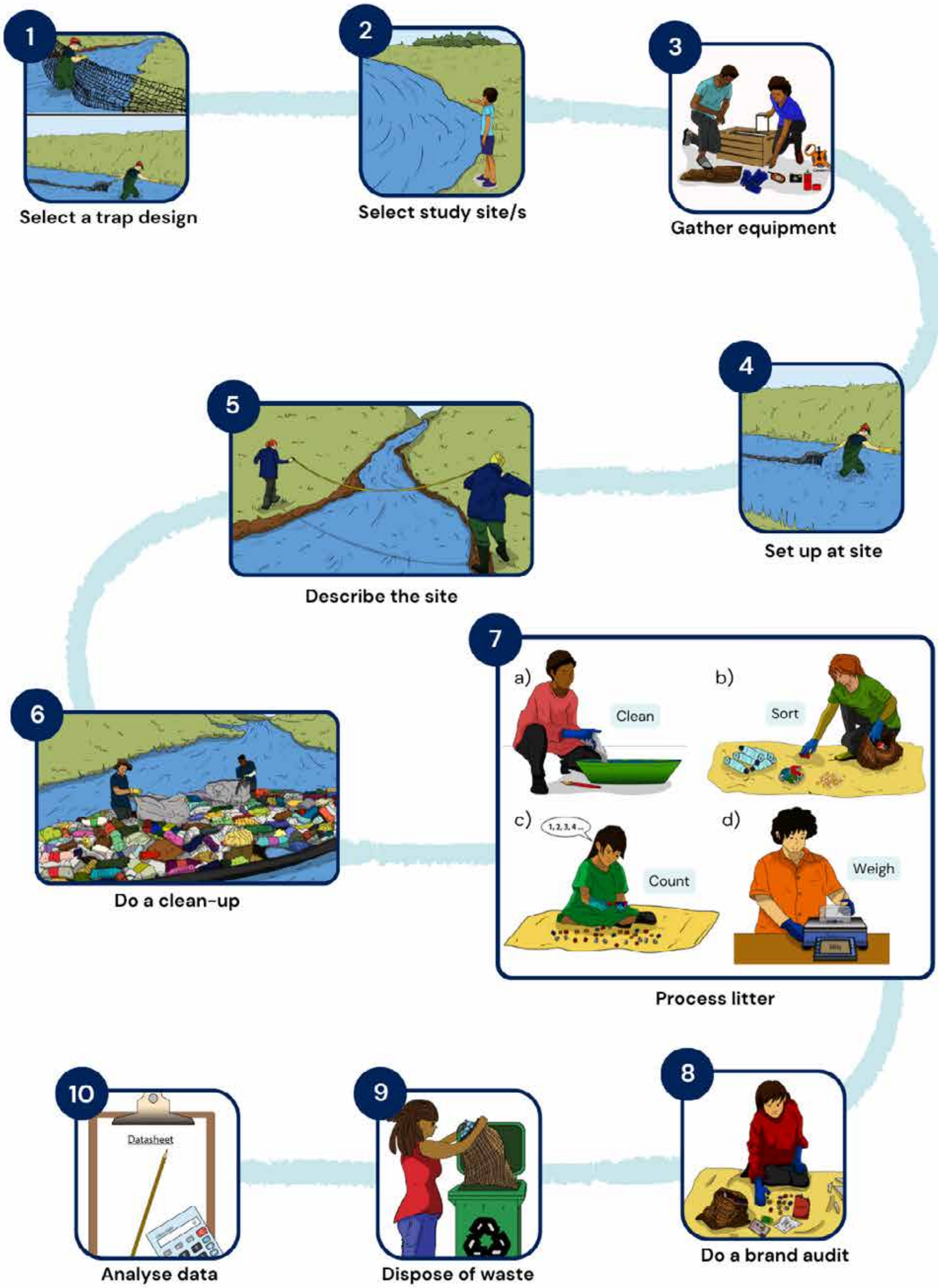

Figure 3: The protocol for litter-trap surveys consists of 10 steps.

Select a trap design

Table 1 outlines the differences between litter booms and nets and indicates when to use each device. Note that various parameters may influence the litter-trapping ability of a litter trap at a given study site, so some trial and error may be needed to find a suitable setup. If surveyors are unsure about which option to use, it is recommended that litter booms are tested first during both low- and high-rainfall periods. Booms are easy to install and can be made from repurposed materials. If booms are then found to be unsuitable for the study site, some of their components (e.g. rope, steel rods or other securing mechanisms) can be repurposed for a net. Various boom and net designs are provided in this section.

Litter boom designs

Litter booms are among the simplest and most affordable litter-trapping devices used in waterways. These floating barriers extend across a channel or surround a stormwater outfall to prevent floating plastics and other buoyant litter from continuing downstream. Installing the boom at an angle across a channel directs litter into the slow-moving waters against the bank, where it can be easily removed. This design type requires minimal upkeep and management, reduces the risk of theft and poses little threat to the environment. During high-flow events, trapped litter may escape from booms or may increase the risk of flooding to surrounding properties, although the anchors on the banks can be modified to release the booms during such events[5]. The three boom designs presented here have been used successfully in Africa and can be produced at relatively low cost.

1. **High-Density Polyethylene (HDPE) pipe**: This piping material, typically used for irrigation, can be purchased at agricultural and plumbing stores. The

Table 1: A comparison between litter booms and nets.

	Litter Booms	Litter Nets
Advantages	• Cheap (can be made from repurposed materials) • Easily movable • Easy to install • Low maintenance • Low environmental impact	• Traps buoyant and non-buoyant litter • Useful in turbid waters where booms are not effective • Relatively cheap compared to high-tech solutions
Disadvantages	• Only traps buoyant litter	• More difficult to install • More maintenance required • May obstruct animal movements in natural rivers • Not easily movable
Ideal conditions for use	• Wide rivers • Deep water • Slow-flowing water	• Rocky rivers • Shallow waters • Turbid rivers • Canals
Non-ideal conditions for use	• Rocky rivers • Shallow waters • Turbid rivers	• Wide rivers • Deep water

Figure 4: An HDPE pipe boom installed by The Litterboom Project in South Africa.

Figure 5: A plastic bottle boom uses empty plastic bottles as floats.

Figure 6: A plastic bottle boom with a mesh curtain weighed down by rocks.

pipe will need to be sealed shut on both ends so that it is airtight and will float above the water surface (**Figure 4**).

2. **Plastic bottle boom**: Empty 5 L or 2 L plastic bottles are used as floats within a mesh tube (**Figure 5**). One row of 5 L bottles or three rows of 2 L bottles will ensure that the boom is sturdy and buoyant. It may be necessary to put some water in the bottles to weigh down the boom, allowing it to sink slightly below the surface of the water.
3. **Plastic bottle boom with curtain**: This boom is similar to the previous one but includes a weighted mesh net hanging as a curtain in the water column below the boom to retain litter floating below the surface (**Figure 6**). Strongly flowing rivers will need heavy weights to ensure that the curtain remains perpendicular to the flow of water. It is recommended that the curtain extends to a depth of 50 cm, since a large portion of buoyant plastic floats within 50 cm of the water surface[6]. However, shorter curtains may be needed in shallow rivers to allow the movement of animals below the boom.

Litter net designs

Netting in litter traps is typically used in two basic designs: litter nets or 'socks' over stormwater outlets (see **Pristine Earth Collective**), and net barriers across a channel. While litter socks are useful to monitor urban litter[7], they require regular maintenance and cleaning to prevent tearing and flooding. It can also be difficult to get permission from the relevant authorities to install such traps due to the flood risk. The following section therefore focuses on litter traps using net barriers.

Net barriers are attached on either side of a channel and extend above and below the water surface to capture litter as the water level changes. These litter traps are relatively low cost but require more maintenance than booms to prevent breakage or flooding and may have a greater impact on animals living in rivers. Typically, the net extends to 50–100 cm below the water surface. The bottom of the net can be weighed down using weights or may be bolted in on either side of a concrete channel. The height of the net above the water depends on the water level during rainfall conditions. Ideally, nets should not extend more than 2 m above the water surface (**Figure 7**).

It is recommended that at least two nets are installed in series, with nets of a large mesh size (e.g. 10 cm) used upstream and a smaller mesh size (e.g. 2.5 cm) downstream. This will help to reduce the strain on each individual net.

Figure 7: The bottom of a litter net in Gqeberha, South Africa, is secured with concrete blocks. Note that the net is reinforced with wire at the top and in the middle.

**For more details about boom or net equipment, assemblage and installation, please contact the authors of this chapter.*

Select study sites

As discussed in **Chapter 2** (*A Guide to Litter Monitoring in Africa*), the research questions will determine where surveys need to be conducted. It is therefore important to consider that litter amounts and composition may vary along the course of the waterway due to different types of land-use, socio-economic status and population density. Furthermore, the amount of litter transported and trapped downstream will likely vary based on the physical characteristics of the waterway (e.g. the presence of stormwater outlets and other wastewater inputs, as well as the site topography). The general considerations for selecting sites to study litter in urban waterways are provided below. It is best to have multiple study sites to be able to compare and interpret results.

Study site features

Key features that need to be identified at a study site (as shown in **Figure 8**) are:

- **Anchor points**: The points where booms or nets are secured on either side of the waterway. Anchor points must be placed above the normal water level (the water level under normal flow conditions). The anchor points, as well as the booms and nets themselves, must be able to withstand the large forces associated with flowing water and trapped litter and organic matter.
- **Accumulation point**: The point where litter is expected to accumulate based on the angle of the boom or net. The accumulation point should be easily accessible to facilitate litter removal.
- **Floodline**: The water level typically reached during relatively frequent flooding events. It is recommended that booms and nets extend above the normal water level (to capture litter when the water rises during rainfall events) but below the floodline (to avoid flooding or breakage of equipment during strong flows).

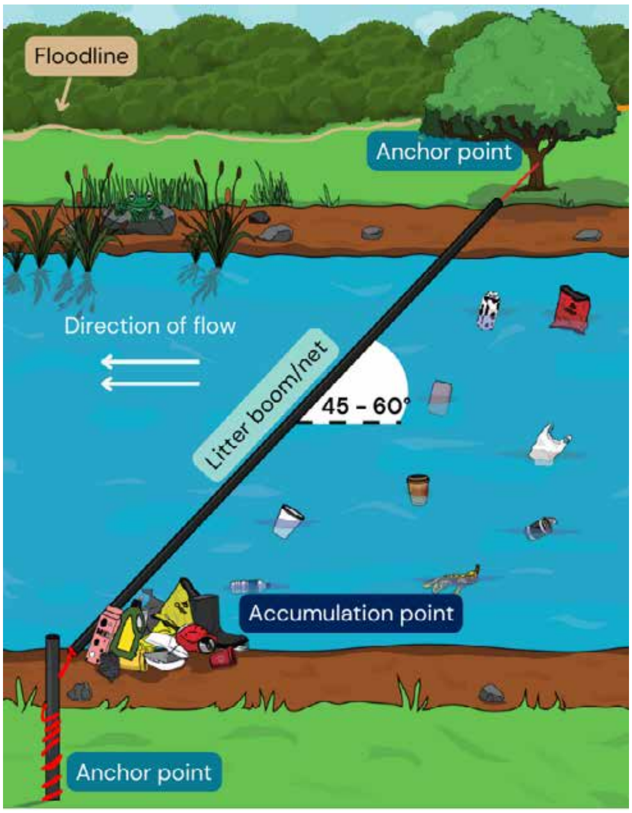

Figure 8: Schematic of a litter boom/net installation for trapping riverine litter.

Study site considerations

Ideally, study sites for litter boom and net surveys should meet the following requirements:

- **Water depth**: Waterways should be deep enough to ensure that the boom or net does not rest on the bottom. This allows aquatic animals and non-buoyant objects to move beneath the litter trap. The water should be shallow enough for safe standing while cleaning the trap, unless all litter in the accumulation zone can be collected with a long-handled pool net without entering deep water.

- **Flow velocity**: The flow of the water should be fast enough to transport litter towards the boom or net (at least 0.1 m/s). Note that the flow can vary greatly depending on the amount of rain and the hydraulic characteristics of the waterway, influenced by natural topography and artificial structures. Litter traps need to be secured to withstand the forces associated with moderate flows. However, no attempt should be made to capture litter during high-flow conditions as this may break the equipment and damage the surrounding infrastructure and/or environment. It might be necessary to temporarily remove installations if extreme rainfall events are forecast, to avoid loss of equipment.
- **Bank slope/height**: Riverbank slopes should be relatively gentle to ensure easy access to the litter accumulation point. In the case of vertical canal walls, these should be low enough to allow effective litter sampling.
- **Access to sites**: The study sites should be accessible year-round, ideally with road access to avoid the need to carry heavy litter samples over great distances. If a permit or authorisation is required to access a study site or to secure attachment points, this must be arranged before installation.
- **Absence of clean-up activities by third parties**: No regular clean-up activities should take place at or upstream of the potential site where the litter trap is to be installed.
- **Safety**: Surveys should not be conducted in areas that may pose a risk to surveyors (crime, very strong water flow, dangerous animals, etc.).
- **Low environmental impact**: Surveys should not be conducted at sites where sampling may pose a risk to endangered or protected habitats and species. Care must be taken to select a trap design that is not damaging to the local ecosystem and infrastructure. For example, some trap designs may obstruct the movement of fish, frogs and large invertebrates in shallow rivers. Protected tree species should not be used as anchor points because this may damage the tree.

Gather equipment

A printable checklist of the equipment needed to conduct litter surveys using booms and nets in waterways is provided in **Figure 9**.

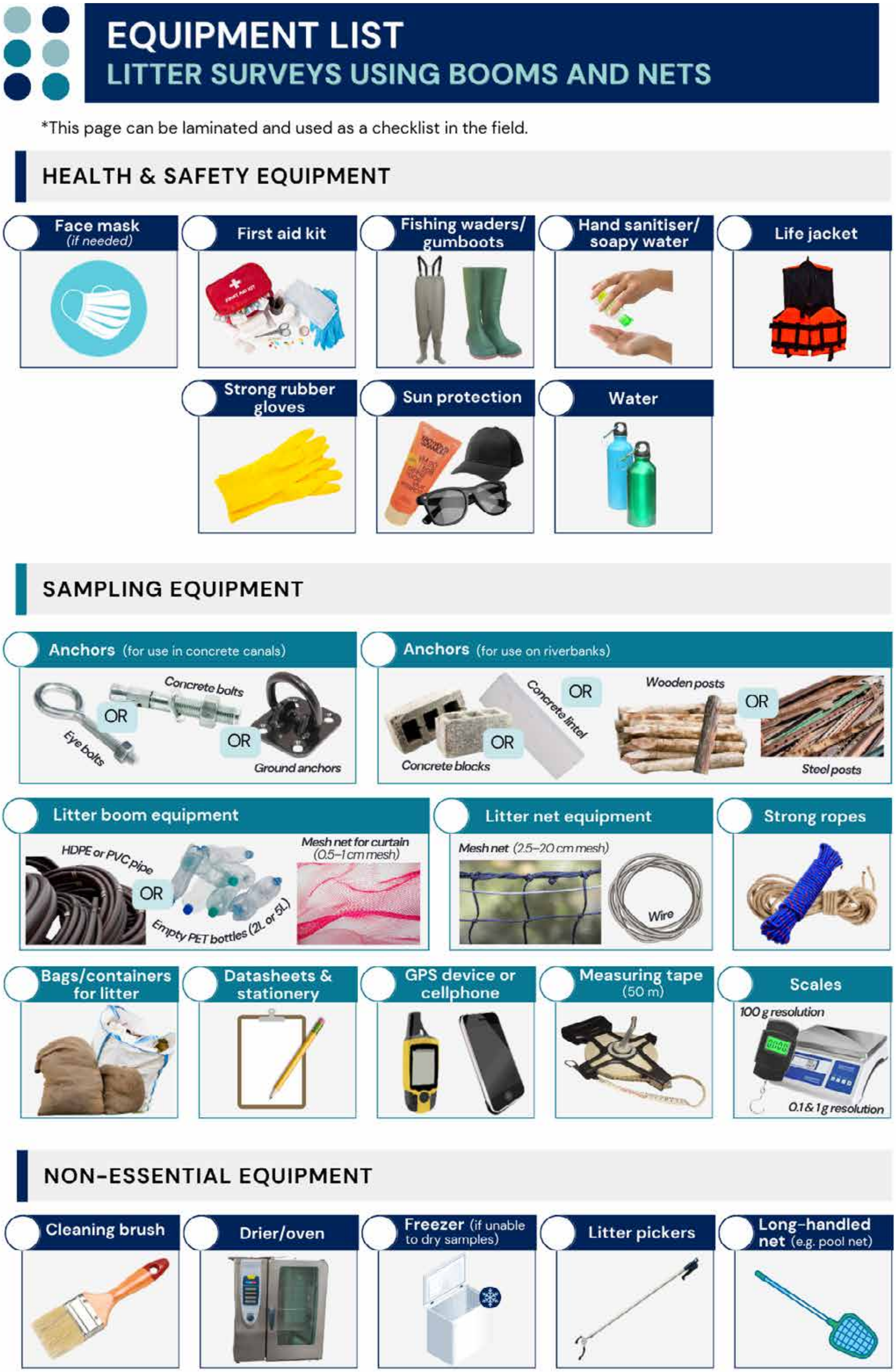

Figure 9: A printable checklist of the equipment needed to trap and study litter using litter booms and nets.

Set up at the study site

When installing the boom/net, it is recommended that it be placed at a 45–60° angle to the flow of water (**Figure 10**). This will help direct the litter to a suitable collection point near the edge of the waterway and make it easier and more efficient to remove the litter. The total length of the trap (excluding ropes) should be ~40% longer than the width of the waterway to ensure that the device extends from one side to the other at the required angle. Booms/nets must be anchored on either side of the waterway below the floodline but above the normal waterline to allow the device to rise with increased flow.

The type of anchoring method used will depend on the features of the waterway and the type of device used. For example, the rope from the boom/net can be tied around a weight and buried (**Figure 11**). Concrete lintels are preferred as weights because they are relatively cheap. The weight should be buried at least 1 m above the normal high-water mark (the water level during normal rainy periods) to avoid it being pulled out of waterlogged sediment. Other options include securing the ropes from the trap to a metal pole/rod hammered into the ground, to a tree on the riverbank, or to eye bolts (see **Figure 9**) drilled into the canal walls.

Figure 10: By placing the boom/net at a 45–60° angle, litter is directed to one side of the waterway, reducing drag force on the trap and making it easier to clean.

Figure 11: Workers anchoring a litter boom by attaching it to a boulder, to be buried in the bank above the floodline.

Describe the study site

It is important to collect information about the study site to help understand trends or patterns in the survey results. See **Datasheet 7** (*Site Description: Waterways*) for the information needed to describe the site (e.g. GPS coordinates, channel width, the presence of stormwater outlets, the nearest town). For long-term monitoring, this datasheet should be completed once every six months to detect any changes in site characteristics.

Changes in weather conditions and activities or factors that may influence litter accumulation are also important to note. **Datasheet 2** (*Daily Site Conditions*) should be completed at each sampling event. The occurrence of heavy rain or strong wind in the preceding days should be recorded in the Comments/Notes box.

Measuring water flow rate

The water flow rate (the amount of water transported over time) is calculated by multiplying the area (m^2) of the channel by the water velocity (m/s). Channel area is determined by measuring the average water depth at the study site and multiplying it by the channel width. Water velocity must ideally be measured using a flow meter placed on the underside of the boom/net. Alternatively, an orange peel/stick can be used to measure crude velocity at the time of sampling, as detailed below:

1. Measure a 5–10 m line parallel to the channel and mark the start and end points.
2. Drop a stick/orange peel upstream of the start point and once it reaches that point, start the timer.
3. Stop the timer as soon as the stick/orange peel reaches the end point.
4. The water velocity is calculated by dividing the distance (m) by the time (s) taken for the stick/orange peel to travel between the start and end points.
5. The water depth, width and velocity must be measured weekly or at each sampling event and recorded in

Datasheet 2. Water flow rate is then calculated using the following formula:

$$Flow\ rate_{(m^3/s)} = Velocity\ x\ (Depth\ x\ Width)$$

Do a clean-up

When to clean

Since rainfall is a key factor determining litter input in waterways and subsequent transport downstream, sampling schedules should be closely linked to rainfall patterns and flow conditions. Furthermore, traps in heavily polluted waterways will likely need to be cleaned frequently, as litter may accumulate rapidly. There is therefore no one-size-fits-all rule on when to sample in waterways.

Surveyors will need to do a trial installation and monitor the net or boom under all weather conditions for a few weeks to find a suitable sampling schedule. During dry periods and/or low-flow conditions, cleaning and sampling may be done less frequently but at consistent intervals. For sites with constant high flow or during rain events, the traps will need to be cleaned regularly to prevent a build-up of litter, which risks causing local flooding and/or breakage of the equipment. A typical sampling schedule in a waterway with low flows or small volumes of litter would be:

- **During dry periods**: Clean-ups either once per week or every two weeks, depending on the site. An initial clean-up of the trap is needed before starting with the regular sampling. Litter collected during the initial clean-up can be discarded without further analysis as this clean-up only serves to clean the trap for the coming accumulation surveys.
- **During rainfall events**: An initial clean-up the day before the rain starts, followed by daily clean-ups until the rain stops, unless this is not possible due to safety concerns. As with surveys during dry periods, the litter collected during the initial clean-up may be discarded without further analysis.

It is important to monitor weather forecasts and prepare for high litter loads in stormwater associated with rainfall events. Consideration should be given to removing the devices temporarily if extreme weather is predicted, to avoid equipment loss or breakage.

What to clean

The simplest and most efficient way to clean a litter trap is to remove all items caught by the trap and to separate litter from natural items (**Figure 12**) at the site but away from the water. Macrolitter (>25 mm) can then either be processed on site or placed in bags/containers for processing at a secondary location. Natural items and litter <25 mm should be disposed of responsibly.

Litter items that are too large (e.g. tyres, ropes, nets) or dangerous (e.g. chemicals, weapons, ammunition) to remove should be counted but not handled. Mark these items with paint or photograph them to ensure they are not counted again in future surveys. The weights of heavy or large items can be estimated by multiplying the estimated volume of the item by the density of the material as per **Appendix 2**. Notify the relevant authorities of any large or dangerous items so they can be safely removed.

Used hygiene objects such as diapers, condoms and feminine hygiene products

NATURAL ITEMS VS LITTER

Figure 12: Only remove litter items during surveys. Natural items must not be removed.

can be removed, noted and disposed of responsibly. During litter processing, a clean and dry proxy can be used to estimate the weight of any unsanitary item recorded at the site (see **Appendix 2**).

Process litter

Litter processing refers to the cleaning, sorting, counting and weighing of litter. There are two different ways to process litter after collection. These are *routine monitoring* (for quick and simple surveys) and *intensive sampling* (for more detailed studies). The difference between routine monitoring and intensive sampling is outlined in **Figure 13**.

It is recommended that the routine monitoring approach is used for regular clean-ups of the litter traps (e.g. once a week), especially when resources are limited. This approach is quick and easy to conduct, but only provides broad trends in the amount of litter transported down the waterway. Intensive sampling can then be used once a month or during rainfall events to gather more detailed information about litter at the study site. Ultimately, the decision on which approach to use will depend on the research questions, the pollution level and the available resources.

After the clean-up, all bags of litter need to be counted and weighed to the nearest 0.1 kg

LITTER TRAP SURVEY APPROACHES
ROUTINE MONITORING VS INTENSIVE SAMPLING

	ROUTINE MONITORING	INTENSIVE SAMPLING
Used for	Quick, simple surveys	Detailed surveys
Low-flow sampling schedule *(during drier periods)*	Once a week or Once every two weeks	Once a week or Once every two weeks
High-flow sampling schedule *(during rainfall events)*	Daily	Daily
Record total litter volume *(number of refuse bags filled)*	Yes	Yes
Record litter wet weight	Yes. Each litter-filled bag is weighed.	Yes. Each litter-filled bag is weighed.
Categorise and count each piece of litter	No	Yes. All or some of the litter is categorised and counted.
Record litter dry weight	No	Yes. All or some of the litter is cleaned, dried and weighed.

Figure 13: Differences between routine monitoring and intensive sampling for litter traps. Routine monitoring is recommended for regular check-ups on traps (e.g. once a week), while intensive sampling can be done less frequently (usually during rainfall events).

using a luggage scale. When determining the wet weight of litter in the field, bags must be drained to remove as much excess water as possible. For intensive sampling, all or some (i.e. a subsample – see **Appendix 2**) of the bags must be taken to a suitable location for further processing.

At the secondary location all pieces of macrolitter in the sample or subsample must be processed. The detailed methods for litter processing are provided in **Appendix 2** and a graphical summary is depicted in **Figure 14**. Macrolitter must be sorted, counted and weighed according to either **Datasheet 4** (*Basic Litter Datasheet* with 36 litter categories) or **Datasheet 5** (*Comprehensive Litter Datasheet* with >140 litter categories). Visual guides for these two datasheets are provided in **Appendix 4** and **5** respectively. **Appendix 6** can be used to measure macrolitter fragment sizes.

Litter dry weight should be measured to the nearest 0.1 g per litter category, although surveyors conducting more detailed, scientific studies may choose to weigh each piece of litter. Ovens can be used to dry litter more quickly (approximately 40°C is recommended). If the litter cannot be cleaned and dried within a week of collection, it can be stored in a freezer to prevent insect infestations and rotting of biological material. The total mass of dry litter per bag can be used to estimate a wet:dry mass conversion factor to more accurately

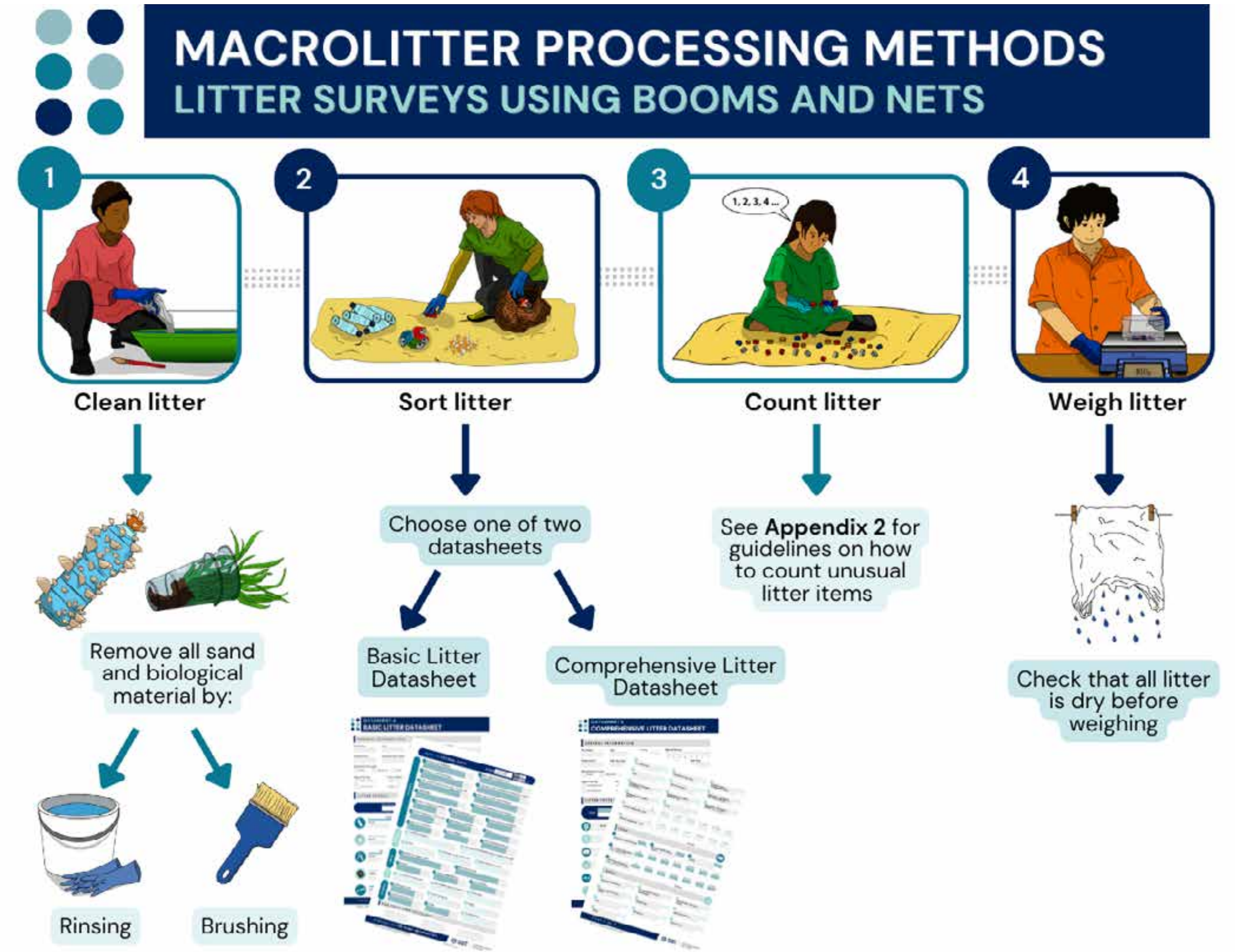

Figure 14: Summary of macrolitter processing methods. See Appendix 2 for a detailed description of the methods.

estimate litter weight from the wet weights obtained during routine monitoring.

Optional: To estimate the trapping efficiency of the litter boom, it is recommended that litter items are measured and categorised into size classes as per **Datasheet 5** (*Comprehensive Litter Datasheet*).

Separate litter datasheets should be completed for each day of the survey. A total of two datasheets must therefore be completed each time a litter boom or net is surveyed:

0. Site Description Datasheet (completed once every six months) – **Datasheet 7**
1. Daily Site Conditions – **Datasheet 2**
2. Litter Datasheet (basic data for routine monitoring and more detailed data for intensive sampling) – **Datasheets 4** or **5**.

Do a brand audit

Most consumer products have information about the product (or the brand owner of the product) printed on them (**Figure 15**).

BRAND AUDITS
IMPORTANT INFORMATION ON BRANDED LITTER

*Figure 15: Brand audit data are useful when addressing plastic pollution. *Recording of manufacture/best before dates is optional.*

The recording of information from branded litter is called a 'brand audit'. The following product information should be recorded in **Datasheet 3** (*Brand Audit Information*):

- Brand name (e.g. Choco-Snow),
- Manufacturer (e.g. Barnadoo International),
- Where the item was produced/ packaged (e.g. South Africa),
- Type of product (e.g. food packaging),
- Type of material (e.g. other plastic [#7]), and
- Number of layers (for plastic items).

Brand audits are recommended during intensive sampling. Surveyors can perform brand audits on branded litter from the entire sample of litter, or from a smaller subsample. The detailed protocols for brand audits are provided in **Appendix 3**.

Dispose of waste

Once the survey has been completed, litter should be disposed of correctly or stored for further analysis. Biodegradable organic waste can be composted, and recyclable materials can go to recycling collection points or material recovery facilities.

Analyse data

The litter flux (amount of litter transported past the study site) is expressed as items/year or kg/year. Litter flux should be calculated as a total (i.e. all litter), per litter size class where feasible (2.5–5 cm, 5–10 cm, 10–25 cm, 25–50 cm, etc.), per litter material type/category (e.g. plastic, glass) and/or per litter type (e.g. drink bottle). This allows surveyors and researchers to compare broader results (per category and in total) between sites and over time, while also being able to detect changes in the number and weight of types of litter items over time. Litter loads intercepted by the device(s) can be coupled with rainfall data (amount of rainfall and time since last rain), land-use type and population density to investigate spatial and temporal trends. Results could also be compared with surveys on land, along shorelines and/or in mangroves.

TRAWL SURVEYS FOR FLOATING MESOLITTER

Eric Okuku, Kenneth Otieno, Gilbert Owato, Catherine Sezi Mwalugha, Maureen Kombo, Purity Chepkemboi, Mary Mbuche Chiphatsi & Chrispine Otieno

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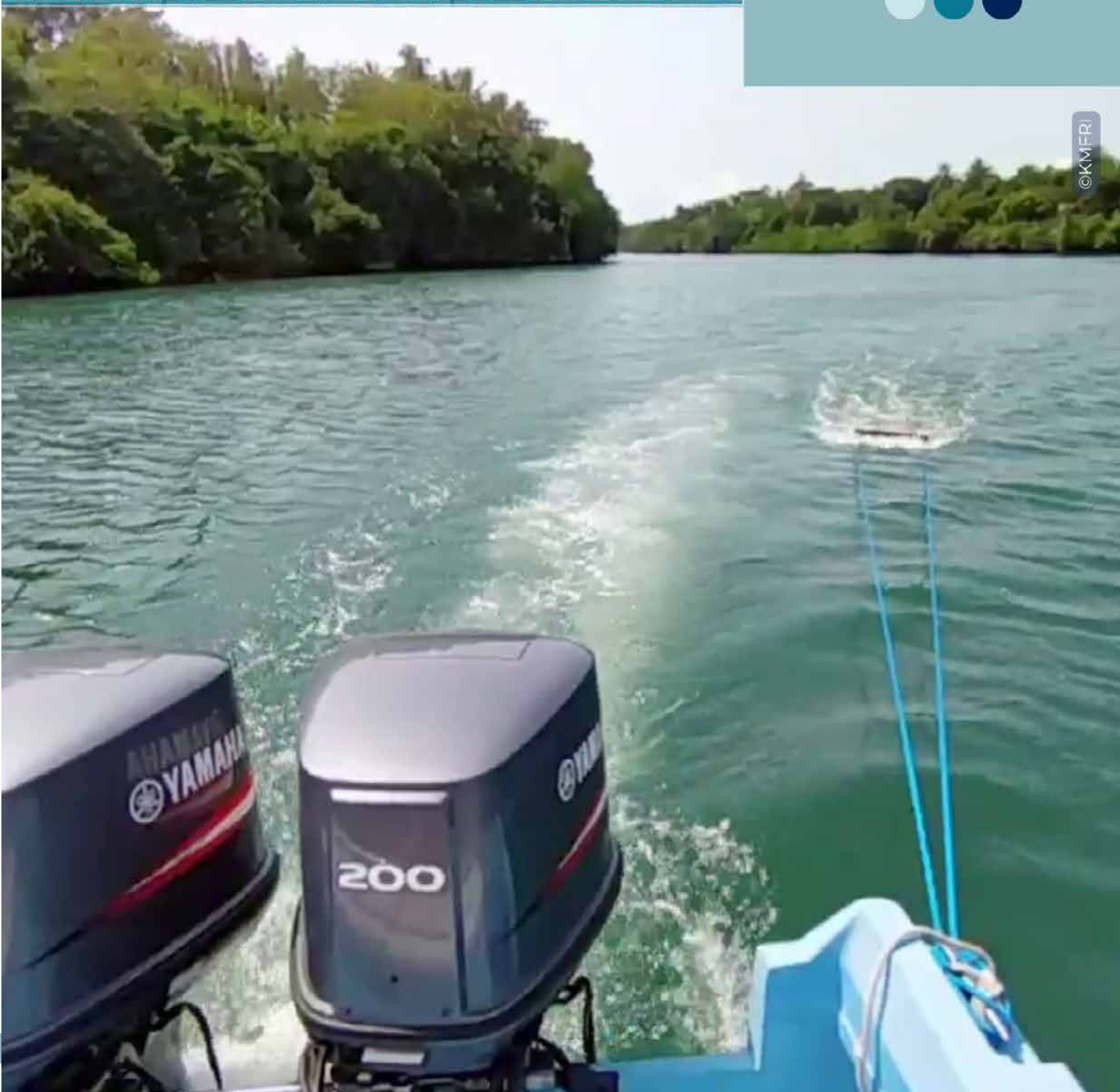

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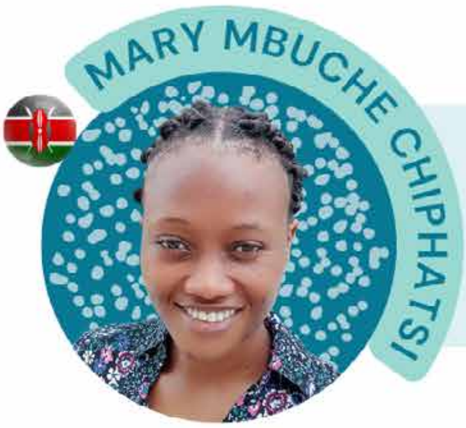

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Introduction

Surface trawling is a common method of litter monitoring that involves towing a net behind a boat to collect floating litter at the surface of a river, estuary or the sea[1,2]. Special nets can be used to collect different sizes of litter[3]. This chapter describes how to use manta nets (**Figure 1**) to collect and study floating mesolitter (5–25 mm).

Manta nets were originally developed to sample plankton, insects and other small biota in surface waters[4] but have since been proven useful for collecting small pieces of floating litter[3,5]. These nets filter large amounts of water, can be deployed from small vessels and are easy to use. Disadvantages of manta nets include the risk of clogging by organisms (e.g. jellyfish, algae) and the need for relatively calm waters to sample effectively. Despite these limitations, manta trawling yields accurate data on the density of floating litter and can be done by researchers and community/citizen scientists in ordinary fishing or recreational boats. Floating mesolitter data can be used to raise awareness and guide waste management interventions and policies by indicating litter sources and hotspots.

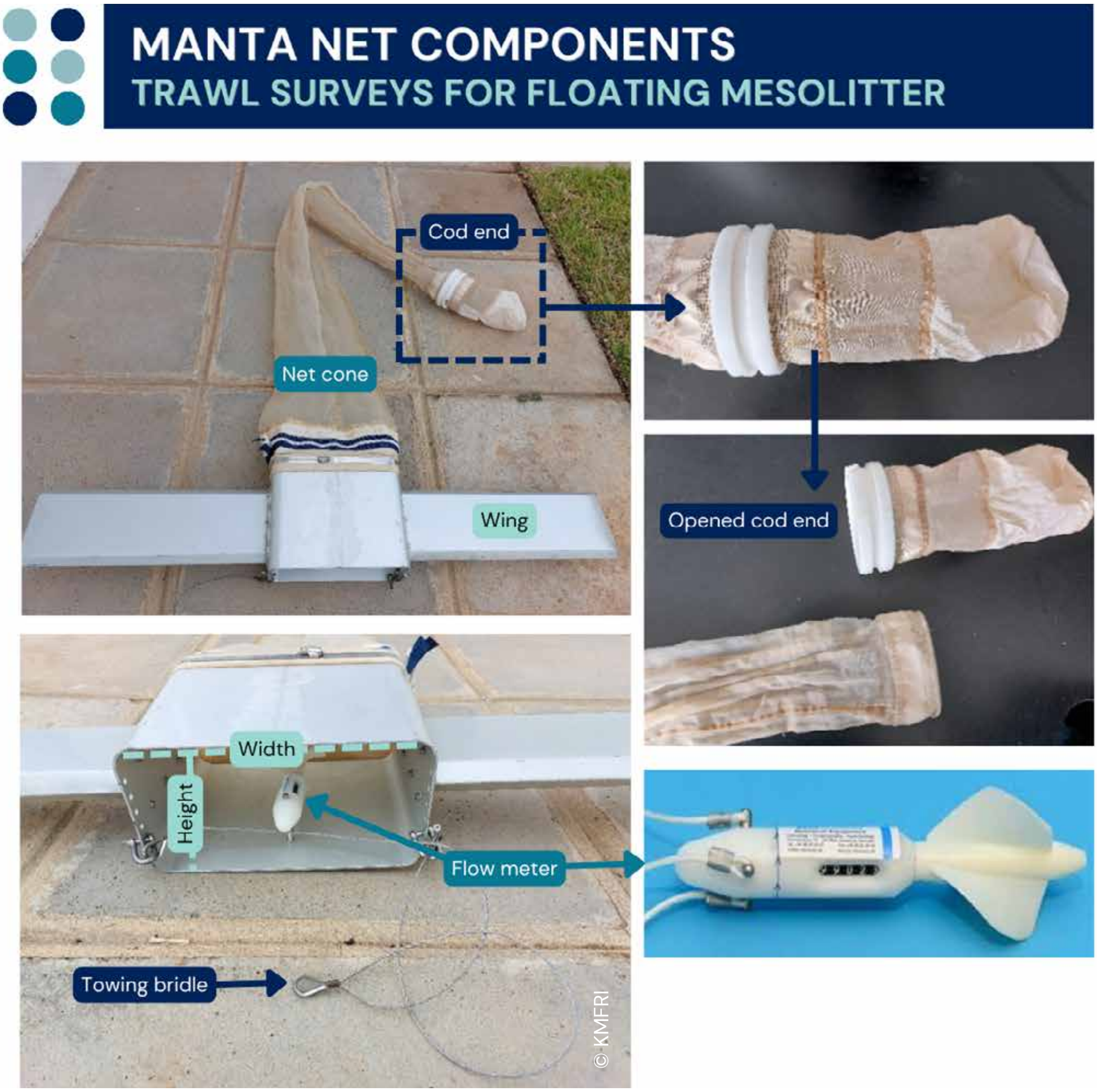


Figure 1: The components of a manta net.

Protocols

Trawl surveys of floating mesolitter involve selecting an appropriate study area that is navigable by the available boat, which is then used to tow a manta net along the waterbody's surface. The collected sample is processed on board to remove large pieces of natural material before processing (sorting, cleaning, counting and weighing) the remaining sample at another location (e.g. a laboratory). These surveys provide an estimated concentration (items/m^3 or g/m^3) of floating mesolitter at the study site.

Figure 2 provides a summary of the basic steps involved in floating mesolitter surveys using boats.

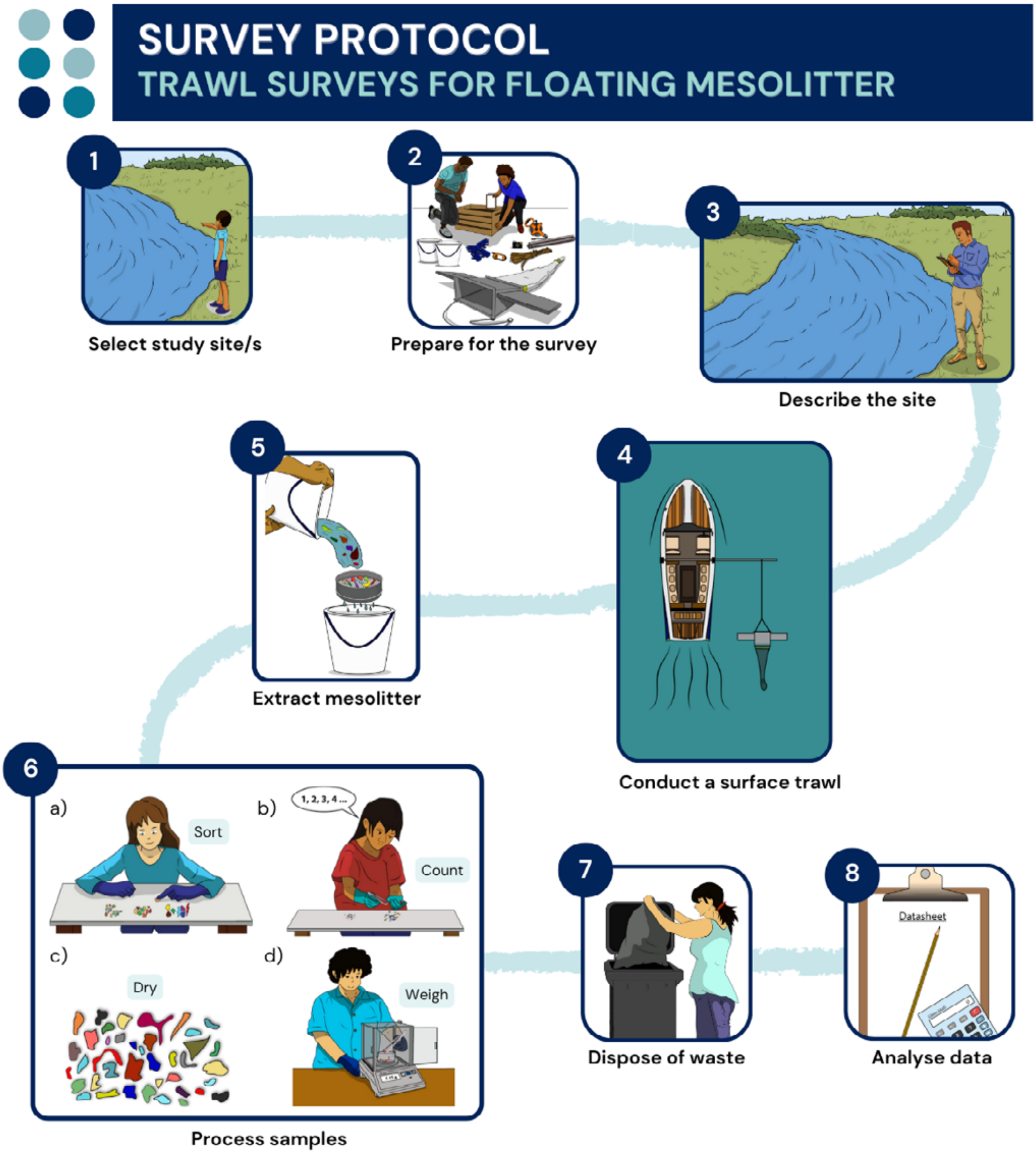


Figure 2: The protocol for surface trawl surveys for floating mesolitter consists of eight steps.

Select study site(s)

Considerable care must be taken to select an appropriate study site. Site selection will depend on the objective of the trawl survey programme (e.g. long-term monitoring or once-off survey). Ideally, multiple different sites should be studied to compare and interpret results. Potential study sites for comparative purposes include river/estuary mouths versus coastal waters, urban versus rural coasts, nearshore versus offshore sites, harbour/bay areas of touristic versus commercial traffic, and inland lakes/dams receiving runoff from urban versus rural areas.

Surveyors must ensure that they can feasibly survey the chosen study site(s) – especially for monitoring projects where regular surveys are necessary. It is therefore important to carefully consider the location of the study site, frequency of surveying and number of replicates needed. All decisions regarding site selection should be related to the research questions of the study. Since the characteristics and distribution of floating litter typically show spatio-temporal variation, multiple replicate trawls are recommended per site for more reliable concentration estimates.

Study site considerations

The following aspects should be considered when selecting study sites:

- **Accessibility**: Ensure that study sites are easily accessible (consider the bathymetry, launching area and protection status of the site). The water must be deep enough to navigate in the available boat and there should be no subsurface obstacles (e.g. boulders or shipwrecks) that could hinder safe travel. Any permit or authorisation that is required to access a study site must be obtained before the survey.
- **Low environmental and social impact**: Surveys should not be conducted at sites where sampling may pose a risk to endangered or protected habitats and species. Surveyors may need to avoid areas where they might disrupt normal activities of aquatic species or endanger themselves, such as trawling through a herd of hippopotamuses. They should also have consideration for other people who are using the site for economic or recreational purposes.

Prepare for the survey

Thorough planning is required to prepare for surveys. Relatively calm waters are needed to effectively collect floating mesolitter, so surveyors must check the weather forecast to avoid sampling in unsuitable weather (e.g. heavy rain and strong winds). Use the link provided here to determine the sea state (relating wind speed to wave conditions) and only proceed with surveys if conditions are between 0 and 3 on the Beaufort scale. If weather and water conditions are favourable for trawling surveys, gather the necessary equipment using the checklist provided in **Figure 3**.

Assemble the manta net using the steps shown in **Figure 4** and inspect it for any damage that will have to be repaired. The need for assembly will depend on the type of manta net used, since some come already assembled.

Figure 3: A printable checklist of the equipment needed for trawl surveys for floating mesolitter.

HOW TO ASSEMBLE A MANTA NET

TRAWL SURVEYS FOR FLOATING MESOLITTER

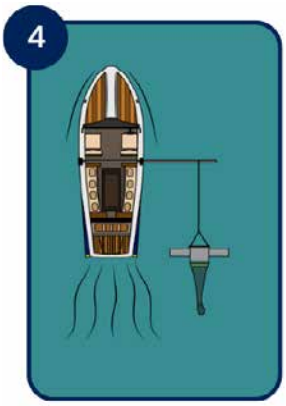
Figure 4: The steps required to assemble a typical manta net.

Describe the study site

Once at the study site, it is important to collect information about the site and prevailing conditions to help understand trends or patterns in the survey results. **Datasheet 7** (*Site Description: Waterways*) and **Datasheet 8** (*Trawling Information*) can be used to describe the site and record relevant information such as:

- Manta net dimensions and mesh size,
- The initial flow meter reading before towing,
- Wind and wave conditions,
- Vessel information (such as the set towing speed, boat colour to allow for easy identification of vessel paint chips contaminating the sample, etc).
- Notes of any material brought along into the working area that may contaminate the sample.

Datasheet 7 must be completed once per sampling trip to reflect changes in site information, while **Datasheet 8** must be completed for each trawl.



Conduct a surface trawl

Preparing for deployment

Once assembled, the net can be prepared for deployment using the following steps:

1. Ensure that the flow meter is turning freely. Note the flow meter constant in **Datasheet 8**. The flow meter constant is the number of revolutions the impeller makes per unit of distance towed (e.g. number of revolutions per metre). If the flow meter constant is unknown, calibrate the flow meter by conducting 20 calibration tows following the towing procedure described in the towing and timing section. The calibration formula below is used to calculate the flow meter constant per tow. The results from all 20 tows must then be averaged and the final flow meter constant recorded in **Datasheet 8**.

$$\textit{Flow meter constant} = \frac{\textit{Trawling distance in metres}}{\textit{Number of flow meter revolutions}}$$

2. Attach the flow meter to the manta net.
3. Confirm that the tow rope is attached to the net.
4. Attach the free end of the tow rope to a strong wooden or metal towing arm either extending off one side of the boat or off the back of the boat (**Figure 5**). Whether deployed alongside the boat or behind it, the net must be towed well away from the boat and its wake because the turbulence may drive marine litter away from the net.

Note: Towing a manta net creates considerable drag force. Always ensure that the towing arm is strong enough and fixed to a firm support, and that all net components are tightly secured.

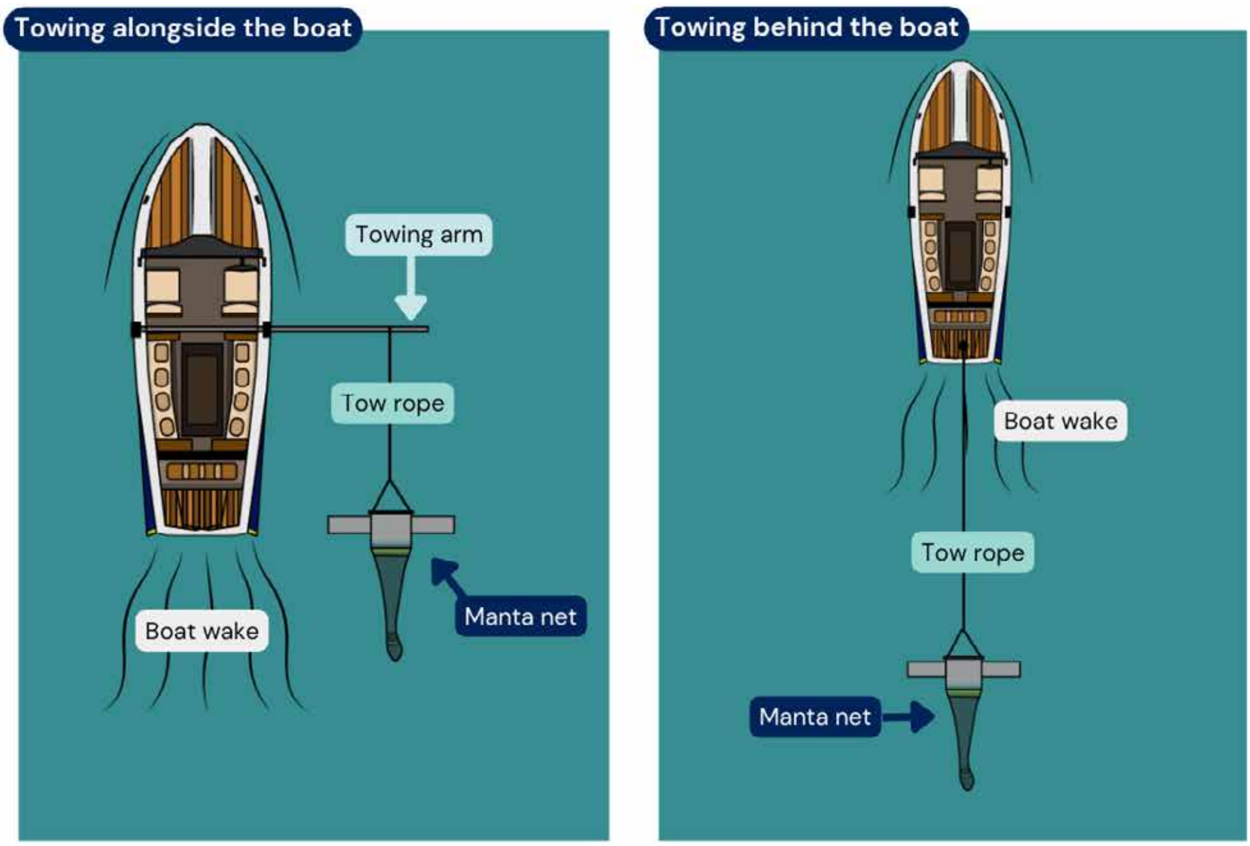


Figure 5: Manta nets can be towed alongside (left) or behind the boat (right), but must be far enough away to avoid any influence of the boat and its wake.

Towing and timing

Ensure that at least two personnel are on hand to perform the following tasks during towing:

1. **Deploy the net**: Release the manta net into the water after the boat has attained 3–4 knots. At the same time, the assistant(s) must start the stopwatch and record the start time and GPS coordinates in **Datasheet 8**.
2. **Start trawling**: Tow the net at 3–4 knots for 15 minutes while ensuring that the net mouth is submerged. Towing in a straight line is recommended to avoid sampling bias, but the path can be altered to avoid obstacles that might jeopardise the safety of personnel and equipment. Tows in narrow channels can be conducted from edge to edge in a zig-zag pattern to achieve a representative sample, as illustrated in **Figure 6**. Towing against a strong current may necessitate adjustment of boat power. Towing with or against the current does not affect the flow meter reading.
3. **Monitor the net for blockages**: Monitor the manta net while towing to identify and rectify anomalies such as blockage, improper floatation, etc. If the mouth of the net is clogged or obstructed, pause the timer, retrieve the net and sample as per step 5, and then redeploy the net (and unpause the timer) to ensure that a full 15-minute tow is completed.
4. **Retrieve the net**: Stop the boat after the 15-minute tow and record the end time and GPS coordinates in **Datasheet 8**. Retrieve the manta net and record the final flow meter reading in **Datasheet 8**.
5. **Retrieve the sample**: Remove the cod end of the net where the floating material has collected and empty its contents into a clean bucket. Wash off the residual contents of the cod end

Figure 6: Zig-zag towing patterns are recommended to collect floating mesolitter in narrow channels.

into the bucket using litter-free water (to avoid introduction of new materials with the water). Proceed to *Extract Mesolitter* to retrieve mesolitter from the collected sample. Repeat steps 1–5 for subsequent and/or replicate tows as per the sampling plan. A minimum of three replicates are recommended per sampling site.

Extract mesolitter

Dealing with organic material

Manta trawl samples will often include a combination of litter and organic material (**Figure 7**), especially in transects that go through patches of aquatic plants or seaweed. These kinds of samples are usually too large to fit into the sample containers. To reduce the size of samples and make them easier to process later, remove large and easily identifiable organic material from the collection buckets containing the contents of the cod end, taking care not to dispose of any litter stuck to it. The following steps should be followed:

1. Pick large bunches of weeds/organic material from the collection bucket and wash them off in a clean bucket of litter-free water by dipping and shaking them in the water to detach any adhering litter. Larger mesolitter can be picked outright and placed into

Note:
1. Record detailed site information as well as any anomalies, changes or problems experienced while sampling.
2. Avoid towing at dusk as the net might get clogged by plankton migrating to the water surface.

Figure 7: The contents of a cod end after trawling for mesolitter.

sample containers. Any animals caught by the net should be released back into the water as soon as they are spotted.

2. Inspect organic material for any stuck litter and remove manually by hand. Once cleared of litter, weeds/organic material should be discarded responsibly.
3. Filter the water in which the organic material was rinsed using a sieve with a 2 mm mesh size.
4. Transfer the contents of the sieves to the sample container.
5. Repeat steps 1–4 until all large items of organic material have been removed.
6. Finally, transfer any mesolitter remaining in the original collection bucket to the sample container. All mesolitter will now have been retrieved.
7. Label the sample container, as for the standard procedure outlined below.

Sieving the sample

After removing the bulk of the organic material, drain the water from the sample by placing a sieve with a 2 mm mesh over a second bucket and emptying the first bucket (the collection bucket) over it (**Figure 8**). Rinse the first bucket with litter-free water to ensure that no litter is left inside. Transfer all items (>2 mm) retained on the sieve into a labelled sample container. The label must contain the site name, date of sampling, tow station and tow number. Samples are now ready to be processed at a secure location on land.

To preserve the samples for processing at a later stage, add 40% ethanol before sealing the sample container. Unpreserved samples must be processed on the same day as sampling. All samples should be stored in cool boxes/refrigerators until processed.

Ensure that all the necessary site information is recorded in **Datasheets 7** and **8** before returning to shore. Once on shore, the manta net should be dismantled and rinsed with plenty of fresh water, using a pressure wash if the net is clogged, and then air-dried before storage. Proceed to the litter processing stage or store samples for future analysis.

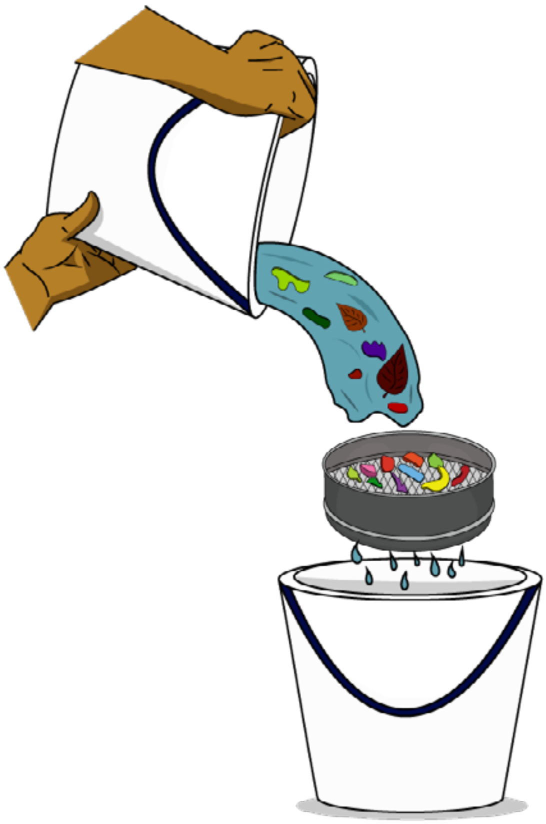


Figure 8: Remove items >2 mm from the water by pouring it over a 2 mm sieve.

Process samples

Mesolitter samples must be processed in a secure location (e.g. a laboratory). Note that samples may contain fine mesolitter fibres and clear plastics that may be difficult to detect. It is therefore recommended that three people sort through each sample to ensure that all mesolitter items are retrieved. This is a means of quality control to improve the accuracy of results. Sorting should be done following the steps below:

1. Transfer the sample into a tray (preferably a white one) for sorting.
2. Rinse out the sample container with clean water and pour the contents into the tray with the sample.
3. Pick out all pieces of mesolitter using metal tweezers or forceps and put them in a clean petri dish.
4. Sort and tally the mesolitter into the categories defined in **Datasheet 9** (*Mesolitter Datasheet: Trawling Surveys*). **Datasheet 10** (*Mesolitter Datasheet: General*) can be used to record more comprehensive data, since it groups mesolitter into more categories.
5. Steps 3 and 4 should be completed by three different observers. Observers 2 and 3 will therefore inspect the same samples to ensure that no pieces of mesolitter were overlooked.
6. Once all items have been counted and recorded, they must be dried before weighing. Litter can be dried using an oven at 40°C for 24 hours or can be air-dried in a well-ventilated room over a longer period, with samples monitored closely to ensure complete dryness.
7. Dry litter should then be weighed per litter category to the nearest 0.001 g (one milligram) using an analytical balance, and the weights recorded on **Datasheet 9** or **10**. Ensure that separate litter datasheets (**Datasheet 9** or **10**) are completed for each sample, with both counts and weights recorded.

A total of two datasheets must be completed for each trawl:

0. Site Description Datasheet (completed once per survey) – **Datasheet 7**
1. Trawl Information – **Datasheet 8**
2. Litter Datasheet – **Datasheet 9** or **10**.

Dispose of waste

Once the survey has been completed, mesolitter should be disposed of correctly. Due to the small size of mesolitter and plastic pellets, recycling may not be possible for most mesolitter. Any remaining biodegradable organic material (e.g. algae) can be composted.

Analyse data

Data from replicates should be aggregated at the site level. The flow meter is used to calculate the distance travelled during each trawl by multiplying the difference between the initial and final readings of the flow meter by the correction factor specific to the flow meter, i.e. Formula 1.

The distance is then multiplied by the area of the net mouth to determine the volume of water filtered, i.e. Formula 2.

Finally, the concentration (items/m^3 or g/m^3) of litter items is calculated, i.e. Formula 3.

Using these formulas, surveyors must calculate litter concentrations for each transect trawled during a sampling event. The results from the replicate transects at the same study site must then be averaged to get the mean concentration of mesolitter at the site.

Formula 1:

$$\text{Distance travelled}_{(m)} = (End_{fmr} - Start_{fmr}) \times \text{flow meter constant}$$

Where: End_{fmr} is the end flow meter reading and $Start_{fmr}$ is the starting flow meter reading.

Formula 2:

$$V_{m^3} = \text{net mouth width}_{(m)} \times \text{net mouth height}_{(m)} \times \text{distance travelled}_{(m)}$$

Where: V is the volume of water filtered, expressed as per cubic metre (m^3)

Formula 3:

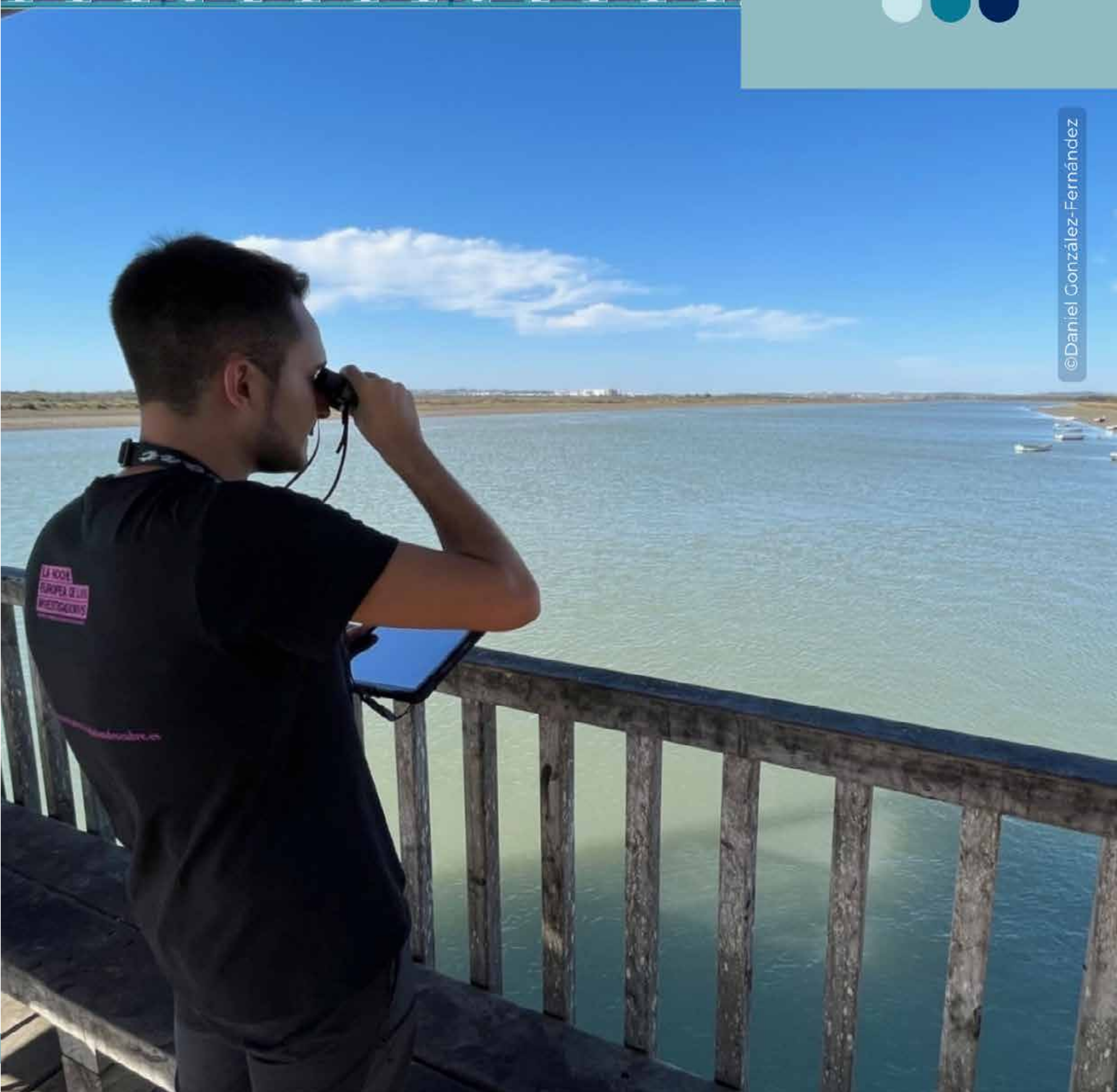
$$c = \frac{n}{V}$$

Where: c is the concentration of litter items (items/m^3 or g/m^3), n is the number or weight of litter items sampled, and V is the volume of water filtered as calculated in Formula 2.

VISUAL OBSERVATIONS OF FLOATING MACROLITTER

7

Toshka Barnardo, Kenneth Otieno & Daniel González-Fernández



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Introduction

The simplest way to quantify floating macrolitter (>25 mm) in a waterway, such as a river, canal or estuary, is to observe and record it as it floats past a vantage point. Methods for visual litter surveys were first developed and used in marine environments[1–3] but have subsequently been adapted for use in other waterbodies such as waterways, lakes and harbours[4,5]. Despite some limitations (e.g. observers only have a small window of time to identify items as they float past and only basic information can be recorded), these surveys are widely used and recommended to collect reliable floating litter data in waterways[4–9].

Visual observations of floating macrolitter are quick and easy as there is no need to collect and process the litter[4]. Accordingly, a greater number and range of sites can be sampled more frequently than alternative approaches relying on physical sample collection (e.g. litter traps or surface trawls; **Chapters 5** and **6**). Visual surveys can be paired with any of these approaches to gather more comprehensive data (e.g. litter weight, type of material, age of litter and brand information)[5,6] and to assess the accuracy of visual observations.

While high-tech alternatives like mounted cameras and drones can be used to observe and identify (using artificial intelligence) floating litter[8,9], these methods are not feasible for citizen scientists and many organisations. Equipment is expensive and at risk of theft if left unattended. As such, in-person observations currently remain the most widely applicable approach to studying floating litter in African waterways. The methods and recommendations described here are mostly based on those successfully used for monitoring floating macrolitter on other continents, where their applicability has been demonstrated in large-scale assessments, such as a regional study to quantify the amount of litter entering the sea from European rivers[7].

Protocols

This chapter outlines two ways to conduct visual observations of floating macrolitter (**Figure 1**). Surveys from a *fixed point* are conducted from a stationary point above or alongside a waterway (e.g. a bridge or anchored boat). These surveys can only be used at sites where litter is transported in flowing water. In contrast, surveys from a *moving boat* are conducted from a boat moving at a constant speed in any waterbody navigable by boat, including those without naturally moving water (e.g. dams or lagoons). These surveys may also be used alongside other sampling methods such as mesolitter trawl surveys.

When doing observations of floating litter, surveyors must categorise and count buoyant litter from above as it passes their vantage point. The observation width (or the track inspected for litter) will differ depending on the approach used and the site characteristics. The protocol for visual observations of floating litter is described below and a summary is provided in **Figure 2**. The recommended methods detailed below can be altered to suit local conditions and needs. A summarised guide on how surveys can be modified is provided in **Figure 10** at the end of this chapter.

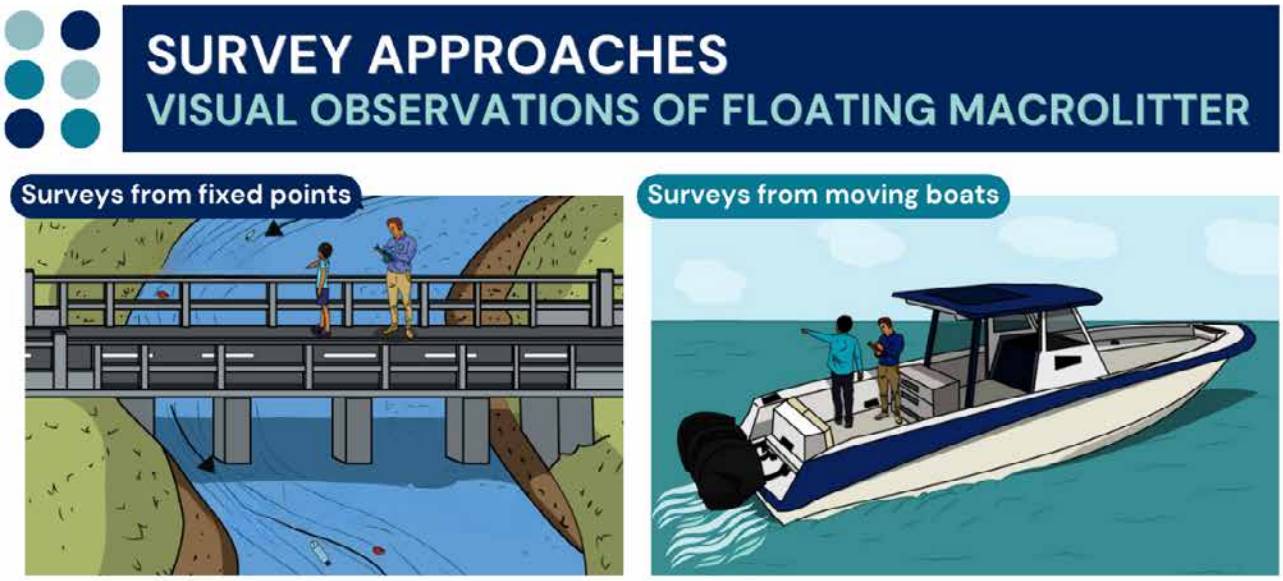


Figure 1: The two approaches most widely used to survey floating macrolitter in waterbodies involve visual observations from fixed points or moving boats. The observation width (or area surveyed) will depend on the approach used and study site characteristics.

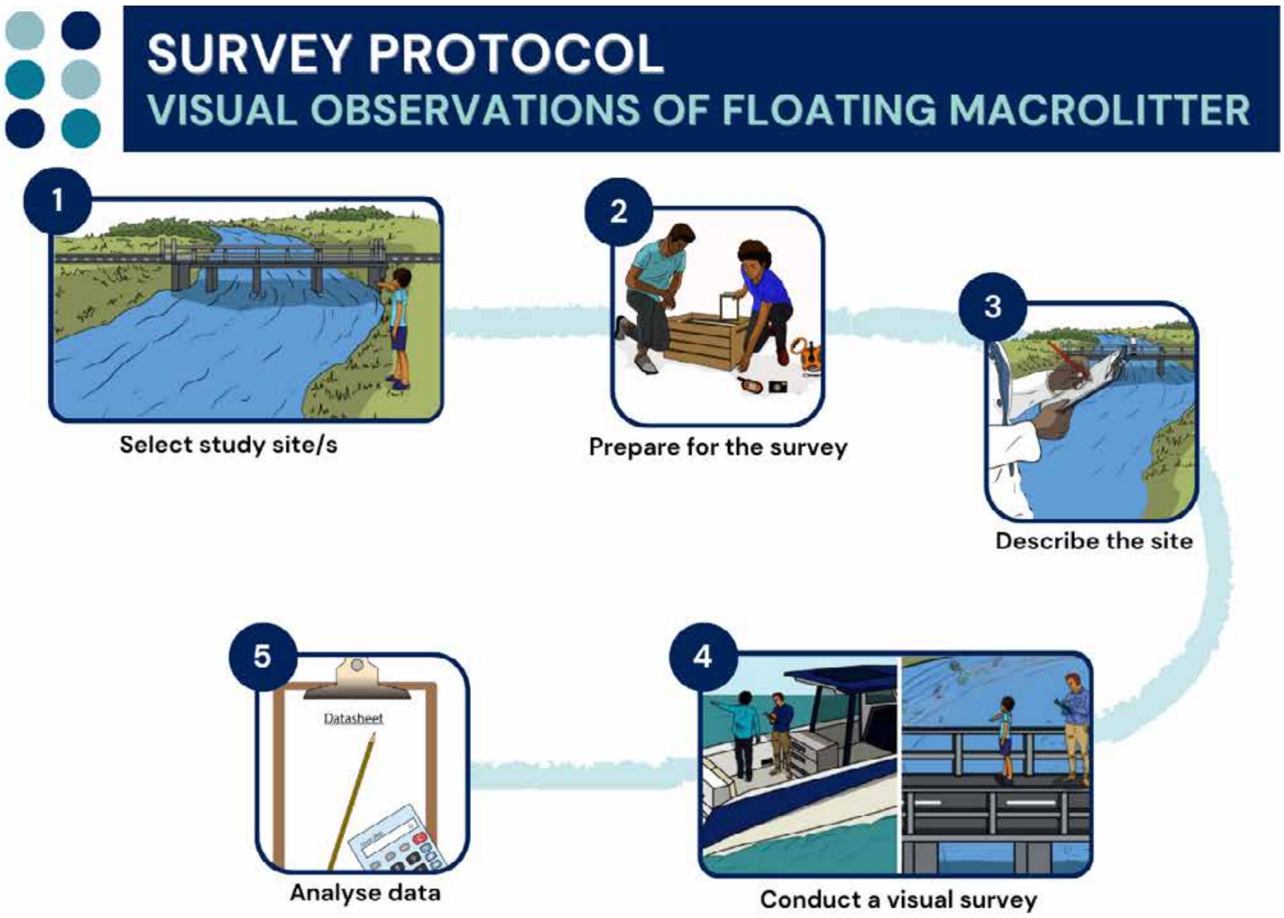


Figure 2: The protocol for visual observations of floating macrolitter, whether conducted from a fixed point or moving boat, consists of five main steps.

Select study sites

Observations of floating litter can be conducted at any point along a waterway where observers have an unobstructed view of the water (for surveys from fixed points) or where a small boat can safely navigate at a constant speed (for surveys from moving boats). The study site locations will depend on the research questions. For example, a study to determine the amount of riverine litter entering the sea will require observations near the river mouth. In contrast, a study on litter entering waterways from a specific neighbourhood must include observations at a point immediately downstream from key stormwater outlets.

Note: Litter can be retained in estuaries for long periods as it is pushed back and forth by tides and river flows[5]. Surveys conducted near estuary mouths may therefore overestimate the flux of litter from rivers to the sea.

Regardless of their location, all study sites must meet specific criteria to ensure that the data collected are reliable. These are discussed below in terms of ideal vantage points and key considerations. To better interpret results and compare between sites, it is recommended that multiple sites are surveyed.

Note: Study sites should ideally be visited prior to the surveys to plan accordingly (e.g. number of surveyors/helpers needed, conditions at the site, potential safety risks or issues).

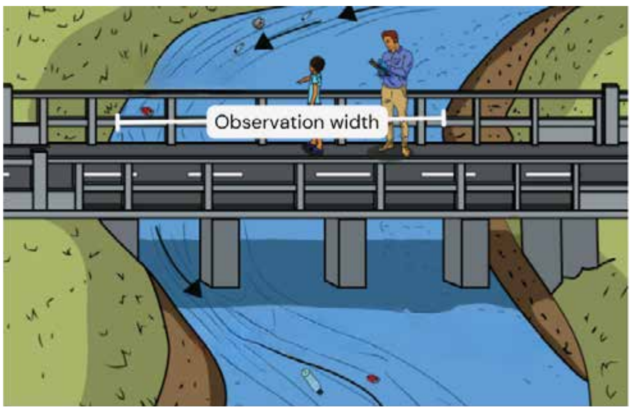
Ideal vantage points

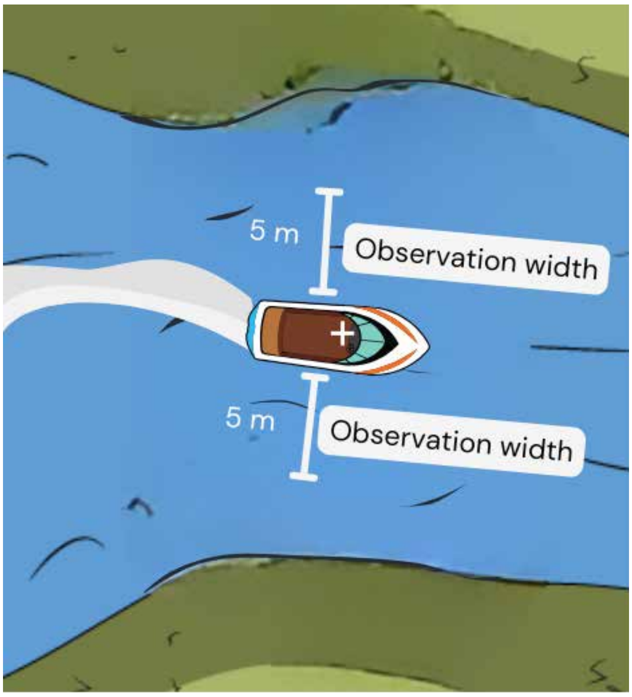
For visual observations from both fixed points (e.g. bridges, anchored boats) or moving boats, observers must have an unobstructed view looking down to the water from an angle as close as possible to 90° (perpendicular to the water surface). For very small vessels, observers must stand at the bow (or front) of the boat to view incoming litter before it is obstructed or displaced by the movement of the boat.

Study site considerations

Aspects that should be considered when selecting study sites include:

- **Water depth**: Floating litter can be surveyed in waterways of any depth, but the water must be deep enough for safe navigation when using a boat. When conducting surveys from boats, ensure that the skipper knows the bathymetry (bottom topography) of the area, and is aware of potentially dangerous obstructions, such as submerged objects, low bridges or overhead powerlines.
- **Observation width**: When surveying from fixed points, observers must ideally record litter within the *entire width* of the waterway since litter transport may vary across the channel cross-section depending on the hydrodynamics[5]. For example, litter may be concentrated against one bank during low-flow conditions as it gets caught in vegetation or obstruction-induced eddies but may be more





evenly distributed as flow increases and it is swept into the fast-flowing main current. See Step 4 (*Conduct a Visual Survey)* for more details on how to ensure that the entire channel cross-section is surveyed adequately.

For surveys from moving boats, the observation width will depend on the observation height and pollution level of the waterway. For an average river boat elevated 1–2 m above the water, a 5 m observation width is recommended on both sides of the boat[1,2]. The observation width can be increased for larger, taller boats or decreased for heavily polluted waters.

- **Observation height**: Vantage points must be high enough to view litter from an angle of 45-90°. The closer the angle of view to perpendicular (90°) to the water surface, the easier it is to spot and identify litter. However, vantage points must not be so high that it becomes a safety risk or that observers are unable to recognise and identify litter from so far away. Ideally, observers must be able to recognise a 25 mm piece of litter floating at the surface of the water without the use of binoculars.

Note: To calculate a suitable observation width from an angle of view between 45-90°, use the link provide **here.**

- **Observation depth**: The depth to which litter can be observed and recorded is determined by the water transparency (see below). Observation depth must be recorded during each survey for comparison.
- **Accessibility**: Sites should be accessible to observers for the entire duration of the study. Permission or authorisation should be obtained from landowners or relevant authorities, where applicable.
- **Safety**: Surveys should not be conducted in areas that may pose a safety risk to observers (heavy traffic, crime, very strong water flow, very high bridges, etc.). When sampling from a fixed point, ensure that the structure is secure and that observers can safely stand and observe the water. If surveys are conducted from road bridges, it is recommended that observers wear safety vests to alert passing motorists to their presence.

Prepare for the survey

Gather equipment

A printable checklist of the equipment needed to conduct visual observations of floating litter is provided in **Figure 3**.

Figure 3: A printable equipment list for visual surveys of floating litter.

Set a sampling schedule

- **Consider the seasonality of fresh-water flow**: In river reaches beyond the influence of oceanic tides, visual surveys can only be conducted when there is sufficient water flow to transport litter. As such, the sampling schedule will depend on the seasonality or regularity of water flow at the study site. For example, in waterways with perennial or year-round water flow, sampling can be conducted at regular intervals (e.g. weekly or monthly) for the entire duration of the project. In periodic waterways with well-defined seasonal flows, surveys will be limited to the wet periods when the water is flowing sufficiently to transport litter. Waterways with unpredictable flow patterns will require a customised sampling schedule. Observations of floating litter can even be conducted in waterways that only flow sporadically, as long as observers are prepared to respond rapidly to significant rainfall events. A significant rainfall event is defined here as any rainfall (whether low rainfall for extended periods or high rainfall over short periods) that causes a noticeable change in water level and litter transport.
- **Consider rainfall patterns**: For the most accurate estimates of litter transport in waterways, litter loads must be measured and compared

in high- and low-flow periods (i.e. rainy and drier periods). Surveys can proceed as long as the water is deep enough and the flow sufficiently strong to transport litter. Rainfall data must be tracked closely for the duration of the survey (ideally using local weather stations), as rainfall patterns may help explain trends in litter loads.

- **Plan around the tide**: When assessing macrolitter flux and inputs from river to sea, monitoring sites must ideally not be influenced by oceanic tides. If tidal influence cannot be avoided, sampling should take place a maximum of one hour before low tide (i.e. when the outgoing freshwater river flow is predominant). This will provide a clearer idea of how much litter is flowing down the river, rather than being brought in from the sea. Tidal conditions should be considered along with freshwater flow data (if available) for better planning.

Recruit and train helpers

A visit to the study site prior to the survey will help determine how many helpers/ surveyors are needed to conduct visual surveys. Recruit enough helpers to ensure that information can be recorded efficiently and reliably along the entire width of the channel. Before starting the survey, ensure that all helpers understand the purpose of the study and their role in the survey. Assign roles such as 'observers' (helpers who observe and identify floating litter) and 'scribes' (helpers who record the data on the datasheets) to ensure efficient data collection.

Observers and scribes must be familiarised with **Datasheet 4** (*Basic Litter Datasheet*) so that no time is wasted while recording data. This datasheet is recommended for visual surveys of floating litter as it categorises key sources of waste, while also allowing observers to identify and record litter rapidly as it flows past. For more detailed litter categories, use **Datasheet 5** (*Comprehensive Litter Datasheet*).

Note that various factors may influence the observers' ability to see litter floating in the surface waters (**Box 1**). A training session is recommended when using a new group of observers. A survey should only continue once all observers are aware of the potential biases in spotting litter and have received training to reduce this.

BOX 1
VISIBILITY OF FLOATING LITTER

Multiple factors may influence an observer's ability to spot and identify floating litter near the surface of the water. Observers must therefore receive brief training to reduce any potential observation bias resulting from the factors listed below:

1. **The size of the items**: Larger items are generally more visible and distinguishable than smaller items. Ensure that observers also look out for smaller items.
2. **The colour of the item**: Brightly coloured items are more visible than dull items. Train observers to be on the lookout for dull items.
3. **Litter buoyancy**: Submerged items floating near the surface are more difficult to identify at a distance than items emerging from the water. The visibility of litter below the surface depends on the water turbidity and environmental conditions[4]. Water visibility must thus be recorded during each survey. To avoid underestimations of submerged litter near the surface, ensure that all observers are trained to spot litter in the surface layer of the water column (in addition to above the water surface).
4. **Observation height**: The higher the vantage point, the more difficult it becomes to identify pieces of litter[8]. When conducting observations from high vantage points, ensure that observers use binoculars to confirm litter identifications if needed, and that they also investigate seemingly small items.
5. **Lighting conditions**: Floating litter is best observed under adequate daylight and minimal reflectance off the water[4]. Observations should preferably be conducted at least an hour after dawn and stop an hour or more before dusk. Ensure that the observers' vision is not impeded by the glare of the sun on the water surface. For surveys from bridges, the observers could monitor the river facing upstream or downstream depending on the best lighting conditions.
6. **Water/Boat speed**: Observers will have less time to identify litter when the water/boat is moving rapidly. Maintain a steady speed of 5-6 knots (or less) when surveying from a moving boat to allow observers sufficient time to identify passing litter. To assist with litter identification during rapid flows, ensure that observers are adequately trained to identify litter and use experienced observers whenever possible.
7. **The distance of items from the boat**: Litter closer to the boat is more likely to be spotted. A maximum distance of 20 m should be set for observations from large, tall boats as the probability of spotting litter beyond this decreases dramatically.

Describe the study site

It is important to collect information about the study site to help understand trends or patterns in the survey results. See **Datasheet 7** (*Site Description: Waterways*) for the information needed to describe the site (e.g. GPS coordinates, channel width, nearest town). This datasheet should only be completed once per survey or once per year for long-term surveys. Daily changes in factors that may influence litter at the site (e.g. weather, water velocity and visibility) must be recorded on **Datasheet 2** (*Daily Site Conditions*) on every day of a survey. Rainfall data for the entire study period must ideally be obtained from nearby weather stations. If this is not possible, rainfall can be recorded using weather applications or measured using rain meters.

Measuring water depth and observation height

Observers must note the height from which they are observing the water in **Datasheet 2**. Water depth can also be measured from fixed points to describe the study site. Water depth and observation height is measured as follows:

1. Lower a weighted measuring tape from eye level on the observation point down to the water surface to measure the observation height (**Figure 4**). Ensure that the weight can withstand wind and current force as much as possible without breaking the measuring tape.
2. To measure water depth from bridges or anchored boats, keep the measuring tape in the same position and lower the weight into the water until it touches the bottom. Record this height and then subtract the observation height from it to determine the water depth. This method is not recommended in fast-flowing waters.
3. Repeat the depth measurements at regular intervals across the width of the channel. An average water depth is then calculated by dividing the sum of all the depth readings by the number of measurements made. A minimum of 10 depth measurements is recommended per study site.

Figure 4: A weighted measuring tape is used to measure water depth from a bridge in Gqeberha, South Africa.

Measuring observation depth/ water transparency

A Secchi disc (**Figure 5**) is a simple black and white disc that is used to measure water transparency, in order to indicate the maximum depth to which submerged litter can be identified. To determine the water transparency (and hence the observation depth) from a vantage point, use the following steps:

1. Lower the Secchi disc into the water using a rope until it is no longer visible.
2. Pull the rope up and measure the distance from the Secchi disc to where the rope is no longer wet. This is the depth of water transparency.
3. Repeat the measurements at regular intervals across the entire width of the vantage point. An average water transparency or observation depth is then calculated by dividing the sum of all the readings by the number of measurements made. A minimum of 10 water transparency measurements is recommended per study site. Click here for guidance on how to make and use a Secchi disc.

Figure 5: A Secchi disc, used to measure water transparency, can be made with cheap materials.

Measuring water flow rate

Patterns in litter flux may be explained by the amount of water transported past the vantage point over time (i.e. the water flow rate). It is therefore recommended that flow rate is calculated as regularly as possible by multiplying the area of the channel by the water velocity. Channel area is determined by measuring the average water depth at the study site and multiplying it by the channel width. Water velocity (m/s) should ideally be measured by placing a flow meter in the water at the study site or by attaching it to the side of an anchored boat. A flow meter gives the most accurate measure of water velocity and can be left at the site to collect continuous flow data. However, since flow meters are often expensive and may be at risk of theft, another method can be used to calculate the approximate water velocity at the time of sampling – the *Stick/Orange Peel Method*. This entails timing how long it takes for a stick or orange peel to float a known distance downstream, as detailed below:

Note: The *Stick/Orange Peel Method* cannot be used on a moving boat. Instead, the boat will maintain a constant speed through the water to determine how fast litter is flowing past.

1. Measure the width of the bridge or length of the anchored boat (assuming the front and back of the boat are positioned parallel to the flow direction). The start and end of the bridge/boat will be the starting and end point between which the travelling time of the stick/orange peel will be measured. Alternatively, select a starting point on the banks of the river or side of the canal (e.g. a recognisable rock or crack) and measure five metres downstream to find an end point.
2. Drop a stick/orange peel upstream of the designated starting point and once it reaches that point, start the timer (**Figure 6**).
3. Stop the timer as soon as the stick/orange peel reaches the designated end point. The water velocity is calculated as follows: distance travelled (m) divided by the time(s) the stick/orange peel took to travel between the start and end points.
4. The water depth, width and velocity must be measured weekly or at each sampling event and recorded in

Datasheet 2. An approximate water flow rate is then calculated using the following formula:

$$Flow\ rate_{(m^3/s)} = Velocity \times (Depth \times Width)$$

The stick/orange peel method only provides a rough estimate of the water velocity and subsequent flow rate since these parameters will vary across the channel cross-section. To improve estimates of flow rate, water velocity can be measured in each observation track across the channel width. If hydrological data are available for the waterway, this can be compared with the measured water velocity and flow rate.

Figure 6: Surveyors from Sustainable Seas Trust in South Africa using the stick/orange peel method to measure flow rate of a river.

Conduct a visual survey

Surveys from fixed points

1. **Divide the work between observers**: To adequately survey the entire width of the channel, divide the channel cross-section into equal sections or observation tracks (**Figure 7**). If enough helpers are available, all observation tracks may be surveyed simultaneously by assigning observers to each track. However, without enough helpers, observation tracks can be surveyed in successive order during the same monitoring session (i.e. on the same day)[5]. This will prolong the total time spent in the field but will provide more reliable estimates of litter flux than surveys conducted in only a portion of the channel. The ideal observation track width per observer will depend on the field of view (influenced by observation height) and the pollution level of the waterway. Observers whose field of view may overlap must communicate clearly to ensure that items in the

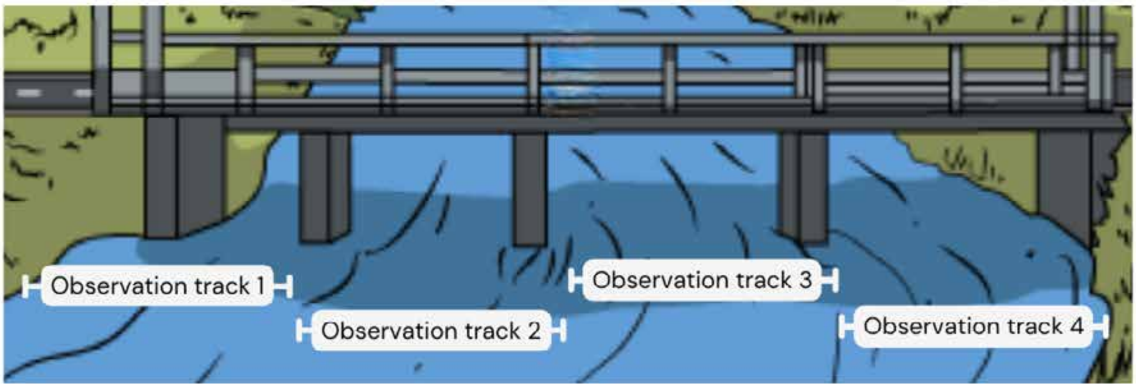


Figure 7: The total observation width must be divided into multiple observation tracks in which floating macrolitter will be recorded. These observation tracks can be surveyed at the same time, or successively, depending on the number of helpers available.

NATURAL ITEMS VS LITTER

Figure 8: Only record man-made litter items during surveys.

overlap zone are counted only once. For example, adjacent observers may state out loud when they record an item near the overlap zone.

2. **Work in pairs**: Where possible, it is recommended that observers are paired with a scribe. The observer verbally records the floating litter, while the scribe records the spoken data on a datasheet.
3. **Record all floating litter items**: Once all observers have been assigned a spot to observe, the project leader/lead surveyor must announce the start of the survey and start a stopwatch. For 30 minutes, observers must record the amount and type of man-made litter (**Figure 8**) floating past their vantage point using **Datasheet 4** and the visual guide in **Appendix 4**. **Datasheet 5** and its visual guide (**Appendix 5**) may be used to record more detailed litter categories. Ensure that all identifiable litter at the surface and in the surface layer of the water column is recorded, but not natural items such as biological material, organic foam or bubbles. Binoculars may be necessary to confirm identifications of floating litter. While longer surveys would be more informative, observers have been found to experience observer fatigue, becoming tired and less accurate in their data 'recording' as more time passes. An observation time of 30 minutes is therefore advised, but surveys can last for as little as 15 minutes in very polluted waterways. If no litter is observed during the initial surveys, this may be indicative of insufficient monitoring effort. In such instances, ensure that the entire channel width is monitored (if only a portion was surveyed previously) and/or increase the observation time to 60 minutes. If zero litter counts are still recorded, then it is more likely due to low levels of pollution.
4. **Repeat the process**: Visual observations should ideally be repeated to

have a total of three measurements of litter loads at the site (i.e. each observation track must be monitored three times during the same monitoring session). Average results and variability can then be calculated for the total channel width, giving a more reliable estimate of litter loads and flux.

Surveys from moving boats

1. **Position of observers and scribes**: At least two observers are necessary to record floating litter from a moving boat (one on each side of the boat). Where possible, one person should observe and verbally identify the floating litter, while another records the spoken data on a datasheet. Ensure that everyone is standing (observers) or sitting (scribes) in a secure place before starting the survey.
2. **Indicate the observation width**: Observation widths (i.e. how far from the boat floating litter is being recorded) will depend on how far an observer can reliably identify floating litter. Given that observers are unlikely to have a high vantage point on river boats, an observation width of 5 m is recommended on each side of the boat (**Figure 9**)[1,2]. The total observation width will therefore be 10 m. This can be increased to a maximum of 20 m when surveying from very high vantage points or decreased to 3 m at heavily polluted sites. Visual guides (e.g. outrigged poles or beams) can be used to delineate transects of 5 m to ensure that the observation widths are constant between observers and surveys. These poles or beams must be secured properly to ensure that they remain in place for the duration of the survey. String or lightweight rope can be suspended from the furthest end of the pole so that it is dragged through the water as the boat moves, forming a clear transect boundary.
3. **Record site and survey details**: Before starting the survey, ensure that all relevant details relating to the survey

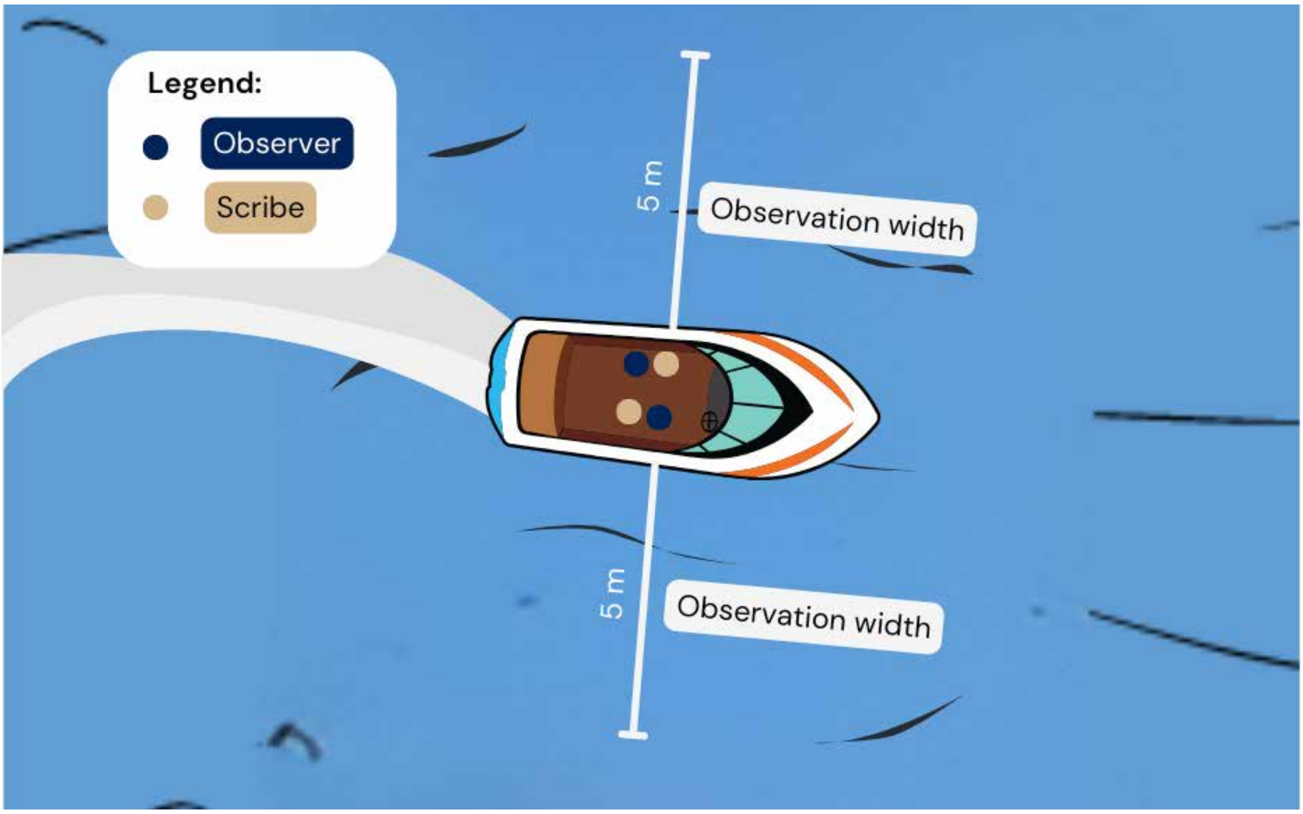
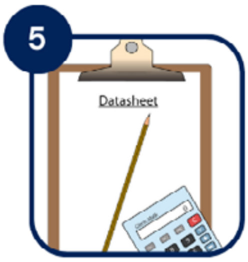


Figure 9: Surveyors must record floating litter passing within 5 m of the boat on both sides.

method and prevailing conditions are recorded in **Datasheet 2**. In addition, record the GPS coordinates at the start and end of the transect, as well as the boat speed (see below).

4. **Conduct visual observations**: Once ready, accelerate the boat until it reaches a speed of 5–6 knots. This speed is recommended to cover a large area in the time allocated to a visual observation survey, while also ensuring that observers have sufficient time to identify passing litter. Once the desired speed has been achieved, start the stopwatch, and note the starting time and GPS coordinates on **Datasheet 2**. Observers must identify and record man-made litter (**Figure 8**) floating in the observation track for 30 minutes to gather representative data. Surveys may last as little as 15 minutes in heavily polluted rivers. Litter data must be recorded in **Datasheet 4** or **Datasheet 5** depending on how detailed the litter categories need to be. Once the time has lapsed, record the time and GPS coordinates at the end of the transect. If no litter is observed, it may be indicative of insufficient monitoring effort. In such instances, ensure that a representative portion of the channel is monitored and/or increase the observation time to 60 minutes. If zero litter counts are still recorded, then it is more likely due to low levels of pollution.
5. **Repeat the process**: Visual observations must ideally be repeated to have a total of three measurements of litter loads for each monitoring session at the site. This allows average results and variability to be calculated, giving a more reliable estimate of true litter loads.

Note: The maximum speed may be reduced to 3–4 knots if visual observations are conducted at the same time as a mesolitter trawling survey (**Chapter 6**).



Analyse data

Survey results will be expressed differently depending on the survey approach used. Surveys from fixed points measure the number of surface litter items floating past a point per hour (known as litter flux), while surveys from moving boats measure the number of surface litter items per area surveyed (surface litter density). It is important to note that observations of floating litter do not provide reliable estimates of the total litter amount in the waterway, because litter is also transported deeper in the water column (below the observation depth) and along the bottom.

Visual surveys from fixed points

The surface litter flux (items/h) can be calculated for all litter (i.e. all categories combined) or for each litter category (e.g. plastic beverage bottles), according to the formula below:

$$\text{Litter flux}_{\text{(items/h)}} = \frac{\text{Litter observed}}{\text{Sampling time}_{\text{(min)}}} \times 60$$

To calculate litter flux from multiple observation tracks covering the entire river width, use the formula above to calculate litter flux (items/h) for each observation track. The fluxes from the individual tracks are then summed to provide the total litter flux past the study site. This is the most realistic estimate of litter flux across the entire river.

If surveys were only conducted over a portion of the total channel width, there are two options to calculate litter flux past the study site. The first option uses data gathered in the observation track to extrapolate the litter flux for the entire channel. To do this, the litter flux (items/h) calculated for the observation track is divided by the total number of metres surveyed in the observation track width (to obtain flux/m) and multiplied by the total channel width to provide an estimate of litter flux across the entire channel. This approach assumes that litter is evenly distributed across the width of the channel and can either provide an over- or an underestimation of litter flux. The second option is an approximation that assumes that the litter flux calculated in the observation track represents the total litter across the entire channel width, so no further calculations are needed. This is a conservative approach that avoids overestimates of litter flux. When describing the methods in a report or paper, remember to state whether the entire channel width was surveyed or only a portion. If only a portion was surveyed, also state how litter flux was calculated (i.e. which of the two approaches was used).

Visual surveys from moving boats

The surface litter density (items/m^2) of macrolitter items is calculated as follows:

$$\textit{Litter density} = \frac{\textit{Number of litter items observed}}{\textit{Area surveyed}}$$

To calculate the area surveyed, transect width (observation width) must be multiplied by the transect length. The transect length is determined by multiplying the boat speed by the time taken to survey the transect. For example, if a 15-minute (900-second) survey was conducted from a boat travelling at 5 knots (2.57 m/s), and litter was recorded within an observation width of 20 m on both sides of the boat, then the area surveyed would be: (900 s x 2.57 m/s) x 40 m = 92 520 m^2. Alternatively, transect length can be calculated by measuring distances on a map, based on start and end GPS tracking coordinates.

If replicate trawls were conducted at the same site, calculate the average litter density for the site by adding the litter densities together and then dividing by the number of replicates.

Alternative methods

The protocols discussed above are recommended to collect the most reliable data. However, depending on the study's research questions and available resources (e.g. funds, time and number of helpers) simpler methods can be used. For this reason, three different protocol standards – *Gold, Silver* and *Bronze Approaches* – have been provided as guidelines to modify the survey protocols to suit specific needs and resources. By allowing flexibility in the methods, these standards ensure that data from litter surveys are always reliable and comparable while surveys remain feasible and sustainable. **Figure 10** shows how visual surveys of floating litter can be modified.

The minimum requirements for a reliable survey are provided in the *Bronze Approach*, while the *Gold Approach* is recommended for greatest accuracy. Survey methods can be customised within the range specified by the *Gold* and *Bronze Approaches*.

SURVEY APPROACHES
VISUAL OBSERVATIONS OF FLOATING MACROLITTER

	GOLD APPROACH	SILVER APPROACH	BRONZE APPROACH
Litter size	>25 mm	>25 mm	>25 mm
Total observation width (surveys from a fixed point)	Entire channel width	Entire channel width	Portion of channel
Total observation width (surveys from a boat)	Depends on the observation height	Depends on the observation height	Depends on the observation heights
Survey duration	30 min (60 min if needed)	30 min (increase time if needed)	15 min (increase time if needed)
Survey frequency	Weekly	Biweekly	Monthly
Survey replicates	3 (or more)	2	1
Litter classifications/ categories	>144 (as per Datasheet 5)	36 (as per Datasheet 4)	10 (as per main litter types from Datasheet 4)

Figure 10: Visual surveys of floating litter can be modified using the guidelines above.

SECTION INTRODUCTION C

LITTER MONITORING ON BEACHES

BY TOSHKA BARNARDO, TANNA HEWETT, ERIC OKUKU & MARY MBUCHE CHIPHATSI

Beaches hold aesthetic, cultural, religious, recreational, spiritual and commercial value for coastal communities and tourists from around the world[1]. These shoreline ecosystems filter large amounts of seawater[2] and support a variety of organisms, including primary producers (e.g. diatoms and cyanobacteria)[3,4], beach-dwelling organisms (e.g. crabs and clams) and beach visitors (e.g. turtles and seabirds)[5]. Unfortunately, the normal functioning of these valuable ecosystems is under threat as beaches around the world are subjected to alarming levels of plastic pollution (**Figure 1**).

It is estimated that 67% of all buoyant riverine plastics (>5 mm) ever released into oceans can be found along the shorelines (beaches and other coastal habitats) of the world[6]. Once stranded, beach litter movement is affected by both natural and human-induced (anthropogenic) factors[7,8]. Natural events such as flooding, wind, wave action and movement by animals (e.g. burrowing crabs) may disperse, bury or expose beach litter[9], while human-induced factors include litter displacement through activities such as clean-ups, beach trampling, raking of seaweed and bait harvesting[10]. As a result, litter may be delivered to the sea, deposited onto the backshore, trapped by vegetation, fragmented into smaller pieces, or periodically buried and exhumed (**Figure 2**)[6]. Consequently, sandy beaches have been identified as litter sinks, where litter may become trapped or buried for extended periods.

Figure 1: Large volumes of litter stranded on a beach in South Africa after heavy rainfall.

Beach litter can have a wide range of negative ecological and socio-economic impacts. Large plastic litter may entangle or smother plants and animals (**Figure 3**)[11], inhibit gas exchange between seawater and coastal sediments[12] and lead to habitat degradation[12,13]. Macrolitter has also been shown to reduce the aesthetic value of beaches, with polluted beaches receiving fewer visitors than cleaner beaches[14]. A decrease in coastal tourism and threat to coastal resources directly translates into socio-economic costs, as many African countries and communities depend on tourism and coastal resources as a source of

Figure 2: Factors affecting the dynamics of litter on sandy beaches.

income and employment opportunities[14–16]. Furthermore, beach clean-up efforts cost local municipalities large sums of money that could be used elsewhere[17]. In turn, smaller pieces of plastic (such as broken-down fragments of larger items) can be ingested by animals. This may cause intestinal blockages, which may lead to starvation and death[18]. Additionally, some plastics carry harmful substances that may leach into the surrounding environment and have negative repercussions for organism health[19]. Immediate and effective action is therefore needed to reduce plastic pollution on shorelines. To do this, information is needed about where shoreline litter is coming from, how it is distributed and how it can be reduced.

Figure 3: Plastic pollution poses a threat to marine organisms, such as this comorant with synthetic line tangled around its neck.

Sandy beaches are some of the easiest and most convenient places to study marine litter[20]. There are three main reasons for this:

1. Very little training and special equipment are needed to study litter along shorelines, making it cheaper than other types of litter surveys[20].
2. Beaches are generally easier to access than other places where marine litter is studied (e.g. seabeds and the open ocean)[20].
3. Beaches are connections between ocean and land. Beach litter surveys can therefore give valuable insight into both land-based and sea-based sources of marine litter[21].

This section explains how to measure the amount of both macro- and mesolitter on beaches. Protocols to study macrolitter (>25 mm) are provided in **Chapter 8** (*Macrolitter Surveys on Beaches*), and the steps to extract and measure mesolitter in shallow (5 cm deep) buried strandlines are provided in **Chapter 9** (*Mesolitter Surveys on Beaches*). To explore how much litter may be buried and retained on beaches, especially after floods, **Chapter 10** (*Buried Litter Surveys on Beaches*) provides protocols to study buried litter at depths of 25–100 cm.

MACROLITTER SURVEYS ON BEACHES

Toshka Barnardo, Tanna Hewett, Lorien Pichegru & Peter Ryan

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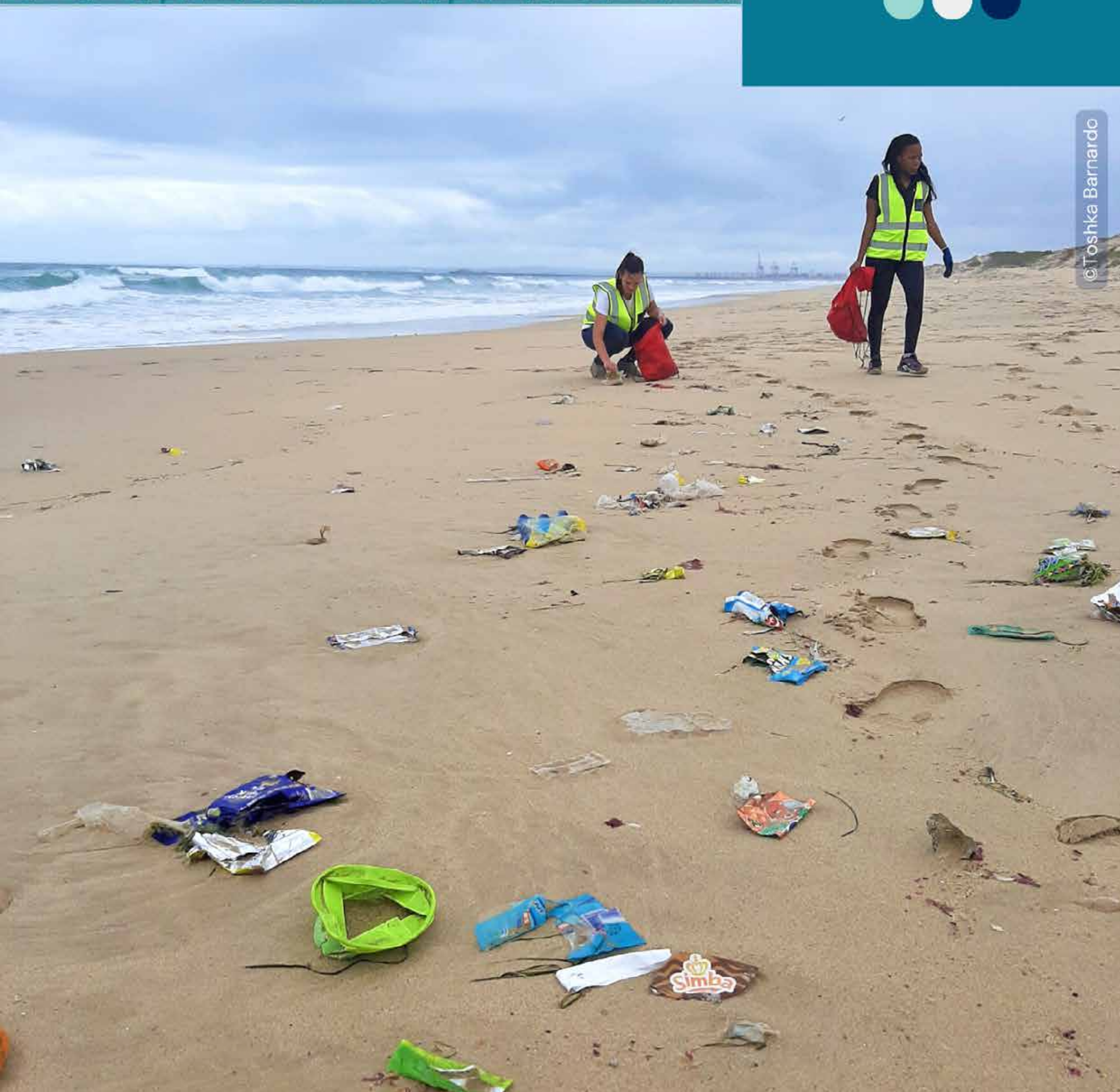

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Introduction

Beach macrolitter (>25 mm) surveys (and continued long-term monitoring) provide important information about the amount and types of macrolitter found on beaches. This information can be used to determine the sources of litter and identify areas in which remedial action is required. Although various other publications have provided methods to study beach macrolitter[1,2], the methods described here have specifically been developed (and tested) to identify trends in beach litter around Africa. The protocols outlined in this chapter make surveys feasible for those with limited resources and experience while ensuring that the data are comparable, reliable and useful. Clarifications, simplifications and solutions based on the in-field experience of numerous teams using these methods are also provided.

Protocols

During a beach macrolitter survey, all man-made macrolitter (>25 mm) is collected from a stretch of beach spanning from the edge of the water to the back of the beach. The litter is then processed (cleaned, sorted, counted and weighed). At the end of the survey, the number and weight of macrolitter items per metre or square metre of beach is calculated. These protocols can be altered to suit local conditions and needs using **Figures 14** and **15** at the end of the chapter.

This chapter considers two types of surveys to study macrolitter on beaches (**Figure 1**). *Standing-stock surveys* are done at one specific point in time (e.g. in a single day) and provide a 'snapshot' of litter at that time. They are useful in identifying litter hotspots but provide limited information regarding the sources and pathways of waste and how litter loads change over time. The steps of a typical standing-stock litter survey are shown in **Figure 2**. *Accumulation surveys* are repeated regularly over short periods (e.g. daily or weekly) to measure the build-up rate or accumulation of litter over a unit of time. They give a more comprehensive estimate of litter generation and are useful in determining the sources and pathways of waste. The steps of a litter accumulation survey are shown in **Figure 3**.

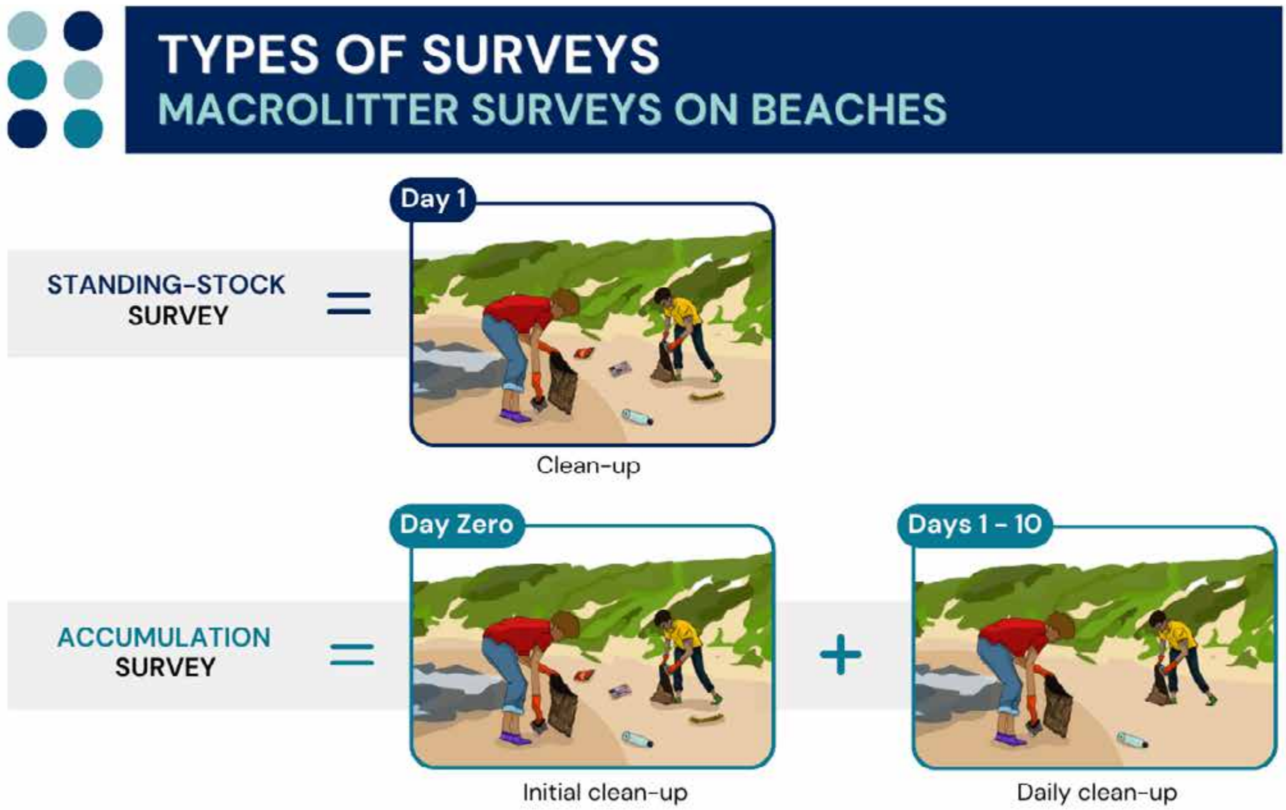

Figure 1: There are two main types of macrolitter surveys that can be conducted on beaches. The suitability of each survey type will depend on the specific research questions and goals.

The differences between accumulation and standing-stock litter surveys are explained in more detail in **Appendix 1**. The type of survey chosen will depend on the particular research questions as per **Chapter 2** (*A Guide to Litter Monitoring in Africa*). However, accumulation surveys are recommended where possible, as they provide more information about the pollution, such as the frequency of deposit and quantity of different types of litter. Daily accumulation surveys (i.e. a survey once per day) are recommended when doing litter surveys on beaches, since litter can rapidly be removed, added, buried or exhumed in in these high-energy environments. One complete beach litter accumulation survey should ideally last 10 consecutive days (after the *Day Zero* initial clean-up). The detailed steps to conduct macrolitter accumulation surveys on beaches are described on the following pages. Standing-stock surveys adhere to the same basic steps as *Day Zero* of an accumulation survey and are therefore not discussed in detail.

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STANDING-STOCK SURVEY PROTOCOL
MACROLITTER SURVEYS ON BEACHES

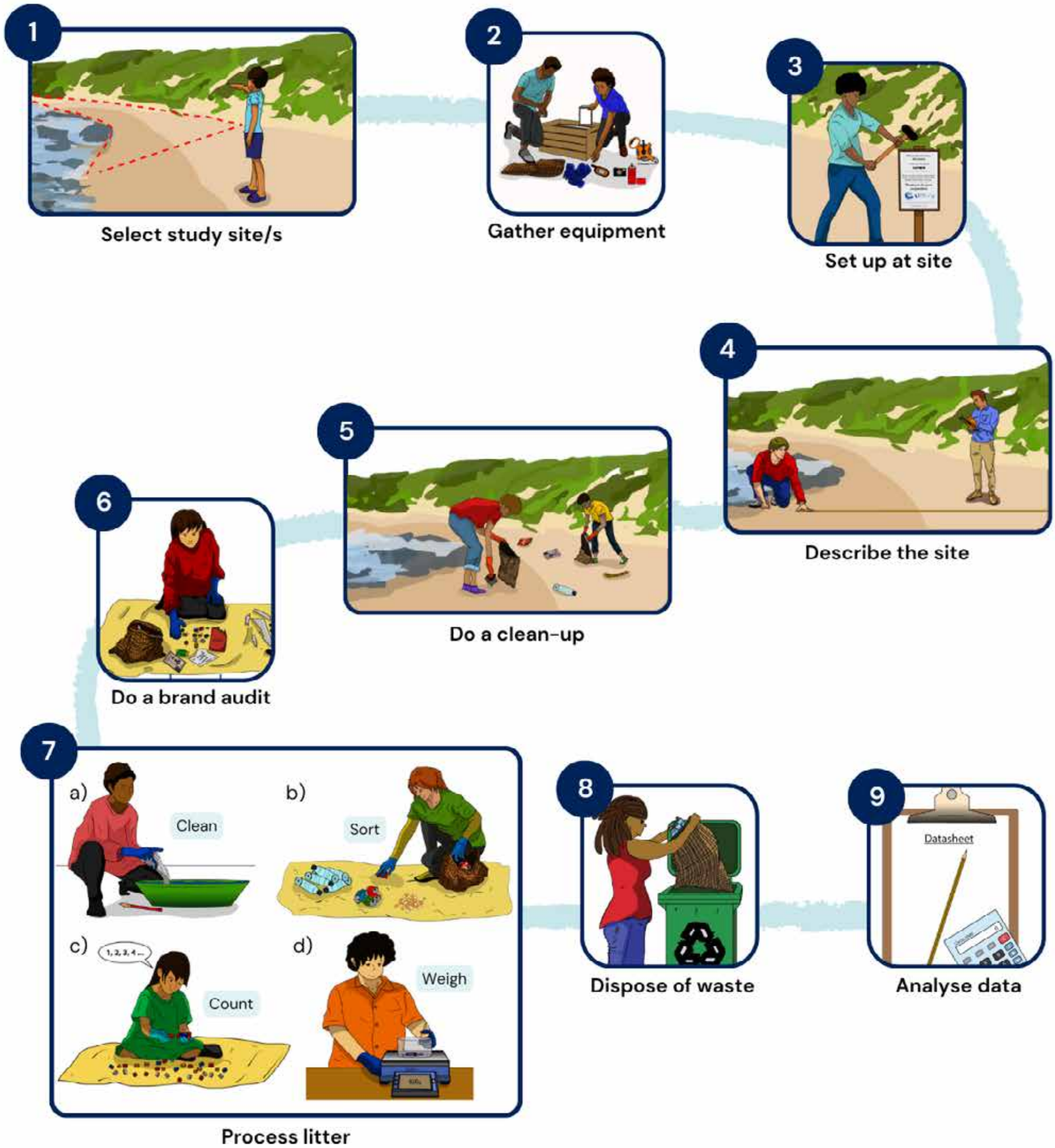


Figure 2: The protocol for a standing-stock macrolitter survey on beaches consists of nine steps.

ACCUMULATION SURVEY PROTOCOL

MACROLITTER SURVEYS ON BEACHES

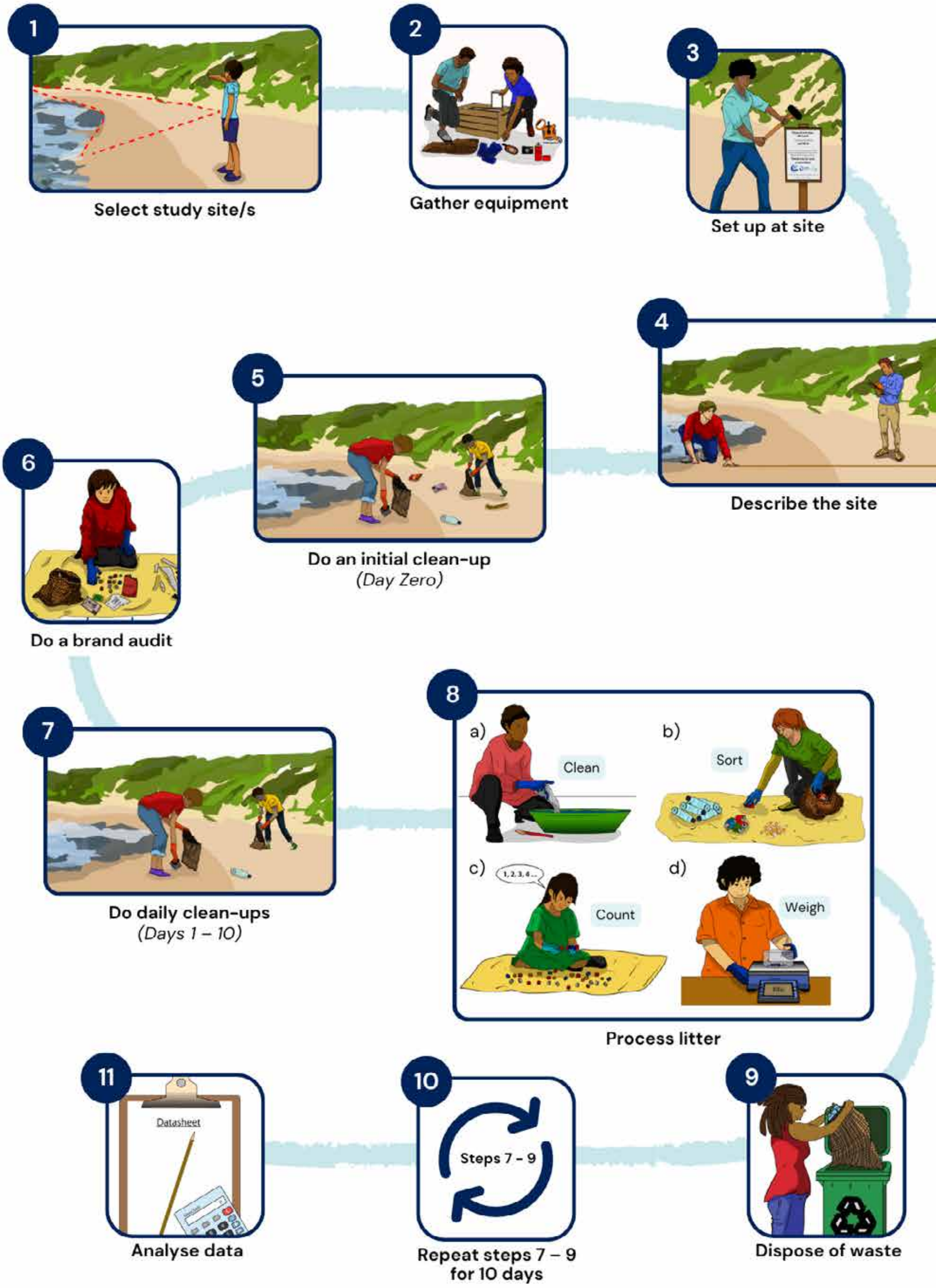


Figure 3: The protocol for an accumulation survey of macrolitter on beaches includes daily clean-ups and litter processing over 10 days.

Select study sites

As discussed in **Chapter 2**, the research questions of the study will determine where surveys need to be conducted, but some general considerations for selecting sites are provided below for macrolitter surveys designed to identify sources and pathways of litter. It is best to have multiple study sites to be able to compare and interpret results. Surveyors must also ensure that they can feasibly survey the chosen study site(s) – especially for monitoring projects where regular surveys are necessary.

Study site features

Macrolitter accumulation surveys are conducted along a predetermined length (ideally 500 m) of beach in the area that extends from the edge of the water to the back of the beach. Key features (**Figure 4**) of a typical beach litter study site are:

- **Edge of the water**: The boundary where incoming waves are washing over the beach during the time of the survey. This limit is also known as the swash zone boundary.
- **High-tide mark**: The highest point that the current tide has reached. The high-tide mark is usually easy to spot as there will be wet sand on one side of it and dry sand on the other. Litter and natural items like seaweed, that have been washed up by the tide, may be evident as a clear line of debris, called a strandline or drift line.
- **Back of the beach**: The boundary of the sea's landward limit, where storm waves leave a strandline. The back of the beach can usually be easily identified by the presence of cliffs, dunes, vege-tation or permanent structures such as roads, buildings, fences and seawalls. In some instances, it may be identifiable by a change in dominant substrate type or topography, such as a change from sand to vegetation or a substantial change in slope.
- **Wet zone**: The area of the beach between the high-tide mark and the edge of the water – or simply, the area of the beach inundated by the previous tide. The term 'wet sand' is also used when referring to this zone.

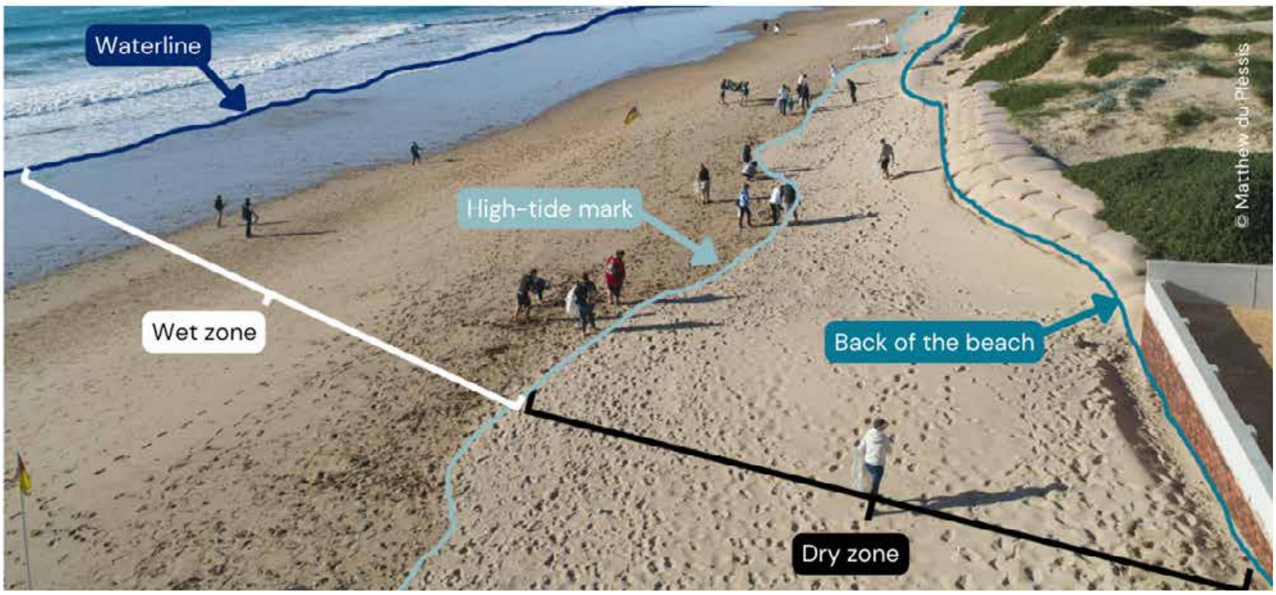


Figure 4: Several key features can be identified in all study sites for macrolitter surveys on beaches.

- **Dry zone**: The area of the beach between the high-tide mark and the back of the beach, beyond the reach of the tide. The term 'dry sand' is also used to refer to this zone.

Study site considerations

Ideally, study sites for beach litter surveys should meet the following requirements:

- **Site length**: The recommended study-site length is 100 m for standing-stock surveys and 600 m (500 m survey area with 50 m buffer zones on each side) for accumulation surveys. However, the total length of beach that can feasibly be surveyed will depend on the pollution level at the site and available resources for collecting and processing the litter. Site lengths may therefore be shorter at very polluted beaches and longer at very clean beaches. Guidelines for the selection of study-site length and other important factors are provided at the end of this chapter.
- **Site width**: The beach width is the distance from the edge of the water to the back of the beach, but surveyors may need to clean beyond the back boundary if windblown litter has accumulated there. Beach litter surveys can be done on beaches of any width, although wider beaches may require a lot more time and effort to clean daily. Very wide beaches with low slopes (and extreme tidal reaches) are therefore not recommended as study sites (**Figure 5**).
- **Accessibility**: Sites should be accessible to surveyors for the entire duration of the study. Permission or authorisation should be obtained from landowners or relevant authorities, where applicable.
- **Obstructions**: Sites where waves are obstructed should be avoided. For example, there should be no road infrastructure or bridge pylons within the site. If waves are breaking against a seawall at the back of the beach, it is unlikely that litter will accumulate, while breakwaters and jetties may influence water circulation and litter loads washing up on the beach.
- **Substrate**: Beach litter surveys can be done on any substrate (e.g. sand, gravel, pebbles), but it is preferable to avoid very rocky beaches, as these may pose a risk to surveyor safety.
- **Slope**: The slope or steepness of a beach influences the accumulation of litter[2] since litter is less likely to accumulate on steep beaches. However, flat beaches may be too wide to be suitable for litter surveys. Sites with a low to moderate slope are therefore recommended. Some researchers indicate that beaches with 15–45° (or 26–100%) slopes are ideal for litter surveys[1]. The methods for measuring slope are provided in **Appendix 8**.

Figure 5: Macrolitter surveys can be done on beaches of any width (A), but are not recommended on very wide beaches (B) due to the resources required for sampling.

- **Absence of clean-up activities by third parties**: No regular public clean-up activities should take place at the study site. If potential sites are regularly cleaned, surveyors should make the appropriate arrangements with local authorities to ensure that study sites are not cleaned during the entire period of the survey(s).
- **Safety**: Surveys should not be conducted in areas that may pose a risk to surveyors (crime, extreme tides, dangerous animals, etc.).
- **Low environmental impact**: Surveys should in no way cause disruption or harm to natural ecosystems (e.g. by trampling dune vegetation). Sites with endangered or protected habitats and species (e.g. nesting turtles) should be avoided. Where possible, surveyors should refrain from raking beaches or removing natural material such as seaweed, as this may be detrimental to the organisms occurring on the beach.

Note: It may be necessary to avoid sampling on beaches with large volumes of stranded seaweed or vegetation since considerable effort is needed to sort through the material to find litter.

Gather equipment

A printable checklist of the equipment needed to conduct macrolitter surveys on beaches is provided in **Figure 6**.

Figure 6: A printable checklist of equipment needed to conduct a beach macrolitter survey.

Set up at the study site

Identify the survey area

As previously mentioned, litter should be collected from the area between the edge of the water and the back of the beach (**Figure 7**). However, litter can often be found accumulating at or beyond the back of the beach. This is because vegetation and dunes act as traps for lightweight litter items washed up by the tide and/or blown up the beach by the wind[3]. Neglecting to include this litter in surveys could mean that lightweight items are underestimated – especially in windy locations. It is therefore recommended that a strip of at least 2 m beyond the back of the beach is also cleaned, while taking care not to damage the dunes or vegetation. Ensure that all volunteers/helpers can identify important boundaries and zones within the study site and that they know where to clean.

Mark out the study area

Demarcate the start and end of the area with semi-permanent markers that can be left at the site during a survey. Markers may include flags, lines drawn in the sand, or rocks placed in a line. These clear boundaries will help surveyors to sample the same area each day of an accumulation survey (especially if new helpers are used on different days).

Beach-cleaning by well-intentioned beach-goers should be prevented to avoid biasing the results of a litter survey. It may be useful to erect signs throughout the study site to indicate to the public (or any potential stakeholders) that a study is being conducted and that the beach should not be cleaned during the survey. The signs could also double as markers for the study site boundaries. The number of signs required would be dependent on the width of the study site, the number of access points to the beach, and the number of likely visitors to the study site. When choosing materials for signs, consider that the signs will be exposed to the elements for the duration of the survey and that they may be removed or stolen, in which case they would need to be replaced. Materials that can withstand strong winds, rain and sun but are relatively cheap are therefore recommended.

Figure 7: The study site for a litter survey spans from the edge of the water to the back of the beach.

Describe the study site

It is important to collect information about the study site to help understand trends or patterns in the survey results. See **Datasheet 11** (*Site Description: Shorelines*) for the information needed to describe the site (e.g. beach width, substrate type, tidal range, the nearest town). This datasheet should be completed once per survey.

Daily changes in weather condition, activities or other factors that may influence litter accumulation are also important to note. These need to be recorded on **Datasheet 2** (*Daily Site Conditions*) on every day of a survey.

Do an initial clean-up (*Day Zero*)

To measure the daily accumulation of litter, it is important to do an initial clean-up of the study site so that it is completely clean for the start of the accumulation survey the next day. This initial clean-up is referred to as the *Day Zero* clean-up, as it prepares the site for an accumulation survey. Upon returning the day after *Day Zero*, surveyors can reliably measure litter accumulation over a 24-hour period. The same principle applies for each day of an accumulation survey – since the site was cleaned the day before, each daily survey provides a measurement of litter accumulation over a single day (or the rate of litter accumulation).

> **Note**: Litter collected on *Day Zero* can be used as a standing-stock survey but must not be processed and analysed with litter from the accumulation survey (*Days 1–10*).

Where to clean

The *Day Zero* clean-up should ideally be completed along a 600 m stretch of beach, comprised of a 500 m survey area and 50 m buffer zones on each side (**Figure 8**). Buffer zones are included to reduce the likelihood of old litter blowing into the survey area from the immediate surroundings. All macrolitter (>25 mm) must be removed from the area between the edge of the water and the back of the beach (**Figure 7**). For *Day Zero*, also remove any items further inland, such as those accumulating in dune slumps, that may blow into the study site. This litter must be discarded without further processing.

What to clean

All visible macrolitter (>25 mm) on the sand surface or protruding from the sand should be removed from the study site on *Day Zero*. Smaller items such as cigarette butts and plastic bottle caps/lids should also be included since these are common beach litter items. Avoid removing any natural materials from the beach (**Figure 9**).

Figure 8: For the Day Zero clean-up, litter should be removed from the entire site and adjacent inland areas. For the daily accumulation surveys, litter is removed from the entire site but only the litter removed in the survey area is processed.

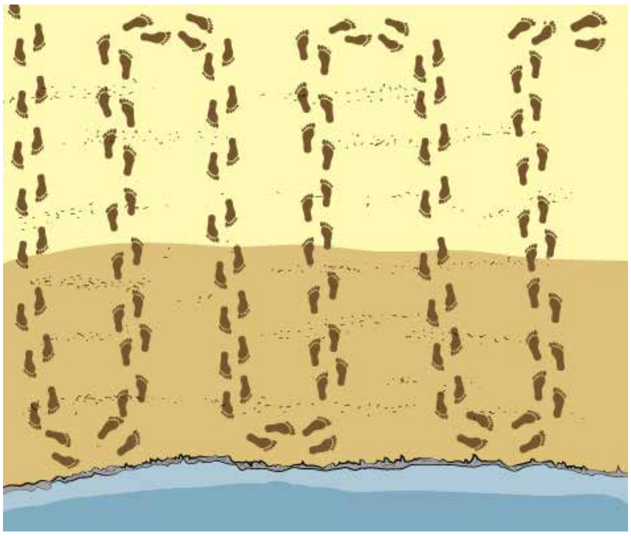
> **Note**: It is recommended that all visible litter is collected, even items that seem smaller than 25 mm, as they may be part of a larger, buried item. Items smaller than 25 mm can be excluded during the processing stage.

Figure 9: Only collect litter items during surveys. Biological/natural items should not be removed.

When collecting litter, it is useful to walk in a zig-zag pattern to thoroughly inspect the beach for litter. At least one person, called the 'sweeper', must do a final check to pick up litter items the surveyors might have missed.

Litter items that are too large (e.g. tyres, ropes, nets) or dangerous (e.g. chemicals, weapons, ammunition) to remove should be counted but not handled. Mark these items with paint or photograph them to ensure they are not counted again in future surveys.

The weights of heavy or large items can be estimated by multiplying the estimated volume of the item by the density of the material as per **Appendix 2**. Notify the relevant authorities of any large or dangerous items so they can be safely removed. Used hygiene objects such as diapers, condoms and feminine hygiene products can be removed, noted and disposed of responsibly. During litter processing, a clean and dry proxy can be used to estimate the weight of any unsanitary item recorded at the site (see **Appendix 2**).



Note: It helps to have the sweeper(s) walk in the opposite direction to that of the initial cleaners as they may be able to spot missed items by approaching from a different angle.

Do daily clean-ups (*Days 1–10*)

The day after the *Day Zero* clean-up, another clean-up must be done at the same site to allow surveyors to measure how much litter has accumulated within the last 24 hours. Where possible, these daily surveys should be repeated for 10 consecutive days to account for variation in daily litter loads due to external factors (e.g. weather, tide, number of beachgoers). Remember to record the daily site conditions on **Datasheet 2**.

Surveys should ideally be done at the same time every day to ensure that the time between surveys is constant. However, this may not always be possible, since rising tides may pose a safety risk to surveyors at sites where tides regularly flood the entire beach. In these instances, daily surveys can be timed to take place at specific points in the tidal cycle (e.g. as the high tide is receding).

Where to clean

Daily litter surveys should be done in the 500 m survey area within the larger 600 m study site cleaned on *Day Zero* (**Figure 10**). As on *Day Zero*, the litter will be collected from the edge of the water to the back of the beach. Remember to clean 2 m beyond the back of the beach where litter is known to accumulate. The 50 m buffer zones on each side of the 500 m survey area should be cleaned daily, but litter collected here should be disposed of and not included in the study.

It is important to keep the litter from the wet zone separate from the litter collected in the dry zone for *Days 1–10*. Litter found in the wet zone is assumed to have washed up from the sea, whereas litter from the dry zone is assumed to come from beachgoers

Note: It is likely that the width of the beach will change during an accumulation survey as the tidal cycle changes over time. Daily measurements of beach width may therefore be done to calculate litter per square metre (m^2). However, the tidal range may change substantially between the start and end of a survey, complicating daily measurements. Beach width can more easily be measured during the preceding spring low tide and that value used to represent beach width for the duration of the survey. This approach is simpler than daily measurements but will likely underestimate litter density.

Figure 10: Daily clean-ups of the survey area should be conducted from the edge of the water to just beyond the back of the beach. Litter collected in the buffer zone must not be included in the litter accumulation data.

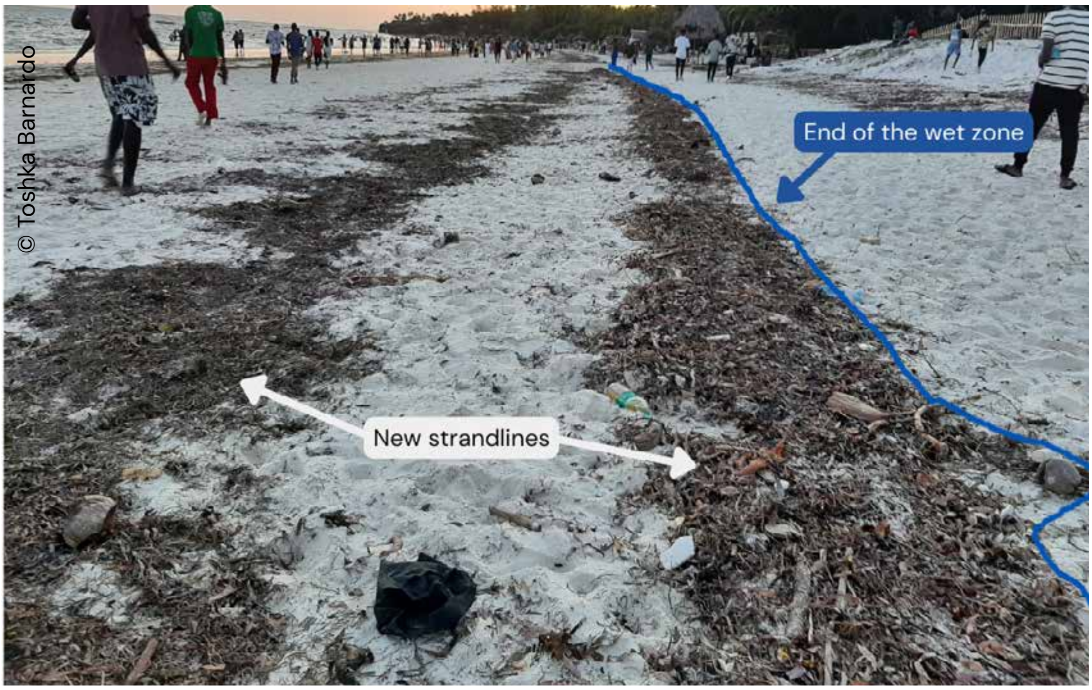


Figure 11: The wet zone spans from the edge of the water to the end of the highest new strandline left by the tide over the past 24 hours.

and other land-based sources[4]. The wet zone starts at the edge of the water and includes all new strandlines that were not present the day before (**Figure 11**). This zone is often characterised by moist sand. In areas where there are two tidal cycles over a 24-hour period, two new strandlines may be expected for each day of the survey.

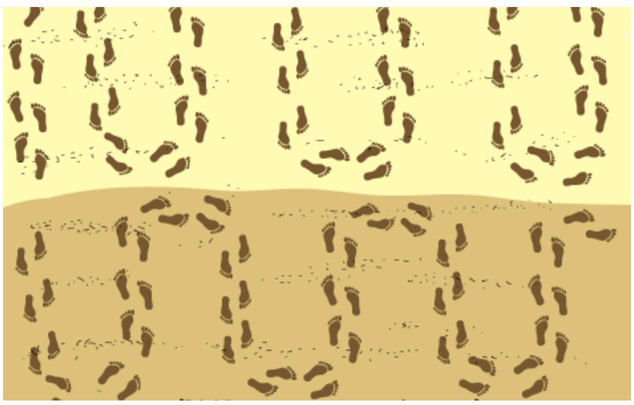
It may be difficult to distinguish between wet and dry sand during/after rainfall events. In such cases, the strandline at the highest high-water mark in the last 24 hours should be used as an indication of where the wet zone ends. Strong winds may bury strandlines in the sand and may blow litter from the wet zone onto the dry zone and towards the back of the beach. Discretion should therefore be used to determine whether litter items have been washed up by the tide, in which case they should be included with litter collected in the wet zone. Similarly, if it is obvious that beachgoers left litter in the wet zone, these items must be included with those from the dry zone.

What to clean

As with *Day Zero*, all visible macrolitter (>25 mm) should be removed from the study site. Remember to collect and store litter from the dry and wet zones separately. Natural items should not be collected. Do not remove items that are clearly still in use (e.g. beach towels, clothes) or those used for cultural or religious rituals or activities (e.g. charms and ceremonial objects).

The site should be walked in a planned pattern with the sweeper(s) doing a follow-up check to ensure that all macrolitter items (>25 mm) have been collected from the survey area. Helpers can be split into two groups – one to clean the dry zone and one to clean the wet zone (see below). Collection bags/containers should be clearly labelled to include the study site name, date of collection and the zone of collection, i.e. wet zone or dry zone.

Litter that can be identified as beachgoer litter (e.g. a concentration of beverage bottles and/or food packaging) should be included with litter collected on the dry sand regardless of where it was found on the beach. This reduces the chance of overestimating litter washed up by the tide.



Note: In the spirit of reducing single-use plastic waste, it is recommended that surveyors use reusable bags or containers to collect daily litter whenever possible.

Noticeably older litter items that could not have been introduced to the site since the previous day may be found on the dry sand. These items were likely buried and may have been exposed as sand was disturbed during surveys. These items should not be included in an accumulation survey and can be discarded without processing.

Do a brand audit

Most consumer products have information about the product (or the brand owner of the product) printed on them (**Figure 12**). The recording of information from branded litter is called a 'brand audit'. The following product information should be recorded in **Datasheet 3** (*Brand Audit Information*):

- Brand name (e.g. Choco-Snow),
- Manufacturer (e.g. Barnadoo International),
- Where the item was produced/packaged (e.g. South Africa),
- Type of product (e.g. food packaging),
- Type of material (e.g. other plastic [#7]), and
- Number of layers (for plastic items).

It is recommended that a brand audit is done on the litter collected on each day of the survey but excluding *Day Zero* (see **Appendix 1** for the biases associated with litter from *Day Zero*). The detailed protocols for brand audits are provided in **Appendix 3**.

BRAND AUDITS
IMPORTANT INFORMATION ON BRANDED LITTER

*Figure 12: Brand audit data are useful when addressing plastic pollution. *Recording of manufacture/best before dates is optional.*

Process litter

Litter processing refers to the cleaning, sorting, counting and weighing of litter. The detailed methods for litter processing are provided in **Appendix 2** and a graphical summary is depicted in **Figure 13**. All macrolitter collected from the survey area must be sorted, counted and weighed according to either **Datasheet 4** (*Basic Litter Datasheet* with 36 litter categories) or **Datasheet 5** (*Comprehensive Litter Datasheet* with >140 litter categories). Visual guides for these two datasheets are provided in **Appendix 4** and **5** respectively. **Appendix 6** can be used to measure macrolitter fragment sizes.

Separate litter datasheets should be completed for litter collected in the wet and dry zones. This must be done for each day of the survey. A total of three datasheets must therefore be completed on each day of an accumulation survey:

0. Site Description Datasheet (completed only on *Day Zero*) – **Datasheet 11**
1. Daily Site Conditions – **Datasheet 2**
2. Litter Datasheet (wet zone) – **Datasheet 4** or **5**
3. Litter Datasheet (dry zone) – **Datasheet 4** or **5**.

Note: Surveyors conducting more detailed, scientific studies may choose to weigh each piece of litter.

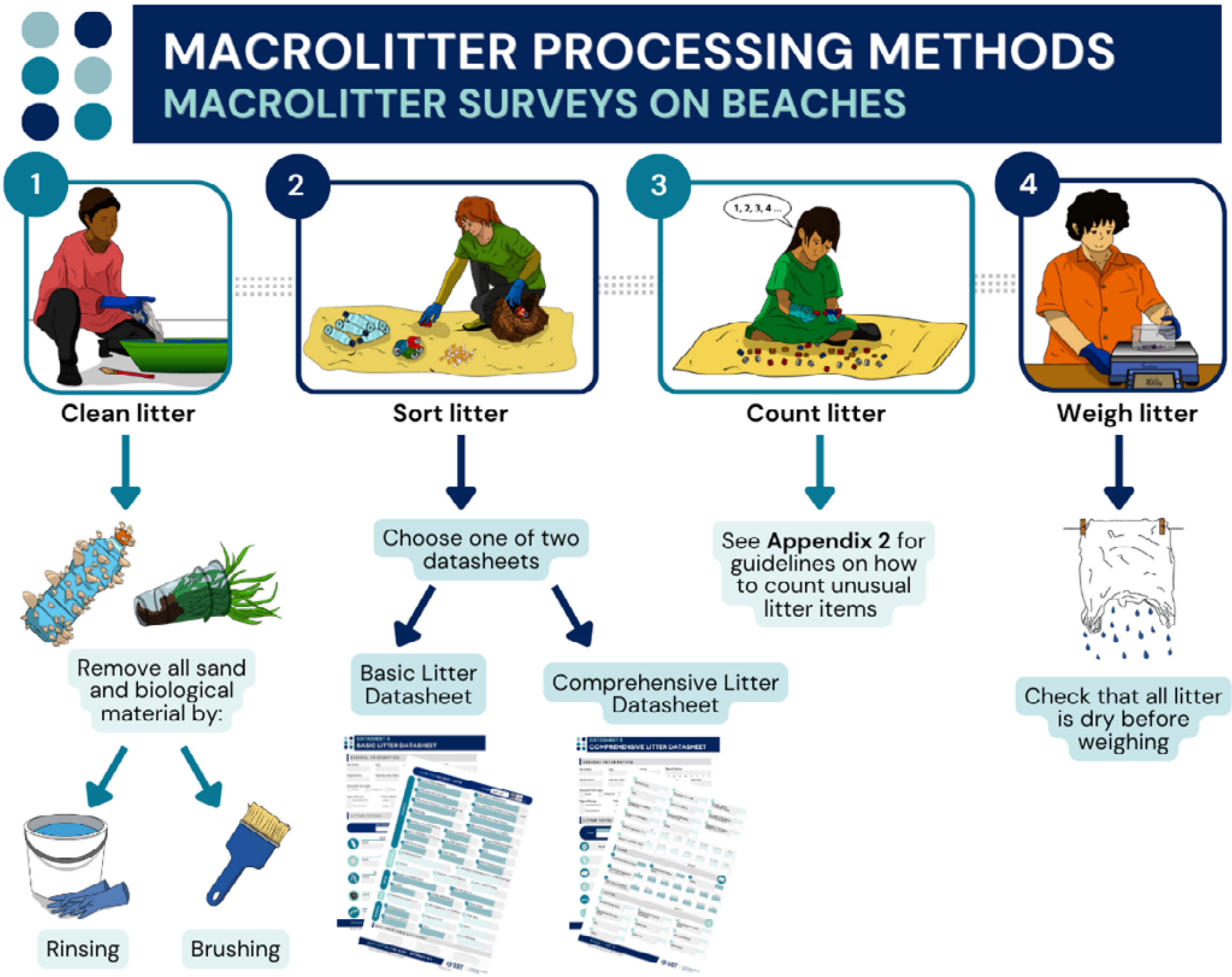


Figure 13: Summary of macrolitter processing methods. See Appendix 2 for a detailed description of the methods.

Dispose of waste

Once the survey has been completed, litter should be disposed of correctly or stored for further analysis. Biodegradable organic waste can be composted, and recyclable materials can go to recycling collection points or material recovery facilities (MRFs).

Analyse data

Macrolitter density can be expressed per linear metre (m) and/or per square metre (m^2) of beach. The reasoning behind reporting beach litter per length of beach (m) is that litter is deposited in linear strandlines along the beach, so beach width must be omitted

Table 1: An example of how litter totals must be calculated for standing-stock and accumulation surveys.

	Standing-Stock Survey		Accumulation Survey	
	Count	**Weight**	**Count**	**Weight**
Linear deposition (m)	36 items/m	20.0 g/m	2 items/m/day	3.3 g/m/day
Density (m^2)	2 items/m^2	3.2 g/m^2	0.1 items/m^2/day	0.1 g/m^2/day

when surveyors are interested in measuring litter deposition by the tide[5].

However, since litter accumulation from land-based sources (e.g. littering from beachgoers) may be influenced by beach width, an indication of litter per m^2 is also useful. It is therefore recommended that both values of macrolitter density are calculated to ensure the results can be compared to other studies.

The number and weight of items will thus be calculated per m and per m^2 of beach for standing-stock surveys and per m and per m^2 of beach per day for accumulation surveys (**Table 1**). Macrolitter density should be calculated for all macrolitter (by totalling all items found), per litter category (e.g. plastic, glass, rubber), and per litter type (e.g. lollipop sticks, earbuds). This will allow for comparison of broad results (per totals and categories) between sites and over time, while also revealing site differences and long-term changes relating to particular litter items. The latter is important to inform and monitor the effectiveness of litter reduction methods.

Alternative methods

The aforementioned protocols are recommended for collecting the most reliable data. However, depending on the research questions of the study and available resources (e.g. funding, time and number of helpers), simpler methods can be used. For this reason, three different protocol standards – *Gold, Silver* and *Bronze Approaches* – have been provided as guidelines to modify the survey protocols to suit specific needs. By allowing flexibility in the methods, these standards ensure that data from litter surveys are always reliable and comparable while surveys remain feasible and sustainable. **Figures 14** and **15** show how standing-stock surveys and accumulation surveys can be modified respectively.

The minimum requirements for a reliable accumulation survey are provided in the *Bronze Approach*, while the *Gold Approach* is recommended for best accuracy. Survey methods can be customised within the range specified by the *Gold* and *Bronze Approaches*.

Note: By calculating litter loads by length (m) or area (m^2) of beach per day, results remain comparable regardless of the methods used. However, once methods are altered to below the standard of the *Bronze Approach*, the variation and uncertainty in the data increase substantially.

STANDING-STOCK SURVEY APPROACHES
MACROLITTER SURVEYS ON BEACHES

	GOLD APPROACH	SILVER APPROACH	BRONZE APPROACH
Litter size	25 mm	25 mm	25 mm
Survey area length	500 m	100-500 m	100 m
Survey area width	Edge of water to back of the beach	Edge of water to back of the beach	Edge of water to back of the beach
Days of surveying	1	1	1
Litter counts	Yes	Yes	Yes
Litter weights	Yes	Yes	Optional
Weighing individual pieces	Yes	Optional	No - Weigh per litter type (e.g. earbuds)

Figure 14: Using the guidelines above, standing-stock surveys can be modified according to available resources and the complexity of the study.

ACCUMULATION SURVEY APPROACHES
MACROLITTER SURVEYS ON BEACHES

	GOLD APPROACH	SILVER APPROACH	BRONZE APPROACH
Litter size	25 mm	25 mm	25 mm
Survey area length	500 m	250-500 m	250 m
Survey area width	Edge of water to back of the beach	Edge of water to back of the beach	Edge of water to back of the beach
Day Zero clean-up	Yes	Yes	Yes
Days of surveying	*Day Zero +* Days 1-10	*Day Zero +* next 7-10 days	*Day Zero +* Days 1-7
Litter counts	Yes	Yes	Yes
Litter weights	Yes	Yes	Optional
Weighing individual pieces	Yes	Optional	No - Weigh per litter type (e.g. earbuds)

Figure 15: Using the guidelines above, accumulation surveys can be modified according to available resources and the complexity of the study.

MESOLITTER SURVEYS ON BEACHES

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Introduction

Unless it is collected and disposed of appropriately, most plastic litter is destined to degrade and fragment into smaller pieces when exposed to the elements (e.g. ultraviolet radiation, wind abrasion, wave action)[1,2]. These fragments and other small plastic items (<25 mm) are often overlooked, as cleaning efforts are typically directed at larger items that are more visible and easier to remove. As a result, small plastic items tend to accumulate in beach sand over time, with particularly high densities found near urban areas[3,4]. These accumulated plastics can negatively impact beach ecosystems (e.g. by altering water movement and sand temperatures) as well as marine animals, especially if they end up in the sea[5–9].

Buoyant plastics that wash up on beaches are usually concentrated in strandlines – the line of accumulated debris and/or seaweed deposited on beaches (**Figure 1**). Studies on the amount and type of mesolitter (5–25 mm) polluting beaches therefore often sample the most recent strandline and use the results to extrapolate mesolitter density per square metre of beach[10]. However, this approach does not provide a reliable estimate of mesolitter density since older, buried strandlines are not sampled[10].

Figure 1: Small plastics are typically concentrated in strandlines.

This chapter presents a protocol to assess mesolitter in both visible and buried strandlines to provide better estimates of mesolitter density on beaches. Unlike macrolitter surveys (see **Chapter 8**: *Macrolitter Surveys on Beaches*), which can be conducted on many different types of shorelines, mesolitter surveys are mainly restricted to sandy beaches, where litter is able to accumulate over time. While focusing on mesolitter, the protocol also recommends the inclusion of industrial plastic pellets/nurdles (sized 2–5 mm), since they make up a substantial portion of beach litter smaller than 25 mm[4]. By extending the targeted size range of litter, surveyors can gain more information about small beach litter with little extra effort. To ensure that the results remain comparable with other mesolitter studies, litter within the 2–25 mm size range (referred to as mesolitter in this chapter) should ideally be separated into distinct size categories.

Protocols

Mesolitter is studied on sandy beaches by doing a once-off standing-stock survey (see **Appendix 1**) of the strandlines on a selected beach. Past and present strandlines are sampled by collecting the upper 5 cm of sand in 0.5 m-wide transects extending from the most recent strandline to the storm strandline and sieving it. Mesolitter is then extracted from the mixture of litter and natural material before being processed (cleaned, sorted, counted and weighed). Finally, the data are compiled and the average density of mesolitter (items/m and g/m) is calculated. The steps required to conduct mesolitter surveys on sandy beaches are provided in **Figure 2**.

SURVEY PROTOCOL
MESOLITTER SURVEYS ON BEACHES

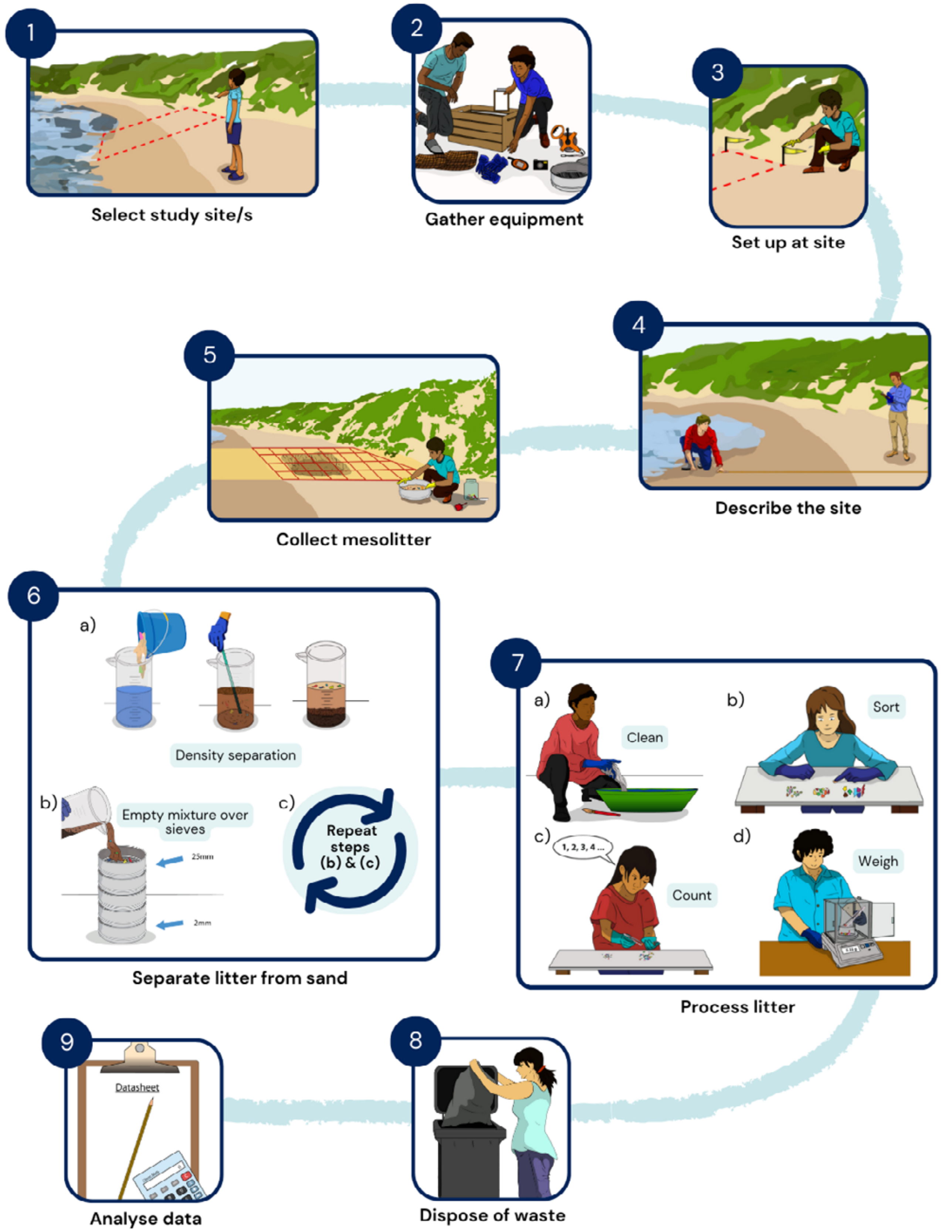


Figure 2: The protocol for mesolitter surveys on beaches consists of nine steps.

Select study sites

Study site features

As discussed in **Chapter 2** (*A Guide to Litter Monitoring in Africa*), the study's research questions will determine where surveys need to be conducted. It is best to have multiple study sites across a range of beach types (e.g. urban, rural, exposed, sheltered) to be able to compare and interpret the results. Mesolitter surveys can typically be conducted within the same study sites as macrolitter surveys on beaches. Mesolitter is collected within a transect that extends from the most recent strandline along the high-tide mark to the storm strandline, which is usually found at the back of the beach (**Figure 3**). Key features that surveyors need to identify at a study site are:

- **Most recent strandline**: The line of debris, consisting of litter and natural items like seaweed, that was deposited by the last high tide.
- **Back of the beach**: The boundary at the sea's landward limit, where storm waves leave a strandline. The back of the beach can usually be easily identified by the presence of cliffs, dunes, vegetation or permanent structures such as roads, buildings, fences and seawalls. In some instances, it may be identifiable by a change in dominant substrate type or topography (e.g. a change from sand to vegetation or a substantial change in slope).
- **Storm strandline**: The line of debris deposited during storms. The storm strandline is often visible towards the back of the beach but may also be buried beneath sand. See Step 5 (*Collect Mesolitter*) on how to locate a buried storm strandline.

Study site considerations

When selecting study sites for mesolitter surveys on sandy beaches, surveyors should consider the following:

- **Obstructions**: Sites where waves are obstructed should be avoided. For example, there should be no road infrastructure or bridge pylons within the site. If waves are breaking against a seawall at the back of the beach, it is unlikely that litter will accumulate, while breakwaters and jetties may influence water circulation and litter loads washing up on the beach.
- **Substrate**: Beach mesolitter surveys are done on sandy beaches where mesolitter accumulates and can be easily sampled.

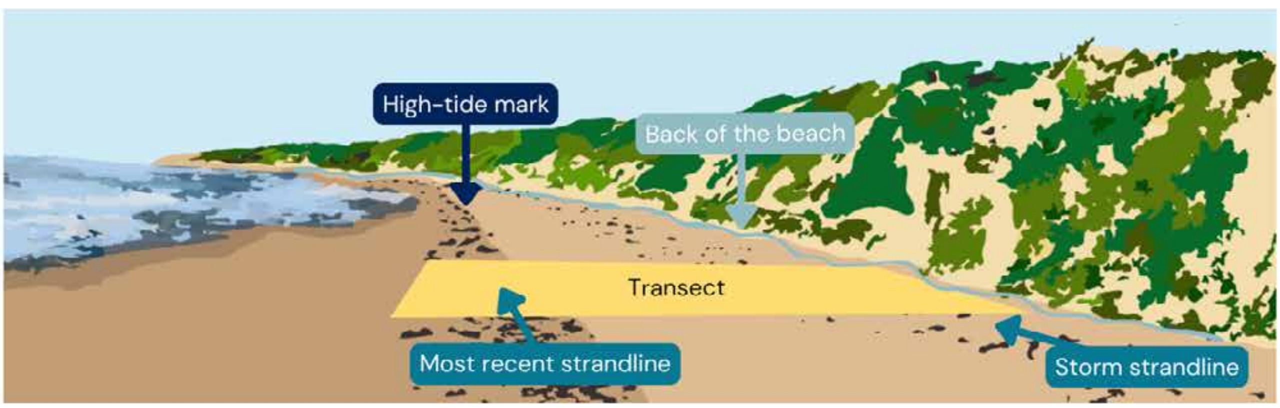


Figure 3: The most recent strandline along the high-tide mark and the storm strandline at the back of the beach are key features that need to be identified at study sites for mesolitter surveys.

Note: It may be necessary to avoid sampling on beaches with large volumes of stranded seaweed or vegetation since considerable effort is needed to sort through the material to find litter.

- **Accessibility**: Surveyors must have the required permission or authorisation to work on their chosen beaches.
- **Safety**: The study sites should not pose a risk to the safety of surveyors. Avoid high-crime areas, habitats of dangerous animals, and sites where rapid or extreme changes in tides may trap surveyors.
- **Low environmental impact**: Surveys should in no way disrupt or harm natural ecosystems (e.g. trampling dune vegetation). Avoid sites with endangered or protected habitats and species (e.g. nesting turtles).

Gather equipment

A printable checklist of the equipment needed to conduct mesolitter surveys on beaches is provided in **Figure 4**.

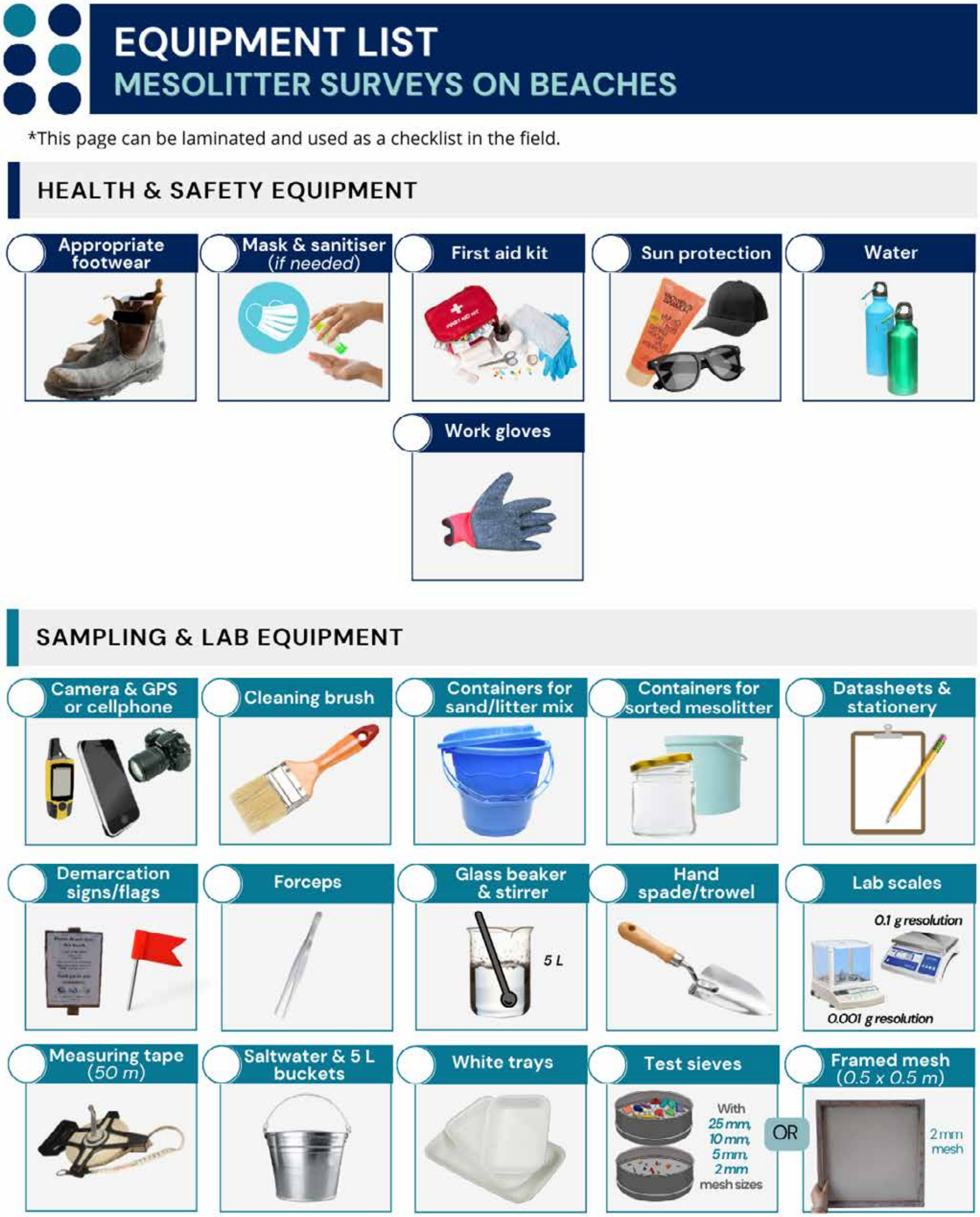


Figure 4: A printable equipment list for mesolitter surveys on beaches.

Set up at the study site

Mesolitter visible at the surface of the sand must be collected within a 0.5 m-wide transect from the water's edge to the back of the beach. However, buried mesolitter is only collected from the most recent strandline to the storm strandline near the back of the beach (**Figure 5**). This is because wet sand below the most recent strandline is substantially more difficult to sieve, but also because the constant erosion and accumulation of sand in the intertidal area inhibits the preservation of buried strandlines. The transect length is measured from the most recent strandline to the storm strandline.

Sampling of three replicate transects per site is recommended to account for spatial variation in mesolitter density. The distance between transects will depend on the beach topography, but transects must be at least 10 m apart. Where possible, transects should be set up in sand bays/slumps (sinuous depressions) oriented perpendicular to the water (**Figure 6**), because these act as accumulation zones for mesolitter.

Flags or other markers may be used to demarcate the transects. Surveyors must avoid stepping on the transect before sampling, as this may compress the sand and influence litter density estimates. Transects must be set up and sampled during low tide to allow access to more strandlines.

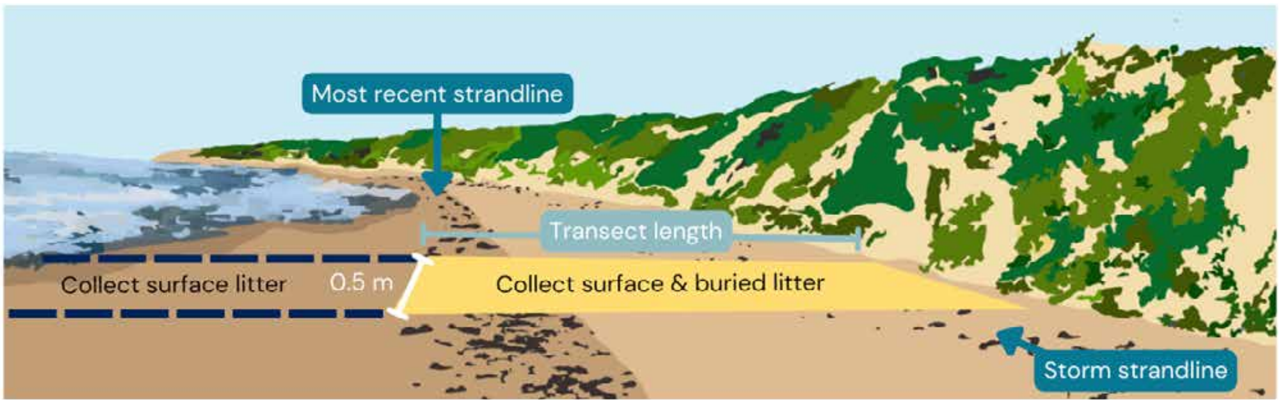


Figure 5: Buried mesolitter is collected in a 0.5 m-wide transect that starts at the most recent strandline and ends at the storm strandline. Mesolitter on the surface of the sand is collected within the transect and all the way to the edge of the water.

Note: It may be difficult to sample three transects on very wide beaches or when resources are limited. In such instances, it is better to sample one complete transect thoroughly than to partially sample multiple transects.

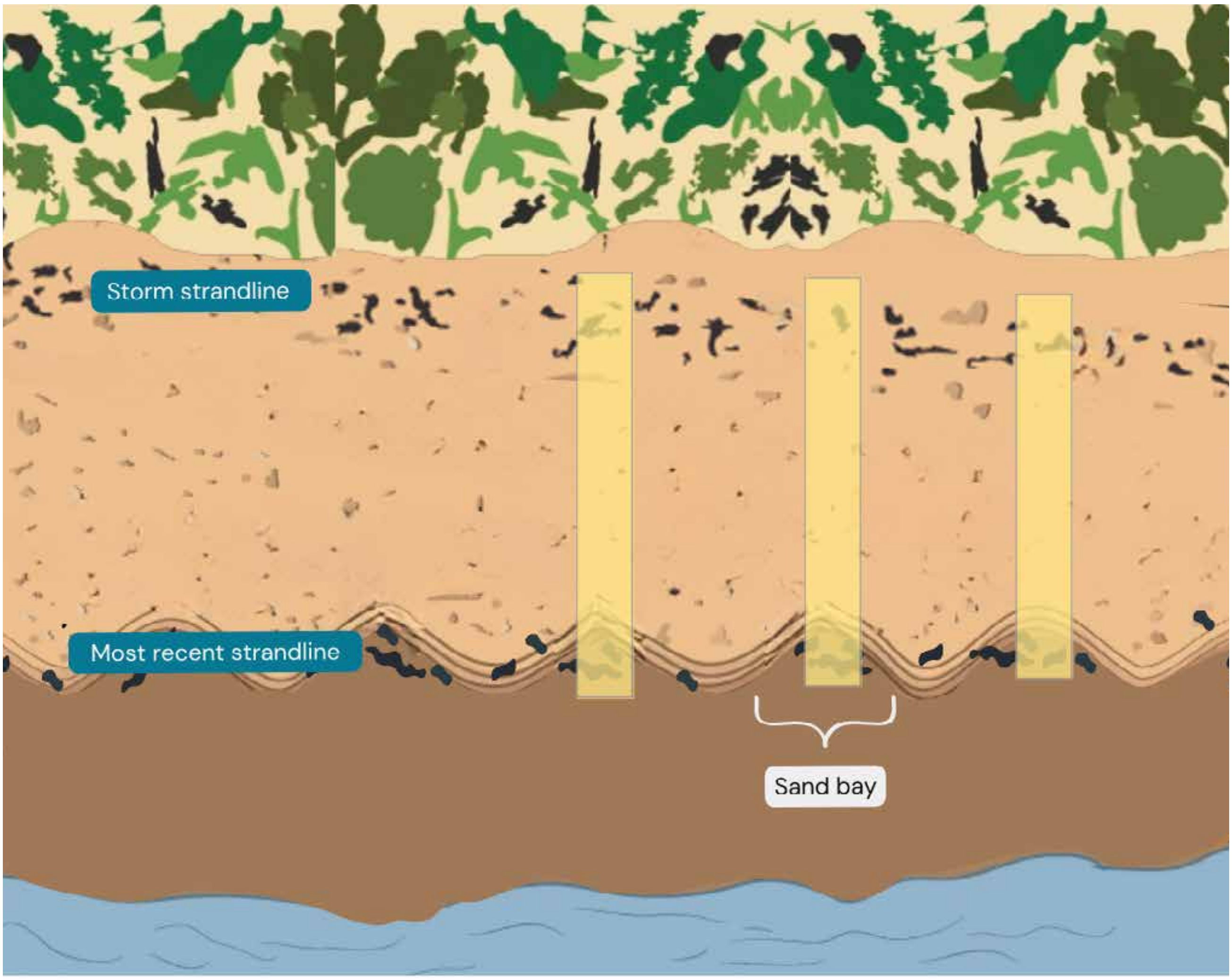


Figure 6: Many sandy beaches have naturally formed bowl-shaped slumps or depressions that occur perpendicular to the water. Sampling transects (indicated in yellow) should be positioned in these slumps where possible, since they act as mesolitter accumulation zones.

Describe the study site

It is important to collect information about the study site to help understand trends or patterns in the survey results. See **Datasheet 11** (*Site Description: Shorelines*) for the information needed to describe the site (e.g. GPS coordinates for the start and end of each transect, transect length, substrate type, tidal range, nearest town).

This datasheet should only be completed once per survey. Surveyors are encouraged to take photographs of the demarcated transects that show the surrounding environment. These photographs can then be used in conjunction with descriptions of the transect location in the Comments/Notes section of **Datasheet 11** to help locate the same transects in the future.

Note: Mobile applications such as Gaia GPS can be used to obtain GPS coordinates with a cellphone.

Collect mesolitter

Collect visible mesolitter at the surface of each transect from the water's edge to the storm strandline and place it in a clearly labelled container. Take care not to step into the transect while sampling. Buried strandlines must then be sampled from the most recent strandline to the storm strandline using the following steps:

1. Insert a ruler or measuring stick 5 cm into the sand.
2. Using a hand spade or scooping by hand, collect the top 5 cm of sand and filter it through sieves with a mesh size of 2 mm (**Figure 7**). Concentrations of natural material and mesolitter in the sand indicate the presence of buried strandlines. Surveyors may have some difficulty identifying the storm strandline if it has been buried. To find a buried storm strandline (and the upper end of the transect), start by sampling lower down the transect and work towards the back of the beach. The sudden absence of buried litter and natural material indicate the end of the storm strandline.
3. Remove easily identifiable natural material and any living organisms (e.g. beetles, sandhoppers) from the sieve and place the remainder of the sample in the same container as the surface mesolitter.
4. Sample containers should be clearly labelled to include the study site name, date of collection and transect number/coordinates.
5. After sampling, remove all equipment from the beach.

Figure 7: A surveyor collects the upper 5 cm of sand during a mesolitter survey.

Note: Given the small size of mesolitter, it is best to limit the time in the field and process the litter in an enclosed location (e.g. a laboratory), where the mesolitter will be extracted from the remaining natural material and grouped into different sizes.

Separate litter from sand

Once in a sheltered and secure location (ideally a laboratory), the collected mesolitter must be separated from sand and natural material using the methods detailed in **Appendix 9**. First, samples must be emptied over a tray and the easily identifiable pieces of mesolitter picked out using forceps. The rest of the sample is then added to saltwater (either seawater or a saltwater solution) to separate any remaining mesolitter from natural material in a procedure known as *density separation*. Density separation allows buoyant plastic items that are less dense than seawater to float near the surface, while the denser items sink to the bottom. A summary of this procedure is shown in **Figure 8**.

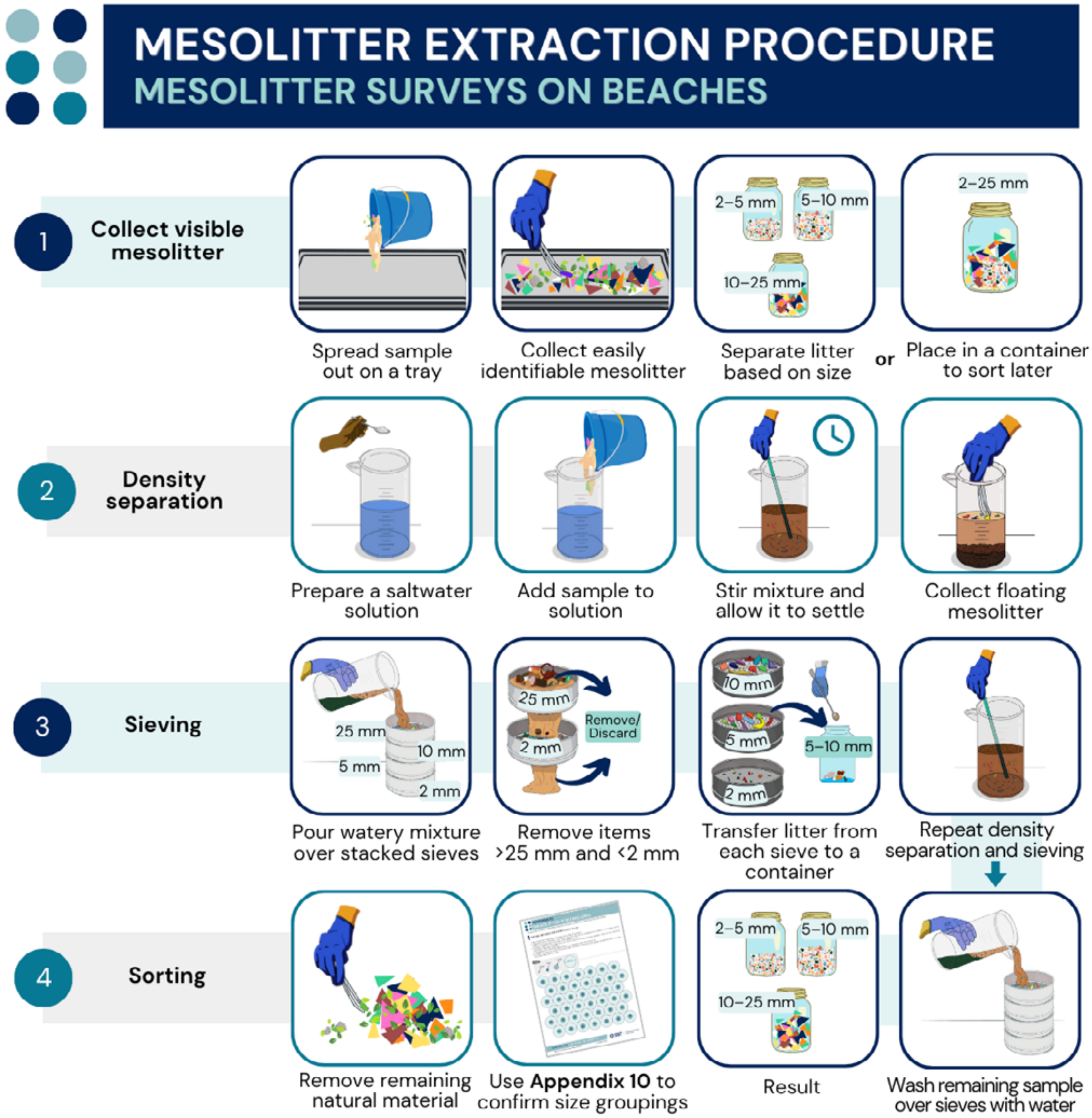
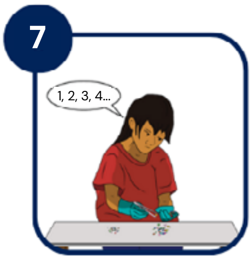


Figure 8: Summary of the procedure to extract mesolitter from a sample. See Appendix 9 for the detailed methods.



Process litter

All pieces of mesolitter must be:

1. Counted and categorised as per **Datasheet 10** (*Mesolitter Datasheet: General*). See **Appendix 10** for the sizing chart used to sort mesolitter into different size categories.
2. Cleaned with water or brushes to remove any remaining sand/natural material that may influence weight measurements.
3. Air-dried to ensure all items are dry before weighing. Note that some pieces of litter, such as fabric, may require more time to dry than others.
4. Weighed per category (e.g. 'Ropes/fibres') to the nearest mg (0.001 g).

Separate litter datasheets should be completed for each of the three recommended replicate transects. A total of four datasheets must ideally be completed:

0. Site Description Datasheet – **Datasheet 11**
1. Mesolitter Datasheet (x3) – **Datasheet 10**.

Note: Surveyors conducting more detailed, scientific studies may choose to weigh each piece of litter.

Dispose of waste

Once the survey has been completed, mesolitter should be disposed of correctly. Due to the small size of mesolitter and pellets, and the frequently degraded state of buried litter, recycling may not be possible for most mesolitter. Any remaining biodegradable organic waste (e.g. seaweed) can be composted.

Analyse data

Mesolitter density is expressed as mesolitter count and/or weight per linear metre of beach (e.g. 5 items/m and 20.0 mg/m). Transect length is omitted from the calculations because litter is deposited in linear strandlines, so expressing mesolitter density per area (m^2) of beach would bias estimates of litter washed up by the tide[4].

Results can be calculated for all mesolitter (by totalling all items collected), per litter category (e.g. plastic, glass, rubber), per litter type (e.g. cigarette butts, plastic beverage bottles) and per fragment size (e.g. 2–5 mm, 5–25 mm).

Calculating mesolitter density

To determine the mesolitter density (by count or weight) in each transect, divide the number or weight of mesolitter items found by the total transect width sampled as per Equation 1.

This same equation can be used to calculate the density of the different types (categories) or sizes (fragment size categories) of mesolitter. To calculate the mean mesolitter density at a site, add the mesolitter densities from each transect together and divide it by the total number of transects sampled.

Determining variation in data

By calculating the mesolitter density per transect (as opposed to per site), surveyors can calculate the variation in litter density within sites. It is important to calculate the variability of samples at the study site, as it is more difficult to make predictions and generalisations when the data variability (how different data points are from each other and the sample mean) is high. The equation used to calculate variability in data depends on which measure of variability is used (e.g. standard deviation, standard error, variance, range). For more information about how to calculate variability, click here.

Alternative methods

The aforementioned protocols are recommended to collect the most reliable data. However, depending on the study's research questions and available resources (e.g. funding, time, number of helpers) simpler methods may be used. For this reason, three different protocol standards – *Gold, Silver* and *Bronze Approaches* – have been provided as guidelines to modify the survey protocols to suit specific needs. By allowing flexibility in the methods, these standards ensure that data from litter surveys are always reliable and comparable while surveys remain feasible and sustainable. **Figure 9** shows how mesolitter surveys can be modified to suit the different protocol standards.

The minimum requirements for a reliable accumulation survey are provided in the *Bronze Approach*, while the *Gold Approach* is recommended for best accuracy. Survey methods can be customised within the range specified by the *Gold* and *Bronze Approaches*.

Equation 1:

$$\text{Density of mesolitter}_{\text{(by count or weight)}} = \frac{\text{Total count or weight of mesolitter per item}}{\text{Total width of transect}}$$

Note: By calculating litter loads per metre of beach per day, results remain comparable regardless of the methods used. However, once methods are altered to below the standard of the *Bronze Approach*, the variation and uncertainty in the data increase substantially.

SURVEY APPROACHES
MESOLITTER SURVEYS ON BEACHES

	GOLD APPROACH	SILVER APPROACH	BRONZE APPROACH
Size of litter to collect	2-25 mm	2-25 mm	2-25 mm
Transect width	0.5 m	0.5 m	0.5 m
Transect length	Latest strandline to storm strandline	Latest strandline to storm strandline	Latest strandline to storm strandline
Depth of soil collected	5 cm	5 cm	5 cm
Number of transects	3	1-3	1
Litter counts	Yes	Yes	Yes
Litter weights	Yes	Yes	Optional
Weighing individual pieces	Yes	Optional	No - Weigh per litter type (e.g. earbuds)

Figure 9: Mesolitter surveys on beaches can be modified using the guidelines above.

BURIED LITTER SURVEYS ON BEACHES

Eric Okuku, Mary Mbuche Chiphatsi, Purity Chepkemboi, Maureen Kombo, Catherine Sezi Mwalugha & Kenneth Otieno

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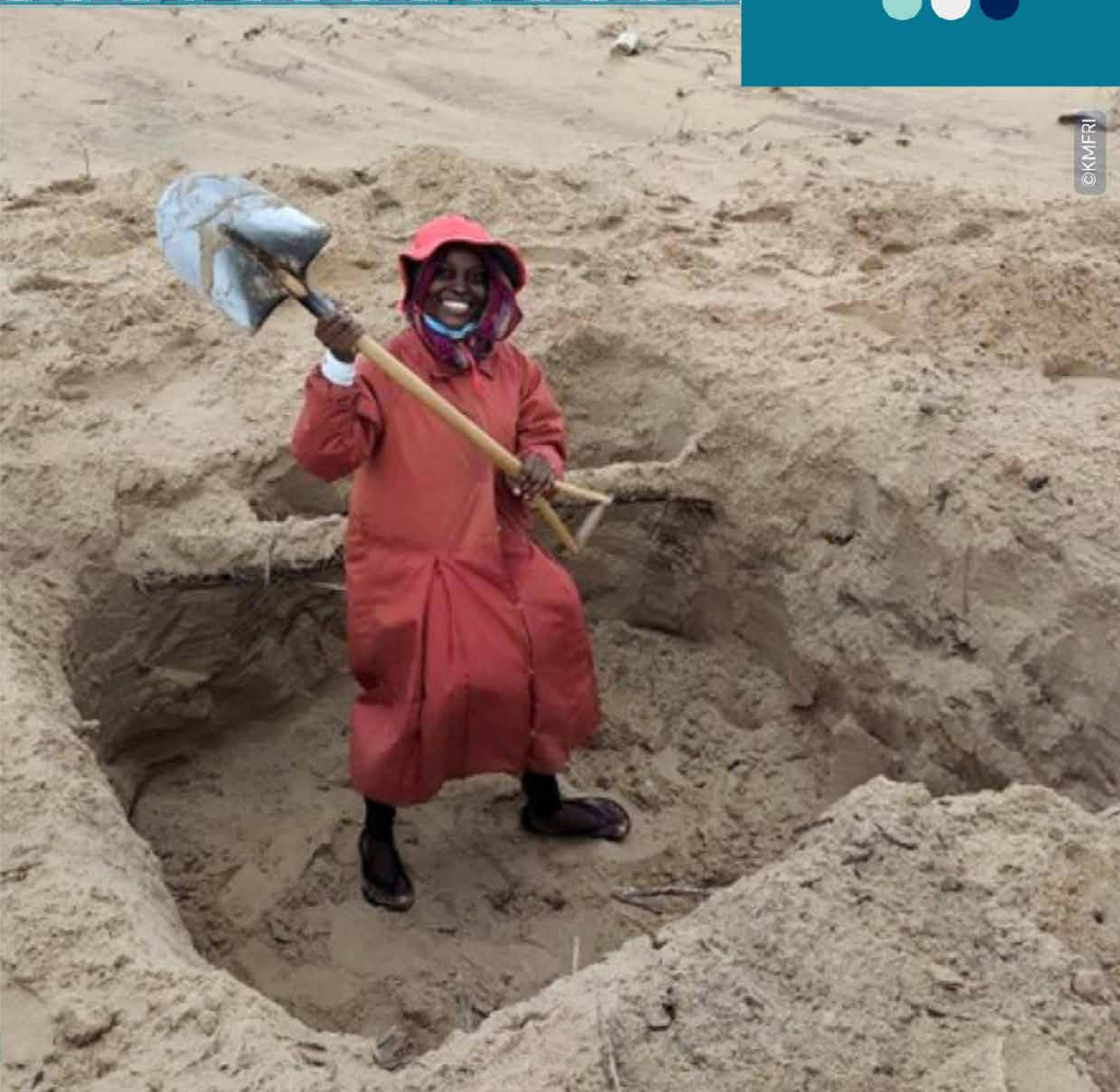

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Introduction

Direct counts of marine litter loads around the world indicate that modelled estimates of plastic leaking into the marine environment are overestimated[1–3]. This could be partially explained by the existence of litter sinks. For instance, litter may become trapped in mangrove forests, may be buried in estuaries or on beaches during flooding events, or may settle on the sea floor[4]. This trapped or 'missing plastic' forms a significant fraction of marine litter[5] and may remain in the environment for decades due to limited exposure to degradational processes (**Figure 1**).

Of the different litter sinks mentioned above, perhaps the easiest and most convenient to study are sandy beaches. They are easy to access and survey, and require no special training and equipment to study, making them the most viable and cost-effective option[6]. Studying the abundance and vertical distribution of buried litter on beaches is essential to understand the role of litter sinks in global estimates of plastic pollution.

This chapter outlines the methods for collecting and studying buried macro- and mesolitter on sandy beaches. Buried litter surveys are valuable for several reasons. These include:

- Ensuring litter pollution on beaches is estimated accurately, as beach cleaning typically removes only visible surface litter.
- Providing a more accurate reflection of litter accumulation over time, given

Figure 1: Buried litter may remain sheltered from the elements for years before it is exhumed naturally. The examples provided here were collected on beaches in East Africa.

that buried litter is rarely affected by waves, winds or clean-ups. Surveys that profile buried litter at various depths can yield valuable information about flooding events, including estimated timelines (based on litter age) and scale of flooding (based on litter density).

- Serving as a valuable tool for assessing the variability of litter accumulation across beaches and depths. The data obtained from buried litter surveys can inform and guide targeted interventions aimed at reducing the impacts of litter on marine ecosystems.

Protocols

These protocols cover two different ways to study buried litter (>2 mm), each with a different goal (**Figure 2**). Both methods involve digging into beach sand to a predetermined depth and sieving it to find buried macro- and mesolitter. The first method, the *transect method*, consists of a transect setup where surveyors look for buried litter in continuous lines/transects that start at the waterline and end at the back of the beach. Litter is sampled to a shallow depth of 25 cm to gain a better understanding of baseline buried litter loads on a beach. In contrast, the *quadrat method* relies on sampling within equally spaced squares between the waterline and the back of the beach. Litter is sampled at various depths to a maximum of 100 cm to gain an understanding of litter deposition during flooding events and to measure long-term trends in buried litter. For both surveys, the collected litter is sorted into categories, counted, cleaned and weighed. A stepwise summary of a buried litter survey is provided in **Figure 3**.

COMPARISON OF SAMPLING DESIGNS
BURIED LITTER SURVEYS ON BEACHES

	TRANSECT METHOD	QUADRAT METHOD
Buried litter depth	0-25 cm	0-100 cm
Litter profiling (assessing litter at different depths)	Not possible	Possible
Ideal sand density	Compact and loose	Loose sand only
Goal	Determine baseline of buried litter	Measure long-term trends in litter deposition

Figure 2: Differences between the transect method and quadrat method of conducting buried litter surveys.

SURVEY PROTOCOL
BURIED LITTER SURVEYS ON BEACHES

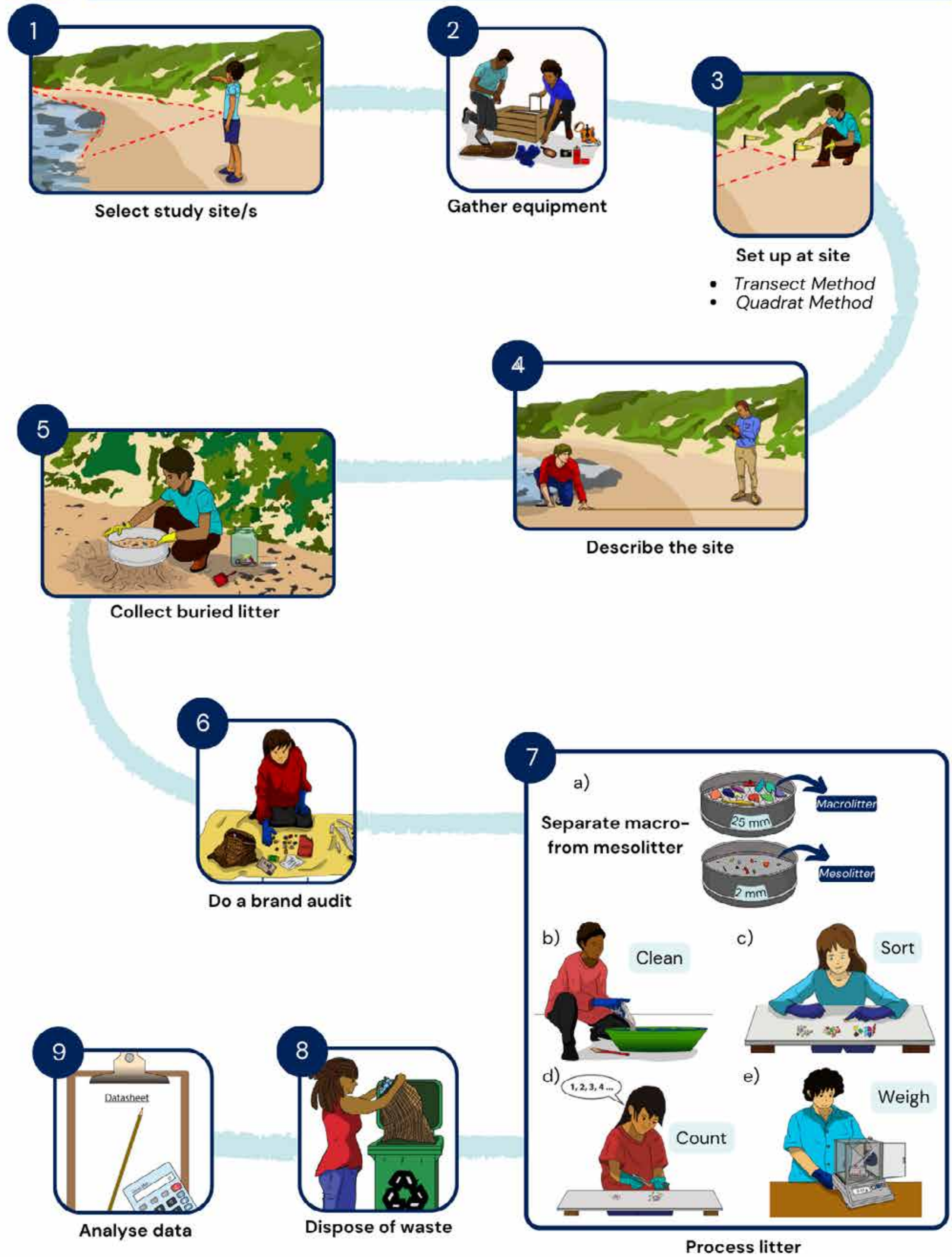

Figure 3: The protocols for buried litter surveys using the transect or quadrat methods follow the same nine steps.

Select study site

Considerable care must be taken to select an appropriate study site. To assist with site selection, a list of site considerations needed to reliably answer the research questions posed in **Chapter 2** (*A Guide to Litter Monitoring in Africa*) is provided below. However, surveyors must also ensure that they can feasibly survey the chosen study site – especially for monitoring projects where regular surveys are necessary. It is therefore important to carefully consider the location and size of the study site, as well as the sampling design used to study buried litter (i.e. transect method or quadrat method). Guidelines to modify the study site dimensions and survey approach are provided in the **Alternative Methods** section at the end of this chapter. It is best to have multiple study sites to be able to compare and interpret results.

Study site considerations

The following should be considered when determining the study site:

1. **Length and width of beach**: Study sites should ideally be 300 m long (measured parallel to the waterline) but no less than 100 m. The site width (measured from the waterline to the back of the beach) will vary between sites but must be more than 10 m. The area surveyed can be modified based on the level of pollution and according to the available resources for litter surveys (e.g. funds, helpers, time).
2. **Substrate**: Avoid beaches with large stones or coral beds.
3. **Accessibility**: Ensure that the study site is accessible throughout the year and that it can be reached via connecting roads or footpaths. Study sites should be at least 50 m away from the public entry points since these areas are usually more polluted compared to other areas of the beach. Obtain any necessary authorisation needed to work at the site. Check the local environmental regulations to confirm whether any impact assessments need to be conducted or whether permits are necessary to excavate large volumes of sand. Note that the sand will not be removed from the site and holes will be refilled after sampling, reducing the potential environmental impact or safety risk.
4. **Absence of clean-up activities by third parties**: Choose an area that is not subjected to regular municipal or private clean-ups as this may bias the results.
5. **Moderate slope**: Sites with a low to moderate slope are recommended. Some researchers indicate that slopes of 15–45° (or 26–100%) are ideal[7]. The methods for measuring slope are provided in **Appendix 8**.
6. **Surveyor safety**: Study sites should not be in areas that pose a risk to surveyors (e.g. crime, dangerous animals, entrapment at high tide). Tide charts and weather forecasts should be consulted to ensure that surveys are conducted during low tide and that extreme weather conditions (e.g. flooding, hurricanes, heavy rains) are avoided.
7. **Minimal negative impact**: Ensure that the study site does not negatively impact animals and vegetation, e.g. turtle nesting sites. Refill excavated transects or quadrats with the sieved sand after each day of sampling to minimise the environmental impact and avoid risk to other beachgoers.

Gather equipment

A printable checklist of the equipment needed to conduct buried litter surveys on beaches is provided in **Figure 4**.

Set up at the study site

The transect method

When using the transect method, buried litter must be sampled within continuous transects running perpendicular to the waterline. Each transect must be 0.5 m wide (measured parallel to the waterline) and will extend from the waterline to the back of the beach (**Figure 5**). The length of transects will therefore vary depending on the distance from the waterline to the back of the beach. Ideally, ten transects should be surveyed for buried litter, but if this is not feasible (either due to resource constraints or the beach being very polluted), a minimum of five transects may be sampled (see **Figure 14** in the **Alternative Methods** section). Transects must be evenly spaced according to the beach topography but should be at least 5 m apart (**Figure 5**).

The quadrat method

When using the quadrat method, buried litter is collected at predetermined depths within square sampling units known as quadrats. Being smaller than transects, quadrats allow surveyors to feasibly study litter at deeper depths. To set up the quadrats for sampling, first mark out five transects that are 2 m wide and spaced at least 5 m apart.

Ideally, five quadrats should be placed along each of the five transects (thus totalling 25 quadrats for the site) and spaced an equal distance of at least 2 m apart (**Figure 6**). A minimum of three transects with three quadrats each (totalling nine quadrats for the site) may be used at very polluted sites or where resources are limited. Guidelines for modifying quadrat size, number of quadrats surveyed, the distance between quadrats, area of beach surveyed, and depth surveyed are provided in **Figure 15** in the **Alternative Methods** section.

Mark out the survey areas

To prevent public cleaning and other disturbances (e.g. excessive trampling of sand) during the survey, place clearly visible signage at each end of the study site. These signs must contain relevant information such as the date, time and purpose of the survey to help beachgoers understand the study and encourage cooperation. Graphics or photos can be used on signs to draw attention and to communicate with larger audiences (e.g. illiterate beach users).

Within the demarcated area, each transect or quadrat must also be marked out using flags or other markings. This will help to easily locate each sampling unit and will ensure that surveyors remain within the boundaries of the survey area.

Figure 4: A printable checklist of the equipment needed to conduct a buried litter survey on sandy beaches.

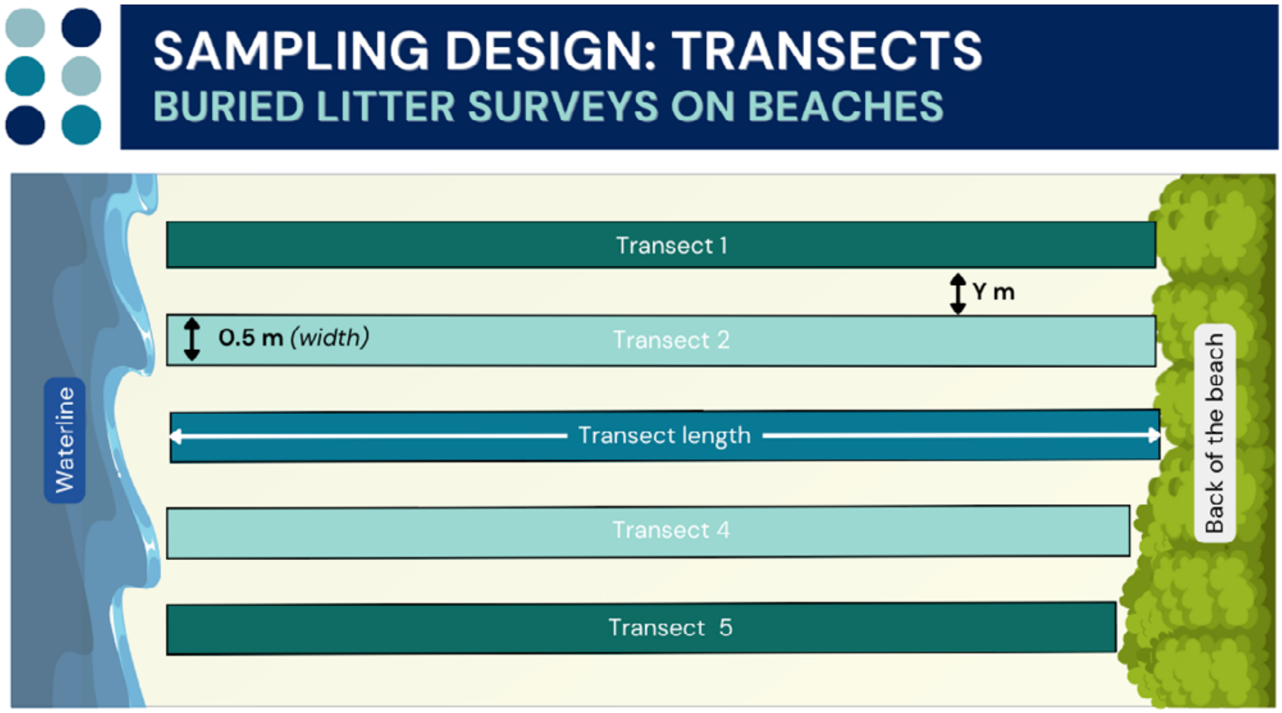

Figure 5: The transect method for buried litter surveys entails setting up 5–10 transects extending from the waterline to the back of the beach. Transects must be 0.5 m wide and spaced at an equal distance (Y m) of at least 5 m.

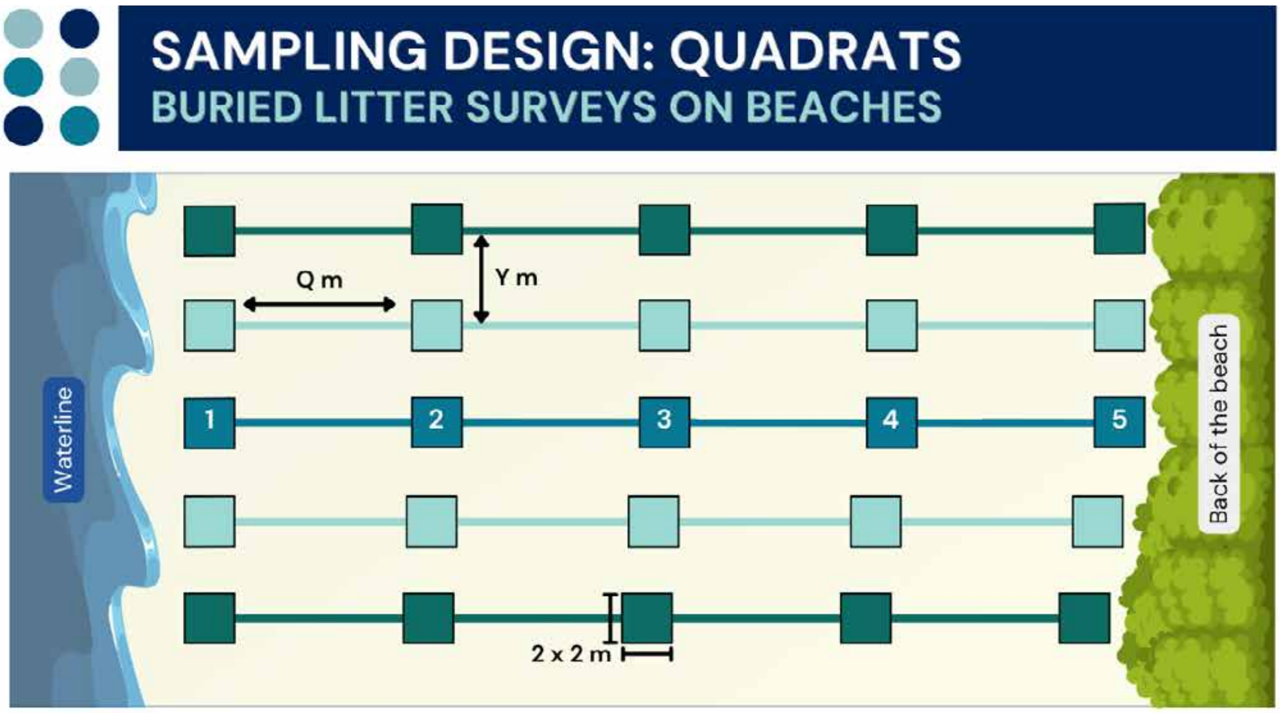

Figure 6: The quadrat method for buried litter surveys entails placing (ideally) five quadrats along five transects extending from the waterline to the back of the beach. Transects must be spaced at an equal distance (Y m) of at least 5 m, and quadrats along the same transect must be spaced at an equal distance (Q m) of at least 2 m.

Describe the study site

It is important to collect information about the study site to help understand trends or patterns in the survey results. See **Datasheet 11** (*Site Description: Shorelines*) for the information needed to describe the site (e.g. GPS coordinates, substrate type, tidal range, the nearest town). This datasheet should be completed at the start of each survey.

Collect buried litter

Litter collection methods are the same for both the transect and quadrat methods. For both methods, sand is excavated to predetermined depths (see below) and then sieved to collect macro- (>25 mm) and mesolitter (2–25 mm).

Buried litter surveys must take place during low tide. Studies looking at the impact of flooding on buried litter must begin as soon as water levels recede and conditions are safe for surveyors. Surveys in dunefields must be conducted quarterly to allow the natural movement of sand between sampling events.

Where to clean

For the transect method, litter will be collected at the surface and to a depth of 25 cm along the entire transect. Buried litter and surface litter must be stored in separate containers. In contrast, for the quadrat method, sand must be collected at the surface and sieved in 25 cm depth intervals, until a recommended depth of 100 cm is reached (**Figure 7**). A minimum depth of 50 cm can be used for heavily polluted sites or where resources are limited (see **Figures 14** and **15**). The samples from each quadrat must be divided as follows: a) surface litter, b) litter collected from 0–25 cm deep, c) litter collected from 25–50 cm deep, etc. (**Figure 7**).

What to clean

All visible litter (>2 mm) must be collected at each depth interval surveyed. Surveyors have the option to only collect macrolitter (>25 mm), but it is recommended that meso-litter (2–25 mm) is included where possible. Avoid removing natural or biological items from the beach (**Figure 8**).

Litter items that are too large (e.g. tyres, ropes, nets) or dangerous (e.g. chemicals, weapons, ammunition) to remove should be counted but not handled. Mark these items with paint or photograph them to ensure they are not counted again in future surveys. The weights of heavy or large items can be estimated by multiplying the estimated volume of the item by the density of the material as per **Appendix 2**. Notify the relevant authorities of any large or dangerous items so they can be safely removed. Used hygiene objects such as diapers, condoms and feminine hygiene products can be removed, noted and disposed of responsibly. During litter processing, a clean and dry proxy can be used to estimate the weight of any unsanitary item recorded at the site (see **Appendix 2**).

COLLECTING LITTER AT DIFFERENT DEPTHS
BURIED LITTER SURVEYS: QUADRAT METHOD

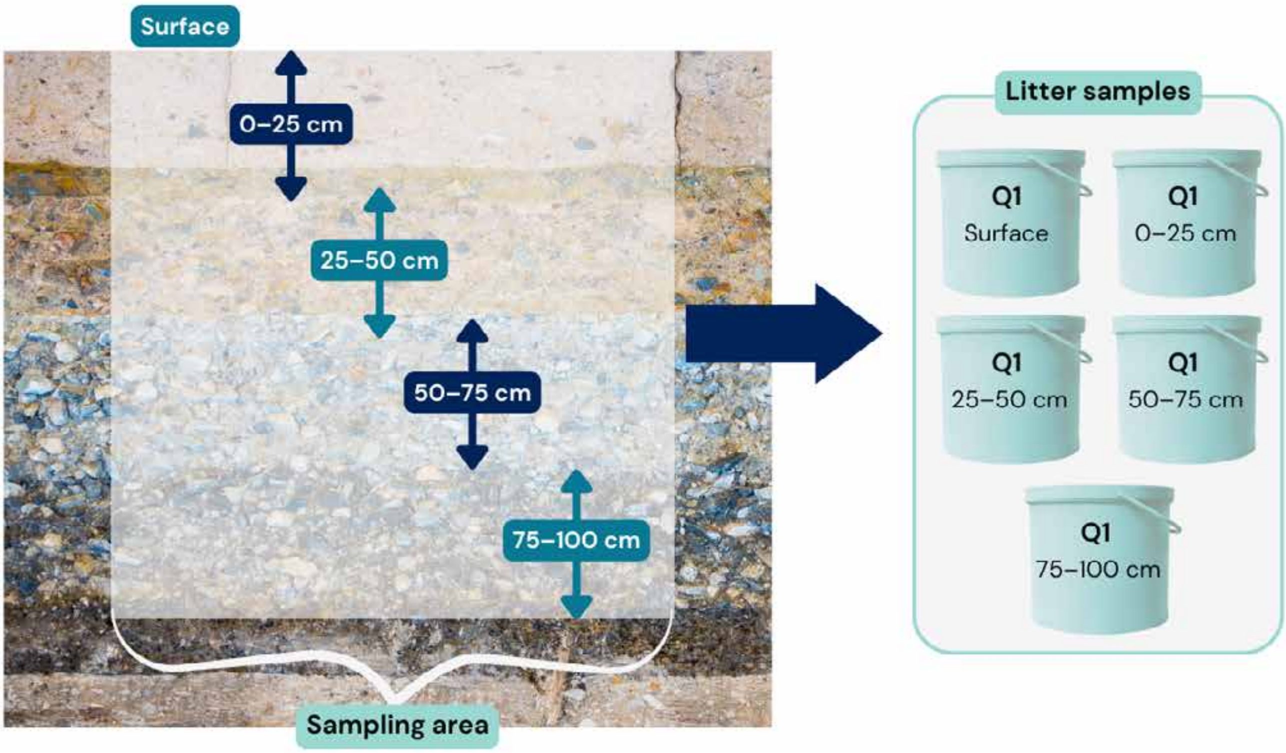

Figure 7: When studying buried litter within quadrats, sand must be collected and sieved in 25 cm intervals up to a recommended depth of 100 cm. Litter samples collected from each 25 cm interval must be stored separately.

How to clean

To collect buried litter, surveyors must dig within the transects/quadrats, using a spade or trowel to scoop up sediment. A ruler, measuring tape or metre stick should be used to adhere to the target depth intervals. Before commencing with the digging, all surveyors must know the target depth intervals and how to collect and store the litter. Containers/bags that are clearly labelled with the transect number, quadrat number and depth interval must be on hand. Once fully prepared, buried litter must be collected using the following steps:

1. Collect all litter (>2 mm) that is visible on the surface of the transect or quadrat and place it in an appropriately labelled bag/container (e.g. *Transect 1/ Quadrat 1: Surface or T1/Q1: Surface*)
2. Scoop out all the sand to the required depths and place it on a sieve with a 2 mm mesh size to separate the litter from the sand. Easily visible litter can be collected as it is encountered during digging.
3. Sieve the sand via dry sieving (sieving without the use of water) or wet sieving (washing water over the sieve or dabbing it repeatedly on the water surface; **Figure 9**). Dry sieving is recommended for dry and loose sand, while wet sieving is best for wet or compacted sand. Note that wet sieving removes sand from the beach and will prevent surveyors from refilling the excavated holes. Wet sieving is therefore not suitable for the dry sand in the supratidal zone, as it may take weeks before the next spring tide replenishes the sand.

NATURAL ITEMS VS LITTER

Figure 8: Only man-made litter items should be collected during surveys. Natural items should not be removed.

4. After sieving, the sieves will likely contain a mixture of litter and natural items such as shells, stones and seaweed. Discard all large or easily identifiable natural material (including living organisms) and place the remaining content of the sieve in a well-labelled bag or container *(e.g. Transect 1/Quadrat 1: 0–25 cm or T1/Q1: 0–25 cm)*. The contents of the containers can then be processed at a later stage in a more controlled environment (e.g. a laboratory) to ensure that all the litter is retrieved.
5. Repeat steps 2 to 4 for every depth interval when using the quadrat method. Ensure that the litter is placed in separate bags/containers labelled according to depth interval (**Figure 7**).

Note: Mesolitter typically describes litter in the 5–25 mm size range. However, since industrial pellets make up a significant portion of small plastics on beaches, the 2–5 mm size range is included as mesolitter in this manual but is processed separately to ensure compatibility with other surveys.

Figure 9: Dry sieving is done by adding sand to a sieve and shaking it (top), while wet sieving involves washing water over the sieve or dipping it on the water surface (bottom). Wet sieving has a greater environmental impact and is not recommended for use on the dry sand.

Do a brand audit

Most consumer products have information about the product (or the brand owner of the product) printed on them (**Figure 10**). The recording of information from branded litter is called a 'brand audit'. These audits are primarily performed on macrolitter, since mesolitter is unlikely to contain enough useful information on small fragments. The detailed protocol for brand audits is provided in **Appendix 3**. The following product information should be recorded in **Datasheet 3** (*Brand Audit Information*):

- Brand name (e.g. Choco-Snow),
- Manufacturer (e.g. Barnadoo International),
- Where the item was produced/ packaged (e.g. South Africa),
- Type of product (e.g. food packaging),
- Type of material (e.g. other plastic [#7]), and
- Number of layers (for plastic items).

BRAND AUDITS
IMPORTANT INFORMATION ON BRANDED LITTER

*Figure 10: Brand audit data are useful when addressing plastic pollution. *Recording of manufacture/best before dates is optional.*

Process litter

Litter processing refers to the cleaning, sorting, counting and weighing of litter. Note that macro- and mesolitter need to be processed separately, according to the methods provided below.

Macrolitter processing

To process macrolitter, first remove all litter >25 mm from the samples collected. Be sure to keep the litter from each quadrat and depth separate. Once separated from the rest of the sample, the macrolitter must be processed using the methods provided in **Appendix 2** and summarised in **Figure 11**.

All macrolitter must be sorted, counted and weighed according to either **Datasheet 4** (*Basic Litter Datasheet* with 36 litter categories) or **Datasheet 5** (*Comprehensive Litter Datasheet* with >140 litter categories). Visual guides for these two datasheets are provided in **Appendix 4** and **5** respectively. **Appendix 6** can be used to measure macrolitter fragment sizes.

Mesolitter extraction and processing

Once in a sheltered and secure location (e.g. a laboratory), the collected mesolitter must

> **Note**: Surveyors conducting more detailed, scientific studies may choose to weigh each piece of litter.

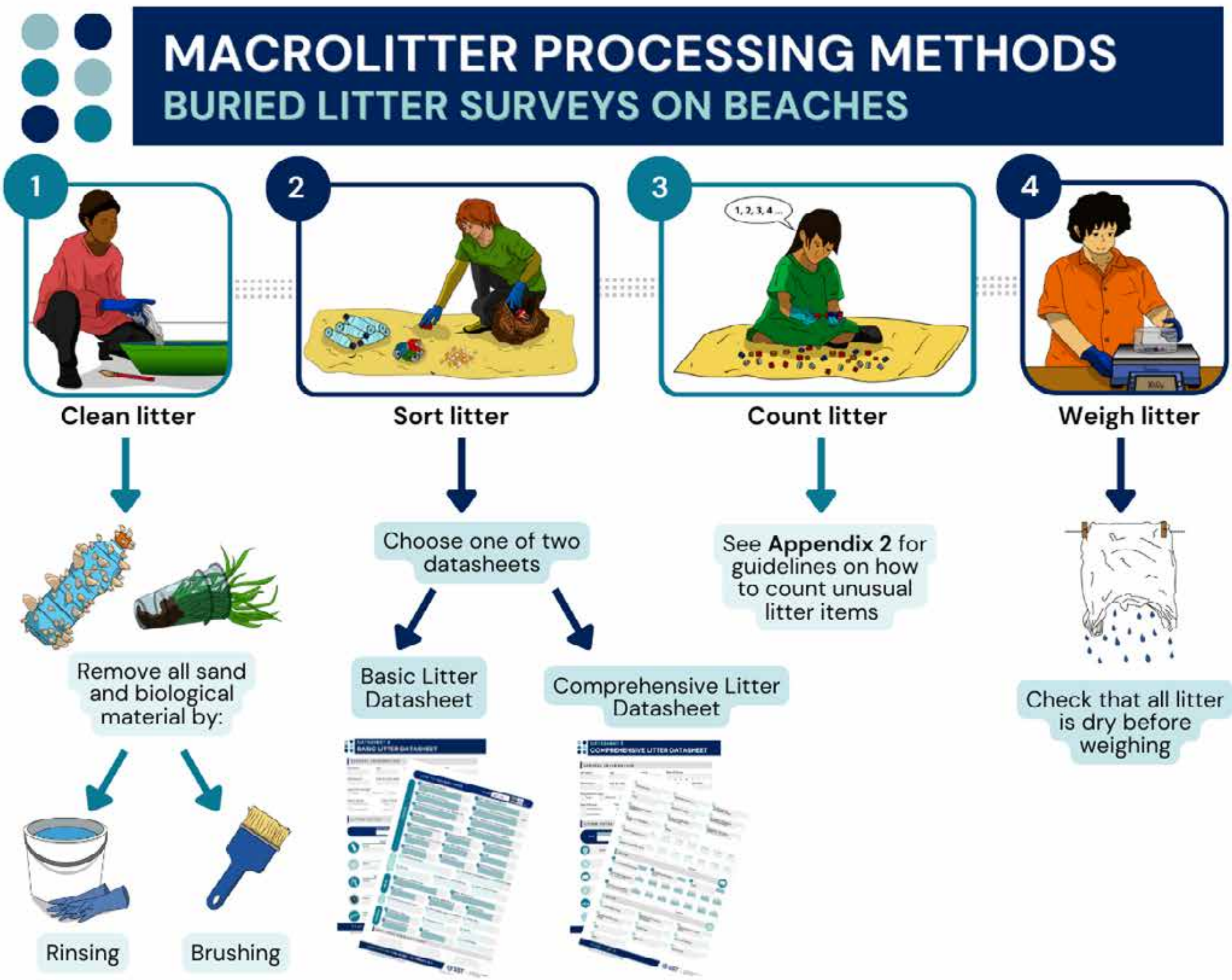

Figure 11: Summary of macrolitter processing methods. See Appendix 2 for a detailed description of the methods.

be separated from sediment and natural material using the methods detailed in **Appendix 9**.

First, samples must be emptied over a tray and the easily identifiable pieces of mesolitter picked out using forceps. The rest of the sample is then added to saltwater (either sea water or a saltwater solution) to separate any remaining mesolitter from natural material in a procedure known as *density separation*. Density separation allows buoyant plastic items that are less dense than saltwater to float near the surface, while the denser items sink to the bottom. A summary of this procedure is shown in **Figure 12**.

After extraction, all pieces of mesolitter must be:

1. Counted and categorised as per **Datasheet 10** (*Mesolitter Datasheet: General*). See **Appendix 10** for the sizing chart used to sort mesolitter into different size categories.
2. Cleaned with water or brushes to remove any remaining sand/natural material that may influence weight measurements.
3. Air-dried to ensure all items are dry before weighing. Note that some pieces of litter, such as fabric, may require more time to dry than others.
4. Weighed per category (e.g. 'Ropes/fibres') to the nearest mg (0.001 g).

Figure 12: Summary of the procedure to extract mesolitter from a sample. See Appendix 9 for the detailed methods.

Separate litter datasheets should be completed for each sample (i.e. each transect or each depth per quadrat). The following datasheets must therefore be completed for a buried litter survey:

0. Site Description Datasheet – **Datasheet 11**
1. Macrolitter Datasheet (per transect/ depth in quadrat) – **Datasheet 4** or **5**
2. Mesolitter Datasheet (per transect/ depth in quadrat) – **Datasheet 10**.

Dispose of waste

Once the survey has been completed, litter should be disposed of correctly. Due to the small size of mesolitter and pellets, and the often-degraded state of buried litter, recycling may not be possible for most litter. Any remaining biodegradable organic material (e.g. seaweed) can be composted.

Analyse data

Buried litter density is expressed as macro- or mesolitter counts (items/m^3) and weights (macrolitter: g/m^3; mesolitter: mg/m^3) per cubic metre of soil sieved. Buried macro- and mesolitter density is calculated per transect (for the transect method) or quadrat depth interval (for the quadrat method) using the following equation:

$$\textit{Litter density}_{(m3)} = \frac{\textit{Litter collected}}{\textit{Area x Depth sampled}}$$

The example below shows how to calculate the density (by weight) of mesolitter obtained from the 50–75 cm depth interval in a single quadrat of 1 x 1 m (1 m^2). If the weight of mesolitter collected in the 25 cm of soil surveyed (75 cm minus 50 cm) was 467 mg, then mesolitter density at a depth of 50–75 cm is:

$$\textit{Litter density}_{(50\text{-}75cm)} = \frac{467\ mg}{1\ m^2 \times (0.75 - 0.50m)} = 1\,868\ mg/m^3$$

Calculating litter density

To calculate the mean litter density per site for the transect method, add the litter densities from each transect together and divide this by the total number of transects sampled. For the quadrat method, the mean litter density per site is calculated per depth interval (surface, 0–25 cm, 25–50 cm, 50–75 cm, 75–100 cm). The litter density at a given depth interval is thus obtained by adding the litter densities at that depth in each quadrat together and dividing it by the total number of quadrats (Example 1 in **Figure 13**). Studies can also compare mean buried litter densities across the beach profile by averaging densities in quadrats that are positioned a similar distance from the waterline (Example 2).

Determining variation in data

By calculating the macro- and mesolitter density per transect or quadrat depth interval (as opposed to per site), surveyors can calculate the variation in litter density within sites. It is important to calculate the variability of samples at the study site, as it is more difficult to make predictions and generalisations when the data variability

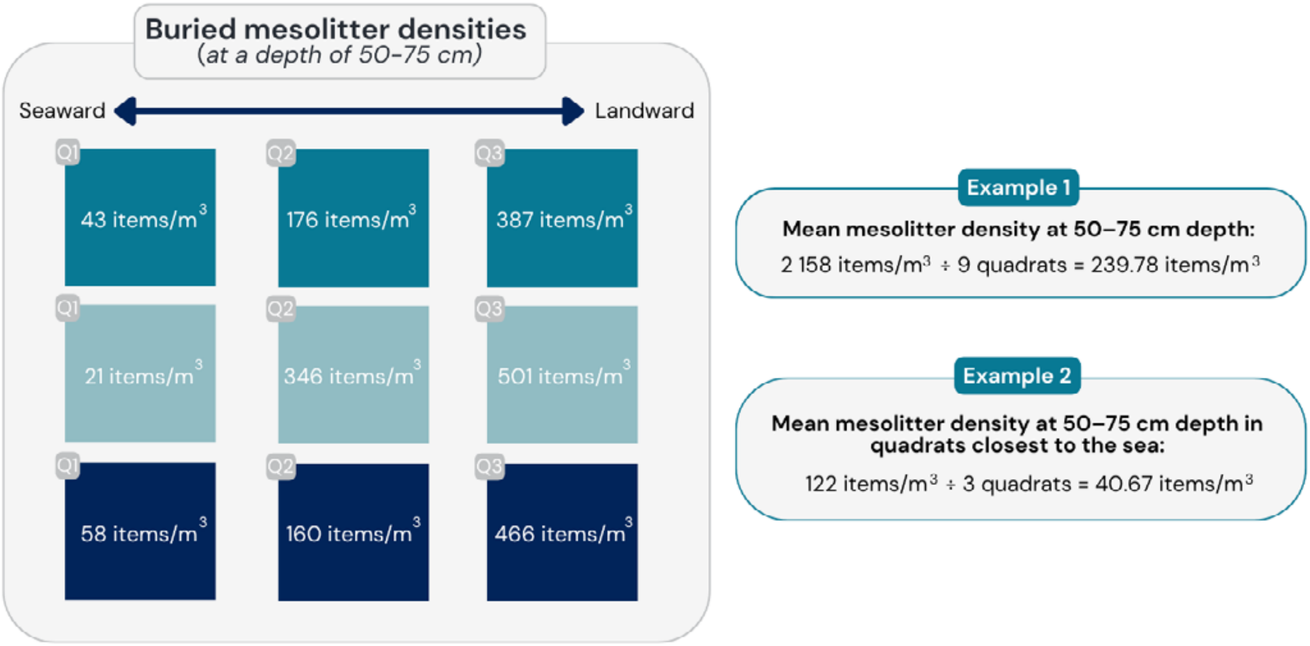

Figure 13: Examples showing how mean litter density is calculated at a depth of 50–75 cm after first obtaining the litter density at that depth per quadrat.

(how different data points are from each other and the sample mean) is high.

The equation used to calculate variability in data depends on which measure of variability is used (e.g. standard deviation, standard error, variance, range). For more information about how to calculate variability, click here.

Alternative methods

The aforementioned protocols are recommended for collecting the most reliable data. However, depending on the research questions of the study and available resources (e.g. funding, time, number of helpers), simpler methods can be used. For this reason, three different protocol standards – *Gold, Silver* and *Bronze Approaches* – have been provided as guidelines to modify the survey protocols to suit specific needs. By allowing flexibility in the methods, these standards ensure that data from litter surveys are always reliable and comparable while surveys remain feasible and sustainable. **Figures 14** and **15** shows how buried litter surveys can be modified when using the transect and quadrat methods.

The minimum requirements for a reliable accumulation survey are provided in the *Bronze Approach*, while the *Gold Approach* is recommended for best accuracy. Survey methods can be customised within the range specified by the *Gold* and *Bronze Approaches*.

Note: By calculating litter loads by cubic metre (m3), results remain comparable regardless of the methods used. However, once methods are altered to below the standard of the Bronze Approach, the variation and uncertainty in the data increase substantially.

BURIED LITTER SURVEY APPROACHES
TRANSECT METHOD

	GOLD APPROACH	SILVER APPROACH	BRONZE APPROACH
Size of litter to targeted	Macro (>25 mm) & Meso (2-25 mm)	Macro (>25 mm) & Meso (2-25 mm)	Macro (>25 mm)
Transect length	Edge of water to back of beach (>10 m)	Edge of water to back of beach (>10 m)	Edge of water to back of beach (>10 m)
Transect width	0.5 m	0.5 m	0.5 m
Transect depth	25 cm	25 cm	25 cm
Number of transects	10	5	5
Data collected	• Litter count • Litter weight (per litter type)	• Litter count • Litter weight (per litter type)	• Litter count • Litter weight (per litter type)
Sampling frequency	Quarterly	Twice a year	Annually

Figure 14: Sampling standards recommended when using the transect method.

BURIED LITTER SURVEY APPROACHES
QUADRAT METHOD

	GOLD APPROACH	SILVER APPROACH	BRONZE APPROACH
Size of litter to targeted	Macro (>25 mm) & Meso (2-25 mm)	Macro (>25 mm) & Meso (2-25 mm)	Macro (>25 mm)
Beach width	Edge of water to back of beach (>10 m)	2/3 of beach (starting at the water)	1/3 of beach (starting at the water)
Number of transects	5	4	3
Number of quadrats	25	16	9
Quadrat dimensions	2 x 2 m	1 x 1 m	0.5 x 0.5 m
Quadrat depth	100 cm	75 cm	50 cm
Sampling depth	Surface, 0-25 25-50, 50-75 75-100 cm	Surface, 0-25, 25-50, 50-75 cm	Surface, 0-25, 25-50 cm
Data collected	• Litter count • Litter weight (per litter type)	• Litter count • Litter weight (per litter type)	• Litter count • Litter weight (per litter type)
Sampling frequency	Quarterly	Twice a year	Annually

Figure 15: Sampling standards recommended when using the quadrat method.

SECTION INTRODUCTION

LITTER MONITORING IN MANGROVES

BY ANTHONY RIBBINK, CHANDANI APPADOO, LINISHA DEVI SEERUTTUN, SUSHMA MATTAN-MOORGAWA & ERIC OKUKU

Mangroves are woody trees and shrubs that form forests along wave-sheltered intertidal coasts and in estuaries of tropical and subtropical areas around the world. These unique trees are adapted to survive in waterlogged, oxygen-poor sediments and are able to tolerate salt, largely by being able to excrete the excess salt that they take up. About 20% of the world's mangroves are found in Africa[1]. Within Africa, 74% of the area occupied by mangroves is found in 19 countries along the west coast (bordering the Atlantic Ocean), while the remaining 26% is found in 15 countries and island states of the Western Indian Ocean and the Red Sea[1]. These ecosystems are highly productive and are of considerable economic and ecological value[1,2] (**Figure 1**).

ECOSYSTEM GOODS AND SERVICES PROVIDED BY MANGROVE HABITATS

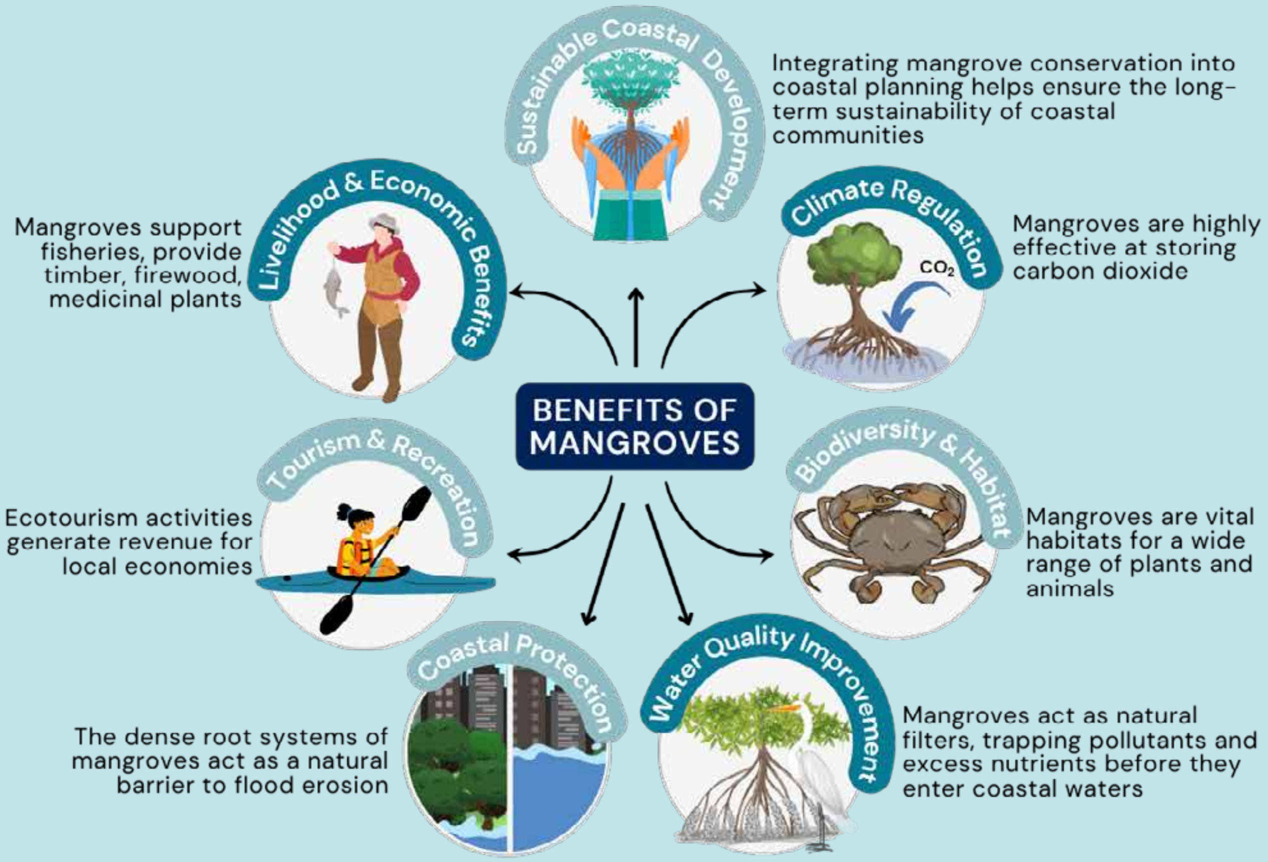

Figure 1: Mangrove ecosystems provide a range of ecosystem goods and services that benefit both the environment and humanity[1,2].

Despite their great value, mangroves are threatened and are declining everywhere in Africa except along the Red Sea. Wood harvesting and the use of estuaries for aquaculture lead to mangrove deforestation. Chemical pollutants from inland and oil spills from land and sea are also serious threats. Plastic pollution is an additional pressure on these vulnerable ecosystems, since plastic items tend to get caught in mangrove root and stem systems[1,3–5].

Mangroves have complex root systems. The extensive underground roots of mangroves anchor and stabilise the trees. In addition to the subterranean roots, there are two aboveground root systems. These are 1) prop roots, which provide added stability in soft sediments and help the trees withstand strong water flows and wave action, and 2) the aerial roots (known as pneumatophores) that extend upwards from the substratum (**Figure 2**). Pneumatophores are adaptations by mangroves to access oxygen when the fine-grained sediments become deoxygenated due to the accumulation of organic matter and its bacterial decomposition. Unfortunately, both root systems act as litter traps, intercepting litter as it flows to or from the sea. As a result of this litter-trapping tendency and their proximity to rivers (sources of large volumes of marine litter globally), mangroves have some of the highest reported densities of plastic pollution[5].

Plastic that gets entangled around mangrove roots, stems and branches causes a stress response, potentially leading to tree damage[4]. Smothering and suffocation may occur

MANGROVE ROOTS AS LITTER TRAPS

Figure 2: Litter trapped in Rhizophora mucronata prop roots in Mauritius and Kenya (top), and litter trapped in pneumatophore roots of Avicennia marina in Kenya (bottom).

when plastic litter covers the sediment surface, preventing the exchange of gases and nutrients between the roots and the surrounding environment, which may result in tree death. Furthermore, burrowing animals that help maintain the mangrove ecosystems are unable to survive under the plastics and either vacate their burrows or die. Meso- and microplastics have been shown to accumulate toxins, which could potentially affect the health of mangroves and disrupt nutrient cycles. These negative impacts result in a loss of ecological functions and life-support processes in mangrove ecosystems.

Understanding the scale and impact of plastic pollution in mangroves depends on reliable data gathered from prescribed measurements that can be duplicated in different localities. While many mangrove forests are limited to a few hectares, others extend along hundreds of kilometres of coastline, and their different habitats and species complicate the development of standardised monitoring methods. Monitoring can be done simply by walking through or alongside mangroves and counting visible plastics, but this is not a reproducible nor a reliable quantitative method that enables comparisons to be accurately made. Remote sensing is also not practical given that the extensive mangrove canopies will hide pollution from aerial and satellite observations.

Accordingly, using grid methods (i.e. quadrats) is the best way forward. Quadrats are placed within transect lines set parallel to the water, allowing surveyors to sample from the coast towards the furthermost landward part of the forest. The methods to assess both macro- and mesolitter in mangroves are described in **Chapters 11** and **12** respectively.

Note that the methods were developed and tested in coastal mangroves in East Africa but are expected to apply equally well to mangroves elsewhere in Africa. Furthermore, mangroves occur in four major habitats: 1) coastal mangrove systems, 2) deltaic systems, 3) estuarine systems, and 4) lagoonal systems, each of which has its own species that are adapted to different specific ecological zones within the systems. The litter monitoring methods described here were developed for use in coastal mangroves but can also be used in other mangrove habitats. Users of the manual are encouraged to provide feedback on the suitability of the manual for use in other mangroves habitats, so that these habitats may be addressed in future versions of the manual.

11

MACROLITTER SURVEYS IN MANGROVES

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Introduction

Given the ecological and economic value of mangrove ecosystems and the costs of litter accumulation in these environments[1,2], the relationship between plastic waste and mangroves is a growing, significant field of research worldwide[3]. Litter monitoring in mangroves is beneficial as it:

- Assesses the severity of the litter problem in this environment,
- Helps to understand the extent and impact of litter in mangroves over time, and
- Guides the adoption of preventive measures and effective management strategies.

This chapter outlines protocols for surveying macrolitter in mangroves within continental and island states of Africa and beyond. By using the protocols described here, results can be directly compared with those from other studies, even on different continents, provided the same methods are used. Note that the suitability of these protocols will depend on the particular mangrove characteristics (e.g. plant species composition, tree density, tidal influence, area covered by mangroves), and may need to be adapted to specific local conditions. Guidelines are given on how to modify the methods if needed.

Protocols

The protocols for macrolitter surveys in mangroves rely on quadrat sampling, which involves collecting litter in defined squares (in this case 10 x 10 m in size) placed within different inundation zones in the mangrove ecosystem. Macrolitter is then processed (cleaned, sorted, counted and weighed). At the end of the survey, the number and weight of macrolitter items per square metre (m^2) of mangrove is calculated.

This chapter considers two types of surveys to study macrolitter in mangroves (**Figure 1**). *Standing-stock surveys* are done at one specific point in time (e.g. in a single day) and provide a 'snapshot' of litter at that time. They are useful in identifying litter hotspots but provide limited information regarding the sources and pathways of waste and how litter loads change over time. The steps of

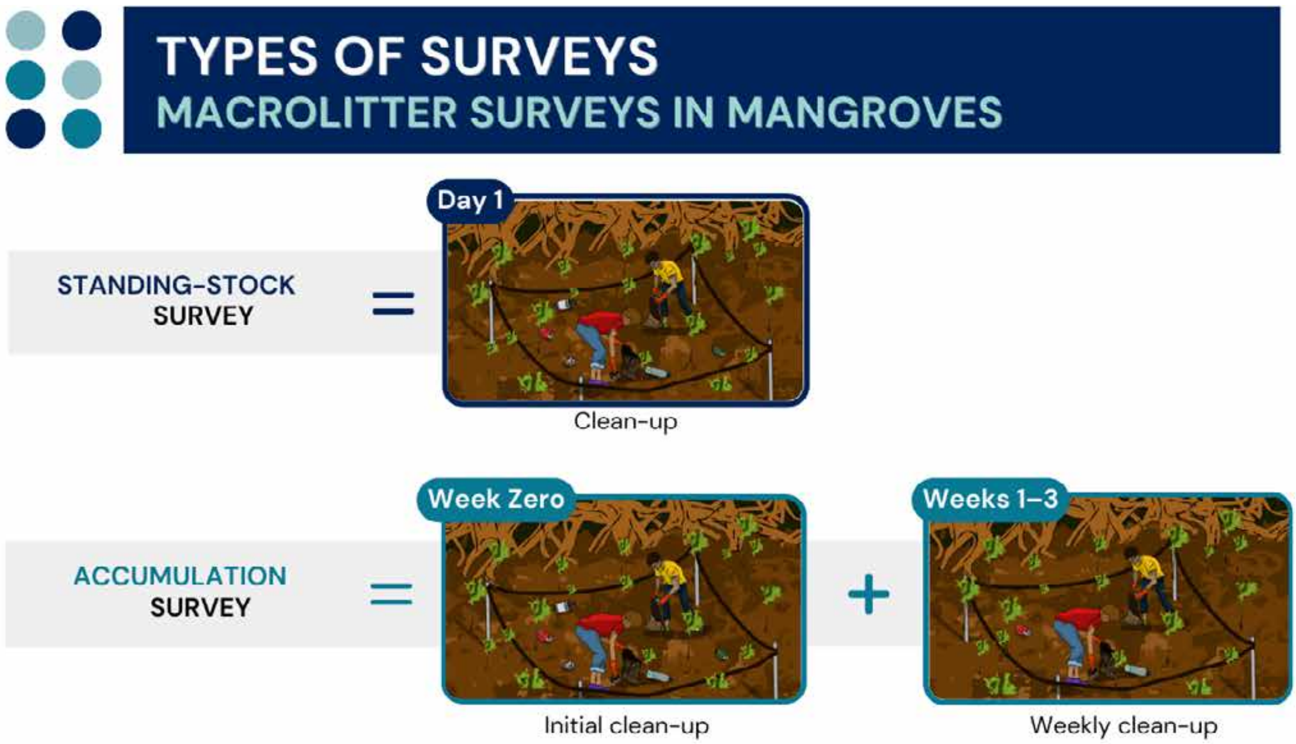


Figure 1: There are two main types of macrolitter surveys that can be conducted in mangroves. The suitability of each survey type will depend on the specific research questions and goals.

Figure 2: The protocol for a standing-stock survey of macrolitter in mangroves consists of nine steps.

a typical standing-stock litter survey are shown in **Figure 2**. *Accumulation surveys* are repeated regularly over short periods (e.g. daily or weekly) to measure the build-up rate or accumulation of litter over a unit of time. They give a more comprehensive estimate of litter generation and are useful in determining the sources and pathways of waste. The steps of a litter accumulation survey are shown in **Figure 3**.

The difference between accumulation and standing-stock litter surveys are explained in more detail in **Appendix 1**. The type of survey selected will depend on the particular research questions and study site as per **Chapter 2** (*A Guide to Litter Monitoring in Africa*). However, accumulation surveys are recommended, where possible, as they provide more information about the pollution, such as the frequency of deposit

ACCUMULATION SURVEY PROTOCOL

MACROLITTER SURVEYS IN MANGROVES

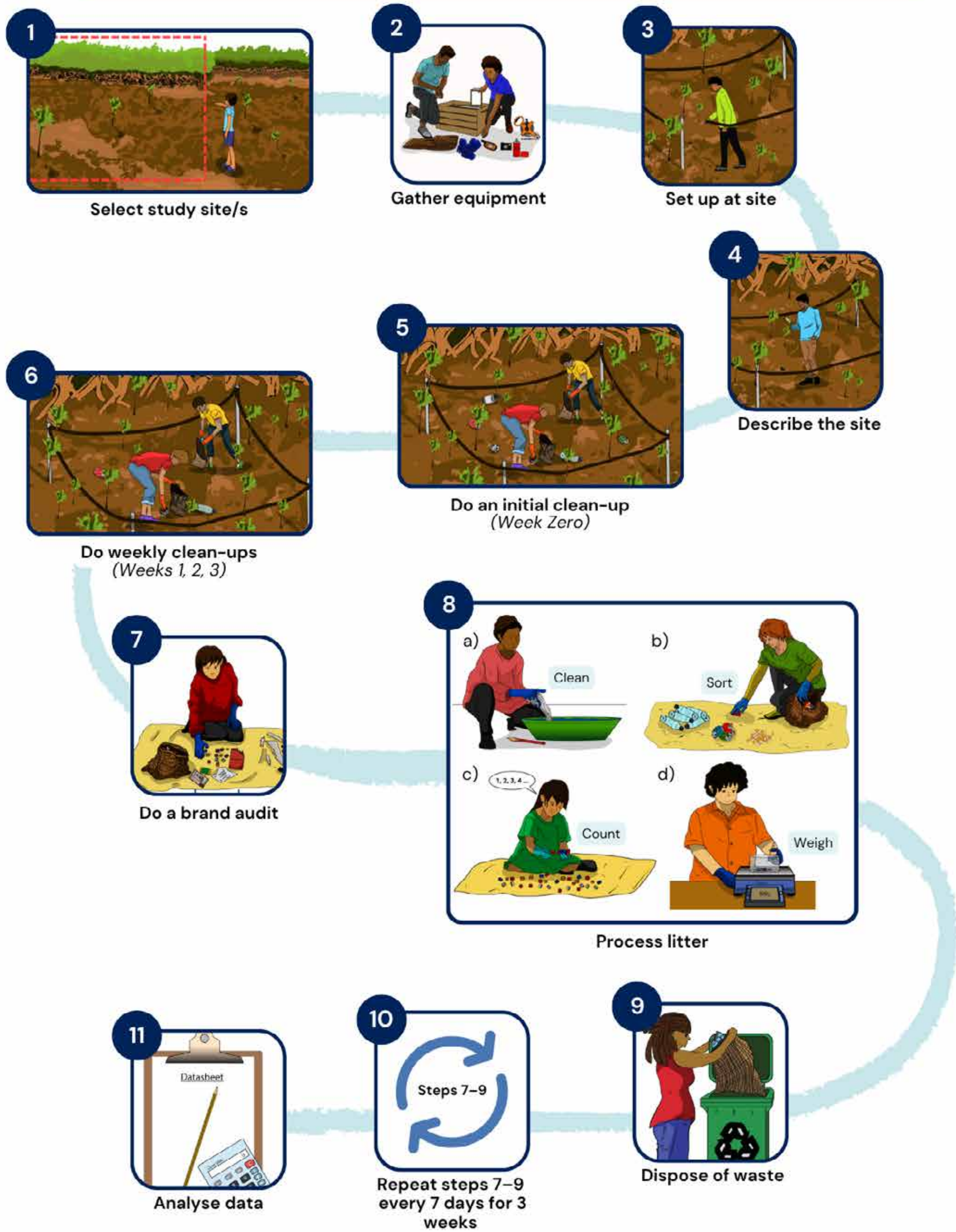
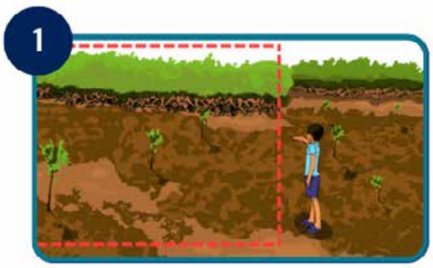


Figure 3: The protocol for an accumulation survey of macrolitter in mangroves includes weekly clean-ups and litter processing over four weeks.

and quantity of different types of litter. Weekly accumulation surveys (i.e. a survey once every seven days) are recommended when doing litter surveys in mangroves. One complete litter accumulation survey will span over four weeks (*Week Zero* – the initial clean-up, *Week 1*, *Week 2* and *Week 3*). The detailed steps to conduct a macrolitter accumulation survey in mangroves are outlined below. Standing-stock surveys follow the same basic steps as *Week Zero* of an accumulation survey and are therefore not discussed in detail.



Select study sites

As discussed in **Chapter 2**, the research questions of the study will determine where surveys need to be conducted, but some general considerations for selecting sites are provided below for macrolitter surveys designed to identify sources and pathways of litter. It is best to have multiple study sites to be able to compare and interpret results.

Study site features

Macrolitter surveys in mangroves are conducted along the shoreline (length) and extend from the low-water mark towards the landward side of the mangrove belt (width). The total length and width of the area sampled will vary depending on site-specific characteristics such as the size of the mangrove forest, density of mangrove plants and ease of access. The recommended setups and methods discussed in this chapter are based on mangroves in East Africa and may need to be modified for mangroves that differ significantly from those described here. The **Alternative Methods** section of this chapter provides guidance on how the setup and methods can be altered based on local conditions and available resources.

Mangroves are divided into three inundation zones (**Figure 4**) based on their proximity to the low-water mark and how often they are inundated by the tides. Since litter retention varies with tidal influence, it is recommended that surveys include litter sampling in each of these zones. Detailed explanations of how to set up and mark out the area to be surveyed are provided under Step 3 (*Set Up at the Study Site)*.

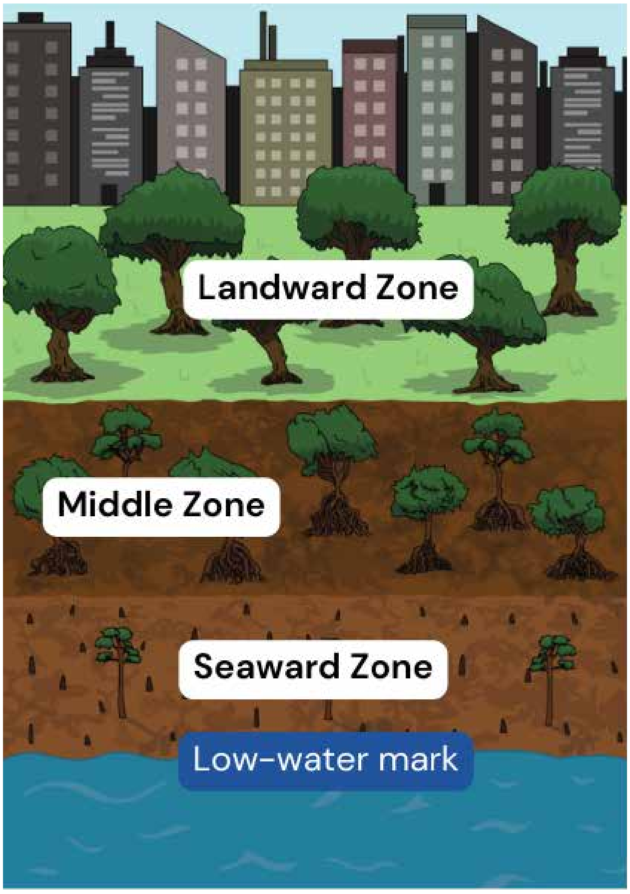


Figure 4: Litter surveys will be conducted in each of the three inundation zones found in mangroves.

Study site considerations

Ideally, study sites for macrolitter surveys in mangroves should meet the following requirements:

- **Access to sites:** Sites should have clear, year-round access for surveyors. Given that mangroves are protected habitats in many countries, sampling in them may require special permits. These or other appropriate authorisation should be obtained from the relevant authorities, where necessary.
- **Suitable site conditions:** Surveyors should be able to walk through the mangrove forest relatively easily during the survey.
- **Absence of clean-up activities by third parties:** No regular public clean-up activities should take place at the study site. If potential sites are regularly cleaned, surveyors should make the appropriate arrangements with local authorities to ensure that study sites are not cleaned during the entire period of the survey(s).
- **Safety:** Surveys should not be conducted in areas that may pose a risk to surveyors (crime, very strong water flow, dangerous animals, etc.).
- **Low environmental impact:** Surveys should not be conducted at sites where sampling may pose a risk to endangered or protected habitats and species. Care must be taken to avoid causing damage to seedlings or mangrove plants during surveys.
- **Study site dimensions:** Typical mangrove study sites are 60 m in width and 220 m in length, but this may vary.

Gather equipment

A printable checklist of the equipment needed to conduct macrolitter surveys in mangroves is provided in **Figure 5**.

Figure 5: A printable equipment list for macrolitter surveys in mangroves.

Set up at the study site

> **Note:** It may not always be possible to sample in each of the three inundation zones. For example, some mangroves may not have three distinct zones, and others may be too large, with substantial distances between inundation zones. In such instances, it is recommended that two zones (the seaward and the middle/landward) are surveyed.

Identify the survey area

Macrolitter surveys in mangroves are conducted along defined transects running parallel to the shoreline within each of the three inundation zones (see **Figure 6**). The transect in the seaward zone should be set up and sampled first, during low tide. Transects can be marked out using rope and should ideally be 220 m in length. Shorter transects may be used in small mangroves or where it is not feasible to sample long transects (see **Figures 15** and **16** under **Alternative Methods**). Transects must be 10 m wide and spaced 15 m apart (amounting to a total site width of 60 m). A minimum gap of 5 m may be used between transects in narrow mangroves. **Box 1** explains how the sampling design may differ depending on the width of the mangrove.

It is recommended that 15 quadrats, sized 10 x 10 m and spaced 5 m apart, are placed along each transect, totalling 45 quadrats for the three inundation zones (**Figure 7**). Fewer quadrats may be surveyed for shorter transects. Quadrats represent the area to be surveyed, and litter is only collected within

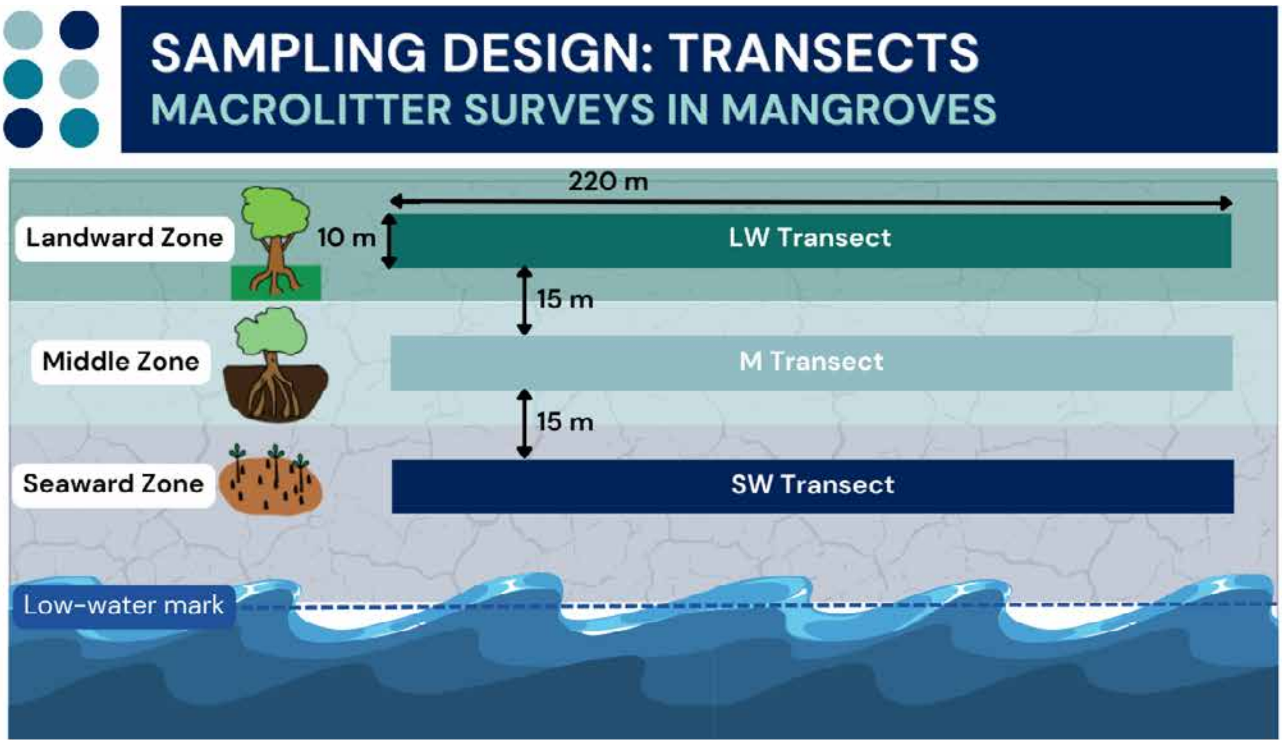


Figure 6: To define the study site, start by measuring out a 220 m-long and 10 m-wide transect in each of the three inundation zones. Transects must be spaced 15 m apart.

BOX 1
MODIFYING SURVEY SET UP BASED ON SITE WIDTH

1. The recommended study area of 220 m x 60 m may be ideal for small island states but may be too narrow in the broad mangroves found in some continental states. In broad mangroves, transects can be spaced much further apart. Ensure that a transect is placed in each of the three inundation zones for comparison.
2. If the study site does not meet the minimum width requirement of 60 m, two transects (one seaward and one middle/landward) can be surveyed instead. These transects should be spaced 15 m apart and will reduce the required study site width to 35 m.
3. If study sites are still too narrow, then the spacing between transects can be reduced to 5–15 m. Note that it is crucial to maintain a quadrat size of 10 x 10 m and to keep the spacing between transects constant during and between surveys.

them. Note that while some aspects (e.g. transect length, number of quadrats, site width, gap distance) may be modified (see **Figures 15** and **16**), it is crucial to maintain a quadrat size of 10 x 10 m and to keep the spacing between transects and quadrats constant between surveys at a given site.

Mark out the survey area

Each of the quadrats is staked out by hammering four poles (e.g. PVC pipes) into the ground to form a square with 10 m-long sides. A border can be formed around each quadrat by tying raffia rope to the poles

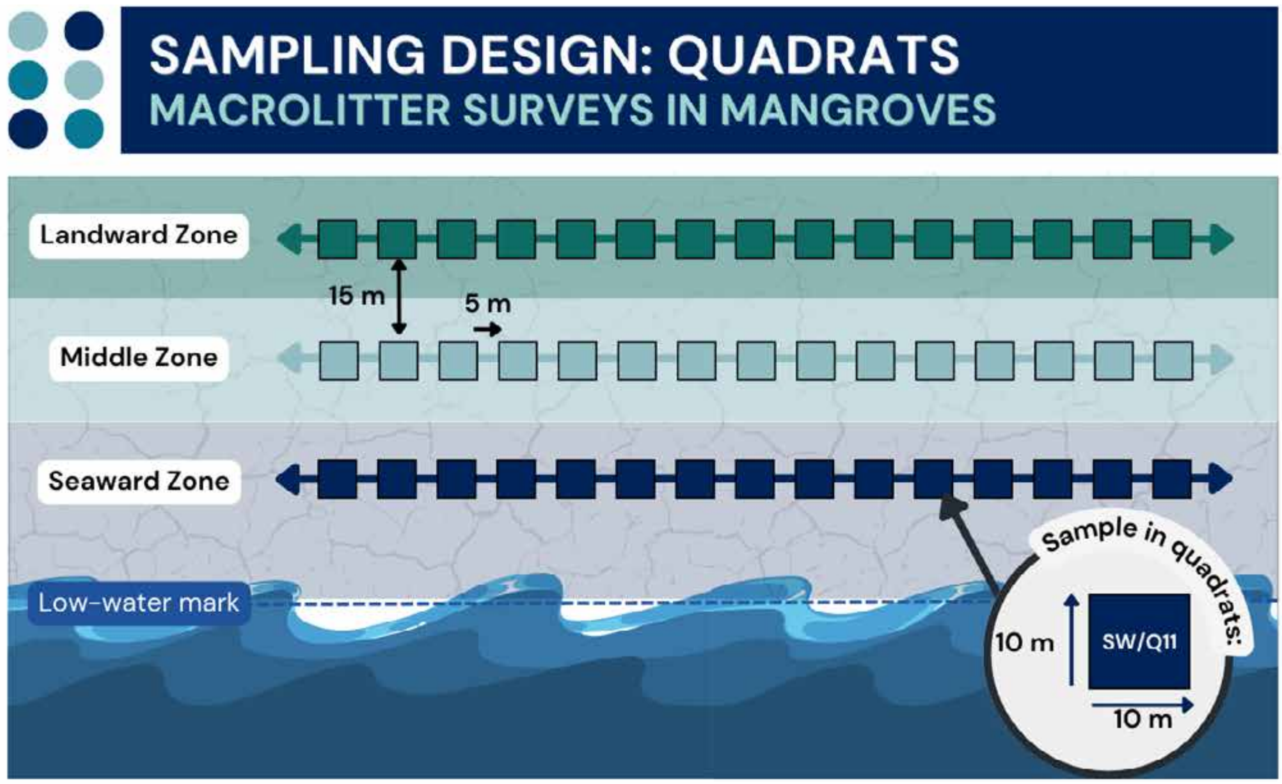


Figure 7: Litter surveys in mangroves are conducted in 10 x 10 m quadrats within the transects shown in Figure 6. It is recommended that 15 quadrats are placed along each transect.

(**Figure 8**). Demarcating the quadrats in this way allows some flexibility if surveyors need to bend the ropes around vegetation along the quadrat edge. At least 1 800 m of rope will be needed for the 45 quadrats (45 x 10 m side x 4 sides).

Once the study areas have been marked out, the GPS positions should be noted, as the transects and quadrats will have to be set up at the same coordinates each day of an accumulation survey and at future dates for the duration of the monitoring period. Specific numbers or codes must be allocated to each quadrat to track what litter was collected in which quadrat (e.g. SW/Q1 for seaward quadrat 1 or LW/Q4 for landward quadrat 4).

Note: If dense forest makes it difficult to mark out the quadrats with rope, it is advisable to count the number of footsteps for 10 m and use this as a guide to set the corners of the quadrats. Surveyors must take care not to damage mangrove plants and their root systems during surveys.

Describe the study site

It is important to collect information about the study site to help understand trends or patterns in the survey results. See **Datasheet 11** (*Site Description: Shorelines*) for the information needed to describe the site (e.g. GPS coordinates for the start and end of the transect, site width, substrate type, tidal range, nearest town). The datasheet also has a section to record information about the plant community (e.g. mangrove species, number of seedlings, tree height, tree density), since these factors may influence litter accumulation at the site. This datasheet should only be completed once per survey. Daily changes in weather condition and activities or factors that may influence litter accumulation are also important to note. These need to be recorded on **Datasheet 2** (*Daily Site Conditions*) on every day of a survey.

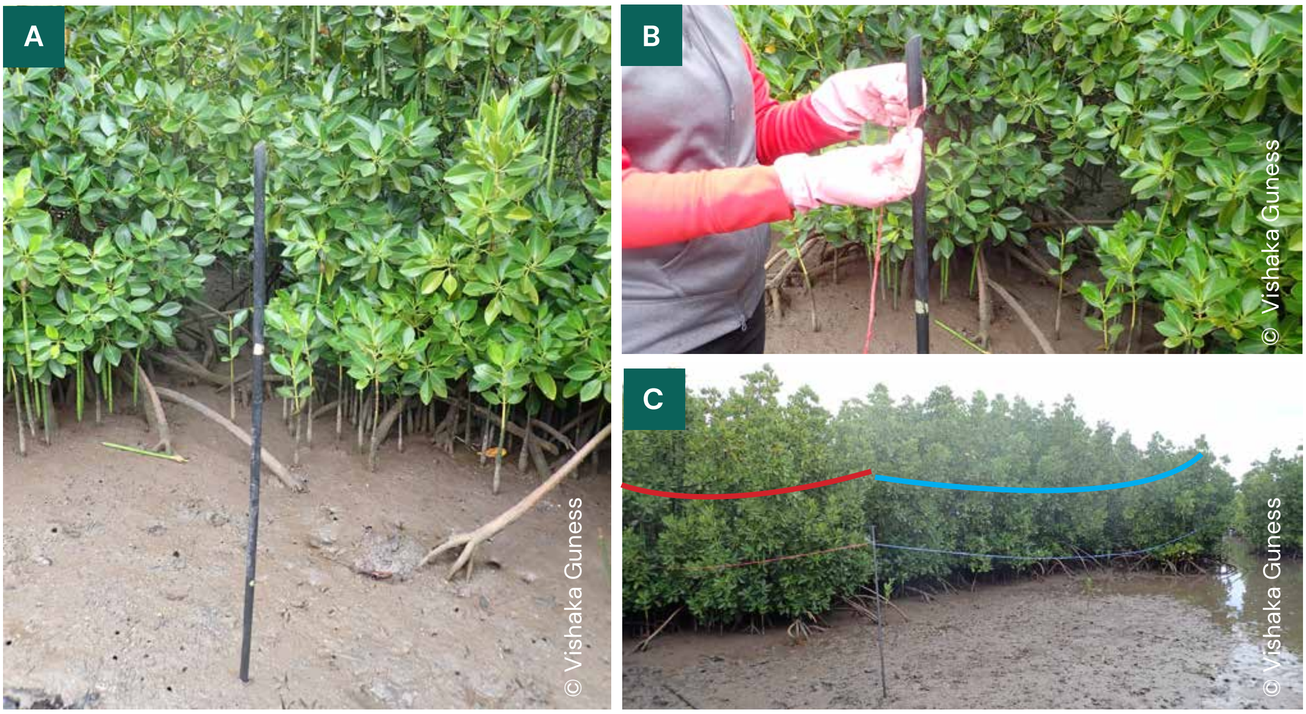


Figure 8: Poles and ropes (A & B) are used to mark out 10 x 10 m quadrats (C) where litter will be collected during mangrove litter accumulation surveys.

Do an initial clean-up (*Week Zero*)

To measure the weekly accumulation of macrolitter, it is important to do an initial clean-up of the study site. This initial clean-up is referred to as the *Week Zero* clean-up, as it prepares the site for an accumulation survey by removing all litter from the site. Upon returning a week later, the litter that has accumulated at the site in the previous seven days can be assessed. The same principle applies for each week of an accumulation survey – given that the site was cleaned a week prior, each weekly survey provides a measurement of litter accumulation over seven days. Litter collected in *Week Zero* can be used as a standing-stock survey but will not be processed and analysed with litter from the accumulation survey.

Where to clean

Before starting the clean-up, all members of the team should know where to start and stop cleaning. The *Week Zero* clean-up for accumulation surveys should be completed within the quadrats marked out in the study site, as described previously. For *Week Zero*, it is recommended that any nearby litter that may blow into the quadrats is also removed.

What to clean

All visible macrolitter (>25 mm) on the mud surface or protruding from the mud should be removed from the study site during the

Figure 9: Only collect litter items during surveys. Natural items should not be removed.

Week Zero clean-up. Smaller items such as cigarette butts and plastic bottle caps/lids should also be included, since these are common litter items. Avoid removing any natural materials from the area (**Figure 9**).

Litter items that are too large (e.g. tyres, ropes, nets) or dangerous (e.g. chemicals, weapons, ammunition) to remove should be counted but not handled. Mark these items with paint or photograph them to ensure they are not counted again in future surveys. The weights of heavy or large items can be estimated by multiplying the estimated volume of the item by the density of the material as per **Appendix 2**. Notify the relevant authorities of any large or dangerous items so they can be safely removed. Used hygiene objects such as diapers, condoms and feminine hygiene products can be removed, noted and disposed of responsibly. During litter processing, a clean and dry proxy can be used to estimate the weight of any unsanitary item recorded at the site (see **Appendix 2**).

Note: It is recommended that all visible litter is collected, even items that seem smaller than 25 mm, as they may be part of a larger, buried item. Items smaller than 25 mm can be removed during the processing stage.

Do weekly clean-ups (*Week 1-3*)

Seven days after the *Week Zero* clean-up, the same 45 quadrats that were marked out and cleaned previously must be cleaned again for the Week 1 survey. Ensure that all surveyors (especially new helpers) know where to clean before starting each survey. Where possible, weekly accumulation surveys should be repeated for three consecutive weeks (Week 1, Week 2, Week 3) to account for variation in litter loads due to external factors (e.g. weather).

As with *Week Zero*, all visible macrolitter (>25 mm) should be collected, taking care that the quadrats are cleared of all accumulated litter, including any items entangled in roots or partly buried. Items that should not be collected include natural items, personal belongings that are obviously still in use (e.g. clothes), and items used for cultural or religious rituals or activities (e.g. charms and ceremonial objects). Items too large, heavy or dangerous to remove must be counted and marked, but not handled.

Litter collected in different quadrats should be kept separate, with collection bags/ containers clearly labelled to include the study site name, date of collection, zone of collection (i.e. seaward, middle or landward zone) and quadrat number. Ensure that all equipment is removed from the study site at the end of a survey.

Do a brand audit

Most consumer products have information about the product (or the brand owner of the product) printed on them (**Figure 10**). The recording of information from branded litter is called a 'brand audit'. The following

Note: In the spirit of reducing single-use plastic waste, it is recommended that surveyors use reusable bags or containers wherever possible.

product information should be recorded in **Datasheet 3** (*Brand Audit Information*):

- Brand name (e.g. Choco-Snow),
- Manufacturer (e.g. Barnadoo International),
- Where the item was produced/ packaged (e.g. South Africa),
- Type of product (e.g. food packaging),
- Type of material (e.g. other plastic [#7]), and
- Number of layers (for plastic items).

It is recommended that a brand audit is done on the litter collected at each weekly survey excluding *Week Zero* (see **Appendix 1** for the biases associated with litter from *Week Zero*). The detailed protocol for brand audits is provided in **Appendix 3**.

*Figure 10: Brand audit data are useful when addressing plastic pollution. *Recording of manufacture/best before dates is optional.*

Process Litter

Litter processing refers to the cleaning, sorting, counting and weighing of litter. The detailed methods for litter processing are provided in **Appendix 2** and a graphical summary is shown in **Figure 11**.

All macrolitter must be sorted, counted and weighed according to **Datasheet 4** (*Basic Litter Datasheet* with 36 litter categories) or **Datasheet 5** (*Comprehensive Litter Datasheet* with >140 litter categories). Visual guides for these two datasheets are provided in **Appendix 4** and **5** respectively. **Appendix 6** can be used to measure macrolitter fragment sizes. Surveyors conducting more detailed, scientific studies may choose to weigh each piece of litter.

Separate litter datasheets should be completed for each of the 45 quadrats on each survey day. A total of 46 datasheets must therefore be completed on each day of an accumulation survey:

0. Site Description Datasheet (completed only in *Week Zero*) – **Datasheet 11**
1. Daily Site Condition Datasheet – **Datasheet 2**
2. Litter Datasheet (for each of the 45 quadrats) – **Datasheets 4** or **5**.

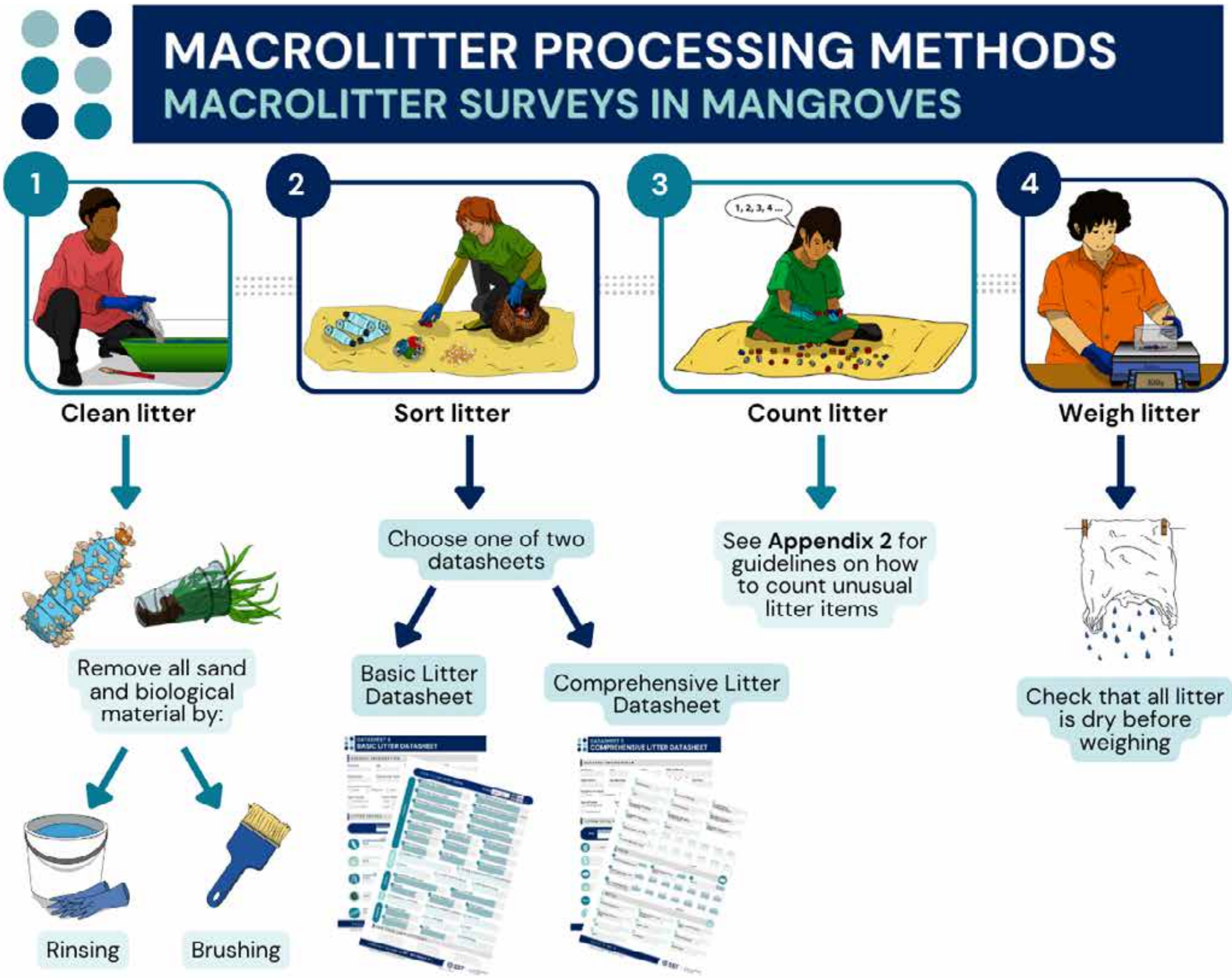


Figure 11: Summary of macrolitter processing methods. See Appendix 2 for a detailed description of the methods.

Dispose of waste

Once the survey has been completed, litter should be disposed of correctly or stored for further analysis. Biodegradable organic waste can be composted, and recyclable materials can go to recycling collection points or material recovery facilities (MRFs).

Analyse data

Macrolitter density

Estimates of macrolitter in mangroves will be expressed as density (items/m^2 or g/m^2) per inundation zone. To calculate the density per inundation zone (LW, M, SW), add the total count or weight of litter collected in all the quadrats of that zone and divide it by the overall area sampled within the zone.

This equation is written as:

$$\textit{Macrolitter density}_{\textit{(by count or weight)}} = \frac{\text{Total count or weight of macrolitter per zone}}{\text{Total area surveyed per zone}}$$

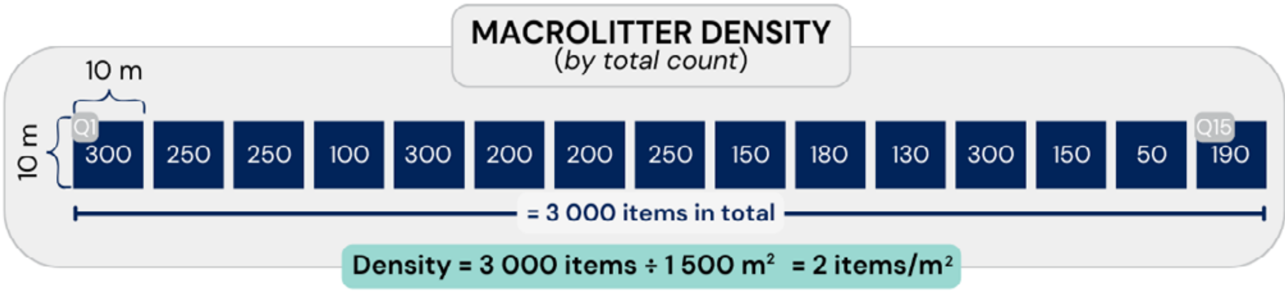


Figure 12: Example of litter counts obtained from 15 quadrats (each sized 10 x 10 m) within the landward inundation zone of a hypothetical mangrove.

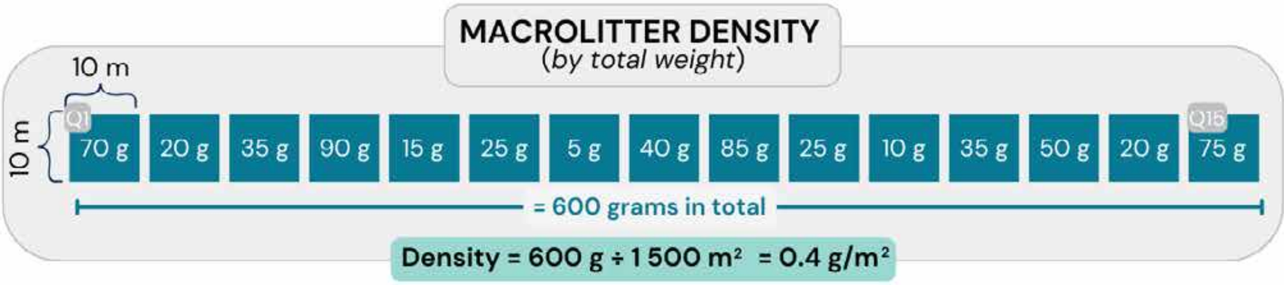


Figure 13: Example of litter weights obtained from 15 quadrats (each sized 10 x 10 m) within a single inundation zone.

Figures 12 and **13** show hypothetical results obtained by collecting macrolitter within 15 quadrats (each sized 10 x 10 m = 100 m^2) in the landward zone of a mangrove. Based on these results, the litter density by count would be 3 000 items (the total count of all items in the quadrats) ÷ 1 500 m^2 (15 quadrats of 100m^2 each, i.e. the total area sampled) = 2 items/m^2. The litter density by weight is calculated as: 600 g (the total weight of all items in the quadrats) ÷ 1 500 m^2 = 0.4 g/m^2.

Variation in data

By calculating the macrolitter density per quadrat (as opposed to per zone), surveyors can calculate the variation in litter density within inundation zones or sites. The greater the variability in data (how different data points are from each other and the sample mean), the more difficult it is to make predictions and generalisations based on the data. The equation used to calculate variability in data depends on which measure of variability is used (e.g. standard deviation, standard error, variance, range). For more information about how to calculate variability, **click here**.

Alternative Methods

The aforementioned protocols are recommended for collecting the most reliable data. However, depending on the research questions of the study and available resources (e.g. funding, number of helpers, and time), simpler methods can be used.

For this reason, three different protocol standards – *Gold, Silver and Bronze Approaches* – have been provided as guidelines to modify the survey protocol to suit specific needs. By allowing flexibility in the methods, these standards ensure that data from litter surveys are always reliable and comparable while surveys remain feasible and sustainable. **Figures 14** and **15** show how standing-stock and accumulation surveys can be modified.

The minimum requirements for a reliable accumulation survey are provided in the *Bronze Approach*, while the *Gold Approach* is recommended for best accuracy. Survey methods can be customised within the range specified by the *Gold and Bronze Approaches*.

Note: By calculating litter loads per square metre of mangrove per day, results remain comparable regardless of the methods used. However, once methods are altered to be below the standard of the *Bronze Approach*, the variation and uncertainty in the data increase substantially.

STANDING-STOCK SURVEY APPROACHES
MACROLITTER SURVEYS IN MANGROVES

	GOLD APPROACH	SILVER APPROACH	BRONZE APPROACH
Size of litter to collect	>25 mm	>25 mm	>25 mm
Number of quadrats (per inundation zone)	15	10	5
Transect length	220 m	145 m	70 m
Transect/Quadrat width	10 m	10 m	10 m
Gap between transects	15 m	10 m	5 m
Site width	60 m	50 m	40 m
Days of surveying	1	1	1
Litter counts	Yes	Yes	Yes
Litter weights	Yes	Yes	Optional
Weighing individual pieces	Yes	Optional	No – weigh per litter type (e.g. earbuds)

Figure 14: Macrolitter standing-stock surveys in mangroves can be modified using the guidelines above. Note that transect and quadrat dimensions may need to be customised for mangroves that differ significantly from those described in this chapter.

ACCUMULATION SURVEY APPROACHES
MACROLITTER SURVEYS IN MANGROVES

	GOLD APPROACH	SILVER APPROACH	BRONZE APPROACH
Size of litter to collect	>25 mm	>25 mm	>25 mm
Number of quadrats (per inundation zone)	15	10	5
Transect length	220 m	145 m	70 m
Transect/Quadrat width	10 m	10 m	10 m
Gap between transects	15 m	10 m	5 m
Site width	60 m	50 m	40 m
***Week Zero* Clean-up**	Yes	Yes	Yes
Days of surveying	*Week Zero* + Weeks 1, 2 & 3	*Week Zero* + Weeks 1 & 2	*Week Zero* + Weeks 1 & 2
Litter counts	Yes	Yes	Optional
Litter weights	Yes	Yes	Optional
Weighing individual pieces	Yes	Optional	No – weigh per litter type (e.g. earbuds)

Figure 15: Macrolitter accumulation surveys in mangroves can be modified using the guidelines above. Note that transect and quadrat dimensions may need to be customised for mangroves that differ significantly from those described in this chapter.

MESOLITTER SURVEYS IN MANGROVES

Chandani Appadoo, Linisha Devi Seeruttun, Sushma Mattan-Moorgawa & Eric Okuku

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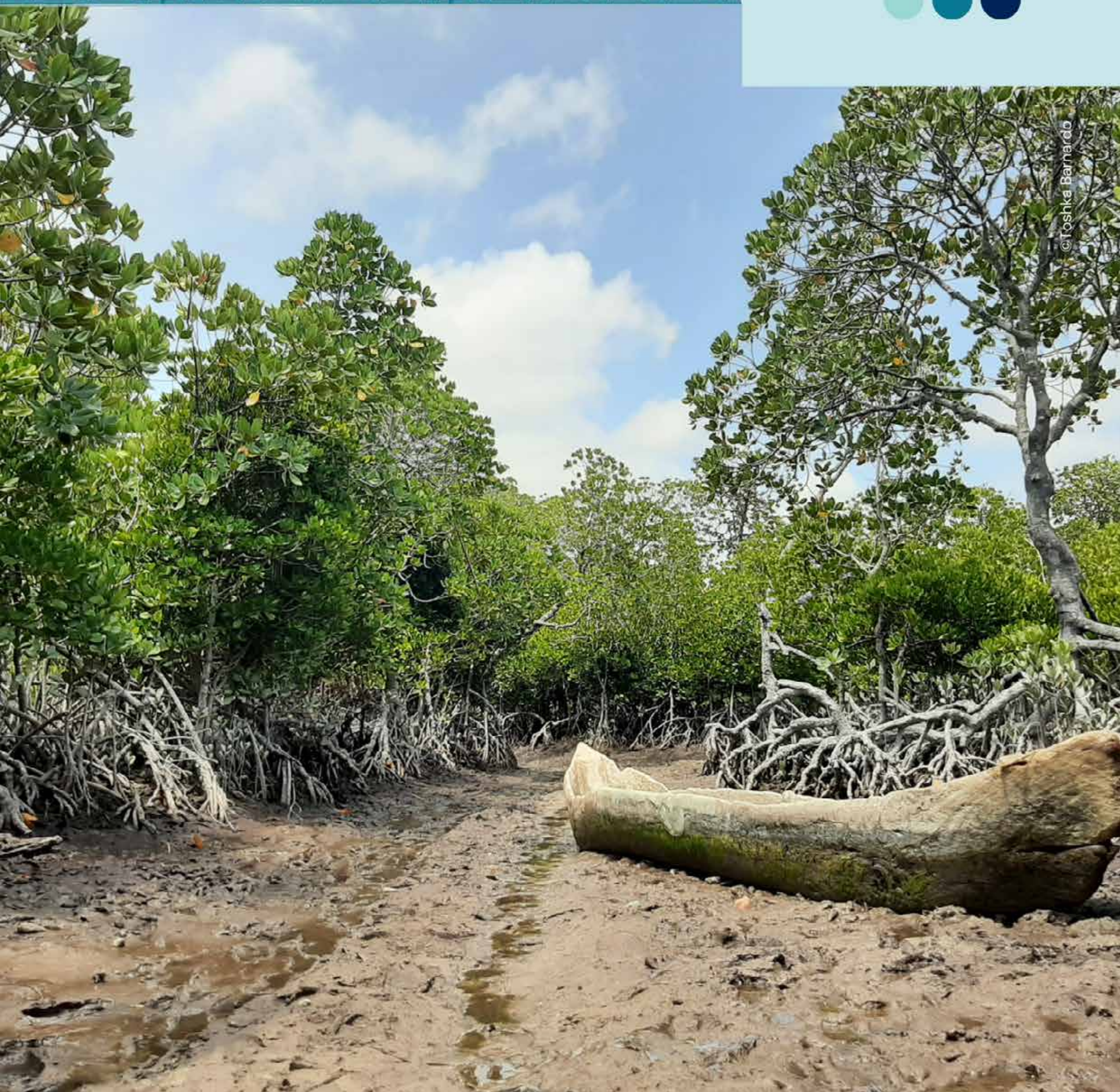

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Introduction

Litter in the environment is destined to degrade and break into smaller pieces when exposed to the elements[1,2] (e.g. wave action, ultraviolet radiation, wind abrasion). The resulting litter fragments and other litter <25 mm (e.g. cigarette butts) are usually overlooked during clean-ups, so they often become buried and accumulate in sediments over time[3–5]. This is also true in mangrove ecosystems, where small litter items, especially plastics, have a variety of negative impacts[6–8] (**Figure 1**). For example, small plastics are composed of chemicals that tend to adsorb pollutants and toxic metals, which can have adverse effects on biota and pose a risk to human seafood safety[3,9].

This chapter presents a simple protocol to assess small litter in mangrove sediments. It focuses on mesolitter (5–25 mm) since the collection and assessment of microlitter typically requires special equipment and training. However, items 2–5 mm in size, such as plastic pellets (nurdles), make up a significant portion of marine litter and are relatively easy to collect and identify. It is therefore recommended that these items are also collected when doing mesolitter surveys. The resulting small litter can then be grouped by size to compare results with other studies.

Mesolitter monitoring in mangroves is important because it provides a more complete picture of pollution levels, the fate of waste and its potential repercussions.

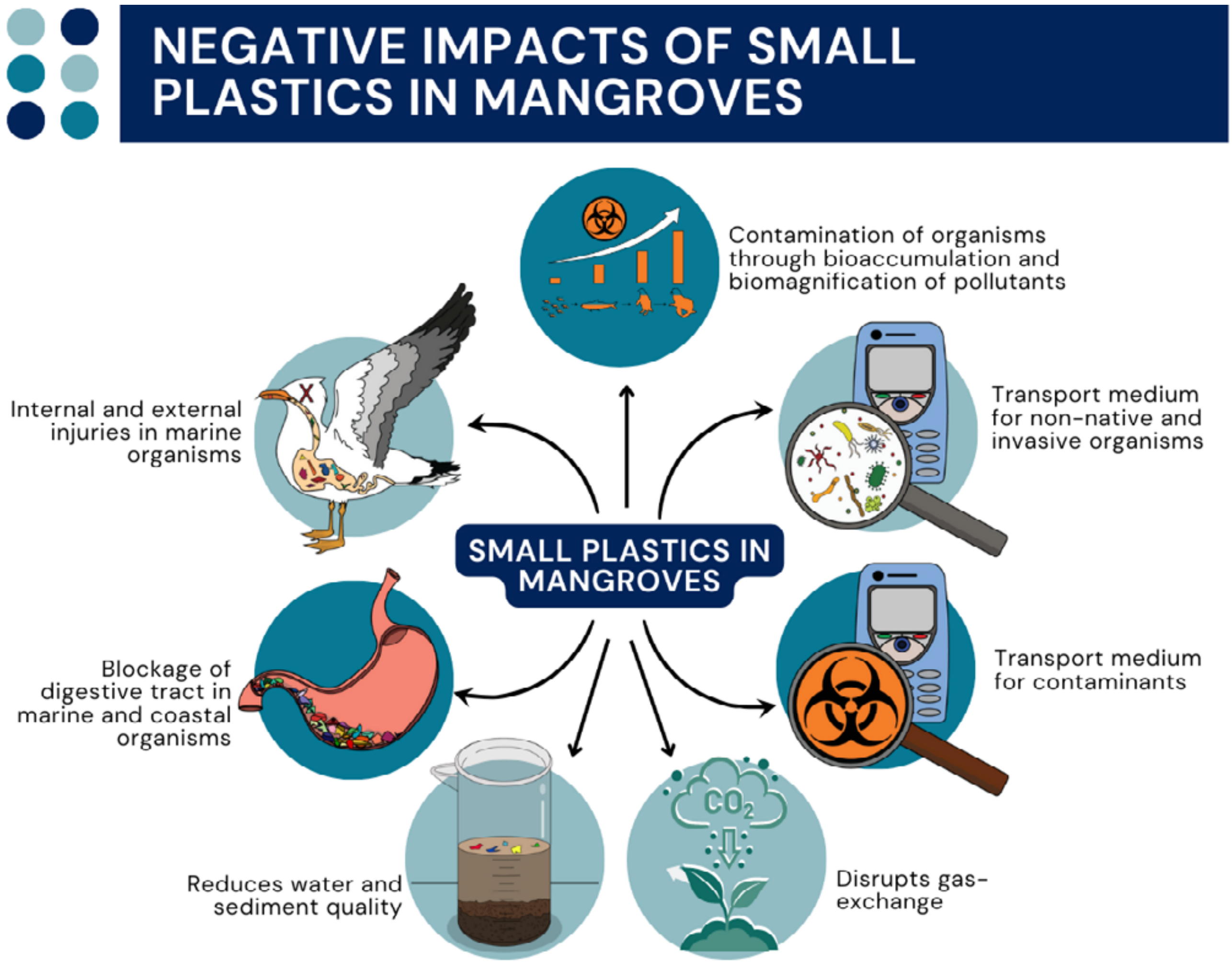


Figure 1: Ways in which small plastics may negatively affect mangrove ecosystems.

It also gives an indication of microlitter abundance and can be used to develop preventive measures for pollution. While macrolitter surveys mainly focus on litter lying on or just below the surface, mesolitter surveys require the collection and study of small litter items that have been retained in the mangrove sediments.

Protocol

The protocol for mesolitter surveys in mangroves relies on quadrat sampling, which involves collecting sediment samples within defined squares (in this case 0.5 x 0.5 cm size) placed within different inundation zones in the mangrove ecosystem. The sediment samples are transported to a laboratory for air-drying, after which mesolitter is extracted by density separation and sieving, and then processed (cleaned, sorted, counted and weighed). At the end of the survey, the number and weight of mesolitter items per kilogram of sediment can be calculated.

The detailed protocol is elaborated below according to the steps depicted in **Figure 2**.

SURVEY PROTOCOL
MESOLITTER SURVEYS IN MANGROVES

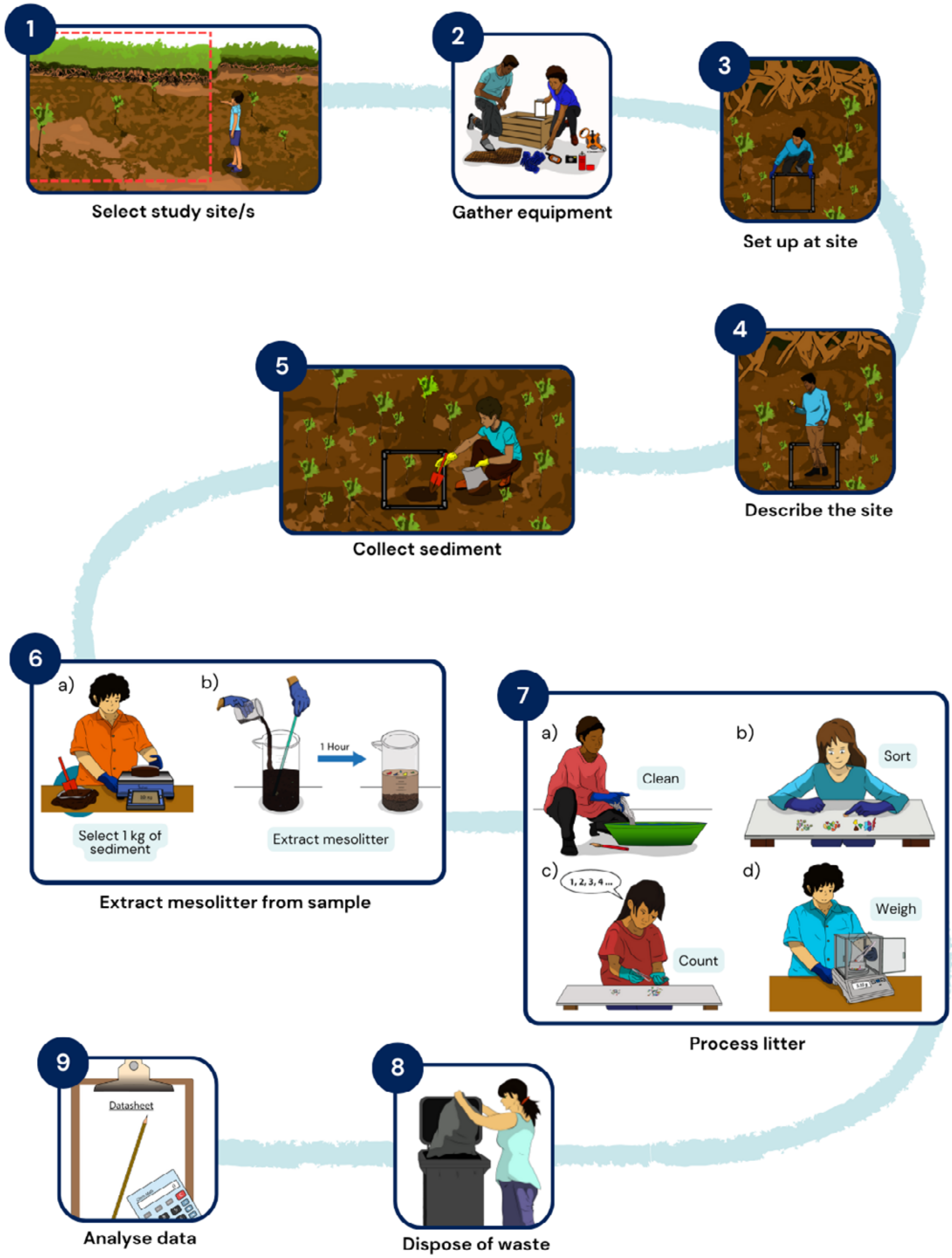
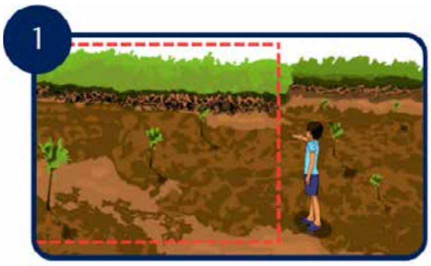


Figure 2: The protocol for a mesolitter survey in mangroves consists of nine steps.



Select study sites

As discussed in **Chapter 2** (*A Guide to Litter Monitoring in Africa*), the study's research questions will determine where surveys need to be conducted, and it is best to have multiple study sites to be able to compare and interpret results. Some general considerations for selecting sites are provided below for surveys designed to identify the sources and pathways of litter in mangroves.

Study site features

Mesolitter surveys in mangroves are conducted along the shoreline (length) and extend from the low-water mark towards the landward side of the mangrove belt (width). The total length and width of the area sampled will vary depending on site-specific characteristics such as the size of the mangrove forest, density of mangrove plants, and ease of access. The recommended setups and methods discussed in this chapter are based on mangroves in East Africa. The **Alternative Methods** section provides guidance on how the setup and methods can be altered based on local conditions and available resources.

Mangroves are divided into three inundation zones (**Figure 3**) based on their proximity to the low-water mark and how often they are inundated by the tides. Since litter retention varies with tidal influence, it is recommended that surveys include litter sampling in each of these zones. Detailed explanations of how to set up and mark out the areas to be surveyed are provided under the *Set Up at the Study Site* section below.

Note: It may not always be possible to sample in each of the three inundation zones. For example, some mangroves may not have three distinct zones, and others may be too large, with substantial distances between inundation zones. In such instances, it is recommended that two zones (the seaward and the middle/landward) are surveyed.

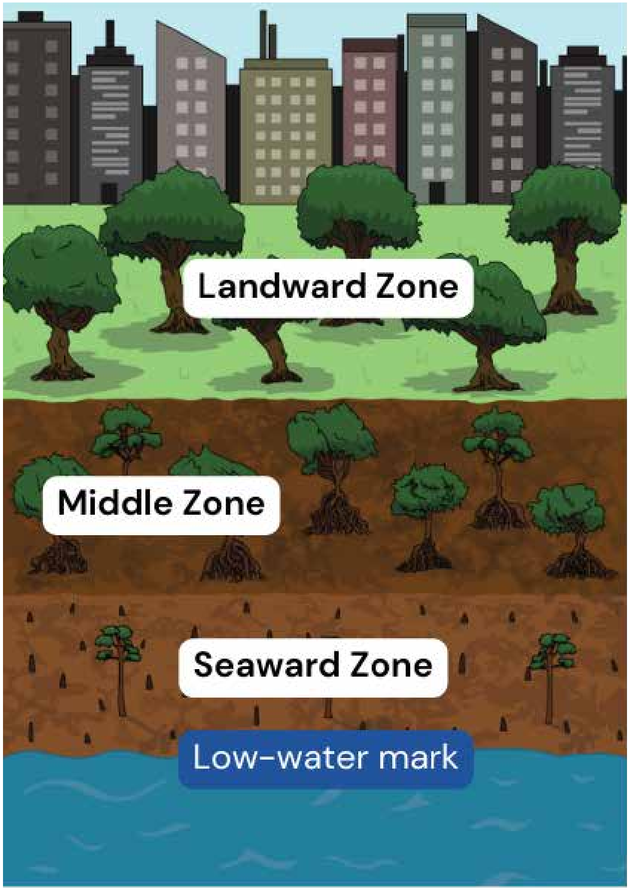


Figure 3: Litter surveys will be conducted in each of the three inundation zones found in mangroves.

Study site considerations

Mesolitter surveys in mangroves can be conducted within the same study sites as macrolitter surveys as per **Chapter 11** (*Macrolitter Surveys in Mangroves*), so site selection criteria are the same:

- **Access to sites**: Sites should have clear, year-round access for surveyors. The appropriate permits or authorisation should be obtained from the relevant authorities, where necessary.

- **Suitable site conditions**: Surveyors should be able to walk through the mangrove forest relatively easily during the survey.
- **Absence of clean-up activities by third parties**: No regular public clean-up activities should take place at the study site. If potential sites are regularly cleaned, surveyors should make the appropriate arrangements with local authorities to ensure that study sites are not cleaned during the entire survey period.
- **Safety**: Surveys should not be conducted in areas that may pose a risk to surveyors (crime, very strong water flow, dangerous animals, etc.).
- **Low environmental impact**: Surveys should not be conducted at sites where sampling may pose a risk to endangered or protected habitats and species. Care must be taken to avoid causing damage to seedlings or mangrove plants during surveys.

Gather equipment

A checklist of the equipment needed to conduct mesolitter surveys in mangroves is provided in **Figure 4** as a separate printable page.

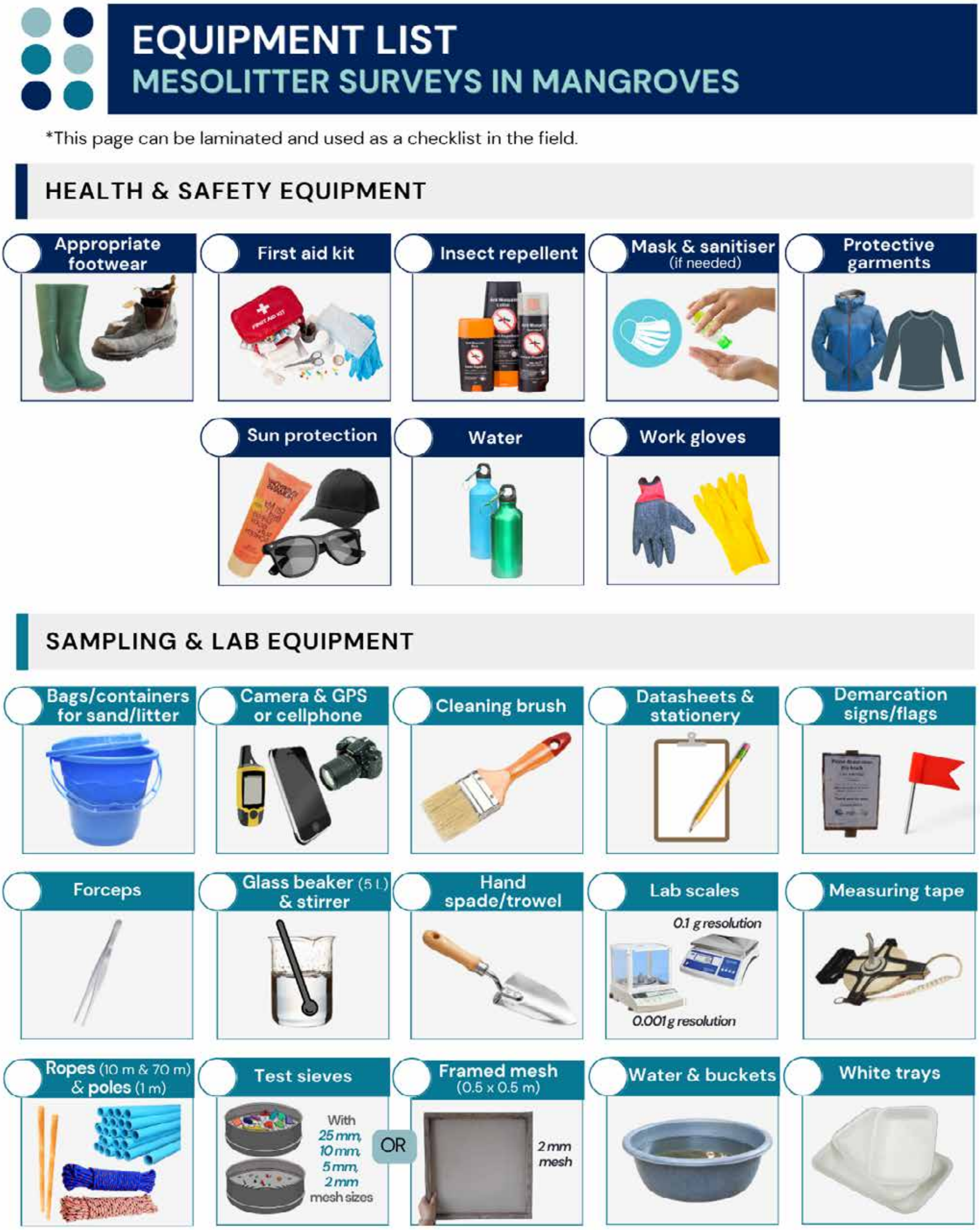


Figure 4: A printable equipment list for mesolitter surveys in mangroves.

Set up at the study site

Mesolitter surveys in mangroves are conducted along defined transects running parallel to the shoreline within each of the three inundation zones (**Figure 5**). Transects can be marked out using rope and should be 84.5 m in length. Shorter transects may be used in small mangroves or where it is not feasible to sample long transects (see **Figure 11** in **Alternative Methods** section).

A gap of 15 m is recommended between transects, but a minimum gap of 5 m may be used in narrow mangroves. The transect in the seaward zone should be set up and sampled first, during the low or ebbing tide. It is recommended that nine 0.5 x 0.5 m quadrats, spaced 10 m apart, are placed along each transect (**Figure 6** and **Table 1**). These 27 quadrats represent the area to be surveyed, and litter is only collected within them. Fewer quadrats may be surveyed for shorter transects.

Note that while some aspects (e.g. transect length, number of quadrats, site width, gap distance) may be modified, it is crucial to maintain a quadrat size of 0.5 x 0.5 m and to keep the spacing between transects and quadrats constant between surveys at that particular site.

Quadrats can be demarcated using small flags, PVC squares or metal frames of the appropriate size (**Figure 7**). It is recommended that unique numbers or codes are allocated to each quadrat to track what litter was collected in which quadrat (e.g. SW/Q1 for seaward quadrat 1 or LW/Q4 for landward quadrat 4).

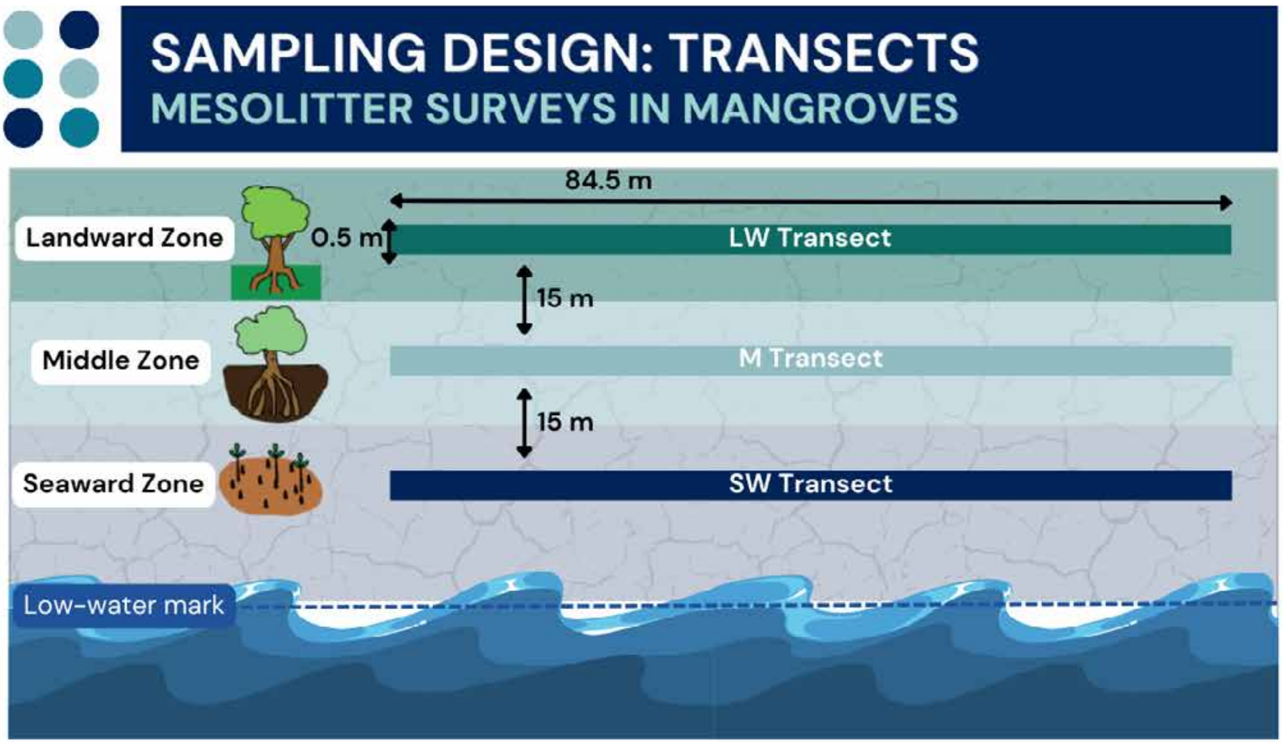


Figure 5: To define the study site, start by measuring out an 84.5 m-long and 0.5 m-wide transect in each of the three inundation zones. Transects must be spaced 15 m apart. See Figure 6 for the next step.

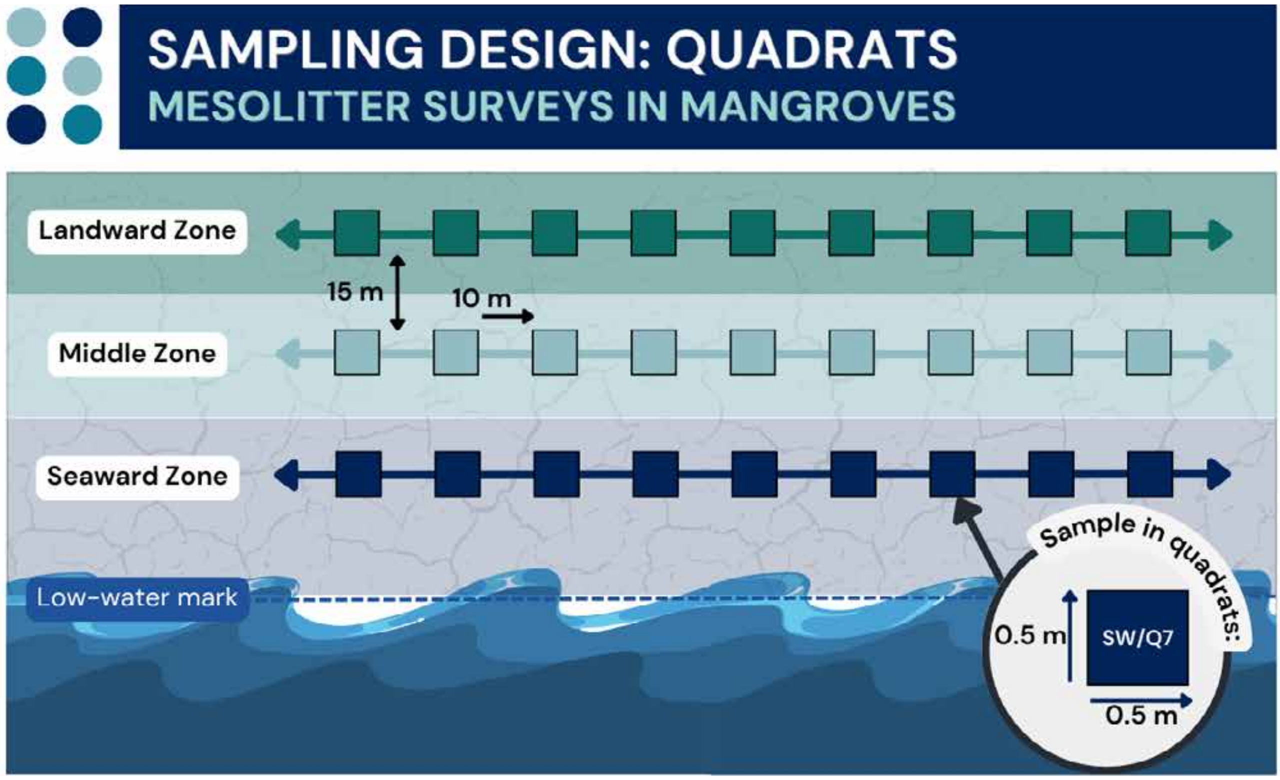


Figure 6: Litter surveys are conducted in 0.5 x 0.5 m quadrats within the transects shown in Figure 5.

Table 1: A summary of the recommended dimensions and layout of the sampling area.

Transects	Number of transects	**3** (LW, M, SW)
	Transect length	**84.5 m**
	Spaces between transects	**15 m**
Quadrats	Number of quadrats per transect	**9**
	Quadrat size	**0.5 x 0.5 m**
	Distance between quadrats in same transect	**10 m**

Describe the study site

It is important to collect information about the study site to help understand trends or patterns in the survey results. See **Datasheet 11** (*Site Description: Shorelines*) for the information needed to describe the site (e.g. GPS coordinates for the start and end of the transect, site width, substrate type, tidal range, nearest town, etc.). The datasheet also has a section to record information about the plant community (e.g. mangrove species, number of seedlings, tree height, tree density), since these factors may influence litter accumulation at the site. This datasheet should only be completed once per survey.

Collect sediment

One sediment sample should be collected from each quadrat as follows (**Figure 7**):

1. Insert a ruler or measuring stick 5 cm into the sediment.
2. Using a hand spade, collect the top 5 cm of sediment from each quadrat, moving the ruler or stick as necessary.
3. Place the collected sediment in re-usable zip-lock bags or containers for subsequent analysis. Ensure that a separate, clearly labelled bag is used for each quadrat.
4. Collection bags/containers should be clearly labelled to include the study site name, date of collection, zone of collection (i.e. seaward, middle or landward zone) and quadrat number.
5. Remove equipment from the field once all quadrats have been sampled.

Tip: If enough helpers are available, the collected sediment can be sieved in the field to extract mesolitter (see *Extract Mesolitter from Sample*). This avoids the need to transport large volumes of sediment to the laboratory. However, since mangrove sediments may be muddy and difficult to sieve, it may be more feasible to dry sediment samples in the lab and then select a smaller subsample to analyse. When sieving in the field, ensure that the rising tide will not present a safety concern.

Figure 7: Sample collection for mesolitter using 0.5 m x 0.5 m quadrats. A marked stick is used as a ruler to indicate depth.

Note: When subsampling by weight, the dry weights of both the complete sample and the subsample must be measured. These values are important when calculating mesolitter per volume of sediment in the *Analyse Data* section.

Extract mesolitter from sample

Select a subsample of sediment

Analysing smaller subsamples of sediment from each quadrat allows faster extraction and processing of litter. Before subsampling, sediment samples from each quadrat must first be air-dried, either in a laboratory or at a sheltered location. Once completely dry, the sample must be weighed, after which a 1 kg subsample of dried sediment from each quadrat can be randomly selected for further processing. Dry weights are used to standardise the sample sizes, since the collected samples might contain different amounts of water, which would influence wet weights.

Extract mesolitter

To process the mesolitter items, they must first be separated from the sediment and other natural material. This is done through a procedure called *density separation*. Density separation allows buoyant plastic items that are less dense than seawater to float near the surface, while the denser natural materials sink to the bottom. A summary of the procedure to extract mesolitter is shown in **Figure 8**, and the detailed methods within the procedure are provided in **Appendix 9**.

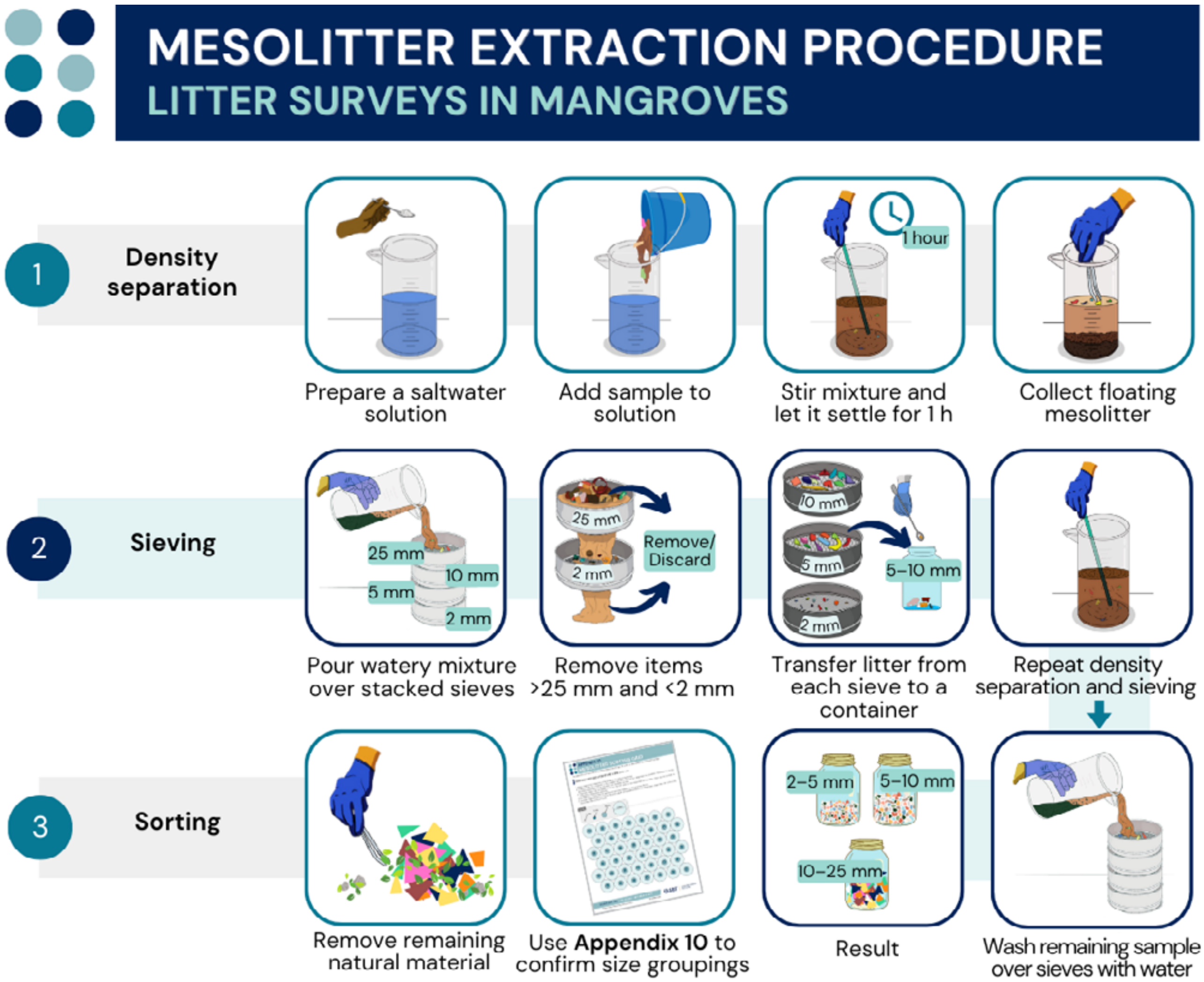


Figure 8: Summary of the procedure to extract mesolitter from a sample. See Appendix 9 for the detailed methods.

Process litter

After extraction, all pieces of mesolitter must be:

1. Counted and categorised as per **Datasheet 10** (*Mesolitter Datasheet: General*).
2. Cleaned with water or brushes to remove any remaining sediment or biological material that may influence weight measurements.
3. Air-dried to ensure all items are dry before weighing. Note that some pieces of litter, such as fabric, may require more time to dry than others.
4. Weighed per category (e.g. 'Ropes/fibres') to the nearest mg (0.001 g).

Separate litter datasheets should be completed for each sediment sample. A total of 28 datasheets must therefore be completed:

0. Site Description Datasheet: Shorelines – **Datasheet 11**
1. Mesolitter Datasheets (x27) – **Datasheet 10**.

Note: Surveyors conducting more detailed, scientific studies may choose to weigh each piece of litter.

Dispose of waste

Once the survey has been completed, mesolitter should be disposed of correctly. Due to the small size of mesolitter and pellets, and the often-degraded state of buried litter, recycling may not be possible for most mesolitter. Any remaining biodegradable organic waste (e.g. plant material) can be composted.

Analyse data

Mesolitter surface density is expressed per square metre of sediment sampled (e.g. items/m^2 or mg/m^2). Sampling depth is omitted from the calculations, because only the surface layer of sediment was sampled and mesolitter density tends to vary with depth[10]. If densities were expressed per cubic metre (m^3) using the methods outlined here, estimates of mesolitter loads would likely be unreliable.

Mesolitter density

For each inundation zone, add the number of items or weight of litter collected from all the quadrats and divide this number by the total surface volume of sediment processed in that zone. Given that each quadrat was

0.5 m x 0.5 m (i.e. 0.25 m^2) and nine quadrats were sampled within each inundation zone, the total amount of sediment sampled per zone is 2.25 m^2 (0.25 m^2 x 9). In this case, the surface density of mesolitter (items or weight) must be calculated using Equation 1 below.

If surveyors are unable to feasibly process and analyse complete sediment samples, 1 kg subsamples of sediment may be processed from each quadrat. Equation 2 must then be used to determine the surface density of mesolitter per zone.

Figure 9 provides an example of litter counts obtained by processing 1 kg sediment subsamples from nine quadrats within an inundation zone. If 36 kg (dry weight) of sediment was collected initially from the nine quadrats, the surface mesolitter density in that zone would be 1 152 items/m^2.

Variation in data

By calculating the mesolitter surface density per quadrat (as opposed to per zone), surveyors can calculate the variation in litter density within inundation zones or sites. It is important to calculate the variability of samples at the study site, as it is more difficult to make predictions and generalisations when the data variability (how different data points are from each other and the sample mean) is high. The equation used to calculate variability in data depends on which measure of variability is used (e.g. standard deviation, standard error, variance, range). For more information about how to calculate variability, **click here**.

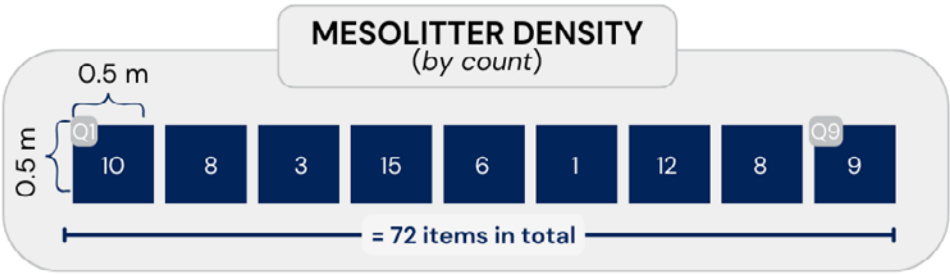
Equation 1

$$\textit{Mesolitter density}_{\text{(by count or weight)}} = \frac{\text{Total count or weight of mesolitter per zone}}{\text{Total surface volume of sediment processed}}$$

Equation 2

$$\textit{Mesolitter density}_{\text{(by count or weight)}} = \frac{\text{Mesolitter per zone}}{\text{Total surface volume of sediment collected} \times \dfrac{\text{DW of subsamples *}}{\text{DW of complete samples}}}$$

** where DW is dry weight*



$$\textit{Mesolitter density}_{\text{(by count)}} = \frac{\text{72 items}}{(0.50 \times 0.50) \times \dfrac{\text{9 kg}}{\text{36 kg}}} = \text{1 152 items/m}^2$$

Figure 9: Example of litter counts obtained by processing 1 kg sediment subsamples from nine quadrats in an inundation zone.

Alternative methods

The aforementioned protocols are recommended for collecting the most reliable data. However, depending on the study's research questions and available resources (e.g. funding, time, number of helpers), simpler methods can be used. For this reason, three different protocol standards – *Gold, Silver and Bronze* – have been provided as guidelines to modify the survey protocols to suit specific needs. By allowing flexibility in the methods, these standards ensure that data from litter surveys are always reliable and comparable while surveys remain feasible and sustainable. **Figure 10** shows how surveys can be modified to suit the different protocol standards.

The minimum requirements for a reliable accumulation survey are provided in the *Bronze Approach*, while the *Gold Approach* is recommended for best accuracy. Survey methods can be customised within the range specified by the *Gold* and *Bronze Approaches*.

Note: By calculating litter loads per metre of mangroves per day, results remain comparable regardless of the methods used. However, once methods are altered to below the standard of the *Bronze Approach*, the variation and uncertainty in the data increase substantially.

SURVEY APPROACHES
MESOLITTER SURVEYS IN MANGROVES

	GOLD APPROACH	SILVER APPROACH	BRONZE APPROACH
Size of litter to collect	2-25 mm	2-25 mm	2-25 mm
Transect length	84.5 m	53 m	21.5 m
Site width	31.5 m	31.5 m	31.5 m
Quadrat size	0.5 m x 0.5 m	0.5 m x 0.5 m	0.5 m x 0.5 m
Quadrats per inundation zone	9	6	3
Depth of soil collected	5 cm	5 cm	5 cm
Litter counts	Yes	Yes	Yes
Litter weights	Yes	Yes	Optional
Weighing individual pieces	Yes	Optional	No – weigh per litter type (e.g. earbuds)

Figure 10: Mesolitter surveys in mangroves can be modified using the guidelines above.

THE WAY FORWARD

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Introduction

The *African Litter Monitoring Manual* is an evolving document that aims to incorporate important updates and additional litter monitoring protocols as needed over time. The protocols and tools provided here can be applied and modified to study litter in various other circumstances and environments. They can also be used to answer research questions other than those mentioned in **Chapter 2** (*A Guide to Litter Monitoring in Africa*). **Box 1** provides an example of how methods from this manual have been modified in other studies.

BOX 1
MEASURING THE SUCCESS OF FISHING LINE BINS

Fishing line bins are commonly used in South Africa to encourage responsible disposal of unwanted fishing gear by recreational fishers. The bins have been widely supported by the community and viewed as a success, despite a lack of compelling evidence to support this. Beach macrolitter accumulation surveys conducted by Sustainable Seas Trust (SST) in Gqeberha, South Africa, revealed that abandoned, lost or otherwise discarded fishing gear (ALDFG) made up a substantial portion of litter polluting the city's beaches. Fishing line bins were subsequently introduced to eight popular fishing beaches around the Gqeberha coast. Litter surveys were conducted before and after the bin installations to test the efficacy of the bins. Since conventional beach accumulation surveys were not feasible at so many study sites, SST developed a new litter monitoring protocol based on concepts and tools of the *African Litter Monitoring Manual*.

Baseline surveys were conducted once weekly for four consecutive weeks on rocky shores and sandy beaches near where the bins would eventually be installed. Study areas were surveyed for ALDFG using similar methods to those outlined in **Chapter 8** (*Beach Macrolitter Surveys*). Litter was processed as per **Appendix 2** and categorised according to the 'marine & fishing gear' section of **Datasheet 5** (*Comprehensive Litter Datasheet*). Fishing line bins were then placed close to the study sites in visible, accessible spots to encourage use. Two months after the bins were installed, weekly surveys of nearby beaches/rocky shores were repeated for another four weeks. Over the course of the study, fishing line bins were emptied and the litter recorded once every two weeks. This enabled SST to link potential changes in the occurrence of ALDFG on beaches with use of the bins to assess whether the bins are effective in reducing ALDFG.

A critical tool for effective waste management

Plastic pollution is a global crisis, necessitating changes across the entire lifecycle of plastics. Accordingly, governments throughout Africa and the rest of the world are recognising the urgency of the situation and are dedicating more of their resources to addressing plastic waste issues. Support for change is also strengthening among the public and the plastics industry. With key roleplayers more willing than ever to collaborate, a strategic action plan must be developed to clearly define the roles of all sectors of society in combatting plastic pollution.

A global plastics treaty

The United Nations Environment Assembly (UNEA) is spearheading the development of a legally binding global plastics treaty to address plastic pollution. The treaty will require that countries commit to taking action across the lifecycle of plastics within a specified time to manage plastic usage and waste, with the goal of ending plastic pollution. To meet these requirements, countries must develop strategies with achievable, affordable targets. For interventions to be successful and sustainable (i.e. reducing plastic waste while also promoting local economies and livelihoods), they must be guided by reliable data and expertise across the plastics value chain. Measurements are key to adequate management and are essential to assess progress and demonstrate success. The *African Litter Monitoring Manual* equips countries with the necessary tools to measure pollution baselines and track the success of their efforts through continued monitoring.

Given the rapid pace at which changes occur within the realm of plastics, the protocols outlined in this manual offer excellent starting points for monitoring litter from its source on land to the seas. The methods and tools provided are designed to be robust enough to keep pace with ongoing developments and guide future strategies. By leveraging the insights gained from comprehensive measuring, African countries can enhance waste management practices, combat pollution and tangibly demonstrate progress toward ending plastic waste.

Using data to make a positive difference

The final and perhaps most important stage of litter monitoring is to utilise the data and findings to make a positive difference. Sharing and communicating findings with the relevant stakeholders increases the impact of litter monitoring efforts and ensures that the time, effort and funding dedicated to the project is not wasted. Examples of how litter monitoring data and findings can be used to drive and inspire change are provided below.

Decision-making and effective waste management

Litter data provide a comprehensive understanding of the quantities and types of litter prevalent in specific areas, enabling authorities to devise tailored strategies to address litter sources effectively. Indeed, litter monitoring data was incorporated in the first Kenyan National Marine Litter Management Action Plan (2021–2030), launched in 2022. The action plan outlines strategic objectives and actions Kenya aims to implement over the next decade. Using litter monitoring data gathered by the Kenya Marine and Fisheries Research Institute (KMFRI), it was possible to estimate that 80% of marine litter originates from land-based sources and then formulate a plastic-focused action plan that includes targeted actions, key performance indicators and proposed timelines[1].

Baseline development and target setting

To effectively manage plastics and plastic waste, initial pollution baselines need to be established, future targets must be set, and progress must be measured toward achieving goals[2]. Progress is assessed by comparing future findings with baseline data. For example, the Tanzanian NPO Nipe Fagio coordinated litter monitoring efforts in which 32 151 participants conducted waste and brand audits to highlight the waste composition in urban areas and beaches in Tanzania[3]. The data were used to establish baselines and develop targeted interventions for the major application and sector hotspots.

Identification of patterns and trends

Long-term litter data is critical in identifying patterns, trends and hotspots of litter pollution. By analysing data collected from different locations and over time, authorities can identify recurring patterns in the distribution of litter, seasonal variations and emerging trends. Comprehensive studies such as the *National Guidance for Plastic Pollution Hotspotting and Shaping Action* conducted for Kenya[4], Mozambique[5] and South Africa[6] demonstrate the importance of long-term data in identifying major leakage points across waste management, applications, polymers and sectors. By understanding these hotspots, authorities can implement site-specific and targeted action plans to stop pollution at its source.

Predictive modelling and scenario planning

Litter data provide a foundation for predictive modelling and scenario planning. By analysing historical data and identifying patterns, current trends and anticipated developments, predictive models can estimate the potential trajectory of plastic pollution and its environmental impacts. Models need to examine plastic data within the context of growing populations, increased urbanisation, economic planning (including the growing affluence of the middle class in Africa), urban development plans and predictions regarding climate change. These models assist in understanding the consequences of different management strategies and help to devise proactive measures to mitigate pollution.

Scenario planning involves developing hypothetical scenarios based on different assumptions and variables. By incorporating litter data into scenario planning, decision-makers can evaluate the potential outcomes of various interventions, policy changes or technological advancements. This enables them to anticipate challenges, evaluate trade-offs and select strategies most likely to achieve desired outcomes.

Awareness raising

Studies have shown that people care more and are more willing to support interventions when they have a better understanding of an issue[7,8]. By sharing findings from litter surveys, surveyors can raise awareness and inspire positive behavioural changes among community members, practitioners and policymakers. Furthermore, sharing updates on progress toward goal achievement motivates the public, particularly the youth, increasing their enthusiasm. When sharing survey results and appealing for change, it is crucial to identify the appropriate platform to address the chosen target audience (e.g. social media, presentations in public spaces, conventional media) and ensure that the messaging is reliable, clear, concise and relevant. Findings must never be distorted or misrepresented to make unsubstantiated claims, since trust is fundamental in gaining and retaining public support[9].

Not all the data collected during litter surveys will be relevant when addressing a specific problem. Instead of overwhelming the target audience with irrelevant information, the most important results should be packaged in a way that engages and inspires (**Figure 1**). Clear guidance should be given about the measures needed to solve the problem and how the target audience can help. Proposed solutions need to be supported by evidence to help ensure that awareness campaigns alter the perception and behaviour of others in a constructive manner.

In conclusion, data are central to developing evidence-based management strategies to tackle plastic pollution. They provide valuable insights for formulating targeted interventions, support predictive modelling and scenario planning, and guide decision-makers in refining strategy over time. By tracking trends, decision-makers can adjust activities to ensure that goals are achieved.

This latest edition of the *African Litter Monitoring Manual* is an essential tool for all who are likely to be involved in helping countries of Africa meet commitments to end plastic pollution.

Figure 1: A researcher from SST shares results from litter monitoring at the 12th WIOMSA Scientific Symposium held in Gqeberha, South Africa, in 2022.

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Appendix 1: Macrolitter Survey Types

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GLOSSARY

The definitions below refer to the use of terms in this manual only and care should be taken when applying them in other contexts.

Accumulation litter surveys: Litter surveys that involve repeated (daily or weekly) clean-ups and data collection at the same site to determine the rate at which litter is accumulating (building up) over time.
Adaptive management: A procedure for implementing management while learning about which management actions are most effective at achieving specified objectives.
Aerial roots: Plant roots that develop aboveground.
Aesthetic value: The value an object, event or environment has based on appearance and its capacity to give emotional pleasure or displeasure.
Baseline: The starting point against which future comparisons can be made, as in the initial estimate of the amount and type of litter in a given study area.
Bathymetry: The study of underwater depths (or bottom topography) of waterbodies, including rivers, streams, lakes and oceans.
Beaufort scale: A scale from 1 to 12 that describes wind strength based on the observed state of the sea or water, where 1 represents light wind (observed as ripples on the water without crests) and 12 represents a hurricane (observed as extremely high waves with white crest and driving spray).
Bias: Any deviation from the truth that causes distorted results and wrong conclusions. Bias can occur at any stage of research, including during data collection, data analysis, interpretation or publication.
Biodegradable: An object or material that can break down into natural components (e.g. water, carbon dioxide, methane and minerals) through biological activity i.e. the action of microorganisms such as bacteria, fungi, algae or earthworms.
Boat wake: The ripples/waves that a boat makes as it moves through water.
Boom curtain: The mesh netting hanging from a litter boom in the water column. It is used to trap submerged litter below the water surface.
Brand audit: The process of recording information found on branded litter items, such as brand name, manufacturer name, country of manufacture, date of manufacturing, best before/expiry date, etc.
Buoyant: Able to float in a liquid.
Canal: An entirely artificial/man-made waterway or a deepened/concrete-lined watercourse to allow the flow of water from one body of water to another.
Channel: The passage through which water flows in a waterway.
Citizen scientist: A member of the general public who voluntarily helps to collect data for scientific research relating to the natural environment, typically as part of a collaborative project with professional scientists.
Cod end: The narrow end of a trawl net in which the sample of interest (e.g. plankton, fish or mesolitter) collects as the net is dragged through the water.
Community scientist: A community member who assists with data collection and/or contributes to scientific knowledge, sometimes called a citizen scientist (see **Citizen scientist**).
Data: Factual information such as quantity, size measurements and material type that can be used in analysis and decision-making.
Data analysis: The process of summarising, inspecting, transforming and/or modelling collected data to determine patterns, relationships or trends, in order to inform conclusions and support decision-making.
Day Zero: The day before the start of an accumulation survey in which all visible litter items are cleared from the survey area and immediate surroundings.
Decomposition: The breaking down of organic matter into smaller parts through biological activity (see **Biodegradable**).
Degradation: The breaking down of non-organic/inanimate objects (e.g. plastic) into smaller parts through exposure to the elements, mechanical action (e.g. trampling, digging) and bacterial activity.

Discharge: The volume of water flowing through a channel section per unit time, also called the volumetric flow rate.
Dumpsite: See **Legal (controlled)** and **Illegal (uncontrolled)** open dumpsites.
Ecosystem: A biotic assemblage of plants, animals and other organisms living in a geographic area or habitat (see **Habitat**) and interacting with each other and their abiotic environment (e.g. climate, soil and water).
Ecosystem goods & services: The benefits people obtain from ecosystems, including goods (e.g. fuel, fresh water), services (e.g. water purification, pollination) and non-material benefits (e.g. aesthetic values, recreation).
Endangered species: Organisms that are at risk of becoming extinct (dying out).
Ebbing tide: The tidal phase when water is receding (moving away) from the shore or flowing seaward in estuaries and tidal rivers, resulting in a lowering of water level.
Eddies: A circular current of water that moves independently of the main current.
Episodic streams: Streams that flow when sporadic rain occurs and cease flowing or have a low flow during dry periods.
Floodline: The water level typically reached during relatively frequent flooding events.
Flow meter: A device that measures the amount of liquid, gas or vapour flowing through or past it. In riverine litter monitoring, a flow meter measures the movement of water over a given period of time.
Flow rate: The volume of water passing a particular point during a period of time, typically expressed as cubic metres per second.
Fragment: A small part broken off from an item.
Greenhouse gases: Gases in the atmosphere that absorb infrared radiation emitted by the Earth, trapping and re-radiating this heat and thereby raising the surface temperature of the planet and contributing to the greenhouse effect. One such gas is carbon dioxide.
Habitat: A place where an organism or a community of organisms lives, including all living and non-living factors or conditions of the surrounding environment that are needed for the organisms to survive and reproduce.
Harmonised monitoring methods: Methods that are conducted in the same way in different areas or countries so that data collected to detect trends and report on progress in meeting national or international obligations are reliable and comparable.
Hazardous items: Items that are potentially dangerous or harmful to humans or the environment.
High tide: The time during each tidal cycle when the sea reaches its highest level and comes furthest up the beach.
Hydrodynamics: The motion/flow of water and how it changes over time.
Illegal dumping: Any activity that involves purposefully discarding relatively large volumes of waste (compared to **Littering**) at unauthorised places.
Illegal (uncontrolled) open dumpsite: A site where waste is indiscriminately and illegally dumped with no measures to control the site or protect the surrounding environment.
Ingestion: The process of taking in, or consuming, a substance (e.g. food or water) by an organism.
Intensive sampling: Sampling that involves a period of doing detailed surveys to collect comprehensive data, which can be done less frequently than **Routine monitoring**.
Intertidal zone: The area on the shore between the highest and lowest tides.
Inundation zone: A zone that is usually dry but becomes inundated with water occasionally.
Land-based sources: Human activities and sectors (municipal, industrial or agricultural) on land that cause solid waste pollution in terrestrial, aquatic and/or marine environments.
Landfills: Designated sites where waste collected by municipalities or waste-removal companies is deposited and regularly covered by soil. Fencing and waste compaction to control access and prevent wind dispersal may be used to reduce the waste's negative impacts.
Leakage: The process whereby materials do not follow an intended pathway and 'escape' or are otherwise lost to the environment.
Legal (controlled) open dumpsite: A designed site to dispose waste (often limited to municipal waste) that complies with some legal requirements but where waste is not covered, and there is no lining for leachate management nor management of dumpsite gas.
Litter: Processed and manufactured items (including plastic, rubber, metal, paper and processed wood, textiles and glass) that have been discarded and are likely to end up in the environment.

Littering: The action of deliberately throwing trash/rubbish/litter on the ground in a public place or leaving it without ensuring its correct disposal.
Litter boom: A device that floats on water and acts as a barrier preventing litter from continuing downstream.
Litter composition: The types of different items/materials, and their amounts, that make up litter.
Litter flux: The amount of litter transported past a given point.
Litter hotspots: An area with a comparatively high amount of litter or where litter loads are concentrated.
Litter loads: The quantity of litter (either by weight or number of items) in a specific area at a point in time.
Litter monitoring: The repeated and systematic collection of data on litter to provide information on sources and amounts of litter, and detect trends in space and time.
Litter net: A net used to intercept and trap litter in flowing water and prevent it from moving downstream.
Litter processing: A stepwise process during which the litter is cleaned, dried, weighed, counted and the data collected.
Litter sinks: Places where litter may become trapped or buried for extended periods.
Litter trap: A barrier or device that is used to trap litter and prevent it from moving downstream.
Litter turnover: The rate at which litter is deposited and removed from a site.
Low tide: The time during each tidal cycle when the sea has receded to its lowest level, leaving a wider area of the beach exposed.
Macrolitter: Litter that is larger than 25 mm in diameter at its longest point.
Mangrove: A coastal habitat consisting of trees and shrubs that are specially adapted to survive in tidal saltwater environments.
Manta net: A type of trawl net that is towed along the surface of the water to sample plankton or small floating litter.
Material recovery facilities (MRFs): Facilities that receive, separate and process recyclable materials to recover them from the waste stream.
Mesolitter: Litter that is 5–25 mm in diameter in its longest dimension.
Microlitter: A small piece or fragment of litter that is 0.5–5 mm in its longest dimension.
Mismanaged waste: Waste that is disposed at a place where it can move into the natural environment. This includes both uncollected waste and collected waste deposited in open dumpsites and landfills that are not fully contained or covered.
Natural items: Objects that occur naturally in the environment, including animals, plants, soil, rocks, etc.
Observer: A person who is visually observing and identifying litter without collecting it.
Observation depth: The depth to which litter can be observed in the water column.
Observation height: The height from which litter is identified from a vantage point above.
Observation track: The area observers survey for floating litter. A large survey area can be divided into imaginary equal-sized portions (or observation tracks) to be surveyed separately.
Organic material: Any material that is derived from plants and animals and can decompose, including food waste.
Pathways of litter: The means in which litter is transported from its source to where it is deposited in the environment.
Periodic rivers: Rivers that only flow during the rainy season.
Perennial rivers: Rivers that continue flowing throughout the year.
Plankton: Small and/or microscopic aquatic organisms (including animals, eggs and larvae, plant-like microalgae, protists and bacteria) that drift or float in the water column.
Pneumatophores: Specialised aerial roots of some mangrove species and other wetland plants that grow upward from underground roots to protrude above the mud and water surface, allowing them to take in oxygen from the air.
Pollution: Any natural or man-made substance that contaminates the environment and causes harm or damage.
Primary producers: Any plant or microorganism that converts light energy (usually from the sun) into organic matter, which is a food source for other organisms.

Prop roots: Roots that grow from the aboveground stem of certain plants (e.g. mangroves) down into the ground for added stability.
Protected habitat/species: A habitat or a species of plant or animal that it is forbidden by law to harm, destroy, kill or capture.
Protocol: In monitoring, a detailed plan of study explaining how data are to be collected, analysed and reported to ensure data are reliable and comparable, and used in this manual to describe the steps required to perform litter surveys.
Proxy: A substitute for an item when direct observations or measures are not possible or practical, e.g. weighing a clean tissue in place of a used one.
Quadrat: A frame, usually a square of a set size, used to mark out small, representative areas within a larger study site for sampling (e.g. collecting, counting or listing the contents of interest). The data obtained from the sampled quadrats can then be extrapolated to infer information about the entire area.
Quality control: The process of monitoring data to ensure that data are complete, accurate and valid. Quality control should take place from the time of data collection through to processing and analysing, until the dataset is finalised.
Quantify: To determine the quantity or measurement of something and express it as a numerical value. Litter can be quantified either by weight or by number of individual items.
Recycle: Transform a product or component into its basic materials or substances and reprocess them into new materials and products.
Remediation: The action of reversing or stopping environmental damage, e.g. by removing litter or other pollutants.
Remote sensing: Obtaining information about an object or an event/phenomenon without making physical contact with it, usually through use of sensors carried by satellites, airplanes or **Unmanned Aerial Vehicles** (UAVs).
Replicates: Data collected by repeating the same experiment/procedure/survey multiple times to measure variation, increase accuracy and detect outliers. In surveys of floating macrolitter or mesolitter, visual observations or manta-net tows are ideally conducted at least three times along the same transect or observation track on any given survey day.
Research objectives: Clear and concise statements explaining what the research aims to achieve, and the actions or measurable steps needed to achieve the overall goal.
Research question: A specific question which the research sets out to answer.
Resources: The staff, equipment, money and other assets needed to function effectively or perform an action (e.g. conduct a litter survey).
Riverbank: The land on each side of a river.
River mouth: The place where a river enters a lake, larger river or ocean.
Routine monitoring: Quick, simple surveys done regularly (e.g. weekly) to monitor litter and record basic data, as opposed to **Intensive sampling**.
Sampling schedule: Predetermined dates and times when sampling is planned to occur.
Sanitary landfill: An engineered, controlled facility that is designed and operated to minimise impacts of waste on human health and the environment. Waste is routinely compacted and covered, leachate and gas is collected, and the landfill is capped (sealed) once full.
Scribe: A person who is responsible for writing down information, usually given to them verbally by another person.
Sea-based sources: Marine activities (e.g. fishing) and sectors (e.g. shipping) that contribute to pollution at sea, including marine litter.
Sea state: The general condition of the surface of the open sea or of a waterbody, at a particular place and time, considering wind, waves and swell.
Seawall: A wall that protects land from being flooded or damaged by the sea or shelters boats in a port from powerful waves.
Secchi disc: A simple disc with black and white quadrants that is used to measure water transparency.
Shoreline: The strip where land and a large body of water, such as a sea, meet.
Slope: The gradient or 'angle' of a beach that depicts its steepness and therefore the likelihood of litter accumulation.
Sources of waste: The activities (e.g. littering) or sectors (e.g. motor industry) that create waste, or the points where waste 'leaks' into the environment.

Spatio-temporal variation: The variation or change in something (e.g. litter quantities) at different times and locations.
Stakeholders: Any party that may be affected by, take an interest in or have influence over activities or decision-making (e.g. schools, businesses, citizens).
Standing-stock litter surveys: Surveys that provide a snapshot of litter at the time of sampling, typically conducted in a single day.
Stormwater outlet: The end of a stormwater pipe from which stormwater is released into a larger stormwater canal or the environment.
Strandline: The line of accumulated debris and/or seaweed deposited by the high tide.
Study site: The physical location at which a surveyor conducts a study.
Subsample: A portion of a sample, as in using a portion of a bag of litter when it is not feasible to process the entire bag.
Substrate: The surface type on which a survey is conducted (e.g. sand, rock, grass).
Subterranean roots: Plant roots that develop underground.
Supernatant: A liquid above a solid residue (e.g. sediment) that has settled at the bottom of a container.
Supratidal zone: The area above the spring high tide line, on a coastline or estuary, that is regularly splashed but is not submerged by seawater. In litter monitoring, it is known as the 'dry zone'.
Surface trawling: The towing of a net behind a boat to collect organisms or floating litter at the surface of the water.
Surveys: An activity in which individuals undertake research by gathering data and information to answer research questions.
Survey area: The area in which data are collected, usually a smaller portion of the study site.
Test sieve: A sieve used to separate items (e.g. mesolitter) into size categories. The smaller pieces will fall through the mesh or perforations while bigger pieces remain in the sieve.
Textiles: Types of cloth or woven fabric.
The sweeper: An individual who follows behind the rest of the surveyors to pick up litter items that may have been missed and ensures that the entire site has been thoroughly cleaned.
Tidal cycle: The period covering a high tide and consecutive low tide. In general, most areas of the world experience two high tides and two low tides within 24 hours (semidiurnal tidal cycle).
Tidal range: The difference in height between high tides and low tides, accompanied by a horizontal movement of water on the shore. The smallest tidal range occurs during neap tides and the largest during spring tides.
Transect: A narrow area marked out at the start of a survey for sampling purposes (e.g. collecting, counting or measuring items). The data collected within transects are assumed to represent the larger study site.
Trawl: The action of pulling a net through water behind a boat.
Unmanned Aerial Vehicles (UAVs): Aircraft operated via remote control, also called drones.
Unsanitary items: Unhygienic or dirty items (e.g. dirty diapers, used condoms) that should not be handled without proper personal protective equipment (PPE).
Upsstream sources of pollution: Sources of pollution (e.g. plastic leakage during manufacturing or transport) originating from a direction opposite to that of the flow of the river, stream, etc.
Urbanisation: The increase in the proportion of people living in cities and towns, which occurs when people move from rural areas into urban areas. Urban areas have high population densities and are characterised by their built-up infrastructure.
Urban litter: Visible solid waste originating from or occurring in an urban (city or town) environment.
Velocity: The distance an object moves in a unit of time, i.e. per second, minute, hour, day, etc.
Waste management services: Services that are usually provided by a municipality or private sector company to remove waste from an area and take it to a waste facility such as a landfill or dumpsite.
Waterbody: A clearly distinguishable body of water such as a lake, dam, river or ocean.
Waterway: A channel for flowing water, such as a river or canal, in which litter and other pollutants may be carried downstream.
Water column: The vertical expanse of water between the surface and the floor of a waterbody.
Water transparency: The clarity of water, which determines whether underwater objects can be seen clearly or not at all. Transparent water allows light to pass though it such that objects in the water are visible.

APPENDICES

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APPENDIX 1
MACROLITTER SURVEY TYPES

Chapters in this manual that pertain to macrolitter monitoring refer to two specific types of surveys: standing-stock surveys and accumulation surveys. The main difference between these survey types is the survey period and survey frequency (i.e. the time span of a single survey, and how often the surveys are repeated). A standing-stock survey usually consists of a single day of surveying (recording the litter at that point in time) and can be completed once-off or repeated every few months, or even less frequently[1]. In comparison, accumulation surveys are usually conducted over consecutive days or weeks (measuring the daily or weekly accumulation rate of litter), and work best when repeated at least every three months. The total number of consecutive days or weeks surveyed during an accumulation survey will depend on the research questions, available resources and the particular ecosystem or environment.

More information on the two survey types is provided here to help surveyors choose which to use. A summarised comparison is given in **Figures 1** and **2**.

COMPARISON OF SURVEY TYPES
STANDING-STOCK VS ACCUMULATION SURVEYS

	STANDING STOCK	ACCUMULATION SURVEYS
Frequency of sampling	Once-off, monthly, yearly	Daily or weekly
Type of data that can be collected	• Litter density • Litter weight • Types of litter • Brand data	• Litter accumulation rate (count & weight) • Types of litter • Brand data
Ideal use	• Identifying litter hotspots • Understanding the impact of big events (e.g. festivals & storms) on litter loads • Educational/awareness campaigns	• Identifying sources & pathways of litter • Measuring changes in litter loads over time • Measuring the impact of waste management interventions
Advantages	Quick, easy, cheap	More informative & reliable data
Disadvantages	Limited use of data	More resources required (time, money, effort)

Figure 1: Basic differences between standing-stock surveys and accumulation surveys.

MACROLITTER SURVEY TYPES
STANDING-STOCK VS ACCUMULATION SURVEYS

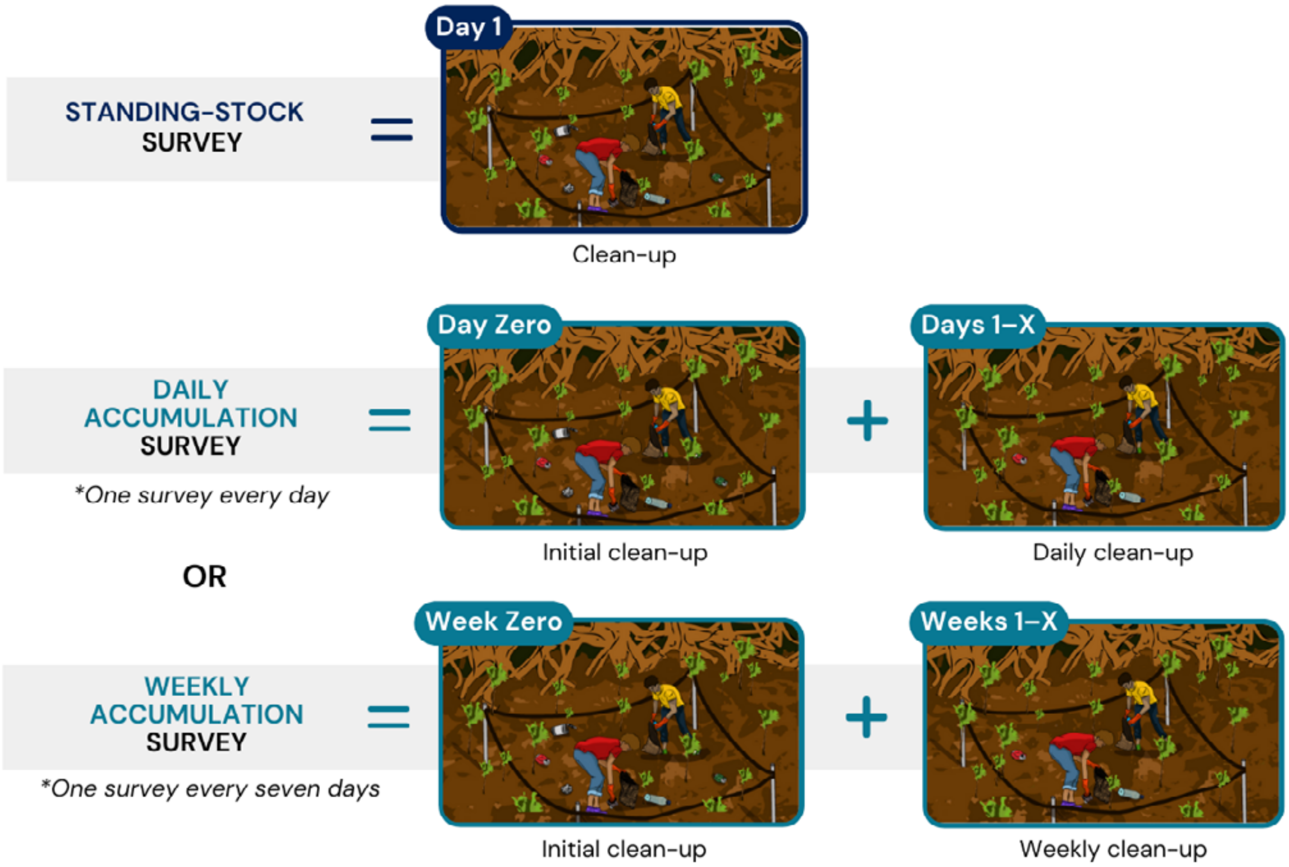


Figure 2: While standing-stock surveys entail a one-day clean-up that may be repeated over time, accumulation surveys require clean-ups over consecutive days or weeks. Mangrove surveys are used as an example.

Standing-stock surveys

Standing-stock surveys give a snapshot of litter loads at a specific point in time or on a specific day. These surveys provide valuable information about the pollution level of a site, give an overview of the types of litter found there, and can help identify litter hotspots[1]. Despite these benefits, standing-stock surveys reveal little about the sources and pathways of litter, and do not account for short-term changes in litter loads[1].

A study on two sub-Antarctic islands found that monthly beach litter surveys provided substantially lower estimates of litter accumulation on beaches than daily surveys[2]. This can be explained by litter turnover rates, where litter deposited at a site may be removed during clean-ups, may become buried, or may be moved off-site by winds, tides or rain runoff. Lightweight items like polystyrene are underestimated during standing-stock surveys because they have faster turnover rates than heavier items[3].

Furthermore, these snapshots of litter loads can misrepresent the true situation. For example, when using standing-stock surveys to compare the pollution level of two sites, one may have been cleaned by the public a day before the survey, while the other may never have been cleaned. Results from the standing-stock survey will likely indicate that the first site is less polluted, but this may not be the case. Subsequently, standing-stock surveys are most useful to study the impact of big events (e.g. festivals or extreme weather) on litter loads at a given site. They are also useful if the goal of a survey is to educate or raise awareness, as opposed to increasing the understanding of the sources of pollution.

Accumulation surveys

Accumulation surveys investigate how much litter builds up or accumulates at a site over a specific timeframe, such as daily or weekly. By doing an initial clean-up followed by regular surveys at the same site, the accumulation of litter can be linked to external factors (e.g. weather or specific events) to gain a better understanding of where litter is coming from (the source of litter) and how it is making its way to the site (the pathway of litter).

Daily surveys are recommended at sites where litter loads are expected to change very quickly (e.g. on beaches, where litter can be washed up, buried or removed daily). A study on beaches near Cape Town, South Africa, found that daily litter surveys provided litter accumulation estimates that were 2.5 times more by litter count, and 1.7 times more by weight, than estimates from weekly surveys[3]. It is best to continue with daily surveys for at least seven days to see how daily changes, such as those associated with weekends or municipal waste removal days, may influence litter loads.

At sites where litter loads are not expected to change constantly, accumulation surveys can be done once per week, for at least a month, to account for any variation within a month (e.g. there may be more litter after a monthly payday). Accumulation surveys are best for scientific surveys with the goal of finding the sources of litter and tracking changes in litter over time.

APPENDIX 2
MACROLITTER PROCESSING METHODS

Once all litter has been collected from the study site, the next step is to record important information about it. This is the step that sets litter surveys apart from basic clean-ups. To record the information needed, each piece of litter must be cleaned, sorted into categories, counted and weighed. This is called 'litter processing'. The steps needed to process litter and record the necessary information for further analysis are discussed below.

General considerations

Quantity of litter to be processed

It is recommended that *all* macrolitter (>2.5 cm) collected within the study site during the survey period (excluding *Day/Week Zero* for accumulation surveys) is processed where possible. However, if resources (e.g. time, helpers and finances) are limited or sites are very polluted, it may not be feasible to do so. In such instances, a subsample of the litter can be selected for processing.

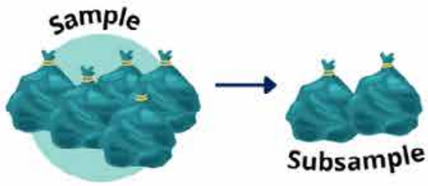
A subsample is a subset or portion of the total sample (i.e. collected litter) that is selected for further analysis. The subsample must be representative of the complete sample. This means that it is important to avoid bias when selecting subsamples, such as only processing small, large or recognisable items. The lead surveyor must set the rules for subsampling and ensure that the team adheres to them. While subsamples must represent at least 10% of the volume of the complete sample, the size selected should be feasible for a long-term study. For example, it may be possible to process 15 bags of litter, but to do it each day of a long-term survey will require a significant amount of time and effort. See **Box 1** for an example of how to choose a subsample.

Note: To avoid bias when subsampling, ensure that the litter is not sorted while it is being collected. For example, first-time helpers often collect larger items first, which means that the bags filled first will mostly contain larger litter items, while bags filled later will include smaller items. Subsampling such bags will misrepresent the litter found at the site. If such biases cannot be avoided during the collection stage, it is advisable to set aside the first and last bags so that they are not included in the subsample.

BOX 1
SELECTING A SUBSAMPLE

1. Before selecting a subsample, all bags of litter must first be counted and weighed.
2. Determine the maximum number of litter-filled bags that can comfortably and feasibly be processed for each litter survey (i.e. set a *bag limit*).
3. If the total number of bags collected is equal to or less than the bag limit, all bags must be sampled/processed. If the total number of litter-filled bags exceeds the bag limit, proceed to **Step 4** for instructions on how to select a subsample.
4. To select a subsample, first determine how many bags are needed – this will likely equal the bag limit but may also exceed the bag limit since the subsample must always represent **at least 10%** of the total sample volume. Select bags randomly to make up the subsample.

A good way to avoid bias when selecting bags is to rank each bag by weight or size (e.g. *Bag 1* is the lightest and *Bag X* is the heaviest or vice versa). To sample both lighter and heavier bags, select bags at *equal intervals* (e.g. every second bag or every third bag) based on their rank number. To determine at which interval to select



bags, divide the total number of bags by the number of bags processed. For example, if 10 bags are collected and 5 are processed, then 10/5 = 2, so every second bag must be sampled until 5 bags have been sampled. Examples of subsampling are provided in the table below:

Hypothetical Bag Limit = 5	Example 1	Example 2	Example 3
Total Number of Bags Collected	2	10	60
Subsample (Yes/No)	No	Yes	Yes
Number of Bags Processed	2	5 (as per bag limit) (Represents 50% of total)	6 (Represents 10% of total)
Bags Sampled	1 & 2	Bags 1, 3, 5, 7, 9 OR Bags 2, 4, 6, 8, 10	Bags 5, 15, 25, 35, 45, 55 OR Bags 10, 20, 30, 40, 50, 60

After processing the subsample and recording the litter data, remember to extrapolate the results to reflect the total sample using the equation below. Total results must be rounded down to the closest whole number to avoid overestimation of litter.

$$\textit{Total Results} = \frac{\textit{Subsample Results}}{\textit{Number of Bags Processed}} \times \textit{Total Number of Bags Collected}$$

For example, if four bags were subsampled from a total of 10 bags, results would be calculated using the formula below:

$$\textit{Total Results} = \frac{\textit{789 items of litter}}{4} \times 10 = 1\,972$$

5. Large items that fill most of, or more than a bag must be counted and weighed separately and added to the total results at the end. This ensures that the abundance of such items is not overestimated when subsampling. Examples of these items are blankets, large electrical appliances, crates, and buckets.
6. When describing the study methods, indicate that 'subsampling occurred when the number of litter-filled bags exceeded x (i.e. the bag limit) and represented at least 10% of the total sample size. Large items (e.g. blankets, crates, appliances) were counted and weighed separately.'

Processing location

Before starting a litter survey, it is important to decide when and where the litter will be processed and plan accordingly. The approach chosen will influence planning, as extra helpers, transport for litter, and storage space may be needed.

There are three main approaches to processing litter. These are:

1. Categorise and count litter items as they are picked up at the study site.
2. Process the litter at the site on the same day it was collected.
3. Process the litter at another location either on the same day or a different day.

The advantages and disadvantages of each approach are outlined in **Figure 1**. The selected approach will depend on the research questions and available resources. The approaches may also be modified where necessary.

LITTER PROCESSING APPROACHES
MACROLITTER SURVEYS



	1 COUNT LITTER AS YOU GO	2 PROCESS LITTER AT THE STUDY SITE	3 PROCESS LITTER AT ANOTHER LOCATION
Description	Litter is counted and recorded as it is picked up	Litter is processed at or near the study site immediately after the clean-up	Litter is taken to another location and can be processed at a convenient time
Data collected	• Litter counts • Total combined weight	• Litter counts • Weight per litter category	• Litter counts • Weight per litter category
Advantages	• Fast & cheap • No need to transport litter • No need for storage space to keep litter	• No need to transport litter • No need for storage space to keep litter	• Freedom to process litter at a convenient time
Disadvantages	• Only works for simple data collection *(i.e. Basic Litter Datasheet)* • Cannot record weight per litter type	• Requires many helpers • Survey days can be long • Only possible in favourable weather	• Requires transport of litter • Requires storage space to keep litter

Figure 1: There are three approaches to litter processing. Choose an approach before starting a survey, and plan accordingly.

Processing procedure

Cleaning

The first step of processing litter is to clean and dry the litter so that it can be weighed. Weight is a useful indication of litter abundance because some types of litter may be found less often but can account for a large percentage of the total litter by weight (e.g. metal items and wooden pallets). On the other hand, while plastic litter is common, it may only contribute a small portion of the total weight of litter. It is therefore recommended that litter is both counted and weighed to gain a better understanding of litter abundance in the environment.

Unsanitary items such as condoms, diapers and feminine hygiene products should not be cleaned. These items must be recorded and responsibly disposed of as soon as possible after collection. Clean, dry versions of the same items can then be used as proxies (stand-ins) and weighed instead. It is useful to compile a list of such items and pre-record the weights – see **Figure 2** for an example of a proxy weight list used by Sustainable Seas Trust in South Africa. For increased accuracy, the proxy must be as physically similar to the litter item as possible, so it is best to create a proxy list to match locally available products.

Note: Litter weights can be obtained without cleaning and drying, but these numbers will not be reliable for scientific studies or those that measure change over time. They will only be useful for surveys with awareness as the main goal.

To get an accurate measurement of litter weight, any natural material (e.g. food, soil, sand, plants, animals) that may influence the weight must be removed from the litter before weighing. Dry pieces of litter can be cleaned using brushes (e.g. paintbrushes), while dirty or wet items can be rinsed in a bucket of water and then air-dried (or oven-dried at a maximum of 40°C in a laboratory oven). The litter must be completely dry before it is weighed. Note that materials such as fabric may take longer to dry and may be replaced by dry proxies. The weight of very dirty or soiled items can similarly be estimated by using clean and dry proxies.

Tip: To save time, litter can be sorted and counted while waiting for it to dry.

EXAMPLE PROXY LIST OF LITTER WEIGHTS

Litter Category	Item	Dry Weight (grams)
Hygiene Objects	Condom	1.9
Hygiene Objects	Disposable diaper/nappy	36.5
Hygiene Objects	Disposable face mask	3.3
Hygiene Objects	Earbud/cotton bud	0.2
Hygiene Objects	Nitrile glove	3.3
Hygiene Objects	Panty liner	1.7
Hygiene Objects	Sanitary pad	6.9
Hygiene Objects	Tampon	2.3
Hygiene Objects	Wet wipe	1.8
Plastic	Cigarette butt	0.2
Plastic	Lollipop stick	0.6
Plastic	Empty refuse bag	46.2

Figure 2: An example of proxy weights for litter that is unsafe to handle.

Sorting & counting

All pieces of macrolitter (>2.5 cm) must be sorted, counted and recorded according to the litter type in the litter datasheet selected for the study. The lead surveyor must choose between two different datasheets provided: **Datasheet 4** (*Basic Litter Datasheet*) with 36 litter categories, and **Datasheet 5** (*Comprehensive Litter Datasheet*) with >140 litter categories. These easy-to-use datasheets were designed to help identify problem items (i.e. frequently littered items) and sources of litter, while also making data comparable to that collected using other litter datasheets.

COMPARISON OF DATASHEETS
BASIC VS COMPREHENSIVE LITTER DATASHEETS

	BASIC LITTER DATASHEET	COMPREHENSIVE LITTER DATASHEET
No. of litter categories	36	>140
Example of categories	Hygiene & medical objects	Diapers, condoms, earbuds
Advantages	• Quick & simple to use • Collects data on the most common sources of litter • Data can be used to inform and evaluate waste-reduction strategies	• Fragment sizes can be included • Collects detailed data on the sources of litter • Includes more litter categories, making it easier to identify problem items • Data can be used to inform and evaluate waste-reduction strategies
Disadvantages	Not as detailed	Time-consuming
Recommended use	• Public clean-ups/ awareness campaigns • Simple surveys	• Detailed surveys • Scientific surveys
Recommended users	• Citizen scientists • NGOs	Academics

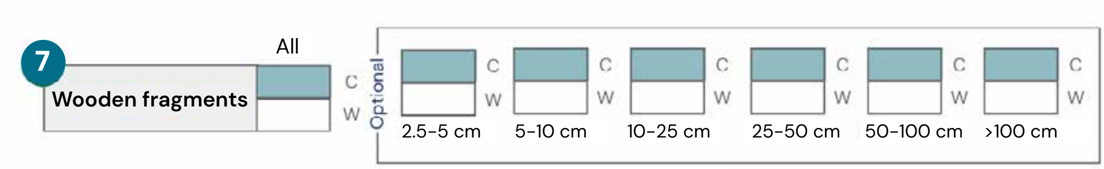
Figure 3: A summarised comparison between the Basic Litter Datasheet and the Comprehensive Litter Datasheet.

The differences between the *Basic and Comprehensive Litter Datasheets* are summarised in **Figure 3** and visual guides of the litter categories are given in **Appendix 4** and **Appendix 5**, respectively. See **Box 2** for how to measure and record fragment sizes of broken litter as per the *Comprehensive Litter Datasheet*.

When categorising and counting litter, it is important to be consistent to ensure that the data are comparable to others using the same methods. All helpers must be trained on how to sort and count litter before they start processing the litter. Guidelines for categorising litter are given in **Figure 4**.

BOX 2
CATEGORISING FRAGMENTS BASED ON SIZE

Some studies may involve recording the size categories of broken pieces of litter. Measuring the abundance of different sizes of litter fragments provides a better understanding of the litter problem in the area and the way litter breaks down. When using the *Comprehensive Litter Datasheet*, surveyors have the option to either count and categorise all litter fragments under one category, or to sort fragments into the six size classes provided below:



Litter fragments can be measured using **Appendix 6**. This sizing chart should be printed on an A1 page to ensure that the scale is maintained, and then laminated to prevent water damage.

Weighing

Once the litter has been cleaned and allowed to dry, items can be weighed. Litter should be weighed per litter category so that each litter category has one count and one weight measurement. For example, if 56 plastic 'bottle caps, lids and lid rings' are collected, all 56 must be weighed together because these items make up a single category on the litter datasheets.

Litter must be weighed to the nearest 0.1 g using a kitchen or laboratory scale. Large and heavy items that exceed the weight limit of the scale can be weighed using a different scale (e.g. luggage scale) with a 100 g resolution. Remember to use the weights of clean, dry proxies for unsanitary or hazardous items.

Optional: For more detailed studies, each piece of litter may be weighed individually.

GUIDELINES FOR CATEGORISING AND COUNTING LITTER

CATEGORISING BROKEN FRAGMENTS OF LITTER

If fragments are recognisable as being part of a larger item, they should be recorded as that item. For example, if a fragment of a beverage bottle (see image) can clearly be identified as such, it should be counted and weighed as a beverage bottle. However, if there is doubt regarding the origin of the fragment, it should be categorised as a fragment of that material e.g. 'glass fragment (2.5–5 cm)'.

COUNTING ITEMS THAT HAVE FRAGMENTED INTO MULTIPLE PIECES

If broken pieces can be identified as being from a single item, they should be counted as one item, not as multiple pieces of litter. For example, a broken glass bottle should be counted as one glass bottle.

RECORDING ITEMS WITH COMPONENTS FROM DIFFERENT CATEGORIES

Litter items made of multiple materials or with various components may be difficult to categorise and count. For example, a plastic beverage bottle may also have a plastic bottle cap and a plastic label. These components can technically be grouped into different litter categories. However, splitting such items into their components would over-represent the number of items found. These items should therefore only be recorded once – under the category that makes up most of the item by volume or weight. The example on the right will therefore be recorded simply as a 'plastic beverage bottle'. Similarly, a wooden beam with nails embedded will be recorded as 'wooden fragment'.

CATEGORISING ITEMS NOT LISTED IN THE LITTER DATASHEETS

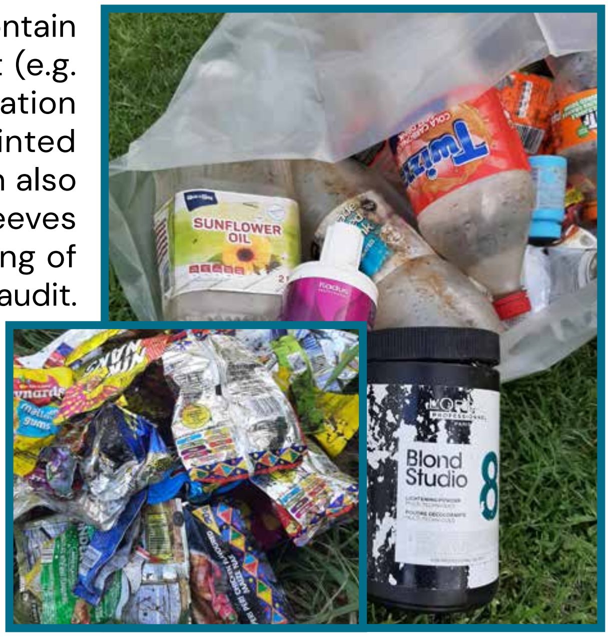
Items that do not fit into the litter categories provided can be added under the 'other' category in each datasheet. Remember to also provide the material type, take a photograph, and describe the item for future reference.

RECORDING TANGLED ITEMS

Pieces of litter that are tangled together should be untangled, if possible, and recorded separately.

Figure 4: Guidelines on how to categorise and count items of macrolitter.

APPENDIX 3
CONDUCTING A BRAND AUDIT



Most consumer products and littered items contain some form of information about the product (e.g. brand name, manufacturer, material type, location of distribution). This information is often printed or imprinted directly on the products but can also be printed on a separate component (e.g. sleeves wrapped around plastic bottles). The recording of information from branded litter is called a brand audit.

Brand audits provide useful data about the type of litter, the recyclability of litter, the age of litter, and the origin of litter, so they are recommended for every litter survey. The brand audit protocols presented here were adapted with permission from the '#BreakFreeFromPlastic' official brand audit protocols[1] (**Box 1**). Note that there are key differences between the protocols presented here and that of '#BreakFreeFromPlastic'. The primary goal of brand audits as presented in this manual is to obtain information regarding the source and origin of the litter as well as the persistence of litter in the environment (i.e. the age of litter). However, brand audits can also be used to identify brands and manufacturers whose products pollute the environment[1,2]. This knowledge can be used to steer stakeholder engagement and guide the effective implementation of Extended Producer Responsibility (EPR).

BOX 1
#BREAKFREEFROMPLASTIC BRAND AUDITS

'#BreakFreeFromPlastic' has developed a protocol to conduct plastic brand audits on a global scale. The coalition gathers the results of global brand audits to compile annual reports highlighting the brands and types of plastics commonly found during clean-ups around the world (click on the image to download the 2022 annual report, Branded). To maximise the impact of clean-ups, it is recommended that official brand audits are submitted to the '#BreakFreeFromPlastic' website. Surveyors interested in performing the official '#BreakFreeFromPlastic' plastic brand audit can obtain all the necessary information from the website at: https://brandaudit.breakfreefromplastic.org/.

How to do a brand audit

The first step of a brand audit is to separate the litter collected during a survey into branded and non-branded items. An item is considered 'branded' and must be recorded when it has any of the following information on it (**Figure 1**):

- Brand name,
- Manufacturer,
- Country of origin (i.e. where the product was made),
- Whether it is distributed locally (i.e. where the item was likely thrown away),
- Date manufactured, or 'best before' (BB) date if date manufactured is not available, and/or
- Distributor/Location of sale (if available).

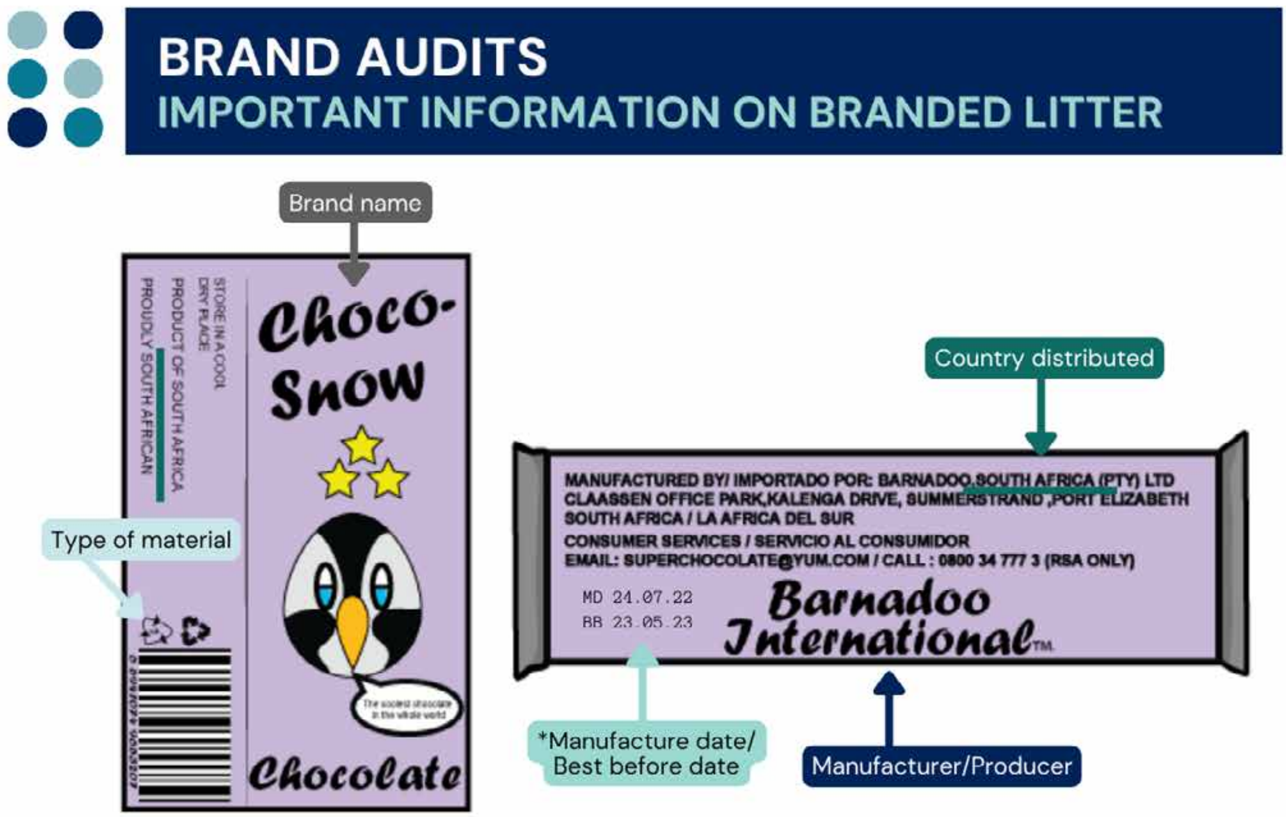


Figure 1: Typical information that can be found on branded items.

Each piece of branded litter must be counted and categorised as per **Datasheet 3** (*Brand Audit Information*). The type of product and material can be determined using the visual guides in **Figures 2** and **3**.

Note that some required information may not be present or visible on branded litter – especially for fragmented or stained litter. In some instances, the available information (e.g. brand name) can be used to research other required information (e.g. manufacturer or source). If information cannot be found by researching it, write 'N/A' (i.e. 'Not Available') under the relevant column.

TYPES OF PRODUCTS
WASTE BRAND AUDITS

Figure 2: Categories used to group types of branded products in a brand audit.

Product origin versus source of litter

The *country of origin* is defined here as the country where the product was manufactured or packaged. While important to know, this information does little to confirm where it was littered or where it entered the environment, as some products may be imported from foreign countries, then bought and thrown away locally. It is therefore important to note whether products of foreign origin that were collected during local litter surveys are sold or distributed locally.

This is especially true for litter surveys along the coast or in estuaries since litter of foreign origin and sources may wash up on local sites[2–4]. For example, litter may originate from foreign ships or may have been transported from its original source via ocean currents. Subsequently, brand audits from litter surveys on land can be used to compile a master list of branded items which are known to be sold/found locally. This list could help determine where litter is coming from and reduce the uncertainty and potential bias regarding the source of beach litter.

Figure 3: Categories used to group types of materials and material layers in a brand audit.

APPENDIX 4
BASIC LITTER DATASHEET: VISUAL GUIDE

PLASTICS

1 Sweets/crisp wrappers

2 Beverage/drinking bottles

3 Bottle caps, lids & lid rings

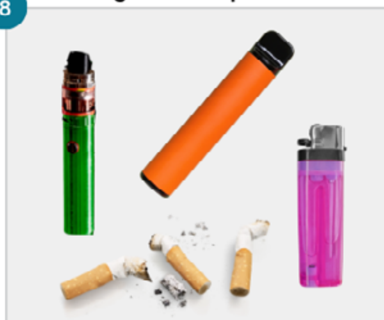
4 Take-away/fast-food items & containers – Plastic

5 Take-away & food-related items – Polystyrene

6 Other food/drink-related plastics

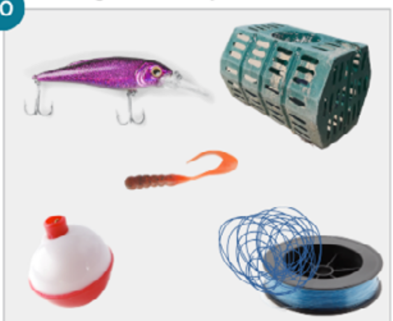
7 Plastic bags

8 Cigarettes & smoking-related plastics



9 Buckets, crates & containers

10 Fishing-related plastics



11 Hygiene & medical objects

12 Plastic packaging (non food-related)

BASIC LITTER DATASHEET VISUAL GUIDE

13 Synthetic ropes & nets

14 Toys

15 Other plastic bottles

16 Other plastics & unidentified fragments

17 Other polystyrene/foam & unidentified fragments

PAPER & CARDBOARD

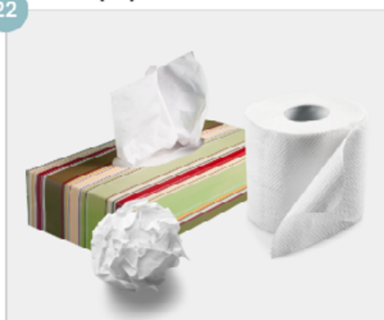
18 Cardboard & papers

19 Take-away & food-related items – Cardboard & paper

20 Cartons

21 Smoking-related cardboard

22 Toilet paper & tissues



METAL

23 Food/drink-related items

24 Metal bottle caps/lids/pull tabs

25 Electronic waste

26 Fishing-related metals

27 Other metals

GLASS

28 Food/drink-related items

29 Other bottles, jars & containers

30 Other glass

GENERAL

31 Textiles

32 Processed wood

33 Rubber

34 Construction material/rubble

35 Other

36 Pre-filled bags

APPENDIX 5
COMPREHENSIVE LITTER DATASHEET: VISUAL GUIDE

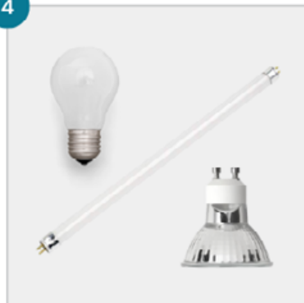
GLASS & CERAMICS

1 Construction material

2 Glass beverage bottles

3 Glass/ceramic tableware

4 Light bulb/tube



5 Other glass bottles/containers/jars

6 Other glass/ceramics

METAL

1 Aerosol/spray cans

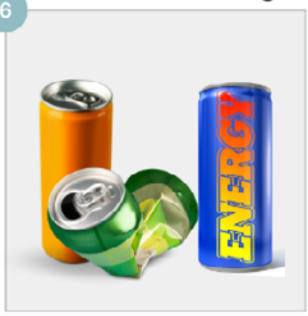
2 Bottle caps/lids/pull tabs

3 Electronic waste

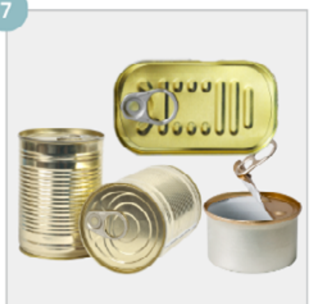
4 Fishing-related metals

5 Foil

6 Metal cans – Beverages



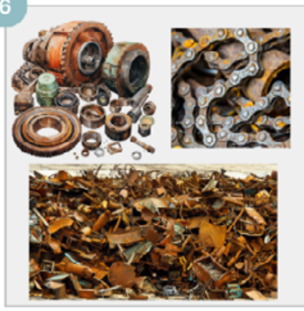
7 Metal cans – Food



8 Metal cans – Other

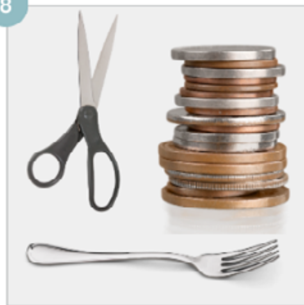
5 Metal drums/barrels

6 Scrap metal



7 Wire/mesh

8 Other metals



PAPER & CARDBOARD

1 Cardboard boxes

2 Cartons – Food & beverages

3 Cigarette packets

4 Food-related containers/packaging

5 Other paper/cardboard containers/packaging

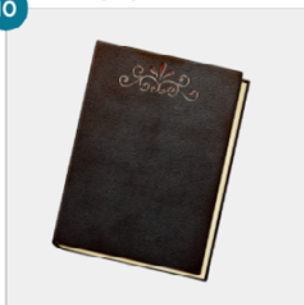
6 Paper

7 Paper bags

8 Paper cups

9 Tissues/serviettes/ toilet paper

10 Other paper/cardboard

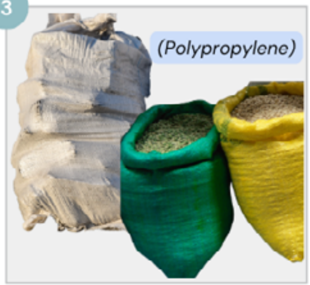


PLASTIC

1 Bags – Shopping

2 Bags – Transparent

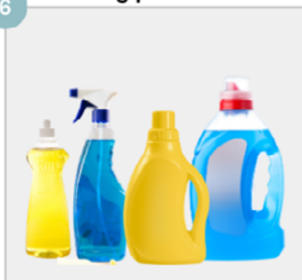
3 Bags – Woven



4 Bags – Other

5 Bottles – Beverages

6 Bottles – Cleaning products



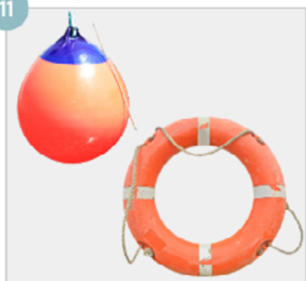
7 Bottles – Personal care

8 Bottles – Other

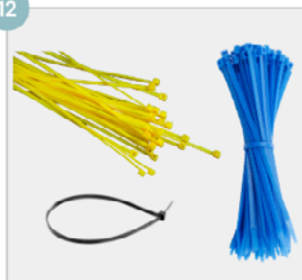
9 Bubble wrap

10 Buckets (reusable)

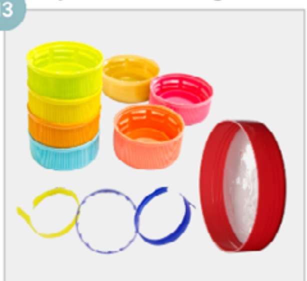
11 Buoys



12 Cable ties



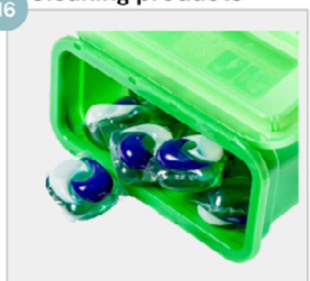
13 Caps/lids/lid rings



14 Carpets/flooring

15 Condoms

16 Containers – Cleaning products



17 Containers – Food

18 Containers – Personal care

19 Containers – Other

20 Crates

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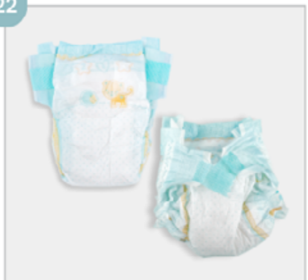
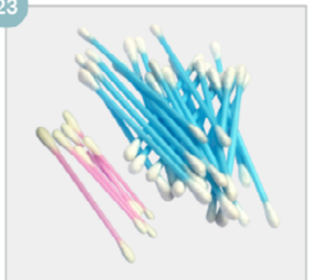
21 Cups

22 Diapers



23 Earbuds (plastic)



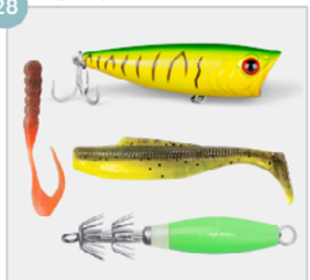
24 Fibreglass

25 Fishing line

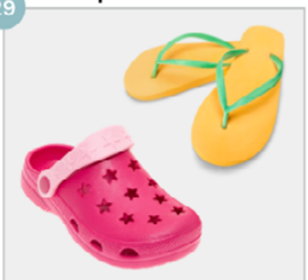
26 Fishing net

27 Fishing traps

28 Fishing-related plastics – Other



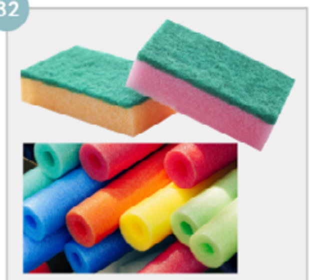
29 Flip flops & other plastic shoes



30 Foam – Cushioning/packaging

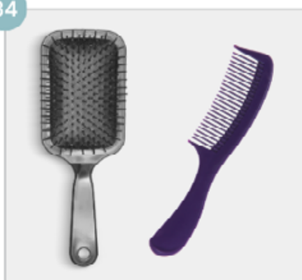
31 Foam – Food & beverages

32 Foam – Other



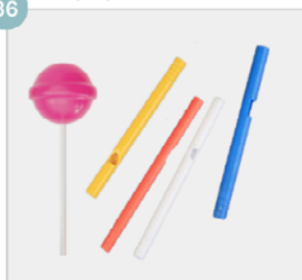
33 Glow/light stick

34 Hairbrushes/combs



35 Jerry cans

36 Lollipop sticks



37 Medical containers/ tubes/packaging

38 Medical items – Other

39 Menstrual products

40 Mesh

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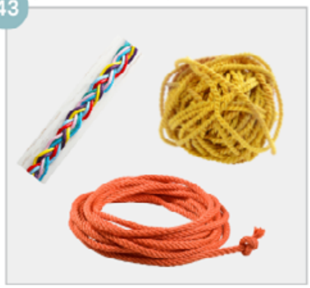
41 Personal protective equipment (PPE)

42 Plates & trays

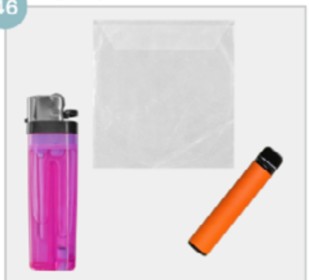
43 Rope/synthetic string (<1 cm diameter)



44 Rope/synthetic string (>1 cm diameter)

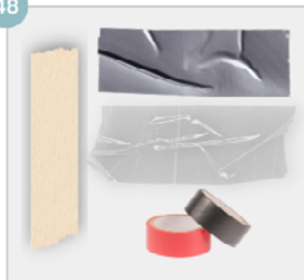
45 Smoking-related plastic – Cigarettes

46 Smoking-related plastic – Other

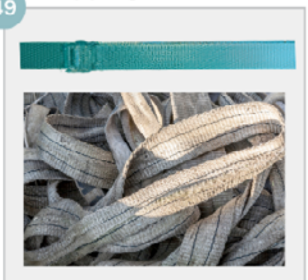


47 Stationery

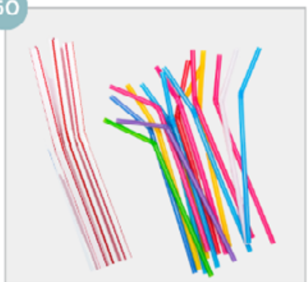
48 Stickers/tape



49 Strapping bands



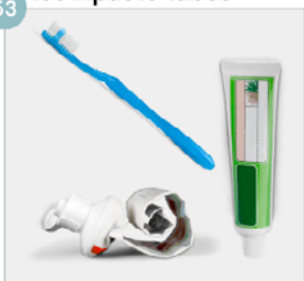
50 Straws



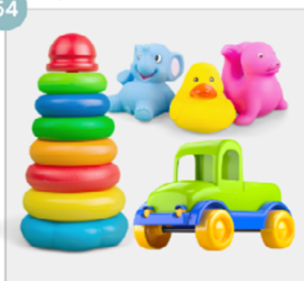
51 Synthetic hair

52 Tarpaulin/sheeting

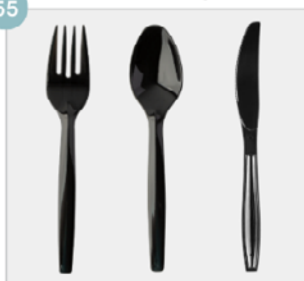
53 Toothbrushes/ toothpaste tubes



54 Toys



55 Utensils/cutlery

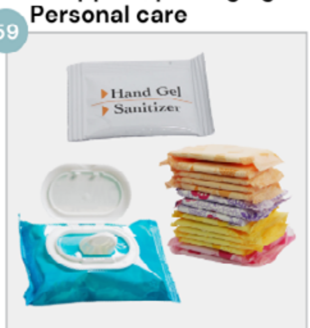


56 Wet wipes

57 Wrappers/packaging – Cleaning products

58 Wrappers/packaging – Food/drinks

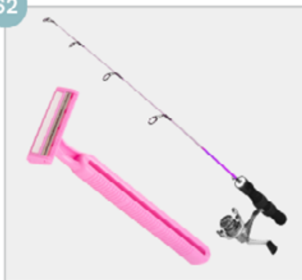
59 Wrappers/packaging – Personal care



60 Wrappers/packaging – Sweets & crisps

61 Wrappers/packaging – Other

62 Other plastics

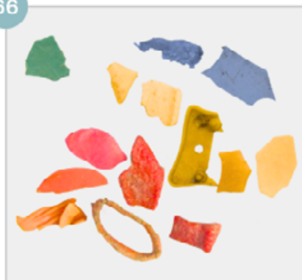


63 Foam fragments – Hard

64 Foam fragments – Soft

65 Plastic fragments – Film

66 Plastic fragments – Hard



PROCESSED WOOD

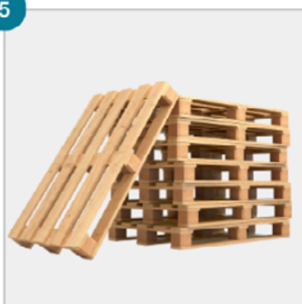
1 Crates, boxes & baskets

2 Cork

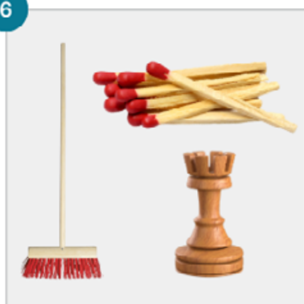
3 Fishing-related wood

4 Food-related items

5 Pallets



6 Other wood



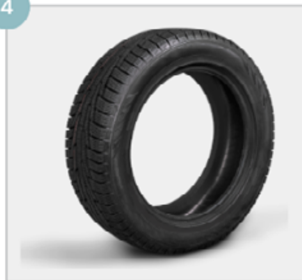
RUBBER

1 Balloons

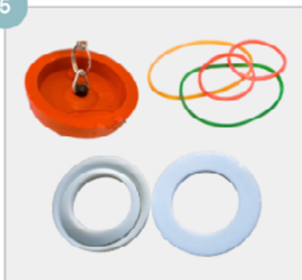
2 Boots

3 Gloves

4 Tyres

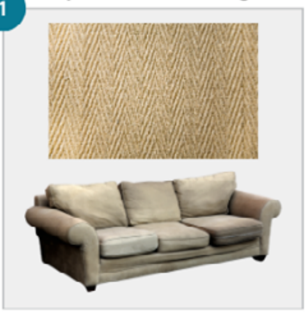


5 Other rubber



TEXTILES

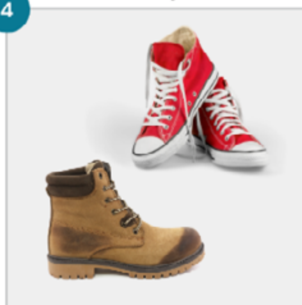
1 Carpet & furnishing



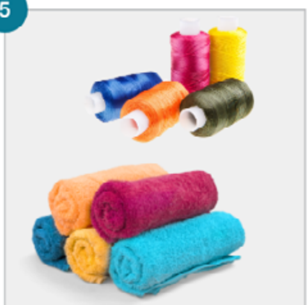
2 Clothing

3 Fabric bags

4 Shoes (non-plastic)



5 Other textiles

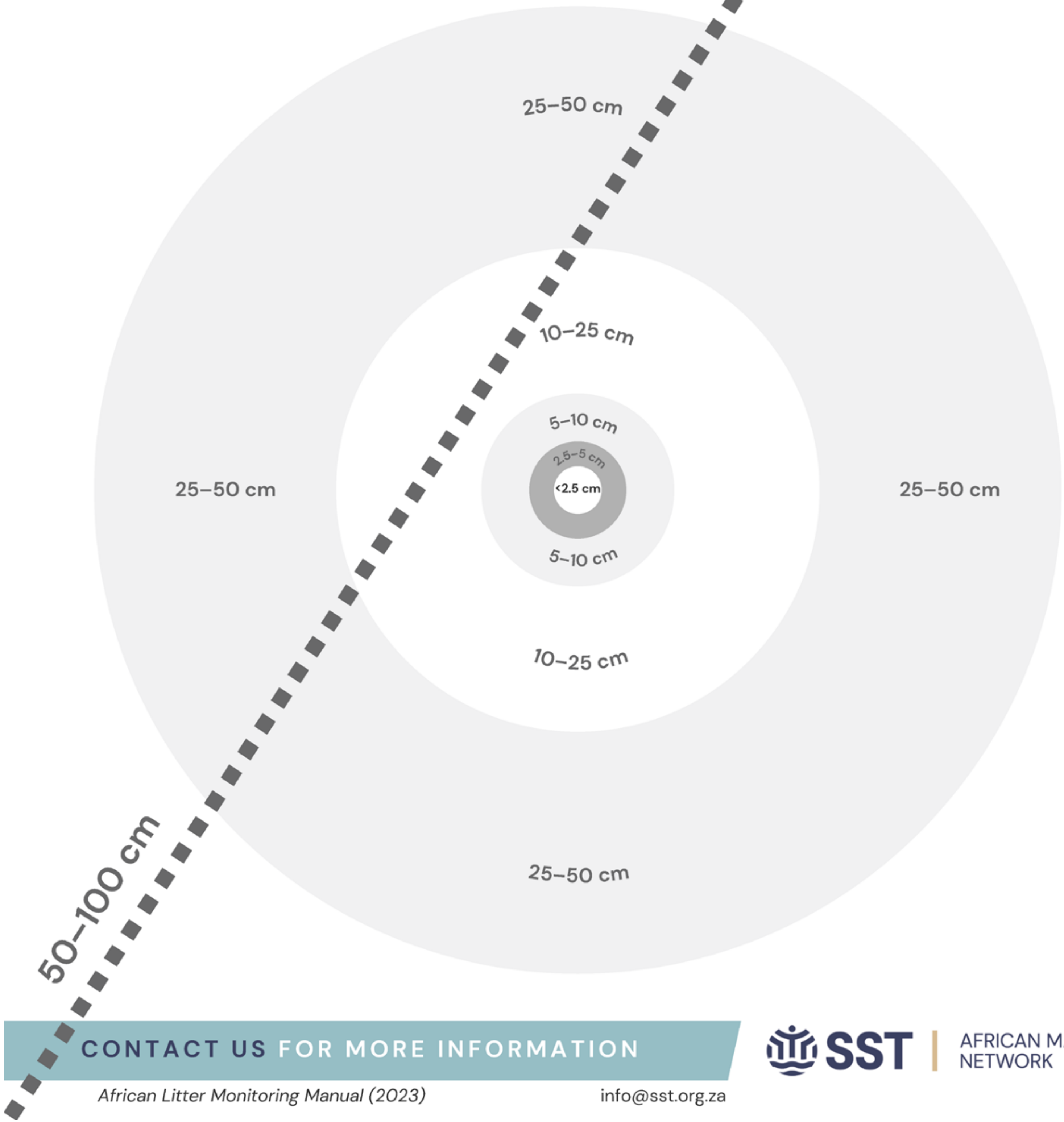


APPENDIX 6
MEASURING MACROLITTER FRAGMENTS

SORTING METHODS

1. Place a fragment of litter in the centre of the smallest circle (<2.5 cm).
2. Fragments that fit completely in the smallest circle are not categorised as macrolitter. These pieces should be discarded responsibly or can be used for mesolitter surveys.
3. Sort fragments into appropriate size classes based on the circle it fits into.
4. Fragments are sorted into the 50–100 cm size range if the longest dimension of the fragment is longer than the biggest circle (>50 cm), but shorter than the dashed line (100 cm).
5. Fragments larger than the dotted line are >100 cm.

This illustration is to scale. Please print on an **A1** page.



APPENDIX 7
DUMPSITE MAPPING IN PRACTICE

The following case study shows how dumpsite mapping and visual characterisation (described in **Chapter 4**) can be used to gather important information about open dumpsites that can be shared with municipal authorities and stakeholders to promote better waste management.

Background

Dar es Salaam is the largest city in Tanzania, with a rapidly growing population of over 5.4 million people[1,2]. As the city continues to grow, especially in the form of informal settlements[1], it becomes increasingly difficult for authorities to manage waste and minimise dumping. Consequently, city-wide dumping causes blockages of waterways, which is the main cause of flooding in Dar es Salaam. In severe cases this waste-related flooding may result in a loss of infrastructure and human lives.

*Nipe Fagio is a non-profit organisation in Dar es Salaam, dedicated to the pursuit of systemic change in the waste management sector.

To address illegal dumping and reduce risks of mismanaged waste to the environment and community, Nipe Fagio* conducted dumpsite characterisation and mapping in four municipalities of Dar es Salaam in 2020. The goal of this project was to identify and assess dumpsites along rivers and in open spaces following a drone survey conducted by partner organisations. The results of these surveys would then be used to guide local authorities in prioritising clean-ups of dumpsites that pose a risk to communities.

Methodology

The project was conducted in 49 sub-wards within four Dar es Salaam municipalities (Kinondoni, Temeke, Kigamboni and Ubungo). The locations of potential dumpsites were identified through drone imagery collected by Nipe Fagio's partners and satellite imagery from Geographic Information System (GIS) software. The open-source software OpenMapKit was used to map potential dumpsites, which were then verified in-person by the Nipe Fagio Data Team and Youth Ambassadors. The team also collected relevant data about the dumpsites using **Datasheet 6** (*Dumpsite Information*) and OpenDataKit (ODK). To gain a more complete understanding of the local waste challenges, community members were interviewed to determine whether the area was served by waste contractors and how often waste was removed.

Results

Over 120 illegal dumpsites were identified along the seven rivers in the Msimbazi River area of Dar es Salaam. The dumpsites ranged from small piles of rubbish (45 m^2) to large-scale waste-dumping areas (1 600 m^2). The data were used to create an interactive map showing the location of dumpsites, size of dumps, types of waste and other important information. The map (**Figure 1**) was shared with the local community and government officials.

MAP OF ILLEGAL DUMPSITES
DAR ES SALAAM, TANZANIA

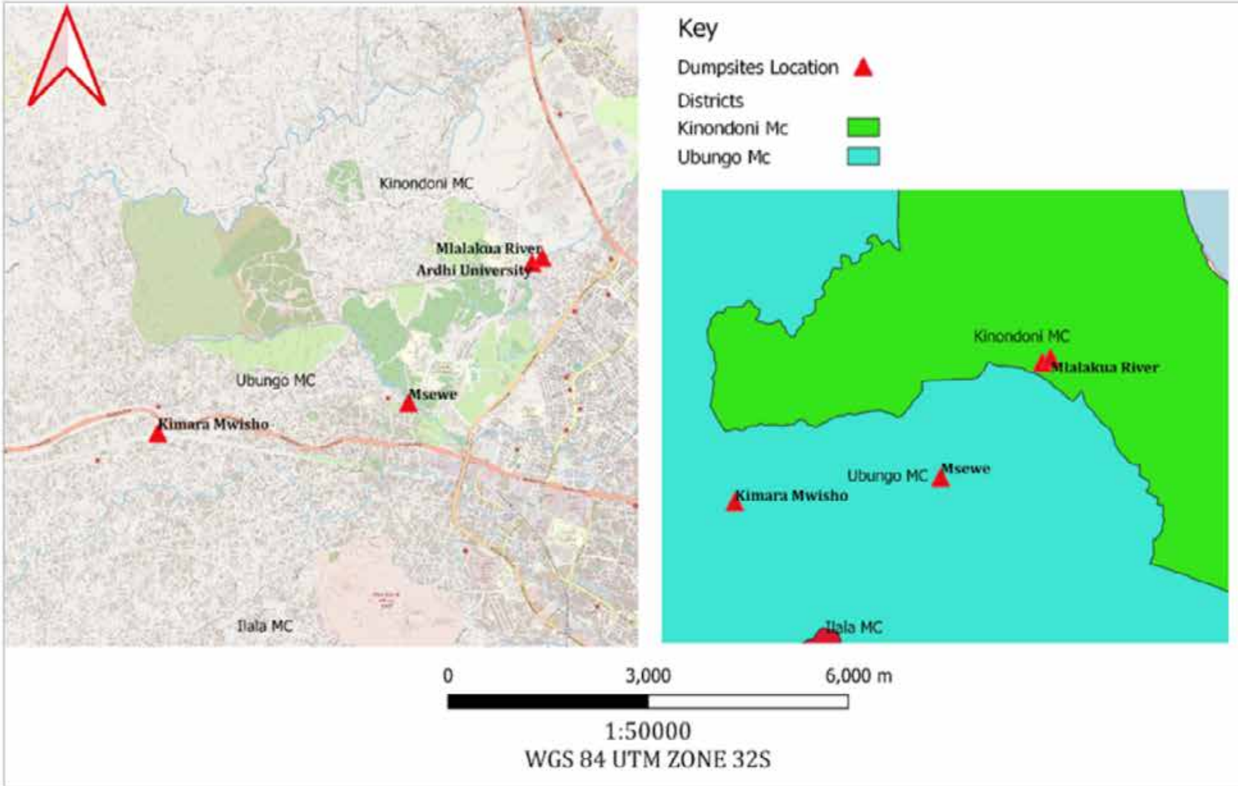


Figure 1: A map of illegal dumpsites in two municipalities of Dar es Salaam.

Impact

The project had several positive impacts for the local communities in Dar es Salaam:

- It raised awareness among the local community and informed residents of the scale and location of dumpsites in their area.
- The interactive map empowered citizens to act and advocate for better waste management.
- The project helped Nipe Fagio better understand the city's waste management challenges and to develop more effective strategies to address them.
- The maps and findings from this project were used extensively in local, national and regional advocacy for better waste management systems and restrictions on plastic production.

APPENDIX 8
CALCULATING SLOPE

The accumulation of litter on beaches is influenced by the steepness or slope of the beach-face – the area between the low-tide mark and high-tide mark. Simple methods for measuring and calculating beach slope are provided below. It is recommended that slope is measured during a spring low tide, when the beach is at its widest.

Equipment needed

The following equipment is needed to measure beach slope:

- **Measuring tape or rope**: Ensure that the measuring tape/rope is longer than the study site is wide. If using a rope, mark out 1 m intervals to assist with measurements.
- **Rope**: Another rope is needed to connect two points.
- **Stakes/poles**: Two stakes (e.g. broomsticks, measuring sticks) or poles are needed. Both sticks must be marked at 10 cm intervals for easy measurement.
- **Helpers**: Three or four helpers are needed to assist with measurements and recording of information.

Measuring slope

The Emery Method is recommended to measure the slope of a beach. This method measures the slope at fixed intervals and calculates the average slope from the low- to the high-water mark. Fixed intervals of 5 m can be used on narrow beaches and intervals of 10 m on wide beaches. Average slope is expressed as a percentage, with higher percentages representing steeper beaches. The steps of the Emery Method are provided below.

1. **Identify the low-tide mark**: Select a spot anywhere within the beach survey transect and place a stake/pole vertically in the sand at the low-tide mark. Assign a helper (*Helper 1*) to hold the stake in place.
2. **Place a second stake further up the beach**: A second helper (*Helper 2*) must hold the starting point (zero point) of the measuring tape or rope where *Helper 1* is standing. A third helper (*Helper 3*) then carries the other end of the measuring tape/rope 5 m towards the high-tide mark for narrow beaches and 10 m for wide beaches. Place a stake/pole vertically in the sand at the 5/10 m point.
3. **Extend a rope horizontally between the two stakes**: Extend a rope between the poles held by *Helper 2* and *Helper 3*. Ensure that it is completely horizontal between the two poles (i.e. it must not sag or touch the surface of the sand, unless the beach is perfectly flat). The person standing at the higher spot (on a depositional beach, this will usually be towards the high-tide mark) must hold the rope at the bottom of the stake/pole at the surface of the sand. The person at the lower point must then start at the bottom of their stake/pole and raise the rope until it is level with the starting point of the higher pole.
4. **Measure the horizontal and vertical distance between the two points**: *Helpers 2* and *3* must keep the rope in the horizontal position while a fourth helper (*Helper 4*) does the required measurements. The horizontal distance (known as the 'run') between the two poles is measured using the measuring tape or marked rope as it is held in place (**Figure 1**). Ensure that the zero mark is held at the stake/pole closest to the low-tide mark. At the point where the rope is above the ground, *Helper 4* must measure the

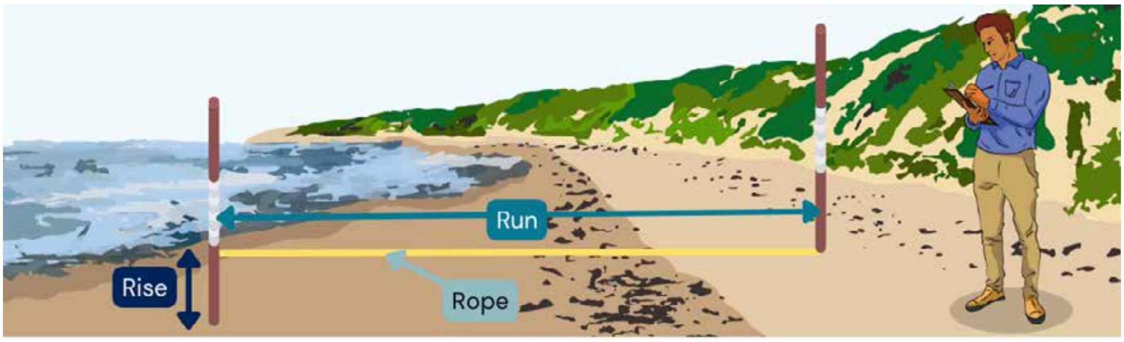


Figure 1: Measuring beach-face slope entails measuring elevation change (rise) over a known horizontal distance (run).

vertical distance (known as the 'rise') by measuring the distance from the surface of the sand to the rope.

5. **Repeat steps 1–4 up to the high-tide mark**: After measuring the rise and run, keep the stake/pole closest to the high-tide mark in place and move the stake near the low-tide mark towards the back of the beach using steps 1–4. Repeat these steps as many times as necessary until the entire distance is measured between the high- and low-tide mark.

Calculating slope percentage

The percentage slope between each of the points is calculated as follows:

$$Slope\ (\%) = \frac{\text{Rise (vertical distance)}}{\text{Run (horizontal distance)}} \times 100$$

Ensure that the same units (e.g. cm or m) are used for both the rise and the run. The average slope is calculated by averaging each of the slope measurements (see the example in **Table 1** below). For beach macrolitter surveys, the average slope should be between 26% and 100%.

Table 1: Example of how to calculate slope on a beach that is 15 m wide.

	Low-tide mark (Point 1) to Point 2	Point 2 to Point 3	Point 3 to high-tide mark (Point 4)
Horizontal distance between stakes (Run)	500 cm	500 cm	500 cm
Vertical distance between stakes (Rise)	10 cm	20 cm	30 cm
% Slope	2%	4%	6%
Average slope	*(2+4+6)/3 = 4%*		

APPENDIX 9
MESOLITTER EXTRACTION PROCEDURE

Mesolitter samples collected in the field will likely be a mixture of mesolitter, sediment, stones and biological material. The procedure described here explains how mesolitter is separated from the other material. Easily identifiable pieces of mesolitter are first picked out by hand and then, where necessary, the remaining sample is placed in a saltwater solution to undergo density separation. Floating mesolitter is collected before the remaining mixture is poured over a stack of sieves to separate different-sized particles. Mesolitter should ideally be sorted into size categories (2–5 mm, 5–10 mm and 10–25 mm) as per **Datasheet 10** (*Mesolitter Datasheet: General*). The extraction procedure must be carried out in a sheltered and secure place, such as a laboratory.

Remove visible mesolitter

The easiest way to separate mesolitter from natural materials in the sample is to pick it out by hand or using forceps. This is done by spreading each sample out on a tray and collecting the easily identifiable pieces of mesolitter. Mesolitter items can be measured using **Appendix 10** as they are collected and stored in containers for each size category (see **Datasheet 10**). Alternatively, all mesolitter can initially be stored in a single container and then separated by sieving at a later stage (see **Sieving**).

Some mesolitter may be hidden within plant material or may be difficult to identify. To ensure that these pieces are also collected, the sample is added to saltwater to separate the sample content based on density. However, before starting with density separation, first discard any easily identifiable natural items from the sample.

Density separation

Stirring the sample though a saltwater solution will separate mesolitter from other material in a process called 'density separation'. Most mesolitter pieces have a lower density than the saltwater solution and will float to the top, while organic material and sediment will sink. Some denser mesolitter pieces (e.g. glass and metal) may also sink to the bottom, but will be removed later by sieving the sample. The steps for density separation are given below.

1. Add approximately 3 L of salt water to a 5 L bucket or container. The saltwater can either be seawater or a more concentrated self-made solution. To prepare a saltwater solution, add 3.6 kg of table salt to 3 L of clean freshwater and stir it until all the salt particles dissolve. The resulting solution will have a salt concentration of 1.2 g/ml.
2. Add the mesolitter sample to the saltwater and stir vigorously with a stirrer (e.g. metal rod or wooden spoon) for 5 minutes (or until all particles are separated and floating freely) and then

wait for the mixture to settle. Most mesolitter particles will float to the top. Remove the floating mesolitter and place it in the appropriate container. Some natural material will be less dense than the saltwater and will float to the surface, but these can be removed and discarded.

3. Samples that contain large amounts of sediment (e.g. samples collected in mangroves) must be left to stand for one hour to ensure sufficient time for the sediment and non-buoyant material to sink to the bottom.
4. Once all the floating mesolitter has been collected from the surface of the water, stir the mixture again and collect any litter floating in the water column as the water swirls.
5. Once all the visible and floating mesolitter has been collected, proceed to the next step to extract any remaining mesolitter.

Note: When using seawater for density separation of mesolitter, special care must be taken to avoid contaminating the sample with any mesolitter that may already be present in the seawater. To prevent contamination, a 2 mm mesh net must be placed over the bucket when collecting seawater.

Sieving

1. Stack sieves with mesh sizes of 25 mm, 10 mm, 5 mm and 2 mm with the smallest mesh (2 mm) at the bottom. Be sure to place the sieves over a bucket to collect the water passing through. Pour the remaining sample onto the top of the sieve stack to separate the mesolitter particles by size as per **Datasheet 10**. If samples have a large amount of sediment at the bottom, only empty the supernatant (the watery mixture above the sediment) over the sieves, taking care not to disturb the sediment. The sludge/sediment will be addressed in Step 4 below.
2. Litter found on top of the 25 mm sieve is too large to be counted as mesolitter and should be discarded responsibly. Similarly, items that passed through the 2 mm sieve are too small and should also be discarded (unless they will be investigated in further studies).
3. After removing both the macrolitter (>25 mm) and microlitter (<2 mm), empty the contents of each of the three remaining sieves onto a tray or surface for sorting (see **Sorting**). Make sure that the contents of each sieve are kept separate so that there are three different piles of mesolitter representing the size categories 10–25 mm, 5–10 mm and 2–5 mm.

4. For samples containing a lot of sediment, repeat the **Density Separation** and **Sieving** for the non-buoyant mixture at the bottom of the beaker/container. This can be done using the water collected in the bucket below the sieves or, if necessary, by making a new saltwater solution. This step maximises the recovery of mesolitter pieces. After pouring the supernatant over the sieves, remove mesolitter using Steps 2 and 3.
5. If any material is still left at the bottom of the beaker/container, pour this remaining material over a clean set of sieves. Pour freshwater over the sieves to separate any remaining, non-floating mesolitter from the other material. Add the mesolitter on each sieve to the container for that size category.

Top sieve: Pieces of 10–25 mm,
Middle sieve: Pieces of 5-10 mm,
Bottom sieve: Pieces of 2–5 mm.

Sorting

1. Confirm that all mesolitter pieces are in the correct size group. Although litter is measured according to the longest dimension, sieving separates items based on their shortest dimension, so some longer items may have been included in a smaller size group. The sizes of mesolitter pieces can be checked using **Appendix 10**.
2. While sorting, remove any remaining natural material (e.g. rocks, shells, seaweed) from mesolitter samples.
3. The mesolitter has now successfully been extracted from the samples (**Figure 1**) and is ready to be processed (cleaned, categorised, counted and weighed).

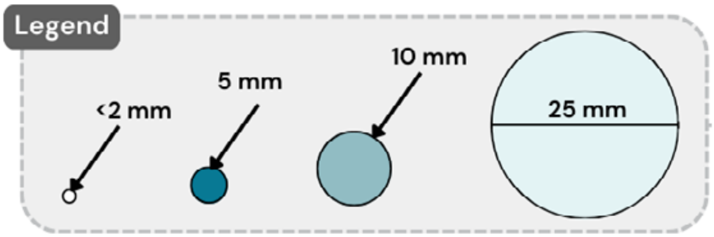
Figure 1: A mesolitter sample collected from a beach in Gqeberha, South Africa.

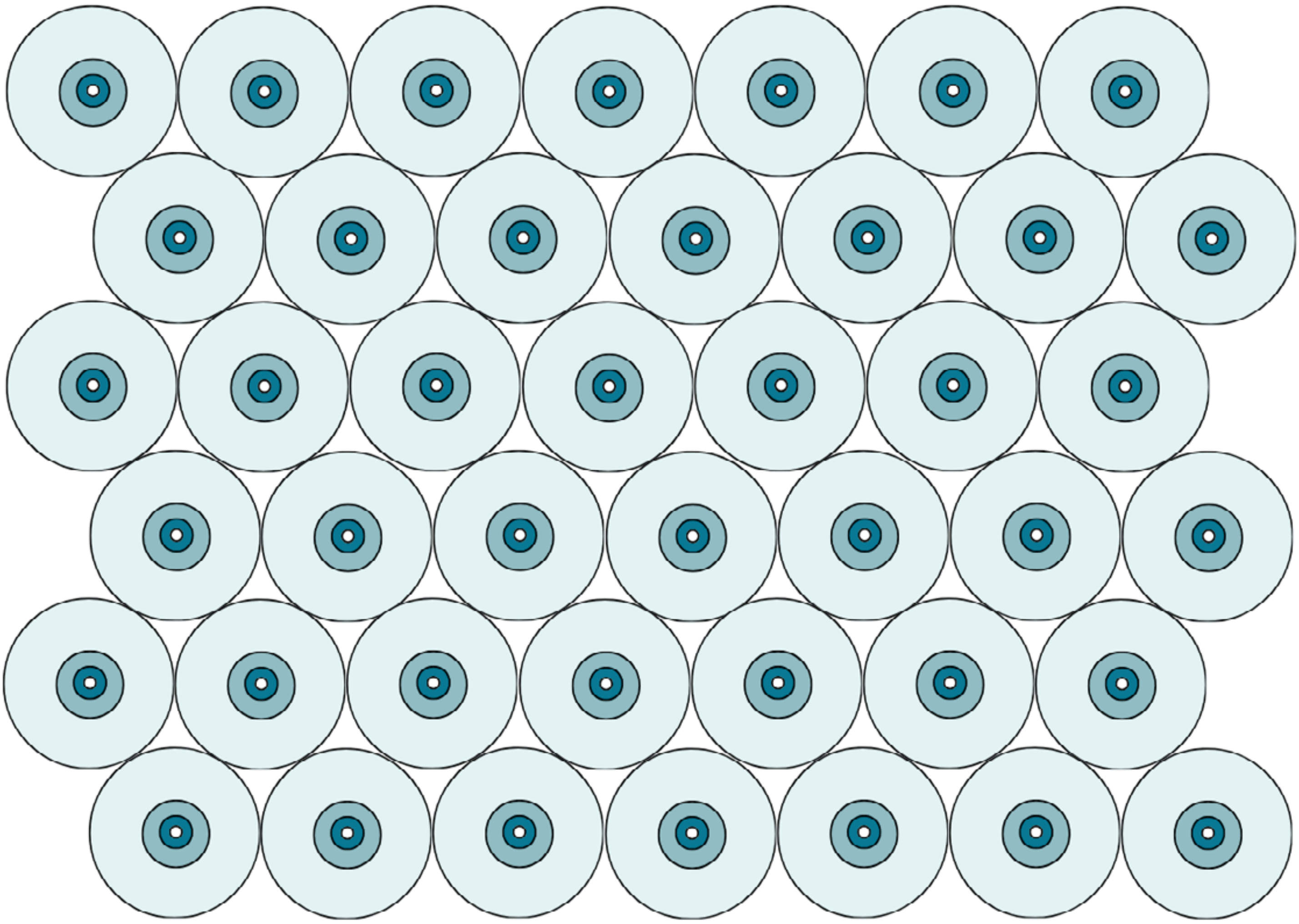
APPENDIX 10
MESOLITTER SORTING GRID

This appendix is to scale and should be printed on an A4 page. It should be laminated to prevent water damage.

SORTING METHODS FOR ITEMS SIZED 2–5 mm

- Place a fragment of mesolitter in the centre of one of the circles below.
- Fragments that fit completely in the smallest circle (<2 mm) are not categorised as mesolitter. These pieces can be discarded responsibly and not included in the mesolitter surveys.
- Fragments larger than the largest circle are >25 mm and are not categorised as mesolitter. These can be counted as macrolitter or discarded responsibly.
- Sort fragments (2–25 mm) into appropriate size classes based on the circle they fit into.
- Example: Fragments are in the 5–10 mm size range if the longest dimension of the fragment is longer than the 5 mm circle, but shorter than the 10 mm circle.





CONTACT US FOR MORE INFORMATION

SST | AFRICAN MARINE NETWORK

info@sst.org.za

DATASHEETS

DATASHEET 1
SITE DESCRIPTION: LAND SURVEYS

This datasheet must be completed once per survey

GENERAL INFORMATION

Site name | **City/Town** | **Country** | **Date of survey** (D D M M Y Y Y Y)

Organisation | **Data recorder name** | **GPS coordinates of transect/site** Start ____ End ____

Site type
- Linear site
- Non-linear site

Specify (e.g. street, public park) :

Datasheet code SD

Add year and month of survey plus unique number for site (e.g. SD202208#4)

SITE CHARACTERISTICS

Site length (m) | **Site width** (m) | **Site area** (m^2)

Polygons can be drawn in Google Earth to determine the area of non-linear sites

Substrate uniformity

% cover of main substrate type

Terrain/Substrate type (select the dominant substrate)
- Cement/Paving
- Grass
- Soil
- Shrubs (<3 m)
- Trees (>3 m)
- Other:

Barrier/obstruction at the boundary of the site
- Cement/Paving
- Wall/Building
- Fence (<25 cm mesh)
- Fence (>25 cm mesh)
- Shrub (<3 m)
- Trees (>3 m)
- Other:

LAND-USE CHARACTERISTICS

Location type
- Urban — *Built-up area close to commercial or industrial zones; high population density*
- Suburban — *Residential area outside or within a city or town; lower population density than urban areas*
- Rural — *Open areas of countryside or small villages without extensive infrastructure; low population density*

Foot-traffic per day
- 0–100
- 101–1000
- >1000

Regularity of use
- Seasonal
- Year-round
- Isolated/ Restricted

Major land usage (select all that apply)
- Industrial
- Commercial
- Residential
- Communal space (e.g. public park)
- Rural community
- Other:

Frequency of waste collection
- Daily
- Weekly
- Bimonthly (twice monthly)
- Monthly
- Never
- Other:

Waste bins provided in study area? Yes No

Are there any stormwater drains/catch-pits present? Yes No

Comments/ Notes

DATASHEET 2
DAILY SITE CONDITIONS

This datasheet must be completed on each day of a survey

GENERAL INFORMATION

Site name	City/Town	Country	Date of survey
			D D M M Y Y Y Y

Organisation	Data recorder name	Number of helpers	Start time	End time

Site/Channel width (m)	*Hours after high tide		Datasheet code	
		This field only needs to be completed if the study site is influenced by oceanic tides	SC	*Add year and month of survey plus unique number for site (e.g. SC202208#4)*

SITE CONDITIONS

Visibility: Low | Medium | High

Evidence of dumping: None | Construction | Household | Other:

*** Wind speed** (km/h)

Current weather: Clear | Drizzle/ Light rain | Fog/Mist | Storm/ Heavy rain | Overcast | Other:

*** Wind direction**

NW	N	NE
W	None	E
SW	S	SE

Wind category: Calm (no wind) | Light breeze (<10 km/h) | Moderate breeze (10–24 km/h) | Strong breeze (25–49 km/h) | High wind (50–64 km/h) | Gale (65–85 km/h)

** This information can be obtained using a weather application (e.g. Windy.com) on a mobile device or computer*

SURVEYS IN WATERWAYS

Visual observations

Observation width (m)	Observation height (m)	Observation depth (m)

Water/Boat speed (m/s)	Water depth (m)		State of the water	
		Take multiple measurements across the channel to calculate an average		*e.g. calm, turbulent (natural foam present)*

Comments/ Notes

This datasheet has been adapted and modified from OSPAR Commission (2010) & Schuyler et al. (2018)

DATASHEET 3
BRAND AUDIT INFORMATION

Site name	City/Town	Country	Organisation	Data recorder name	Date of survey
					D D M M Y Y Y Y

Number of helpers	Start time	End time	Habitat surveyed
			Beach / Mangrove / River / Land / Other:

Transect dimensions (m): Width ___ Length ___

Type of survey: Standing-stock / Accumulation / Booms/Nets

GPS coordinates: Start of transect ___ End of transect ___

BRAND INFORMATION

	Brand name	Manufacturer	Item description	Country of origin	Distributed locally (Y/N)	Distributor/ Store of sale	Product type*	Material type**	Plastic layers***	Total pieces
e.g.	Choco-Snow	Barnadoo International	Chocolate sweet wrapper	South Africa	Y	N/A	FP	Other plastics	ML	146
1										
2										
3										

*PRODUCT TYPE			
FP	**Food packaging:** e.g. bottles, cans, cutlery, foam, tubs, wrappers, chip bags, cups, straws.	SM	**Smoking materials:** e.g. cigarette butts, lighters, cigar tips, tobacco packaging.
PC	**Personal care:** e.g. soap, shampoo, medical waste, diapers, makeup, sanitary products.	FG	**Fishing gear:** e.g. nets, bait, lures, hooks, buoys, floats, rope, fishing lines, traps.
HP	**Household products:** e.g. cleaning products, shoes, textiles, bags, toys, crates, tarps, pens.	PM	**Packing materials:** e.g. boxes, styrofoam (non-food), film, bubble wrap, delivery envelopes, tape.
O	**Other/Unknown:** e.g. pellets, balloons, metals, automotive waste, zip ties, papers.		

*** PLASTIC LAYERS		
	SL	Single layer, e.g.. clear flexible plastic film, wrappers, polythene bags.
	ML	Multi-layer, e.g., composites, laminates, sachets, packets, "Tetra Pak".

**MATERIAL TYPE			
PET	#1 Plastic: e.g. clear or tinted drink bottles, cups, or containers.	LDPE	#4 Plastic: e.g. trays, film, six-pack rings, snap-on lids, wraps.
HDPE	#2 Plastic: e.g. hard & opaque bottles, milk jugs, polythene bags.	PP	#5 Plastic (polypropylene): e.g. food tubs, bottle caps & hinged lids, pill bottles
PVC	#3 Plastic: e.g. pipes, shower curtains, toys.	PS	#6 Plastic (polystyrene): e.g. foam or hard plastic food containers, cups, lids.
OP	Other plastics: e.g. #7 plastic, unknown or unidentifiable plastics.	CP	Cardboard & paper
G	Glass	M	Metal
O	Other material: Any other material not specified above, including rubber, fabric, wood, ceramics, other unknown or unidentifiable material.		

This datasheet has been adapted with permission from the #BreakFreeFromPlastic brand audit datasheet. Their official datasheet can be accessed at: https://www.breakfreefromplastic.org/.

CONTACT US FOR MORE INFORMATION

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DATASHEET 4
BASIC LITTER DATASHEET

GENERAL INFORMATION

Site name

City/Town

Country

Date of survey
D D M M Y Y Y Y

Organisation

Data recorder name

Number of helpers

Start time

End time

Habitat surveyed
- Beach
- Mangrove
- River
- Land
- Other:

Zone sampled

Type of survey
- Standing-stock
- Visual observations
- Accumulation
- Boom/Net surveys

Transect dimensions (m)
- Width
- Length

Codes of matching datasheets (see other datasheets)
- Site description datasheet
- Site conditions datasheet

LITTER TOTALS

Total count

Total weight (grams)

	Count	Weight (grams)
PLASTIC		
PAPER & CARDBOARD		
METAL		
GLASS		
TEXTILES		
PROCESSED WOOD		
RUBBER		
CONSTRUCTION MATERIAL		
OTHER		
PRE-FILLED BAGS		

HOW TO RECORD DATA

Example: Count 9 | Weight 10.5 grams

PLASTICS

1 Sweets/crisp wrappers — C / W

2 Beverage/drinking bottles — C / W

3 Bottle caps, lids & lid rings — C / W

4 Take-away/fast-food items & containers – Plastic — C / W

5 Take-away & food-related Items – Polystyrene — C / W

6 Other food/drink-related plastics — C / W

7 Plastic bags — C / W

8 Cigarettes & smoking-related plastics — C / W

9 Buckets, crates & containers — C / W

10 Fishing-related plastics — C / W

11 Hygiene & medical objects — C / W

12 Plastic packaging (non food-related) — C / W

13 Synthetic ropes & nets — C / W

14 Toys — C / W

15 Other plastic bottles — C / W

16 Other plastics & unidentified fragments — C / W

17 Other polystyrene/foam & unidentified fragments — C / W

PAPER & CARDBOARD

18 Cardboard & papers — C / W

19 Take-away & food-related items – Cardboard & paper — C / W

20 Cartons — C / W

21 Smoking-related cardboard — C / W

22 Toilet paper & tissues — C / W

METAL

23 Food/drink-related items — C / W

24 Metal bottle caps/lids/pull tabs — C / W

25 Electronic waste — C / W

26 Fishing-related metals — C / W

27 Other metals — C / W

GLASS

28 Glass beverage bottles — C / W

29 Other bottles, jars & containers — C / W

30 Other glass — C / W

GENERAL

31 Textiles — C / W

32 Processed wood — C / W

33 Rubber — C / W

34 Construction material/rubble — C / W

35 Other — C / W

36 Pre-filled bags — C / W

ADD YOUR OWN CATEGORY

________ — C / W

________ — C / W

________ — C / W

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DATASHEET 5
COMPREHENSIVE LITTER DATASHEET

GENERAL INFORMATION

Site name	City/Town	Country	Date of survey
			D D M M Y Y Y Y

Organisation	Data recorder name	Number of helpers	Start time	End time

Habitat surveyed

☐ Beach ☐ Mangrove ☐ River ☐ Land ☐ Other: ______

Zone sampled

Type of survey

☐ Standing-stock ☐ Visual observations

☐ Accumulation ☐ Boom/Net surveys

Transect dimensions (m)

Width

Length

Codes of matching datasheets (see other datasheets)

Site description datasheet

Site conditions datasheet

LITTER TOTALS

Total	
Count	
Weight (grams)	

Category	Count	Weight (grams)
PROCESSED WOOD		
GLASS & CERAMICS		
RUBBER		
METAL		
TEXTILES		
PAPER & CARDBOARD		
OTHER		
PLASTIC		
PRE-FILLED BAGS		

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GLASS & CERAMICS

		C	W
1	Construction material (e.g. bricks, cement, tiles)		
2	Glass beverage bottles		
3	Glass/ceramic tableware (e.g. plates, mugs)		
4	Light bulb/tube		
5	Other glass bottles/containers/jars		
6	Other glass/ceramics		
7	Glass/ceramic fragments (All)		

Optional

	2.5–5 cm	5–10 cm	10–25 cm	25–50 cm	50–100 cm	>100 cm
C						
W						

METAL

		C	W
1	Aerosol/spray cans		
2	Bottle caps/lids/pull tabs		
3	Electronic waste		
4	Fishing-related metals (e.g. traps, sinkers, hooks)		
5	Foil		
6	Metal cans – Beverages		
7	Metal cans – Food		
8	Metal cans – Other		
9	Metal drums/barrels		
10	Scrap metal		
11	Wire/mesh		
12	Other metals		
13	Metal fragments (All)		

Optional

	2.5–5 cm	5–10 cm	10–25 cm	25–50 cm	50–100 cm	>100 cm
C						
W						

PAPER & CARDBOARD

		C	W
1	Cardboard boxes		
2	Cartons – Food & beverages		
3	Cigarette packets		
4	Food-related containers/packaging		
5	Other paper/cardboard containers/packaging		
6	Paper (e.g. newspaper)		
7	Paper bags		
8	Paper cups (e.g. coffee cups)		
9	Tissues/serviettes/ toilet paper		
10	Other paper/cardboard		

PLASTIC

1 Bags – Shopping (C / W)	2 Bags – Transparent (e.g. freezer bags) (C / W)	3 Bags – Woven (polypropylene) (C / W)
4 Bags – Other (C / W)	5 Bottles – Beverages (C / W)	6 Bottles – Cleaning products (C / W)
7 Bottles – Personal care (C / W)	8 Bottles – Other (C / W)	9 Bubble wrap (C / W)
10 Buckets (reusable) (C / W)	11 Buoys (C / W)	12 Cable ties (C / W)
13 Caps/lids/lid rings (C / W)	14 Carpets/flooring (C / W)	15 Condoms (C / W)
16 Containers – Cleaning products (C / W)	17 Containers – Food (C / W)	18 Containers – Personal care (C / W)
19 Containers – Other (C / W)	20 Crates (C / W)	21 Cups (C / W)
22 Diapers (C / W)	23 Earbuds (plastic) (C / W)	24 Fibreglass (C / W)
25 Fishing line (C / W)	26 Fishing net (C / W)	27 Fishing traps (C / W)
28 Fishing-related plastics – Other (e.g. lures, jigs) (C / W)	29 Flip flops & other plastic shoes (C / W)	30 Foam – Cushioning/packaging (C / W)
31 Foam – Food & beverages (C / W)	32 Foam – Other (C / W)	33 Glow/light stick (C / W)
34 Hairbrushes/combs (C / W)	35 Jerry cans (C / W)	36 Lollipop sticks (C / W)
37 Medical containers/ tubes/packaging (C / W)	38 Medical items - Other (e.g. plasters, bandages) (C / W)	39 Menstrual products (e.g. pads, tampons) (C / W)
40 Mesh (e.g. vegetable bags) (C / W)	41 Personal protective equipment (PPE) (C / W)	42 Plates & trays (C / W)

43 **Rope/synthetic string** (<1 cm diameter) — C / W

44 **Rope/synthetic string** (>1 cm diameter) — C / W

45 **Smoking-related plastic – Cigarettes** — C / W

46 **Smoking-related plastic – Other** (e.g. lighters, packets) — C / W

47 **Stationery** (e.g. pens) — C / W

48 **Stickers/tape** — C / W

49 **Strapping bands** — C / W

50 **Straws** — C / W

51 **Synthetic hair** — C / W

52 **Tarpaulin/sheeting** — C / W

53 **Toothbrushes/ toothpaste tubes** — C / W

54 **Toys** — C / W

55 **Utensils/cutlery** — C / W

56 **Wet wipes** — C / W

57 **Wrappers/packaging – Cleaning products** — C / W

58 **Wrappers/packaging – Food/drink** — C / W

59 **Wrappers/packaging – Personal care** — C / W

60 **Wrappers/packaging – Sweets & crisps** — C / W

61 **Wrappers/packaging – Other** (e.g. pet food) — C / W

62 **Other plastics** — C / W

Item	All	*Optional*: 2.5–5 cm	5–10 cm	10–25 cm	25–50 cm	50–100 cm	>100 cm
63 **Foam fragments – Hard**	C / W	C / W	C / W	C / W	C / W	C / W	C / W
64 **Foam fragments – Soft**	C / W	C / W	C / W	C / W	C / W	C / W	C / W
65 **Plastic fragments – Film**	C / W	C / W	C / W	C / W	C / W	C / W	C / W
66 **Plastic fragments – Hard**	C / W	C / W	C / W	C / W	C / W	C / W	C / W

PROCESSED WOOD

1 **Crates, boxes & baskets** — C / W

2 **Cork** — C / W

3 **Fishing-related wood** (e.g. traps, fish boxes) — C / W

4 **Food-related items** (e.g. chopsticks, cutlery, toothpicks) — C / W

5 **Pallets** — C / W

6 **Other wood** — C / W

Item	All	*Optional*: 2.5–5 cm	5–10 cm	10–25 cm	25–50 cm	50–100 cm	>100 cm
7 **Wooden fragments**	C / W	C / W	C / W	C / W	C / W	C / W	C / W

RUBBER

#	Item		
1	Balloons (including ribbons, strings, valves)	C	W
2	Boots	C	W
3	Gloves	C	W
4	Tyres	C	W
5	Other rubber	C	W
6	Rubber fragments — All	C	W

Optional:

2.5–5 cm	5–10 cm	10–25 cm	25–50 cm	50–100 cm	>100 cm
C	C	C	C	C	C
W	W	W	W	W	W

TEXTILES

#	Item		
1	Carpet & furnishing	C	W
2	Clothing	C	W
3	Fabric bags	C	W
4	Shoes (non-plastic)	C	W
5	Other textiles	C	W
6	Textile fragments — All	C	W

Optional:

2.5–5 cm	5–10 cm	10–25 cm	25–50 cm	50–100 cm	>100 cm
C	C	C	C	C	C
W	W	W	W	W	W

OTHER

OTHER

#	Item		
1		C	W
2		C	W
3		C	W
4		C	W
5		C	W
6		C	W
7		C	W
8		C	W
9		C	W
10		C	W
11		C	W
12		C	W
13		C	W
14		C	W
15		C	W
16		C	W
17		C	W
18		C	W

DATASHEET 6
DUMPSITE INFORMATION

This datasheet must be completed for each dumpsite

GENERAL INFORMATION

Site name | City/Town | Country | District/County/Ward

Organisation | Data recorder name | Lead surveyor name | Date of survey

D D M M Y Y Y Y

COMMUNITY ACCESS TO WASTE REMOVAL SERVICES

Are there existing waste removal services in the area? Yes No

Are there any recycling initiatives in the area? Yes No

Cost of waste removal services
- Free (included with rates or taxes)
- Paid

Type of waste removal service
- Municipal
- Private
- Informal

Frequency of waste removal

DUMPSITE INFORMATION

GPS coordinates of dumpsite

Site length (m) | Site width (m) | Site area (m^2)

Is the dumpsite visible to the public? Yes No

Is the dumpsite easily accessible to the public? Yes No

Ease of accessibility
- On foot
- Car
- Pushcart
- Truck

Transport needed to remove waste
- Wheelbarrow
- Pickup truck
- Pushcart
- Garbage/tipper truck
- Car & trailer
- Multiple garbage trucks

Distance to legal dumpsite/landfill (km)

Potential hazards posed by dumpsite

Aesthetic & visual impact	*Degradation of the surrounding area's appearance*
Air pollution	*Release of toxic gases and particulate matter*
Fire hazards	*Increased risk of fires and release of toxic smoke*
Odour & pest problems	*Strong and unpleasant odours, attract pests*
Soil contamination	*Presence of hazardous substances in the soil*
Water contamination	*Pollution of groundwater and nearby waterbodies*
Other:	

Nature of waste (select all that apply)
- Building rubble
- Food & beverage products/packaging
- Garden waste
- Household products/packaging
- Industrial products/packaging
- Medical waste
- Personal care products/packaging
- Other:

Types of plastic present (select all that apply)
- PET
- HDPE
- LDPE
- PP
- PS
- PVC
- Other:

Optional

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Types of waste present in the dumpsite

Types of waste (select all that apply)	Percentage contribution by volume (mark with an 'x')				
Cardboard/paper	Rare: 1–20%	Low abundance: 21–40%	Medium abundance: 41–60%	High abundance: 61–80%	Dominant: 81–100%
Clothing	Rare: 1–20%	Low abundance: 21–40%	Medium abundance: 41–60%	High abundance: 61–80%	Dominant: 81–100%
Construction/ building materials	Rare: 1–20%	Low abundance: 21–40%	Medium abundance: 41–60%	High abundance: 61–80%	Dominant: 81–100%
Electronics	Rare: 1–20%	Low abundance: 21–40%	Medium abundance: 41–60%	High abundance: 61–80%	Dominant: 81–100%
Hard plastics (e.g. water bottles)	Rare: 1–20%	Low abundance: 21–40%	Medium abundance: 41–60%	High abundance: 61–80%	Dominant: 81–100%
Medical waste	Rare: 1–20%	Low abundance: 21–40%	Medium abundance: 41–60%	High abundance: 61–80%	Dominant: 81–100%
Metals	Rare: 1–20%	Low abundance: 21–40%	Medium abundance: 41–60%	High abundance: 61–80%	Dominant: 81–100%
Oil	Rare: 1–20%	Low abundance: 21–40%	Medium abundance: 41–60%	High abundance: 61–80%	Dominant: 81–100%
Organic food waste	Rare: 1–20%	Low abundance: 21–40%	Medium abundance: 41–60%	High abundance: 61–80%	Dominant: 81–100%
Other organic waste (e.g. plant/animal materials)	Rare: 1–20%	Low abundance: 21–40%	Medium abundance: 41–60%	High abundance: 61–80%	Dominant: 81–100%
Processed wood	Rare: 1–20%	Low abundance: 21–40%	Medium abundance: 41–60%	High abundance: 61–80%	Dominant: 81–100%
Rubber & tyres	Rare: 1–20%	Low abundance: 21–40%	Medium abundance: 41–60%	High abundance: 61–80%	Dominant: 81–100%
Sanitary waste (e.g. condoms, diapers, pads)	Rare: 1–20%	Low abundance: 21–40%	Medium abundance: 41–60%	High abundance: 61–80%	Dominant: 81–100%
Soft plastics (e.g. plastic bags)	Rare: 1–20%	Low abundance: 21–40%	Medium abundance: 41–60%	High abundance: 61–80%	Dominant: 81–100%

DATASHEET 7
SITE DESCRIPTION: WATERWAYS

This datasheet must be completed once per survey

GENERAL INFORMATION

Site name

City/Town

Country

Date of survey

D D M M Y Y Y Y

Organisation

Data recorder name

GPS coordinates of site

Type of survey

- Litter boom/net
- Surface trawling (mesolitter)
- Visual observations

Datasheet code

SD

Add year and month of survey plus unique number for site (e.g. SD202208#4)

SITE CHARACTERISTICS

Habitat surveyed

- River
- Estuary
- Canal
- Other: ______

Presence of water

- Permanent
- Seasonal
- Sporadic

Surrounding barriers (select all that are present at the site)

- Grass/Reeds
- Trees (>3 m)
- Mangrove
- Marsh
- Artificial structure
- Shrubs (<3 m)
- Sediment
- Rocks

Connected to the ocean? Yes No

Tidal influence? Yes No

Channel width (m) — *Width at sampling site*

Drainage area size (km^2) — *Obtained from the literature or online*

Distance from the ocean (km) — *If connected to the ocean*

LAND-USE CHARACTERISTICS

Location type

- Urban — *Built-up area close to commercial or industrial zones; high population density*
- Suburban — *Residential area outside or within a city or town; lower population density than urban areas*
- Rural — *Open areas of countryside or small villages without extensive infrastructure; low population density*

Major land usage (select all that apply)

- Industrial
- Communal space (e.g. public park)
- Commercial
- Rural community
- Residential
- Other: ______

Public access — *e.g. vehicular, boat, none*

Nearest town information

Town name

Distance from study site (km)

Direction from study site

Population size

Are there any stormwater drains/catch-pits present? Yes No

Comments/Notes

DATASHEET 8
TRAWLING INFORMATION

This datasheet must be completed on each day of a survey

SITE & NET INFORMATION

Site name

City/Town

Country

Date of survey

D D M M Y Y Y Y

Organisation

Data recorder name

Number of helpers

Datasheet code

TIS

Add year and month of survey plus unique number for site (e.g. TIS202208#4)

Boat colour

Flow meter constant (revs/m)

Trawling net type

Net mesh size (mm)

Net mouth dimensions (cm)

*Salinity (ppt)

*Sea surface temperature (°C)

TRAWL INFORMATION

	Tow 1	Tow 2	Tow 3
Wind speed (knots)			
Wind direction (degrees)			
Sea state (Beaufort scale)			
Start latitude (decimal degrees)			
Start longitude (decimal degrees)			
Start time			
Start flow meter reading			
End latitude (decimal degrees)			
End longitude (decimal degrees)			
End time			
End flow meter reading			
Average vessel speed (knots)			
Average vessel direction (degrees)			
Average depth (m)			
Comments/Notes			

**Optional fields*

CONTACT US FOR MORE INFORMATION

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DATASHEET 9
MESOLITTER DATASHEET: TRAWLING SURVEYS

This datasheet must be completed on each day of a survey

SITE INFORMATION

Site name	City/Town	Organisation	Date of survey
			D D M M Y Y Y Y

LITTER RESULTS

		Name of sorter	Hard plastic	Soft plastic	Plastic line/fibre	Foam/Styrofoam	TOTAL	Notes
TOW 1	1							
	2							
	3							
		Weight (mg)						
TOW 2	1							
	2							
	3							
		Weight (mg)						
TOW 3	1							
	2							
	3							
		Weight (mg)						

DATASHEET 10
MESOLITTER DATASHEET: GENERAL

GENERAL INFORMATION

Site name | City/Town | Country | Date of survey (D D M M Y Y Y Y)

Organisation | Data recorder name | Number of helpers | Start time | End time

Habitat surveyed
☐ Beach ☐ Mangrove ☐ River ☐ Land ☐ Other: ______

Sampling design
☐ Transect ☐ Quadrat

Transect/Quadrat dimensions (m)
Width
Length

Codes of matching datasheets (see other datasheets)
Site description datasheet
Site conditions datasheet

Mangrove surveys:
Quadrat code
e.g. LW 3

LITTER DATA

How to record data

Count	9
Weight	10.523 grams

PLASTICS

Total C W

1 

Cigarette butts	All	
		C
		W
2–5 mm	5–10 mm	10–25 mm
C	C	C
W	W	W

Optional

2 

Fishing line	All	
		C
		W
2–5 mm	5–10 mm	10–25 mm
C	C	C
W	W	W

Optional

3 

Flexible packaging	All	
		C
		W
2–5 mm	5–10 mm	10–25 mm
C	C	C
W	W	W

Optional

4 

Foamed plastics	All	
		C
		W
2–5 mm	5–10 mm	10–25 mm
C	C	C
W	W	W

Optional

5 

Bottle caps, lids & lid rings	All	
		C
		W
2–5 mm	5–10 mm	10–25 mm
C	C	C
W	W	W

Optional

6 

Rigid pieces	All	
		C
		W
2–5 mm	5–10 mm	10–25 mm
C	C	C
W	W	W

Optional

7

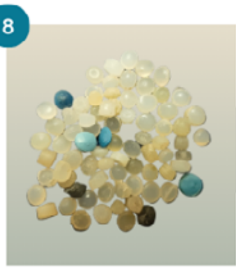
Ropes/fibres

	All
C	
W	

	2–5 mm	5–10 mm	10–25 mm
C			
W			

Optional

8



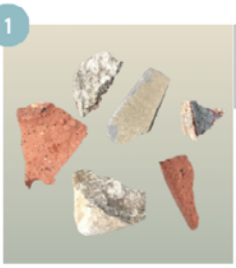
Industrial pellets/nurdles

	All (2–5 mm)
C	
W	

NON-PLASTICS

Total	
C	
W	

1



Construction material & ceramics

	All
C	
W	

	2–5 mm	5–10 mm	10–25 mm
C			
W			

Optional

2

Fabric/cloth

	All
C	
W	

	2–5 mm	5–10 mm	10–25 mm
C			
W			

Optional

3

Glass

	All
C	
W	

	2–5 mm	5–10 mm	10–25 mm
C			
W			

Optional

4

Metal

	All
C	
W	

	2–5 mm	5–10 mm	10–25 mm
C			
W			

Optional

5

Paper/cardboard

	All
C	
W	

	2–5 mm	5–10 mm	10–25 mm
C			
W			

Optional

6

Processed wood/cork

	All
C	
W	

	2–5 mm	5–10 mm	10–25 mm
C			
W			

Optional

7

Rubber & silicone

	All
C	
W	

	2–5 mm	5–10 mm	10–25 mm
C			
W			

Optional

8

Wax

	All
C	
W	

	2–5 mm	5–10 mm	10–25 mm
C			
W			

Optional

9

Other

	All
C	
W	

	2–5 mm	5–10 mm	10–25 mm
C			
W			

Optional

DATASHEET 11
SITE DESCRIPTION: SHORELINES

This datasheet must be completed once per survey

GENERAL INFORMATION

Site name | **City/Town** | **Country** | **Date of survey** D D M M Y Y Y Y

Organisation | **Data recorder name** | **GPS coordinates of survey area/transect** Start | End

Habitat surveyed
☐ Beach ☐ Mangrove ☐ Riverbank ☐ Other: ______

Datasheet code SD — *Add year and month of survey plus unique number for site (e.g. SD202208#4)*

HABITAT CHARACTERISTICS

BEACH SURVEYS — **Survey area length** (m)

MANGROVE SURVEYS — **Quadrat dimensions** (m) Length | Width

Site width (m) — *Low-tide mark to back of the beach*

Horizontal tidal distance (m) — *Distance from low- to high-tide mark*

Vertical tidal range Min | Max — *Use tidal chart*

Slope — *See Appendix 8*

Substrate type (select the dominant substrate)
☐ Sand ☐ Boulders ☐ Mangrove ☐ Other: ______
☐ Mud ☐ Pebble/ Gravel ☐ Rock slab

Back of the study area
☐ Cliff ☐ Dune ☐ Forest/Trees (>3 m) ☐ Mangrove
☐ Grass ☐ Seawall ☐ Shrub (<3 m) ☐ Other: ______

Substrate uniformity — *% cover of main substrate type*

Prevailing current — *Dominant current along coastline*

Prevailing winds — *Direction of dominant winds*

Aspect/Orientation — *Direction when facing the water*

LAND-USE CHARACTERISTICS

Major land usage (select all that apply)
☐ Fishing ☐ Recreational (e.g. sunbathing) ☐ Sporting activities (e.g. surfing) ☐ Unutilised by the public/restricted access ☐ Other: ______

Number of visitors per day
☐ 0–100 ☐ 101–1000 ☐ >1000

Regularity of use
☐ Seasonal ☐ Year-round

Public access — *e.g. vehicular, boat, none*

Location type
☐ Urban — *Built-up area close to commercial or industrial zones; high population density*
☐ Suburban — *Residential area outside or within a city or town; lower population density than urban areas*
☐ Rural — *Open areas of countryside or small villages without extensive infrastructure; low population density*

	Name of nearest	**Distance to** (km)	**Direction from site**
Town			
River			
Port/ Harbour			

River input at beach Yes | No

Pipe/Drain input at beach Yes | No

Town population size

Type of harbour — *e.g. commercial, fishery, military*

Comments/ Notes

This datasheet has been adapted and modified from OSPAR Commission (2010) & Schuyler et al. (2018)

MANGROVE FOREST STRUCTURE

Add the description of three random 10 x 10 m quadrats from each inundation zone to characterise the mangrove forest structure. Print this page as many times as necessary to record all species per quadrat.

Zone	Quadrat code	Mangrove species name	No. of seedlings	No. of saplings	No. of adults (trees)	*Mean tree height	**Tree circumference (at ~1 m height)
Example	SW/Q4	Rhizophora mucronata	8	4	1	4.5 m	12.9 cm
SEAWARD ZONE							
MIDDLE ZONE							
LANDWARD ZONE							

**Record the height of each tree and divide by the total number of trees to get the mean tree height*
***Circumference (c) is used to calculate diameter (d) using the following equation: $d = c/\pi$*

SUSTAINABLE SEAS TRUST

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Pretoria

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